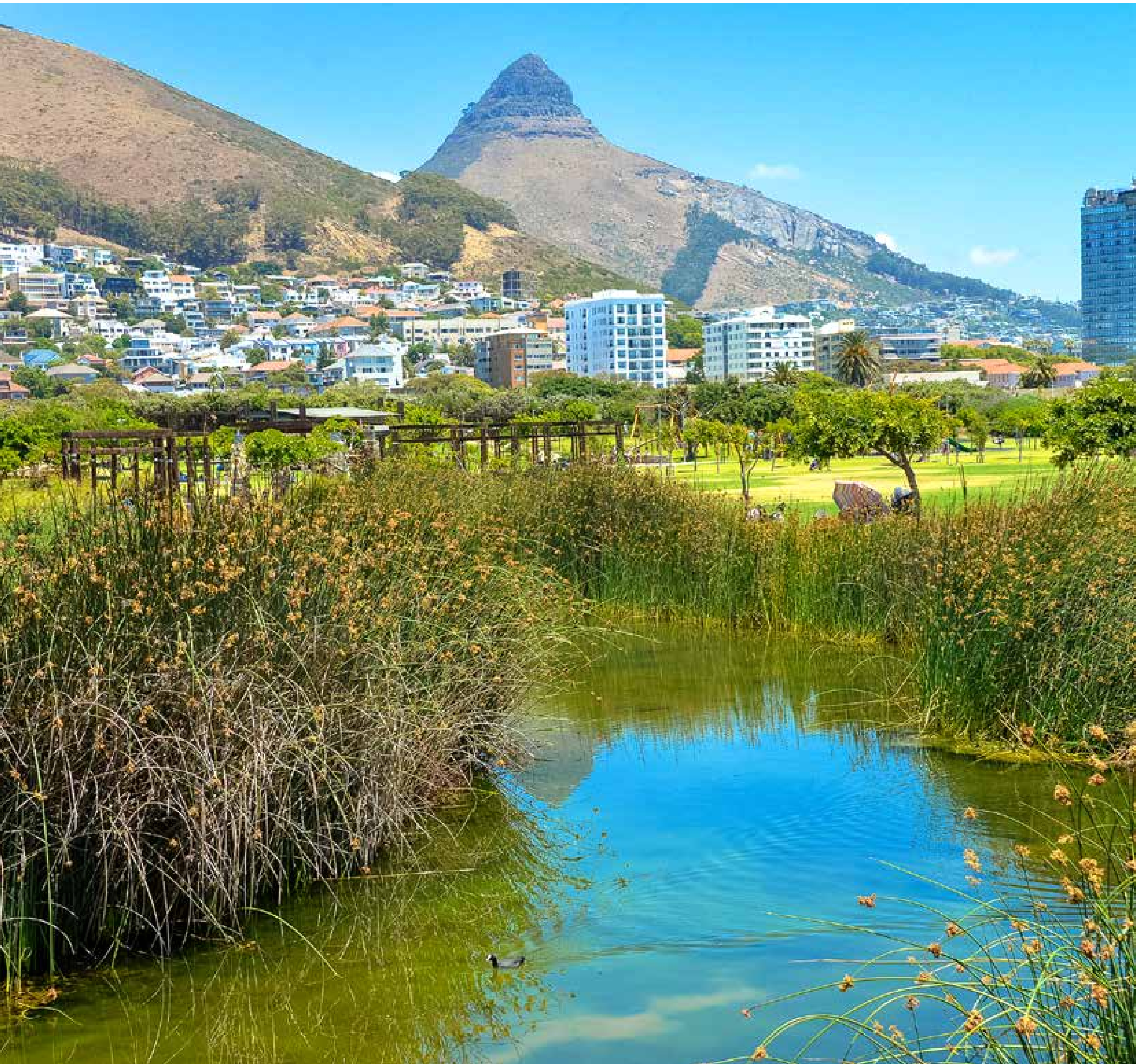
URBAN METABOLISM IN CAPE TOWN:
Resource Flows and the 2018 Water Crisis



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Acronyms

DAFF	Department of Agriculture, Forestry and Fisheries (of Cape Town)
DMR	Department of Mineral Resources (Cape Town)
DOE	Department of Energy (Cape Town)
GAIN	Growth and Intelligence Network
GI-REC	Global Initiative for Resource Efficient Cities
ISO	International Organization for Standardization
uMAMA	Urban Modelling and Metabolism Assessment
UNEP	United Nations Environment Programme
WSDP	Water Service Development Plan
ZAR	South African Rand

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Introduction

Urban metabolism is a field of research that has found growing interest in the academic world. At the core of this field is the idea that urban (un)sustainability can be better understood by monitoring the full cycle of resource flows within a city. At the same time, cities have started using urban metabolism concepts to get a more holistic understanding of material flows and improve monitoring of resource requirements and impacts.

This document provides a description of urban metabolism geared towards the City of Cape Town. It looks into the potential as well as the challenges for Cape Town to use urban metabolism as a tool for environmental monitoring and reporting. It is written for people without in-depth knowledge of this topic, but who are familiar with environmental challenges and efforts around sustainability at the City of Cape Town. The first part of this report explains what urban metabolism is and how it is being used. Next, data sources, departments, and other relevant units or reports that currently exist in the City of Cape Town are described. The report then illustrates the concept through a deeper dive into a specific application to the city's ongoing water crisis. Finally, an overview of the difficulties as well as the potential options to use urban metabolism in Cape Town is provided. The report concludes with an overview of concrete recommendations that would allow the City to take this idea forward and get the most out of urban metabolism.

What is urban metabolism?

A city is a complex living system that needs resources in order to function, enabling its residents to live quality lives and supporting the economy which services and employs the population. Similar to an ecosystem, in cities we can observe a myriad of relationships, interactions and flows of food, materials, water, energy, money, information and people. These flows manoeuvre through the city with the aid of infrastructure systems, such as roads, treatment works, pipes, buses, electric-lines, power-plants, fibre-optic cables, garbage trucks, radio waves, train-tracks and people. We have all learned how to access and use these infrastructures and the flows they provide – our perceptions, expectations and behaviours are part of these systems and have far reaching consequences.

However, we often don't look further to understand how these systems function or how resources arrive at our home or work. Improving our understanding of these systems is important, given that the production, transportation and consumption of resource services and goods are the main causes of humanity's negative environmental impact. Improving how we produce, transport and consume these resources has direct consequences for current and future sustainability. In places where there are large inequalities, improving sustainability also means improving access to decent services for large parts of the population. Doing this would typically increase overall resource demands, so innovative approaches are required to improve service access in the most resource-efficient ways.

Urban metabolism assessments help us understand how cities provide and consume resources and allow us to reshape cities to be more sustainable and resilient to change. By quantifying and mapping different resource flows, we can show decision-makers where resources are most used, where interventions may be possible, and what types of interventions are necessary (e.g. policies, technical changes, behavioural changes).

The stages of a resource flow show that it is (a) sourced in the environment, (b) converted for use, (c) used by urban residents or for economic production by business and industry, (d) reconverted to re-enter the environment, and then is (e) dumped, disposed of or sunk back into the environment. Each stage has implications for the resilience or sustainability of the city and can be improved with appropriate interventions. One popular approach is to create circular metabolisms which keep resources circulating in the city, rather than following only the linear path described above. This means that less resources need to be sourced from nature, and less of the 'wastes' pollute the environment.

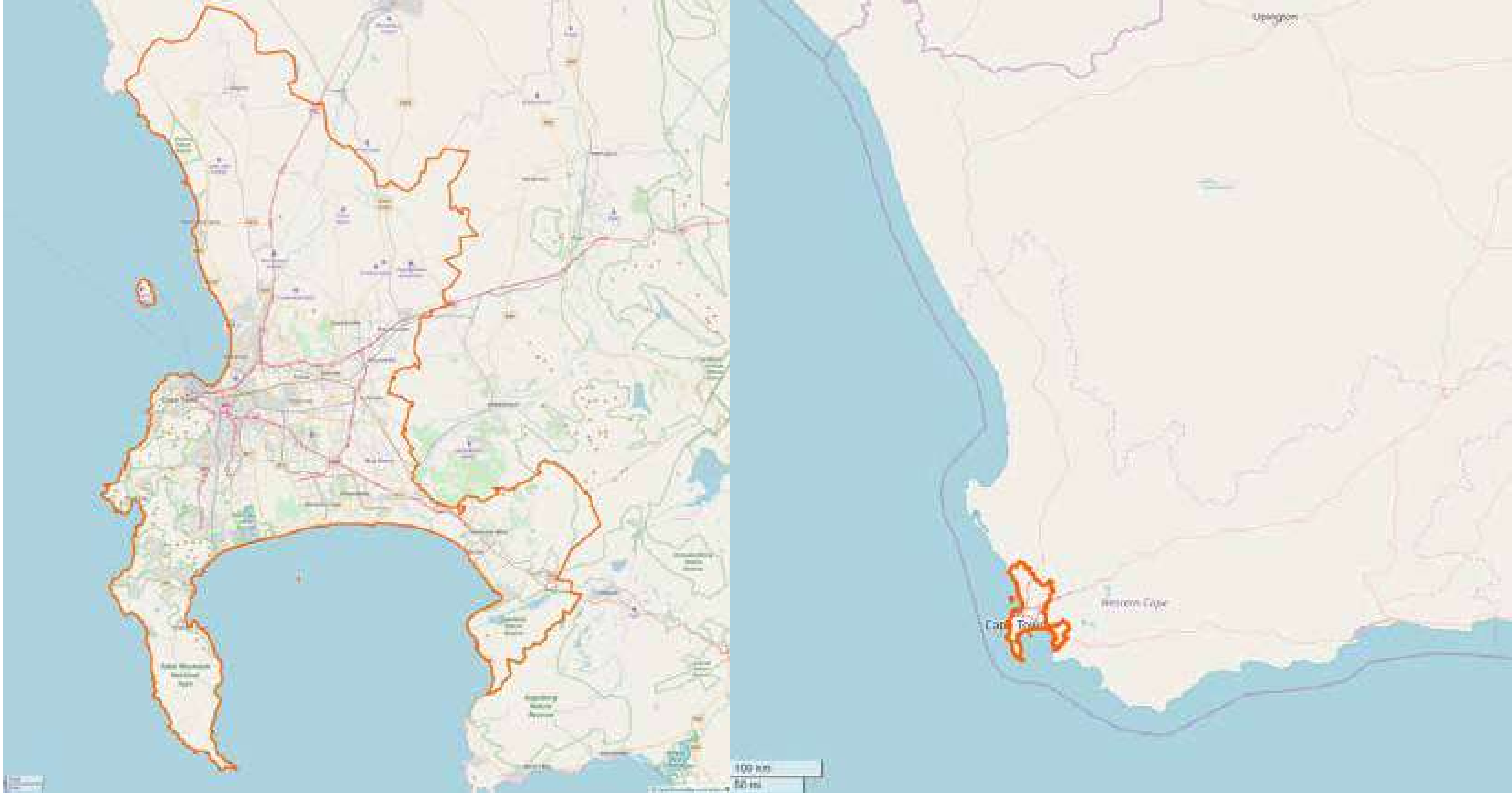


Figure 1: Boundaries of the Metropolitan Municipality of Cape Town (left) and the location of Cape Town in the southwestern tip of Africa (right). Source: Open Street Map.[i]

City governments and urban metabolism

Local governments can use urban metabolism in different ways. In fact, many governments already use concepts related to urban metabolism in their environmental reporting or policy, without necessarily giving it this name. The first main use of urban metabolism is to provide structure and vision within environmental data collection efforts. Many city governments often collect and report (internally or externally) on a variety of different environmental indicators. These efforts are not necessarily coordinated, centralized, or cross-validated. By using an urban metabolism approach, data collection can become a more unified activity, that connects the work and data from different departments and that looks at the city and its resources as a whole, taking into account the entire life-cycle of each resource flow. This approach can significantly improve the usage, understanding and quality of environmental data.

A second use of urban metabolism relates to the tools and indicators that can be applied using urban metabolism data. By using well-documented frameworks, the resulting data will comply with the required formats for tools like ecological footprint analysis, carbon footprints, quality of life and city services assessments, and tools related to life-cycle assessments. This will allow cities to standardize reporting and increase compatibility and comparability with other cities.

The uptake of urban metabolism at local governments varies significantly, depending on data availability, political interest, local knowledge, and environmental priorities. For many decades, academic work has focused on cities in the global north.[1] However, in the past ten years a lot of new work has been undertaken to study a larger variety of cities.[2] After an initial purely academic pursuit, the use of urban metabolism at a practical level, within local governments, is now becoming more commonplace as well. Some of these efforts include the implementation of tools and reporting by city governments (for instance, work done in Amsterdam, Brussels, or Sorsogon City, Philippines), as well as efforts by global initiatives (including urban metabolism *mainstreaming* work by the World Bank and the Global Initiative for Resource Efficient Cities by the UN). Through these kinds of collaboration, cities not only gain additional insight into solutions and policies from their peers but individual cities also receive additional international exposure.

1 See for instance the following review paper: Kennedy, C., Pincetl, S. and Bunje, P., 2011. *The study of urban metabolism and its applications to urban planning and design.* Environmental pollution, 159(8), pp.1965-1973.

2 See for instance the urban metabolism work on Asian Cities by the Asian Development Bank or the urban metabolism studies by the World Bank.

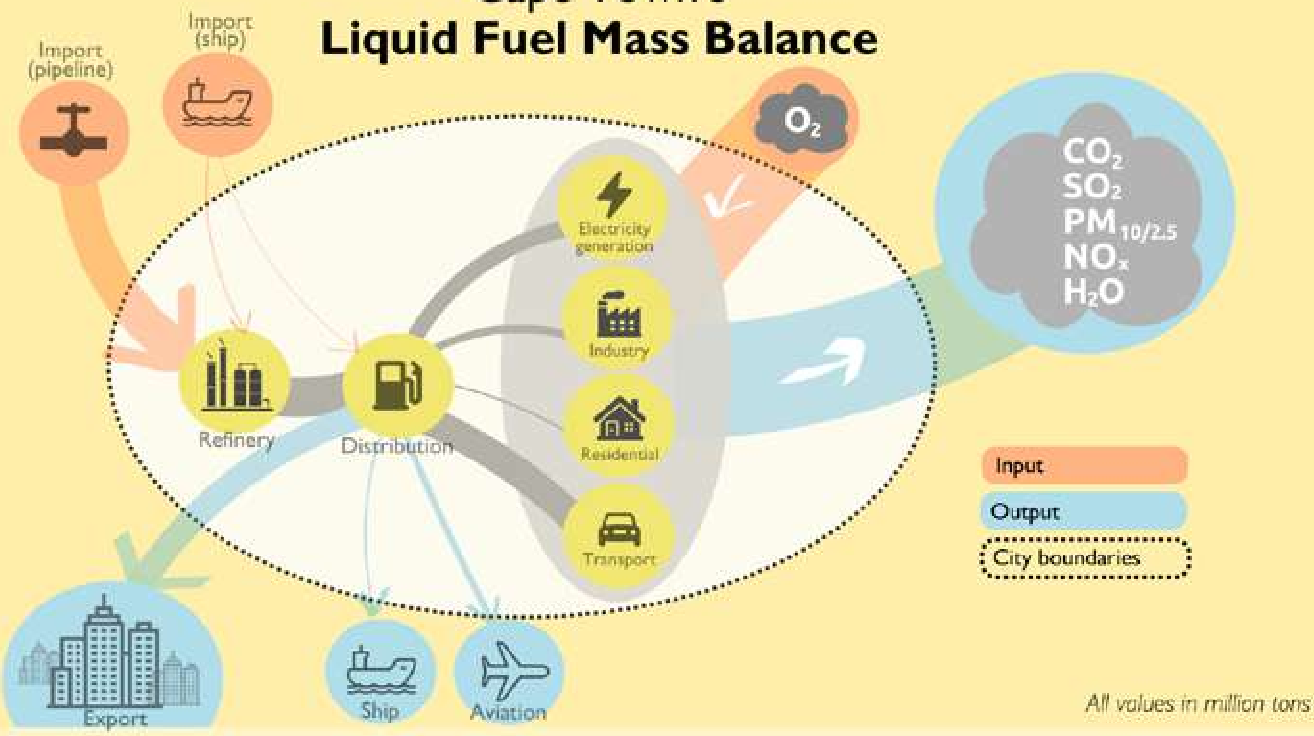
Cape Town urban metabolism data

Currently, environmental monitoring and reporting at the City of Cape Town mostly considers individual flows and materials (e.g. emissions of pollutants or solid waste quantities). The principal benefit of urban metabolism, however, is to look at the city as a large, connected system. After describing the individual datasets, this alternative approach and its benefits will be discussed.[3]

- **Agriculture:** A large variety of crops are produced within Cape Town, primarily wheat, lucerne, and wine grapes, and claims a significant portion of Cape Town's surface area (> 40,000 hectares). The most important organization with comprehensive data on the agricultural production of Cape Town is the Western Cape Department of Agriculture (Elsenburg), which uses aerial surveys to map all land in the province dedicated to agriculture, and to identify crops grown on each plot.
- **Fisheries:** Various large, international fishing companies own vessels, processing plants, and other infrastructure in and around Cape Town. Data on fish catches throughout the country are reported to the Department of Agriculture, Forestry and Fisheries (DAFF). Some species are monitored more closely, such as hake and horse mackerel. Data on recreational and small-scale fishers are not readily available.
- **Mining:** Mining operations in Cape Town principally include sand, aggregate, and to a lesser extent clay and industrial minerals. Most of these minerals are used within Cape Town for construction, brick, and glass manufacturing, among other uses. The Department of Mineral Resources regulates mines and collects data on mineral production.
- **Energy and fossil fuels:** Fossil fuels are brought into Cape Town either as processed product, or as crude oil, which is subsequently processed at the Chevron refinery. Monthly data on fossil fuel sales is made available by the Department of Energy.[4] The Air Quality Management Unit at the City of Cape Town also keeps an inventory of fossil fuel consumption in the City. The City has released various *Cape Town State of Energy* reports,[5] at four to five year intervals. It is the most detailed report when it comes to fossil fuel consumption and emission data on a city-wide level and various data sources and datasets associated with this report can be linked with fossil fuel and energy flows. Figure 4: Cape Town's Fossil Fuel Mass Balance provides an overview of how fossil fuels flow through the City of Cape Town. In addition to a visual representation of the different production and distribution networks, interaction through imports and exports is also shown. The width of the arrows indicates the size of each flow.
- **Freight:** Cape Town is a regional hub for freight and goods transported by rail, road, air, and sea. Detailed, city-wide, and up-to-date freight information is available through the Growth and Intelligence Network (GAIN).[6] This organization, a consultancy firm operating from Stellenbosch, provides a Freight Demand Model for the whole country, broken down by magisterial district. Data are furthermore broken down by different commodities (based on the Harmonized System).
- **Water:** Nearly all of Cape Town's water supply (98%) comes from surface water. Depending on the location and technology used at the wastewater treatment plant, treated effluent is discharged into the natural environment (rivers, vleis, or the ocean), or used in agriculture or for irrigation purposes. One of the most relevant reports published by the Water and Sanitation Department at the City of Cape Town is the *Annual WSDP Performance and Water Services Audit Report*.
(A more detailed study of the water situation can be found in the next section).
- **Waste:** Solid waste is generally disposed of at landfills within Cape Town's boundaries. Various projects exist in the city to increase re-use and recycling and to minimize waste, including recycling drop-off centres, material recovery facilities, food waste collection and industrial symbiosis projects. The City Solid Waste Department has data on landfilled waste including a broad breakdown of types of waste, as well as data on diverted waste. Recycling rates and figures are more difficult to obtain, as many private operators exist in the city.

3 Unless noted otherwise, figures on material flows come from the following material flow analysis done on Cape Town: Hoekman, P. and Blottnitz, H., 2017. Cape Town's Metabolism: Insights from a Material Flow Analysis. *Journal of Industrial Ecology*, 21(5), pp.1237-1249.
4 See: the website of the Department of Energy.
5 Download the 2015 State of Energy report here.
6 Website: http://gaingroup.co.za.

Cape Town's
Liquid Fuel Mass Balance



All values in million tons

Crude oil import and processing

Input		Output	
Crude oil imports		*Processed product*	
By boat	500	Diesel	1,790
By pipeline	3,929	Petrol	1,762
		Jet fuel	299
For combustion		Other	433
Oxygen	492		
		Due to combustion	
		CO_2	447
		SO_2	3
		Water	186
	4,920		**4,920**

Local fossil fuel consumption

Input		Output	
Fuels		*Emissions*	
Diesel	1,156	CO_2	6,941
Petrol	926	SO_2	13
Jet fuel	0	NO_x	30
Other	143	VOCs	50
		PM_{10}	10
Gases		$PM_{2.5}$	8
Oxygen	7,579	Water	2,752
	9,804		**9,804**

Fossil fuel flow breakdown

	Import	Local Production	Export	Local Consumption
Diesel	328	1,790	961	1,156
Petrol	172	1,762	1,008	926
Jet fuel	0	299	299	0
Other	97	433	388	143
	597	**4,284**	**2,656**	**2,225**
	4,881		**4,881**	

All figures are based on 2013 Material Flow Analysis. Fuels include crude oil, petrol, diesel, jet fuel, LPG, paraffin, aviation gasoline and heavy furnace oil. Simplified overview for illustration purposes.
(Hoekman, P. and Blottnitz, H., 2017. Cape Town's Metabolism: Insights from a Material Flow Analysis. Journal of Industrial Ecology, 21(5), pp.1237-1249)

Figure 2: Cape Town's Fossil Fuel Mass Balance Source: Hoekman & von Blottnitz 2016).[ii]

Material Flow	Custodian
Agriculture	Western Cape Department of Agriculture (Elsenburg)
Fish catch	Department of Agriculture, Forestry and Fisheries (DAFF)
Mining	Department of Mineral Resources (DMR)
Fossil Fuels	Department of Energy (DoE)
Freight	Growth and Intelligence Network (GAIN)
Water	City of Cape Town Water and Sanitation Department
Waste	City of Cape Town Solid Waste Department

Table 1: overview of the principal data sources and the relevant custodians

Opportunities

Obtaining high-quality material flow data on an urban level is challenging, and Cape Town is no exception. However, compared to other cities Cape Town does have a large number of available and relevant datasets. This makes Cape Town stand out from its peers in the global South and provides opportunities for the city to use urban metabolism in its environmental monitoring and reporting activities.

Given the relatively large number of datasets, there is potential in Cape Town to embed urban metabolism at the core of the City's resource monitoring efforts. The key target should be to implement a systems approach to resource monitoring. Rather than monitoring singular flows (emissions, consumption, etc.), Cape Town can put together a city-wide system that provides insight into how particular resources move through the city. The advantages of this approach, as described earlier, include a better, more holistic understanding of how different resource flows affect each other and how production, import, export, consumption, recycling and waste relate to each other.

Systems thinking refers to the theory that a complex system can best be understood by studying the different components as connected and interrelated units that all form part of a larger system. This theory has a direct link with cities and their resource flows, because there is a complex relationship between the socio-economic system and the resource requirements of a city. There is often a direct link between energy and water use, for example. Similarly, the transport infrastructure has a direct impact on fossil fuel consumption. To understand Cape Town's resource requirements, it is therefore important to try and get a holistic, city-wide understanding of material flow. This also links to concepts around a circular economy and it can allow Cape Town to understand the potential for improving its resource intensity in different sectors and resource flows.

There are various flows in Cape Town that can be monitored and unpacked within an urban metabolism framework. The most prominent ones include construction materials, energy carriers and emissions, water metabolism, and food flows. These flows are of interest because the available data makes it possible to set up a mass balance and, over time, create a system-wide understanding of these resources. At the same time, these resources directly affect Cape Town's environmental impact and resource intensity and are therefore worth monitoring more closely and holistically.

CASE STUDY:
Cape Town's Water Crisis

How to change an urban metabolism in 18 months

Understanding Cape Town's Water Metabolism

Urban metabolism studies are normally focused on helping to plan a city's long-term sustainability and resilience strategy. The current Cape Town water crisis represents a different experience of urban metabolism application: instead of using urban metabolism as a planning tool, it must be used to inform an effective response to crisis. The rest of this case study will explore how water is metabolized in the city of Cape Town, how the water system could be more sustainable, and how the water crisis has changed and will continue to shape the city's water metabolism.

Figure 3 shows a map of general stages of Cape Town's urban water cycle (icons do not show exact location). Cape Town's water is (A) abstracted from surface water and transported in bulk to 12 water treatment works which (B) treat the water to drinkable quality before distributing the potable water for (C) consumption by residents, businesses, and urban or peri-urban farms. Most of this water is then returned to the wastewater network and transported for (D) wastewater treatment before being (E) piped to the ocean through marine and river outfalls. Water used for gardening, outdoor cleaning, farming, or industry may infiltrate into the underground aquifers, run off into the oceans, or evaporate or transpirate into the atmosphere to become clouds, skipping Stage D. The bulk water system uses fresh water and is driven mostly by gravity, requiring minimal treatment and pumping,

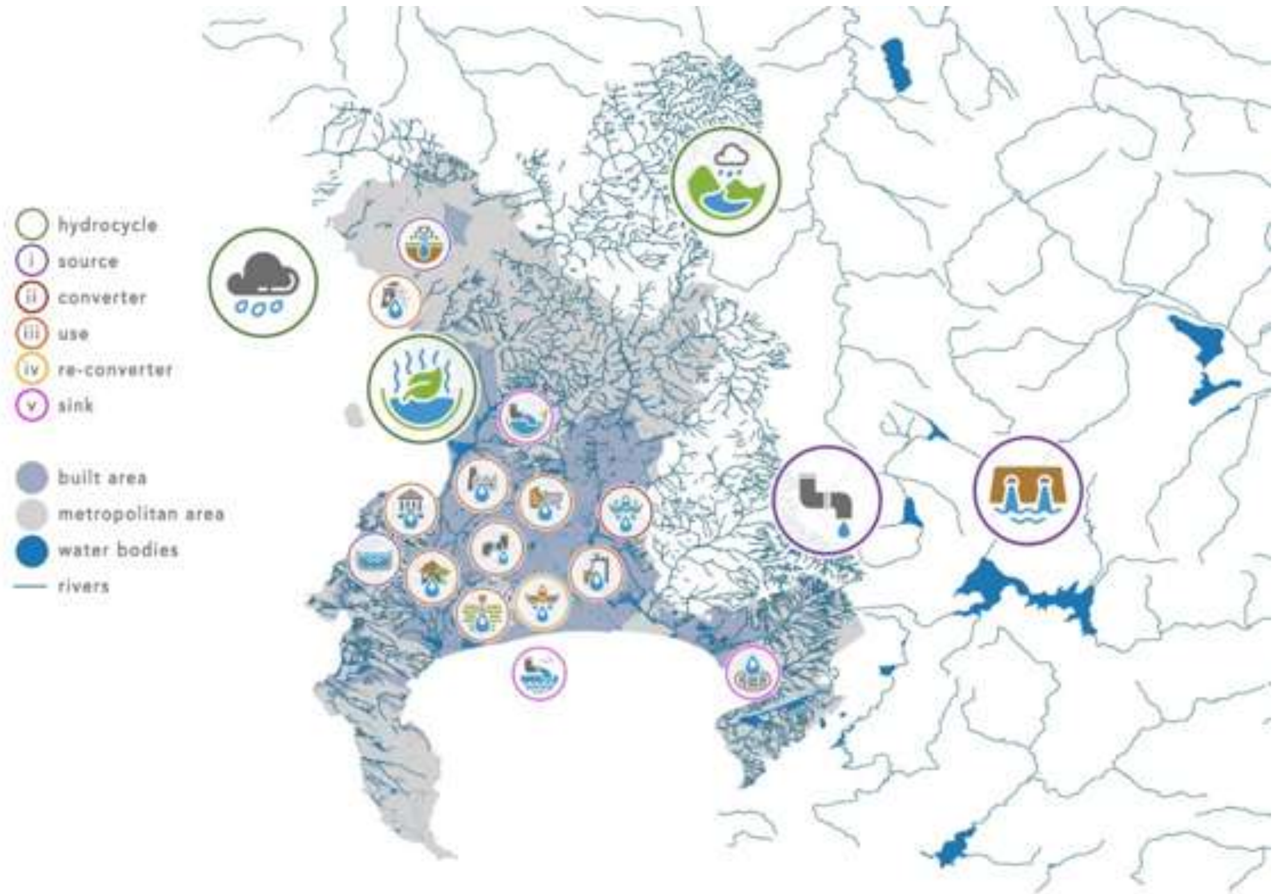


Figure 3: Cape Town's Urban water cycle. Source: Authors

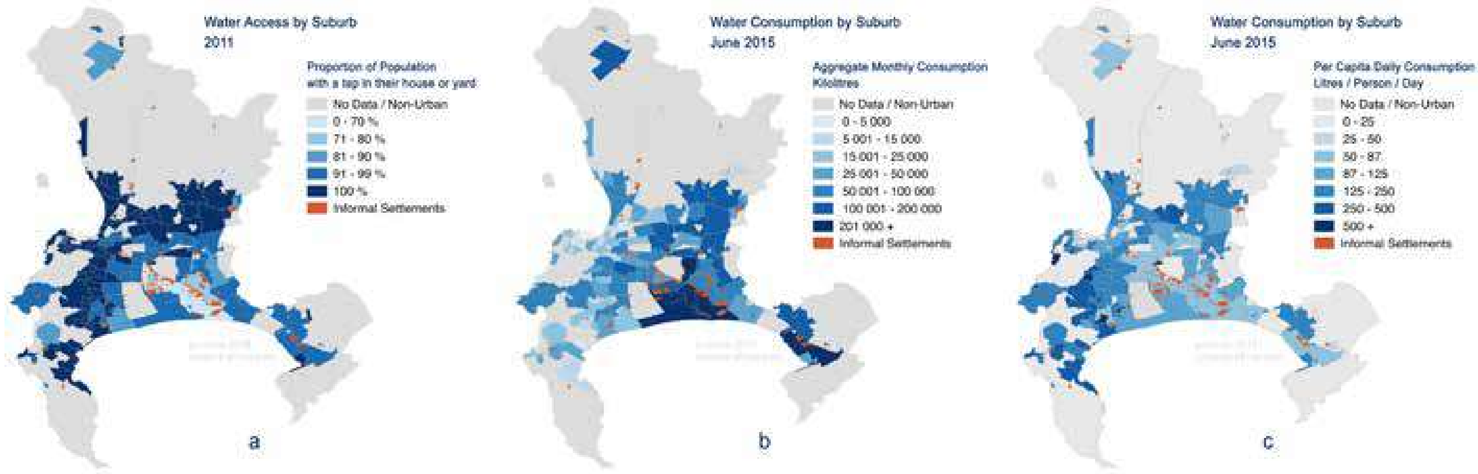


Figure 4: Different ways to spatially understand residential water consumption in Cape Town. Source: Author

making the city's water relatively cheap to produce (ZAR 4 per 1,000 litres).

Each stage of the urban water cycle can be understood to have sustainability challenges and may be improved upon. For example:

- **At Stage A**, we can see that Cape Town's water supply is reliant mainly on rainfall, reducing the city's resilience to climate change, as seen by the current drought. Improving Cape Town's resilience to climate shocks would require a diversity of supply options.
- **At Stage B** the treatment and transportation of water experiences losses due to pipe leaks. All cities experience losses (the global average is 30% whereas Cape Town is at 18%), and these can be addressed with improved reporting and maintenance systems across the city.
- **At Stage C**, perhaps the most complex part of the water metabolism, the various behaviours and consumption patterns of residents and economic sectors determine demand for water. Improving the sustainability of this stage requires improving how efficiently water is used, while at the same time ensuring that everyone has sufficient access to water. These interventions must typically be a combination of city-wide policies, behavioural changes, and technical improvements.
- **At Stage D** there must be enough capacity to treat all water flushed through the sewerage system, and the quality of treatment must ensure that whatever is released into the environment can be diffused or absorbed properly. In Cape Town, 13 of the 27 wastewater treatment works were noted to be releasing poorly treated effluent into the environment,[iii] with negative repercussions for groundwater. This stage is also where water re-use can be explored. Currently, treated effluent is being used to recharge the groundwater aquifer at the Westfleur wastewater treatment works. A feasibility study of treating wastewater at Faure works has shown a few challenges in recycling wastewater. However, despite the potential challenges, it is estimated that the re-use of potable water could create economic value of over ZAR 4.7 billion for the city.[iv]

For a city to grow its economy and improve the quality of life for its residents, a certain level of water supply is needed, though few studies speculate about what a sufficient level of water should be per person. Water is also consumed unevenly in most cities: houses with lawns and swimming pools certainly have different water needs relative to households in apartment blocks or informal dwellings.[7] An industrial area will use water in a different manner from a business district. In Cape Town, 87.3% of residents have a water tap in their home or yard, while the rest – mostly living in informal dwellings – must walk to a tap to collect water.[v] The three maps below tell different stories of water in the city: (a) which areas have what level of access to water (b) which areas consume the most water overall, and (c) which areas use the most water per person. As we can see, those with higher water access (a) are in the north, west and far east of the metropolitan area – these are typically areas of low density and more affluence, so it is no surprise that higher per person consumption (c) is witnessed there too. The highest aggregate consumption (b) in the city is found in the east – these are higher density areas, where about a third of Cape Town's population live and where we find most informal settlements.

To decide where the most effective interventions could be made to improve access to and efficient use of water, quantifying the flow of water in Cape Town is necessary. One way to do this is with a Water Balance, shown in Figure 6: Cape Town Water Balance 2016,[vi] which shows

7 Informal dwellings are typically self-built houses made with wooden frames and zinc sheeting. They are built in settlements or in the backyards of formal brick houses.

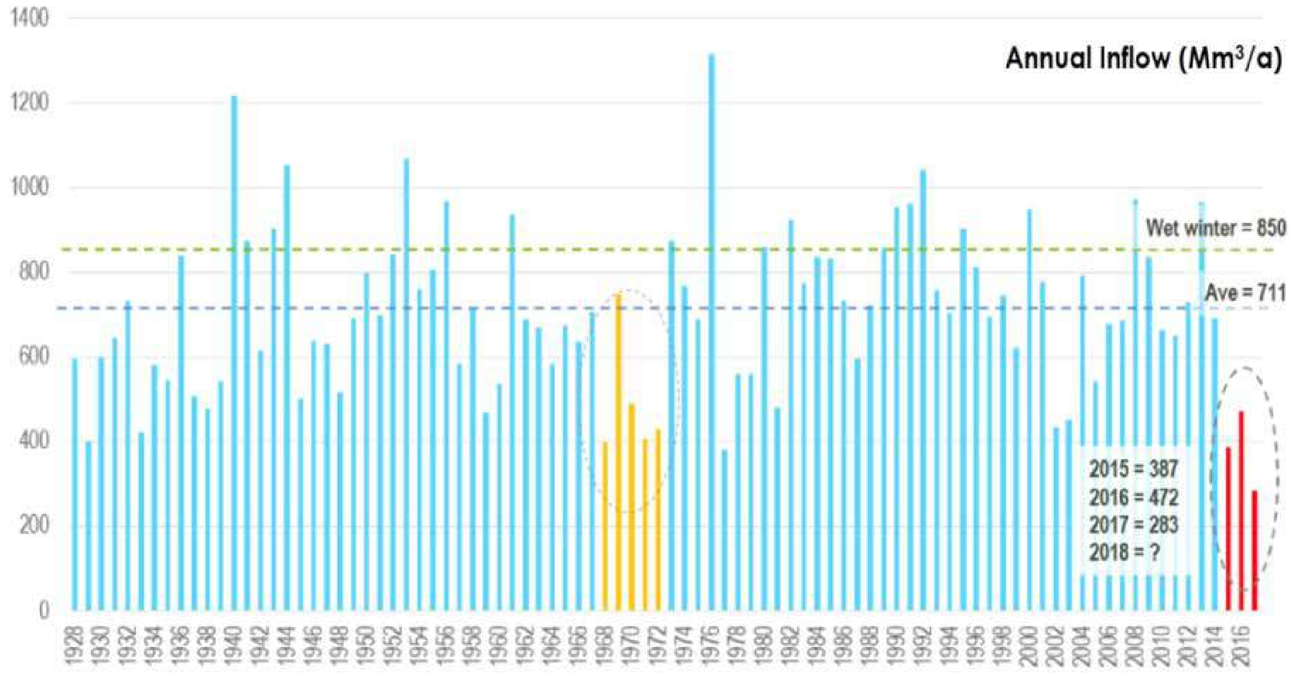


Figure 5: Rainfall 1928-2017. Source: Department of Water and Sanitation 2018.

how much water is sourced, consumed, lost and treated. The City also uses a few categories to show how water is billed – this is important as 8-9% of the City's revenue typically depends on water sales to customers, yet, as part of a redistributive economy, about 23% of water is provided free of charge to informal and certain domestic customers (noted as "Free Basic Water").

If a more circular metabolism is adopted and water recycling becomes a more mainstream source of water, it will become necessary to track the use of this type of water more accurately. Gaps in the water balance demonstrate where water is unaccounted for, lost to the system or where more data are required. Improving the tracking of water would effectively fill in these gaps, accounting for where water interacts with the environment.

Urban metabolic studies can be done at a number of system levels, allowing for resource efficiencies to be improved within each component of the system. Following the five steps of the urban metabolism framework, most water is (a) sourced from the municipality (though a household may install a rainwater harvesting tank to improve its resilience), and has likely already been (b) treated by the city.[8] Water is then (c) used for personal hygiene, cooking, washing clothes and flushing toilets and, depending on the type of home and amount of income, water could be used for entertainment, home farming or gardening, car-washing and more. Most of this water will be (d) drained back into the city sewerage system for treatment, though some will (e) sink into gardens, evaporate off pools or find its way into the environment in other ways. Understanding and encouraging change at household level has proven to be of vital importance in dealing with the city's water crisis.

How to change an urban metabolism in 18 months – Cape Town Water Crisis

The Cape Town water crisis poses a major threat to the livelihoods of Cape Town residents and the growth of its economy. What is notable is that while discussions of future urbanization suggest that rapid population growth and a swelling middle class will cause increasing demand for resources[vii, viii] Cape Town's water crisis has largely been due to supply side constraints following a very unlikely weather event in which rains failed for three consecutive years.

Average rainfall since 1928 has been about 711mm, while 2015, 2016 and 2017 produced 387, 472 and 283mm respectively[ix] (Figure 5). Whereas Cape Town's long-term water strategy suggested that demand would outstrip supply around 2022, requiring new augmentation schemes before then,[x] the suddenness of this drought took most people by surprise, particularly given that dams were overflowing as recently as 2014. This was not a slow reduction in rainfall over time, but an effective halving of rainfall and available water in just three years.

In 2015, when rains failed to supply water, the City reacted with level 2 water restrictions, a familiar response to previous droughts. While there was talk of drought, the

8 Though certain households take precautions and have filters for drinking water.

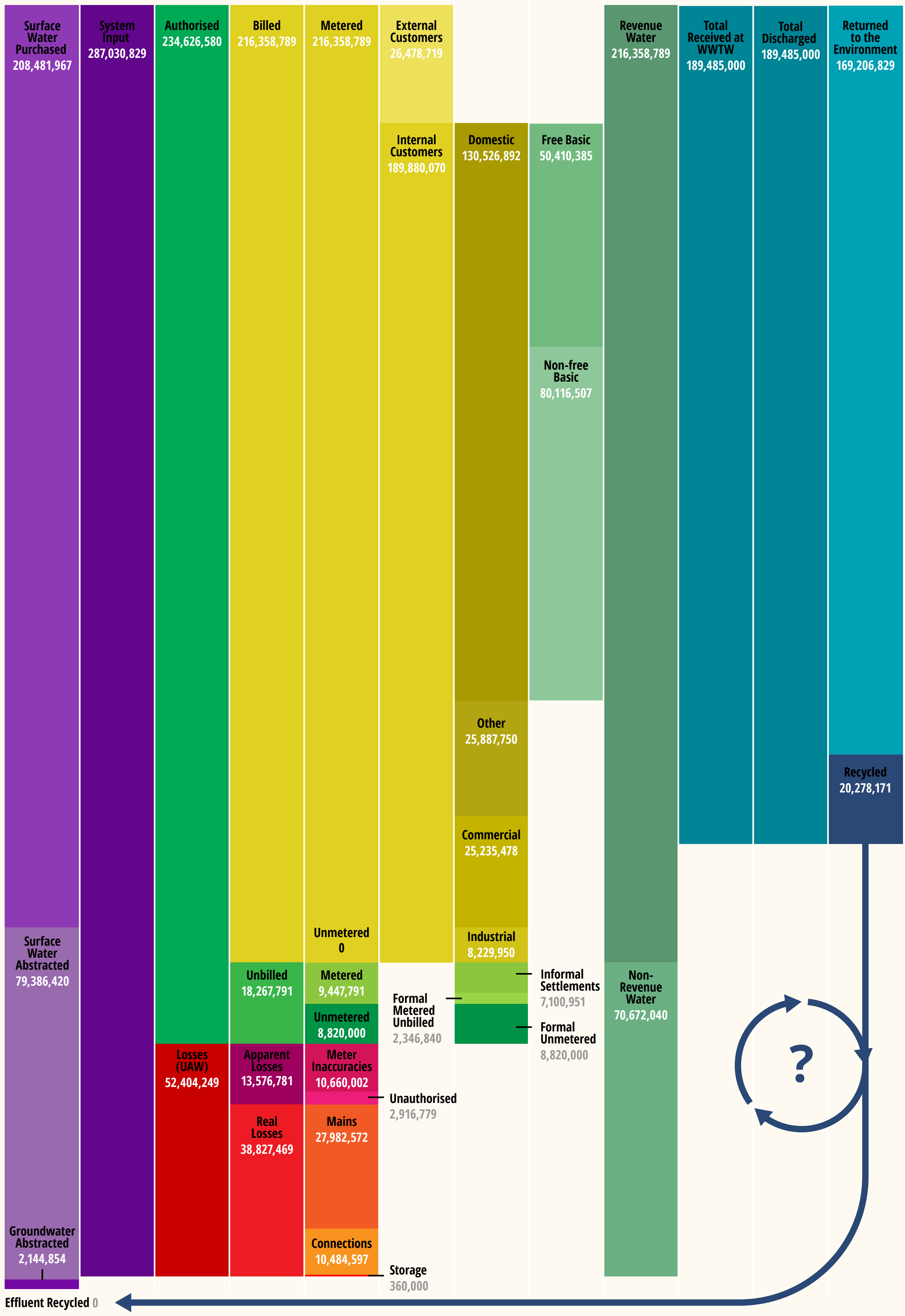


Figure 6: Cape Town Water Balance 2016. Source: graph designed by authors, data from City of Cape Town 2017

crisis was only recognized in 2016, and higher restrictions (level 3) were implemented in October 2016 – 4 months after the rains failed a second time. Significant reductions in consumption can be observed from that point onwards, constituting shifts in Cape Town's water metabolism. From January 2017, the City took greater steps to manage demand, rolling out more direct communications and implementing a number of technical and behavioural interventions. Water consumption reduced marginally, but it was nowhere near the 500 million litres per day goal. Starting in 2016, radio, newspaper and social media played a role in building lots of attention around water, both to encourage everyone to change their water use patterns and to challenge fears and misconceptions. Public bathrooms started disconnecting taps and offering hand sanitizer instead, and many restaurants started refusing tap water to diners. A level of paranoia and protectiveness over the city's water emerged, to the point that the sound of open taps became abrasive, where tourists were subjected to lectures on saving water, and fights broke out at a number of freshwater springs where residents were queuing to fill containers.

In 2017 the term "Day Zero" entered everyday conversation, referring to the day when the city would turn off the reticulation system and implement a disaster strategy to manually distribute 25 litres of water per person per day via about 200 water collection zones across the city.[xi] At the beginning of 2018, Day Zero was declared to be probable,[9] sparking renewed and somewhat panicked efforts to reduce water consumption, and attracting international media attention. In March 2018, due to these efforts and the disconnection of agricultural use from the Western Cape Water Supply System, Day Zero was delayed another year, providing some much-needed relief for anxious Capetonians.

While the city had plans from mid-2017 to augment the water supply with groundwater, desalination, and treated wastewater, many of these projects were delayed or cancelled. The crisis was thus delayed mostly through effective demand-side management rather than increasing supply capacity. Water consumption levels were reduced from a peak of 1.1 billion litres of water a day (275 per person per day) in February 2015 to below the goal of 500 million litres of water a day in May 2018 (less than 125 litres per person per day) – a truly remarkable feat.

What this crisis reinforces is that the City has knowledge and technical capacity, but that the "barriers to implementation of sustainable practices in Cape Town are social or institutional".[xii] Communication about the crisis and how to reduce consumption was delayed until urgency required clearer communication with the public. Since November 2017, more direct communication about the crisis, as well as the realities of what Day Zero would mean, saw the level of consumption drop to finally reach a 500 million litre per day goal. There have also been concerted efforts to provide much more detailed information about how the water system works, how its plans are made, and what the City is doing to address short term shortages and long-term water planning.

Scholars in *political ecology* suggest that quantifying resource flows is not enough to build sustainable infrastructures and cities, as quantifications ignore the fact that resources aren't just shaped by society but that they shape society in turn.[xiii, xiv] We can see this as a result of the water crisis: residents' relationship with water has been thoroughly changed and a new perspective with regards to how we use this resource is likely to remain even if rainfall patterns return to previous levels. It is expected that Cape Town's new identity as a water-sensitive city will shape policies and interventions in the future.[10] There are likely to be a number of shifts in the way in which water infrastructure is developed and the resource is distributed, namely from over-consumptive behaviours to those based on conservation of a limited resource, from a single water source (surface water from mountain catchments) to multiple sources (groundwater, desalination and wastewater reuse), from centralized infrastructure systems to decentralized systems, from water management solely as state responsibility to multi-stakeholder responsibility, and from hard urban design and stormwater management systems to ecological designs which absorb and capture water.

Outlook for Urban Metabolism Study

While examination of single flows is useful to illustrate how cities can make resource flows more efficient and accessible, we know that resources are interdependent and that water, energy and food flows all rely on the effective functioning of each system. Therefore, when we reimagine the systems conveying each flow, it is worth taking into account the whole system. For example, wastewater contains nutrients (in the form of sewage), and its treatment requires energy. Thus we could possibly extract these nutrients from wastewater and use them as fertilizer in urban agriculture, as has been done in other cities.[xv] Alternatively, the chemical energy held in these nutrients could be converted into energy that could power the wastewater system, as suggested in a resilience assessment of Toronto.[xvi] Feasibility studies are needed to understand how much potential chemical energy is available in Cape Town's wastewater system.

To improve the accuracy and usefulness of urban metabolic assessments, more data are required. Therefore, it is vital that cities invest in frequent,

9 Though the dates of day zero varied from March to May 2018.
10 In conversation with Claire Pengelly, Green Cape.

detailed efforts to collate data, much of which exists in disaggregated form. Efforts to make data available are incredibly valuable as they allow different stakeholders to investigate the information and provide novel or alternative interpretations. The difficulty with this is that raw data can be interpreted problematically by people who lack analytical expertise. Thus, more detail about the data collection methods and types of data must accompany any open data to avoid shaping incorrect narratives about what is happening. Some stakeholders may choose to represent only specific data which supports their agendas, but this should not be a deterrent to providing open data. Further, the crisis has shown the usefulness of having live-updating information – setting up this capability would allow narratives around resource use to evolve quickly and improve response times.

Efforts by GI-REC and metabolismofcities.org to develop wider datasets – more detail over space and time –are valuable endeavours so that cities can learn from each other and residents can learn more about their cities, understand the resource systems and take effective actions to improve their sustainability and stability. The team at metabolismofcities.org has collated existing data from academic urban metabolism publications, and now increasingly from cities' reports or open-data portals. These data are supporting interactive open data portals that different parties can explore. As this portal develops, urban metabolism studies could be executed faster by minimizing the amount of time researchers need to spend collecting primary data. Here, advocating for cities to include metabolic indicators in their household surveys and efforts to gather information will speed up the process of building this database, as well as mainstream urban metabolism as a tool for continually improving the sustainability of cities.

Challenges

Implementing urban metabolism concepts as discussed above also comes with several challenges at the level of implementation, roll-out, and continuity.

The first challenge that was identified is related to the implementation and data collection. As discussed before, data are scattered and of varying quality levels. For datasets that are currently managed by City departments there may be internal reluctance to share information. This can likely be overcome through agreements with regards to use of the data, as well as awareness and communication around the benefits of data sharing. External datasets may be more difficult to obtain. To ensure continuous and prompt data delivery, it may be necessary to create formal data sharing agreements with the relevant institutions. However, once the data format and delivery methods have been agreed upon, it is likely a relatively small effort for these institutions to provide annual or quarterly updates, which makes it a feasible request.

To successfully roll out these efforts, central coordination will be required. Urban metabolism reporting inherently relates to a large variety of departments, units, and teams at the City of Cape Town. In order to be able to roll out a project like this, a central unit or person will need to coordinate these efforts to ensure collaboration, timely delivery, and participation from all these different people. This can be achieved either by support from the top or by great communication and collaboration skills on behalf of the coordinator. In an ideal scenario, a combination of these two factors is present.

Urban metabolism reporting and monitoring efforts should be considered a long-term activity. Analysis of data from a single year or only a few years will yield some insights, but in-depth understanding comes from monitoring and reporting over a longer period of time. This will require that funding, institutional arrangements, and coordination of this project be all geared towards this longer term. In an environment of budgetary restraints, general support staff and units are more easily let go than units that directly relate to operations and services. Fortunately, additional staff requirements will be relatively low as most of the data is already in place, one way or another. However, ensuring continuity of central coordination is key. Budget cuts could furthermore restrict capacity of different departments to provide data so this is also a challenge to keep in mind.

Recommendations

In this last section, various suggestions are provided to take urban metabolism forward at the City of Cape Town. Depending on the level of desired engagement, different recommendations are provided, starting with the most low-key involvement and finishing with the highest level of urban metabolism implementation.

Scenario A: Active monitoring and reporting

In this scenario the role of the City is to actively monitor and report on material flows using urban metabolism concepts. As discussed before, data availability already allows the City to implement an urban metabolism approach with regards to its reporting on resource flows. However, a decision should be made with regards to Cape Town's resource priorities. What are the material flows or resources that are of primary interest to the City? Are data available for these different resources or will additional sources need to be found?

Before the City can start reporting, it should put in place a system to monitor the resources of interest. This will require that a suitable unit or department be put in charge of collecting, collating, and storing this information. The most suitable candidates include the **Environmental Management Department**, the **Organizational Policy and Planning Department**, or the new **City Resilience** unit.

Below follows an overview of specific steps that can be taken to start monitoring the following resources:

➤ Construction materials

Through the Freight Demand Model for the Western Cape, data on imports and exports of mineral resources can be obtained. This will require conversing with the Western Cape Department of Transport and Public Works to obtain these figures. Data on local mining can be obtained through the Department of Mineral Resources. The mass balance can be completed by using the City's internal data on building plans and infrastructure projects, and data on solid waste.

➤ Water

The existing water balance can be used as a baseline. Further improvements can be made by generating a finer-grained overview in spatial or temporal scales (for instance by creating a monthly water balance or by generating a water balance on suburb or ward level). Data from the water balance can be improved by applying data quality indicators to the figures and understanding strengths and weaknesses of these numbers.

➤ Energy and fossil fuels

An energy and fuel balance can be created by combining data already available to the City with publicly available information from the Department of Energy. These balances will require some collaboration between different City Departments, but this can provide very useful insight into an important part of the city's resource flows. By using the Department of Energy's fossil fuel sales figures, combined with freight data from the Freight Demand Model, data can be obtained on net consumption of fuel within Cape Town. After adjusting for fuel that leaves the city (through planes and ships), combustion within city boundaries can be estimated. The next step is to use emission factors that can be provided by the Air Quality Management branch and to approximate fuel use by sector. Data can be further enhanced by adding emission figures from known users including the Ankerlig power plant. Finally, the fossil fuel mass balance can be complemented with an energy balance, which is already in large parts available through the City's energy reporting efforts.

Other resource flows can also be monitored but will require a similar investigation into data availability. For different resources, the City can set different levels of data processing and quality control. For instance, the water data may be highly relevant during the drought crisis, and improving the data quality around the water balance could therefore be prioritized over improving the data quality on the other flows. Even if data on all these flows is not perfect, it is still worthwhile to build up a database of material flow data that can be improved over time, especially if baseline data is already available.

Scenario B: Full integration

As outlined in this document, urban metabolism has the potential to be used as a tool for environmental monitoring and reporting, as well as to support environmental policy in Cape Town. In order to get the most out of urban metabolism, the City can decide to fully integrate urban metabolism tools and practices.

In addition to the active monitoring described above, this can entail **embedding urban metabolism in the**

city's relevant programmes and integrating the mass balancing principles throughout the various environmental reporting departments, through the help of a central coordinating unit.

Active involvement of stakeholders from different departments (Solid Waste, Water & Sanitation, Air Quality Management, etc.) is a key step in this process. Development of a city-wide model that links with the concept of systems thinking is another important ingredient. Effort should be made to set up a database that aims to link different industries and material flows, which will enable cross-checking and provide insights into the linkage between different industries and material flows.

Another step is collaboration with other cities and integration of these principles with existing networks. UN Environment's Global Initiative for Resource Efficient Cities (GI-REC) brings cities together around urban metabolism, and this network can help facilitate integration with other existing alliances including Cape Town's enrollment in the C40 programme and the 100 Resilient Cities network.

Linking with GI-REC can provide opportunities for collaboration with other cities that are taking urban metabolism concepts to the next level, and it will also provide international exposure to Cape Town.

Another goal to aim for is ISO 37120 certification. By embedding urban metabolism indicators in environmental reporting, the City will already have fulfilled part of the requirements for this certification. International organizations including GI-REC can provide support to comply with the other requirements and obtain this ISO certification.

In the long term, one of the golden standards in urban metabolism is the concept of a (near) real-time dashboard with data on water, energy, waste and other material flows. This could be a great target to aim for. Obtaining and processing this data currently takes quite some time and effort, but most of the required steps are mechanical and can be automated. Not only can this place Cape Town at the top of its class, but it will also provide exciting opportunities to monitor and evaluate the city's resource requirements.

Finally, once urban metabolism data are being centrally collected and analysed, the same data could be shared and made available through the City's Open Data Portal. This would encourage academics and other people to review the data and help improve and unpack the datasets. It would also allow other cities to compare their figures.

Full integration of urban metabolism practices is not easy or straightforward. However, it can yield great benefits to the City of Cape Town and given the large potential that is already present, it is worth exploring this in more detail.

Scenario C: Micro-scale urban metabolism

In the aforementioned scenarios, urban metabolism is used as a tool to understand the city as a whole. Data are collected on a city-wide scale and indicators are provided for the City of Cape Town. However, a more nuanced insight can be obtained by studying the city on a micro scale. This could be at suburb level, ward level, or on another smaller scale.

By studying Cape Town at this level, better insights can be obtained into the heterogeneity of resource patterns across different areas of the city. Resource requirements, consumption, and waste flows can be affected by income levels, lifestyle, infrastructure, industrial and commercial activity, and other factors. In a city like Cape Town where large inequality exists, large differences in resources requirements are also expected. It can be of great help to better understand these differences.

Obtaining micro-level data is harder than obtaining city-wide data. However, various datasets do exist that report on a fine-grained level. Water consumption and electricity consumption originate from household-level data, for instance. Furthermore, it is possible to use consumption models that look at demographic data and household surveys and that enable micro-scale simulation of urban metabolism data, even if actual data is unavailable.[11]

11 For instance, the Spatial Microsimulation Urban Metabolism (SMUM) model.

Conclusion

This report outlined the concepts around urban metabolism, and looked at this within the context of the city of Cape Town. Urban metabolism tools and methodologies can provide various benefits to cities. Most importantly, unpacking the entire urban life cycle of resource flows and consequently analysing the city as a whole allows for a better understanding of the city's sustainability.

Cape Town's resource requirements are influenced by a variety of factors, which can be better understood when looking at the city's metabolic profile. What comes to the fore is the city's reliance on fossil fuels, the importance of Cape Town as a regional hub and its significant regional role in food processing, as well as local extractive processes including mining, agriculture and fisheries that impact the city's infrastructure and resource profile.

There are various relevant datasets available for the City of Cape Town around resource flows.
There is therefore great potential for the City to start using urban metabolism in its environmental monitoring and reporting. Ensuring continuity and fostering collaboration across city departments is key. The possible results of using urban metabolism reporting include a greater understanding of urban resource requirements, flows, and drivers, improved environmental monitoring and reporting,
as well as opportunities for international collaboration and exposure.

Organization	Details	Contact person
GI-REC	Cooperation platform by UN Environment to connect institutions and cities using urban metabolism approaches towards building low-carbon, resilient, and resource efficient cities	Sharon Gil
GreenCape	Green economy non-profit organization focused on the Western Cape; many active projects around resource flows and waste as well as urban metabolism research knowledge.	Lauren Basson
ICLEI – Local Governments for Sustainability	ICLEI is the leading global network of over 1,500 cities, towns and regions committed to building a sustainable future. The 'urban systems' workstream at ICLEI Africa undertakes metabolic assessments of water, energy, waste, food, mobility, housing, finance and communication systems to provide decision support to local and regional government leaders	Paul Currie ; Blake Robinson
Metabolism of Cities	Metabolism of Cities is a digital research lab with members from 8 countries working together on urban metabolism. Metabolism of Cities' online, open source platform hosts a suite of tools, data and literature around resource flows, fostering a community involved in the uptake of urban metabolism in policy and practice.	Paul Hoekman
Stellenbosch University	The Urban Modelling and Metabolism Assessment (uMAMA) research group is focused on urban metabolism research in African cities, including Cape Town.	Josephine Musango
University of Cape Town	Various researchers and departments work on resource flows and stocks in Cape Town.	Harro Von Blottnitz

Table 2: provides an overview of key organizations and contacts that can help the City take urban metabolism forward.

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URBAN METABOLISM IN CAPE TOWN:

Resource Flows and the 2018 Water Crisis

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