POSITION PAPER

Global Water Partnership Caribbean

ADVANCING WASTEWATER MANAGEMENT AND WATER REUSE IN THE EASTERN CARIBBEAN

JULY 2022

This Position Paper was prepared by Miguel Montoute and Joyce Thomas Peters.
It is intended to galvanise discussion within the GWP-C network and the larger water and development community.

www.gwp-caribbean.org

ABOUT GLOBAL WATER PARTNERSHIP-CARIBBEAN

The vision of the Global Water Partnership-Caribbean (GWP-C) is for a water secure Caribbean. Our mission is to support Caribbean countries in the sustainable management of their water resources at the community, national and regional level.

GWP-C is 1 of 13 Regional Water Partnerships of the Global Water Partnership (GWP). It was established in 2004 to foster the application of Integrated Water Resources Management (IWRM) in the Caribbean region. IWRM is the coordinated development and management of water, land, and related resources, in order to maximise economic and social welfare without compromising the sustainability of ecosystems and the environment.

Any organisation with an interest in water sustainability in the region, can become a GWP-C Partner. GWP-C currently has over 100 partners in more than 20 Caribbean countries. These include water management agencies, water user associations, private water management agencies, government institutions, academic and research institutions, private sector companies, non-governmental organisations, community-based organisations, civil society organisations, youth organisations, regional agencies, consultancy firms, among others.

This Position Paper was prepared by the GWP-C Technical Committee members:

- Miguel Montoute
- Joyce Thomas Peters

Cover Photo by Aviavlad | Pixabay

Global Water Partnership Caribbean

TABLE OF CONTENTS

Global Water Partnership
Caribbean

INTRODUCTION

Wastewater can be a valuable resource because approximately 99.9 percent is water and the remaining 0.1 percent contains impurities such as organic matter, microorganisms and inorganic compounds (Von Sperling, 2007; Aguilar et al., 2014). It therefore has immense potential as a supplementary source of water for a myriad of commercial, industrial and agricultural purposes.

The term wastewater refers to a combination of one or more of several types of aqueous effluents from domestic, commercial, industrial and agricultural processes, inclusive of stormwater and urban runoff (Tuser, 2021). The domestic component is composed of blackwater (which comprises excreta, urine and faecal sludge) and greywater (which emerges from kitchens and bathrooms). The commercial component, which some authors also classify as domestic (Amoatey and Bani, 2011; Von Sperling, 2007), typically originates from commercial establishments, institutions and hospitals. Manufacturing industries also produce wastewater as part of their production processes. Stormwater and urban runoff typically contain wastes and contaminants from the environment and are considered a type of wastewater. Agricultural run-off originates from crop and animal husbandry activities and may contain a range of pollutants including agrochemicals, heavy metals and solid faecal waste.

Wastewater can also be classified as raw, partially treated, or fully treated. It is referred to as raw when water has undergone a transformation in its quality after being used or exposed to contaminants[1], becoming liquid waste (Von Sperling, 2007). Treated wastewater, however, is wastewater which has undergone varying levels of treatment to remove its main pollutants[2], before being discharged into the environment or being reused. A wide range of options for treating wastewater exists and as such, treatment can take place at varying levels. This therefore has direct implications for how treated wastewater is reused.

---

[1] Contaminants can be defined as inputs of alien and potentially toxic substances into the environment and not all contaminants cause pollution, because concentrations may be too low (Stengel et. al, 2006).

[2] Pollutants can be defined as anthropogenically-introduced substances that have harmful effects on the environment and the concentrations at which contaminants become pollutants cannot always be defined (Stengel et. al, 2006).

The treatment process, thus, improves wastewater quality based on prescribed effluent quality criteria or effluent standards which may vary according to the intended fate of these effluents (disposal or reuse). Wastewater must be properly treated because it usually has a high contaminant load in its raw form, which may exceed the assimilative capacity of water bodies when disposed of indiscriminately (Amoatey and Bani, 2011). This could lead to a plethora of adverse public health and environmental problems.

This paper will illustrate that treated wastewater is increasingly being treated as a resource because it can be effectively reused, rather than being disposed of. Prolonged seasonal dry spells brought about by climate variability and climate change have increased the demand for water resources during drought conditions in the dry season. Making more water accessible through wastewater reuse, complemented with sufficient water storage and rainwater harvesting, could help to improve the climate resilience of households, industries, agriculture, and tourism establishments. Some ways in which wastewater can be reused include: recharging aquifers; irrigating golf courses and cooling manufacturing equipment.

There has been global recognition of the importance of improving wastewater management as a critical part of Integrated Water Resources Management (IWRM), which promotes the sustainable use of water across sectors such as food production, health services, environmental protection and industry. As such, the relevance of wastewater management is increasingly being reflected in global and regional commitments, and multilateral environmental agreements (MEAs). Wastewater treatment is specifically highlighted in Sustainable Development Goal Target 6.3 (SDG 6.3), which seeks to improve water quality and reduce untreated wastewater, by aiming to cut half of the proportion of untreated wastewater by 2030 (United Nations, 2018; Roopnarine et al., 2019). Additionally, there are at least five other SDGs (SDG 9.4, SDG 11.6, SDG 12.4, SDG 12.5, and SDG 14.1) which are linked to wastewater and its contaminants, technologies, and reuse.

The United Nations Environment Programme (UNEP) Global Programme of Action and the Global Wastewater Initiative are two other mechanisms which are relevant to the wastewater sector. These frameworks could facilitate transboundary cooperation among countries which share water resources. They also promote best practices on wastewater management and the reuse of treated wastewater.

In terms of the coastal and marine space, the Cartagena Convention is also relevant as it pertains to wastewater disposal from land-based sources, as specified by one of its three technical protocols, namely, Land-Based Sources of Marine Pollution Protocol (LBS Protocol) (UNEP-CEP, 2019). The Eastern Caribbean Region, which will be highlighted in this paper, includes the nineteen Eastern Caribbean Sub-region territories covered under the Cartagena Convention Area (referred to as Sub-region IV)[3]. Sub-region IV also includes the eleven-member grouping of islands of the Organisation of Eastern Caribbean States[4] (OECS).

The LBS protocol is relevant to the wastewater sector because it specifies two classes of water which require varying degrees of environmental protection based on their sensitivity and vulnerability to ecosystem disruption. Class I refers to waters that are particularly sensitive to the impacts of wastewater and these waters include ecosystems such as mangroves, seagrass beds and coral reefs (Sealy, 2021). This water class should therefore be protected by properly regulating the type and concentration of effluents which may pose adverse impacts within its boundaries. Class II waters are less sensitive to the impacts of domestic wastewater. Discharges in Class II waters therefore pose an insignificant risk to humans and living resources, due to limited exposure (UNEP-CEP, 1999).

In the OECS territories, the St. George's Declaration of Principles for Environmental Sustainability is applicable, as the guiding framework for Environmental Management (OECS, 2006). Principle No. 10 speaks to waste management, pollution control and prevention, from land-based sources to protect freshwater resources, coastal water and marine environments (OECS, 2006). These land-based sources would include raw wastewater from inland watersheds (UNEP-CEP, 2019).

The challenge of wastewater management and effluent based pollution is an issue for developing and more developed countries alike, but they may exist in diverse ways. For example, in Central and Eastern Europe (CEE), rural wastewater systems in small and medium-size settlements have been reported to offer an inappropriate level of treatment for preventing surface and groundwater pollution (GWP, 2022), while big cities and towns have functional systems requiring costly upgrades, which have stressed

[3] Cartagena Convention Sub-Region IV (Eastern Caribbean): Anguilla, Antigua and Barbuda, Barbados, British Virgin Islands, Dominica, Grenada, Guadeloupe, Martinique, Montserrat, Saba, St. Eustatius, St. Martin, Sint Maarten, St. Lucia, St. Barthelemy, St. Kitts and Nevis, St. Vincent and the Grenadines, US Virgin Islands, Trinidad & Tobago [Source: UNEP-CEP (2019)].

[4] The OECS is an eleven-member grouping which comprises seven protocol members (Antigua and Barbuda, Commonwealth of Dominica, Grenada, Montserrat, St. Kitts and Nevis, St. Lucia and St. Vincent and the Grenadines) and four associate members (Anguilla, the British Virgin Islands, Guadeloupe and Martinique) - (Source: http://oecs.org).

the available economic resources in these countries (Bodik and Ridderstolpe, 2007). In the Eastern Caribbean Region however, although improved sanitation levels have been reported as being high, there is extremely low centralised wastewater treatment coverage in urban areas, partly due to: cost; expertise; and inadequate land use planning. Rural areas within the Eastern Caribbean apply the use of septic tank systems as an adequate sanitation solution, however as these areas become more urbanized or peri-urban[5], more appropriate wastewater systems may be required.

There is a need to re-think our approach to sanitation, wastewater management and water reuse and how opportunities can be leveraged within the circular economy. We need to be more innovative and adaptive, by using technologies and solutions which are based on the particular urban and rural contexts, and user needs.

SANITATION, WASTEWATER MANAGEMENT AND THE CIRCULAR ECONOMY

Sanitation, wastewater and the circular economy are interlinked due to the possibility of economic benefits such as resource recovery and reuse. Sanitation and wastewater management are sometimes used interchangeably. However, for this paper, a distinction between sanitation and wastewater management will be made for greater clarity. This distinction is in keeping with the Sustainable Development Goals (specifically SDG 6) which have different targets relating to sanitation and wastewater management. These SDGs address both sanitation and wastewater from the angles of dignity, equity, social inclusion, environmental protection and public health.

Sanitation

The term sanitation refers to the practices of separating human excreta from human contact. It involves disposing of this faecal matter in a manner which is hygienic in nature and not harmful to public health and the environment (Asian Development Bank, 2006). The type of technology involved in the sanitation process determines whether it is classified as good or improved sanitation. Improved sanitation technologies refer to

[5] Peri-urban settlements are former rural areas or rural areas in transition, located on the outskirts of established towns and cities which are becoming more urban in character - many peri-urban areas, are still considered rural (Webster and Muller, 2011).

facilities with: sewer connections; septic tanks; pour-flush latrines; pit latrines[6] with slabs; ventilated-improved pit latrines; or composting toilets (Burdescu et al., 2020). Access to these improved technologies/facilities is a vital indicator for the achievement of basic public health and socioeconomic development.

Access to improved sanitation in the Caribbean Region is considered high with above 90 percent of residents having improved access (Cashman 2014). According to a World Bank report, the Eastern Caribbean countries of Dominica, Grenada, Barbados, Trinidad and Tobago and Saint Lucia have been shown to have an elevated level of access to improved sanitation, which is equal to or greater than the Latin American and the Caribbean average of 88 percent (Burdescu et al., 2020). It should be noted that good national sanitation coverage and services do not preclude environmental pollution. This is because having good or improved sanitation does not necessarily mean that wastewater is safely treated and managed. This is evident in the many Eastern Caribbean countries where municipal wastewater from centralised sewerage networks is untreated or poorly treated (UNEP-CEP, 2019).

Wastewater management

Wastewater management is a more complex approach which involves the safe transition of raw wastewater along a value chain, from generation to disposal, resulting in discharge of raw, partially treated, or fully treated effluent. This value chain may involve a wastewater sewerage system with collection, treatment, and disposal phases, which are either on-site or off-site (Von Sperling, 2007).

The treatment phase may involve various stages as depicted in the wastewater treatment train in Figure 1 (Deiters, 2022). These stages are typically preliminary treatment, primary treatment, secondary treatment, and tertiary treatment (Amoatey and Bani, 2011; Burdescu et al., 2020; Deiters, 2022). While some treatment is better than no treatment, only tertiary treatment eliminates nutrients, heavy metals, pathogens, and toxins from wastewater (UNEP-CEP, 2019).

[6] Pit latrines which are classified as improved are: Septic tank pit latrines, ventilated-improved pit latrines, pit latrines with slabs and composting toilets – source: https://www.who.int/data/nutrition/nlis/info/improved-sanitation-facilities-and-drinking-water-sources

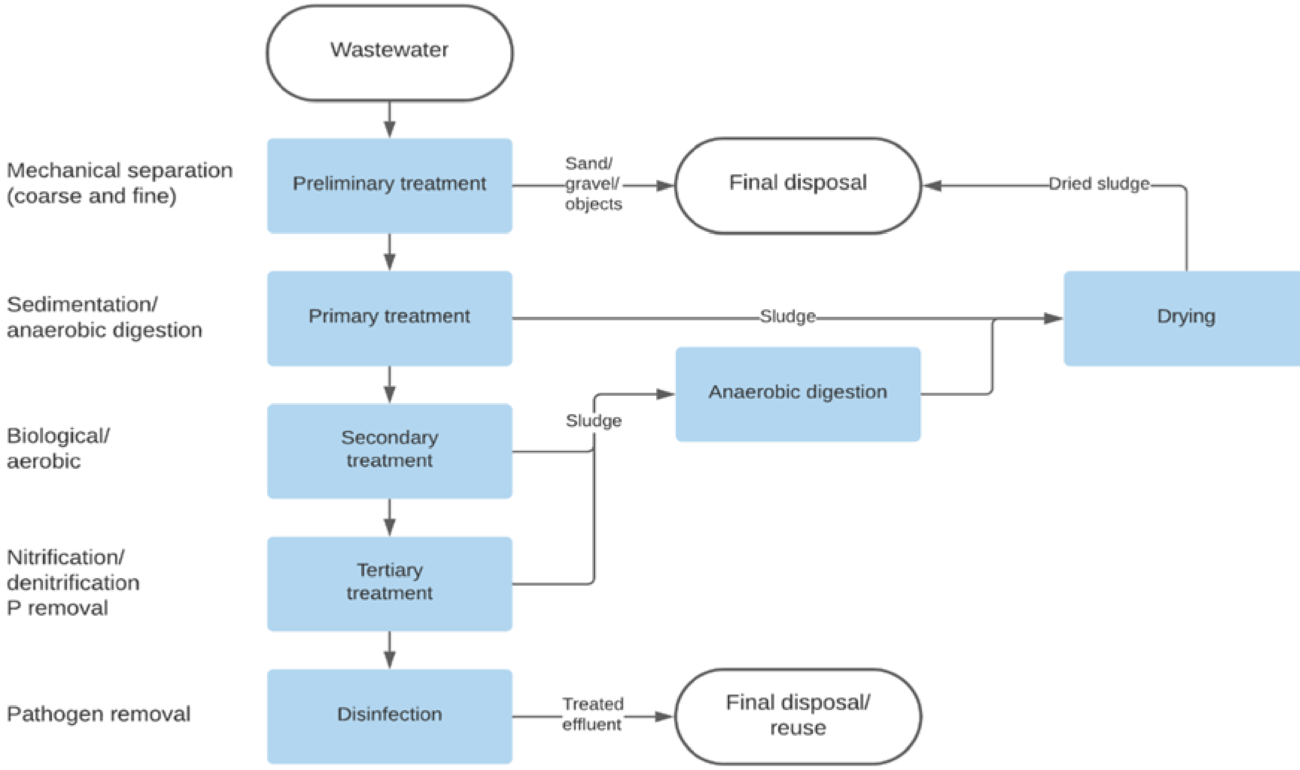


Figure 1: Description of a classic wastewater treatment train [Source: Deiters (2022)]

On-site systems usually refer to sanitation technologies such as improved latrines and septic tank systems, which are preferable in sparsely populated and rural regions (Von Sperling, 2007). These technologies are avoided in urban or densely populated areas, due to the substantial risk of groundwater contamination resulting from the infiltration of effluents of high contaminant load. Conversely, off-site systems are centralised municipal facilities. They can be classified as either separate sewage systems which separate rainwater from sewage or combined systems which accommodate both sewage and rainwater (Von Sperling, 2007).

A major advantage of these centralised systems and their treatment plants is the capacity to perform all stages in the treatment train, to produce a safe, high-quality effluent. Conversely, a significant disadvantage is that their capital and operational costs are relatively high. These costs are typically borne by communities which discharge wastewater into these systems (Amoatey and Bani, 2011). This has therefore made on-site systems more economically attractive in low-income areas.

As a means of cost reduction, an attractive alternative to off-site centralised systems are package plants[7], commonly called decentralised wastewater treatment systems (DEWATS), which can also be installed on-site. This has been recognised as a viable option for developing countries, such as Eastern Caribbean Small Island Developing States (SIDS), because it may be easier to manage, more sustainable and practical (Amoatey and Bani, 2011).

Circular Economy

Adoption of more circular economy[8] approaches to development is gaining increased regional and global interest, in particular for ensuring greater sustainability and minimizing use and degradation of natural resources. In the water sector, it generally seeks to recover and reuse water as a means of reducing external pressures on the resource, which may be stressed either seasonally or perennially. It is also a way of providing environmental protection and improving long-term sustainability (Byrne et al., 2019) of water resources.

This approach encourages actions to prevent and/or reduce generation of wastewater and the processing of wastewater once it has been generated. It also entails processes as specified in a conceptual framework[9] developed by Smol et al. (2020) (see Figure 2):

- **Reduction**: Pollution may be limited by decreasing the amount of raw wastewater produced as a prevention measure. This can be achieved by lowering the amount of potable water used through water conservation practices and improving water use efficiency. Water use efficiency includes the use of water efficient toilets, showerheads and faucets.

- **Removal**: Raw water and wastewater are treated as a means of removing harmful contaminants through the application of effective technologies. These may be improved sanitation technologies, centralised wastewater treatment plants or DEWATS.

[7] Package plants are treatment facilities which have been pre-manufactured and are used to treat wastewater in small communities or on individual properties (US EPA, 2000): https://www3.epa.gov/npdes/pubs/package_plant.pdf

[8] "*A circular economy reduces material use, redesigns materials to be less resource intensive, and recaptures waste as a resource to manufacture new materials and products*" (US EPA, no date): https://www.epa.gov/recyclingstrategy/what-circular-economy

[9] NB: This conceptual framework is based on the European water and wastewater sector but may be used as a guide for the Eastern Caribbean. Source: https://link.springer.com/article/10.1007/s10163-019-00960-z/figures/4

- **Reuse:** Treated wastewater is used as an alternative to water in accordance with appropriate water quality safety standards. The water can be reused for agricultural and/or industrial activities.

- **Recycling:** The reclamation of potable water from raw wastewater in accordance with potable water safety standards. This water can be re-injected into the municipal water supply system.

- **Recovery:** The extraction of nutrients and energy from water-based wastes. This includes biogas and plant fertilizer.

- **Rethinking:** A systematic, holistic, adaptive and iterative process of viewing the wastewater value chain within the circular economy, for creating solutions based on technological, organisational, societal and financial conditions. It also involves transformational change and learning lessons through South-South cooperation and case studies, as a means of improving the circular water economy.

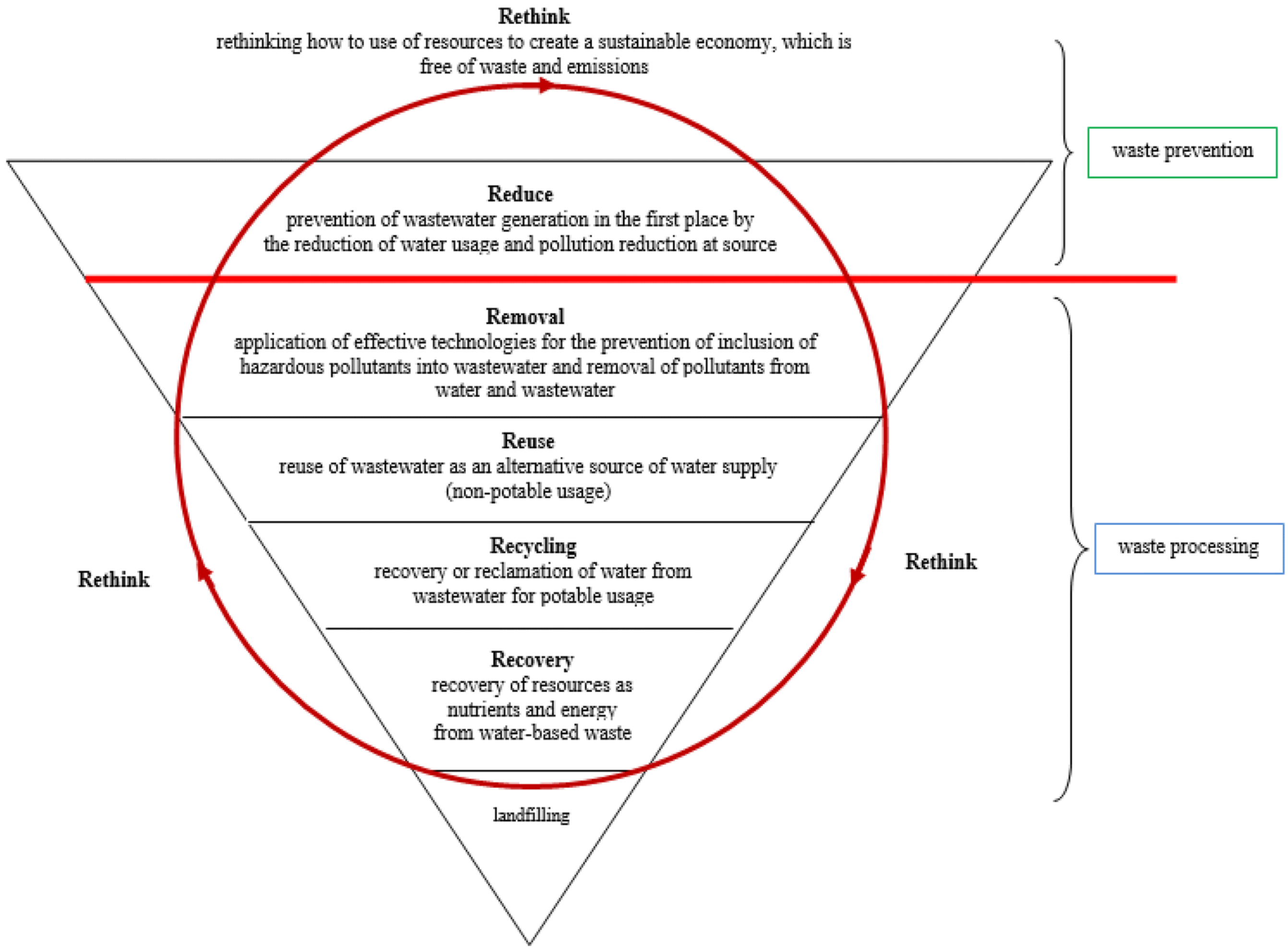


Figure 2: The circular economy model framework in the European water and wastewater sector according to Smol et al. (2020)

The framework developed by Smol et al. (2020) therefore helps with the distinction between the terms reuse and recycling, which are sometimes used interchangeably in wastewater literature. It also shows that the concepts of the circular economy can be applied through practical technologies and techniques.

In terms of the recovery process, processed effluents and sludge are resources from which fertiliser (from sludge) and energy (from biogas and energy pellets) can be produced. This can provide some form of sustainable cost recovery through value creation. Reused and recycled water may offer the biggest value by creating resilience during periods of water stress and droughts (Amoatey and Bani, 2011).

Reuse should be guided by the appropriate quality standards/guidelines. The WHO has published guidelines for the safe use of wastewater, excreta and greywater for aquaculture and agriculture, which also advises on the appropriate policy and regulatory approach (WHO, 2006). In 2012, guidelines for wastewater reuse were also published by the United States Environmental Protection Agency (US EPA, 2012). In the Caribbean, the National Environment and Planning Agency (NEPA) of Jamaica has commendably published effluent standards which apply to discharges from sewage treatment systems (Jamaica Environment Trust, 2017). NEPA and the Natural Resources Conservation Authority (NRCA) have also published interim irrigation standards[10] as a benchmark for the suitability of water for agricultural use.

After meeting the appropriate discharge/effluent standards, treated wastewater can have many applications, which include but are not limited to: irrigation; aquaculture; fire protection; toilet/urinal flushing; and industrial cooling/heating (Helmer and Hespanhol, 1997; Byrne et al., 2019). Figure 3 shows the percentages of wastewater reuse applications on a global scale. These applications would only be acceptable if the risks to public and environmental health are low, through the implementation of good management and continuous monitoring of wastewater treatment plants and facilities (Amoatey and Bani, 2011). Table 1 shows the descriptions of the various categories of reuse and Figure 4 shows that the level of treatment depends on the reuse application.

[10] List of standards published by NEPA: https://www.nepa.gov.jm/publications/standards

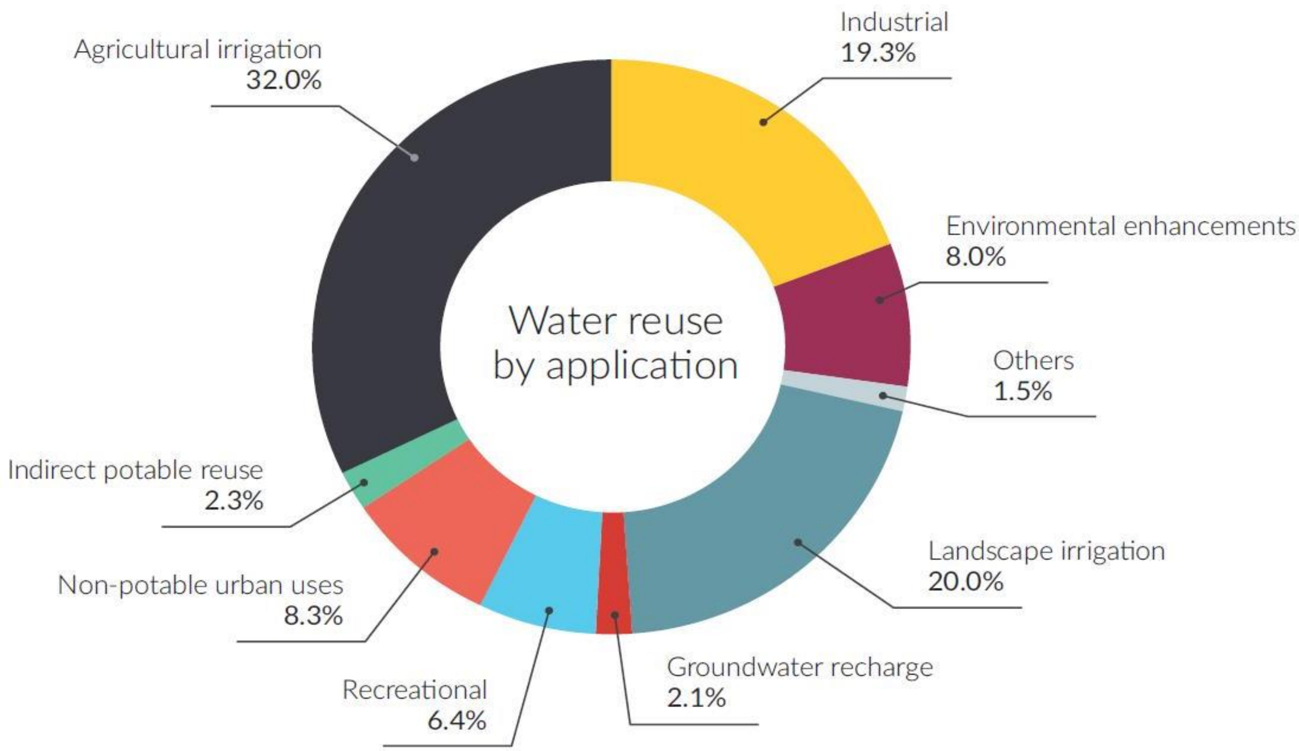


Figure 3: Market share by application of global water reuse in the context of the circular economy
Source: Lautze et al. (2014) cited in Byrne et al. (2019)

Table 1: Categories of reuse applications – Source: US EPA (2012)[11]

Category of Reuse		**Description**
Urban Reuse	*Unrestricted*	The use of reclaimed water for non-potable applications in municipal settings where public access is not restricted
	Restricted	The use of reclaimed water for non-potable applications in municipal settings where public access is controlled or restricted by physical or institutional barriers, such as fencing, advisory signage, or temporal access restriction
Agricultural Reuse	*Food Crops*	The use of reclaimed water to irrigate food crops that are intended for human consumption
	Processed Food Crops and Non-food Crops	The use of reclaimed water to irrigate crops that are either processed before human consumption or not consumed by humans

[11] 2012 Guidelines for Water Reuse published by US EPA: https://www.epa.gov/sites/default/files/2019-08/documents/2012-guidelines-water-reuse.pdf

Impoundments	*Unrestricted*	The use of reclaimed water in an impoundment in which no limitations are imposed on body-contact water recreation activities
	Restricted	The use of reclaimed water in an impoundment where body contact is restricted
Environmental Reuse		The use of reclaimed water to create, enhance, sustain, or augment water bodies including wetlands, aquatic habitats, or stream flow
Industrial Reuse		The use of reclaimed water in industrial applications and facilities, power production, and extraction of fossil fuels
Groundwater Recharge – Non-potable Reuse		The use of reclaimed water to recharge aquifers that are not used as a potable water source
Potable Reuse	*Indirect Potable Reuse (IPR)*	Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes normal drinking water treatment
	Direct Potable Reuse (DPR)	The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a water treatment plant, either collocated or remote from the advanced wastewater treatment system

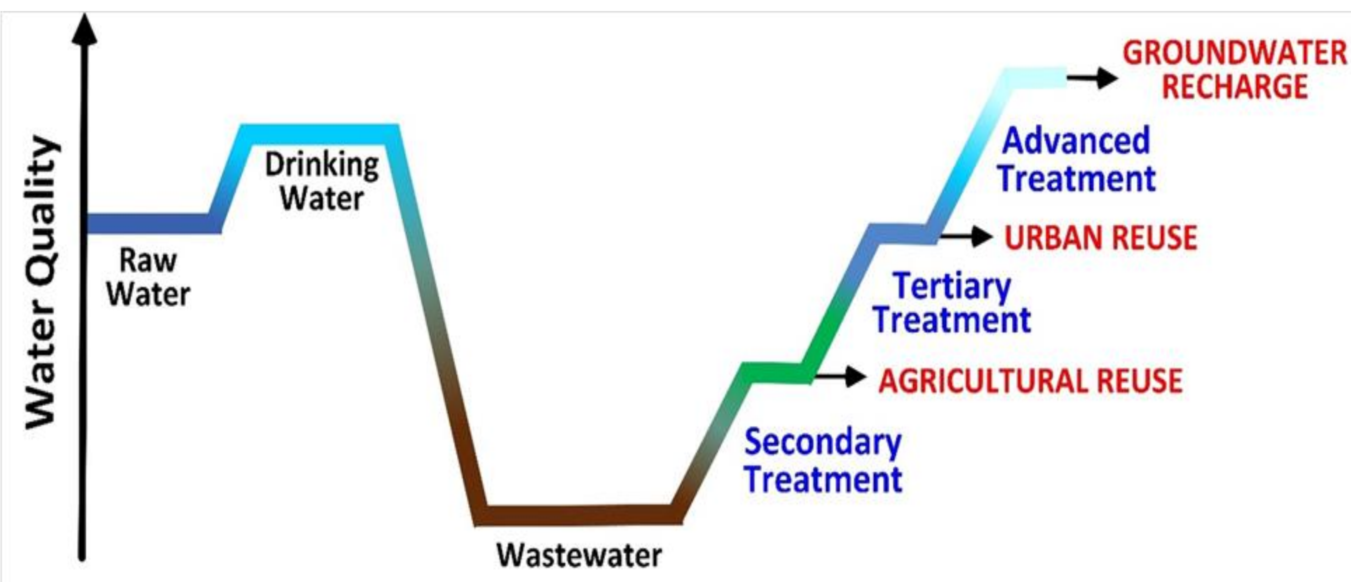


Figure 4: Water quality variations based on level of treatment and uses – Source: US EPA (2012)

THE STATE OF WASTEWATER MANAGEMENT IN THE EASTERN CARIBBEAN

According to a recent report commissioned by the Caribbean Public Health Agency (CARPHA), wastewater-based pollution is an issue which needs to be addressed in some Eastern Caribbean territories, especially in coastal areas and bays, which are near urban centres and peri-urban[12] settlements (Didier, 2021). This pollution may exist in small towns and villages with inadequate wastewater infrastructure which is not adapted to the coastal terrain and geology. In some cases, the appropriate infrastructure may not exist, and when it exists, it may be faulty (through leakage) or not maintained properly.

Some countries in the Wider Caribbean Region[13] have made commendable progress in the wastewater sector, sharing lessons-learnt for Eastern Caribbean[14] territories (see Table 2). These lessons include applications and opportunities for wastewater reuse as part of a circular economy. Wastewater reuse is of particular importance because estimates indicate that it can significantly satisfy water demand (Peters, 2015; UNEP-CEP, 2021). This therefore presents an opportunity for Eastern Caribbean territories, where the national water demands have not been fully met (Peters, 2015), and are exacerbated by competing domestic, industrial and tourism sectors. This is especially critical during the dry season, which is projected to be increasingly severe with climate change.

Table 2: Cartagena Convention Area Sub-regions inclusive of the Eastern Caribbean (Sub-region IV) [Source: UNEP-CEP (2019)]

Sub-region	Name	Countries/Territories
I	Gulf of Mexico	United States of America, Mexico
II	Western Caribbean	Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Panama
III	Southern Caribbean	Colombia, Venezuela, Guyana, French Guiana, Suriname, Aruba, Bonaire, Curacao
IV	Eastern Caribbean	Anguilla, Antigua and Barbuda, Barbados, British Virgin Islands, Dominica, Grenada, Guadeloupe, Martinique, Montserrat, Saba, St.

[12] Nb: many peri-urban areas are still considered rural (Webster and Muller, 2011).

[13] Wider Caribbean: Sub-regions I to V within the Cartagena Convention Area (UNEP-CEP, 2019).

[14] Eastern Caribbean: Sub-region IV within the Cartagena Convention Area (UNEP-CEP, 2019).

		Eustatius, St. Martin, Sint Maarten, Saint Lucia, St. Barthelemy, St. Kitts and Nevis, St. Vincent and the Grenadines, US Virgin Islands, Trinidad & Tobago
V	North-eastern and Central Caribbean	The Bahamas, Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Turks and Caicos Islands

Caribbean water and sewerage utilities are generally state-owned entities and they have traditionally placed a greater focus on the provision of pipe-borne potable water supply, as opposed to wastewater treatment services (Cashman, 2014; Diez et al., 2019). The regulation of these utilities by independent agencies is also insufficient (Cashman, 2014) and resulting in adverse implications for regularising the regional wastewater sector in an effective manner. This is especially relevant because in the recent past, wastewater management has been perceived as a low priority sector among water utility managers and high-level stakeholders (Cashman, 2014).

According to Groom et al. (2006), effective economic and environmental regulation of the water sector is very important. Economic regulation of the sector entails legal restrictions concerned with addressing the monopoly power of water utilities by preventing water and sewerage service prices from being too high for consumers. This form of regulation should require utilities to provide quality service which is satisfactory to customers, while charging a tariff which is reasonable and sufficient, to cover the cost-of-service provision and allow a reasonable return on investment. However, the Eastern Caribbean state-owned water and sewerage utilities generally suffer from the problem of charging too little for their services, which does not allow some of them to comfortably recover production and service costs. This makes them rely on government subsidies, cut back on service quality, neglect maintenance and impede investments.

Environmental regulation is also important to incentivise these utilities to care about the natural environment (Groom et al., 2006). It is necessary to prevent the over-abstraction of water resources and discharge of pollutants from untreated wastewater. In the Eastern Caribbean, environmental regulation tends to be better developed in terms of legislation. However, its application may still be problematic. Unfortunately, economic regulation lags behind and it is this that can incentivise investment and set appropriate standards of service.

Saint Lucia has established a regulatory structure for the water and sewerage sector which includes the National Utilities Regulatory Commission (NURC)[15], as the statutory economic regulator. The NURC was established by the NURC Act in 2016 and it is a step in the right direction. In terms of environmental regulations, oversight is provided by core governmental entities such as the Water Resources Management Agency (WRMA) which was created in 2005 (Government of Saint Lucia, 2020). The WRMA plays a key regulatory role in water abstraction and raw water quality, and collaborates with the Department of Environmental Health (DOEH). The DOEH is responsible for regulating wastewater and sludge discharges, establishing public health standards for construction of wastewater facilities and approving applications for septic tanks and wastewater treatment plants[16].

This collaborative approach is therefore needed not just on the national level. There should be enough buy-in from key regional and national stakeholders to highlight the need for proper regulation and integrated management within the sector. Thankfully there is some progress on that front, because of a regional action framework for Integrated Water Resources Management (IWRM) for the CARICOM Region which has been commissioned by CARPHA (CARICOM, 2020). This framework has featured wastewater management among activities within the Roadmap of Actions for IWRM in the Region, through extensive stakeholder consultation. This presents an opportunity to bring wastewater management into the conversation by elevating the issue as a regional priority, as it pertains to matters such as: using appropriate technologies/solutions; improving climate change resilience through wastewater reuse and recycling; and reducing coastal and marine pollution.

According to the 2019 Cartagena Convention Area Report (SOCAR), more than 15×10^9 m^3 of wastewater was generated in the Wider Caribbean Region in 2015 (UNEP-CEP, 2019). Approximately 37 percent of this amount underwent some form of treatment by wastewater treatment plants and the remaining 63 percent was released into coastal waters in an untreated form. The contribution of untreated wastewater by volume from the Eastern Caribbean Region in the whole year 2015 was about 0.24 km^3 (UNEP-CEP, 2019). If this wastewater is effectively treated and reused/recycled, it might provide up to 38 percent of the total water needed for this sub-region (Peters, 2015; UNEP-CEP, 2019; UNEP-CEP, 2021).

[15] See NURC website for details: https://nurc.org.lc/

[16] Extracted from: CReW+ Project - GEF Full Size Project Document - Annex Y- National Package for Saint Lucia (Final Draft).

Estimates for the Eastern Caribbean Region show that about 20 percent of generated municipal wastewater is collected, but only about 5 to 8 percent is being treated (Burdescu et al., 2020; Peters, 2015). A recent World Bank study, which assessed benchmark regional water and sewerage utilities, reported that wastewater system coverage through centralised pipes in the Caribbean Region was very low, with an average coverage of about 9 percent, based on data available from 2015 (Burdescu et al., 2020). Of the Eastern Caribbean utilities being assessed, all fell below the 9 percent average. In terms of the percentage of wastewater treated, there was generally an unavailability of data for most benchmark Eastern Caribbean utilities being assessed. The general sentiment is that coverage and treatment in the Eastern Caribbean territories are significantly lacking for municipal piped systems, which are owned and operated by water utilities (Peters, 2015).

Table 3 shows whether some Eastern Caribbean benchmark water utilities undertook municipal wastewater collection and treatment as per 2015 data. Only 1 in 6 did not provide any collection and 2 in 6 provided no treatment. The level of wastewater treatment by most of these utilities was not provided, due to the unavailability of data during the benchmark study conducted by the World Bank.

Table 3: Wastewater collection and treatment by some benchmark Eastern Caribbean utilities (data regarding the level of treatment was mostly unavailable)
[Source: Burdescu et al. (2020)].

Benchmark Eastern Caribbean utilities based on 2015 data sourced by the World Bank	**Wastewater collection**	**Wastewater treatment**
APUA (Antigua)	no[17]	no
BWA (Barbados)	yes	yes
DOWASCO (Dominica)	yes	no
NAWASA (Grenada)	yes	yes[18]
WASA (Trinidad and Tobago)	yes	yes
WASCO (St. Lucia)	yes	yes

[17]GEF-CReW (Antigua and Barbuda): https://www.gefcrew.org/index.php/participating-countries/antigua-barbuda

[18] Only the screening of solids is done.

In terms of the wastewater coverage in four Eastern Caribbean countries (see Table 4) by various types of sanitation and wastewater systems (centralised sewerage, septic tanks and pit latrines), coverage ranged from 93 to 100 percent, with Trinidad and Tobago having the highest total coverage (full coverage). Trinidad and Tobago had the highest centralised sewerage coverage of 30 percent.

Table 4: Wastewater coverage in some Eastern Caribbean countries by technology type, according to the World Bank
[Source: Burdescu et al. (2020)].

Country and year of data capture	Coverage by wastewater technologies			
	Centralised sewerage systems (%)	Septic tanks (%)	Pit latrines (%)	Total (%)
Grenada (2012)	5	55	36	96
St. Lucia (2006)	7	63	23	93
St. Vincent and the Grenadines (2012)	12	57	30	99
Trinidad and Tobago (2012)	30	64	6	100

Trinidad and Tobago had also planned to make some strides in the wastewater sector through the Beetham Water Treatment and Recycling Plant, which was positioned to be one of the largest wastewater treatment facilities in the Caribbean Region (McTaggart et al., 2007). Once completed, it was expected to provide a high level of treatment, to produce at least thirty thousand cubic meters per day of high-quality industrial water (UNEP, 2021). The plan was to supply the industrial water to industrial users (for example the Point Lisas Industrial Estate). However, there have been great challenges which have hindered the successful completion of the project (Javeed, 2022). The main challenge was the non-acceptance of the price at which this water would be sold to the Water and Sewerage Authority (WASA), prior to distribution for industrial use. As a way forward, the necessary business arrangements/models for making the reuse of this water a reality are still being considered. If this initiative becomes successful and the plant is commissioned, this may free up potable water which the national water utility can provide to domestic users (Water & Wastes Digest., 2015), hence alleviating some demand-based stresses caused by the industrial users.

On a household level, Eastern Caribbean countries preferably use on-site septic systems which are connected to soak-aways or drain-fields (Didier, 2021). This is alluded to in Table 4 which shows that septic tanks generally provide the highest percentage of wastewater coverage. Pit latrines are also used to a lesser degree and there have been reported cases of open defecation in some peri-urban and rural communities, such as socio-economically deprived coastal villages with shared public water and sanitation facilities (UNEP, 2020; Montoute and Cashman, 2015).

As opposed to centralised municipal systems, there has been greater traction in the Eastern Caribbean hotel sector which has made use of DEWATS. This is partially driven by pressures to engage in water reuse, due to high water demand, high commercial water prices, and the emergence of stricter environmental regulations (Peters, 2015). Many hotels and resorts own and operate relatively small on-site package decentralised plants (Didier, 2021; Peters, 2015; UNEP-CEP, 2019) in countries such as Grenada, Saint Lucia, Antigua and Barbuda and Trinidad and Tobago. They are often required by legislation or regulations to have package plants. For instance, in Antigua and Barbuda most hotels with a capacity of at least 50 rooms have on-site wastewater package plants (Peters, 2015). Many of these hotels are located along the coastline and the marine environment and are often impacted by poorly treated wastewater from these facilities, which do not meet appropriate safety standards, due to poor operation and maintenance, coupled with inconsistent regulation and enforcement.

The contribution of yachts towards marine and coastal pollution is also significant, due to the direct disposal of raw wastewater into the marine space (Didier, 2021, ECLAC, 2002). This is a delicate issue for Eastern Caribbean countries because tourism is a major economic contributor. In Barbados, yachts are encouraged to use prescribed sewage reception facilities on shore or dispose of sewage at least four miles away from land[19]. Yachts which are equipped with holding tanks are also given preference for anchoring closer to the shore within established anchorage zones.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention which covers the prevention of pollution of the marine environment by ships. However, the MARPOL regulations for the prevention of sewage pollution only apply to ships of at least 400 gross tonnage that are engaged in international voyages, or ships that are certified to accommodate 15 or more persons

[19] Source: Barbados Yacht Masters' Guide (revised March 2020).

(Didier, 2021). There is a need to develop and enforce regulations which target smaller pleasure vessels which frequent the region's nearshore coastal waters.

It has been estimated that Antigua and Barbuda, Saint Kitts and Nevis, Grenada, Saint Lucia, and Saint Vincent and the Grenadines generated more than one hundred and eighty thousand cubic meters of wastewater from the boating sector in the year 2019 (Didier, 2021). The two Eastern Caribbean countries which generated the majority (above 75 percent) of this total were Saint Lucia and Saint Vincent and the Grenadines, due to their higher demand as sailing destinations (Didier, 2021).

WHY WASTEWATER MANAGEMENT AND WATER REUSE ARE IMPORTANT TO THE EASTERN CARIBBEAN?

Wastewater management is important because it confers many important benefits. However, many of these benefits are not easily quantified in monetary terms for facilitating decision making. One challenge is that benefits are spread among many beneficiaries who do not realise that they are benefitting. They all have an equal stake in the benefits, which are collectively for the good of the public (Shattuck and Risse, 2021).

A broad economic analysis is needed to examine the holistic costs and benefits for society. This will assist in making more informed decisions regarding public policy on wastewater management (UNEP-CEP, 2015a). The health, environmental and socio-economic benefits of good wastewater management can be referred to as the difference between the costs associated with no action (inadequate management/treatment) as compared to the cost of action (capital expenditures and operational expenditures), the difference being the avoided costs and hence the benefits. The balance between these two types of costs can help put forward an economic justification for making wastewater management investments (Figure 5; UNEP-CEP, 2015a).

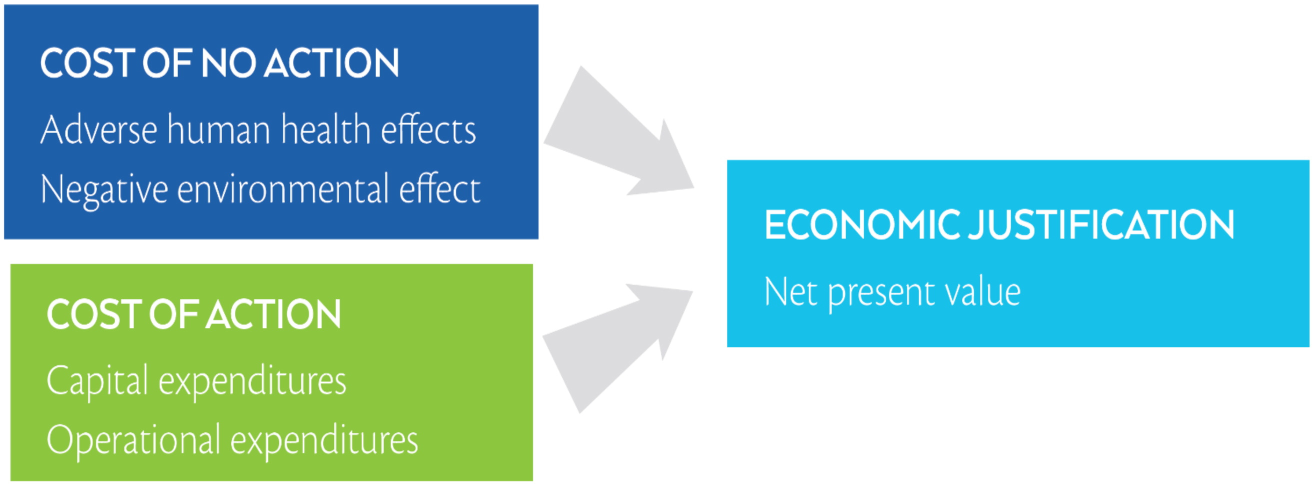


Figure 5: Benefits (costs of no action) versus costs of wastewater management investments [Source: UNEP-CEP, 2015a]

The benefits of these wastewater treatment investments are usually categorised as:

- Safeguarding human health due to improved drinking and recreational water quality.
- Environmental regeneration due to improvement in the quality of natural water sources and ecosystems.
- Maintaining and enhancing economic activity in areas which rely on good water quality, for example: crop production, fisheries, and tourism.

Economic valuations may therefore serve as a means of conducting more robust cost-benefit analyses (CBA) and Multi-Criteria Decision Analyses (MCDA) for potential wastewater treatment initiatives (Hernández-Sancho et al., 2015; UNEP-CEP, 2015a). These kinds of analyses may make project proposals more attractive to donors such as the Green Climate Fund (GCF), which could require a demonstration of the benefits for climate change adaptation.

The valuation process should include the full benefits and costs of wastewater interventions by incorporating non-market benefits (costs of no action) and costs of action. These should include factors related to the environment, public health, recreation, and touristic appeal. A well-balanced approach with the full costs therefore helps to determine whether a project focusing on wastewater management is truly socio-economically justified (Hernández-Sancho et al., 2010; Ćetković et al., 2022). CBAs and MCDAs should consider studies which evaluate a willingness to pay by users or by the public (Chopra and Das, 2019). Various wastewater management technology options should also be known (Chopra and Das, 2019; Arena et al., 2020) as a means of gaining public buy-in and factoring in the sustainability of operations.

Water reuse plans along with good economic valuations can improve the business case, hence making these investments more bankable for gaining financing and covering operational expenses. However, when considering reuse there are some complexities and pertinent factors which should be carefully analysed, such as: the need for additional costly infrastructure and the willingness of end users to pay[20] for capital and operations costs.

Good wastewater management helps to maintain ecosystem services, many of which provide both market (private) and non-market (public) goods and services (Ezebilo, 2016). Wastewater management in the region impacts the blue economy (fisheries and sustainable tourism), public health, the environment and socio-economic development. There are clear benefits to the blue economy due to the value which tourists place on recreational waters in the coastal and marine space.

In the Eastern Caribbean, some market goods and services that are derived from maintaining a healthy coastal and marine space are fisheries and recreational tourism services. Untreated wastewater may adversely affect coral reefs which serve as productive ecosystems for an abundance of marine biodiversity. Coral reefs may become less productive[21] from the effects of land-based sources of pollution (inclusive of wastewater) and this could adversely affect fishers, who depend on these reefs for their livelihood (Rogers et al. 2017). Healthy reefs are also important because they attract tourists who value recreational activities such as scuba diving and snorkelling.

Figure 6 is a framework[22] which illustrates the total economic value (TEV) of water resources. The TEV has two main types of benefits, namely, use values and non-use

[20] This is related to the business model which will be applied and the price at which treated wastewater will be sold for reuse applications.

[21] Use the following link to access the National Oceanic and Atmospheric Administration (NOAA) infographic which illustrates the ways in which land-based sources of pollution threaten coral reefs: https://oceanservice.noaa.gov/facts/coral-pollution.html

[22] This framework illustrates the TEV from the Armenian context: https://www.oecd.org/env/outreach/AM%20Water%20Value.pdf

values (Baker et al. 2021). Use values are commodity benefits such as drinking, irrigation and ecosystem function/services (including associated benefits such as wastewater services and navigation) (Shatanawi and Naber, no date). Non-use values are values which are intrinsic regardless of whether the resources are used by the public. Cultural, aesthetic or heritage values are examples of non-use values; because they are based on the satisfaction of knowing that an ecosystem is preserved for the benefit of future generations.

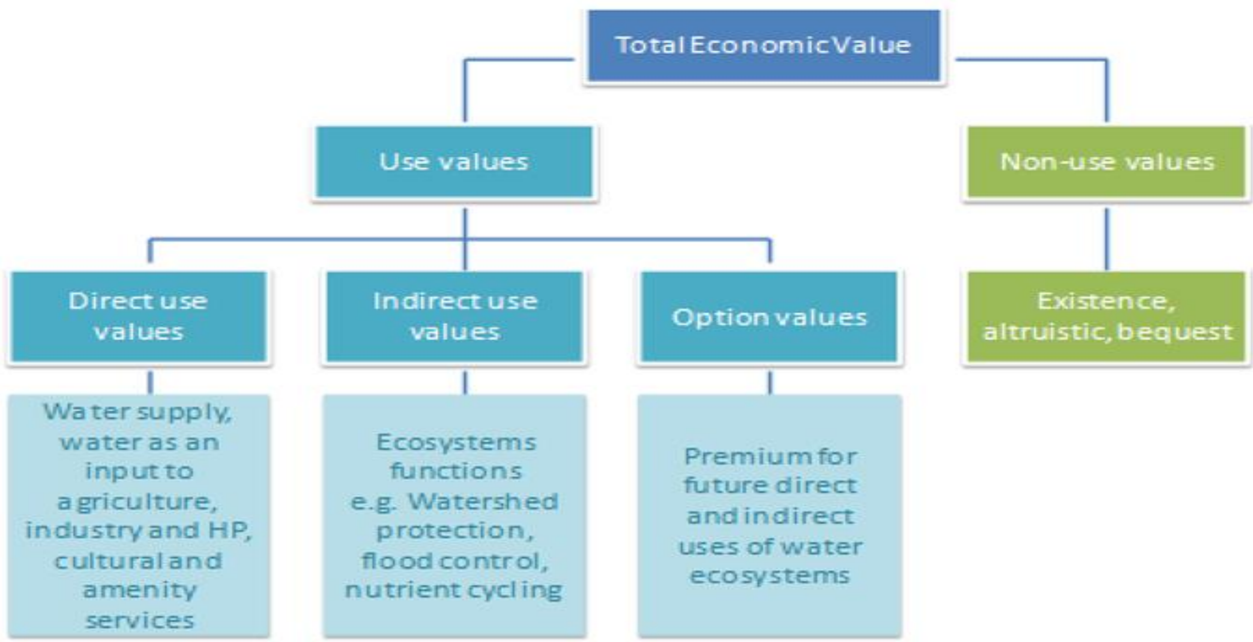


Figure 6: Total economic value (TEV) framework for water resources (modified[23])

An Economic Valuation Resource Guide for the Wider Caribbean Region prepared by the UNEP Caribbean Environment Program (CEP) looked at the effects of wastewater treatment problems in Southwest Tobago (UNEP-CEP, 2015a) (see Appendix 1 and 2 for guide on methodology used). It was found that tourism and recreational users would respond adversely to the resulting degradation of the Buccoo Reef as well as to information of recreational water quality impairment. This reef was a major tourist attraction (attracting over 60 percent of Tobago's visitors) and a primary source of gross domestic product (GDP) in Tobago (contributing between US$7.2 and US$8.8 million in

[23] Source: (OECD, no date) - Assessing the environmental and economic value of water: review of existing approaches and applications to the Armenian context (Final Report) - https://www.oecd.org/env/outreach/AM%20Water%20Value.pdf

2006) (UNEP-CEP, 2015a). In terms of fisheries, the contribution to GDP was between US$0.8 and $1.5 million in 2006 (UNEP-CEP, 2015a).

Other studies which focused on Barbados have also inferred potential economic loss due to unfavourable tourism responses to poor coastal water quality (UNEP-CEP, 2015a; Schuhmann et al., 2019). This suggests that, indirectly, the adequacy of wastewater management influences tourists' experience and their willingness to return to a destination. It is a critical factor for selecting Eastern Caribbean countries as tourist destinations.

The Simpson Bay Lagoon in Saint Martin was recently assessed due to issues with wastewater pollution (Duijndam et al., 2020) and it was shown that the baseline environmental state of the Lagoon had a value of US$12.1 million per year to residents. It was concluded that the installation of a sewage treatment plant would increase this annual economic value to US$16.5 million. The addition of mangrove restoration measures would enhance the economic value to a further US$26.3 million because they confer benefits which include coastline stabilisation, preventing land degradation and sediment loss. This demonstrated that improved environmental management of the lagoon, inclusive of wastewater treatment, would be beneficial to the environment, society and economy, by increasing the value of this natural asset, hence attracting more tourists, enhancing livelihoods and commerce within the blue economy.

The changes in thinking towards a circular economy and the opportunities for water reuse and recovery have sparked interest, because of the added market benefits of recovering resources from wastewater (Stacklin, 2012). This is especially relevant regarding the increasing demand for potable water in the Eastern Caribbean due to seasonal water stresses and droughts. Water demand is expected to increase by about 30 percent by 2050 in the region, and this may be truly relevant in Antigua and Barbuda, Barbados and Saint Kitts and Nevis, which have less than one thousand cubic meters of freshwater resources per capita (Ewing-Chow, 2019), hence being classified as water scarce territories. Other Eastern Caribbean territories are experiencing water stresses (Ewing-Chow, 2019), especially during the dry season. These stresses are expected to increase significantly, because of a projected 30 to 50 percent decrease in average annual rainfall in the coming years (Ewing-Chow, 2019; Peter, 2020). This is because of climate variability and climate change (Deutsche Welle, 2021).

There could be significant cost savings if higher priced potable water is replaced by suitably priced treated wastewater for non-potable processes, on a domestic, recreational, industrial, manufacturing, commercial and agricultural level. In addition to water, other resources which can be commodified as recoverable components of wastewater are, energy (gas and electricity) and nutrients (Stacklin, 2012). The extra revenue generated by the sale of recovered products can then be used to partially cover the operations and maintenance costs of treatment plants. With the right business models in place, these wastewater treatment plants could also be easier to finance due to lower capital financing risks (Rodriguez et al., 2020; Javeed, 2022). Notwithstanding, sound feasibility/cost-benefit studies should be done to determine whether cost recovery will be sufficient to cover capital costs, based on the inflow into these plants and the expected volumes of recovered resources.

There are opportunities for private sector involvement and the trickledown effect of job creation and income generation, which positively impact national economic development. Opportunities also exist for linking reuse and recovery to the private sector by selling treated wastewater to various industries. This creates a viable market for treated wastewater, hence creating better incentives due to a potentially greater return on wastewater capital investments.

Public education, awareness and sensitisation are also critical to change perceptions towards reuse for public buy-in and willingness to pay for appropriate wastewater services. Changing public perception towards reuse requires the public to be confident in the treatment processes being applied and the conformity to effluent quality standards. Enforcement and monitoring are also essential to give the assurance of public safety. The public will have to be reassured that the correct quality assurance mechanisms are being properly applied across the sector. This will be necessary for gaining the public’s trust.

Wastewater management and treatment in the Eastern Caribbean should also aim to prevent pollution from emerging pollutants. These are chemicals and compounds which have been recently identified as being dangerous to humans and the environment. These new contaminants include micro-plastics, antibiotics, drugs, steroids, endocrine disruptors, hormones, industrial additives and chemicals which have been shown to exist in municipal wastewater (UNEP, 2020). In terms of micro-plastics, more research is required to determine the adverse effects in humans (Diez et al., 2019), however they have been found in the intestinal tract of zooplankton, river-bed orgasms and mussels, causing gut blockage and starvation (UNEP, 2020). Wastewater treatment should therefore be done at a level to remove these emerging pollutants with the support of the right legislation, technologies, economic instruments, education, awareness (UNEP, 2020), and research.

STATUS OF WATER REUSE IN THE EASTERN CARIBBEAN

Some Eastern Caribbean countries like Saint Vincent and the Grenadines have traditionally used greywater for watering backyard gardens[24], but in general, reuse is not yet widespread (Peters, 2015). This is partly because most of the state-owned wastewater treatment plants only offer preliminary or primary treatment (UWI/CERMES/IRI, 2015). Many Caribbean countries, however, are beginning to acknowledge the potential of reusing wastewater, and some have already learnt that enhancing the reuse of wastewater requires significant investment in the sector (Williams, 2018).

Some of these countries have benefited from the GEF CReW+ Project (from 2019 to 2023), funded by the Global Environment Facility (GEF), and co-implemented by UNEP, the Inter-American Development Bank (IDB) and the Organization of American States (OAS). This project is being implemented in eighteen countries of the Wider Caribbean Region. Six of these eighteen countries are part of the Eastern Caribbean namely, Barbados, Grenada, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines and Trinidad and Tobago (GEF-CReW+, no date). The project has incorporated Integrated Water and Wastewater Management (IWWM) based on the *Four Rs* (reduce, reuse, recycle and recover) of the circular economy approach, for guiding the development and implementation of project activities in these beneficiary countries. The project's regional outcomes are geared towards: improved and reformed institutional frameworks; updated national data platforms; piloting small scale solutions; and sustainable financing mechanisms for IWWM within the participating countries (UNEP, no date).

As an example, for national activities under the GEF CReW+ Project, Saint Vincent and the Grenadines, Saint Kitts and Nevis, Saint Lucia and Trinidad and Tobago have planned pilot projects. Saint Vincent and the Grenadines has conceptualised a decentralised wastewater treatment system for the Belle Isle Correctional Facility. The pilot project aims to improve the wastewater treatment system at the facility. The

[24] This can be seen as a traditional nature-based solution (NBS): "*NBS have long been used to treat wastewater, stretching back to the use of wetlands for wastewater disposal by ancient civilizations, for example in Egypt and China. NBS for wastewater treatment also include ponds and soil infiltration, as well as innovative approaches such as willow systems, living walls, constructed rooftop wetlands, aquaponics and hydroponics.*" (Cross et. al. 2021).

treated wastewater would then be used for crop irrigation on the premises, by the inmates themselves. The completed project will be an example of reuse and would help to raise public awareness regarding the value of reusing water in this way. There would also be the significant added value of skills training and the rehabilitation of inmates who served as the project's beneficiaries. Planned activities under this initiative include the development of integrated legislation on wastewater management, including reuse, design standards for sewage treatment plants and regulations for environmental discharge (UNEP, no date).

With preparatory funding, Barbados is preparing its Reduce, Reuse and Recycle for Climate Resilience and Wastewater Systems (3R-CReWS) project proposal to the Green Climate Fund (GCF), to upgrade its wastewater treatment infrastructure to include reuse. Through this, the country will have taken a significant step towards wastewater reuse for agriculture and managed aquifer recharge. This project is being promoted as a climate change adaptation measure to address water scarcity issues in Barbados. Upgrades would involve: the inclusion of tertiary treatment to meet water quality reuse standards; photovoltaic (PV) renewable energy systems to offset fossil fuel consumption; and the development of a treated wastewater system for supplying farmers. Together, the upgrades will eliminate the need to routinely discharge wastewater into the marine environment (Hickson, 2020). The 2022 Water Reuse Act provides a supportive legislative environment for the project (Barbados Parliament, 2022).

In Antigua and Barbuda, the government started the implementation of a wastewater reuse pilot project with GEF-IWCAM Project funding in 2011. It aimed to put in place a management structure for the McKinnon's Wastewater Treatment Plant which served as a decentralised wastewater system. Under the project there were plans[25] to build a membrane bioreactor to facilitate the reuse of the effluent for landscaping, sustainable livelihoods, animal husbandry and other economic activities. Plans also included support for enhancing the enabling environment (legislation, regulations, policies, and standards), for the reuse of treated wastewater. Capacity building (for the operators of the facility) and raising public awareness were also highlighted within the project's scope. Further upgrades were earmarked for the McKinnons Wastewater Treatment Facility under the GEF-IWEco Project (from 2016 to 2023) (GEF-IWEco, no date).

[25] GEF-IWEco, (no date). *Integrating Water, Land and Ecosystems Management in Caribbean Small Island Developing States (IWEco). Antigua & Barbuda Sub-project 1.1. APPENDIX 31* https://www.iweco.org/sites/default/files/2019-03/IWEco_ProjectDocument_Antigua_Barbuda_2016.pdf (Accessed 27 February 2022).

The few other examples of wastewater reuse initiatives in the region seem to be primarily targeted towards horticulture. For instance, some hotels have used treated wastewater effluent for golf course irrigation (UNEP-CEP, 2015b). An example exists in Petit Saint Vincent where a wastewater treatment and reuse system was installed in 2018. It was also equipped with a drip irrigation system and ultraviolet disinfection technology to deactivate pathogens. The treated water is reused for irrigation of ornamental landscape and fruit trees (Haase, no date).

The Enabling Environment

In terms of the enabling environment for sustainable wastewater management, the necessary legal, regulatory and policy frameworks for reuse in the region are deficient. However, some territories have made advancements. Trinidad and Tobago is an example of this, because of a preliminary feasibility study conducted by Warwick and Ekwue (2014). The study focused on nation-wide reuse, as a means of augmenting the water required for agricultural irrigation. It indicated that reuse of treated wastewater for agricultural irrigation would be feasible as an alternative to environmental discharge in an untreated or insufficiently treated state. It was recommended that a wide-ranging improvement and revitalisation of the country's wastewater sector would be necessary as a precursor of a national reuse scheme for agricultural irrigation. This revitalisation would include: adequate legislation; effective wastewater treatment according to appropriate standards; and public education regarding the use of wastewater effluents as irrigation water (Warwick and Ekwue, 2014). The Trinidad and Tobago Bureau of Standards has issued a draft version of voluntary wastewater reuse standards[26] for public comment. The standard establishes the sampling, testing and maximum permissible limits for key parameters related to wastewater reuse in three classes, pertaining to agriculture and landscaping. It covers irrigation of crops eaten uncooked and cooked (Trinidad and Tobago Bureau of Standards, 2022).

From the perspective of Barbados, The Water Reuse Act provides the legislative and regulatory framework that would underpin and support the development of the wastewater value chain in the country, setting standards and permitting the reuse of wastewater for various applications (Barbados Parliament, 2022). In Antigua and Barbuda, consideration was given to wastewater within a draft Environmental Protection and Management Act, but regulations were reported to be still in draft. These

[26] Draft voluntary standard for Public Comment: PCTTS 664:20XX, Wastewater reuse – Agricultural and other applications – Requirements. Source: Trinidad and Tobago Bureau of Standards website (Date posted: June 8, 2022).

draft regulations need to further identify criteria and conditions for water reuse for specific purposes UNEP-CEP (2015b).

Jamaica is more advanced than most Eastern Caribbean countries as it relates to the enabling environment. The National Water Sector Policy encourages the reuse of treated effluent where it is safe and economical. It also advises that wastewater that is properly treated at sewage treatment plants may be safe for uses such as irrigation and some industrial processes. This is supported by the enforcement of regulatory standards. As part of the implementation activities of the National Water Sector Policy, NEPA and the Ministry of Health renewed their commitment to monitor and enforce these standards for irrigation of lawns and specific agricultural applications. There was also a commitment to establish standards for other types of wastewater reuse. The government encourages companies which treat wastewater, and the National Water Commission and industrial facilities, to seek buyers for treated wastewater (Dawkins, 2021).

The NRCA of Jamaica has developed Interim Irrigation Standards. It has also created the National Treated Sewage Sludge Standards for fully treated sewage sludge that can be applied to agricultural land, and has a requirement for a nutrient management plan or irrigation reuse plan for effluent reuse. This serves the purpose of determining the nutrient criteria for wastewater and/or sludge and the concentrations for fertiliser applications (Jamaica Environment Trust, 2017).

Although standards are necessary for ensuring public health safety and gaining the public's confidence (once they are properly enforced), the capacity of treatment plants to meet these standards may be a significant challenge if they are too rigorous.

MAKING THE CASE FOR WATER REUSE IN THE EASTERN CARIBBEAN

There are now several starting points for Eastern Caribbean countries to advance wastewater reuse. For one, it would help the countries which have ratified the LBS Protocol to meet their obligations, which include specific contaminant limits, adequate regulations, the promotion of domestic wastewater reuse, and the use of cleaner technologies to reduce discharges. A case in point is Barbados' ratification of the LBS Protocol in 2019, which meant that the Bridgetown Sewage Treatment Plant and the South Coast Sewage Treatment System, which were discharging wastewater into Class 1 waters, had to be upgraded to comply with the Protocol (Sealy, 2021). The recent ratification by Barbados of the LBS Protocol has been a driver for some policy changes at the national level including for wastewater reuse.

All Eastern Caribbean countries subscribe to the SDGs and are working to achieve Agenda 2030, which has identified water and sanitation as a priority area (United Nations, no date). Investing in wastewater reuse could therefore help Eastern Caribbean countries achieve Target 6.3 of the SDGs. This calls for the improvement in water quality by reducing pollution and minimising the release of hazardous chemicals and materials. It also requires efforts geared towards halving the proportion of untreated wastewater and increasing recycling and safe reuse globally.

The increasing negative impacts of climate change on water resources (lower rainfall and more extreme dry conditions) in the Eastern Caribbean, is another reason countries would be forced to consider wastewater reuse. In fact, the negative impacts of climate change on water resources were used to justify financing for the previously highlighted Barbados 3R-CReWS wastewater initiative by the GCF (Green Climate Fund, 2019). Other islands such as Antigua and Barbuda and Saint Vincent and the Grenadines have also been able to attract funds under GEF funded projects (IWCAM, CReW, IWEco and CReW+) to implement wastewater reuse initiatives as part of climate change adaptation measures. These financing opportunities are especially relevant for other Eastern Caribbean countries, as projections also show that dry weather conditions are expected to be greater in the south and south-eastern Caribbean (Campbell et al., 2021).

Additionally, the region is already experiencing drought-like conditions every year with low water availability impacting agriculture and water supply services. Agriculture in the Eastern Caribbean is mostly rain fed and if it is to remain viable, it will have to depend more on irrigation water which could be provided by treated wastewater. There are a few success stories of wastewater reuse for irrigation in the hotel sector in the Eastern Caribbean, such as the case previously mentioned on the secluded island of Petit Saint Vincent.

Wastewater resource recovery is an opportunity to give sanitation and wastewater management a more significant role in the circular economy (UNEP, 2021). Hotels in many Caribbean islands are already operating small on-site wastewater treatment plants and are reusing the treated effluent to irrigate lawns and golf courses. For example, CARPHA recognised Sandals Resorts International for its investment in plant and equipment to recycle wastewater for reuse applications, in 2017. This investment helped to ensure that wastewater does not find its way back into natural water systems without first being treated (The Barnacle News, 2017).

There has been optimism due to an increase in support for funding opportunities for wastewater reuse initiatives, and the World Bank Group has announced its intention to launch a global initiative that can provide solutions to implement circular economy principles in wastewater projects (Burdescu et al. 2020). Eastern Caribbean territories should therefore lay the foundation through the development of the wastewater policies, plans, guidelines, standards and project concepts, to take advantage of these funding opportunities as they arise.

BARRIERS TO WATER REUSE IMPLEMENTATION IN THE EASTERN CARIBBEAN

While wastewater reuse is gaining prominence globally, the barriers to its use are also well documented in the UNEP 2020 publication titled, *Sanitation, Wastewater Management and Sustainability: from Waste Disposal to Resource Recovery (2nd ed.)* (Andersson et al., 2020). These barriers are health, environmental, social, institutional, technical, and financial in nature and are applicable to the Eastern Caribbean.

The inadequate collection and treatment of wastewater in most Eastern Caribbean countries would be the biggest barrier to the reuse of wastewater; this is not surprising since state owned utilities collect only about 20 percent of wastewater. Furthermore, the adequate treatment of collected wastewater is often limited. Other than treatment performed by state owned utilities, most wastewater collection and treatment from privately owned companies is also limited.

Only a few countries have invested in upgrading the government owned wastewater treatment plants to deliver advanced level treated effluent. Barbados and hopefully Trinidad and Tobago are the two Eastern Caribbean countries to invest in making major upgrades to their state-owned wastewater treatment infrastructure. The estimated high financial costs required to upgrade these centralised municipal systems has been identified as a major barrier. Achieving substantial increases in wastewater collection and treatment will therefore require significant capital investment (Burdescu et al. 2020) and without this required investment, wastewater cannot be reused safely.

Most of these Eastern Caribbean wastewater treatment plants are dysfunctional and provide only preliminary or primary treatment. These plants are also located in coastal cities (Diez et al., 2019) and they were designed to discharge wastewater via marine outfalls. The location of the treatment plants could be a barrier to the reuse of wastewater for agricultural irrigation, because the areas where the treated effluents are generated may not be near to where they would be best applied. Separate distribution networks for non-potable water would also have to be installed to transport the treated wastewater to agricultural areas inland. This would therefore mean additional investment costs.

Additionally, the high cost of operating and maintaining centralised wastewater treatment systems is another significant barrier which could be overcome by shifting to smaller scale decentralised/on-site wastewater treatment systems which are less costly. This could also allow proper treatment to be applied near where wastewater is generated, hence, reducing the cost of installing these additional distribution networks. In areas where wastewater reuse is practical and in demand, decentralised systems would also allow treated wastewater to be closer to users, as opposed to centralised systems which require additional expensive pipelines for supplying non-potable treated wastewater over great distances where the demand exists.

Another barrier identified includes low private sector involvement due to the financial unattractiveness of the wastewater sector in the region. This is owed to high capital intensity, political pressures to keep tariffs low, and poor regulatory frameworks (Rodriguez et al., 2020). There may be opportunities to further incentivise the hotel sector into integrating decentralised systems with a reuse component into their development plans and operations, because reuse and pollution control can be seen as good corporate social responsibility (CSR), for improved brand recognition.

There is a need to develop and apply standards and guidelines for wastewater reuse for agriculture within Eastern Caribbean territories. This would guide and specify the level of treatment for effluent to be used for irrigation of crops (such as raw edible crops). The *FAO irrigation and drainage paper 47- Wastewater treatment and use in agriculture* provides some guidance regarding standards which can be applied in the agricultural sector, as a point of reference (Pescod, 1992).

The inadequate policy and legislative frameworks do not create an enabling environment for wastewater reuse which is especially necessary for regulation and monitoring. Through regional collaboration, the institutional framework model in Jamaica (NEPA and NRCA: effluent and irrigation standards/guidelines and associated regulatory mechanisms) could be used as a guide for Eastern Caribbean countries.

There are also barriers related to the public's perception of wastewater reuse. Overcoming these barriers require effective communication regarding the benefits of reuse, coupled with improved public confidence in the technical competence of wastewater treatment facilities, and their compliance to the appropriate effluent safety standards.

Despite the well documented benefits to be derived from enhanced wastewater treatment and reuse of treated effluent, the Eastern Caribbean is yet to grab the significant opportunities which exist for the reuse of treated wastewater in two of the most important economic drivers for the Caribbean, the agriculture and tourism sectors (Fletcher, 2019).

KEY MESSAGES AND CONCLUSION

Decentralised wastewater treatment plants may be a more practical option for the Eastern Caribbean countries due to their lower capital costs. These package plants are gaining traction in the hotel sector, and they may also be practical in small scale residential developments. These systems could also be coupled with irrigation systems for agricultural purposes without the need for the more costly distribution networks which municipal systems would require.

In keeping with the principles of the circular economy a straightforward way of limiting wastewater production is by reducing water use/consumption. This could be done using water devices and appliances which are more water efficient (e.g., faucets, toilets, and showerheads). It is also a low-cost measure which can be implemented in the short term.

Wastewater reuse for non-potable agricultural and industrial use is a more practical approach for Eastern Caribbean countries as opposed to recycling to more rigorous potable water quality standards. However, the necessary regulatory and enforcement environment is vital for ensuring public and environmental safety. The right business models should also be applied so that reused water is sold at a fair price.

National wastewater policies (with associated regulations, guidelines, and standards) are required for elevating wastewater as a priority sector in the region. Jamaica can be used as a model for its Eastern Caribbean counterparts in terms of the required enabling environment. This can be achieved through regional and inter-agency collaboration for fostering knowledge transfer and information exchange.

Improved data collection and management are required for accurately determining the technical and financial performance of wastewater infrastructure. It is also needed for taking an inventory of the Eastern Caribbean wastewater sector, to establish baselines and facilitate reliable reporting. Quality data is required for requisite feasibility studies, project proposal preparation and reporting to external partners based on signed conventions (such as the Cartagena Convention-LBS Protocol, SDG 6.2, and SDG 6.3).

Wastewater management regulations should also extend to the yachting sector due to the significant contribution to coastal and marine pollution from pleasure vessels. This should be incorporated into wastewater management policies. This issue is of utmost importance for countries with a vibrant tourism sector. Increased tourism activities could both contribute and be adversely affected by this source of coastal/marine pollution.

The perceived pollution of beaches and bays from untreated wastewater adversely impacts the behaviour of tourists, and their recreational experiences from activities such as bathing and fishing. This reduces the non-market value of these natural assets and in turn reduces the willingness of tourists to pay for a recreational experience. This could result in economic losses due to lower visitor arrivals.

Public education, awareness and sensitisation are necessary for changing attitudes towards reuse. This should be complemented with improved technical and human resource capacity for operating wastewater facilities, along with the requisite monitoring and mandatory compliance to appropriate regulatory standards. This will help to increase public confidence, acceptance, and buy-in.

Eastern Caribbean countries should capitalize on grant funding for improving the wastewater sector. Lessons learnt should be used for scaling up successful pilots with the necessary budgetary allocations for proper operation and maintenance.

Some Caribbean countries such as Jamaica, Trinidad and Tobago and Barbados have made commendable strides towards improving the wastewater sector. Neighbouring Eastern Caribbean countries could benefit from this, through bilateral exchanges, with the goal of making the sector more sustainable.

For improving the wastewater sector, Eastern Caribbean countries may consider decentralised wastewater systems, nature-based solutions, and low-tech on-site options, based on the characteristics of the targeted land-use zone. Implementing the most appropriate options in Eastern Caribbean territories is vital, owing to the smaller island watersheds, which are very intimately connected to the environmentally sensitive coastal and marine space and the blue economy.

Moving into full scale reuse of treated wastewater might be a difficult initial entry point for many Eastern Caribbean countries because of the strong socio-cultural resistance towards water reuse. This is something which may gain focus in the longer term as far as changing public awareness and perception. The initial priority might be to focus on promoting water reuse for industries within the manufacturing sector (such as factories), and then promote reuse for irrigation (for example: golf courses and landscaping within hotels) and agriculture (for processed food crops and non-food crops), all with the appropriate standards and criteria in place.

Aguilar Y., Tadiosa, E. and Tondo, J. (2014). 'A comparative study on wastewater treatment methods of selected multinational and local beverage companies in the Philippines and their effects on the Environment.' *International Journal of Environmental and Sustainable Development* 5, (6) pp. 570-574. Available at:http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.685.1053&rep=rep1&type=pdf. (Accessed 25 April 2022)

Amoatey P. and Bani R. (2011). Wastewater Management. In Einschlag, F.S. (editor) Wastewater - *Evaluation and Management*. IntechOpen. 379-398. Available at: http://www.intechopen.com/books/waste-water-evaluation-and-management. (Accessed 26 March 2022)

Andersson, K., Rosemarin, A., Lamizana, B., Kvarnström, E., McConville, J., Seidu, R., Dickin, S. and Trimmer, C. (2020). *Sanitation, Wastewater Management and Sustainability: from Waste Disposal to Resource Recovery.* 2nd edition. Nairobi and Stockholm: United Nations Environment Programme and Stockholm Environment Institute. Available at: https://cdn.sei.org/wp-content/uploads/2021/03/sanitation-wastewater-management-and-sustainability-by-sei-and-unep.pdf (Accessed 1 April 2022)

Antigua and Barbuda Public Utilities Authority (2015). '*Antigua and Barbuda National Policy Statement'* Antigua and Barbuda, Available at: [Online] https://chm.cbd.int/api/v2013/documents/9C93ACC6-EF3E-AC74-9C48-929942AA1FAD/attachments/207452/APUA%20WRM%20Policy.pdfhttps://chm.cbd.int/api/v2013/documents/9C93ACC6-EF3E-AC74-9C48-929942AA1FAD/attachments/207452/APUA%20WRM%20Policy.pdf (Accessed 1 April 2022)

Arena C., Genco, M. and Mazzola, M.R. (2020). 'Environmental Benefits and Economical Sustainability of Urban Wastewater Reuse for Irrigation—A Cost-Benefit Analysis of an Existing Reuse Project in Puglia, Italy.' *Water 12*(10), p.2926. Available at: https://www.mdpi.com/863328 (Accessed 15 March 2022).

Asian Development Bank (2006). *Sanitation and Wastewater Management: Saving Public Health and Sustaining Environment.* Available at: https://www.adb.org/publications/sanitation-and-wastewater-management-saving-public-health-and-sustaining-environment (Accessed 8 March 2022).

Baker J.S., Van Houtven G., Cai Y., et al. (2021). A *Hydro-Economic Methodology for the Food-Energy-Water Nexus: Valuation and Optimization of Water Resources*. RTI Press Available from: https://doi.org/10.3768/rtipress.2021.mr.0044.2105 (Accessed 8 March 2022)

Barbados Parliament (2022). *Water Reuse Act- Barbados -2022.* Available at: https://www.barbadosparliament.com/uploads/bill_resolution/ce3db8a3288717c47330188797016748.pdf (Accessed 18 March 2022)

Bodik, I. and Ridderstolpe, P. (editors). (2007). *Sustainable Sanitation in Central and Eastern Europe--addressing the needs of small and medium-size settlements.* 88 pp., Global Water Partnership Central and Eastern Europe. Ridderstolpe_GWP_SustainableSanitation-in-CEE_2008.pdf (wrs.se) (Accessed 9 March 2022)

Burdescu, R., van den Berg, C., Janson, N. and Alvarado, O. (2020). *A Benchmark for the Performance of State-Owned Water Utilities in the Caribbean." Development Knowledge and Learning*. Washington, DC.: World Bank Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/33251/K880429.pdf?sequence=2&isAllowed=y (Accessed 10 March 2022)

Byrne, E. et al., (2019). *Water Reuse in the Context of the Circular Economy*. Environment Protection Agency Research, 293. Available at: https://www.epa.ie/publications/research/water/Research_Report_293.pdf. (Accessed 13 March 2022)

Campbell, J.D., Taylor, M.A., Bezanilla-Morlot, A., Stephenson, T.S., Centella-Artola, A., Clarke, L.A and Stephenson, K.A. (2021). 'Generating Projections for the Caribbean at 1.5, 2.0, and 2.5 °C from a High-Resolution Ensemble.' *Atmosphere*, 12, 328. Available at: https://www.researchgate.net/publication/349895398_Generating_Projections_for_the_Caribbean_at_15_20_and_25_C_from_a_High-Resolution_Ensemble (Accessed 5 July 2022)

CARICOM (2020). *Terms of Reference for Consultancy to develop a regional action framework for Integrated Water Resources Management (IWRM) for the CARICOM region CARICOM*. Available at: https://caricom.org/procurement/consultancy-to-develop-a-regional-action-framework-for-integrated-water-resources-management-iwrm-for-the-caricom-region/ (Accessed 21 February 2022)

Cashman, A. (2014). *Integrated Water Resources Management in the Caribbean: The Challenges Facing Small Islands Developing States*, Global Water Partnership (GWP). Available at: https://play.google.com/store/books/details?id=iMm8jwEACAAJ. (Accessed 21 February 2022)

Ćetković, J. et al., (2022). Financial and Economic Investment Evaluation of Wastewater Treatment Plant. *Water*, 14(1), p.122. Available at: https://www.mdpi.com/2073-4441/14/1/122 (Accessed 15 March 2022)

Chopra, V. and Das, S. (2019). Estimating willingness to pay for wastewater treatment in New Delhi: Contingent valuation approach. *Ecology, Economy and Society-the INSEE Journal*, 2(2354-2020-1322), pp.75–108. Available at: https://ageconsearch.umn.edu/record/304044/files/EES%202-2%2075-108.pdf. (Accessed 22 February 2022)

Cross K., Tondera K., Rizzo A., Andrews L., Pucher B., Istenič D., Karres N., and McDonald R. eds., (editors). (2021). *Nature-Based Solutions for Wastewater Treatment: A Series of Factsheets and Case Studies*, IWA Publishing. Available at: https://doi.org/10.2166/9781789062267. (Accessed 7 July 2022)

Dawkins, C. (2021). *SRC Encouraging Proper Wastewater Management.* Jamaica Information Service. Available at https://jis.gov.jm/src-encouraging-proper-wastewater-management/ (Accessed 5 July 2022)

Deiters G.H. (2022). *Good Practices in Wastewater Treatment and Reuse. United Nations Environment Programme* (UNEP). GEF CReW+

Deutsche Welle (2021). *Climate change is increasing Caribbean water shortages. EcoWatch*. Available at: https://www.ecowatch.com/water-shortage-caribbean-2650142909.html (Accessed 18 March 2022).

Didier, Cuthbert (2021). *Development of a Public Private Partnership to Reduce Pollution from Pleasure Vessels (Yachts) and Tourism Centres*, Prepared for the IWEco Project, Jamaica: UNEP-CEP

Diez, S.M., Patil, P.G., Morton, J., Rodriguez, D.J., Vanzella, A., Robin, D.V., Maes, T., Corbin, C. (2019). *Marine Pollution in the Caribbean: Not a Minute to Waste*. Washington, D.C.: World Bank Group Available at: https://documents1.worldbank.org/curated/en/482391554225185720/pdf/Marine-Pollution-in-the-Caribbean-Not-a-Minute-to-Waste.pdf (Accessed 23 February 2022)

Duijndam, S., et al. (2020). 'Valuing a Caribbean coastal lagoon using the choice experiment method: The case of the Simpson Bay Lagoon, Saint Martin.' *Journal for Nature Conservation, 56*, p.125845. Available at: https://www.sciencedirect.com/science/article/pii/S1617138120300911. (Accessed 26 February 2022)

ECLAC (2002). *Saint Lucia: The yachting sector. Economic Commission for Latin America & the Caribbean*. Available at: https://www.cepal.org/en/publications/38869-saint-lucia-yachting-sector (Accessed 18 February 2022).

Ewing-Chow, D. (2019). In Search of a Solution for Water Scarcity in The Caribbean. *Forbes Magazine*. Available at: https://www.forbes.com/sites/daphneewingchow/2019/02/12/in-search-of-a-solution-for-water-scarcity-in-the-caribbean/ (Accessed 18 March 2022).

Ezebilo, E.E. (2016). 'Economic value of a non-market ecosystem service: an application of the travel cost method to nature recreation in Sweden.' *International Journal of Biodiversity Science, Ecosystems Services & Management*, 12(4), pp.314–327. Available at: https://doi.org/10.1080/21513732.2016.1202322. (Accessed 28 February 2022)

Fletcher, J. (2019). *White Paper on Governance and Climate Resilience in the Water Sector in the Caribbean,* Caribbean Water and Wastewater Association. Available at: https://cwwa.net/news/white-paper-on-governance-and-climate-resilience-in-the-water-sector-in-the-caribbean-cwwa-2018/ (Accessed 21 February 2022)

Green Climate Fund - Project Preparation Facility (2019). The R's (Reduce, Reuse and Recycle) for Climate Resilience Wastewater Systems in Barbados (3R-CReWS) [Online] Available at: https://www.greenclimate.fund/sites/default/files/document/ppf-application-r-s-reduce-reuse-and-recycle-climate-resilience-wastewater-systems-barbados-3r-crews.pdf. (Accessed 27 April 2022).

GEF – CReW+ (no date). *An integrated approach to water and wastewater management in the Wider Caribbean Region using innovative solutions and sustainable financing mechanisms* GEF CReW+. Available at: https://www.unep.org/cep/gef-crew (Accessed 27 April 2022).

GEF-IWEco (no date). *Integrating Water, Land and Ecosystems Management in Caribbean Small Island Developing States (IWEco). Antigua & Barbuda Sub-project*

1.1. APPENDIX 31. https://www.iweco.org/sites/default/files/2019-03/IWEco_ProjectDocument_Antigua_Barbuda_2016.pdf (Accessed 27 February 2022)

GWP (2022). *Sustainable sanitation task force report released. Global Water Partnership.* GWP Available at: https://www.gwp.org/en/GWP-CEE/WE-ACT/news/2022/sustainable-sanitation-task-force-report-released/ (Accessed 16 February 2022).

Groom, Eric; Halpern, Jonathan; Ehrhardt, David. (2006). Explanatory Notes on Key Topics in the Regulation of Water and Sanitation Services. *Water Supply and Sanitation Sector Board discussion paper series; no. 6.* Washington, D.C: World Bank, https://openknowledge.worldbank.org/handle/10986/17236 (Accessed 27 February 2022)

Government of Saint Lucia (2020). *Water Policy Update for Saint Lucia. Part 1 Strategic Sector Review [Draft]*. Saint Lucia: Government of Saint Lucia

Haase, P. (no date). *Water Reuse at Petit St. Vincent Grenadines*, Available at: https://watereuse.org/wp-content/uploads/2015/01/Petit-St.-Vincent-Presentation_PHH_120518.pdf (Accessed 26 April 2022)

Heileman, S and Voordouw J.J. (2020). *Mid-Term Review of the UN Environment Programme/Global Environment Facility Project "Integrating Water, Land and Ecosystems Management in Caribbean Small Island Developing States (IWEco)"* Available at: https://iweco.org/sites/default/files/2021-05/IWEco_MTR_Report_FINAL_Sept2020_v2.pdf (Accessed 13 March 2022)

Helmer, R. and Hespanhol, I. (1997). *Water Pollution Control: A Guide to the Use of Water Quality Management Principles*, CRC Press. Available at: https://play.google.com/store/books/details?id=xCCnjQC__9QC. (Accessed 19 February 2022)

Hernández-Sancho, F., Molinos-Senante, M. and Sala-Garrido, R. (2010). Economic valuation of environmental benefits from wastewater treatment processes: an empirical approach for Spain. *The Science of the total environment*, 408(4), pp.953–957. Available at: http://dx.doi.org/10.1016/j.scitotenv.2009.10.028. (Accessed 16 March 2022)

Hernández-Sancho, F. et al. (2015). *Economic valuation of wastewater: the cost of action and the cost of no action, United Nations Environment Programme* (UNEP).

Available at: https://www.cabdirect.org/cabdirect/abstract/20163135729. (Accessed 21 March 2022)

Hickson, D. (2020). BWA 'progresses sewage treatment plant upgrades, *Barbados Today,* 3 March Available at: https://barbadostoday.bb/2020/03/03/bwa-progresses-sewage-treatment-plant -upgrades/ (Accessed 20 March 2022)

Hugo, V. (2015). 'Impacts of Climate Change and variability on Wastewater Management', *Water & Climate Discussion Brief, (No.2),* [Online] Available at: https://iri.columbia.edu/wp-content/uploads/2015/07/wastewater_final.pdf (Accessed 26 February 2022)

International Waters Learning and Resource Network (2017). *CReW: Introducing treated water reuse in two Caribbean Small Island Developing States (SIDS)– Lessons Learnt, iwlearn.net experience*

Jamaica Environment Trust (2017). *Review of the Legal and Policy Framework for Air and Water Quality in the Island of Jamaica*. Supported by the Commonwealth Foundation.

Jamaica Gleaner (2021). Earth Today - New report calls attention to marine pollution from pleasure vessels, tourism centres. *Jamaica Gleaner*, 25 November. Available at: https://jamaica-gleaner.com/article/news/20211125/earth-today-new-report-calls-attention-marine-pollution-pleasure-vessels (Accessed 18 February 2022).

Javeed, A., (2022). Gonzales looks into feasibility of Beetham wastewater plant. *Trinidad Express Newspapers.* April 30. Available at: https://trinidadexpress.com/business/local/gonzales-looks-into-feasibility-of-beetham-wastewater-plant/article_55088e74-c8ed-11ec-9e24-8773cc387326.html (Accessed 1 July 2022).

McTaggart M., Stevens, G. M., and Singh K. (2007). *New Beetham Wastewater Treatment Plant – A First Step towards Modernizing Wastewater Treatment in Trinidad and Tobago.* ResearchGate. Available at: https://www.researchgate.net/publication/272138138_New_Beetham_Wastewater_Treatment_Plant_-_A_First_Step_towards_Modernizing_Wastewater_Treatment_in_Trinidad_and_Tobago (Accessed 9 March 2022).

Global Water Partnership Caribbean

Montoute, M.C. and Cashman, A. (2015). *A knowledge, attitudes and practices study on water, sanitation and hygiene in Anse La Raye Village, Saint Lucia*. CERMES Technical Report No. 78.

OECS (2006), *St. George's Declaration of Principles for Environmental Sustainability in the OECS*. (Revised 2006). Saint Lucia: The Organisation of Eastern Caribbean States (OECS) Secretariat.

Peters, E.J., (2015). 'Wastewater reuse in the Eastern Caribbean: a case study. Proceedings of the Institution of Civil Engineers' *Water Management*, 168(5), pp.232–242. Available at: https://doi.org/10.1680/jwama.14.00059. (Accessed 19 February 2022)

Peter, S., (2020). 'Worsening water crisis in the Eastern Caribbean.' *Eos*, 101. Available at: https://eos.org/articles/worsening-water-crisis-in-the-eastern-caribbean (Accessed 18 March 2022).

Pescod, M. (1992). Wastewater Treatment and Use in Agriculture—F*AO Irrigation and Drainage Paper 47*. Rome: Food and Agriculture Organization of the United Nations

Rodriguez, D.J., Hector Alexander Serrano, Anna Delgado, Daniel Nolasco and Gustavo SaltiEzebilo, E.E. (2016). 'Economic value of a non-market ecosystem service: an application of the travel cost method to nature recreation in Sweden.' *International Journal of Biodiversity Science, Ecosystems Services & Management*, 12(4), pp.314–327. Available at:
https://doi.org/10.1080/21513732.2016.1202322.el (Accessed 18 March 2022)

Rodriguez, Diego J.; Serrano, Hector A.; Delgado, Anna; Nolasco, Daniel; Saltiel, Gustavo. (2020). *From Waste to Resource: Shifting paradigms for smarter wastewater interventions*
in Latin America and the Caribbean. Washington, DC: World Bank. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/33436/146823.pdf (Accessed 18 March 2022)

Rogers, A, Blanchard, JL and Mumby, P.J. (2017). Fisheries productivity under progressive coral reef degradation. *Journal of Applied Ecology* 55(3): 1041-1049. Available at: https://doi.org/10.1111/1365-2664.13051 (Accessed July 18 2022)

Roopnarine R., Miguel Montoute, Lise Walter, Schmoi McLean, Simone Lewis and Janet Geoghagen Martin. (2019). *SDG 6 Monitoring Guide for Caribbean SIDS*. Global Water Partnership-Caribbean (GWP-C). Available at:

https://www.gwp.org/globalassets/global/gwp-c-files/monitoring-guide---sdg-6-in-caribbean-sids.pdf (Accessed 13 March 2022)

Schuhmann, P. et al. (2019). 'Coastal and Marine Quality and Tourists' Stated Intention to Return to Barbados.' *Water,* 11(6), p.1265. Available at: http://dx.doi.org/10.3390/w11061265. (Accessed 26 February 2022)

Sealy, H. (2018). Master Plan for Plant. *Nation News*, 21 January. Available at: https://www.nationnews.com/2018/01/21/master-plan-for-plant/ (Accessed 30 April 2022)

Sealy, H. (2021). Information Paper on Nutrients Management Guidelines Standards for Wastewater Discharges into the Wider Caribbean Sea, *Fifth Meeting of the Contracting Parties (COP) to the Protocol Concerning Pollution from Land- Based Sources and Activities (LBS) in the Wider Caribbean Region: Technical Paper on Proposed Criteria for Nutrients Discharges for Domestic Wastewater Effluent and-Based Sources and Activities (LBS) in the Wider Caribbean Region,* Virtual, 26 July. United Nations Environment Programme, Available at: http://gefcrew.org/carrcu/LBSSTAC5/Info-Docs/WG.41-INF.23-en.pdf (Accessed 24 March 2022)

Sealy H. (2021). Technical Paper on Proposed Criteria for Nutrients Discharges for Domestic Wastewater Effluent. *Fifth Meeting of the Contracting Parties (COP) to the Protocol Concerning Pollution from Land-Based Sources and Activities (LBS) in the Wider Caribbean Region.* Virtual, 26 July 2021. UNEP(DEPI)/CAR WG.41/INF.23

Shatanawi, M and Naber, S. (no date.), *Valuing water from social, economic, and environmental perspective. Challenges: Rational Water Use, Water Price*. Faculty of Agriculture, Jordan: University of Jordan. Available at: https://www.idaea.csic.es/meliaproject/node/127 (Accessed 13 March 2022)

Shattuck, J. and Risse, M. (2021). 'Reimagining Rights and Responsibilities in the United States: Equal Access to Public Goods and Services.' *SSRN Electronic Journal*. Available at: http://dx.doi.org/10.2139/ssrn.3802093. (Accessed 16 March 2022)

Smol, M., Adam, C. and Preisner, M. (2020). 'Circular economy model framework in the European water and wastewater sector.' *Journal of Material Cycles and Waste Management,* 22(3), pp.682–697. Available at: https://doi.org/10.1007/s10163-019-00960-z. (Accessed 13 April 2022)

Stacklin C. (2012). The *Value of Wastewater: An Econometric Evaluation of Recoverable Resources in Wastewater for Reuse. In WEF Proceedings At: New Orleans Morial Convention Center*, New Orleans, LA *Volume: TS072: Changing Paradigms*, New Orleans October 2012Available at: https://www.researchgate.net/publication/269037957_The_Value_of_Wastewater_An_Econometric_Evaluation_of_Recoverable_Resources_in_Wastewater_for_Reuse (Accessed 13 March 2022)

Stengel, D., O'Reilly, S., O'Halloran, J. (2006). 'Contaminants and pollutants. In: Davenport, J., Davenport, J.L. (eds) The Ecology of Transportation: Managing Mobility for the Environment.' *Environmental Pollution,* vol 10. Springer, Dordrecht. https://doi.org/10.1007/1-4020-4504-2_15 (Accessed 15 March 2022)

St. Lucia Times News (2021). Regional tourism stakeholders alerted to the hazards of marine pollution. *St. Lucia Times News*. 16 December. Available at: https://stluciatimes.com/regional-tourism-stakeholders-alerted-to-the-hazards-of-marine-pollution/ (Accessed 18 February 2022).

The Barnacle News (2017) Sandals Recognised by CARPHA For Water Conservation, *Barnacle News,* 6 April Available at: https://thebarnaclenews.com/sandals-recognised-carpha-water-conservation/ (Accessed 9 March 2022)

The Natural Resources Conservation Authority Act-The Natural Resources Conservation (Wastewater and Sludge) Regulations- Jamaica (2013) (Vol. CXXXVI No. 29.A) https://websitearchive2020.nepa.gov.jm/new/legal_matters/laws/Environmental_Laws/Wastewater_and_Sludge_Regulations.pdf (Accessed 17 March 2022)

Tuser, C. (2021). *What is Wastewater?* Water & Wastes Digest. Available at: https://www.wwdmag.com/wastewater-treatment/wastewater-treatment/article/10938418/what-is-wastewater (Accessed 30 June 2022).

Trinidad and Tobago Bureau of Standards (2022). *For Public Comment: PCTTS 664:20XX, Wastewater Reuse – Agricultural and Other Applications – Requirements.* Available at: https://gottbs.com/2022/06/08/for-public-comment-pctts-66420xx-wastewater-reuse-agricultural-and-other-applications-requirements/ (Accessed 2 July 2022).

United Nations (2018). *SDG 6 Synthesis Report 2018 on Water and Sanitation.* New York: The United Nations

United Nations Barbados and the Eastern Caribbean (no date). *The Sustainable Development Goals in Barbados and Eastern Caribbean: Sustainable Development*

Goal 6 Clean Water and Sanitation
https://easterncaribbean.un.org/en/sdgs/6 (Accessed 2 March 2022)

UNEP (2020a). *Microplastics in wastewater: towards solutions.* UNEP. Available at: https://www.unep.org/news-and-stories/story/microplastics-wastewater-towards-solutions (Accessed 27 April 2022)

UNEP (2020b). *United Nations Environment Programme Cartagena Convention Secretariat Nature-based Solutions for Wastewater Management: Barriers and Opportunities in the Caribbean.* UNEP

UNEP-CEP (1999). *Protocol Concerning Pollution from Land-based Sources and Activities to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region.* Available at: https://wedocs.unep.org/20.500.11822/34544. (Accessed 16 February 2022)

UNEP-CEP (2015a). *Valuing the costs and benefits of improved wastewater management: An Economic Valuation Resource Guide for the Wider Caribbean Region. Part I: Summary Report.* UNEP

UNEP-CEP (2015b). United Nations Environment Programme - Caribbean Environment Programme (Revised 2015), *Regional Wastewater Management Policy Template and Toolkit* CEP Technical Report:88 Available at: https://wedocs.unep.org/handle/20.500.11822/40140 (Accessed 5 July 2022)

UNEP-CEP (2019). State of the Cartagena Convention Area -An Assessment of Marine Pollution from Land-Based Sources and Activities in the Wider Caribbean Region, UNEP/CEP Technical report number XX. *In Fifth Meeting of the Scientific and Technical Advisory Committee (STAC) to the Protocol concerning Pollution from Land-Based Sources and Activities in the Wider Caribbean.* Virtual 15 to 17 March. UNEP/CEP (Accessed 21 March 2022)

UNEP-CEP (2021). *Regional Nutrient Pollution Reduction Strategy and Action Plan for the Wider Caribbean Region.* UNEP

UNEP (no date). APPENDIX 28. National Package for St. Vincent and the Grenadines. CReW+: An integrated approach to water and wastewater management using innovative solutions and promoting financing mechanisms in the Wider Caribbean Region

UN-Water (no date a) Wastewater Management - A UN-Water Analytical Brief

UN-Water (no date b). *Target 6.2 – Sanitation and hygiene* https://www.sdg6monitoring.org/indicators/target-6-2/ (Accessed 28 February 2022)

University of the West Indies' Centre for Resource Management and Environmental Studies (CERMES) and the International Research Institute for Climate and Society (IRI) (2015). 'Impacts of Climate Change and variability on Wastewater Management', *Water & Climate Discussion Brief, (No.2)* Available at: https://iri.columbia.edu/wp-content/uploads/2015/07/wastewater_final.pdf (Accessed 5 July 2022)

US EPA (2000). *Wastewater Technology Fact Sheet Package Plants -EPA 832-F-00-016.* Washington D.C.: United States Environmental Protection Agency, Office of Water. https://www3.epa.gov/npdes/pubs/package_plant.pdf (Accessed 30 March 2022)

Von Sperling, M. (2007). Wastewater *characteristics, treatment and disposal, IWA publishing. Biological wastewater treatment series, Volume 1.* London: IWA Publishing Available at: https://iwaponline.com/ebooks/book/72/. (Accessed 15 March 2022)

Warwick, J. and Ekwue, E. (2014). 'Preliminary Feasibility of Large-Scale Treated Wastewater Re-use for Agriculture in Trinidad and Tobago', *The West Indian Journal of Engineering,* Vol.36, No. (2), January, pp.20-28 Available at.:*https://sta.uwi.edu/eng/wije/vol3602_jan2014/documents/Manv36n2EEkwue-Jan2014.pdf* (Accessed 13 March 2022)

Water & Wastes Digest (2015). Beetham water recycling plant. Water & Wastes Digest. Available at: https://www.wwdmag.com/beetham-water-recycling-plant (Accessed 9 March 2022)

Webster, D.R. and Muller, L. (2011). 'Peri-Urbanisation: Zones of Rural -Urban Transition.' *Encyclopedia of Life Support Systems (EOLSS)* http://www.eolss.net/sample-chapters/c14/E1-18-02-00.pdf (Accessed 30 April 2022)

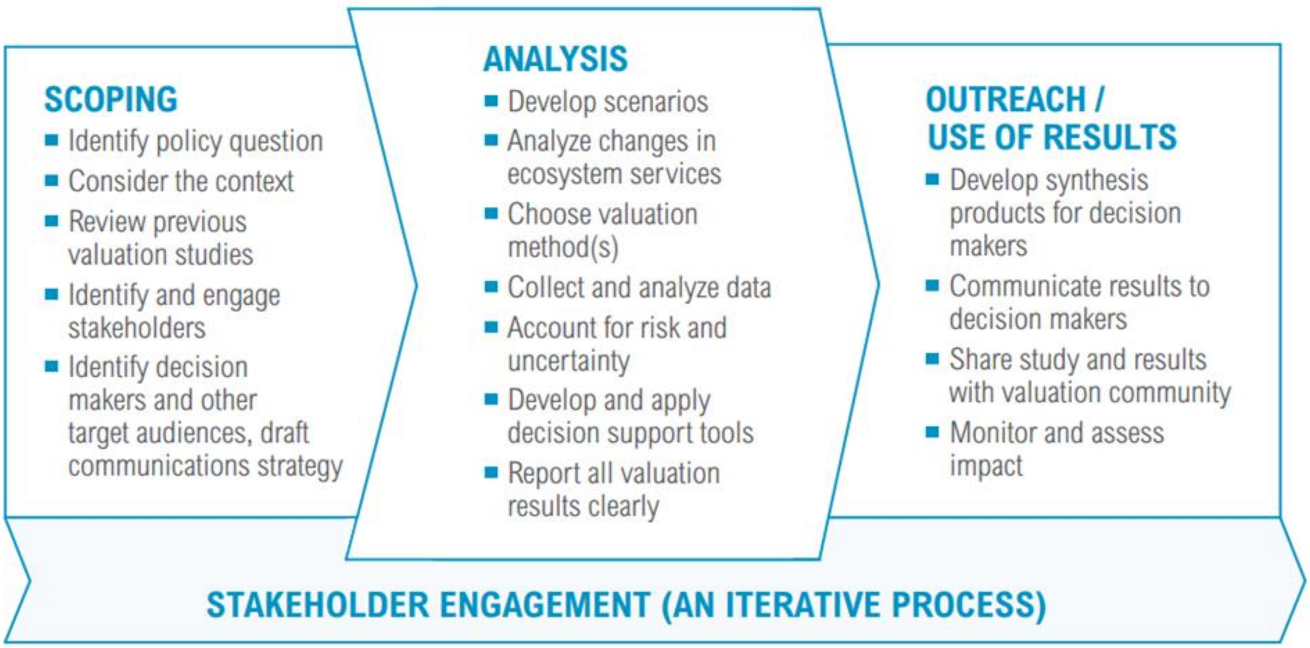
Weststrate, J. et al. (2019). The Sustainable Development Goal on Water and Sanitation: Learning from the Millennium Development Goals. *Social Indicators Research*, 143(2), pp.795–810. Available at: https://doi.org/10.1007/s11205-018-1965-5. (Accessed 15 April 2022)

World Health Organization (2006). *Guidelines for the safe use of wastewater, excreta, and greywater. Volume 2: Wastewater and excreta use in agriculture*. World Health Organization

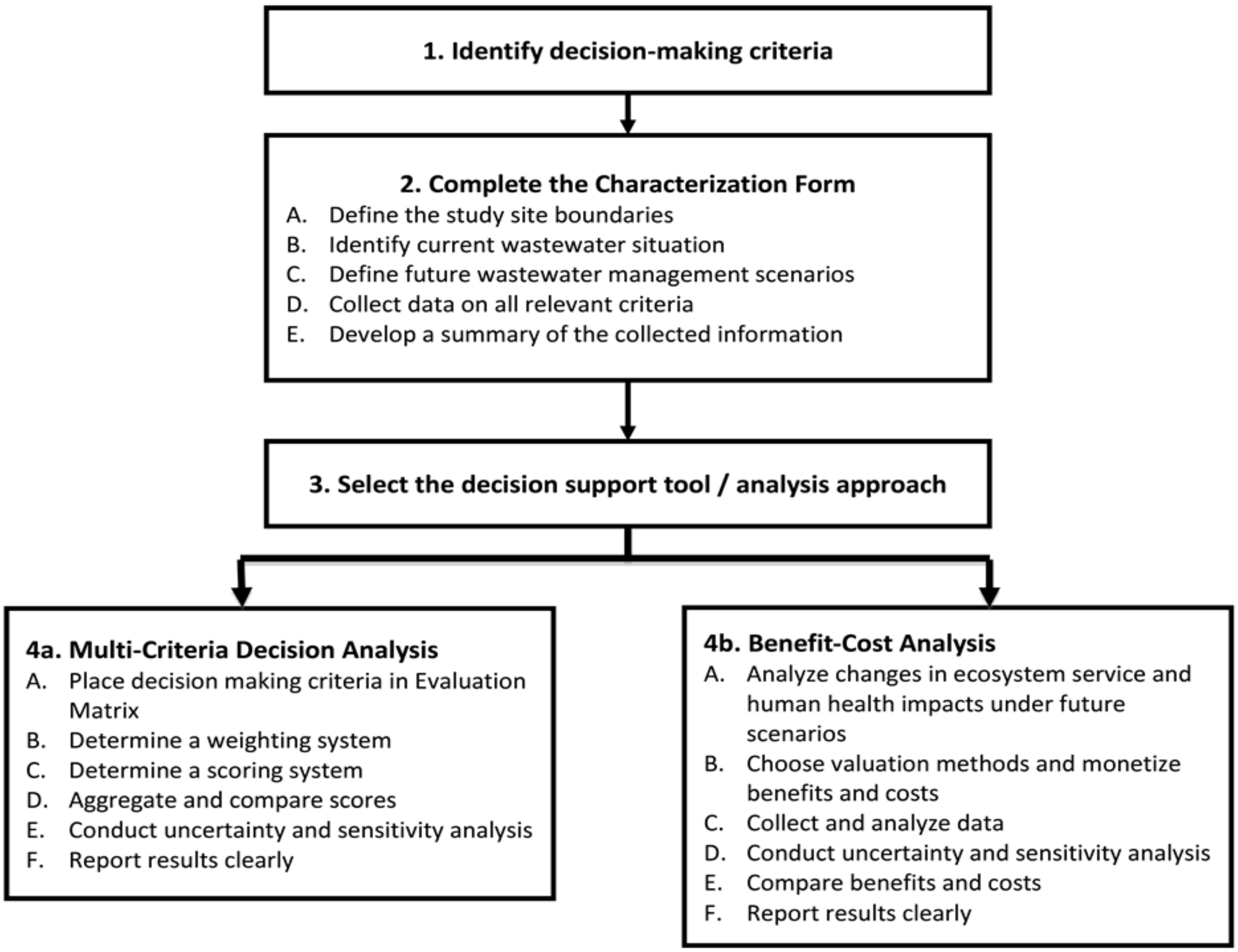
World Health Organisation (no date.) *Improved sanitation facilities and drinking-water sources.* WHO Available at: https://www.who.int/data/nutrition/nlis/info/improved-sanitation-facilities-and-drinking-water-sources (Accessed 23 February 23, 2022).

Williams, C. (2018). 'Repurposing "Waste" Water for Caribbean Small Island Developing States (SIDS)' *SIDS Times the Crowie,* First Edition Available at: https://sustainabledevelopment.un.org/content/documents/Newsletters/SIDS_TIMES_2018_June.pdf (Accessed 26 February 2022

APPENDIX 1: GOOD PRACTICE FOR ECOSYSTEM VALUATION TO INFLUENCE POLICY (FROM WAITE ET AL. 2014 CITED IN UNEP-CEP, 2015A)



APPENDIX 2: ANALYSIS STEPS FOR CONDUCTING A WASTEWATER VALUATION ANALYSIS (UNEP-CEP, 2015A)



Global Water Partnership-Caribbean (GWP-C) Secretariat
St. George's, Grenada
E-mail: info@gwp-caribbean.org
Website: www.gwp-caribbean.org

Global Water Partnership
Caribbean