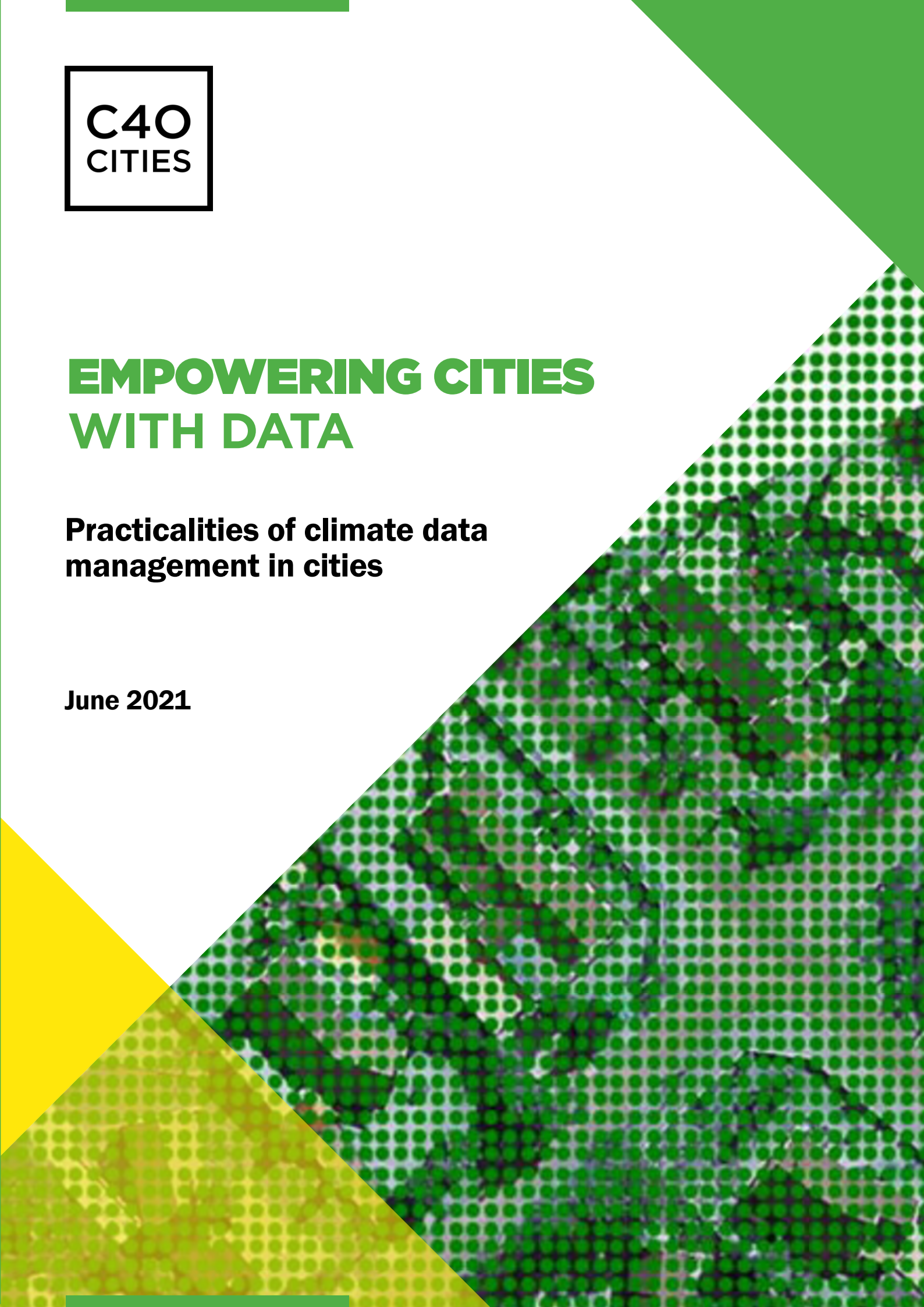
C40 CITIES

EMPOWERING CITIES WITH DATA

Practicalities of climate data management in cities

June 2021



Outline

C40

C40 is a network of nearly 100 mayors of the world’s leading cities that are working to deliver the urgent action needed right now to confront the climate crisis and create a future where everyone, everywhere can thrive. Mayors of C40 cities are committed to using a science-based and people-focused approach to help the world limit global heating to 1.5˚C and build healthy, equitable and resilient communities. Through a Global Green New Deal, mayors are working alongside a coalition of representatives from labour, business, youth movements and civil society to go further and faster than ever before. The current Chair of C40 is Mayor of Los Angeles Eric Garcetti; and three-term Mayor of New York City Michael R. Bloomberg serves as President of the Board. C40’s work is made possible by our strategic funders: Bloomberg Philanthropies, Children’s Investment Fund Foundation (CIFF), and Realdania.

ACKNOWLEDGEMENTS

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CIFF CHILDREN’S INVESTMENT FUND FOUNDATION

C40 thanks city staff from the following cities, who provided valuable inputs during this pilot Empowering Cities with Data Programme through interviews, webinars, workshops, written feedback and completion of the city data readiness self-assessment questionnaire:
Accra, Addis Ababa, Amman, Barcelona, Buenos Aires, Cape Town, Chengdu, Curitiba, Dakar, Dar es Salaam, Durban, Guadalajara, Jakarta, Johannesburg, Kuala Lumpur, Lagos, Lima, Medellin, New York City, Quito, Quezon City, Rio de Janeiro, Sao Paulo, Salvador, San Francisco, Sydney, Tshwane, Vancouver, Yokohama

C40 TEAM

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Executive Summary

The global COVID-19 pandemic has exposed the fragility of our economic, political and social systems. But it has also shown us how quickly things can change in a crisis. The way things are is not the way things have to be.

For both the health and climate crises, data is key to understanding the issues at hand, as well as revealing future opportunities. Thanks to good quality and reliable data, cities can prioritise and make a better case for actions that will deliver the greatest impact and most equitable solutions for their residents.

If cities are to tackle the climate crisis by protecting the natural world around us and limiting global heating to 1.5˚C, they need good climate mitigation and adaptation data across all scopes and sectors.

However, many cities do not yet have access to regularly updated and high-quality data to inform the design and implementation of effective climate actions. Opportunities also exist to improve internal city processes and procedures to reuse available data more efficiently and/or to make a stronger business case to attract new climate investment.

To help tackle the practicalities of urban data management and build in-house capacity at the city department level, the C40 Empowering Cities with Data (ECWD) Programme pilot cities and partners co-developed the City Climate Data Management Framework and an accompanying self-assessment questionnaire. These resources informed cities’ Monitoring, Evaluation & Reporting (MER) strategies that help them track implementation of their Paris Agreement aligned climate action plans. Many cities also used them to self-assess their climate data readiness levels.

A global summary analysis featured in this report identified several common areas where further support to cities would be valuable, including strengthening of city data documentation to improve the rate of data reuse and lower the costs of recurrent analysis, or improving data collection capacity through state-of-the-art solutions, such as use of integrated and transparent climate data platforms or artificial intelligence (AI) and machine learning.

Many of these innovative approaches were also demonstrated by the C40 cities from Africa, Latin America and Southeast Asia that took part in the ECWD Small Grants Programme and are featured in a series of “How to?” case studies in this report. The Programme has supported cities to develop replicable - and in many cases, award-winning - solutions to data-related challenges, enabling them to take action to reduce greenhouse gas emissions, air pollution and climate risk, while increasing economic and health benefits for their residents.

Special acknowledgment

C40 would like to recognise the special efforts by many city officials from C40 cities that made the work featured in this report possible.

As well as tackling the effects of the global COVID-19 pandemic, they also continued their innovative and often award-winning work on climate data that will enable them to take bold climate action as part of a green and just recovery. They are continuing to safeguard and improve the livelihoods of city residents in both the immediate and long term.

Why is good data management key for climate action delivery?

Good climate data management is crucial if cities are to effectively measure their progress on climate actions, the delivery of wider benefits and their distribution. It also enables cities to make better decisions, allocate resources more efficiently, make a strong business case for financial and political support, and demonstrate benefits of climate action locally and globally.

Figure 1: Structure of the City Climate Data Management Framework (C40/EY, 2019)

CLIMATE DATA MANAGEMENT THEMES

	1	2	3	4	5
	Data Management Strategy	**Data Quality and Assurance**	**Leadership and Governance**	**Technology and Systems**	**Data Use and Decision-Making**
Elements	Documented climate data strategy	Data collection purpose	Culture	Capacity and features of system	Data trend analysis
	Data objectives	Data use and re-use	Leadership endorsement	Data visualisation tools	Climate strategy design and evaluation
	Alignment with other data initiatives	Industry standards	Skills and training	Data processing and calculation	Transparency and open data
	Supporting the climate strategy	Reporting boundary	Capacity	Data measurement	External reporting
		External reporting requirements	Governance arrangements	Integration with other systems	Business cases
		Quality controls and assurance		Procedures documentation	Project-based abatement
		Data standardisation			

Climate data challenges

In 2019, C40 teamed up with Ernst & Young and eight pilot cities – Amman; Buenos Aires; Cape Town; Chennai; New York City; San Francisco; Sydney; and Vancouver – to better understand cities' best practices and their unique challenges relating to climate data management. Cities tended to lack consistent and well-documented strategies to handle data gaps or insufficient data quality, which impacted on their ability to make a strong business case to attract climate investment. Cities also struggled to coordinate internally on data challenges due to a lack of formal governance arrangements. Finally, cities often had limited in-house data capacity, leading to a lack of long-term strategy and efficiency.

Climate data management

To assist cities in improving their data management, the City Climate Data Management Framework and accompanying self-assessment questionnaire available in seven languages were developed. The framework outlines key principles and best practice city examples across main data management themes, to be considered when developing a climate data management strategy or improving data management (see Figure 1).

Data management readiness

Across each of the climate data management elements, some cities are likely to be just starting their data management journey ("developing"), while others may be more experienced ("established") or already demonstrate leading practice. However, even the most advanced cities might not view themselves as "leading" across all aspects of data management, and a process of continuous improvement in data management is recommended for all cities.

Piloting the approach

Supported by the C40 Empowering Cities with Data Programme, 24 cities across the world self-assessed their climate data management readiness and identified opportunities for improvement. In many cases, this also directly informed the development of Monitoring, Evaluation & Reporting systems in C40 Global South cities. Such monitoring systems are vital to effectively track the delivery of their Paris Agreement aligned climate action plans.

"The Addis Ababa Empowering Cities with Data project on vehicle GHG and air pollutant emissions has given us a better knowledge to fill data gaps in understanding the city vehicles emission.

City and the Addis Ababa Environmental Protection and Green Development Commission staff participated from proposal preparation to the end of the project. It gave us an opportunity to get a theoretical and practical capacity building for our teams in different sectors. The result from the study will contribute to evidence-based decision-making."

Climate Change Mainstreaming Team Leader, Environmental Protection and Green Development Commission, Addis Ababa

How well do cities manage climate data?

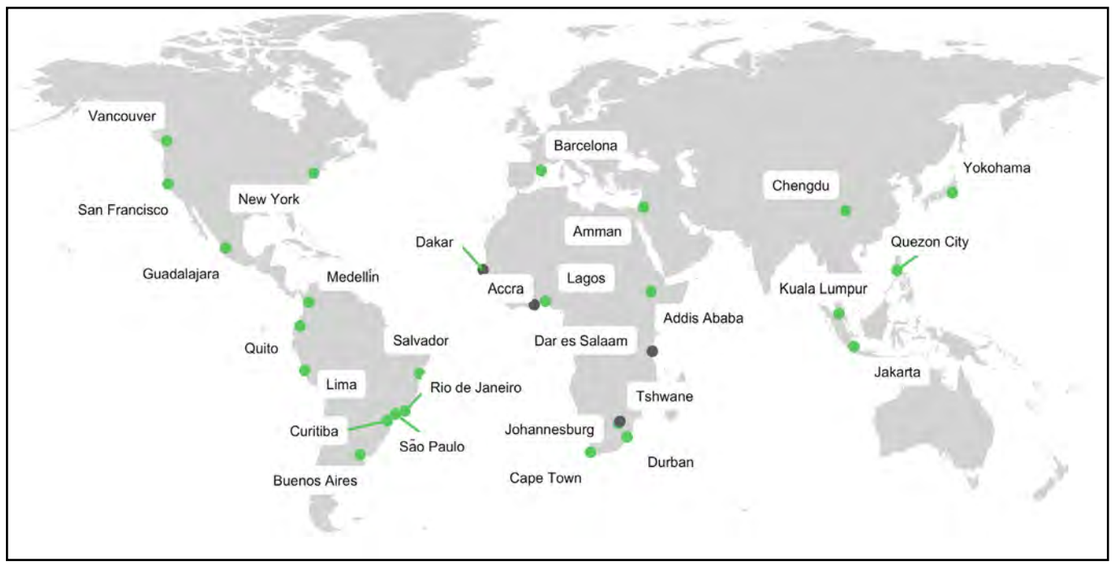
The below analysis provides an overview of C40 cities' climate data management readiness. It also identifies areas where cities might need the most assistance to improve data quality, frequency, usage, and communication to catalyse efficient resource allocation, attract climate investment, and gain broad support for ambitious climate action.

Regional variance and synergies with climate planning

The data management self-assessment was completed by 24 C40 cities shown across all C40 regions (Figure 2). While this analysis focused primarily on Global South cities (80% of respondents), to identify priority areas for their continued data management support, five Global North cities were also included as reference. Cities' Monitoring, Evaluation & Reporting (MER) strategies, developed alongside inclusive city climate action plans aligned with the 1.5˚C ambition of the Paris Agreement, were also examined in additional four C40 cities.

These cities had limited capacity to complete the climate data management readiness self-assessment during 2020, not least due to the impacts of the global COVID-19 pandemic, but reflected on its elements as part of climate planning. C40 wishes to thank all cities that provided inputs used for this analysis during these tough times.

Figure 2: Cities included in data readiness analysis (self-assessments - green; review of MER strategy - grey)



Data readiness relates to city capacity

Data management readiness varied across regions and thematic elements, but there was a correlation between the self-assessed performance and GDP per capita. Cities in Europe and North America tended to perform better overall than those in the Global South, with Latin America slightly ahead of the peer group. This was particularly apparent in the levels of technology and data systems available to cities.

Cities across the board rated strongly on data-informed climate policy design and evaluation. For instance, cities felt that their data visualisation and processing were sufficient to produce one-off analysis, even if its reuse was limited. Cities also performed relatively well on conforming to reporting standards. Tools such as the CIRIS tool for GHG inventory reporting were often mentioned as useful.

Figure 3: Global C40 cities' climate data readiness

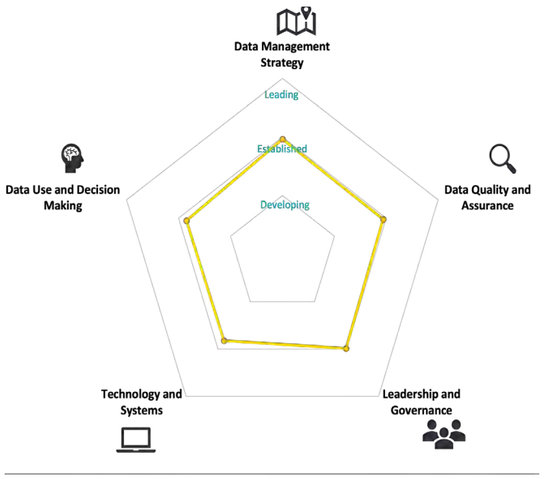
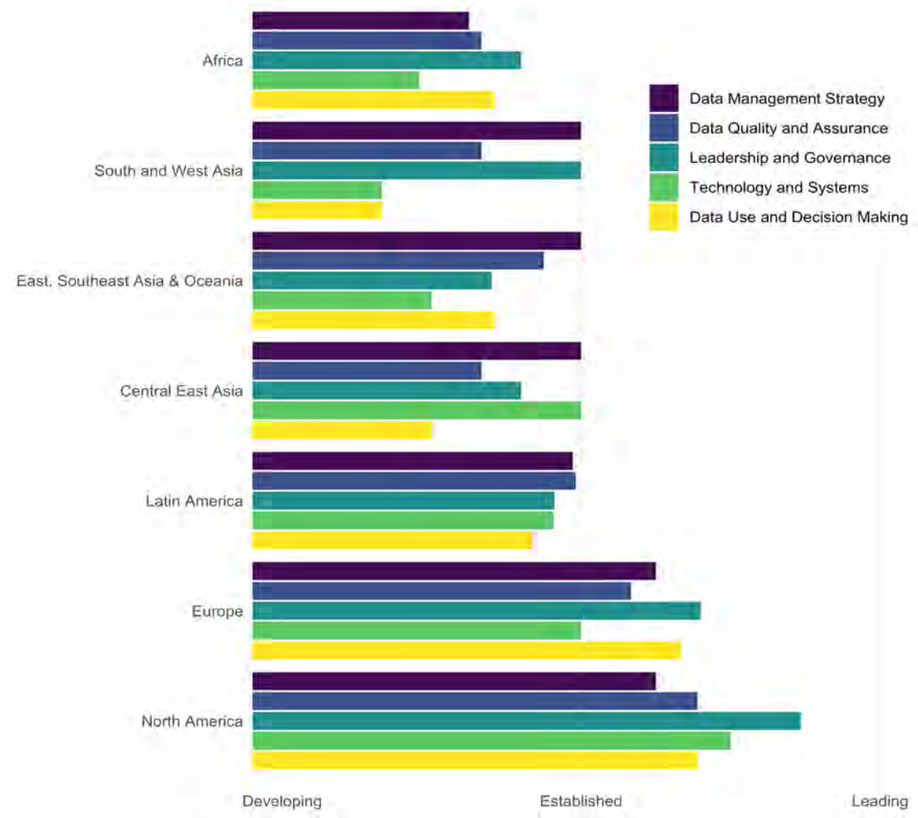


Figure 4: Regional variation of climate data management readiness



Addressing key data management challenges in C40 cities

1. Modern data collection approaches can help boost city capacity

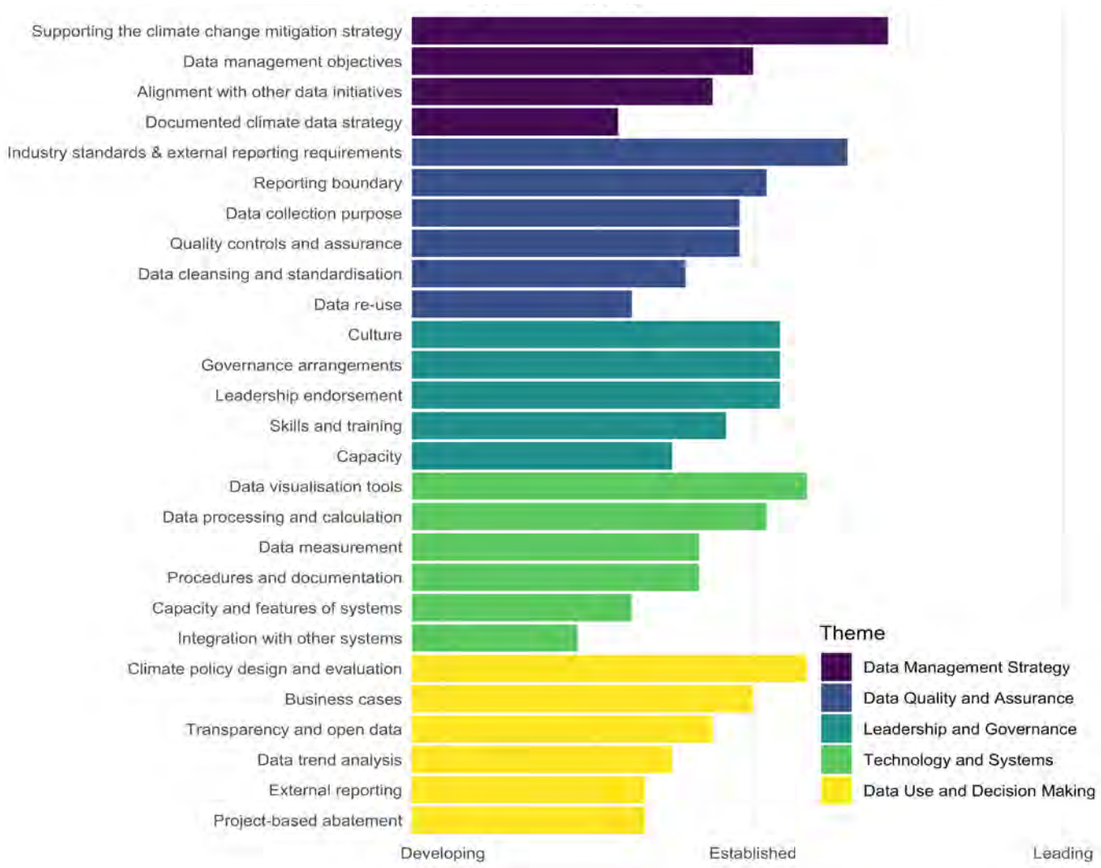
Many cities need continued support with increasing in-house data gathering capacity, to avoid reliance on external data that cannot be easily quality assured or validated. Innovative data collection practices, such as those from Johannesburg or Lagos highlighted later in this report (p.6 onwards), illustrate how public-private partnerships, state-of-the-art artificial intelligence technologies, and locally adapted surveying can help cities improve their data collection capacity.

2. Good data documentation saves time & money

Lack of documentation, both around data strategy and specific datasets, is often a barrier to getting full value from data through reuse, be it for data cleansing, standardisation, communication, or external reporting.

Often, even when data documentation is available, it is not widely accessible across the city. To address this, the actions that cities are taking include assigning specific leads to data documentation or improving recurrent processes. A robust Monitoring, Evaluation & Reporting strategy can also help strengthen this area, as well as build a stronger data culture across the city.

Figure 5: Average climate data readiness by data management element across all cities



3. Data analysis skills are key for better informed decision-making

Technical city staff are often isolated or over capacity, making it difficult to leverage their skills across the city, be it for trend analysis or project-based modelling of climate data. City staff capacity building can help address these gaps, such as on scenario modelling through the C40 Climate Action Planning Programme or on data analysis software as illustrated in the Quito project highlighted below. Cities are also increasingly creating in-house data teams to work on regular updates of city GHG inventories.

4. Integrated climate data platforms help bring together data stakeholders

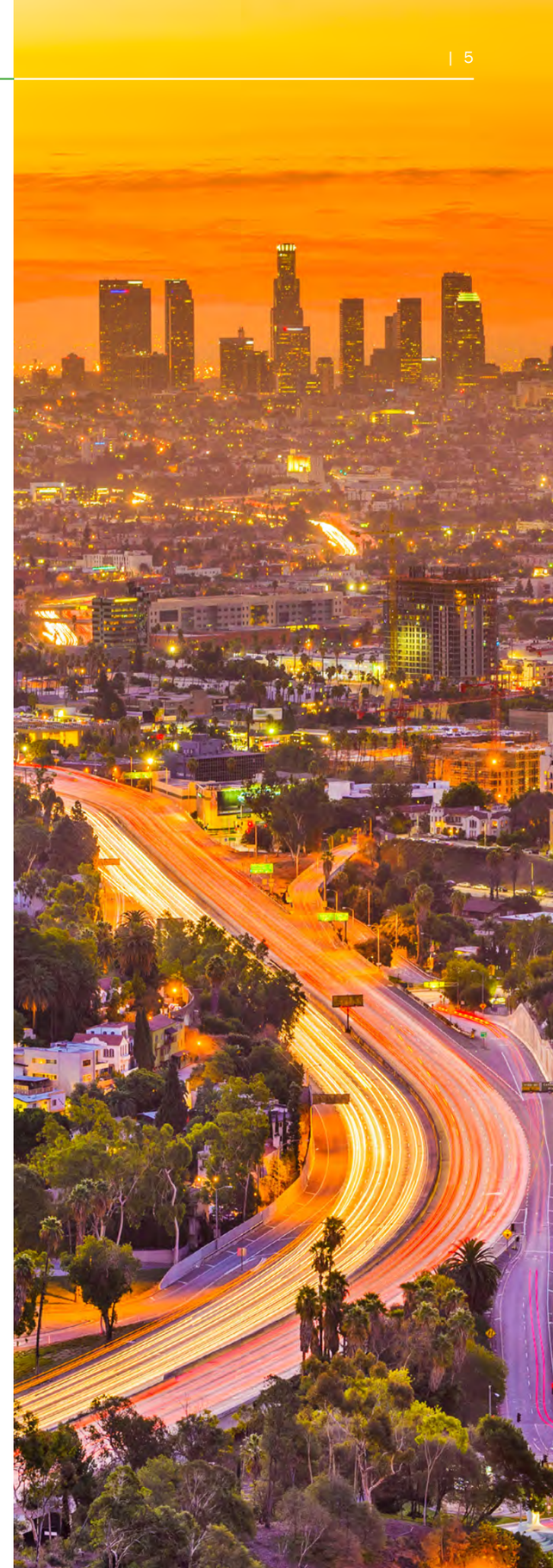
'Integration with other systems' is often the weakest data management element globally. Without an integrated climate data management platform, it is usually difficult for cities to align climate data with other city data initiatives or re-use data across departments. Such platforms also allow for a more transparent data collection and sharing across multiple stakeholders, including the private sector.

5. Strong mandate from city leadership can facilitate data collection

Without a strong buy-in from the city leadership and mandate to all departments, it can be difficult for technical teams to collect climate data from areas outside of their direct remit, such as across different city sectors (transport, energy, waste, etc.). In some cases, informal governance arrangements persist, where data exchanges between departments rely on personal links. Several cities plan to take action in this area by establishing more formal data governance arrangements, which could facilitate more regular data collection, such as for bi-annual GHG inventories.

Potential low-cost & high-impact interventions for city support

- Help improve city data documentation to increase data reuse and lower-cost recurrent analysis.
- Help increase city in-house technical skills through basic data analysis software training.
- Help facilitate data re-use, for example by making it easier to access structured versions of data from C40 or partner Excel tools to use elsewhere.



Solving data challenges with small grants

C40 supports cities to develop and implement climate action plans that deliver on the 1.5˚C ambition of the Paris Agreement and contribute to increased climate resilience and equitable outcomes for city residents, all while driving a green and just recovery from COVID-19. For cities, access to high quality climate data is crucial both to develop effective climate change strategies and to evaluate the impacts of the climate actions being implemented.

Small cost, big impact

Access to robust climate data is often a significant challenge for C40 cities. The C40 Empowering Cities with Data Programme has provided technical assistance to a pilot group of nine city governments to work with local partners to address a key city data challenge. The small grants programme (worth around US $50,000 per city) has helped build technical capacity for data management processes, including data collection, analysis, monitoring and dissemination of data, and has enabled the cities to collect new climate data on energy production and consumption, transport, waste, and air quality.

"The 'eThekwini Port Emissions Inventory' project helped the city of Durban understand in detail the sources of emissions within the harbour and how they contribute to the overall emissions in the city. It also helped us devise mitigation measures to reduce the impact thereof".

Project co-lead & Meteorologist,
eThekwini Municipality

Replicable solutions

Each of the nine projects outlined below highlights how these C40 cities addressed specific data-sourcing challenges and how other cities can replicate some of their best practices. This "How to?" case study collection is also designed to complement the City Climate Data Management Framework with further on-the-ground evidence on how best to tackle challenges across key areas of data management.

There is also a focus on recommendations for overcoming cities' data sourcing barriers in the longer term, such as through increasing political buy-in and stakeholder engagement, inclusive data management planning and training programmes, and the application of modern technologies such as machine learning. These nine case studies further illustrate how cities can improve core aspects of data management to facilitate regular and efficient data collection, for example by generating and standardising data collection templates and building web-based platforms able to receive, store, analyse, and visualise data in real time.

The diagram in Figure 6 outlines the circular approach needed to identify and address a specific data challenge, ensure the process is replicable with existing city capacity and can be adapted to the evolving city context, supporting evidence-based decision making over time.

"The availability and easy access to information in real time is crucial, since it empowers the population and authorities through knowledge."

City Representative

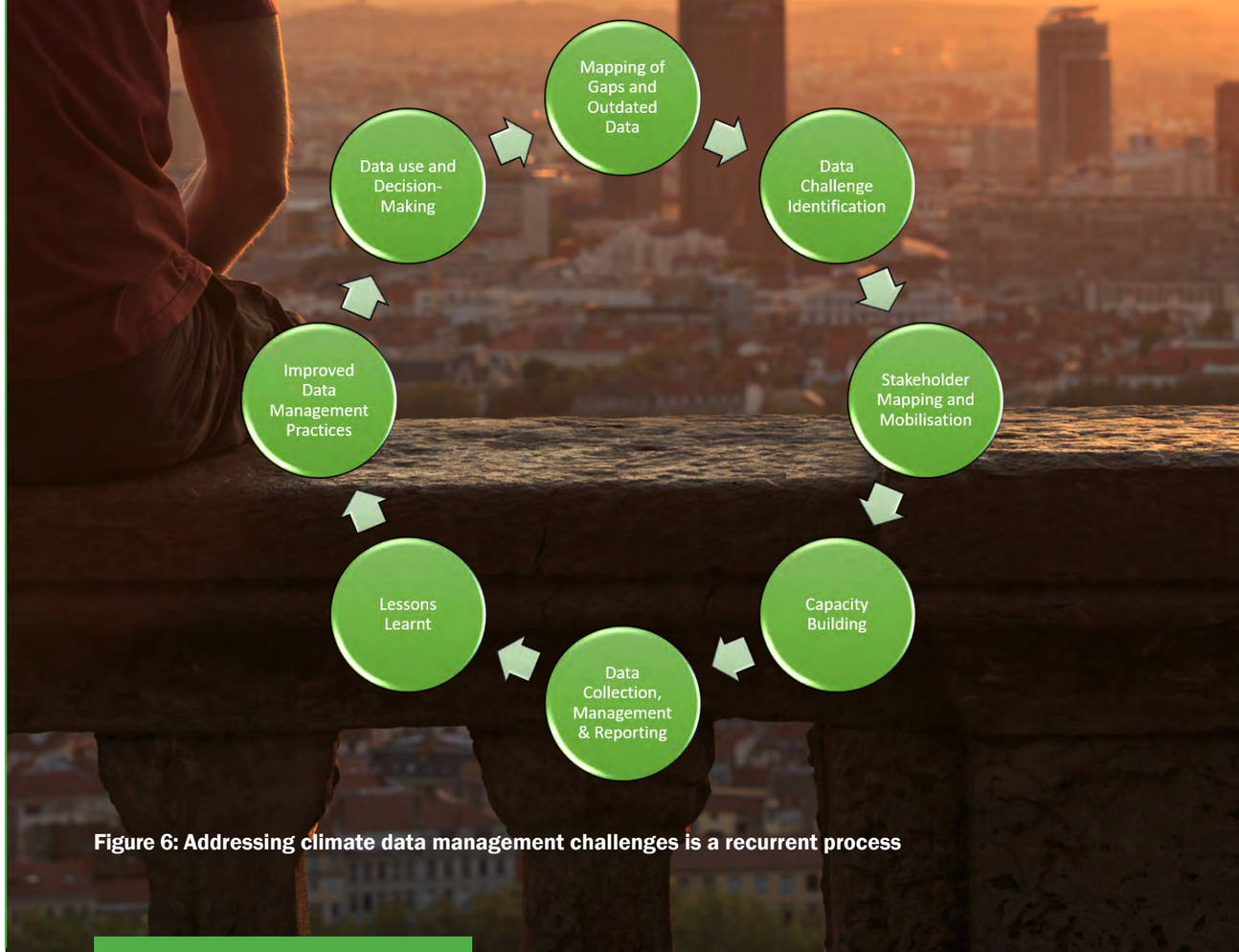


Figure 6: Addressing climate data management challenges is a recurrent process

QUITO

- Air Quality
- Data Management Systems
- Web-based Platform for Data Management
- Leadership & Governance
- Technology & Systems

ACCRA

- Waste
- Access to Data
- New Datasets
- Data Quality & Assurance
- Data Use & Decision Making

LAGOS

- Energy
- Access to Data
- New Datasets
- Data Quality & Assurance
- Leadership & Governance

LIMA

- Air Quality
- Access to Data
- New Datasets
- Leadership & Governance
- Data Use & Decision Making
- Data Quality & Assurance

ADDIS ABABA

- Air Quality
- Access to Data
- New Datasets
- Data Use & Decision Making
- Data Quality & Assurance
- Leadership & Governance

DAR ES SALAAM

- Air Quality
- Access to Data
- New Datasets
- Data Management Strategy
- Leadership & Governance
- Data Use & Decision Making

JAKARTA

- GHG Emissions
- Data Management Systems
- Web-based Platform for Data Management
- Data Management Strategy
- Technology & Systems
- Leadership & Governance

JOHANNESBURG

- Energy
- Access to Data
- New Datasets
- Data Use & Decision Making
- Data Quality & Assurance
- Technology & Systems

DURBAN (ETHEKWINI)

- GHG Emissions
- Air Quality
- Access to data
- New datasets
- Data Management Strategy
- Data Quality & Assurance

ACCRA

Addressing the lack of solid waste characterisation data to help modernise the municipal solid waste management

DATA CHALLENGE

- **Access to data**
- Data management systems

CLIMATE AREA

- Air Quality
- Energy
- GHG Emissions
- Green Infrastructure
- **Waste**

DATA MANAGEMENT BEST PRACTICES

- Data Management Strategy
- **Data Quality & Assurance**
- **Data Use & Decision Making**
- Leadership & Governance
- Technology & Systems

SOLUTION SNAPSHOT

- **New datasets**
- Web-based platform for data management

This project is a great illustration of how to improve city **Data Quality & Assurance**. It aims to fill gaps in municipal data and document methodology to ensure such high-quality analysis can be repeated in the future. It is also relevant to **Data Use & Decision Making**. The knowledge gained in the project has informed understanding of the best options available for waste treatment and has led to a revision of waste-related targets in the Accra Climate Action Plan, aligned with the 1.5˚C ambition of the Paris Agreement and increasing resilience and equitable outcomes.

OVERVIEW

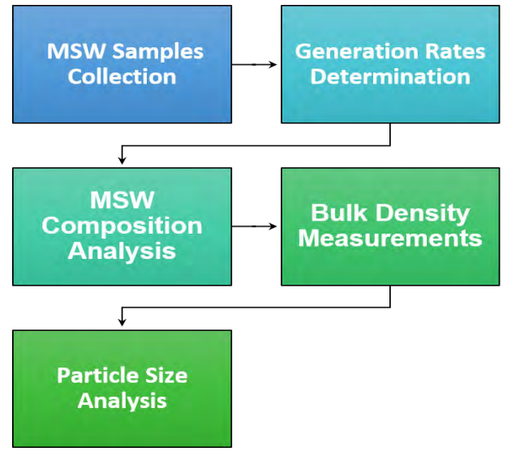
The lack of basic municipal solid waste (MSW) characterisation data has been a significant challenge for the City of Accra, even more so as the amount of waste produced within the next ten years is expected to double with increased urbanisation and economic growth (Silpa et al., 2018).

At the same time, good waste characterisation analysis and GHG emissions measurements enable cities to generate data on the amount and type of waste that is being produced, as well as the corresponding GHG emissions.

Not only does such data allow the City of Accra to develop responsive interventions to modernise its municipal solid waste management systems, but it is also fundamental for attracting development partners and private sector investment.

What has the city achieved?

In order to obtain a MSW characterisation baseline, the city of Accra, supported by the C40's Empowering Cities with Data Programme and the University of Cape Coast, conducted an analysis that measured the physical and chemical properties of the waste (e.g. composition, bulk density, moisture content, calorific value, etc.) across 10 out of the 25 municipalities of the Greater Accra Metropolitan Area, once during the dry season and once during the wet season, to consider the influence of climate on waste characteristics and emissions generation.



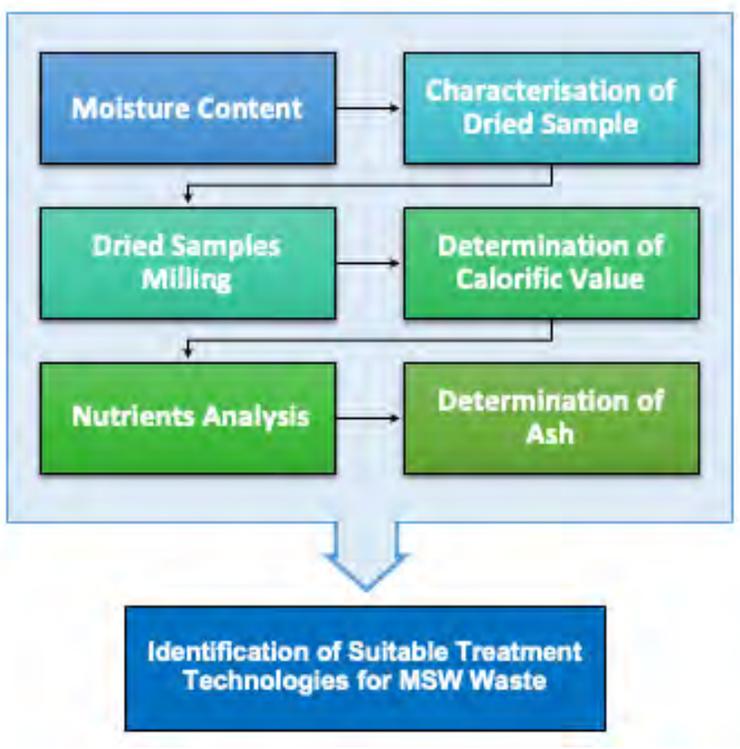
The study found that the average per capita MSW generation rate within the Accra Metropolitan Area is 0.7kg per day. Biodegradable MSW (food waste and garden waste) forms the bulk of the MSW (54% by weight), followed by plastics (16%), paper (4%) and textiles (3%). Metals and glass represent 2% each and there is an increasing sanitary component of 5%. Silt and fines from the sweeping of dirt floors constitutes 13%, and the bulk density and moisture content are 531kg/m^3 and 50% respectively. The calorific value of the waste is 7.31MJ/k.

Accra has used this baseline waste characterisation data for their climate action planning, as such levels of precision are key to help estimate related GHG emissions for the city's inventory. This data can also be used by the city to inform the development of future waste infrastructure and waste treatment technologies, such as investing in composting and anaerobic digestion, as well as the development of better waste management systems, such as introducing recycling systems (three-stream source separation of biodegradables, plastic and other), and the recognition and inclusion of the informal waste sector in separation and collection processes.

"Samples collected for the studies were well above the statistically required for the population size and this improved the quality of the data and results obtained."

City Representative

Figure 7: Data analysis steps to identify the most suitable MSW treatment technologies



Top tips to deliver this solution in your city

1. Set a shared goal with local stakeholders:

Municipal waste characterisation is generally perceived as a relatively elaborate process, but with buy-in from a set of local stakeholders that share interest in the output data, it can be successfully implemented. Stakeholders, including local government decision-makers and solid waste managers, if made aware of the lack of the necessary city baseline data for planning and financing purposes, can commit to help bridge these data gaps. To sustain the modernisation of municipal solid waste management systems in the long term, a commitment to a shared goal from decision-makers and local stakeholders is key.

2. Form partnerships with local research institutions:

The partnership with a local university represented one of the key factors that contributed to Accra's project success, helped build local expertise and contributed to reducing the overall project cost. The capacity of municipal waste departments is often stretched, with limited ability to perform research. Conversely, universities are ideally placed to support this type of project, involving students and building on significant research and analytical experience.

3. Get support from local private sector stakeholders:

Even if this type of project is funded from external sources, collaboration with local private sector stakeholders is recommended for extra support and inclusive planning. In Accra, structural cooperation with private institutions was fundamental for the design and delivery of this project. Logistical support was secured from a local MSW collection company, which provided sorting grounds and additional human resources.

4. Use the Participatory Action Research (PAR) approach:

This approach promotes ownership of the process and empowers participants to collaborate on future implementation programmes, with the participants involved throughout all the process to create social change (MacDonald, 2012). Using this approach - including training - has increased the capacity of Accra's municipal staff in terms of data collection and inclusive decision-making, improved the analysis of field data and strengthened the validation of analysis among experts and stakeholders. It has also encouraged the informal waste sector to work more closely with municipal officials.

5. Prioritise estimation for calculation of GHG emissions:

Accra tested monitoring GHG emissions using two different methods: direct measurements from city landfills (using Aeroqual A-S500 Gas Meter Instruments), and estimation through the City Inventory Reporting Information System (CIRIS) Excel Tool, based on waste characterisation data. The estimation method is recommended, as the processes of outsourcing direct monitoring to private consultants can be laborious and expensive, with potential delays due to lengthy procurement of relevant sensing tools less readily available locally.

ADDIS ABABA

Strengthening air quality and GHG emissions data in the transport sector to support city climate mitigation measures and health benefits

DATA CHALLENGE

- Access to data
- Data management systems

CLIMATE AREA

- Air Quality
- Energy
- GHG Emissions
- Green Infrastructure
- Waste

DATA MANAGEMENT BEST PRACTICES

- Data Management Strategy
- Data Quality & Assurance
- Data Use & Decision Making
- Leadership & Governance
- Technology & Systems

SOLUTION SNAPSHOT

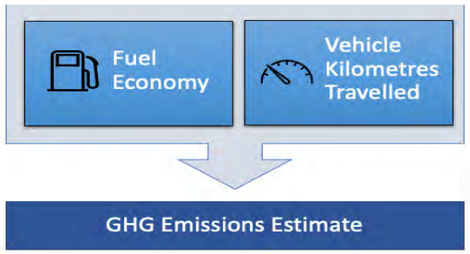
- New datasets
- Web-based platform for data management

This project is an inspiring example of how a city can address the lack of GHG emissions and air pollution data in the transport sector. It is particularly significant for **Data Quality & Assurance** and **Data use & Decision Making**, as it shows how high-quality data can shape and inform climate action, in this case the development of a 10-year Air Quality Monitoring and Control Strategy and Management Plan. It also illustrates the benefit of **Leadership & Governance** by upskilling city staff, to ensure the assessment of air pollution and GHG emissions from the transport sector can be repeated regularly when needed.

OVERVIEW

Addis Ababa aims to fulfil its vision of a safe, healthy, low-carbon and resilient city. However, the lack of reliable GHG emissions data from the transport sector and ambient air quality monitoring was identified as a key challenge. Insufficient air quality monitoring infrastructure or missing data on fuel consumption and travel patterns were the main barriers.

As the city works on mainstreaming climate and air quality policies into the city's urban planning, data is increasingly important to inform the design of emissions and air pollution reduction programmes, and to monitor and track their effectiveness.



What has the city achieved?

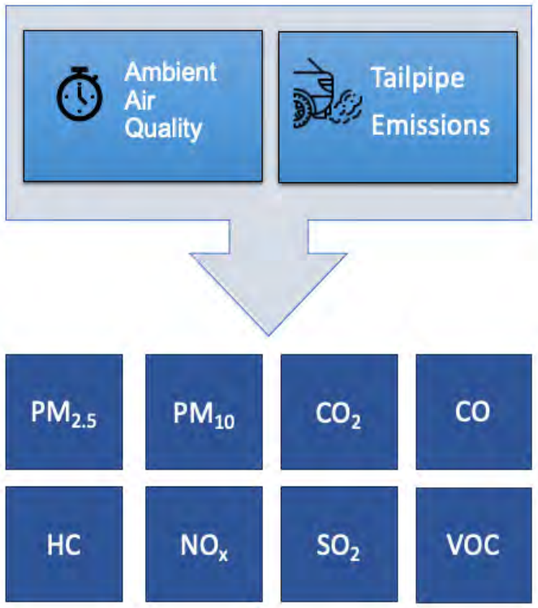
To increase the city government's understanding of the transport sector's impact on city air pollution and the city's GHG emissions, information on fuel economy and vehicles kilometres travelled was collected through interviews with 406 drivers of cars, buses, pick-ups, mini- and midi-buses, and light- and heavy-duty trucks over 30 days. Furthermore, tailpipe emissions testing measured the PM2.5, SO2, CO, NOx, HC, and CO2 emissions of 129 gasoline- and 277 diesel- powered vehicles, while ambient air quality measurements using portable gas sensors assessed PM10, PM2.5, SO2, CO, CO2 and VOC emissions at 20 major congested traffic sites.

This data, combined with the city's existing data on the number of vehicles registered, gave an estimate of the transport-related GHG emissions for the years 2013 - 2019, which increased from 2 million to 3.6 million tCO2e per year due to growth in the number of vehicles. The air pollution data was compared to Ethiopian and WHO guideline standards, and further analysed to show the effect of vehicle manufacturing on reducing pollutant gases and the impact on health and the economy. A detailed analysis suggested that developing city-wide vehicle standards to limit high-emitting vehicles would considerably improve air quality in the city. This could be achieved by replacing

vehicles produced before 1996 with vehicles manufactured from 2014 onwards. By reducing harmful PM2.5 concentration, annually over 200 premature deaths could be avoided, with associated healthcare cost savings of about US$60,000, which is equivalent to almost 1% of Addis Ababa's municipality annual health budget.

Additionally, the above data analysis informed the development of the draft 10-year 'Environment and Air Pollution Monitoring and Control Strategy in Addis Ababa City Transport Sector' (2020-2029), which aims to accelerate action to prevent further increase in ambient air pollution. It sets out guiding principles and recommendations for developing policies and methods to control and regulate vehicle emissions, promotes sustainable transport modes, builds city resources, and ensures coordination with stakeholders and partners for more integrated policies and plans.

Figure 8: Air quality assessment scope



Top tips to deliver this solution in your city:

1. Gain buy-in from key stakeholders and institutions:

Seeking buy-in from key stakeholders from the beginning of the project creates better understanding of the important role that each of them play in the implementation of pollution control strategies. The Addis Ababa project involved a wide range of stakeholders, including the Addis Ababa Environment Protection and Green Development Commission (AAEPGDC) and a Technical Working Group, consisting of ten local and national institutions, including city and national agencies from the transport, environmental and health sectors and academia.

2. Build long-term capacity to conduct measurements:

Project members should receive theoretical and practical 'hands-on' training to enable them to conduct similar monitoring studies in the future. For example, in the Addis Ababa project, members received technical training about equipment calibration and usage, data collection and analysis procedures, and followed the Global Protocol for Community-scale GHG Emissions Inventories (GPC) Standard to estimate related GHG emissions.

3. Develop and maintain clear data collection procedures:

For data comparability and reliability to form the robust evidence needed to develop climate actions, it is crucial to have clear data collection procedures in place. For example, it is recommended to perform a pilot study before the full-scale project launch to test the field conditions, develop the methodology, and ensure that testing locations give a representative sample. It is also important to acquire secondary existing datasets (e.g. type and number of vehicles in the city and health and economic data) for analysis purposes. In this project, it was also necessary for interviews to be conducted to collect data on fuel economy and kilometres travelled because the institutions involved could not provide this information.

4. Strengthen data flow systems:

This is a crucial step for tracking emissions and promotes a culture of data-driven decision making. This can be done by collaborating with different institutions and establishing data governance arrangements to ensure that responsibilities and resources are clearly divided. This will be addressed in the new Environment and Air Pollution Monitoring and Control Strategy in Addis Ababa City Transport Sector (2020-2029). In this project, portable sensors costing around US$9000 each were used to test the different sites. As a result, a few sites were identified where real-time monitors should be installed, as an extremely valuable, sustainable and cost-effective solution. Essential data (e.g. tailpipe emissions and vehicle kilometres travelled) should be gathered regularly through annual vehicle inspections conducted by government-designated private entities or randomised interviews, to better understand changes in vehicle travel behaviour. This can in turn inform evidence-based mitigation actions such as carbon or pollution taxes on vehicles, and the promotion of mass transit, walking and cycling.

DAR ES SALAAM

Developing an air quality data baseline assessment to guide measures to increase clean air and improve public health

DATA CHALLENGE

- **Access to data**
- Data management systems

CLIMATE AREA

- **Air Quality**
- Energy
- GHG Emissions
- Green Infrastructure
- Waste

DATA MANAGEMENT BEST PRACTICES

- **Data Management Strategy**
- Data Quality & Assurance
- **Data Use & Decision Making**
- **Leadership & Governance**
- Technology & Systems

SOLUTION SNAPSHOT

- **New datasets**
- Web-based platform for data management

This project focuses on producing the very first air quality baseline assessment for the city to help inform public policy. It illustrates best practices in data collection, **Data Use & Decision Making**, as well as **Data Management Strategy** with the development of standardised reporting templates and protocols. The project also focused on **Leadership & Governance** by building data management capacity among Dar es Salaam city officials.

OVERVIEW

The City of Dar es Salaam, Tanzania, has already made substantial progress in improving air quality, yet still experiences poor air quality days and faces challenges in assessing the levels of pollution in the city. Dar es Salaam City Council (DCC) is committed to achieving a sustainable, equitable and healthy future for its residents.

As a result, measuring and monitoring air pollution is of critical importance to help gather evidence that will guide mitigation policies and intervention measures to reduce community exposure and improve public health. The purpose of this project was to support DCC to estimate the current baseline for municipal air pollution characteristics and establish the very first low-cost air quality monitoring network.

What has the city achieved?

With support from the C40 Empowering Cities with Data Programme and in collaboration with the Stockholm Environment Institute (SEI) Africa Centre, the City of Dar es Salaam carried out a baseline air pollution assessment by conducting an air monitoring study, and reviewing existing monitoring and satellite data.

Real-time monitoring data for PM10 and PM2.5 was collected from 14 low-cost air sensors deployed across five municipalities. Although the air pollutant levels vary daily for each site location, most levels were higher in areas of major arterial roads and near industrial sites and activities, and also during morning and evening hours, which can potentially be attributed to the heavy motorised traffic at this time.

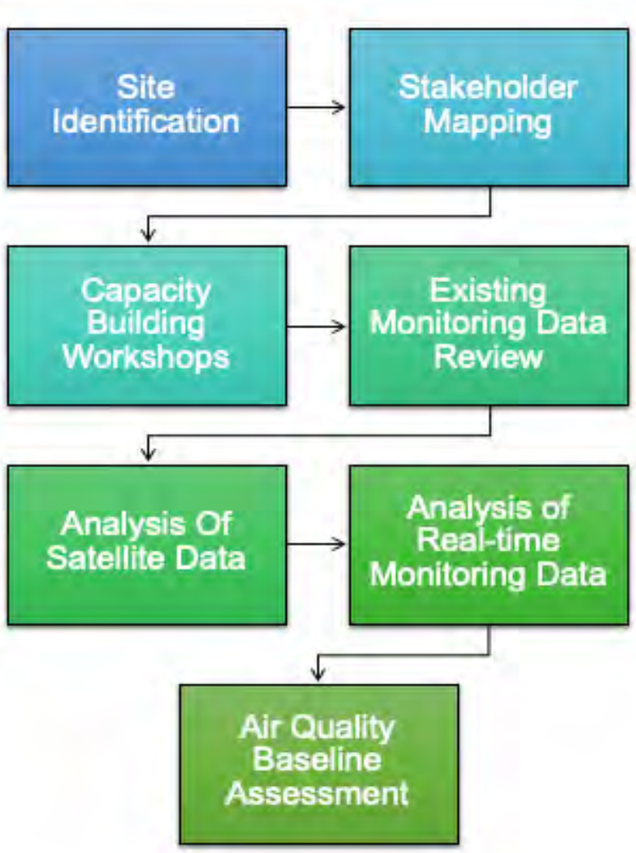
In collaboration with the Regional Centre for Mapping of Resources for Development (RCMRD), three years (2018-2020) of satellite data were also temporally and spatially analysed. High levels of NO2 and CO concentrations were noted in the Central Business District (CBD), with June to July - summertime in Dar es Salaam – showing the highest concentrations, annually. High levels of SO2 were noted in the southern part of the city, especially in March and September, with the concentrations falling in 2020,

potentially due to decreased mobility during the COVID-19 pandemic.

Furthermore, to ensure continuity and replicability, templates and protocols have been developed to enable city staff to consistently monitor air quality in the future. SEI conducted two workshops with municipal officers and stakeholders. The first workshop focused on learning about air pollution issues and included hands on training with air quality measurement. The second workshop concentrated on the basics of air quality data management, such as data processing, analysis, and reporting, and officially handing over the project to the designated authorities. This was an opportunity for DCC and the five municipalities participating in the project (Ilala, Kigamboni, Kinondoni, Temeke and Ubungo) to discuss continuity plans.

Following on from this first air quality baseline assessment, DCC plans to expand the low-cost air quality monitoring network to enable the development of evidence-based air quality targets; develop a monitoring and evaluation system to assess the effectiveness of emissions control strategies; and develop public health recommendations to support governmental and non-governmental actors to design appropriate measures to control ambient air pollution.

Figure 9: How to conduct an air quality baseline assessment



Top tips to deliver this solution in your city

1. Map stakeholders to involve the most relevant institutions:

The relevant stakeholders working directly or indirectly in the field of air quality in Dar es Salaam were mapped into relevant categories: government agencies, academia, local authorities, and research institutes. Out of the 19 relevant institutions identified only four had already been engaged in air quality related activities. Further three stakeholders were identified with high potential for embracing air quality monitoring as part of their mandates. The stakeholder mapping informed the selection of workshop participants and helped ensure the sustainability of the project.

2. Conduct a literature review on past monitoring data:

Reviewing existing literature from various sources and documenting available information and data gaps on the estimation of ground monitoring air quality data early on can save time and resources. In the Dar es Salaam study, the agreed methodology and findings were closely based on past information about the use of remote sensing and satellite images for assessing spatial dynamics of vehicle traffic and spatial distribution and intensity of associated air pollution.

3. Build on existing satellite data:

Earth Observation data is a very useful resource to inform the baseline assessment and can complement real-time monitoring data collected on the ground. NO2, SO2 and CO concentrations can, for example, be extracted from satellite imagery by 'Sentinel 5P', which performs atmospheric measurements with high spatiotemporal resolution. PM2.5 data can be gathered from monthly time series, and area-average of dust surface mass concentration processed from NASA's atmospheric data from 'MERRA-2' satellite and surface observations.

4. Visit monitoring sites to confirm best sensor locations:

Three sites were selected in each of the target municipalities as part of the Dar es Salaam project. The siting exercise was guided by the UNEP siting guidelines, but also included other important factors such as security, power and internet access, or identification of traffic congestion or industrial activities. Air pollution levels can be easily - and considerably - affected by local sources, socioeconomic activities, buildings structures, amongst others, which may affect the results of the study.

DURBAN (eThekwini)

Improving port air quality and reducing greenhouse gas emissions through better data

DATA CHALLENGE

- Access to data
- Data management systems

CLIMATE AREA

- Air Quality
- Energy
- GHG Emissions
- Green Infrastructure
- Waste

DATA MANAGEMENT BEST PRACTICES

- Data Management Strategy
- Data Quality & Assurance
- Data Use & Decision Making
- Leadership & Governance
- Technology & Systems

SOLUTION SNAPSHOT

- New datasets
- Web-based platform for data management

This project helped with producing the very first activity-based emission inventory for the Port of Durban. It illustrates the importance of **Data Quality & Assurance** during new data collection, with elements such as reporting boundaries and industry standards to be considered. It also shows the benefit of a clear **Data Management Strategy** and **Data Use & Decision Making**, with long-term emission scenarios informing the city's mitigation strategy and planning of new port infrastructure.

OVERVIEW

In 2019, Durban published its ambitious Climate Action Plan aligned with the 1.5˚C goal of the Paris Agreement and increasing climate resilience and equitable outcomes. During its development, some data gaps were identified, such as in understanding the Port of Durban's greenhouse gas (GHG) emissions.

According to recent studies (Smith et al., 2015), maritime transport alone is responsible for around 3% of global GHG emissions from fuel combustion, and by 2050 emissions from shipping may increase by 50 to 250% as international trade expands. With proposed expansion of the Port of Durban, the impact of GHG emissions and air pollution is expected to increase. Quantifying and reducing them is key, particularly as the port is located close to the Durban Central Business District and residential areas. The 2nd Generation Air Quality Management Plan also calls for capacity and systems to regularly update emission inventories, including port emissions.

What has the city achieved?

In order to remedy the limited availability of emissions data for the Port of Durban, the city - with support from the C40 Empowering Cities with Data Programme and WSP Environmental - compiled a very first activity-based port emissions inventory. It covered both GHG emissions (CO2, CH4, N2O) and ambient air pollutants (CO, NMVOC, SO2, NOx, PM2, PM10).

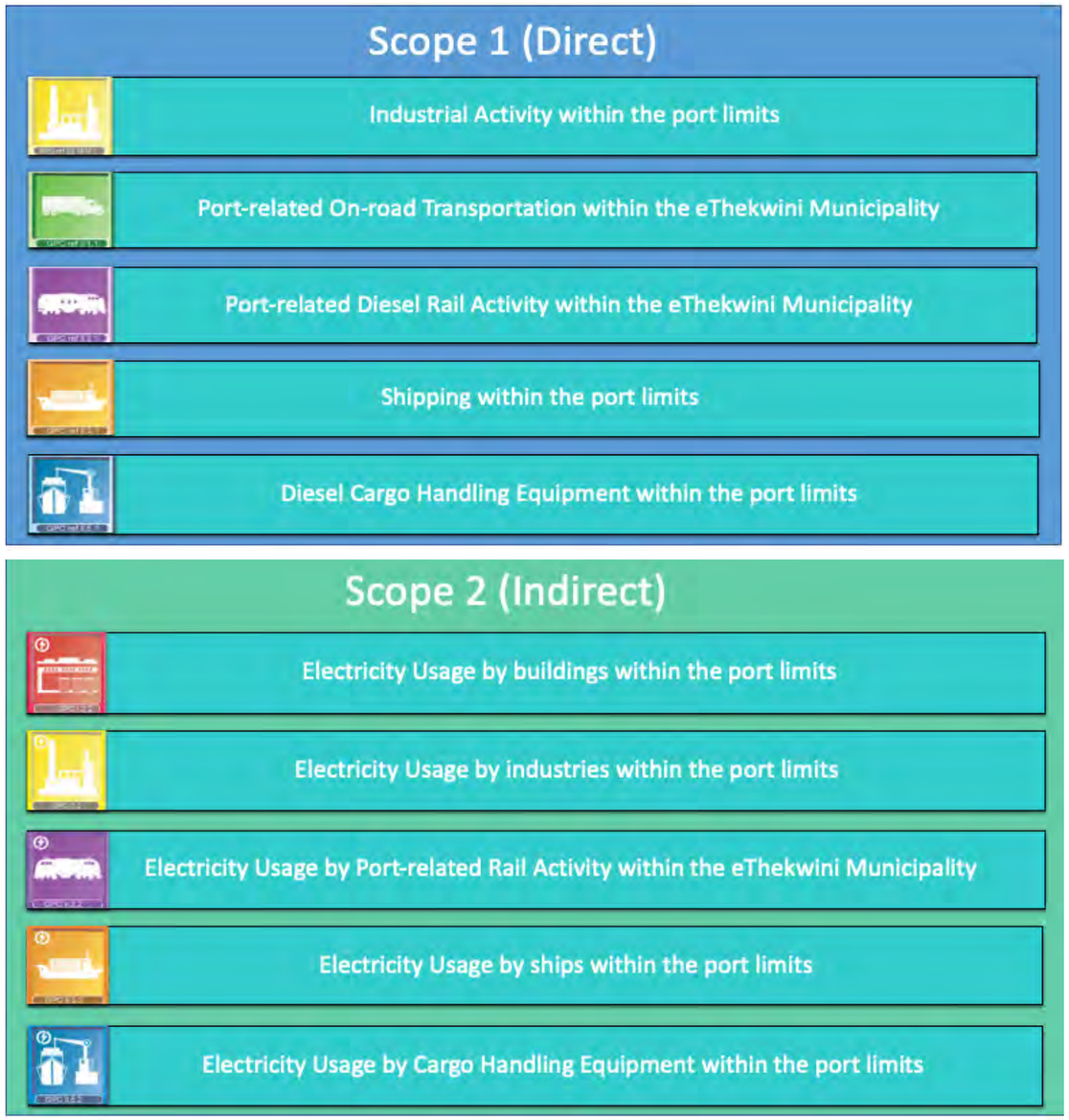
The assessment aimed to analyse Scope 1 and Scope 2 emissions following the Global Protocol for Community-scale GHG Emission Inventories (GPC) and revealed that the Port of Durban represents around 2% of the city's GHG emissions, although for other pollutants such as SO2, NOx and VOC the contribution is much higher, as per Figure 10.

Figure 10: Contribution of port emissions to overall city ambient air pollutant emissions

SO2	NOx	CO	PM10	VOC
21.0%	9.2%	1.2%	0.6%	7.4%

Informed by these findings, the city is considering a range of measures to reduce the port emissions and diminish the congestion of the port precint, while increasing the port capacity. These include a dig-out port further south on the coast and a logistics hub inland at Cato Ridge, which will enable cargo transportation via train rather than on-road and will redistribute the port activities regionally, resulting in a decrease in ambient air pollution in the Durban Port zone itself. The future emissions scenario assessment (for 2030 and 2048) undertaken as part of this study revealed the particular importance of this logistics hub in decreasing port-related emissions in Durban,with the most significant contributions to emissions reduction by 2048 noted for CO2e (13.57%), CO (31.97%), and NMVOC (10.39%) compared to business-as-usual and accounting for planned economic growth.

Figure 11: Activities covered as part of the port emissions inventory according to the GPC standard



Top tips to deliver this solution in your city

1. Clearly define the study boundaries:

Ambient air pollution does not obey defined property boundaries, especially emissions from mobile polluters, such as ships. Nevertheless, the physical boundaries of a study area must be clearly defined to ensure that the study is feasible, clearly contained, and allows a meaningful interpretation of the results. The boundaries for each category were agreed with eThekwini Municipality at the start of the project to ensure the emission inventory could be integrated with the city's other emissions inventories. For some, assessed port emissions were associated with the Durban Municipality boundary, such as port-related vehicle and rail activity. For others only emissions within the port limits were considered.

2. Engage stakeholders to ensure buy-in and data completeness:

In this project, GHG emissions and air pollutants data was collected from various data gatekeepers identified (e.g. industrial facilities based at the Port authority, the Harbour Master, the South African National Roads Agency, Transnet Port Terminals, Eskom, etc.). It is essential that all stakeholders are engaged early in the process to facilitate access to the data. For instance, some industries are not required by law to report emissions data but might agree to do so as part of a public-private partnership. It is particularly beneficial to explain to industry representatives the potential wider benefits of a complete emissions dataset, such as for planning and research purposes.

3. Create a replicable process:

eThekwini plans to update its port emissions inventory every one to two years, therefore it is essential that the port emissions assessment is easily replicable. For a similar approach in other cities, it is recommended to build the capacity of city staff. In Durban, city officials joined three training sessions covering the inventory framework, GPC Protocol, calculation methodologies, GIS and so on. It is also recommended to make data templates available for city staff for future iterations. Due to the large number of ships involved and the multiple steps in calculating shipping emissions, templates can help ensure robust data management.

4. Remember that creating an emissions inventory is an iterative process:

There were remaining data gaps in this project that could not be filled in the first iteration. Creating an emissions inventory for a new sector needs to be built upon over time. Assumptions and limitations need to be fully acknowledged, so that improvements can be made as the City develops better relationships with stakeholders and becomes more experienced in port inventory building.

5. Consider various scenarios:

Ultimately, emissions inventory data seeks to inform decision making on most appropriate climate mitigation measures and technologies. It is good to bear this in mind from inception, so that various future scenarios can be evaluated for emission reduction. Many city economic plans are based on growth, so an expected growth of emissions over time under a business-as-usual scenario need to be considered in comparison to future expected climate mitigation measures. Providing powerful and easy-to-understand emission visualisations can serve well as an addition for planning documents and for stakeholder presentations.

JAKARTA

A GHG reporting platform to improve climate data monitoring, verification & reporting coordination across multiple stakeholders

DATA CHALLENGE

- Access to data
- **Data management systems**

CLIMATE AREA

- Air Quality
- Energy
- **GHG Emissions**
- Green Infrastructure
- Waste

DATA MANAGEMENT BEST PRACTICES

- **Data Management Strategy**
- Data Quality & Assurance
- Data Use & Decision Making
- **Leadership & Governance**
- **Technology & Systems**

SOLUTION SNAPSHOT

- New datasets
- **Web-based platform for data management**

This project demonstrates the importance of **Leadership & Governance** through the clear arrangements with all data owners involved in GHG data collection and reporting. It also highlights the benefit of a good **Data Management Strategy** and an integrated climate data management system with clear data protocols and consolidated verification, analysis and evaluation. Such a strategy can be further enhanced with improved **Technology & Systems**, such as the development of a city-wide GHG reporting platform.

OVERVIEW

As Indonesia develops their national GHG inventory, the role of regional governments in measuring and reporting GHG emissions needs strengthening.

This is why the city of Jakarta committed to develop and regularly update their own community-scale GHG inventory. In addition, the City of Jakarta is aiming to reduce GHG emissions by as much as 35 million tCO2e by 2030 and take further ambitious climate mitigation and adaptation measures through robust climate action planning.

However, the lack of consolidated reporting and monitoring processes, as well as clarity in institutional arrangements and data collection procedures, has affected the city's ability to gather high-quality data and undertake robust data analysis to support ambitious and inclusive climate action and bring wider benefits to residents.

What has the city achieved?

Supported by the C40 Empowering Cities with Data Programme and partners, Jakarta analysed their 2015–2017 inventory reports in order to identify the gaps in the city's current GHG inventory data collection, management and governance.

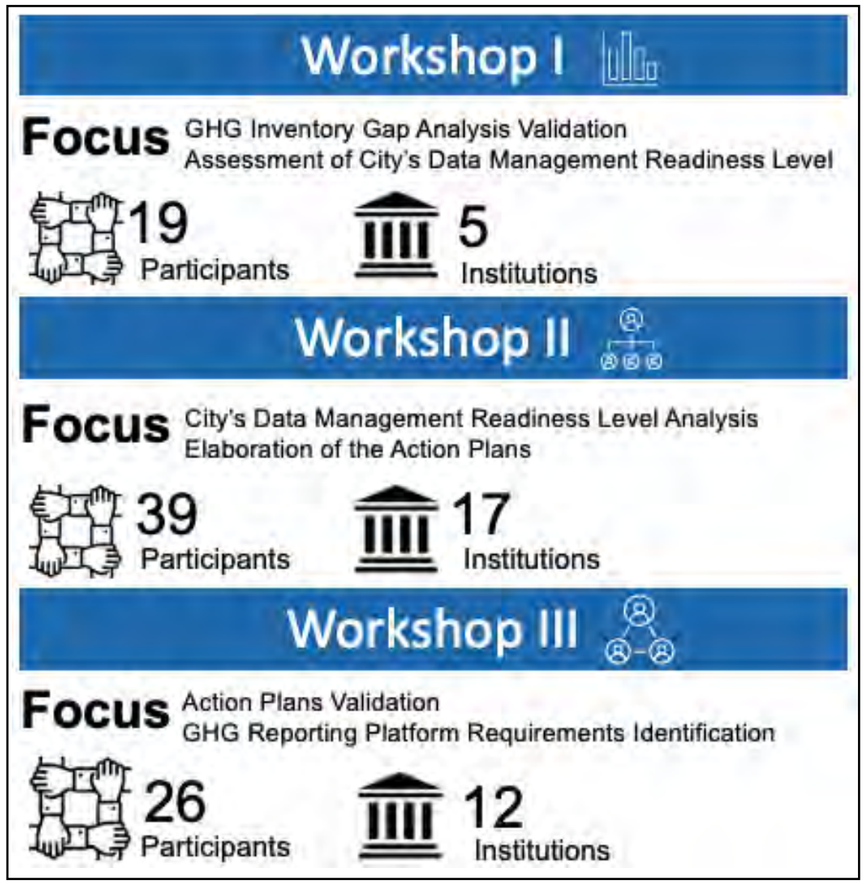
This helped identify opportunities for improvement both in the quality of data and the systems applied in managing such data. Several key recommendations have been made, including the need to strengthen data verification and validation procedures and to develop official guidelines for each of the data stakeholders involved to ensure consistency, accuracy and timeliness of data reporting.

Following on from the analysis of the GHG inventories, three workshops took place which gathered together 80+ participants from 30+ institutions, including the Jakarta Environmental Agency and other city agencies and bodies responsible for providing the data (e.g. Transportation; Public Housing; Spatial Planning; Food Security; Maritime Affairs and Agriculture agencies amongst others). The stakeholder workshops helped assess the city's data management readiness level by using the ECWD framework and questionnaire, and

led to the creation of a roadmap with specific actions across 12 data challenges, as identified during the gap analysis, to improve the city's data management processes and systems in the near future.

A transparent, user-friendly and easily accessible GHG reporting platform was identified as key to help facilitate the city's GHG data collection and reporting process across the multitude of data stakeholders. The platform allows data stakeholders to input their activity data according to consolidated reporting templates, automatically calculate GHG emissions, and display all the new and historical information with a visually appealing data trend dashboard for each of the priority sectors as mandated by the Minister of Environment and Forestry regulation No. 73/2017, i.e. energy, waste, and agriculture, forestry and other land use. The platform is also able to export GHG data in the required format for easy integration with the Indonesian National Inventory System and in line with the national guidelines on implementing and reporting greenhouse gas Inventories.

Figure 12: Stakeholder engagement overview



Top tips to deliver this solution in your city

1. Establish a clear strategy and process:

It is worth to invest time and resources into the early stages of climate data management strategy development. These might include: I) GHG inventory gap analysis, identifying areas for improvement in existing climate data management policies, practices, systems and processes; II) stakeholder mapping, where all relevant stakeholders and their roles in data ownership and management are identified; III) stakeholder engagement, for example through workshops, where initial mapping can be discussed and validated, and action plans agreed. This strategy allows all stakeholders to be involved in the development of the data management action plan, which increases the likelihood of successful delivery. In Jakarta's case, stakeholders such as the Waste Water Management Regional Company, the Food Security, Maritime Affairs and Agriculture Agency, or PT Indonesia Power were identified as key actors and data providers.

2. Clearly define data providers' roles and build ownership:

Given the multidisciplinary and inter-departmental nature of climate solutions and, therefore, of city climate data management, it is important that the city department in charge of climate data management provides guidelines to data providers. This helps to establish clear data governance arrangements and creates transparency on how their inputs are used, helping to improve data provider buy-in and overall city climate data management.

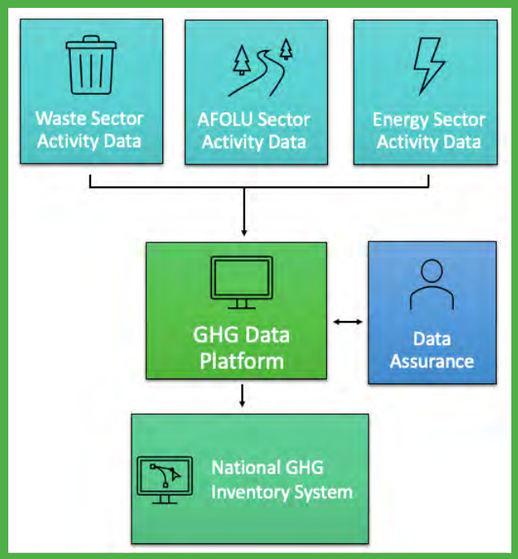
3. Ensure that the data management system suits the needs of the city and users:

It is becoming increasingly important to think strategically and holistically about climate data needs to enable cities to extract the most value from the data they collect. Jakarta's GHG reporting platform's requirements and features were developed by incorporating direct feedback from stakeholders involved in the city's data management strategy improvement process. For example, the platform is tailored to convert urban activity data inputted by data providers into GHG emissions; limits access to certain confidential data to only authorised users; has quality control procedures; and is easily integrable with the National GHG Inventory System, amongst other features.

4. Build skills to maximise efficient use of the platform:

Comprehensive training should be delivered to both the administrators - in this case the Jakarta Environmental Agency - and data contributors (those city departments/ agencies/bodies and enterprises required to report activity data). Furthermore, a clear and detailed user manual should be developed and made accessible via download directly from the platform. This will help to ensure the continued high-quality and comparability of data collected.

Figure 13: GHG emissions platform architecture



JOHANNESBURG

A low-cost approach to assessing the performance of urban solar water heaters and photovoltaic systems to boost their efficiency

DATA CHALLENGE

- **Access to data**
- Data management systems

CLIMATE AREA

- Air Quality
- **Energy**
- GHG Emissions
- Green Infrastructure
- Waste

DATA MANAGEMENT BEST PRACTICES

- Data Management Strategy
- **Data Quality & Assurance**
- **Data Use & Decision Making**
- Leadership & Governance
- **Technology & Systems**

SOLUTION SNAPSHOT

- **New datasets**
- **Web-based platform for data management**

This project shows the relevance of **Data Quality & Assurance** and **Technology & Systems**. It focused on establishing a standard framework and process to generate accurate data about the location and performance of solar water heaters and photovoltaic systems installed across the municipality, using an innovative AI Machine Learning approach. Showcasing **Data Use & Decision Making**, it helps the city understand and improve the effectiveness of their approach to carbon emissions reduction and renewable energy deployment.

OVERVIEW

Johannesburg's Department of Housing installed about 76,000 household solar water heaters (SWHs) over 2008 - 2016, to reduce energy bills for residents. During the same period, private organisations and households also started installing solar photovoltaic systems (SPVs) on their roofs.

However, the lack of formal records of their location and operational status had limited further rollouts and prevented performance assessments. City Power, Johannesburg's electricity utility, could not confidently attribute the decline in electricity demand to either their energy efficiency strategies, or behavioural change among residents, or its transmission or distribution losses. The city also lacked sufficient data to report to the National Energy Regulator of South Africa, which requires this information to assess the impact of these measures on the national electrical grid. Johannesburg urgently needed a low-cost tool to acquire the missing data.

What has the city achieved?

With the support of the C40 Empowering Cities with Data Programme, the University of Johannesburg's Process, Energy and Environmental Technology Station developed an innovative artificial intelligence (AI) and machine learning (ML) approach to compare aerial imageries of Johannesburg from 2015 and 2019 and generate a dataset of the installed solar water heaters and photovoltaic systems, including their geospatial distribution and orientation relative to the sun.

Together with physical performance verification conducted through surveys, this enabled Johannesburg to determine not only the location and operational status of part of these systems, but also the energy and greenhouse gas (GHG) savings associated with their operation.

This AI model identified 133,986 SWHs installed as of 2019, an increase of 3.5% since 2015. However, 50% of SWHs were reported as being non-functioning at the time of the physical verification, prompting Johannesburg to implement a maintenance strategy to protect the investment made.

Nevertheless, energy savings compared to a business-as-usual scenario have been estimated to be 48.9 GWh/annum, with CO2e emissions savings amounting to 49,000 t/annum, and the social cost of carbon gained calculated to be US$2.2 million per annum.

The AI model also identified 6,830 privately installed solar photovoltaic systems in 2019, an increase of 51% since 2015. However, due to low participation in physical surveys of the SPVs, the operational status could not be determined across a significant enough sample.

In a scenario where the SPVs are assumed to have an average capacity of 5kW per system, electricity demand from the grid would be reduced by 36.4 GWh per annum, with CO2 savings estimated at 36,000 tonnes per annum, and the social cost of carbon gained of US$1.6 million per annum.

Figure 14: Geospatial distribution of AI-derived solar water heaters and solar photovoltaic systems in Johannesburg

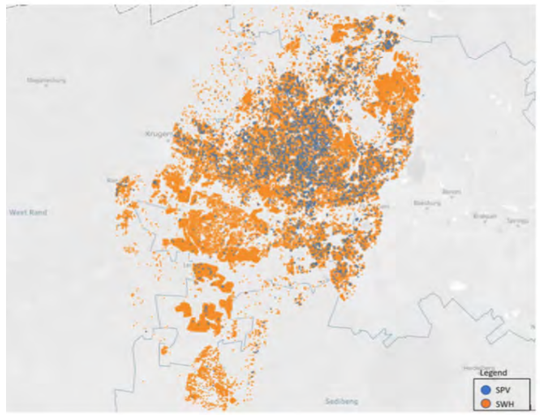
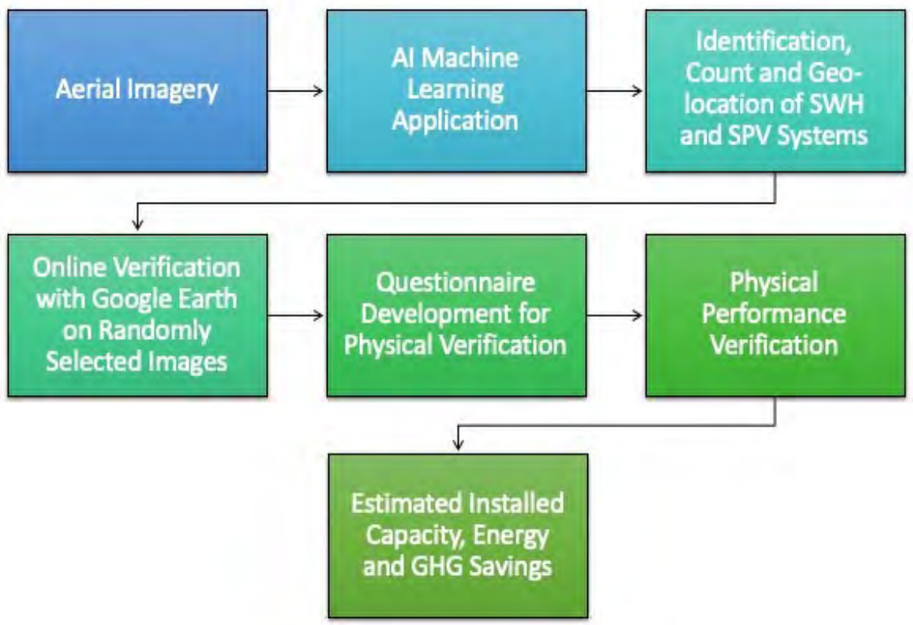


Figure 15: Methodological framework for assessing the performance of urban solar water heaters and photovoltaic systems



Top tips to deliver this solution in your city:

1. Use artificial intelligence to analyse aerial imagery:

Estimating the installed capacity of the SPVs and SWHs might be a challenge in many cities, as city governments have limited resources (staff and budgets) to monitor and respond to changes in the clean energy landscape. The application of machine learning to aerial images to geo-locate the SPVs and SWHs is an innovative and low-cost solution, often best carried out in partnership with a local university. The spatial data can be captured by the city (e.g. Johannesburg's City GIS Department) or by third-party or open-source providers. To ensure the project is replicable, use standard computer packages, such as a geocoordinates database in CSV format, and Google Earth to verify the locations accuracy.

2. Collect good spatial imagery:

Both projection misalignment and loss of detail may be experienced when comparing spatial imagery between different years, which partly affected this project's 2019 dataset, because images were captured during the winter season. Additional image processing, validation from Google images and a physical verification exercise were required. It is recommended to capture aerial images during summer months to allow for a more refined spatial analysis.

3. Create a replicable project:

It is fundamental to develop a knowledge package to facilitate the repeatability of the project at low cost and making it applicable to other municipal sectors. In this case, artificial intelligence and machine learning technology demonstrations have been delivered to Johannesburg's Environmental and Infrastructure Service Department for the identification of illegal dumpsites, and to City Power to assess solar power installation potential for rooftop space across the city.

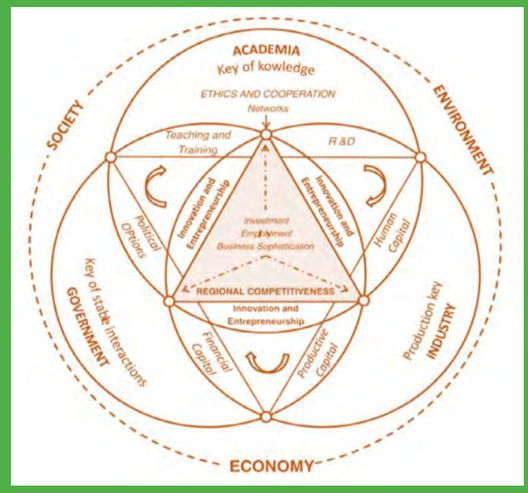
4. Encourage collaboration between academia, municipal governments and industry:

This project implemented a triple helix innovation and collaboration model, promoting multidisciplinary and multistakeholder research and development. City staff across sectors and other stakeholders, such as the Smart Cities Technical Steering Committee and City Power, received training on the model. The regional knowledge ecosystem created opportunities for localised innovation and knowledge transfer supporting data-driven decision making.

5. Consider business partnership for survey verification:

Physical verification on a representative data sample is essential to confirm the operational status of the solar systems and inform the modelling of energy and GHG emissions saved. However, determining the operational status of privately-owned SPVs might be challenging, if the target groups (SPVs owners) are reluctant to take part in the survey. In such cases, it is recommended to partner with local SPV installers who have access to a wide network. Additionally, engagement with the SPVs users on the regulatory requirements for grid and off-grid connections over a longer period can create buy-in and increase verification rates.

Figure 16: Triple Helix collaboration model (link)



LAGOS

Understanding the energy consumption patterns in informal settlements to improve livelihoods

DATA CHALLENGE

- **Access to data**
- Data management systems

CLIMATE AREA

- Air Quality
- **Energy**
- GHG Emissions
- Green Infrastructure
- Waste

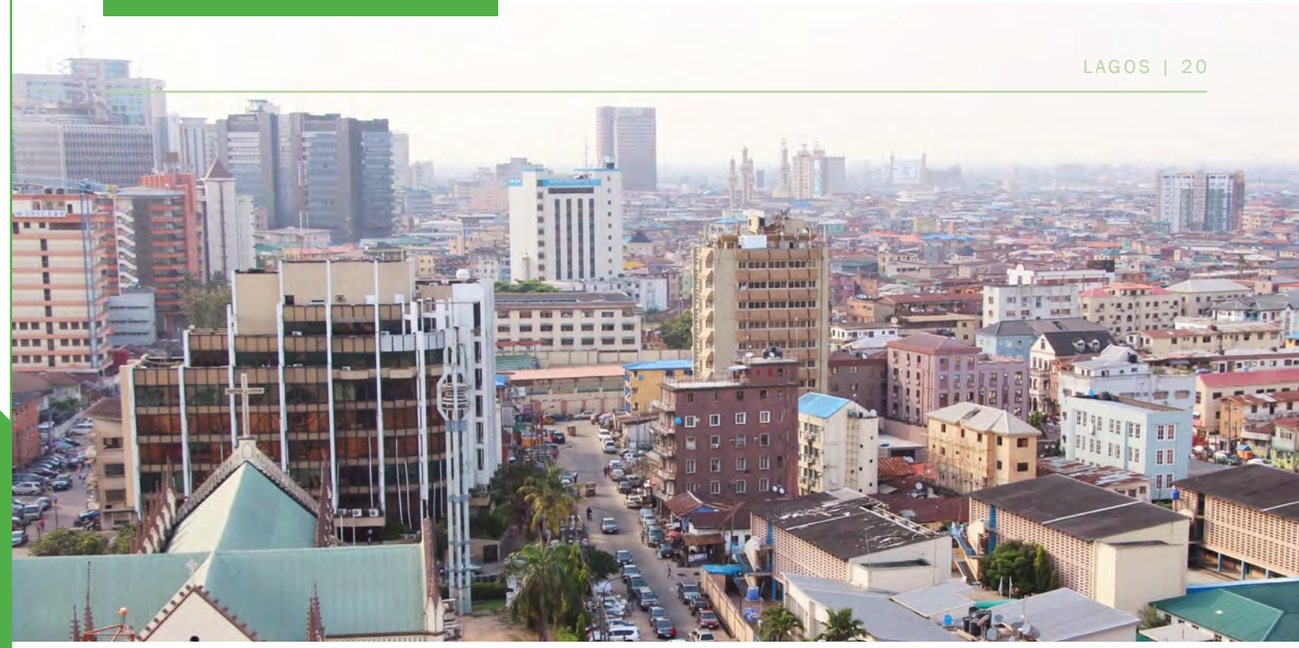
DATA MANAGEMENT BEST PRACTICES

- Data Management Strategy
- **Data Quality & Assurance**
- Data Use & Decision Making
- **Leadership & Governance**
- Technology & Systems

SOLUTION SNAPSHOT

- **New datasets**
- Web-based platform for data management

This project illustrates best practice localised approaches to **Data Quality & Assurance** during a development of a new climate dataset. Data collection process with a clear methodology adapted to the local context and focus on quality control ensured responses were standardised and comparable. This project is also a great example of **Leadership & Governance**, as it included skills development for city officials and local community representatives on survey design, while building on their local knowledge and experiences.



OVERVIEW

As in other rapidly growing African cities, the majority of Lagos' residents are believed to live in informal settlements. At the same time, data used to estimate city-wide energy use and GHG emissions is usually extracted from datasets not covering informal settlements for a number of reasons, including lack of energy meters and informal connections to electricity grids.

This project aimed to address the gaps in the available city data on energy consumption patterns from cooking and electricity/ lighting in informal settlements, as well as associated GHG emissions. The data was collected through participatory surveys co-designed and carried out together with the local communities, to improve clean energy access and quality of life through better indoor air quality, while avoiding an increase in local carbon emissions.

What has the city achieved?

With support from C40, a study was carried out across 181 informal settlements in metropolitan Lagos by Justice & Empowerment Initiatives (JEI), in partnership with the Nigerian Slum/Informal Settlement Federation, both affiliates of Slum Dwellers International (SDI). The project involved a five-part survey, which gathered data to understand behaviours related to cooking and lighting. The survey was deployed using mobile phones and tablets operated by local community field surveyors and included a household energy inventory. The data collected enables planning of actions that can enable greater access to clean energy in informal settlements to improve quality of life.

Based on the survey results, households in Lagos' informal settlements were categorised as Tier 2-3 for cooking and electricity/lighting related energy access according to the World Bank/ESMAP Multi-Tier Framework for Energy Access (with Tier 0 being no access and Tier 5 being the highest level of access). For electricity access, for example, this corresponds to limited hours per day during which power is accessible and also some voltage problems that might damage appliances. For cooking solutions access, for example, this characterises average fuel expenditure of >5% of household income or can indicate lack of primary fuel availability.

Although lower energy access means households have a relatively low carbon footprint, numerous interventions could improve quality of life through better indoor air quality thanks to clean energy access and keep the carbon footprint low:

- To encourage greater rates of transition to LPG for cooking (a cleaner fuel when compared to traditional kerosene, charcoal or firewood), government programmes can help to address the real and perceived cost of cleaner energy (e.g. initial purchase of a gas canister) and fear barriers (e.g. fear to handle gas equipment). Financial support schemes should be tailored to the cashflow realities of urban poor households, for example by supporting the upfront costs of purchasing an LPG canister and allowing longer repayment timelines. Households that switch to LPG were found to spend the least in ongoing costs compared to others using traditional fuels, therefore incresing their ability to repay the loans.
- To encourage transition to cleaner energy for other uses, creating solar mini-grids, supported by targeted 'hands-on' training and financing schemes, can help spread the upfront costs and tackle the cost and knowledge barriers.

Through this study, the city of Lagos also estimated the median annual per capita GHG emissions in informal settlements - 0.16 tCO2e per person per year - based on responses from over 3,000 diverse households across 16 local government areas. However, the total volume of GHG emissions from informal settlements cannot yet be estimated reliably and will require further reseatch, due to lack of confidence in existing estimates of Lagos slum population numbers.

While this study helped establish the current baseline, to track changes in energy consumption resulting from new government or private initiatives put in place, it should be replicated regularly. Given the level of effort required to reach the scale of the current study – over 3,000 surveys requiring up to two months of fieldwork – it is recommended to replicate this exercise about every three years, involving both local communities and city officials in survey design, training and the fieldwork to help build a greater rapport and synergy.

3,129 households

181 settlements

Oke Philomena

My name is Oke Philomena. I have been in Makoko for 55 years now. I gave birth to all my children in Makoko.

I use firewood for cooking before but now I'm using charcoal. I also use stove at times. I stopped using firewood because of the heat and the smoke coming from it is not good for my health. But the charcoal doesn't have much smoke. I cook every day, I also sell grinded tomatoes after grinding it I cook it so that it won't spoil.

I can also use gas for my cooking because gas is faster, but I don't use gas because I don't know how to use it. Before I will use gas someone will have to train or teach me how to use it.

Top tips to deliver this solution in your city

1. Conduct a pilot survey to gather broader context:

A pre-survey questionnaire is useful to collect general settlement-level data on community connections to public electricity supply, the typology of household structures, the predominant ethnic/language groups, and location factors (e.g. proximity to water bodies, railways, etc.). This helps identify the minimum representative number and types of informal settlements for the study.

2. Tailor the survey to local community:

Forming the surveyor teams primarily of field surveyors from informal communities in each local area can help leverage local familiarity and language skills and reduce the distances travelled. In addition, testing a pilot version of the survey can help identify challenging questions, clarify terminology, improve the answer options, and standardise common units of measurement. For example, informal households might not use standard measures in their purchase of fuel (e.g. kg). The surveyors should help respondents identify standard quantities by, for example, showing local charcoal bags and firewood bundles for reference. Households may also struggle to identify chronic health conditions. Therefore, answer options should be tailored to local lived experiences (e.g. 'persistent cough', 'difficulty breathing'). The full survey process is best approached in a participatory manner, valuing both the knowledge of professionals and their grassroots counterparts who bring a unique understanding of the local terrain.

3. Build local capacity:

In the Lagos project, all field surveyors went through a day-long training which covered the purpose of the survey and each question; interview techniques and strategies to overcome challenges in the field; and the sampling methodology. A rolling training is recommended, as it allows more experienced surveyors to help train the next group or to offer on-site support. Furthermore, as trainees might sometimes have lower levels of formal education, training should include the basics of climate change, as well as practical skills such as how to identify the capacity of a generator or a solar panel, or how to calculate expenditures.

Temitope Adugba

My name is Temitope Adugba. I have been in Makoko now for a very long time. I was born and brought up in the community.

I use solar for lighting. I used electricity before but the bill is high so I stop using it. If the solar damage, I throw it away and buy new one because if it is faulty I don't know where to repair it. I bought the panel at N4,500 and the bulb at N13,000.

The difference between the solar that I am using and electricity is that the panel is small one it can't power anything. It is being used for lighting only. But with [public] electricity you can use it to power everything like the radio, television, charging of phone and so on. If I see any other alternative that I can I used for powering and lighting I will use. But I don't like anything with smoke. I don't like anything with smoke because I am a fashion designer I don't want smoke to stain my work.

LIMA

Implementation of a low-cost accessible air quality network to support city interventions for clean air

DATA CHALLENGE

- Access to data
- Data management systems

CLIMATE AREA

- Air Quality
- Energy
- GHG Emissions
- Green Infrastructure
- Waste

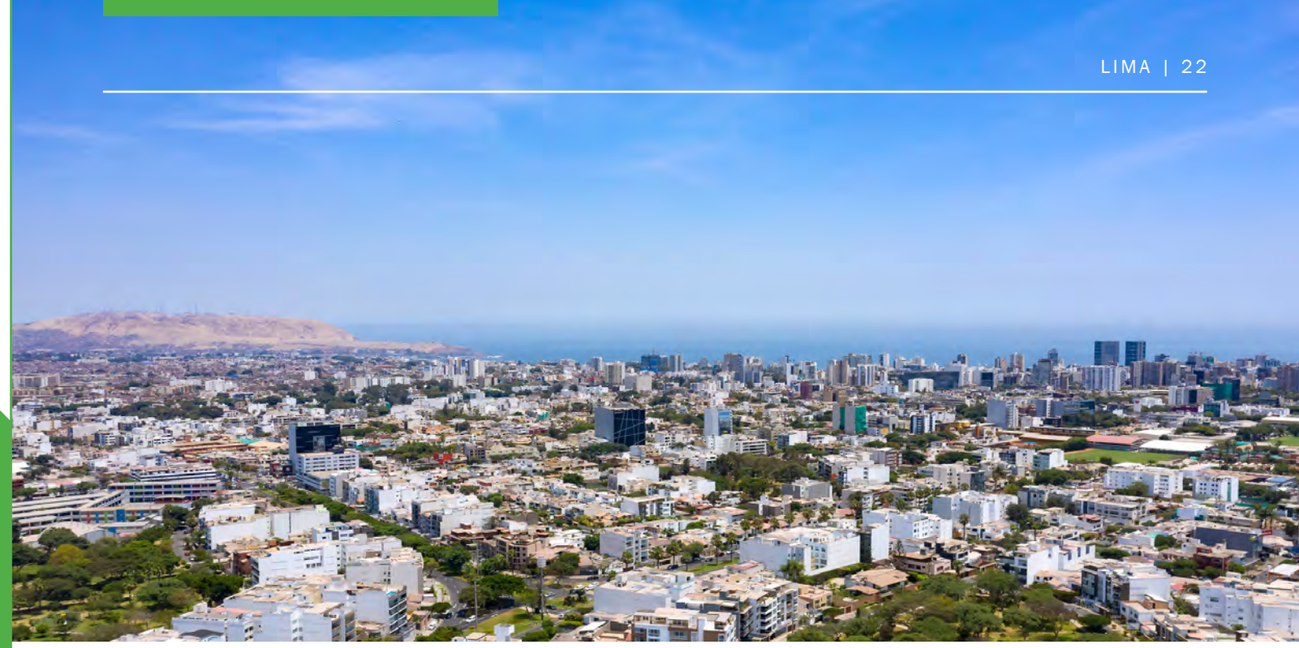
DATA MANAGEMENT BEST PRACTICES

- Data Management Strategy
- Data Quality & Assurance
- Data Use & Decision Making
- Leadership & Governance
- Technology & Systems

SOLUTION SNAPSHOT

- New datasets
- Web-based platform for data management

This project is an inspiring example of how a city can strengthen their air quality monitoring efforts through the deployment of low-cost sensors. It is particularly relevant for **Data Use & Decision Making** as it informs evidence-based actions to safeguard residents from dangerous levels of air pollutants. The project also illustrates the benefits of **Data Quality & Assurance** and **Leadership & Governance** by following precise monitoring guidelines and setting up the institutional arrangements required when it comes to site identification and equipment maintenance.



OVERVIEW

In Latin America and the Caribbean, at least 100 million people are exposed to air pollution levels above those recommended by the WHO (Cifuentes et al, 2005). Metropolitan Lima, which is home to 32.5% of the Peruvian population with its 10 million inhabitants, records the highest national levels of air pollution, due to high population density, growing automobile fleet and an extensive presence of industry and retail businesses.

In the past, air quality monitoring within Metropolitan Lima had been carried out by 19 fixed stations, with ten owned by the National Meteorology and Hydrology Service (SENAMHI), seven by the General Directorate of Health (DIGESA) and two by the Urban Transport Authority. These stations only cover 18 of the 49 districts of the metropolitan area. Expanding the air quality monitoring network in Lima was key, especially so as to include areas with high population density and neighbourhoods with high amounts of projected urban growth.

What has the city achieved?

With support from the C40 Empowering Cities with Data Programme, and in collaboration with qAIRA, the Municipality of Lima has deployed a new network composed of ten low-cost air quality sensors across eight additional districts of Metropolitan Lima, complementing and supporting the existing air quality monitoring system.

These sensors (qHAWAX), which collect data on CO, NO2, SO2, O3, H2S, PM10 and PM2.5, as well as meteorological conditions such as humidity, temperature, UV, atmospheric pressure and noise level, can also be easily expanded to new areas. This is due to their low cost, mobility, ease of installation, data download functions, and the possibility of working online with real-time measurement data.

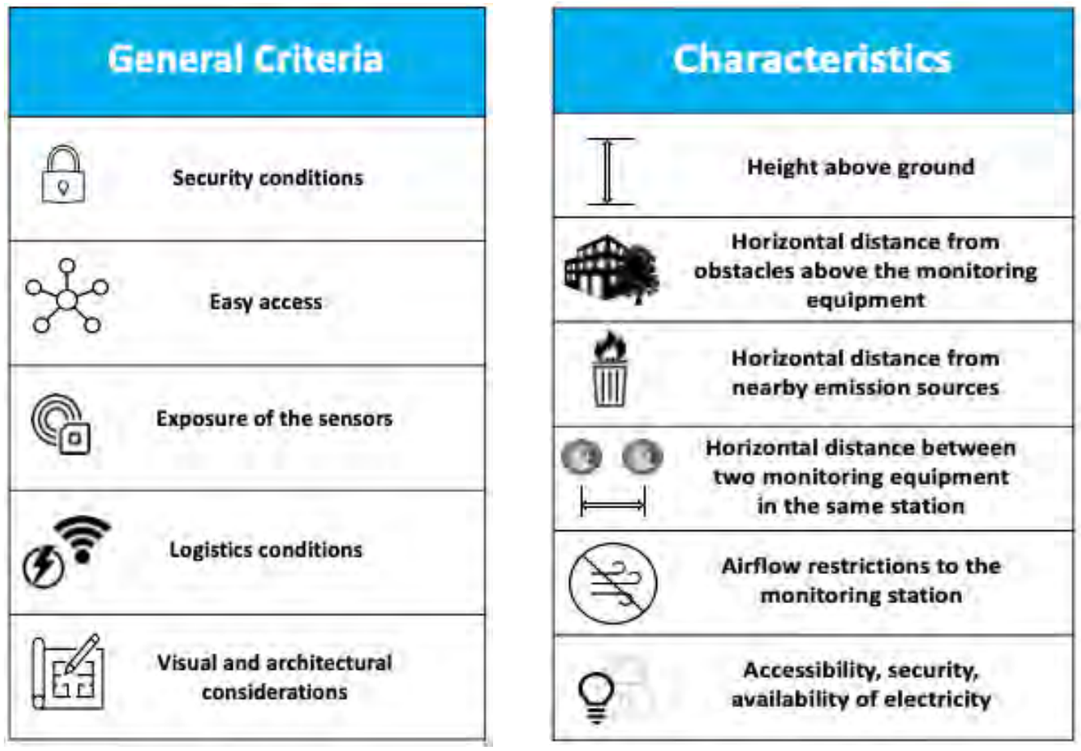
The pilot data, which was collected between February and May 2021, shows that although air quality concerning H2S, CO, NO2 and O3 was largely ‘good’ or ‘moderate’ across all locations, SO2, PM10 and PM2.5 concentrations exceeded the Peruvian Environmental Quality Standard and WHO guidelines in many instances. This was the case particularly in the northern and eastern districts of the city, with its high concentration of industrial and commercial areas (such as brick and animal food production, perfumery,

hygiene products, cosmetics, plastics and paper industries, and concrete and cement manufacturers), as well as in most of the central areas of Lima, which are prone to high rates of traffic congestion.

These findings informed the 'Air Quality Assessment in the Context of Covid-19 – Challenges for Environmental Improvements' paper, in which 14 measures are proposed to improve air quality to levels experienced when Covid-19-related movement restrictions were in place. Finally, districts with high levels of air pollution, especially of particulate matter, have been identified and a more targeted assessment is being carried out with more sophisticated but also costly equipment (recommended by the Peruvian guidelines).

Following the successful deployment of these ten low-cost sensors, the municipality of Lima purchased twenty additional low-cost monitors as part of increasing efforts to strengthen the air quality monitoring network. Additionally, the city and the 'Horizonte Ciudadano' Foundation are in the process of executing the "New Air for Early Childhood" initiative, which aims to implement a monitoring network focused specifically on air pollutant exposure by children. Five additional sensors have already been deployed in places such as paediatric centres and schools.

Figure 17: General principles for identifying air quality monitoring locations



Top tips to deliver this solution in your city

1. Carefully identify the air quality monitoring locations:

In the project which took place in Lima, the National Air Quality Monitoring Protocol and the recommendations of the US Environmental Protection Agency for monitoring were used to guide the positioning and location of air quality monitoring stations. In general, it is recommended to locate stations I) in areas with the highest expected concentrations of pollutants; II) in areas with the highest population density (optimised to measure the exposure of air pollutants on the population and the transport of pollutants, together with all meteorological variables); III) in areas of projected urban growth. On the left are some of the recommended characteristics to consider when evaluating where to install the monitoring stations.

2. Evaluate any low-cost equipment performance before deployment:

It is recommended to always compare performance of a new type of sensor against a regulation-grade tested monitor. In Lima, the intercomparison phase was carried out according to the "National Protocol for the Monitoring of Environmental Air Quality" (2019), by taking measurements simultaneously with a DIGESA station between September to December 2020. Determining if the low-cost equipment has a sufficient level of accuracy to carry out the precise measurements of the pollutants present in the air is fundamental to ensure a high-quality dataset. A series of performance procedures and parameters should be evaluated during the intercomparison phase, such as: data recovery, quality control, intra-model variability, coefficient of variability and bias, Pearson's correlation coefficient, root mean square error, and determination coefficient.

3. Develop complementary actions to institutionalise and improve the assessment of air pollution:

The Municipality of Lima is continuously exploring activities to improve the evaluation of air pollution in the city. For example, the city approved a "Protocol for the implementation of the network of air quality monitoring modules based on alternative procedures", whose purpose is to deploy a low-cost network within each district jurisdiction to evaluate air quality where it had not been possible before, due to high costs involved with traditional monitoring stations. The "Guidelines for evaluating the field performance of low-cost sensors for monitoring environmental air quality" established the procedures and methodology to perform intercomparison tests with a reference station, in order to guarantee the reliability of data from any new candidate low-cost sensors.

4. Strengthen collaboration with district municipalities of the metropolitan area:

The involvement of district municipalities is a crucial step for the successful deployment of a city-wide monitoring network, as well as to prepare local action plans to improve air quality. In Lima, this was very useful not only to guarantee the safety of the installed equipment, but also gave this project confidence, viability and sustainability over time. In metropolitan areas such as Lima, district municipalities should be involved not only during the identification of the monitoring locations, but also during the installation and maintenance of such stations. This can help strengthen notions of local ownership of the monitoring campaign and build necessary skills among local staff to keep the equipment functional over time.

QUITO

Integrating various air quality data analyses in a unified visualisation platform

DATA CHALLENGE

- Access to data
- **Data management systems**

CLIMATE AREA

- **Air Quality**
- Energy
- GHG Emissions
- Green Infrastructure
- Waste

DATA MANAGEMENT BEST PRACTICES

- Data Management Strategy
- Data Quality & Assurance
- Data Use & Decision Making
- **Leadership & Governance**
- **Technology & Systems**

SOLUTION SNAPSHOT

- New datasets
- **Web-based platform for data management**

This project is a great example of how **Technology & Systems** can assist cities in interpreting large datasets, undertake historical trend analysis and inform the evaluation of the impacts of a particular programme or initiative. This project is particularly relevant for **Leadership & Governance** as it illustrates the benefits of capacity building amongst city staff, helps derive meaningful insights from the air quality data collected, and generates health alarms using forecasted data to protect the most vulnerable residents.

OVERVIEW

Over the past 15 years, air quality data in Quito has been collected by sensors of the Metropolitan Air Quality Monitoring Network (REMMAQ). However, such data was stored by different systems with different databases, each with its own architecture, structure and access. The latest system launched in 2016 only contained data from that date and up to the present day. This caused problems when end users required data over longer periods. In such cases, they had to separately approach the Secretariat of Environment to access data from the previous years.

Additionally, the existing system was not available in Spanish and did not display all the relevant detail easily. To integrate all the data in one database and provide more analytical and visualisation outputs, the City of Quito commissioned a new integrated system that would allow it to make better informed decisions based on meaningful insights from the data collected through REMMAQ.

What has the city achieved?

With support from the C40 Empowering Cities with Data Programme and in collaboration with a local software developer, the City of Quito has developed its new 'REMMAQ|Visor' platform. This platform, available in Spanish and English, is able to interrogate, analyse, visualise and download over 300 million data points which REMMAQ has generated to date, concerning PM10, PM2.5, SO2, O3, NOx, CO as well as meteorological conditions such as wind, temperature, relative humidity, rainfall, UV radiation and air pressure.

Furthermore, it integrates five-day forecasted air pollution data generated by NASA's forecasting system, which helps issue warnings to areas that are expected to experience hazardous levels of air pollution.

The platform has an internal and public-facing interface. The internal interface shows the spatial distribution of the REMMAQ, provides summary statistics such as minimum, maximum, and one-hour, eight-hour and 24-hour average concentrations, and offers the opportunity to filter, visualise and download all data according to the monitoring station, pollutant, date and timeframe selected.

Data is visualised through the platform not only with concentration values (e.g. µg/m3) but also according to the Air Quality International Index (AQI) and Quito Air Quality Index (IQCA) classification to facilitate immediate understanding of the public health risks associated with the specific pollution level recorded.

The public-facing interface consists of a dashboard where Quito residents can access a real-time snapshot (up to 30 days old) of the air quality and meteorological conditions in their city.

This platform will not only allow the city of Quito to access all the data generated to date by REMMAQ from one place, but will also assist the city in generating annual air quality reports in accordance with the current national regulations and, most importantly, measure the effectiveness of city clean air policies implemented over time.

"The new REMMAQ|Visor has been developed considering the millions of data collected since 2004.

As a local government institution, the intention was to make this data available for the general public in a comprehensive way, so the visualization of our data was a key concern during the development. The data is displayed in graphics easy to understand by anyone.

This will become an important tool for the Metropolitan Air Quality Monitoring Network (REMMAQ) staff to analyse, correct and validate historic data."

Coordinator of Monitoring, Analysis and Research Unit, City of Quito

Figure 18: A public-facing view of the REMMAQ|Visor air quality monitoring platform

Top tips to deliver this solution in your city

1. A citizen portal helps inform the most sensitive population:

Air pollution is one of the biggest environmental health threats of our time. Residents of Quito can now access near real-time data about the local air quality on the citizen portal of the REMMAQ|Visor platform, which is also available for mobile phones. This is especially important for sensitive population groups, such as elderly people, people with chronic diseases and/or pregnant women. Moreover, a public web-platform can increase awareness of air quality among the citizens.

2. Integrate air pollution forecasted data:

Real-time or near real-time data gives a snapshot of the air quality status at the present time. However, if accurate early warnings of poor air quality are to be issued, especially to protect the most vulnerable communities, the integration of forecasted data into the analytical platform can help reduce their risk of exposure to poor air, for example, by prompting local authorities to limit outdoor activities at these times.

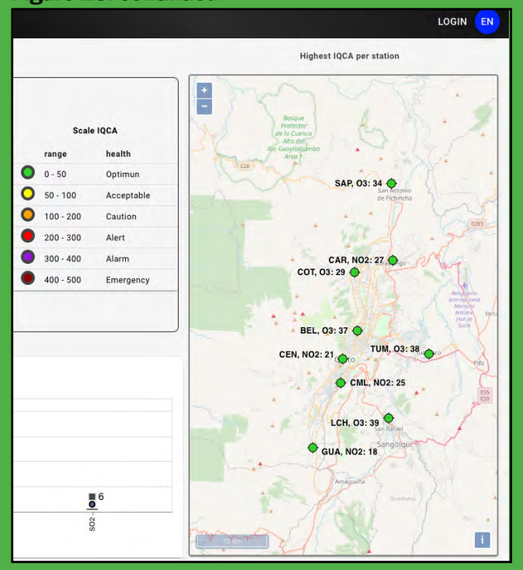
3. Build analytical outputs to derive powerful insights from the data:

Building an air quality platform able to perform basic analysis on the 'live' data constantly generated by the monitoring stations is crucial if meaningful insights are to be derived from the data collected. The types of analytical outputs should be aligned with any national or local reporting requirements and should allow easy interrogation of the data. The analysis should include basic aspects of the air quality levels, such as minimum, maximum and mean level for each pollutant within a specific timeframe and location, and, as in the case of Quito, more complex calculations such as how many days in a given period experienced air quality worse than the city's Air Quality Index standards. Any analytical outputs should be closely tailored to the specific city needs and type of decision-making they should inform.

4. Build city capacity on programming for statistical computing and graphics:

An important factor for efficiently administering and adjusting an interactive website such as the REMMAQ|Visor platform is to build in-house city capacity on the source code and the system functionalities. In Quito, 20 hours of basic training on a wide variety of statistical and graphical techniques has been delivered to city officials in charge of research, analysis and monitoring of air quality and meteorological data. The training covered the basis of 'R', the platform's programming language and environment for statistical computation and graphics. City staff will be able to resolve issues that may occur with the system and meet any new user requirements. To ensure long-term use, it is important that all training material is packaged together in an accessible way, so that it can be re-used in the future to build extra capacity within the city.

Figure 18: *continued*



Conclusion

Timely and accurate climate and air quality data is more important than ever as world cities seek to reduce the health and economic impacts of the COVID-19 pandemic, and as they implement their ambitious inclusive climate action plans aligned with the 1.5˚C goal of the Paris Agreement.

The Climate Data Management Framework and the innovative best practice "How to?" case studies featured in this report aim to help cities put in place the best data strategies and processes. These can then inform robust decision-making, help attract investment and secure broad support for ambitious climate actions by demonstrating their benefits. We hope you found this report helpful and invite you to visit the C40 Knowledge Hub to find out even more about data in C40 cities!

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"Tough questions need to be asked."

City Representative

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