

Progress on urban energy access and energy poverty in the Global Covenant of Mayors initiative

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Supplemental Information

Supplemental note on the Energy Access and Energy Poverty Pillar development process

The Energy Access and Energy Poverty Pillar (EAPP) was developed by the Global Covenant of Mayors (GCoM) as part of the scientific and methodological work delivered to help cities take action against climate change and address energy access and poverty issues. To ensure a coherent and coordinated approach to developing the EAPP, the GCoM established a dedicated subcommittee within its Data Technical Working Group. This working group handles the initiative's data standardization, data management, action planning, monitoring, and reporting. The EAPP subcommittee's specific goal was to develop and implement the Energy Access and Energy Poverty Pillar. The subcommittee included representatives from partner organizations such as the European Commission, C40, CDP, ICLEI, UN-HABITAT, WWF, Covenant of Mayors Europe, and others. The EAPP design phase was driven by the need to combine global consistency with local flexibility. It aimed to apply shared global principles while incorporating regional and local perspectives to recognize and respect the specific needs and capacities of cities that have signed on to the initiative.

The GCoM Common Reporting Framework (CRF) for climate mitigation and adaptation established a methodological foundation that enables cities worldwide to operate under a shared approach while maintaining regional flexibility⁴⁰. Building on these principles, the Energy Access and Poverty Pillar (EAPP) includes reporting requirements, indicators, and guidelines designed to help GCoM signatories collect data, track progress, and implement ambitious energy-focused initiatives across three phases: assessment, target setting, and action planning. These phases formed the core of subcommittee work in developing the EAPP framework.

The subcommittee developed this process between 2018-2023 through three global consultations (Supplementary Figure 1) that collected inputs from thirteen Regional/National Covenants via a multi-stakeholder engagement process integrating expertise from urban planners, energy experts, and local communities across GCoM regions. Regional and National Covenants are locally specific coalitions of cities that have all made a commitment to act on climate change through the Global Covenant of Mayors for Climate & Energy. Regional Covenants do not represent specific countries, but aggregate local authorities in countries in specific world regions to ensure a suitable governance of the initiative and that GCoM common principles are adapted to meet local realities. This approach ensured that local realities were reflected in the common principles outlined in the EAPP framework, as the Regional/National Covenants maintain direct contact with engaged cities in each region, guaranteeing consideration of all relevant local, regional, and national partner inputs. In 2018-2019, based on the broad literature covering energy access and poverty and the wide

definition of this theme and a first pilot exercise for Energy Access in Sub-Saharan Africa⁷⁸, the sub-committee produced worldwide mapping exercise and a consultation note, which framed the need for the energy access and poverty pillar. This consultation note served as a foundation for developing the EAPP. The key challenge was to determine how energy access and energy poverty could be effectively assessed at the local level, maintaining the relevance of local contexts. This required making cities able to report on their local realities in a manner that reflects key concerns, priorities, data limitations and specific capacities of their governance systems.

The first consultation round was launched in 2020 when Regional and National Covenants received the consultation note requesting inputs, recommendations, and potential indicators for assessing EAPP at the local level. Partners drew on their territorial knowledge, literature reviews, other local initiatives, and existing standards. In total, 47 active GCoM alliance partners provided insights into regional priorities, collectively indicating 120 EAPP-relevant indicators. The sub-committee then analyzed this input, identifying common elements, key priorities, and attributes to design a first draft of the EAPP methodology.

Based on the proposed draft, a second consultation round was conducted in 2021. More than one hundred GCoM Partners provided feedback on the EAPP approach. Their inputs revealed the profound and diverse priorities across Regional and National Covenants. The subcommittee filtered, refined, and incorporated this feedback into an updated methodological framework that accommodated region-specific needs while maintaining scientific robustness and consistency for global aggregation of reported efforts.

The methodology was designed to ensure global and regional relevance, adaptability, flexible reporting burden, alignment with other GCoM pillars and timelines, regional and local sourcing, and simplicity. A key outcome was structuring the EAPP across three attributes: secure, affordable, and sustainable energy, aligned with Sustainable Development Goal 7⁷: Affordable and clean energy¹ and findings from the energy community. These attributes are tracked using dedicated indicators sourced from practitioners and partners across regions, offering a flexible method to track progress based on city contexts

To finalise the EAPP framework, its structure and methodology went through several internal GCoM approval steps, and through a third global consultation. In the last round of consultation, the final version of the developed approach aimed to ensure that the methodology reflected partners' perspectives and considerations. In this last stage, partners were allowed to select the energy attribute best suitable for the region to make sure the EAPP is reflecting the perspective of each GCoM region. The EAPP was officially launched at CoP 27 in 2022 and incorporated in the updated version of the GCoM Common Reporting Framework, which is available for local governments since January 2023⁴⁸.

This pillar has been developed to make sure specific regional needs are considered. In Europe, the affordability attributed selected has been fully declined into Energy Poverty. In addition to the mandatory indicator, signatories are encouraged to use the relevant regional indicators. To uncover the multiple dimensions of energy poverty, the regional relevant indicators have been classified into 6 macro-areas: Climate, Facilities/housing, Mobility, Socio-Economic, Policy and regulatory framework, Participation/Awareness raising.

Supplemental Tables

Indicator Name	Description	Unit
Access to secure energy		
Percentage of municipality population or households with access to electricity	Energy supply that is guaranteed and available when needed in the required quantities. Signatories could detail percentage % of on-grid and % off-grid electricity access.	● Percentage [%] of households with access to electricity or ● Percentage [%] of jurisdiction population with access to electricity
Average duration of available electricity	The average length of time during which electricity is available (or inversely, unavailable) for use.	● Number of hours electricity is available per day (hours/day) or ● Number of hours electricity is available per week (hours/week) or ● Number of hours electricity is available per year (hours/year) or ● Number of days per year electricity is available (days/year)
Average yearly energy consumption per capita	The average yearly energy consumption per capita is a relative factor that allows the understanding of the technological and socioeconomic growth that allows an uninterrupted connection to a secure electricity grid.	● kWh/year/person or ● Tonne of oil equivalent (TOE) /person
Access to sustainable energy		
Installed capacity of renewable energy within local boundary	It refers to the installed capacity of renewable energy within the local boundary disaggregated per type of technology (wind, hydro, solar photovoltaic, solar thermal, etc)	Megawatt [MW]
Total energy generated from renewable energy sources within local boundary	It refers to the total energy generated from renewable energy sources within the local boundary disaggregated per type of technology (wind, hydro, solar photovoltaic, solar thermal, etc)	Megawatt-hour [MWh]
Energy consumption from renewable energy sources	It refers to the energy consumption from renewable energy sources. The local authority could include reference to power purchase agreements (PPAs), or other schemes used to purchase green electricity used within the municipality boundary.	Megawatt-hour [MWh]
Source mix of thermal energy (heating and cooling) consumed in your city	It refers to the energy mix for total thermal (heating/cooling) energy consumed in in the city. Measures the share of the energy mix for each of the following: Coal, Gas, Oil, Bioenergy (Biomass and	Percentage [%] per thermal energy source

	Biofuels), Geothermal, Solar (Thermal), Waste to energy, etc.	
Percentage of households within the municipality with access to clean cooking fuels and technologies ⁵⁵	It provides an indication of the share of access to clean cooking fuels and technologies.	It is measured using the following thresholds 1: <10% 2: 10.01-30% 3: 30.01-50% 4: 50.01-75% 5: >75% 6: Not estimated
Access to affordable energy		
Percentage of households or population within the city boundary that face energy poverty ----- Threshold used for energy poverty	It measures the share of population facing energy poverty based on the percentage of income spent on energy services, compared with a threshold identified by the municipality.	Percentage [%] of income spent on energy services ● Up to 5% of income spent on energy services ● Up to 10% of income spent on energy services ● Up to 15% of income spent on energy services ● Up to 20% or more of income spent on energy services ● Other, please specify

Supplementary Table 1 - Global mandatory indicators

Overview of standardized energy indicators used by Covenant of Mayors signatories, organized by three energy attributes: security, sustainability, and affordability. Each indicator includes description, measurement units, and specific reporting parameters to enable consistent cross-municipal energy assessment and monitoring. The table derives from the Global Covenant of Mayors Common Reporting Framework - Version 7 (2023).

Indicator Name	Description	Unit
Access to secure energy		
Estimated share of electricity consumed within the municipality but not billed (non-technical losses, illegal connections) [1 to 5] 1: 50%	Estimated share of electricity consumed within the municipality but not billed (non-technical losses, illegal connections) [1 to 5] 1: 50%	● Estimated share of electricity consumed within the municipality but not billed (non-technical losses, illegal connections) [1 to 5] 1: 50%
Average number of electric supply interruptions in a typical month (or year)	[n°/month] or [n°/year]	● Interruptions would include power outages, network overload, weak power capacity, extreme voltage fluctuations, other. Signatory may also indicate the average duration or indicate the number of

		significant ones (significant is locally determined)
% energy consumption per capita from - electricity - gas - other sources (please list)	[%]	● Measures the carrier consumption, rather than the source consumption
Access to sustainable energy		
Total installed energy capacity within local boundary	[MW], possibility of disaggregation. Non-renewable energy sources are not mandatory (or Included Elsewhere), while renewable energy sources segments are mandatory (see three indicators below)	Signatories can voluntarily provide a full disaggregation including all type of energy sources.
Number of local energy efficiency programs	[n° (municipality)] / disaggregate per sector plus extra info (n° beneficiaries, n° stakeholders, energy savings, GHG emissions reduced, amount of mobilized investments)	Sub-Saharan Africa (SSA) signatories have the possibility to respond to the regional indicator Financial and regulatory incentives for renewable energies in place.
Number of local renewable energy programs	[n° (municipality)] / disaggregate per sector plus extra info (n° beneficiaries, n° stakeholders, energy savings, GHG emissions reduced, renewable energy generated, amount of mobilized investments)	SSA signatories have the possibility to respond to the regional indicator Financial and regulatory incentives for renewable energies in place.
Access to affordable energy		
Percentage of households within the municipality experiencing heating or cooling discomfort	[1 to 5]	qualitative 1: 50% 1: <5% 2: 5.01-10% 3: 10.01-25% 4: 25.01-50% 5: >50%
% of clean energy investment at local level going to low- and moderate-income households	[%]	This indicator helps provide some starter detail from an equity perspective, helping measure the extent to which clean energy is affordable
Price of green electricity	Price/kWh	Average price of green electricity per kWh

Supplementary Table 2- Global non-mandatory indicators

Overview of standardized global non-mandatory indicators used by Covenant of Mayors signatories, organized by the three energy attributes: security, sustainability, and affordability. Each indicator includes description, measurement units, and specific reporting parameters to enable consistent cross-municipal energy assessment and monitoring. The table derives from the Global Covenant of Mayors Common Reporting Framework - Version 7 (2023).

Attribute	Target Types
Secure Energy	• Increase average duration of available electricity • Increase the percentage of the population or households with access to electricity • Improve the average yearly energy consumption per capita • Other target to advance energy security
Sustainable Energy	• Increase the installed capacity of renewable energy sources (RES) within local boundary • Increase total energy generated from RES within local boundary • Increase energy consumption from RES • Increase the households within the municipality with access to clean cooking fuels and technologies • Improve the greenness of the source mix of thermal energy (heating and cooling) consumed in your city • Other target to address sustainable energy
Affordable Energy	• Reduction in energy poverty (population) • Reduction in energy poverty (households) • Increase energy efficiency of buildings • Other target to address energy poverty

Supplementary Table 3 - Target types of municipal energy target categories by attribute type

Classification of energy targets available to municipalities within the Energy Action and Planning Pillar framework, organized by the three energy attributes (secure, sustainable, and affordable energy). Suggested targets provide standardized options for municipalities to establish measurable energy objectives aligned with local priorities and contexts. At the same time municipalities can decide to define different or additional targets based on their local priorities. The table derives from the Global Covenant of Mayors Common Reporting Framework - Version 7 (2023).

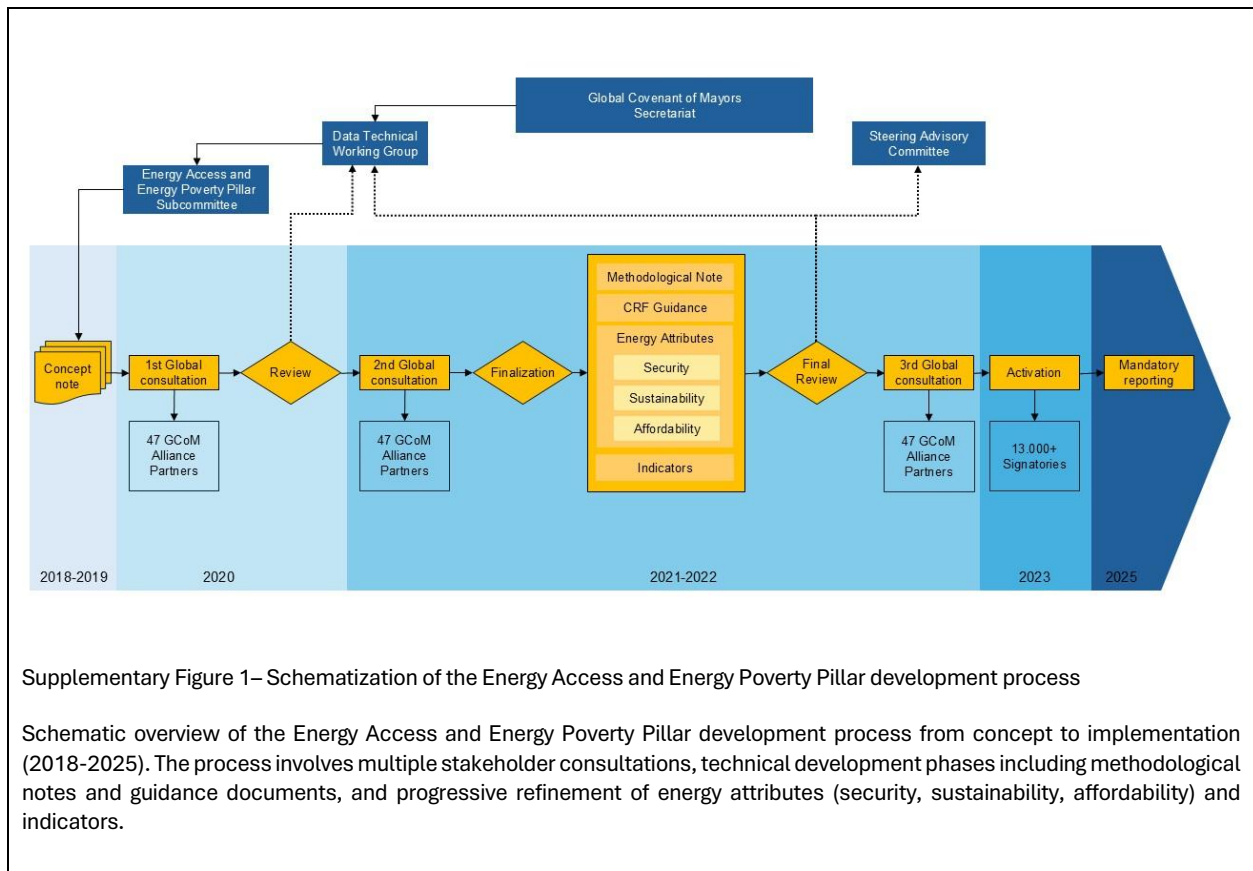
Test	Research Question	Method	Key Finding	Effect Size	P-value	Significant	Robustness	Sample Size	Sensitivity Analyses
Test 1	Do badge distributions vary by region?	Chi-square test of independence	Regional differences significant and robust	Cramér's V = 0.35 (moderate)	< 0.001	Yes	Persists excluding SSA and Europe	n = 1,354 cities, 10 regions	5 scenarios (with/without SSA, with/without Europe)
Test 2	Do frontrunner cities differ in size/wealth?	Mann-Whitney U test	Frontrunners 16-17x larger; wealth effect confounded by SSA	Population: 16.19x ratio; Wealth: confounded	Population: < 0.001; Wealth (no SSA): 0.93	Size: Yes; Wealth: No	Size effect strengthens without SSA (17.2x)	n = 40 frontrunners (3.0% of sample); n = 1,314 others	With/without SSA; SSA temporal advantage (2018 vs 2023)
Test 3	Do city population distributions differ by region?	Kruskal-Wallis H test	Large regional differences (Europe 23.5x smaller than others)	$\epsilon^2 = 0.25-0.31$ (large)	< 0.001	Yes	Persists excluding Europe; EAPP sample 2.1x larger than GCoM	n = 1,354 EAPP; n = 13,506 full GCoM	With/without Europe; EAPP vs GCoM comparison

Test 4	Do large cities show different badge patterns?	Chi-square test of independence	Large cities 9.5-10.7x more likely to complete Assessments	Assessment ratio: 9.48x (with SSA), 10.73x (without SSA)	< 0.001	Yes	Effect strengthens without SSA; 8% of cities = 82% of population	n = 109 large cities (>500k); n = 1,245 small cities	With/without SSA; regional stratification; population concentration (Gini = 0.895)
Test 5	Does GDP predict badge engagement?	Chi-square & Kruskal-Wallis tests	Modest overall effect driven by regional composition	Overall: weak; Within regions: negligible	0.023 (excluding SSA); Within-region: 3 of 4 p > 0.22	Weak overall; Not within regions	Effect disappears in within-region analysis	n = 1,354 cities; Low income n=66, Middle n=692, High n=596	With/without SSA; within-region comparisons (4 regions); income categories
Test 6	Does settlement type influence badge patterns?	Chi-square test of independence	Settlement type influences badge TYPE (small effect) not INTENSITY (negligible)	Type: V = 0.175 (small); Intensity: V = 0.091 (negligible)	< 0.001 for both	Type: Yes (small); Intensity: Negligible	Persists without SSA	n = 1,354 cities; Urban n=674, Rural n=554, Suburban n=126	With/without SSA; badge type vs intensity

Supplementary Table 4 – Statistical tests of municipal characteristics and energy badge engagement patterns

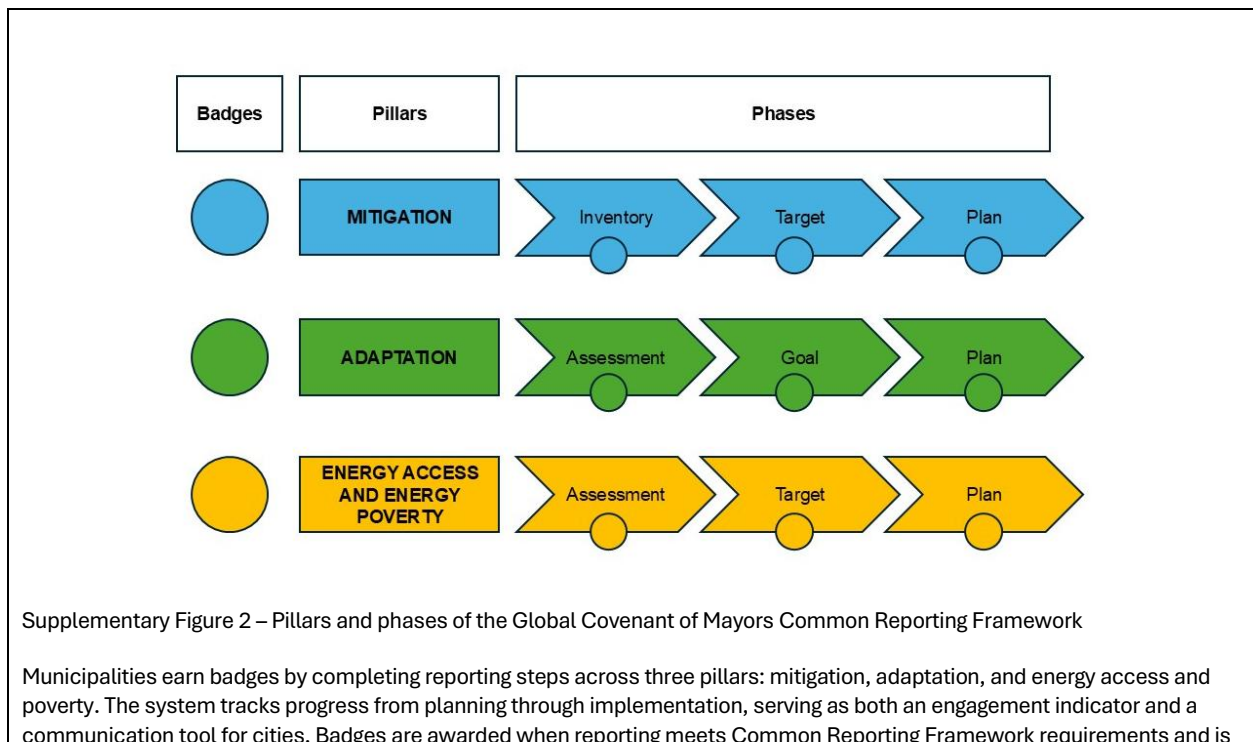
Six complementary analyses examining regional variation, city size, frontrunner characteristics, economic wealth, and settlement type as predictors of energy action completion among EAPP municipalities (n=1,354). All tests include sensitivity analyses excluding Sub-Saharan Africa to control for temporal advantages (2018 vs. 2023 access). Effect sizes reported using Cramér's V (categorical associations), epsilon-squared ϵ^2 (group differences), and ratio measures (magnitude comparisons).

Supplemental Figures



Supplementary Figure 1– Schematization of the Energy Access and Energy Poverty Pillar development process

Schematic overview of the Energy Access and Energy Poverty Pillar development process from concept to implementation (2018-2025). The process involves multiple stakeholder consultations, technical development phases including methodological notes and guidance documents, and progressive refinement of energy attributes (security, sustainability, affordability) and indicators.



Supplementary Figure 2 – Pillars and phases of the Global Covenant of Mayors Common Reporting Framework

Municipalities earn badges by completing reporting steps across three pillars: mitigation, adaptation, and energy access and poverty. The system tracks progress from planning through implementation, serving as both an engagement indicator and a communication tool for cities. Badges are awarded when reporting meets Common Reporting Framework requirements and is

validated through regional/national Covenant channels. The figure is a schematisation made by the author based on the Global Covenant of Mayors Common Reporting Framework - Version 7 (2023) /