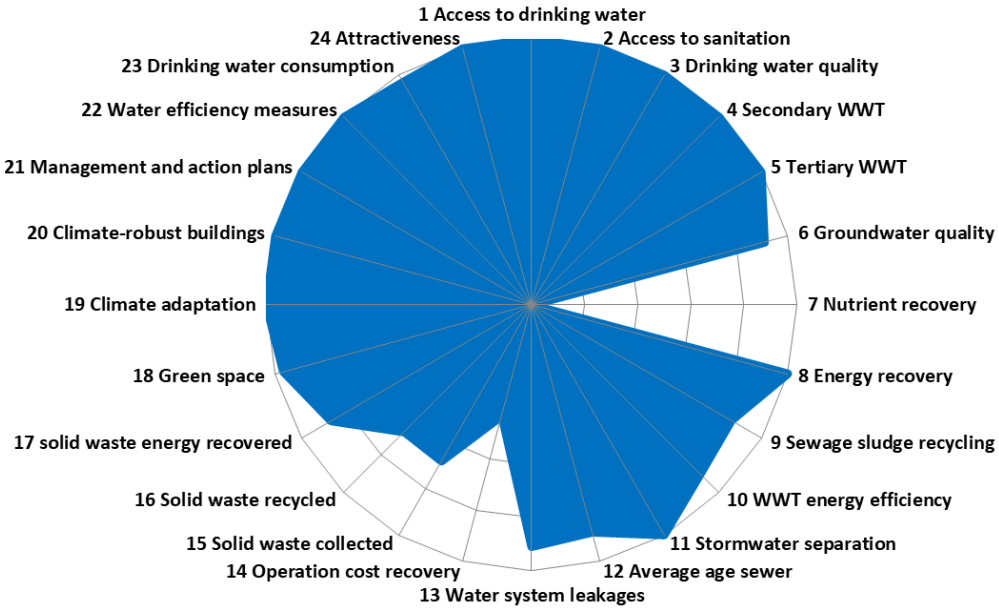
City Blueprint Singapore

The CBF framework consists of 24 indicators divided over 7 main categories (basic water services, water quality, wastewater treatment, infrastructure, solid waste treatment, climate adaptation and management & action plan). An overview of the CBF indicators is presented below.



Categories	Indicators	Scores Singapore
I Basic water services	1. Access to drinking water	10.0
	2. Access to sanitation	10.0
	3. Drinking water quality	10.0
II Water quality	4. Secondary WWT	10.0
	5. Tertiary WWT	10.0
	6. Groundwater quality	9.1
III Wastewater treatment	7. Nutrient recovery	0.0
	8. Energy recovery	10.0
	9. Sewage sludge recycling	8.7
	10. WWT energy efficiency	9.0
IV Infrastructure	11. Stormwater separation	10.0
	12. Average age sewer	8.9
	13. Water system leakages	9.1
	14. Operation cost recovery	4.3
V Solid waste treatment	15. Solid waste collected	6.8
	16. Solid waste recycled	6.8
	17. Solid waste energy recovered	8.7
VI Climate robustness	18. Green space	9.7
	19. Climate adaptation	10.0
	20. Climate-robust buildings	9.0
VII Governance	21. Management & action plans	10.0
	22. Water efficiency measures	10.0
	23. Drinking water consumption	9.6
	24. Attractiveness	9.0

Category I: Basic water services

Indicator 1: Access to drinking water

Principal: The proportion of the population with access to affordable safe drinking water. A lower Indicator score is given where the percentage is lower.

How to calculate
X = Percentage (%) of total urban population with access to potable drinking water.

Indicator 1 = $\frac{\mathbf{X}}{\mathbf{10}}$

WHO/UNICEF: Progress on Sanitation and Drinking Water 2013 update:
http://www.who.int/water_sanitation_health/publications/2013/jmp_report/en/

Singapore, Use of drinking-water sources, urban improved (2011) = 100%; Score = **10.0**

Indicator 2: Access to sanitation

Principal: A measure of the percentage of the population covered by wastewater collection and treatment. A lower Indicator score is given where the percentage is lower.

How to calculate
X = Percentage (%) of total urban population with access to proper sanitation facilities.

Indicator 2 = $\frac{\mathbf{X}}{\mathbf{10}}$

WHO/UNICEF: Progress on Sanitation and Drinking Water 2013 update: http://www.who.int/water_sanitation_health/publications/2013/jmp_report/en/

Singapore, Use of sanitation facilities, urban improved (2011) = 100%; Score = **10.0**

Indicator 3: Drinking water quality

Principal: A measure of the level of compliance with local drinking water regulations. A lower Indicator score is given where compliance is lower.

How to calculate
The result is expressed as a percentage of the samples meeting the applicable standards.
X = Total number of samples meeting standards
Y = Total number of samples

Indicator 3 = $\frac{X}{y}$ *** 10**

https://www.pub.gov.sg/watersupply/waterquality/drinkingwater

Online sensors also monitor water quality at each stage of the treatment process and service reservoirs. Over 400,000 tests are conducted annually on physical, organic, inorganic, radiological and microbiological parameters. The tap water is monitored continuously throughout the year. Singapore's tap water comes from four sources known as the Four National Taps: Water from Local Catchment, Imported Water, NEWater and Desalinated Water.

https://www.mewr.gov.sg/docs/default-source/default-document-library/grab-our-research/KES_2016.pdf

"Water For All"					
	Water Resource Management	Unit	2013	2014	2015
Access	Improved Drinking Water Sources[1]	% access	100	100	100
	Improved Sanitation[2]	% access	100	100	100
System Efficiency	Tests meeting WHO drinking water quality guidelines	%	100	100	100
	Unaccounted for water	%	5.2	5.2	5.0
	No. of leaks per 100 km of potable water pipelines	No.	5.5	5.4	5.7
	No. of disruptions per month per 1,000 km of sewers	No.	12	11	11
	Flood prone areas	Hectares	36	34	32

Therefore, score = **10.0**

Category II: Water quality

Indicator 4: Secondary WWT

Principal: Measure of the urban population connected to secondary waste water treatment plants. The focus on secondary treatment is chosen because primary treatment is considered rather insufficient for BOD and nutrient removal.

How to calculate
X = Percentage of population connected to secondary sewage treatment. We assume that there is only tertiary treatment after secondary treatment has been done.

Definition secondary WWT: Secondary treatment: process generally involving biological treatment with a secondary settlement or other process, with a BOD removal of at least 70% and a COD removal of at least 75% (OECD, 2013).

Indicator 4 = X/10

https://www.pub.gov.sg/usedwater

Singapore is 100 per cent served by modern sanitation today. Used water is collected through a network of sewerage pipes that leads directly to the water reclamation plants. Currently, there are four Water Reclamation Plants serving a population of over 5 million and treating about 223,200 Olympic-size swimming pools of used water per year.

https://www.cscollege.gov.sg/Knowledge/ethos/Issue%202%20Apr%202007/Pages/Water-Management-in-Singapore.aspx

Singapore is 100% sewered to collect all used water. It has constructed separate drainage and sewerage systems to facilitate used water reuse on an extensive scale. From 2002 to 2004, the amount of treated wastewater increased from 1.315 to 1.369 million cubic metres (mcm)/day.

X = 100%, therefore indicator 1 = **10.0**

Indicator 5: Tertiary WWT

Principal: Measure for the urban population connected to tertiary waste water treatment plants. This treatment step is important for water quality because much nutrients and chemical compounds are removed from the water before it inters the surface water.

How to calculate
X = Percentage of population connected to tertiary sewage treatment.

Indicator 5 = X/10

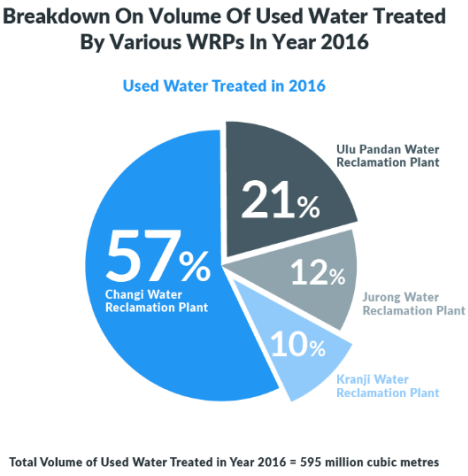
Definitions
Tertiary treatment: Tertiary treatment: treatment of nitrogen or phosphorous or any other pollutants affecting the quality or a specific use of water (microbiological pollution, color, etc.) (OECD, 2013).

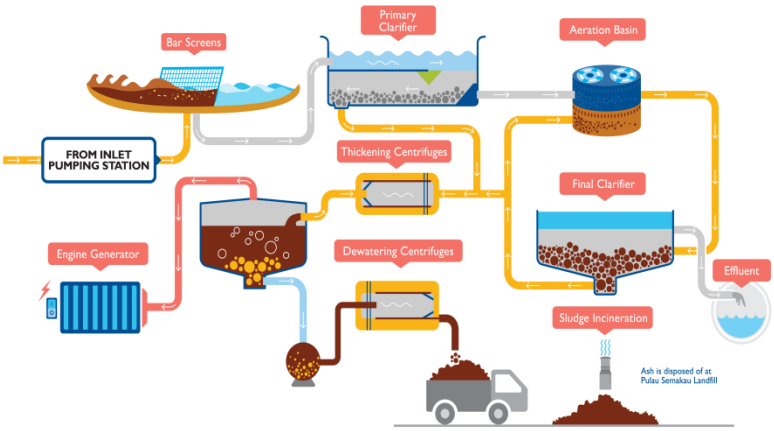
https://www.pub.gov.sg/watersupply/singaporewaterstory

NEWater, Singapore's success story and a pillar of water sustainability, is a high-grade reclaimed water produced from treated used water that is further purified using advanced membrane technologies and ultra-violet disinfection, hence making it ultra-clean and safe to drink. Presently Singapore's five NEWater plants can meet up to 40% of the nation's current water needs.

https://www.pub.gov.sg/usedwater

https://www.pub.gov.sg/usedwater/treatment/usedwatertreatmentprocess

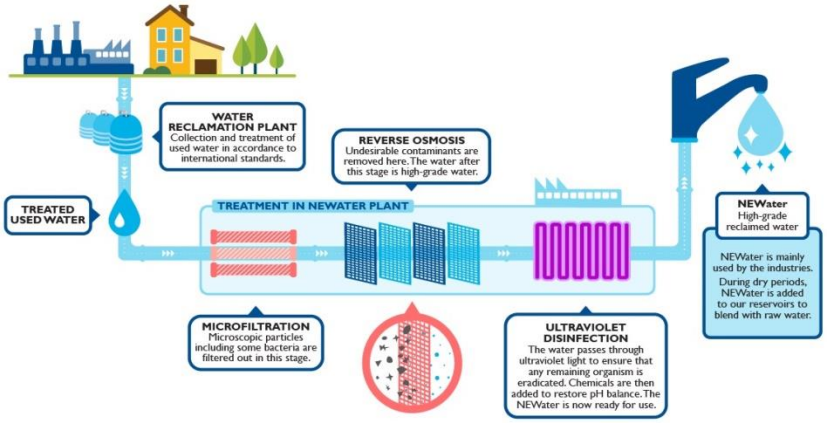




The 100% of collected used water in Singapore is treated in reclamation plant. Unlike a primary WWTP, a reclamation plant produces a higher quality effluent, which can be used for specified function. The final effluent meets the discharge standards of 20 mg/l biochemical oxygen demand (BOD) and 30 mg/l total suspended solids (TSS). Part of the final effluent is further treated to industrial water which is supplied to the industries in Jurong Island. The final effluent is also further treated using advanced membrane and

reverse osmosis technologies to high grade water called NEWater. The NEWater is supplied to the industries for use in the industrial processes to conserve potable water.

- to Jurong Island, a chemical clarification is applied with primary purpose of chemical clarification is for the removal of suspended solids and reduction of phosphates (https://www.pub.gov.sg/usedwater/treatment/industrialwaterworks)
- to NEWater (https://www.pub.gov.sg/watersupply/fournationaltaps/newater)



NEWater technology processes the effluent from the reclamation plant through microfiltration, reverse-osmosis, and UV disinfection. The result is ultra-clean and safe to drink.

In other words, 100% of the collected used water in Singapore is ended up either in Jurong or NEWater plants which both utilize the tertiary process to remove nutrients and chemical compounds. Therefore, score is **10.0**.

Indicator 6: Groundwater quality

Principal: Measure of relative groundwater quality. A lower Indicator score is given for poorer quality.

How to calculate
Base the calculation on national or regional data where city-level data are not available. A limitation is that in any country, city water quality is typically worse than the national average.

For EU countries, data are available to estimate a measure of national groundwater quality. An EU database shows the number of groundwater samples of 'good chemical status' out of a total number of samples.

X = Number of samples of 'good chemical status'
Y = Number of samples of 'poor chemical status'

Indicator 6 = X / (X+Y) x 10

Note: for non-EU countries, an alternative method should be applied, depending what data are available.

Singapore

As mentioned in TPF, Singapore is not yet exploring groundwater as their water source due to its lack natural existence in the city/country. In result, there is only limited research about the quality.

http://www.sciencedirect.com/science/article/pii/S0043135413007653

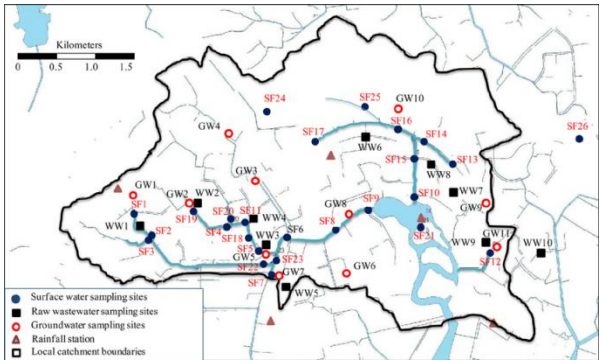
This study provided the first quantitative information on the occurrence of artificial sweeteners in raw wastewater, surface water and groundwater in the urban catchment area in Singapore. The findings shows that artificial sweeteners were found in most groundwater samples at the monitoring well located close to known leaking sewer segment (Tran et al., 2014).

To the best knowledge of the authors, there has been no or little information in the open literature documenting the occurrence of artificial sweeteners in surface water and groundwater in highly urbanized areas like Singapore where both surface water and groundwater are not impacted by the discharge of treated wastewater effluents since there are separate systems to collect stormwater and raw wastewater in Singapore, and treated wastewater effluents from wastewater treatment plants (WWTPs) are directly discharged into the sea.

In the conclusion, it is mentioned that further studies on the use of a suite of these sweeteners together with other chemical/microbial indicators are recommended to detect and discriminate the sources of pollution in surface water and groundwater.

X = 10

Y = 1



Indicator 6 = X / (X+Y) x 10 = (10/11)*10 = **9.1**

Tran, N. H., Hu, J., Li, J., & Ong, S. L. (2014). Suitability of artificial sweeteners as indicators of raw wastewater contamination in surface water and groundwater. *Water research*, 48, 443-456.

Category III: Wastewater treatment

Indicator 7: Nutrient recovery

Principal: Measure of the level of nutrient recovery from the wastewater system.

How to calculate
A. Wastewater treated with nutrient recovering techniques at the wastewater treatment plants (Mm^3 $year^{-1}$)

B. Total volume of wastewater passing the wastewater treatment plants (Mm^3 $year^{-1}$)

Indicator 7 = $\frac{A}{B} * \frac{\%\ \textbf{secondary WWT coverage}}{100} * \mathbf{10}$

https://www.pub.gov.sg/usedwater/treatment/usedwatertreatmentprocess

In the reclamation plant, produced sludge will be thickened and digested to generate biogas. In the digesters (20-30 days), another culture of micro-organism thriving in an oxygen-deficient environment breaks down the organic substances in the sludge. The digestion process converts the organic matter into biogas which contains 60 - 70% methane. The biogas is then used as fuel to power dual-fuel engine generators which helps contribute to the electricity energy required at the plant – the nutrients in wastewater are removed (and contribute to the energy efficiency) not recovered.

The country looks at the possibility to recover resources as mentioned here

http://circulatenews.org/2017/01/applying-the-circular-economy-lens-to-water/

https://repository.ntu.edu.sg/handle/10356/38914

% secondary WWT coverage = 100%

A = Wastewater is treated with phosphorus removal technology and potential nutrient recovery. However, due to the market limitation, there is no phosphorus recovery facility installed at this moment. The technologies are available.

B = 574,8 Mm3/year https://www.mewr.gov.sg/docs/default-source/default-document-library/grab-our-research/KES_2016.pdf

However, recovered nutrient are not recycled at this particular moment although the techniques are available (January 2018).

Therefore, score = **0.0**

Indicator 8: Energy recovery

Principal: Measure of energy recovery from the wastewater system.

How to calculate
A) Total volume of wastewater treated with techniques to recover energy (Mm^3/year).
B) Total volume of water produced by the city (Mm^3/year).

[A / B] * 10 = score

Often only the total volume of wastewater that enters the treatment facilities is known together with wastewater treatment coverage's (% of water going to the treatment facilities). In this case:
C) Total volume of wastewater treated with techniques to recover energy (Mm^3/year).
D) Total volume of wastewater treated in wastewater treatment plants (Mm^3/year).

Indicator 8 = $\frac{C}{D}$ ***** $\frac{\%\ \textbf{secondary WWT coverage}}{100}$ *** 10**

As mentioned in the previous indicators, all collected water in Singapore is connected to the reclamation plants with digesters technology. Therefore score **10.0**.

Indicator 9: Sewage sludge recycling

Principal: A measure of the proportion of sewage sludge recycled or re-used. For example, it may be thermally processed and/or applied in agriculture.

The decision whether or not to apply sewage sludge in agriculture depends on the levels of organic and inorganic micro-contaminants. Often, sewage sludge is contaminated and in many countries it is not allowed to apply sewage sludge in agriculture. Instead, the sludge is burned in waste destruction installations or as biomass in power plants for the generation of electricity.

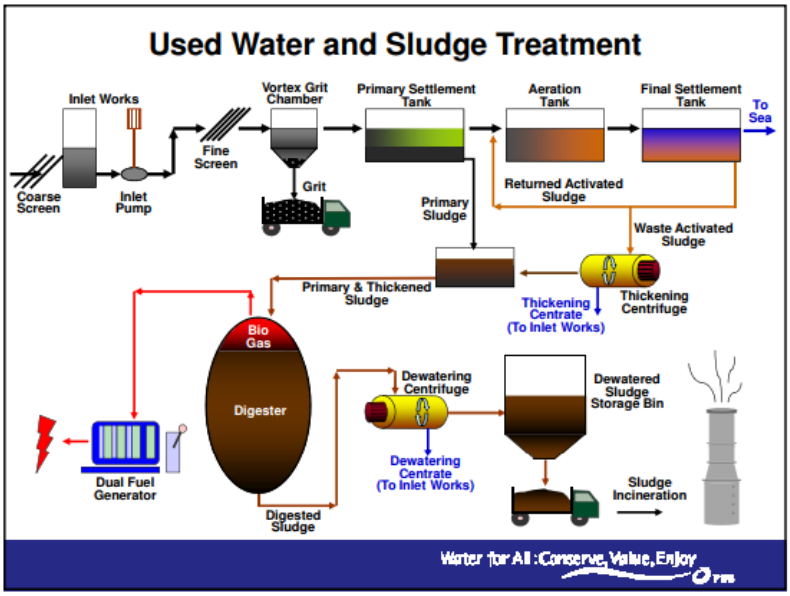
How to calculate

A. Dry weight of sludge produced in wastewater treatment plants serving the city
B. Dry weight of sludge going to landfill
C. Dry weight of sludge thermally processed
D. Dry weight of sludge disposed in agriculture
E. Dry weight of sludge disposed by other means
(As a check, A should = B + C + D +E)

Indicator 12 = $\frac{C+D}{A}$ * $\frac{\%\ \textbf{secondary WWT coverage}}{100}$ * **10**

To measure the full potential of nutrient and energy recovery, it is specifically chosen to multiply the first term in the equation above with the percentage of secondary WWT coverage as secondary WWT produces much more sewage sludge than primary WWT.

http://www.jwrc-net.or.jp/aswin/projects-activities/rd_files/jp-sg_symposium/2011_09_jp-sg_sludge_an02.pdf



Based on above diagram (also explanation on previous indicators), produced sludge is transported to sludge thickening and digesting (to produce biogas). Dry sludge at the end goes to solid waste incinerator. None of them is applied to agriculture field.

https://www.mewr.gov.sg/docs/default-source/default-document-library/grab-our-research/KES_2016.pdf

Waste Stream	Amount of Waste Generated (Mil tonnes/yr)[1]	Amount of Waste Recycled (Mil tonnes/yr)[1]	Recycling Rate (%)[1]
Construction Debris	1.41	1.40	99
Used Slag	0.37	0.37	99
Ferrous Metal	1.35	1.33	99
Scrap Tyres	0.04	0.03	92
Non-ferrous Metals	0.18	0.16	89
Wood/Timber	0.37	0.29[2]	79
Horticultural Waste	0.36	0.24[2]	66
Paper/Cardboard	1.19	0.60	51
Glass	0.08	0.01	19
Food	0.79	0.10	13
Ash and Sludge	0.20	0.03	13
Textile/Leather	0.16	0.01	8
Plastics	0.82	0.06	7
Others (e.g. stones, ceramics, silt, etc.)	0.37	0.01	2
Total	7.67	4.65	61

According to above data, there is 13% of sludge is recycled. Meanwhile incinerating sludge typically reduces its volume by more than 85%, minimizing demand on landfill space (http://www.eco.com.sg/lab.eco).

Therefore indicator 12 = (85% + (13%*15)%)/10 = **8.7**

Indicator 10: Energy efficiency WWT

Principal: A measure of the energy efficiency of the wastewater treatment. A lower Indicator score is given where efficiency measures are more limited.

How to calculate

This measure is unlikely to already have a value applied. Instead, apply a self-assessment based on the plans, measures and their implementation to improve the efficiency of wastewater treatment. Self-assessment based on information from public sources (national/regional/local policy document, reports and websites of actors (e.g. water companies, cities, provincial or national authorities).

Indicator 10 =

Indicator score	Assessment
0	no information is available on this subject
1	limited information is available in a national document
2	limited information is available in national and local documents
3	the topic is addressed in a chapter in a national document
4	the topic is addressed in a chapter at the national and local level
5	a local policy plan is provided in a publicly available document
6	as 5 and the topic is also addressed at the local website
7	plans are implemented and clearly communicated to the public
8	as 7 plus subsidies are made available to implement the plans
9	as 8 plus annual reports are provided on the progress of the implementation and/or any other activity indicating that this is a very high priority implemented at the level of the local community.
10	as 9 and the activity is in place for = 3 years

As observed in the previous indicator, Singapore utilizes a technology to make their reclamation plant acquire high energy efficiency. The R&D department regularly posts their result of research in an open access bulletins //www.pub.gov.sg/ourlibrary/publications. The feature on this bulletin issue https://www.pub.gov.sg/Documents/vol7.pdf discussed: *Moving towards energy self-sufficiency in used water treatment*

PUB also succeeds to get a grant from the national government and invites such collaborations with others https://www.pub.gov.sg/research/industrialwatersolutions/funding.

In the latest PUB's annual report, energy efficiency is included as one of key efforts. The section is written as follows:

PUB aims to reduce our plants, processes and operations' energy use by 20% compared to business-as-usual levels by 2030, through energy-efficient technologies and better

infrastructure planning. This involves optimizing existing processes and implementing new technologies to minimize our energy use (e.g. electrochemical desalting), increasing energy recovery (e.g. biogas generation), and managing our water demand. In striving towards the development and use of new technologies since 2002, PUB had worked on over 467 research and development projects worth $323 million. These efforts will also continue to reduce Singapore's carbon emissions and help transform the country into a smart energy economy

Energy efficiency is a key strategy to reduce Singapore's carbon emissions. In 2015, in accordance with Singapore's Intended Nationally Determined Contributions (INDCs), PUB has plans to reduce reducing the water sector's emissions through energy efficiency improvements in desalination and used water treatment processes.

Reference: Climate Action Plan, NCCS, 2016 This is a PUBLIC SECTORSUSTAINABILITY PLAN 2017-2020

The progress is reported annually and the objective is highlighted as one of key interest of PUB's sustainability. Therefore, score is **9.0**.

Category IV: Water infrastructure

Indicator 11: Stormwater separation

Principal: A measure of the proportion of the wastewater system for which sanitary sewage and storm water flows are separated. In principal, a separate system is better than a combined system as extreme weather events may lead to sewer overflows into surface water. These sewer overflows are a major source of pollution. Also flooding vulnerability is larger if stormwater separation ratio is low. A lower Indicator score is given where the proportion of combined sewers is greater.

How to calculate

A. Total length of combined sewers managed by the utility (km)
B. Total length of stormwater sewers managed by the utility (km)
C. Total length of sanitary sewers managed by the utility (km)

Indicator 10 = $\frac{B+C}{A+B+C}$ x 10

Singapore uses two separate systems to collect rainwater and used water. With two-thirds of Singapore as water catchment, rainwater that falls in these areas is collected through an extensive network of drains, canals, rivers, stormwater collection ponds and reservoirs before it is treated for drinking water supply. This makes Singapore one of the few countries in the world to harvest urban stormwater on a large-scale for its water supply. Singapore has 8,000km of drains & rivers (https://www.pub.gov.sg/drainage).

Meanwhile, used water in Singapore is transported using Deep Tunnel Sewerage System (DTSS), a cost-efficient and sustainable solution conceived by PUB to meet Singapore's long-term needs for used water collection, treatment, reclamation and disposal (https://www.pub.gov.sg/dtss/about).

Phase 1 of the DTSS comprises a 48 km-long deep sewer tunnel running from Kranji to Changi, a centralised water reclamation plant at Changi, two 5 km-long deep sea outfall pipes and 60km of link sewers (https://www.pub.gov.sg/dtss/phase1).

Singapore's DTSS Phase 2 extends the existing deep tunnel system to collect used water from the western and southern parts. When completed, it will have a conveyance system that is made up of 60 km of link sewers and 40 km of deep tunnels; and the Tuas Water Reclamation Plant, i.e., Tuas WRP (https://www.pub.gov.sg/dtss/phase2).

PUB maintains the sewerage reticulation system in Singapore with about 3,500km of public sewers and more than 90,000 sewer manholes. PUB conducts systematic checks and carry out repairs on defective sewers to enhance the structural integrity of the sewerage system and to prevent the pollution to waterways (https://www.pub.gov.sg/usedwater/sewerrehabilitation/publicsewers).

A = - B = 8000 km C = 48+5+60+60+40 = 213 km (DTSS) + 3500 km (public sewers)

Indicator 11 = $\frac{B+C}{A+B+C}$ x 10 = (11713/11713) x 10 = **10.0**

Indicator 12: Average age sewer

Principal: The age of the infrastructure for wastewater collection and distribution system is an important measure for the financial state of the UWCS.

How to calculate
The average age of the infrastructure is an indication of the commitment to regular system maintenance and replacement. The method compares the average age of the system to an arbitrarily maximum age of 60 years. Moreover, it is assumed that an age of <10 years receives a maximum score since younger systems generally well maintained.

X = Average age sewer

Indicator 12 = $\frac{60-X}{60-10}$ **x 10**

NB. All values of x > 60 will lead to an indicator score of 0.

https://www.pub.gov.sg/dtss/phase1

Completed in 2008 at a cost of SGD$3.4 Billion – used water sewerage age = 2017-2008 = 9 years

http://iahr.tandfonline.com/doi/full/10.1080/1573062X.2015.1076488?scroll=top&needAccess=true
Over the last 30 years, Singapore has developed an intricate drainage network of over 8000 kilometres (PUB Annual Report, 2009/2010), and most natural waterways have been enlarged and concrete-lined to increase their conveyance capacity and prevent bank erosion.

The oldest drainage/sewerage age in Singapore was aged 30 but it is still well-maintained. In addition, the second phase of DTSS is also being constructed at the present. The average age of the sewer system in Singapore is 15.71 years as of Oct 2017.

Average age= (30+0)/2 = 15,71 years

Indicator 12 = $\frac{60-X}{60-10}$ **x 10 =** $\frac{60-15{,}71}{60-10}$ **x 10 = 8.9**

Indicator 13: Water system leakages

Principal: A measure of the percentage of water lost in the distribution system due to leaks (typically arising from poor maintenance and/or system age).

How to calculate
Leakage rates of 50% or more are taken as maximum value and thus scored zero. A best score of 10 is given when the water system leakage is zero.

Singapore

Water system leakages in 2009= 4,6% (Siemens, 2011)

X = Water system leakages (%) = 4,6%
Indicator 13 = $\frac{\mathbf{50-4,6}}{\mathbf{50-0}}$ **x 10 = 9.1**

Economist Intelligence Unit – Siemens. (2011). *Asian Green City Index: Assessing the environmental performance of Asia's major cities*. Siemens AG, Munich, Germany. Retrieved from http://sg.siemens.com/city_of_the_future/_docs/Asian-Green-City-Index.pdf

This figure of 5% is still relevant. See:
http://waterlosseurope2017.com/downloads/2017/conference-presentations/Singapore%27s%20experience%20of%20Water%20Loss%20Reduction.pdf

Indicator 14: Operating costs recovery (ratio)

Principal: Measure of revenue and cost balance of operating costs of water services. A higher ratio means that there is more money available to invest in water services, e.g. infrastructure maintenance or infrastructure separation.

How to calculate
Only the operational cost and revenues for Domestic water supply and sanitation services are included.

$$\text{Operating cost recovery (ratio)} = \frac{\text{Total annual operational revenues}}{\text{Total annual operating costs}}$$

Definitions:

Total annual operational revenues: Total annual income from tariffs and charges for drinking water and sanitation services (US$ or any other currency/year).

Total annual operating costs: Total annual operational expenditures for drinking water and sanitation services (US$ or any other currency/year).

If the ratio is >1 than there is no 100% coverage of operating costs. However, ratios <1 are often applied at utilities. This means that there is more than a 100% coverage in many cases (Figure 7.3.1).

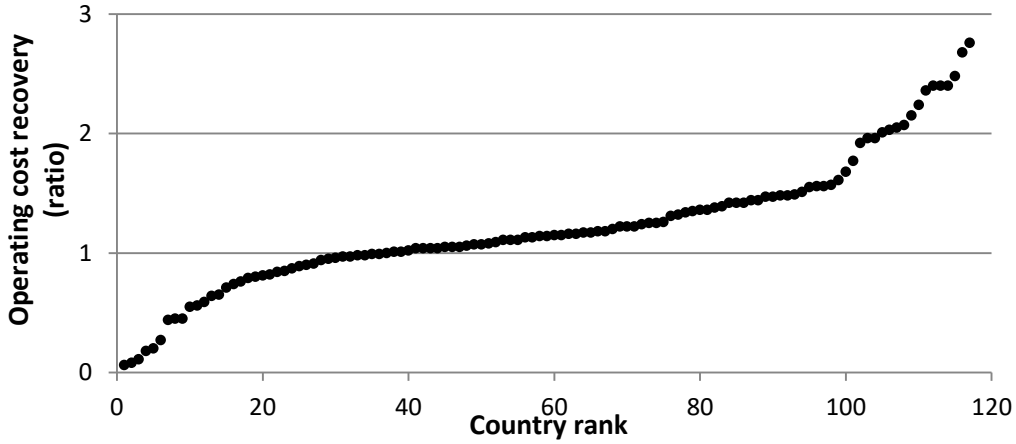


Fig. 7.3.1 Operating cost recovery ratio for all 117 countries available (ib-net.org). Note that the majority of the countries have more than 100% operating cost recovery (which is a ratio of 1).

Of the operating cost recovery ratio's for all countries available (shown in Figure 7.3.1) the highest and lowest 10% are averages and used as minimum and maximum value to rescale the operating cost recovery ratio's to a score between 0 and 10 points. The minimum and maximum are respectively 0.33 and 2.34. The operating cost recovery is X.

X = Operating cost recovery (ratio)

$$\textbf{Score indicator } 14 = \frac{\mathbf{X - 0.33}}{\mathbf{2.34 - 0.33}} \textbf{ x } \mathbf{10}$$

All values of x < 0.33 will lead to an indicator score of 0.

The water services authority in Singapore is PUB (Public Utility Board), Singapore's National Water Agency.

https://www.pub.gov.sg/annualreports/annualreport2017.pdf

Public Utilities Board and its Subsidiaries

Statements of comprehensive income
For the financial year ended 31 March 2017

	Note	Group 31 March 2017 S$'000	31 March 2016 S$'000
Operating income	3	1,222,432	1,201,313
Operating expenses	4	(1,270,242)	(1,239,334)
Net operating loss		(47,810)	(38,021)
Net non-operating income	5	73,459	56,345
Net income before finance expenses and operating grants		25,649	18,324
Finance expenses	6	(84,844)	(87,660)
Net loss before operating grants		(59,195)	(69,336)
Operating grants from government		298,826	270,431
Net income after government grants and before contribution to government consolidated fund and taxation		239,631	201,095
Contribution to government consolidated fund and taxation	7	(40,691)	(34,258)
Net income after government grants and after contribution to government consolidated fund and taxation		198,940	166,837
Other comprehensive income			
Items that will not be reclassified to profit or loss			
Net re-measurement gain/(loss) on pension obligation		145	(1,574)
Total comprehensive income for the year		199,085	165,263

Updated annual report

FINANCIAL HIGHLIGHTS
Ended 31 March 2017

	Group[1]	
OPERATING RESULTS	**FY 2016 $ million**	**FY 2015 $ million**
Operating Income	1,222.4	1,201.3
Net Non-Operating Income	73.4	56.3
Operating Expenses	(1,270.2)	(1,239.3)
Finance Expenses	(84.8)	(87.6)
Net Loss before Government Grants	**(59.2)**	**(69.3)**
Government Operating Grants	298.8	270.4
Net Income after Government Grants and before Contribution to GCF and Taxation	**239.6**	**201.1**
Contribution to GCF and Taxation	(40.7)	(34.3)
Net Income after Government Grants and after Contribution to GCF and Taxation	**198.9**	**166.8**

Cost and revenue quoted are for used water, water supply, storm water management and ABC Waters

Total annual operating revenues and operating grants: 1,521.3 S$ million
Total operating costs: 1,270.2 S$ million

$$\frac{1521,2}{1270,2} = 1.19$$

When we standardized this to a 0-10 score in the city blueprint we get:

$$\frac{1,19 - 0.33}{2.34 - 0.33} \text{ x } 10 = \mathbf{4.32}$$

PUB. (2016). *PUB, SINGAPORE'S NATIONAL WATER AGENCY ANNUAL REPORT for the year 2016/2017*. https://www.pub.gov.sg/annualreports/annualreport2017.pdf

Category V: Solid waste treatment

Indicator 15: Solid waste collected

Principal: Represents waste collected from/ produced by households, small commercial activities, office buildings, institutions such as schools and government buildings, and small businesses that threat or dispose of waste at the same used for municipally collected waste (OECD, 2013).

How to calculate
X = kg/cap/year of collected solid waste. The min-max method is applied. Here the lowest and highest 10% produced solid waste of all countries that are available is taken. These are respectively 136.4 kg/cap/year and 689.2 kg/cap/year.

Indicator 15 = [1 - $\frac{X-136.4}{689.2-136.4}$ **] * 10**

All values of x ≤ 136.4 lead to an indicator score of 10

Singapore
According to Ministry of Environment and Water Resources, waste generated per capita in 2009 = 306,6 kg/cap/year (Siemens, 2011). Meanwhile in 2015 the total domestic waste disposed per capita is 0,86 kg/day/person = 313,9 kg/day/person (NEA, 2015 in data.gov.sg)

[1- $\frac{313,9-136.4}{689.2-136.4}$] * 10 = **6.8**

Indicator 16: Solid waste recycled

Principal: Percentage of solid waste that is recycled or composted.

How to calculate
This indicator represents the percentage of the total collected municipal waste that is recycled or composted. However, when solid waste is used for incineration with energy recovery, it is not possible to also use it for recycling while both practices are sustainable. Therefore the % solid waste that is incinerated is subtracted from the total (100%) of collected municipal waste to obtain the potential percentage of solid waste that can be recycled (in numerator). Thus this indicator is calculated as shown below.

$$\textbf{Indicator 16} = \frac{\%\ \textbf{recycled or composted}}{\textbf{100}-\%\ \textbf{used for incineration with energy recovery}}\ \textbf{x 10}$$

Singapore

http://www.nea.gov.sg/energy-waste/waste-management/waste-statistics-and-overall-recycling

Our domestic waste recycling rate increased to 21 per cent in 2016, up from 19 per cent in 2015. The increase in the domestic waste recycling rate was due to a drop in the amount of domestic waste generated, from 2.13 million tonnes in 2015 to 2.09 million tonnes in 2016; and an increase in the amount of domestic waste recycled, from 403,500 tonnes in 2015 to 435,600 tonnes in 2016.

http://www.nea.gov.sg/energy-waste/waste-management/waste-management

In the 1960s and 1970s, waste was sent to various landfills around the island. However, in the late 1970s, NEA decided to adopt waste-to-energy (WTE) incineration as it is able to reduce waste volume by 90% and reduce landfill space. The first WTE plant was commissioned in 1979. Today, there are four WTE plants located at Tuas and Senoko, as well as an offshore landfill, Semakau Landfill which receives non-incinerable waste and incineration ash via the Tuas Marine Transfer Station. Waste collectors sending waste to the four WTE plants and Tuas Marine Transfer Station must be accompanied by a waybill to indicate the type and source of waste.

https://www.mewr.gov.sg/docs/default-source/default-document-library/grab-our-research/KES_2016.pdf

Total waste landfilled includes non-incinerable waste such as construction and demolition waste, used slag and treated sludge etc. and excludes incineration ash generated from waste disposed through incineration. This process reduces the waste volume to 10% that will be brought to Semakau landfill – all the domestic waste that is not recycled is transported to incinerator (100-21-10= 69)

$$\textbf{Indicator 16} = \frac{\textbf{21}}{\textbf{100}-\textbf{69}}\ \textbf{x 10 = 6.8}$$

Indicator 17: Solid waste energy recovery

Principal: Percentage of solid waste that is incinerated with energy recovery.

How to calculate
This indicator represents the percentage of the total collected municipal waste that incinerated with energy recovery (techniques). However, when solid waste is recycled or composted , it is not possible to also use it for incineration with energy recovery, while both practices are sustainable. Therefore the % solid waste that is recycled or composted is subtracted from the total (100%) of collected municipal waste to obtain the potential percentage of solid waste that can be incinerated with energy recovery (in numerator). Thus this indicator is calculated as shown below.

Indicator 17 = $\frac{\%\ \textbf{incinerated with energy recovery}}{\textbf{100}-\%\ \textbf{recycled or composted}}$ **x 10**

From the data in previous indicator, recycled = 21% and incinerated = 69%

Indicator 17 = $\frac{69}{100-21}$ x 10 = **8.7**

Category VI: Climate adaptation

Indicator 18: Green space

Principal: Represents the share of green and blue area which is essential to combat the heat island effect in urban areas (area defined as built-up area lying less than 200 meters apart).

How to calculate
City specific: Numbers are provided in %
Country average: Share of green and blue areas is available for all European cities. The EEA city database presents data for of 367 European cities. From these data the average of the lowest 10% is taken as minimum (16%) and the average of the highest 10% is taken as maximum (48%). The percentages for the EU cities are standardized according to the min-max method. For non-European cities percentages for green and blue area are mostly not available. A best estimate is given by comparing this city to a similar European city. It is important for these cities to provide better information on the share of green area.

X = Share of blue and green area (%)
Indicator 18 = $\frac{X-16}{48-16}$ **x 10**
All values of x < 16 will lead to an indicator score of 0 and all values > 48 will lead to an indicator score of 10.

Definition of green area (EEA, 2012A): These are green urban areas, sports and leisure facilities, agricultural areas, semi-natural areas and wetlands, forests, discontinuous low density urban fabric as a proxy for private gardens and water bodies.

Singapore
Besides the ABC programme, as part of the process of increasing the amount of vegetation in the city, Singapore supports private initiatives for realising traditional gardens and roof gardens. For example, the city already hosts more than 300 common gardens. Incentives exist for building green roofs to keep the buildings below cool and help reduce the amount of energy used for air conditioning.
http://www.greenfuture.sg/2015/02/16/2015-guide-to-singapore-government-funding-and-incentives-for-the-environment/

The city has 47% green spaces in (National Parks Board, 2011 in http://www.worldcitiesculturefor um.com/data/of-public-green-space-parks-and-gardens)

Indicator 18 = $\frac{X-16}{48-16}$ **x 10 =** $\frac{47-16}{48-16}$ **x 10 = 9.7**

Indicator 19: Climate adaptation

Principal: A measure of the level of action taken to adapt to climate change threats. A lower Indicator score is given where actions or commitments are more limited.

How to calculate

This measure is unlikely to already have a value applied. Instead, apply a self-assessment of the measures and their implementation to protect citizens against flooding and water scarcity related to climate change (e.g. green roofs, rainwater harvesting, safety plans etc.). Self-assessment based on information from public sources (national / regional / local policy document, reports and websites of actors (e.g. water companies, cities, provincial or national authorities).

Indicator	Assessment
0	no information is available on this subject
1	limited information is available in a national document
2	limited information is available in national and local documents
3	the topic is addressed in a chapter in a national document
4	the topic is addressed in a chapter at the national and local level
5	a local policy plan is provided in a publicly available document
6	as 5 and the topic is also addressed at the local website
7	plans are implemented and clearly communicated to the public
8	as 7 plus subsidies are made available to implement the plans
9	as 8 plus annual reports are provided on the progress of the implementation and/or any other activity indicating that this is a very high priority implemented at the level of the local community.
10	as 9 and the activity is in place for = 3 years

https://sustdev.unescap.org/Files/Singapore%20National%20Strategy%20Climate%20Change%20Policy.pdf

In 2012, the Singapore government launched the National Climate Change Strategy 2012 document entitled “Climate Change & Singapore: Challenges, Opportunities, Partnerships” with four key priorities:

I - Mitigation: Reducing Emissions

II - Adapting to Climate Change: A More Resilient Singapore

III - Opportunities for Green Growth

IV - Local and International Partnerships on Climate Change

The policy document available https://www.nccs.gov.sg/sites/nccs/files/NCCS-2012.pdf

In 2015, the Centre for Climate Research Singapore (CCRS) and the United Kingdom’s Met Office Hadley Centre concluded Phase 1 of the Singapore National Climate Change

Study, which analysed Singapore's climate up to the year 2100. The results projected that Singapore is likely to become warmer, experience more frequent and heavier storms, and face rising sea levels. The report can be found here: http://ccrs.weather.gov.sg/Publications-Second-National-Climate-Change-Study-Science-Reports

The climate impacts and adaptation efforts are also communicated in Singapore's Climate Action Plan: A Climate-Resilient Singapore, For a Sustainable Future. The progress of Singapore's climate change plans can be found on the website of the National Climate Change Secretariat (NCCS).

http://www.urbangreenbluegrids.com/projects/singapore/

Singapore's government's funding and incentive schemes related to energy efficiency and clean energy, green buildings and construction, water and environmental technologies, green transport and shipping, waste minimisation, environmental initiatives, and capability development – all funding related to climate change adaptation and mitigation

The overall program is intended for everyone in the city/country. The public is also given a big responsibility to promote related measures. Therefore, score is **10.0**.

Indicator 20: Climate robust buildings

Principal: A measure of whether there is a clear policy for buildings to be robust regarding their contribution to climate change concerns (principally energy use). A lower Indicator score is given where policies are weaker.

How to calculate

This measure is unlikely to already have a value applied. Instead, apply a self-assessment of the policies in place to promote energy efficiency for heating and cooling of houses and buildings, including the use of geothermal energy. Assessment is based on information from public sources (national / regional / local policy documents, reports and websites of actors, e.g. water companies, cities, provincial or national authorities).

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10	as 9 and the activity is in place for = 3 years

http://www.lifestyleasia.com/477340/5-eco-friendly-buildings-making-singapore-greener-than-ever/

Tree House set a Guinness World Record for being the world's largest vertical garden.

NTU School of Art, Design and Media

Eco-friendly functionality needn't come at the cost of stylish design.

https://e360.yale.edu/features/singapore_takes_the_lead_in_green_building_in_asia

Since the rating tool launched in 2005, Singapore's Building and Construction Authority (BCA) has certified 1,534 new buildings and 215 pre-existing ones. Certified green buildings account for more than a fifth of the floor area in the island city-state. Singapore's commitment to greening its built environment is promoted by a generous incentive schemes and a building-rating tool that encourages such improvements as sun-shading exteriors, water-efficient fittings, computer modeling of energy flows and carbon emissions, and highly efficient air conditioning and ventilation systems.

There are also:

- Singapore Green Building Council (SGBC) http://www.sgbc.sg/ Officially launched on 28 October 2009 as the only non-profit organisation with a concerted private-public sector partnership to achieve a world-class and sustainable built-environment in Singapore, our key role is to advocate green building design, practices and technologies and drive environmental sustainability in the building and construction industry.

- Campaign of Clean and Green Singapore http://www.nea.gov.sg/events-programmes/campaigns/clean-green-singapore

- Also government's funding and incentive schemes related to energy efficiency and clean energy, green buildings and construction, water and environmental technologies, green transport and shipping, waste minimisation, environmental initiatives, and capability development http://www.greenfuture.sg/2015/02/16/2015-guide-to-singapore-government-funding-and-incentives-for-the-environment/

There is a Green Building Masterplan which is released by BCA every few years. It is into the 3rd version so far:
https://www.bca.gov.sg/GreenMark/others/3rd_Green_Building_Masterplan.pdf

See also: https://www.nccs.gov.sg/sites/nccs/files/PSSP_2017-2020.pdf

The progress of these green buildings and construction initiatives are described in BCA master plan document and NEA annual reports. The main targets of this program are developers, industry professionals, etc as collaborators (not the local community). Therefore, score is revised to **10.0**.

Category VII: Plans and actions

Indicator 21: Management and action plans

Principal: A measure of the application of the concept of Integrated Water Resources Management (IWRM) in the city. A lower Indicator score is given where plans and actions are limited.

How to calculate

This measure is unlikely to already have a value applied. Instead, apply a self-assessment of local and regional commitments to adaptive, multifunctional, infrastructure and design for IWRM as demonstrated by the ambition of the action plans and the actual commitments by local authorities or utilities. The assessment should be based on information from public sources (national/regional/local policy document, reports and websites of actors (e.g. water companies, cities, provincial or national authorities).

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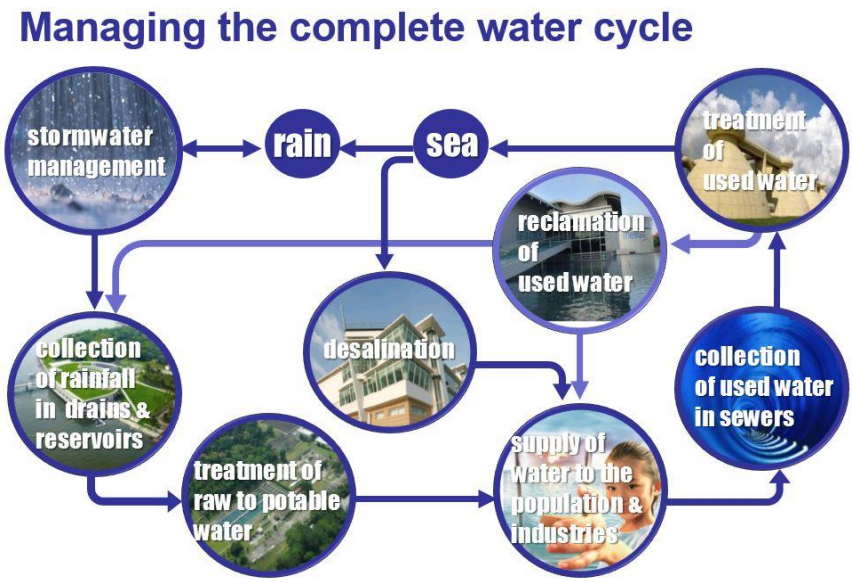
9	as 8 plus annual reports are provided on the progress of the implementation and/or any other activity indicating that this is a very high priority implemented at the level of the local community.
10	as 9 and the activity is in place for = 3 years

http://aseaniwrm.water.gov.my/iwrm-in-singapore/

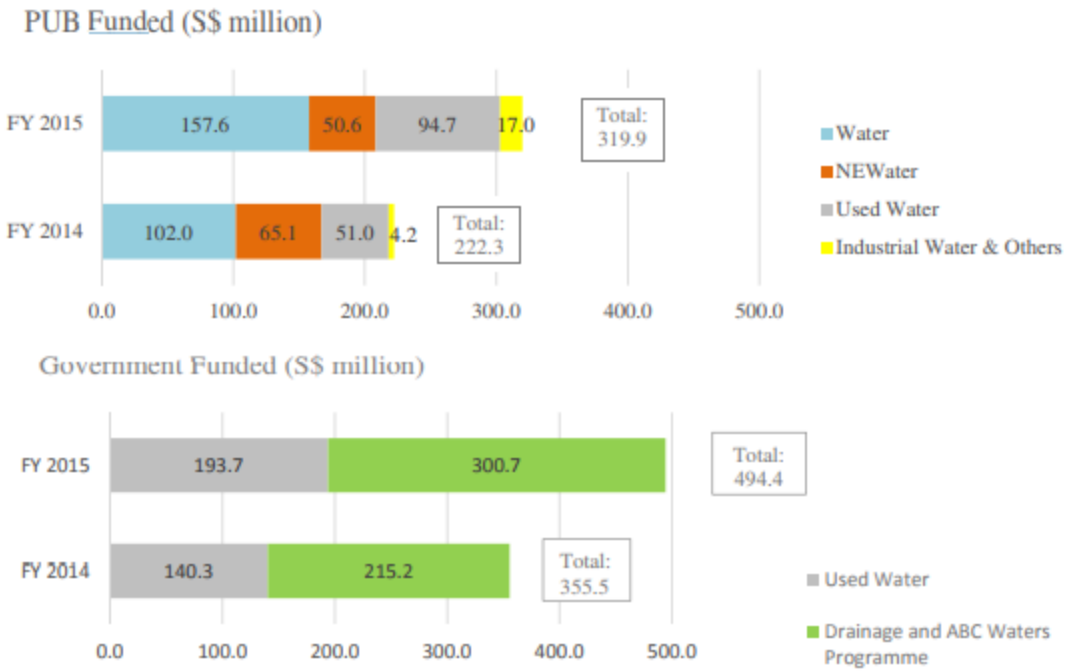


This includes:

- 4 taps (local catchment, imported water, desalinated water, NEWater)
- Stormwater management

- Flood management
- Water pollution management (including ABC Waters)
- Water sanitation management (including DTSS)

Almost every aspects of IWRM in Singapore are coordinated by PUB. The projects descriptions are available online (pdf/websites). From PUB's annual report, it is also known that both PUB and Singapore's government have relatively large budget allocation for these measures.



The overall program is intended for everyone in the city/country, as can be seen from the government efforts to involve the public (https://www.pub.gov.sg/getinvolved) since more than 3 years ago. Therefore, score is **10.0**.

Indicator 22: Water efficiency measures

Principal: Measure of the application of water efficiency measures by the range of water users across the city. A lower Indicator score is given where efficiency measures are more limited.

How to calculate
This measure is unlikely to already have a value applied. Instead, apply a self-assessment based on information from public sources (national/regional/local policy document, reports and websites of actors (e.g. water companies, cities, provincial or national authorities). It should consider plans, measures and their implementation to improve the efficiency of water usage by e.g. water saving measures in taps, toilets, showers and baths, water efficient design, or behavioral changes.

Indicator	Assessment
0	no information is available on this subject
1	limited information is available in a national document
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10	as 9 and the activity is in place for = 3 years

Water Demand Management Strategy

PUB's overall water demand management strategy comprises pricing, mandatory measures as well as facilitation. Mandatory measures include stipulating minimum water efficiency standards for water fittings and mandatory submission of water efficiency management plan by large water users annually. Facilitation includes the sharing of best practices, recognizing/showcasing exemplary cases and providing funding to assist the industry.

https://www.pub.gov.sg/watersupply/singaporewaterstory

Water Conservation Awareness Programme

- Businesses and industries are encouraged to certify their buildings, operations and premises under Water Efficient Building Certification.

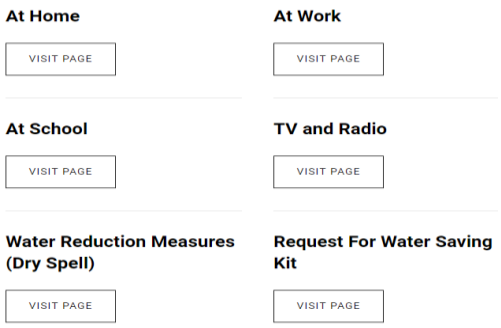
- Mandatory Water Efficiency Labelling Scheme (MWELS) helps consumers choose water efficient products like washing machine.

https://www.pub.gov.sg/savewater

Through the Four National Taps, there is a robust and sustainable water supply for Singapore. However, installing the infrastructure to supply water is only one half of the equation. As the population and economy continue to grow, Singapore needs to ensure that the demand for water does not rise at an unsustainable rate.

PUB Website provides the tips and advices for everyone those want to contribute. There is also funding support available for eligible organizations. Since January 2015, larger non-domestic water users that consume 60,000m3 or more a year are required to install private meters and submit their Water Efficiency Management Plans (WEMP) to PUB annually. Those who need submit WEMPs can also tap on PUB's Water Efficiency Fund (WEF) for support to implement water saving measures at their premises. The range of supportable measures include water audits, feasibility studies, water re

Those who wish to develop their WEMPs voluntarily can refer to this fund to finance installation of water meters https://www.pub.gov.sg/savewater/atwork/managementplan



Wireless Sensors

More than 320 sensors have been installed in Singapore's potable water supply pipelines to detect water leakage. These sensors are able to measure flow rate, water pressure and also detect noise made when water escapes through the cracks in the pipes.

Concurrently, there has been various Automated Water Meter (AMR) trials being rolled out in Singapore. One of the objectives of AMRs is to provide users with more real time feedback on water consumption. This aims to improve leak detection through detection of usage anomalies and also to reduce usage over time.

To date, the largest non-domestic water users have already installed AMR at their premises. Various AMR trials are also underway for the domestic sector in Punggol and Yuhua precincts.

Evaluation

Several water efficiency indicators are tracked and reported annually via the Key Environmental Statistics report which is available on MEWR's website. They include *per capita water consumption*, *Unaccounted for Water (UFW)*, *no. of leakages per 100 km of potable water pipelines.*

The overall program is intended for everyone in the city/country. The public is also given a big responsibility to promote related measures. Therefore, score is **10.0**.

Indicator 23: Drinking water consumption

Principal: Measure of the average annual consumption of water per capita. A lower Indicator score is given where the volume per person is greater.

Definition: In this questionnaire we use authorized consumption as defined by the International Water Association (IWA). This is the total volume of metered and/or non-metered water that, during the assessment period (here: 1 year), is taken by registered customers, by the water supplier itself, or by others who are implicitly or explicitly authorized to do so by the water supplier, for residential, commercial, industrial or public purposes. It includes water exported. It is IWA code A14. This is then divided by the city population.

How to calculate
X = m^3/person/year drinking water consumption

The volume is then normalized against maximum and minimum volumes for European cities. The minimum is for Rotterdam at 45.2 m3/person/yr. The maximum is for Kiev at 266 m3/person/year (European Green City Index).

Indicator 23 = [1 - $\frac{X-45.2}{266-45.2}$] * 10

All values of x < 45.2 will lead to an indicator score of 10 and all values of x > 266 will lead to an indicator score of 0.

Singapore

Based on Singapore National Water Agency, the domestic consumption in Singapore in 2013 was 151 l ppd (OECD, 2015). Meanwhile, the number is decreased to 148 l ppd in 2016 (https://www.pub.gov.sg/watersupply/singaporewaterstory). Therefore, X =148 l ppd = 54,17m3 per capita/year

Indicator 23 = [1 - $\frac{X-45.2}{266-45.2}$] * 10 = [1 - $\frac{54,17-45.2}{266-45.2}$] * 10 = 9.6

Indicator 24: Attractiveness

Principal: A measure of how surface water features are contributing to the attractiveness of the city and wellbeing of its inhabitants. A lower Indicator score is given where 'attractiveness' is less.

Definition: Examples of cities, that attract lot of tourists are Venice, Hamburg and Amsterdam. Water is a dominant feature of those cities. Often the property prices in the vicinity of canals and harbors are much higher than in other parts of the city where the presence of water is not so dominant. Private companies, the owners of the houses, and also the local authorities are often working together to increase the attractiveness of those cities.

How to calculate

This measure is unlikely to already have a value applied. Instead, apply a self-assessment of how surface water is supporting the quality of the urban landscape as measured by the community sentiment/well-being within the city. The assessment should be based on information (policy documents, reports or research articles, or documents related to water-related tourism that deal with the sentiment of the citizens. Provide score between 0 (no role) to 10 (water plays a dominating role in the well-being of citizens).

Indicator	Assessment
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https://www.pub.gov.sg/resources/gallery

http://www.urbangreenbluegrids.com/projects/singapore/

https://www.pub.gov.sg/Documents/managingUrbanRunoff.pdf
The ABC Waters programme, launched in 2006, is a strategic stormwater management strategy which aims to enhance environmental aesthetics and improve the quality of water by harnessing the full potential of our waterbodies. This is done by integrating the waterways and waterbodies with the surrounding environment to create community spaces and a sustainable living environment.

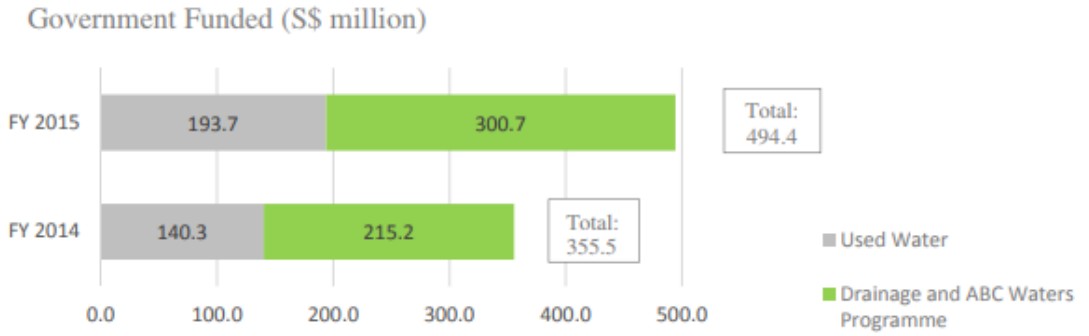
There is also ABC Waters Certification, a scheme designed to provide recognition to public agencies and private developers who embrace the ABC Waters concept and incorporate ABC Waters design features in their developments. Besides providing recognition, the scheme also aims to ensure that the design features incorporated within the developments achieve a minimum design standard. The ABC Waters Professional Programme, an initiative to build up the expertise and ensure qualified Engineers, Architects & Landscape Architects to undertake the design and implementation of ABC Waters design features, has garnered 72 ABC Waters Professionals since its commencement in 2011.

The information on the ABC Waters Programme, ABC Waters Design Guideline, ABC Waters Professional Programme and PUB Annual Report ~~for ABC Waters~~ are available online.

https://www.pub.gov.sg/abcwaters/
https://www.pub.gov.sg/abcwaters/abcwatersprofessionals

https://www.pub.gov.sg/annualreports/annualreport2016.pdf

By 2017, there will be 38 ABC Waters projects open to the community, with an additional 4 pipeline projects at Sungei Tampines (Tampines Ave 7 to TPE), Chestnut Drive Outlet Drain, Sungei Simpang Kanan and Alexandra Sub-Drain A.



Government funded capital expenditure of S$494.4 million were for drainage, used water reticulation network and the Active Beautiful Clean Waters Programme projects belonging to the Government.

(from: PUB's annual report 2016)

https://www.pub.gov.sg/abcwaters/Documents/ABC_DG_2014.pdf
Based on this report, ABC's aims also covers the community as written in the following
The aim of the ABC Waters Programme is to seamlessly integrate the Environment

(Green), Water Bodies (Blue), as well as the Community (Orange) to create new community spaces and to encourage lifestyle activities to flourish in and around the waters.

The progress is reported annually. The overall program is intended for public (local community) focus (as can be seen from the objective). Nevertheless, the guideline of ABC Waters is targeted for developers and industry professionals as collaborators. Therefore, score is **10.0**.