

Analysis of International Best Practices in Effective Resource Management with Reflections on Arabian Gulf Countries

Sabeka Ismaeel

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Executive Summary

Historically, human development has followed a linear consumption model, resulting in resource depletion and environmental degradation. In response, waste management has become crucial for achieving sustainable development. This is particularly pertinent for the Gulf Cooperation Council (GCC) countries with their increasing emphasis on sustainability in economic and ecological vision. Despite growing interest in sustainable practices, GCC countries currently trail behind developed nations in waste management. This presents an opportunity for the region to benefit from a late mover advantage, by learning from the progress of pioneering countries.

This study investigates the vital role of effective waste management policies in reducing environmental impact and combating climate change. It analyzes three benchmark countries—South Korea, Singapore, and Sweden—selected from the 2022 Environmental Performance Index (EPI) for their exemplary waste management practices. These countries were chosen to ensure representation of geographical diversity and continuous improvement, while also being comparable to GCC countries (i.e., similar population densities, GDP per capita, and waste generation per capita).

Through a comparative analysis of these benchmarks, the study identifies key strategy pillars and best practices that can be adapted to the GCC's unique context, as summarized below:

Recommendation 1: Establish clear definitions, standards, and centralized frameworks; and empower policy implementers with higher flexibility and stronger monitoring to enhance their impact. This can include developing unified regional standards and targets for waste management.

Recommendation 2: Invest in emerging technologies and leverage digital systems

for effective governance and structuring of waste management through real-time monitoring and optimized material/energy recovery.

Recommendation 3: Ensure addressing all challenges across the waste management lifecycle by providing adequate treatment solutions and effective waste collection systems. Stakeholder engagement is key throughout this process to achieve set objectives.

Recommendation 4: Strengthen civic engagement through dedicated initiatives, tailored awareness campaigns, and early development to foster a holistic behavioral change.

Recommendation 5: Foster a stable market for waste management through policy enhancements, gradual implementation, and private sector engagement to ensure environmental and fiscal sustainability.

Recommendation 6: Implement economic incentives to minimize waste generation, while focusing on addressing waste generation from source. For maximum effectiveness, economic levers must be tailored to regional social, economic, and environmental characteristics.

By adopting a holistic approach, optimizing human and financial resources, and fostering a culture of environmental stewardship, GCC countries can advance in sustainable waste management and promote a circular economy.

1. Introduction

In today's world is uniquely characterized by growing populations, unprecedented economic growth, and intensified climate change, highlighting the strong anthropogenic effects on the planet. Human development over the past few centuries focused on a linear consumption model, an approach of "take-make-waste", leading to resource depletion and ecological degradation. Propelled by the desire to achieve sustainable development, effective waste management rose in popularity within scientific, industrial, and regulatory domains. Effective waste management is the systematic handling, reduction, treatment, and disposal of waste to minimize environmental impact and promote sustainability. The significance of effective waste management lies in its paramount role in preserving ecosystems, protecting public health, preventing pollution, and conserving valuable resources.

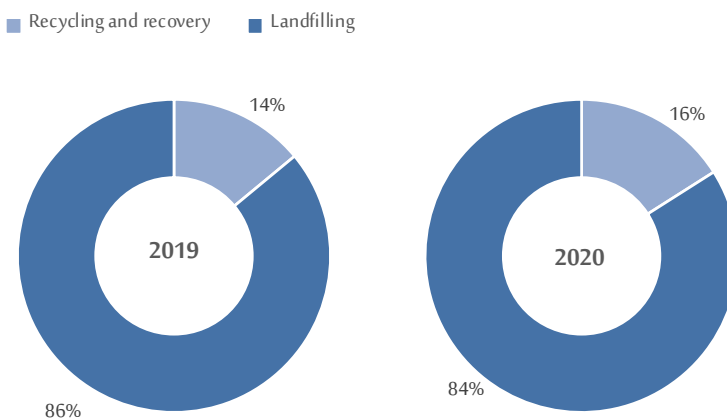
When examining broader implications, the impact of effective waste management on climate change is also noteworthy. This includes the mitigation of greenhouse gas (GHG) emissions from landfills, as well as the reduction of demand for energy-intensive production processes. In this interconnected web of environmental considerations, effective waste management emerges as a practical necessity for immediate well-being, as well as a pivotal strategy in building a resilient future for humanity on the planet.

With the accelerating sustainable transition of the Arabian Gulf Countries in the Gulf Cooperation Council (GCC), effective waste management has the potential to play a key role in wisely exploiting the region's resources. This aligns with the region's renewed interest in harmonizing economic development with ecological restoration and biodiversity preservation, moving towards a circular economy. A circular economy closes the loop between extraction, manufacturing, and disposal by encouraging the design of products to reduce waste, prolonging the lives of

products and materials, and recycling materials from end-of-life products back into the economy (Vergara and Jammi, 2022).

The region's growing economies, rising populations, and diminishing resources emphasize the necessity of adopting the principles of circular economies – a key pillar of which is effective waste management. While there are renewed interests and efforts in waste management across the six Member States of the GCC, it is justifiable to state that the region's waste management sector is still lagging behind (World Bank Group, 2019; 2022). The most prevalent waste management practice across the region is landfilling with no-gas capture and high leakages, as depicted in Figure (1.1) below (World Bank Group, 2022). This is further exacerbated by the low recycling rates and the high per capita waste generation, ranging from 1.1 to 2 kilograms per day (Statistical Centre for the Cooperation Council for the Arab Countries of the Gulf, 2022; World Bank Group, 2022). Therefore, it is crucial to scrutinize the existing gaps in strategies, policies, and practices in order to identify solutions and key areas for improvement.

Figure 1.1. Municipal solid waste (MSW) treatment methods deployed in the GCC between 2019 and 2020



Source: World Bank Group

Nevertheless, Arabian Gulf Countries can leverage their late mover advantage in the field of effective waste management and consumption regulation. This allows the region to capitalize on the lessons learned from mature waste management systems and adopt advanced technologies efficiently. Furthermore, this also allows the region to be agile in responding to market or consumption changes by adjusting strategies based on the experiences of field pioneers. By understanding international best practices, valuable insights can be extracted and mapped out to the Arabian Gulf region's targets and strategies. This study aims to conduct a comparative analysis of three benchmark countries with well-developed waste management systems (South Korea, Singapore, and Sweden), in order to derive the best practices and reflect them on GCC countries. This is further expanded to generate pragmatic recommendations that contribute to the effective assessment of the GCC countries' path towards sustainable waste management.

2. Background

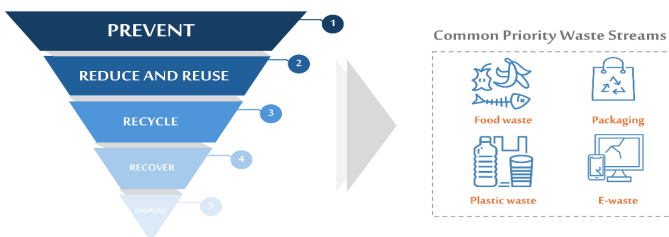
2.1. Waste management

Waste, the silent shadow of modern living, refers to all substances or objects which are disposed of, or are intended to be disposed of (Basel Convention, 1989). As consumption patterns grow, so does the complexity and volume of waste generated. This necessitates streamlining processes that cover the collection, transport and disposal of wastes, including after-care of disposal sites, which is collectively known as waste management.

Effective waste management can be defined as a set of practices and strategies focused on minimizing waste generation, maximizing resource recovery, and ensuring safe treatment/disposal. It is characterized by higher levels of environmental protection, increased public engagement, cost-effectiveness, and continuous improvement. Figure (2.1.1) below highlights these principles, conceptualized through the waste hierarchy, along with common priority waste streams that require specialized treatment methods.

Notably, varying priorities and progress levels among countries can redirect the definition of effective waste management. For example, landfilling can be an efficient solution in a country where open dumping is still practiced, while it would be highly impractical in a country with limited geographical spaces.

Figure 2.1.1. Waste hierarchy along with common priority waste streams



Source: Author

To understand effective waste management comprehensively, it is essential to analyze the entire value chain. For the purposes of this paper, the analysis covered four main stages along the waste management value chain: waste generation, collection, treatment and disposal, and governance. As shown in Figure (2.1.2), these four themes track the full waste lifecycle, from inception to eventual resolution, thus ensuring a systematic analysis.

Figure 2.1.2. Waste value chain conceptualized through the lifecycle stages



Source: Author

Waste management begins with the first stage of the value chain, waste generation. This initial phase involves the creation and accumulation of waste materials from residential, commercial, and industrial sources. Waste generation encompasses a wide range of materials, including municipal solid waste, hazardous waste, construction waste, medical waste and industrial non-hazardous waste (United States Environmental Protection Agency, 2023). The primary focus of this study is municipal solid waste (MSW) and non-hazardous waste, due to their volume and impact. MSW and non-hazardous waste comprise the largest segments of waste generated in the GCC countries and constitute one of the largest anthropogenic sources of methane emissions (Statistical Centre for the Cooperation Council for the Arab Countries of the Gulf, 2022). In comparison to other waste forms, there are also

several advantages for resource recovery from MSW, including cost-effectiveness, lower environmental impact, and higher productivity.

The second stage along the waste management value chain is collection, which involves systematically gathering waste materials generated by households, businesses, and other sources. Effective collection schemes ensure proper segregation for subsequent processing, serving as a pivotal link between generation and treatment/disposal. This is essential for maximizing resource recovery and minimizing environmental impacts. Subsequently, the third stage covers treatment and disposal, which involves processing and managing waste to minimize environmental impact and maximize resource recovery. This includes various methods such as recycling, incineration, landfilling, or other environmentally responsible techniques (United States Environmental Protection Agency, 2024). Finally, the last stage of the waste management value chain is the governance mechanism. In this context, governance is defined as the development and implementation of policies, regulations, and monitoring systems. Effective waste management relies heavily on robust governance structures to coordinate efforts among various stakeholders efficiently, promoting resilience and sustainability (World Bank Group, 2021).

Successful governance requires reframing wastes as valued resources by adopting a holistic approach to waste management. This entails the establishment of a sound institutional structure, with well-defined functions, roles, responsibilities and inter-relationships between all stakeholders. Consequently, there is a great opportunity for policy enhancements that guide the planning process across both local and central government authorities. The legal framework required to enable the achievement of policy objectives and actions must also be determined. Various governance mechanisms around the world also employ nudge policies to advance public objectives by influencing the behavior of waste producers and managers,

thereby making incremental changes in service level and performance at a national scale (World Bank Group, 2021).

2.2. Waste management in the Arabian Gulf Countries

Countries in the Arabian Gulf have witnessed rapid economic growth since the discovery of oil in the past century. Accompanied by significant urbanization and population growth, this economic development led to higher consumption patterns, thereby increasing amounts of waste generated (Meyer et al., 2022). Official statistics indicate a continuous increase in waste generation across GCC countries, averaging 40.1% between 2017 and 2022 (Statistical Centre for the Cooperation Council for the Arab Countries of the Gulf, 2024). This is further exacerbated by the region's robust economic rebound following the COVID-19 pandemic, which continues on the linear consumption model (World Bank Group, 2022). Across the six countries, the majority of municipal and industrial waste ends up in landfills with low adherence to environmental standards (Statistical Centre for the Cooperation Council for the Arab Countries of the Gulf, 2022; 2024; World Bank Group, 2019; 2022). Certain waste streams pose key challenges for GCC countries, including food waste and industrial waste resulting from the energy, mining, and transportation sectors. As indicated above, this study does not investigate the latter, but rather focuses on MSW. GCC countries have recently demonstrated a growing inclination towards addressing these challenges and transitioning to a circular economy, indicated through various strategies and policies.

Focusing on sustainability and environmental preservation, effective waste management has drawn attention as a key target of this agenda, sparking the drive to further develop this sector. While several Member States are still in the process of developing national waste strategies, various initiatives have been announced across the six countries, targeting different stages of the waste management value chain according to each country's needs. For example, Bahrain has announced

plans to build a waste-to-energy plant by 2026 (Zawya by LSEG, 2023). On the other hand, Saudi Arabia has introduced changes in waste governance through amendments, new legislation, and the establishment of dedicated authorities such as the National Center for Waste Management and the National Center for Environmental Compliance (Ministry of Environment, Water, and Agriculture, 2023). In the United Arab Emirates (UAE), federal resolutions were passed in 2018 to promote integrated waste management, while regional initiatives included waste management centers and waste-to-energy plants (The Official Portal of the UAE Government, 2023). In 2022, Qatar launched the Integrated National Solid Waste Management Program, which aims to create an integrated infrastructure to manage solid waste activities, reduce the volume of waste, and strengthen partnership with the private sector (Qatar News Agency, 2022). Kuwait has finalized the National Strategy for Integrated Waste Management 2040 in May 2024, which outlines the country's plans to develop a comprehensive waste management system, in addition to launching the Waste Management Atlas in 2022, which serves as a foundational tool for informed decision-making in waste management planning (Environment Public Authority, 2022; Arab Times, 2024). Oman has also been formulating new policies and updating legislations over the past few years to increase environmental and fiscal sustainability in the waste management sector through technical solutions and privatization initiatives (Oxford Business Group, 2017; Oman Daily Observer, 2024). While these examples do not encompass the full scope of initiatives, they demonstrate the significant efforts dedicated by GCC countries towards achieving effective waste management, in line with broader environmental and economic visions.

These efforts are directed towards reforming the sector, which currently lacks demand-side regulations (i.e., targeting the first stage of the value chain: waste generation). However, the scattering of such initiatives has not enabled the creation

of a mature waste management market. The existence of a stable waste management market is key to driving progress in developing solutions and maintaining a healthy environment. Currently, several waste management companies operate across the GCC countries, mainly covering waste collection and treatment. However, assessments from the World Bank indicate that the industry is not yet well-established, requiring the supplementation of policies to change consumer behavior (World Bank Group, 2022).

This highlights the gap between the challenges resulting from public behaviors, such as high waste volumes and lack of segregation at source, and the policies targeting the reformation of the sector, as well as the market dynamics. Fortunately, this dilemma is not unique to Arabian Gulf Countries, and several developed countries have established mature waste management systems after various experiments and trials. Therefore, there is a significant opportunity for Arabian Gulf Countries to leverage this advantage in adopting and adapting best practices to accelerate their progress towards sustainability, setting the premise for this study.

3. Research methodology

To achieve the objectives of this study, a qualitative analysis is conducted on three benchmark countries with internationally renowned waste management systems. This analysis covers policy documents, national strategies, governmental reports, and scholarly articles. The approach aims to maximize the capitalization on the key pillars of effective waste management strategies and policies, thereby allowing for a targeted reflection on the GCC region.

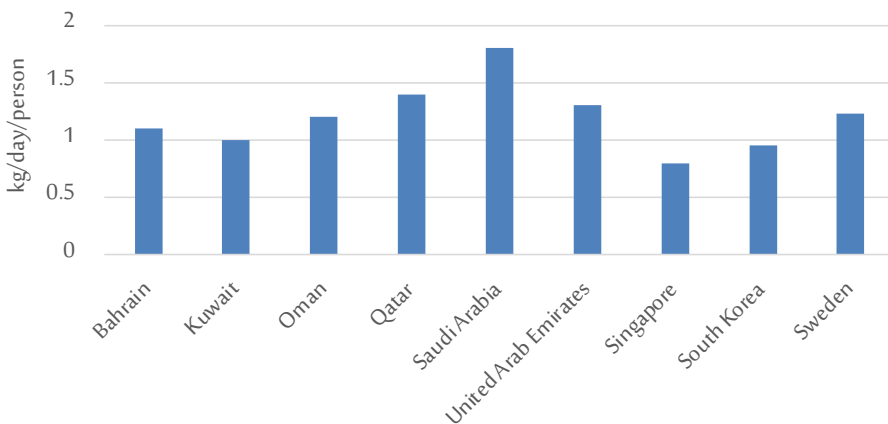
Prior to conducting the analysis, specific selection criteria were set for the benchmark countries. First, the countries have to be internationally recognized for their highly developed and effective waste management systems. The main metric for this evaluation was the Waste Management category within the Environmental Performance Index (EPI) for the year 2022, measured by Yale Center for Environmental Law & Policy and the Center for International Earth Science Information Network at Columbia University (Wolf et al., 2022). This category is based on three indicators: controlled solid waste, recycling rates, and ocean plastic pollution (Wolf et al., 2022). The top ten performing countries were then shortlisted, before being subjected to the second selection criterion, which focuses on representing geographical variations. This ensures that the analysis covers a wide range of experiences, with different countries handling varying socioeconomic factors and cultural norms.

The third criterion taken into account was the 10-year change, as measured within the EPI, which indicates that the selected countries are in a process of continuous improvement (Wolf et al., 2022). Therefore, the three selected benchmarks are: South Korea, Singapore, and Sweden. To further ensure the accuracy of the analysis, two key metrics were used to assess the selected benchmarks in comparison to the six Arabian Gulf Countries: daily waste generation per capita and Gross Domestic Product (GDP) per capita, as shown in Figures (3.1) and (3.2) below.

Waste generation per capita per day provides an indication on public behaviors and the effectiveness of waste management systems. While the amounts of waste generated in the selected benchmarks are generally lower than those of the Arabian Gulf Countries, they are still within comparable ranges. The latter is important as it highlights the effectiveness of waste management systems for similar socioeconomic conditions (i.e., growing consumption, high education levels, etc.).

This is further supplemented by the second metric, GDP per capita, which provides an indication of economic performance and living standards. To reflect the differences in the GDP per capita between the six Arabian Gulf Countries, the selected benchmarks represent varying levels of the metric, as illustrated in Figure (3.2). Notably, the selected countries represent varying population densities; Singapore is one of the most densely populated countries in the world, while Sweden has a low population density (The World Bank, 2020). This is of particular interest as similar circumstances are found within the GCC, with strong regional disparities in population densities across the six countries, as depicted in Figure (3.3) (The World Bank, 2020).

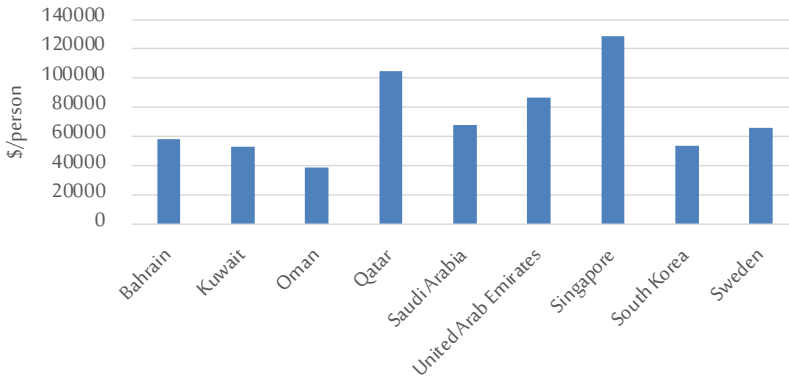
Figure 3.1. Comparison of the waste generated daily per person in GCC countries and selected benchmarks for the year 2022



Source: GCC-STAT, Ministry of Environment, Ministry of Sustainability and the Environment, Avfall Sverige

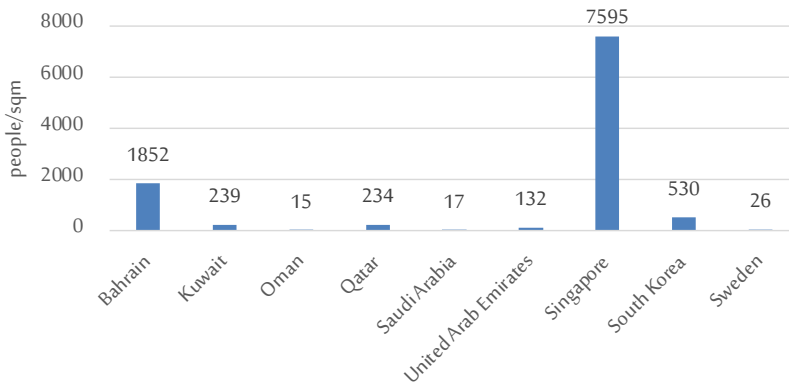
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Figure 3.2. GDP per capita in GCC countries and selected benchmarks for the year 2022



Source: IMF

Figure 3.3. Population densities in GCC countries and selected benchmarks for the year 2021



Source: World Bank

Upon the selection of the three benchmarks, a thorough analysis of the national policies, outcomes, and scholarly articles was conducted. The focus was primarily on understanding the successes and failures faced by each country in its journey towards establishing an effective waste management system, as well as their future plans for improving it. Consequently, qualitative associations were conducted to map out the GCC countries' waste management strategies and action plans to the key insights generated from the analysis of international best practices. Finally, pragmatic recommendations, applicable to the unique status of GCC countries, were generated from this exercise.

4. Overview of best practices in waste management systems and policies

Waste management is a complex process that requires diligence from multiple parties, including individuals, governments, and industries. Therefore, regulating such a sector with multifaceted dimensions, and achieving a high degree of sustainability, entails overcoming formidable challenges. Several countries have made commendable strides in effective waste management, providing a solid foundation for countries in their development process, such as Arabian Gulf Countries in the GCC region, to establish robust systems and evidence-based strategies. At this stage, with the region's sustainable transition, it is particularly important to understand international best practices and derive valuable insights applicable to the region's unique requirements. This section provides an analysis of the policies, strategies, and outcomes of three countries with renowned waste management systems: South Korea, Singapore, and Sweden. To ensure a thorough understanding of best practices, the analysis is presented along the four primary stages of the waste management value chain.

4.1. Waste management in South Korea

Waste management in South Korea exemplifies an efficient system based on robust regulations and strong civic engagement, minimizing environmental impact and advancing sustainability. The country's approach integrates technology, education, and behavioral nudges to ensure effective waste reduction and resource recovery.

4.1.1. Waste generation

In line with the waste hierarchy, South Korea has prioritized the prevention of waste generation. Constrained by limited geographical areas and concerned over environmental degradation, South Korea faced major challenges in increasing waste-processing facilities to cope with growing economic activities in the past century Ministry of Environment and Korea Environment Institute, 2016. Therefore,

policymakers shifted their attention to reducing garbage amounts from the root. Charging flat rate fees on garbage disposal, based on the sizes of property taxes reported, presented little incentive for people to minimize the quantities of garbage thrown out, which demanded a better tool to nudge individuals towards waste reduction and prevention Ministry of Environment and Korea Environment Institute, 2016.

Enforced in 1992, the Act on Resource Saving and Recycling Promotion is the main legislation that considers waste as resources. The act introduces the polluter payment concept, which set the foundation for the implementation of a volume-based garbage rate system and an extended producer responsibility (EPR) system (Yang et al., 2014). The volume-based garbage rate system encourages a reduction in the amount of waste generated, as well as the source separation of recyclables, by imposing a waste disposal cost proportional to the quantity of waste produced (Yang et al., 2014). The fees are not charged for recycled wastes in order to motivate people to increase their recycling habits (Yang et al., 2014). The system consists of each household buying specific volume garbage bags at a supermarket, where higher volume bags have higher costs. Wastes are only disposed of in these prepaid bags, and certain rules clearly specify what wastes may and may not be placed in the bags (Ministry of Strategy and Finance and Korea Advanced Institute of Science & Technology, 2014).

To prevent illegal dumping and ensure adherence to the system, public trash bins were removed from streets, such that only trash bags are collected, treated, and disposed of (Ministry of Strategy and Finance and Korea Advanced Institute of Science & Technology, 2014). This system has shown success in local communities, and MSW generation has reduced significantly (Yang et al., 2014). Notably, prior to full-scale implementation, the system underwent a trial phase in few cities, and a group of nongovernmental organization (NGO) representatives was assembled for

a midterm evaluation Ministry of Environment and Korea Environment Institute, 2016. This allows for the resolution of issues and the preparation of problem-solving strategies before wide-scale application.

On the other end, the extended producer responsibility (EPR) system was adopted to reduce the generation of industrial waste, especially for massive production items. The system places the responsibility of recycling on producers who determine structures and materials, such as packaging producers. This allows for regulating excessive packaging, promoting reduced packaging, and encouraging the production/adoption of refill products. EPR imposes a recycling quota on manufacturers of specific products that come in packaging materials. Failure to adhere to the quota results in a fine imposed on the manufacturer, which exceeds the expenses associated with implementing appropriate recycling practices. In other words, manufacturers of products with a short lifespan are the funders of the required recycling subsidy. EPR's implementation has been effective, with ongoing expansion, as evidenced by an estimated save of USD 1.7Bn of economic value over a span of four years due to reduced treatment/disposal costs (Yang et al., 2014).

Furthermore, businesses are subject to other measures and economic instruments aimed at reducing waste generation and disposal. These include waste product charges, mandatory waste reduction plans for large companies, and planned waste disposal charges for landfilling and incineration. Specifically, South Korea has implemented the Advance Disposal Fee (ADF), a waste product charge that manufacturers and importers must pay for products containing hazardous substances or are challenging to recycle. Businesses participating in voluntary agreements on plastic waste collection and recycling, as well as SMEs and start-ups, can be exempted from the ADF. Additionally, the Business Waste Reduction Program, introduced in 1996, imposes mandatory waste reduction targets on large enterprises, requiring them to submit plans every three years. The digital Allbaro system monitors progress, and

businesses with exceptional performance receive rewards, while underperforming ones receive guidance on waste reduction (OECD, n.d.).

South Korea also encountered a significant challenge in managing food waste generation, necessitating the prioritization of food waste as a distinct category in the waste management system. Initially, the country outlawed disposing food waste in landfills in 2005 (Marshall, 2022). This step is essential in mitigating environmental pollution, reducing methane emissions, and promoting food recycling/reuse. Following that, the government introduced a weight-based food waste fee system, where residents pay a fee proportional to the weight of the food waste generated, and fines are imposed on noncompliance (Marshall, 2022).

Food waste is charged by weight, as opposed to volume, due to its higher densities. The weight-based system also motivates people to minimize their water content in food wastes, making collection and treatment processes more efficient Ministry of Environment and Korea Environment Institute, 2016. Local governments can choose from three methods to manage food waste: (a) using specific garbage bags purchased from grocery stores, (b) employing chips or stickers on designated bins distributed to households, which are removed by garbage collectors upon disposal, and (c) utilizing Radio Frequency Identification (RFID) tags on specially designed bins, with households charged based on monthly waste data obtained through the RFID system (Legislative Council Secretariat, 2013).

4.1.2. Waste collection

South Korea implemented key policy measures to achieve administrative improvements to waste handling and collection. This includes upgrading collection vehicles to include more automated features and fully sealed cargo boxes to prevent leakage and odor Ministry of Environment and Korea Environment Institute, 2016. The collection mechanism is also widely standardized, with flexibility for

municipalities in setting minor details such as waste collection time. Households would place their waste bags in front of their houses (or in a special container within a residential complex), at specified times, to be picked up by regularly scheduled garbage trucks (Ministry of Strategy and Finance and Korea Advanced Institute of Science & Technology, 2014). The entity responsible for collection can be the local municipality or a third-party contractor, depending on the requirements and resources of each area.

To ensure high efficacy in collecting recyclables, many municipalities collect different types of wastes and recyclables on different days to prevent contamination. Municipalities also have the flexibility of choosing to collect recyclables using separate or integrated vessels, where source segregation is required for separate vessels (Ministry of Environment and Korea Environment Institute, 2016). Furthermore, the administrative procedures also regulate the collection of specific types of waste such as bulky objects and hazardous household waste (e.g., batteries, pharmaceuticals, etc.), as well as food waste. Large objects must bear permission stickers issued by local authorities upon payment, while hazardous wastes are required to be separately disposed of in exclusive bins provided by the municipalities (Ministry of Environment and Korea Environment Institute, 2016).

With respect to food waste, there are designated trucks that pick up organic waste on a weekly basis. The waste is then taken to an energy recovery facility, where the byproducts are used as compost and fodder (Marshall, 2022). Notably, the costs of waste collection processes are reflected in the prices of garbage disposal bags, where municipalities reserve discretion over the pricing mechanism (Ministry of Environment and Korea Environment Institute, 2016).

4.1.3. Waste treatment and disposal

In South Korea, policies have shaped up the conceptualization of waste as a resource. Therefore, treatment processes focus largely on material and energy recovery. This includes refuse-derived fuel and biogas plants where waste and biomass are converted into energy, in addition to incineration plants with heat recovery (Cho and Kang, 2017; Yang et al., 2014). Landfill gas is also collected and used for electricity generation, mainly through projects that are public-private partnerships. Treatment facilities are generally the responsibility of local municipalities or third-party contractors, depending on the requirements and resources of each region. Remarkably, South Korea's focus on resource recovery from waste, coupled with its demand control policies, have resulted in a sharp decrease in landfilling rates. Between 1982 and 2010, landfilling rates dropped from 96 to 18%, while recycling rates increased from 1.5 to 60%, and incineration rates increased from 2 to 20% (Yang et al., 2014).

4.1.4. Governance of waste management systems

The oversight of South Korea's environmental policies is entrusted to the Ministry of Environment. The Ministry is responsible for formulating and revising environmental laws and regulations, implementing comprehensive environmental conservation measures, extending administrative and financial support to local governments, and establishing national frameworks for waste reduction, recycling, and energy recovery. This includes preparing a master plan every ten years for proper waste management, as well as a plan for resource recycling every five years, consulting with key stakeholders. By establishing subsidiary public organizations, such as the Korea Environment Corporation, the Ministry aims to streamline policy implementation (Legislative Council Secretariat, 2013).

South Korea's main policy instruments focus on measurable activities, such as setting, monitoring, and revising feasible targets. Allbaro is a well-developed, centralized waste monitoring system that mandates reporting by businesses

and local authorities, utilizing RFID technology to monitor waste generation and treatment in real time. The system proved to be effective in curbing illegal dumping of waste from businesses. South Korea also leverages economic instruments, such as taxes, charges, and financial support, to promote desirable behaviors. For example, governmental financial support through long-term low interest loans has driven the growth of the recycling industry in the country (OECD, n.d.).

4.1.5. Key outcomes, challenges, and strategies

The policies enacted by South Korea had substantial environmental, social, and economic impact over the span of around three decades (Yang et al., 2014). Environmentally, the policies have resulted in the decrease of household waste generation, as well as the increase in waste separation, including food waste, and higher rates of recycling. This was driven by the positive social outcomes of these policies, which affected the attitudes of both producers and consumers, while also instigating a virtuous cycle of resource usage and recycling in South Korea. From an economic perspective, waste reduction and increased recycling led to higher monetary savings. In the first two decades of implementation, the policies reduced waste generation by 1.03 million tons, which has an estimated monetary value of around KRW 14.8 trillion (USD 13.5 billion) in economic benefits Ministry of Environment and Korea Environment Institute, 2016.

While South Korea's approach to tackling waste management focuses on the demand-side, stochastic and uncertain human behavior can still pose challenges to effective policies. Illegal dumping and incineration are a key challenge facing several municipalities, which require targeted awareness campaigns and efficient monitoring. The majority of municipalities across the country adopted laws that reward reports on illegal garbage disposal and incineration. Some municipalities installed surveillance cameras to monitor illegal waste disposal, in addition to utilizing

automated systems that warn citizens suspected of conducting such activities of the fine penalties Ministry of Environment and Korea Environment Institute, 2016.

On the other end, the effectiveness of demand-side policies does not necessarily lead to a stable supply market, as evident by the solid waste management crisis in 2017-2018. Driven by increased solid waste imports and lower oil prices, recycling companies in South Korea refused to recycle certain wastes such as plastic, polystyrene foam, and vinyl, which have decreased in price. This meant that residents were unable to dispose of their recyclable wastes, thereby instigating the crisis (Ko et al., 2020).

The country's strategy leverages several policy instruments to handle these challenges, including economic and information tools. This broadly targets achieving the country's goals of zero-waste, and high material recovery with closed resource loops. Economic instruments, comprising taxes, fines, and financial support, are strategically employed to incentivize waste reduction and recycling efforts. The country also directs investments towards the enhancement of waste treatment and recycling infrastructure, the advancement of relevant technologies, and the pursuit of research and development initiatives for clean production and eco-innovation. Information instruments, on the other hand, include various channels to educate the public on waste management and heighten awareness regarding its significance. These include advertisements, public discussions and conferences, as well as voluntary agreements forged with businesses (OECD, n.d.).

4.2. Waste management in Singapore

Waste management in Singapore relies on a mature system that prioritizes active community participation and advanced technologies to achieve environmental sustainability. Singapore's approach includes innovative waste-to-energy facilities and a zero-waste masterplan, aiming to minimize landfill usage and maximize resource recovery.

4.2.1. Waste generation

Singapore has historically approached waste management by providing supply-side solutions (i.e., the supply of waste treatment/management facilities). Nevertheless, modern challenges and strives for holistic sustainability shifted the perspective towards addressing the waste value chain from the first stage, generation. The country's efforts to address waste generation from households focus more on voluntary participation, such as awareness campaigns and providing centralized recycling depositories, as well as funding initiatives. For example, the Towards Zero Waste Grant was set up in 2019 to fund projects that encourage waste reduction or drive households to adopt proper recycling habits (SG101, 2020).

However, relying on voluntary participation did not result in significant increases of material recovery, as the uptake of recycling is still poor (Wong, Wood and Paturi, 2021). This can be attributed to the lack of a tangible impact, propelled by a culture of "convenience". The environmental impact of recycling cannot be sensed directly by the wider public in a developed and stable market economy such as Singapore's. Therefore, there is minimum motivation for consumers to prioritize recycling over convenience voluntarily, despite broader awareness on sustainable consumption and material recovery.

With respect to businesses, Singapore is planning on implementing an EPR system for packaging waste management by 2025 (National Environment Agency, n.d.). Under the EPR system, producers will be responsible for the collection and treatment of packaging materials they supplied to the market. Currently, there is a Mandatory Packaging Reporting (MPR) scheme, which is setting the premise for EPR application (National Environment Agency, n.d.). Implemented in 2021, MPR requires producers of packaged goods to collect data on the packaging supplied to the market and develop plans to reduce, reuse or recycle, reporting their findings annually to the authorities (National Environment Agency, n.d.).

On a broader scale, the reporting of waste data by businesses and commercial entities is mandatory by law, which also requires them to propose waste reductions plans (SG101, 2020). Businesses are also the main focus of regulations on food waste management, with the aim of closing this priority resource loop. Enacted in 2019, the Resource Sustainability Act (RSA), mandates industrial and commercial entities that produce large amounts of food waste to segregate their food waste for treatment and reporting (National Environment Agency, 2023). As of 2021, developers of new buildings are also mandated to allocate a designated space for on-site food waste treatment systems, such as composting (National Environment Agency, 2023).

4.2.2. Waste collection

In Singapore, a daily district-based collection system is in operation, utilizing a single chute or bulk bin system (Golder Associates Singapore, 2016; Ministry of the Environment and Water Resources and National Environment Agency, 2019). The collection is done by third-party contractors appointed by the National Environment Agency (NEA). Waste that is not segregated at source is directly sent to incineration plants for energy recovery (National Environment Agency, n.d.). Otherwise, recyclables are deposited into specific recycling chutes or blue recycling bins, which are provided for every block/home (National Environment Agency, n.d.).

Singapore employs a commingled collection system, allowing all recyclables (paper, metal, plastic, and glass items) to be placed in blue bins. Collected by designated blue trucks, recyclables undergo sorting and baling, before being sent to local or overseas recycling plants (National Environment Agency, n.d.). Notably, when the National Recycling Programme (NRP) was introduced in 2001, the collection scheme originally provided fortnightly door-to-door collection of recyclables in recycling bags.

However, this scheme posed several issues including household dissatisfaction with waste storage, theft of recycling bags, and a highly labor-intensive collection process

(Ministry of the Environment and Water Resources and National Environment Agency, 2019). Therefore, current schemes involve collecting recyclables thrice or once a week, depending on the volumes (National Environment Agency, n.d.). A key consideration here is that food waste from households is currently not collected for recycling in Singapore (National Environment Agency, n.d.).

Singapore has also pushed for adopting innovative solutions, such as smart Reverse Vending Machines (RVMs) and Pneumatic Waste Conveyance System (PWCS). Offering a convenient recycling method, RVMs take in recyclable drink containers (National Environment Agency, n.d.). The PWCS, on the other hand, is an automated waste collection system which conveys waste by air suction from individual buildings through a network of pipes to a central location for collection. As of 2018, new developments for non-landed private residential developments are mandated to implement PWCS, in an effort to increase the adoption of the system (Ministry of Sustainability and the Environment, n.d.).

4.2.3. Waste treatment and disposal

The main waste treatment method deployed in Singapore is incineration, with one offshore landfill used for disposing ash and other non-incinerable waste. Treatment facilities are mainly operated through public-private partnerships, as a common responsibility of the NEA and third-party contractors. The energy recovered from the incineration plants provides up to 3% of the country's power needs (SG101, 2020). Before being transported to the offshore landfill, 90% of the ferrous metals and more than 75% of the non-ferrous metals are recovered from the ash and residues using special magnets, micro-grain eddy current separators, and multi-stage sieving techniques (Ministry of the Environment and Water Resources and National Environment Agency, 2019).

The offshore landfill was designed to ensure maximum environmental protection, with a perimeter rock bund built between the island and its neighbor. The bund is lined with an impermeable membrane and a marine clay layer, effectively containing leachate within the landfill. Additional facilities have been constructed to ensure the self-sustainability of the landfill operation (Ministry of the Environment and Water Resources and National Environment Agency, 2019; SG101, 2020). However, Singapore is striving to further reduce waste generation as the landfill is projected to run out of space by 2035 (Ministry of the Environment and Water Resources and National Environment Agency, 2019).

As part of the country's plans to advance technological solutions, the Integrated Waste Management Facility (IWMF) was developed, expected to be completed by 2028. The IWMF will utilize new technologies to maximize both energy and resource recovery from solid waste. The main concept behind the IWMF is the exploitation of common processes and beneficial synergies in water reclamation and waste management. Co-located with a water reclamation plant, the facilities are designed to be self-sustaining (SG101, 2020).

4.2.4. Governance of waste management systems

The National Environment Agency (NEA) is responsible for planning, developing and administering Singapore's waste management systems (National Environment Agency, n.d.). NEA collaborates with industry players to implement and provide waste management solutions across the country. For example, public waste collectors are appointed by NEA and several incineration plants are developed under a Design, Build, Own and Operate (DBOO) model (National Environment Agency, n.d.).

Singapore also plans are to establish a circular economy (CE), launching the Zero Waste Masterplan in 2019, to lay out strategies to build three resiliencies in climate, resource, and economics (Ministry of the Environment and Water Resources and

National Environment Agency, 2019). The targets include reducing waste per capita sent to landfill by 30% and achieving 70% overall recycling rate by 2030. This reinforces Singapore's vision to go beyond converting waste into energy, by producing greener energy forms such as syngas, as well as utilizing recovered materials as industrial feedstock. The strategy also aims to reduce the carbon footprint from incineration, and further extend the lifespan of the country's only landfill (Ministry of Sustainability and the Environment, n.d.).

To achieve its ambitious plans in closing consumption loops, Singapore is leveraging three main enablers. The first enabler is technology and innovation, where the country aims to spur innovation through grants and incentives, while also driving the widespread adoption of advanced technology. Second, strengthening the labor market by moderating manpower demand and building a sustainable supply of skilled workforce. Lastly, Singapore is focused on enhancing international market access, growing its capabilities to capture overseas markets, and offering integrated waste management solutions internationally (Ministry of the Environment and Water Resources and National Environment Agency, 2019).

4.2.5. Key outcomes, challenges, and strategies

Singapore's waste management policies resulted in key environmental outcomes, as the country embraced the circular economy approach in several sectors. Primarily, Singapore was successful in closing key resource loops such as construction materials and water. The majority of construction waste and metals are recycled, while combining water and sanitation allowed the country to endlessly recycle and reuse water (Ministry of the Environment and Water Resources and National Environment Agency, 2019). Although the focus on supply-side solutions showed high efficiency, it is proving to be unsustainable without effective demand control. This is driving Singapore's current orientation towards achieving zero-waste by preventing waste generation, particularly with concerns on the landfill reaching full capacity in the

near future. As Singapore is a small state with limited geography, this is considered crucial for the country's socio-economic well-being.

Among the key challenges facing Singapore's waste management system is the difficulty in tracking the level of per capita waste generated due to the predominant usage of chutes and centralized collection schemes. This increases the difficulties in accurately tracking waste generation, assessing consumer behavior, and imposing relevant regulations. The significance of addressing the latter becomes evident when examining the poor recycling uptake in the country, in spite of national initiatives such as awareness campaigns and centralized recycling depositories (Wong, Wood and Paturi, 2021). This indicates that there is a need to evaluate the effectiveness of voluntary policies and soft laws, while effectively tracking key data. Experts have also emphasized the need to consider legislation that mandates household recycling, alongside providing sufficient infrastructure and support services to facilitate this behavioral change (Wong, Wood and Paturi, 2021).

Singapore's strategy prioritizes becoming a zero-waste nation in a sustainable manner, with a focus on building climate, resource, and economic resilience. The country aims to advance beyond waste-to-energy, by generating greener energy like syngas and reclaiming valuable resources from waste for chemical industry feedstock. Simultaneously, Singapore seeks to minimize landfilling of residue, to reduce its carbon footprint and prolong the lifespan of its only landfill (Ministry of Sustainability and the Environment, n.d.). To achieve set objectives, the strategy has four key focus items: labor market, productivity, internationalization, and technology (Ministry of the Environment and Water Resources and National Environment Agency, 2019).

The first item focuses on moderating manpower demand, creating a sustainable manpower supply, and building a skilled and resilient workforce. Second, the strategy highlights productivity, which involves shifting towards performance- or

outcome-based contracts/procurement and optimizing land use. The third item, internationalization, aims to enhance market access, grow capabilities to capture overseas markets, and scale up the offer of integrated solutions. Finally, the fourth item, focusing on technology, targets spurring innovation and driving widespread adoption of technology. This is primarily done through grants and incentive schemes provided for research centers, academic institutions, and start-ups.

Singapore has also targeted interorganizational collaboration, as seen in the Sustainable Manufacturing Centre (SMC) of the Agency for Science, Technology and Research (A*STAR). SMC aims to promote sustainability in the manufacturing industry by bringing industry associations and the research community together to work with government agencies on developing and implementing sustainable manufacturing technologies (Ministry of the Environment and Water Resources and National Environment Agency, 2019).

4.3. Waste management in Sweden

Sweden's waste management system is renowned for its efficiency and environmental focus, prioritizing recycling, industry engagement, and strong communal knowledge. The country has successfully implemented waste-to-energy initiatives and aims to transform into a circular economy that balances sustainability and prosperity.

4.3.1. Waste generation

Sweden's waste management strategy prioritizes waste prevention, with a voluntary target of reducing the total volume of food and residual waste by at least 25% per person by 2025 (Avfall Sverige, 2022). The system places the responsibility of waste separation and depositing (at specified collection points) on households. However, Avfall Sverige, the Swedish waste management association, estimates that over 60% of the disposed household waste is incorrectly sorted at the source, containing recyclables and hazardous waste (Avfall Sverige, 2022). Therefore, as of 2025, it will

be mandatory for households to segregate recyclables such as textiles, paper, metals, and glass (referring to waste other than packaging waste) for separate collection (Avfall Sverige, 2022).

To further incentivize households to reduce waste, municipalities in Sweden use a volume-based or a weight-based tariff system, depending on the local government's strategy (Andersson and Stage, 2018). Similar to the system in South Korea, the volume-based and weight-based tariff systems charge fees on households proportional to their waste generation. Sweden also leverages taxation as a tool to advance its waste management targets. In 2000, taxation was introduced on waste sent to landfills in 2000 to incentivize material or energy recovery (Avfall Sverige, 2022). On the other hand, a deduction in the value-added tax (VAT) is imposed for the reparation of various items to support reuse and longer life cycles, including bicycles, appliances, leather goods, and textiles (European Environment Agency, 2023).

From a business perspective, Sweden applies EPR on various items, such as packaging, pharmaceuticals, and batteries. Notably, a producer is defined as the entity that imports, produces or otherwise puts a product on the market (Avfall Sverige, 2022). Producers are responsible for both collection and treatment/disposal of end-of-life products, with the exception of collecting packaging materials which is the responsibility of municipalities (Avfall Sverige, 2022). Municipalities may also set rules specifying the requirements concerning the composition, reusability and recyclability of packaging materials in their jurisdiction (Swedish Environmental Code, 1998).

With regards to food waste, initially, many municipalities incentivized the voluntary collection of food waste by incorporating a waste charge system, where households separating food waste pay a lower fee compared to those opting for mixed waste collection (Avfall Sverige, 2022). However, from 2024, the separation of food waste has become mandatory for all households and businesses nationwide, where local

authorities must provide separate collection systems for food waste (Swedish Institute, 2024).

4.3.2. Waste collection

In Sweden, the collection is conducted through various methods adapted to the different conditions in each municipality. Generally, however, municipalities collect MSW via weekly doorstep collection schemes, while bulky and hazardous household wastes are collected through municipal recycling centers (Avfall Sverige, 2022; Environmental Protection Agency, n.d.). The collection is done by the local government or third-party contractors, depending on the requirements and resources of each municipality.

To maximize efficacy, bags have been replaced with bins or containers, and manual handling has been replaced with automated systems such as vacuum waste collection and underground container systems. MSW is commonly collected from two bins, one for general waste and one for food waste (Avfall Sverige, 2022). The separate collection of food waste increases the amount of organic waste available for biological treatment, while simultaneously reducing the amount of waste intended for incineration (Andersson and Stage, 2018).

Recyclables are collected in manned and unmanned recycling centers dispersed throughout the country. However, Sweden is aiming to change this scheme into a curbside collection system by 2027 to achieve higher levels of recycling (Avfall Sverige, 2022). This is particularly significant because despite the legal requirement for households to sort specific types of waste, compliance enforcement and monitoring are rarely implemented, relying primarily on voluntary actions (Andersson and Stage, 2018).

4.3.3. Waste treatment and disposal

In Sweden, the majority of the waste is treated using incineration with energy recovery, followed by material recycling. The utilization of energy from waste is estimated to fulfill the heating requirements for over 1,470,000 apartments and supplies electricity to more than 940,000 apartments (Avfall Sverige, 2022). Notably, the capacity for energy recovery in Sweden is greater than the domestic availability of combustible waste, which opens up a waste import market. Treatment facilities are operated by local governments or third parties, according to the requirements of each region.

Food and organic waste are mainly treated through biological treatments, as the country has outlawed landfilling organic and combustible waste since 2001 (European Environment Agency, 2022). This ban has decreased the landfill gas extracted for energy, as mostly inert waste is landfilled. With various treatment facilities for co-digestion and composting, anaerobic digestion is the most common method of treating food waste in Sweden, producing biogas for energy generation (Avfall Sverige, 2022).

Sweden also leverages regulatory instruments to promote certain waste treatment methods. For example, waste incineration is currently exempt from energy and emission taxes (Finnveden et al., 2007). This is intended to raise the economic advantage of waste as fuel over other alternatives. In addition, the exemption also gives waste incineration an economic advantage over other treatment methods, such as landfilling. Thus, Sweden can maintain its goal of limiting the landfill disposal of MSW to a maximum of 10% (Avfall Sverige, 2022).

4.3.4. Governance of waste management systems

The Swedish Environmental Protection Agency (EPA) is the central authority responsible for ensuring that waste management in Sweden is environmentally

acceptable, effective for society, and simple for consumers (Avfall Sverige, 2022). However, under the Swedish Environmental Code, each municipality has a local waste ordinance. Municipalities are responsible for guaranteeing that MSW is transported, treated, or disposed of. This includes formulating waste regulations and providing the appropriate infrastructure, with a legal obligation to consider waste prevention in all strategies. Additionally, municipalities are allowed to collaborate and draw up common regional waste plans (Avfall Sverige, 2022). All municipalities are also obliged to provide information to households on waste prevention measures. Notably, Sweden conducts an annual revision of the intermediate targets of the country's waste prevention program (European Environment Agency, 2023).

Municipalities leverage waste fees to finance local waste management, covering costs for containers, collection, transport, treatment, recycling centers, information campaigns, planning and administration. The cost is commonly split into a fixed fee and a variable fee, such as a fee for waste collection and another for waste treatment (Avfall Sverige, 2022; Environmental Protection Agency, n.d.).

With respect to waste prevention measures, Sweden mainly adopts communicative measures in the form of information campaigns, collaborations, and promotion. Lacking a legal obligation, these measures usually exhibit a low level of governmental intrusion and coercion. As such, few levers in Sweden's waste prevention plans focus on regulative and economic measures. The implementation of this system indicated that soft laws are successful when heterogeneous actors must agree on a politically charged question. Within a developing field, soft laws also function as a test ground to learn and adapt before progressing into a full-fledged legal rule. This has led to the creation of soft spaces, characterized as fluid areas outside formal institutions and processes where non-governmental actors can produce alternative solutions for effective waste management (Johansson and Corvellec, 2018).

4.3.5. Key outcomes, challenges, and strategies

The effectiveness of Sweden's waste management system is evident by its waste diversion rate for household waste, which reaches 99%. Around 15% of household waste is sent to biological treatment, 48% for heat and power production, 35% for material recycling, and less than 1% to landfills (Aid et al., 2017). Policies have also resulted in social outcomes, such as the promotion of environmentally responsible behavior. For example, studies show that collecting food waste separately has had indirect effects on household waste production in Sweden, as recycling is seen as a beneficial act that is linked directly to self-perception (Andersson and Stage, 2018).

Sweden faces a lag in achieving its desired recycling rates, posing a key challenge for the country (Avfall Sverige, 2022). While households are legally obligated to segregate specific waste types, enforcement and monitoring of compliance is minimal, relying heavily on voluntary sorting practices (Andersson and Stage, 2018). This leads to higher levels of incorrectly sorted waste, in addition to increased collection and treatment costs. Avfall Sverige also notes that several of the country's recycling centers frequently face thefts, burglaries, and threats to staff safety (Avfall Sverige, 2022). These incidents discourage people from prioritizing recycling over safety and convenience, which justifies the higher levels of recycling noticed in Swedish municipalities with curbside services (Avfall Sverige, 2022).

With a vision to become a zero-waste nation, Sweden's strategies prioritize the promotion of waste prevention, followed by energy and material recovery. A maximum of 10% of MSW is allowed to go to landfill, while the preparation for reuse and recycling of municipal waste shall be at least 65% by weight (Avfall Sverige, 2022). Sweden is also highly focused on civic engagement in its environmental efforts. For example, in 2020, all municipalities were obligated to provide information to households on waste prevention measures. Around 22% of all communicative measures in Sweden are aimed at increasing capacity, while 21% is aimed at

increasing knowledge among the public (Johansson and Corvellec, 2018). While historically perceived as a strength, Sweden's reliance on public awareness and responsibility now necessitates targeted actions and measurable reforms to address the changing socio-economic trends within the country.

5. Analysis and reflections on the Arabian Gulf Countries

Arabian Gulf Countries stand at a pivotal moment in the development of their waste management sectors. With their current markets still in the development process, GCC countries can leverage this as an advantage by drawing on the experiences and innovations of pioneering countries in waste management. By studying the successes and challenges faced by leading countries, Arabian Gulf Countries can adopt best practices, avoid past mistakes, and implement cutting-edge technologies and strategies. This approach positions GCC countries as a forward-thinking region committed to environmental stewardship and economic modernization, while simultaneously addressing sustainability challenges. This section aims to analyze the key elements of success shared by the benchmark countries, while reflecting on GCC countries.

Recommendation 1: Establish clear definitions, standards, and centralized frameworks; and strengthen policy implementers with flexibility and effective monitoring. This can include developing unified regional standards and targets for waste management.

Across the waste management value chain, all benchmark countries share key pillars that contribute to the success of their schemes. All benchmarks have clear definitions, standards, and classifications for the various types of waste, which leads to systematic policy development. This provides a basis for shared expectations, facilitates effective collaboration, and enables accurate assessments. Notably, all countries have centralized frameworks, policies, and regulators, while maintaining enough flexibility for local governments to implement strategies and policies efficiently. Centralization allows for a cohesive and standardized approach to governance, ensuring a unified direction and adherence to overarching principles.

Complementing centralization by strengthening policy implementers with a certain degree of flexibility enables the enactment of policies and regulations in accordance with the local requirements of each area. This provides local governments with a higher degree of adaptive power, such that there is more resilience and agility when facing uncertainties. Despite minor differences among the benchmark countries, it is evident that the various centralized systems rely on effective monitoring and reporting schemes. Facilitating access to accurate and timely data enables authorities to evaluate the performance of the waste management system, identify strengths and challenges, and expedite evidence-based decision making. This leads to optimizing resource allocation, enhancing policy effectiveness, and mitigating environmental impacts.

In the Arabian Gulf region, the governance and regulation of waste management varies between countries. The majority of countries rely on laws and regulations as the main source to define waste classifications. Some countries, such as Qatar and the Emirate of Abu Dhabi in the UAE have published technical guidelines to support sustainable waste management practices (Environment Agency Abu Dhabi and The Center of Waste Management Abu Dhabi, 2016; Ministry of Municipality, 2023). This indicates the existence of a gap in standardizing the technical aspects of waste management systems, which lowers the effectiveness of policies. Additionally, this also opens up a pathway for creating regional standards within GCC countries, which can facilitate communication and collaboration, thereby improving waste management systems collectively and allowing for an optimized pool of resources. Unified GCC targets and standards for waste management can catalyze sustainable transitions by stimulating constructive competition between the Member States.

Moreover, centralization of policymaking and regulation also varies between GCC Member States, especially given the varying geographic areas and population densities. For larger countries, such as Saudi Arabia, it is crucial to have a certain degree

of decentralization, similar to the benchmark cases presented above. This consists of centralizing policymaking and target-setting on a national level, while simultaneously allowing local authorities to implement the systems that accommodate their unique requirements. The establishment of the National Center for Waste Management in 2019 indicates Saudi Arabia's efforts in this direction, which is also reflected in other GCC countries such as the establishment of Be'ah in Oman and Tadweer Group in Abu Dhabi, UAE. Examining the case of the city-state Singapore above, it is observed that such a model is also applicable for smaller countries. Therefore, a centralized governance structure is adaptable for smaller GCC countries such as Bahrain, where currently the responsibility is shared between several stakeholders including the Supreme Council for Environment and the Ministry of Municipalities Affairs and Agriculture. Nevertheless, these governance models require an efficient data-driven monitoring system to ensure the optimal streamlining of operations.

Recommendation 2: Invest in emerging technologies and leverage digital systems for effective governance and structuring of waste management through real-time monitoring and optimized material/energy recovery.

While all GCC countries are on their path towards digital transformation, it is imperative to leverage data-driven approaches in effectively and consistently monitoring waste management processes. This includes developing a centralized digital system that allows waste producers, collectors, and treatment facilities to engage with the authorities and report on their processes in real-time. Synchronizing this centralized system across the six Member States can also increase opportunities for regional cooperation to close resource loops in the GCC region. Establishing a digital database could further enhance integration and serve as a strong incentive for invigorating the sector, through electricity generation, material extraction, or recycling activities.

Recommendation 3: Ensure addressing all challenges across the waste management lifecycle by providing adequate treatment solutions and effective waste collection systems. Stakeholder engagement is key throughout this process to achieve set objectives.

Furthermore, all benchmark countries have a vision of zero waste societies, targeting the closure of key resource loops (depending on each country's requirements). This has propelled the benchmark countries to increase investments in emerging technologies, environmental startups, as well as research and development. Consequently, these trends stimulate the market for developing, adopting, and commercializing various waste management solutions across the entire value chain. Therefore, an entire sector is created, with potential socio-economic effects through job creation, material recovery, and environmental preservation. However, it must be acknowledged that the benchmark countries are enabled to activate such schemes due to their reliance on multiple waste treatment processes, including digestion, incineration, recycling, and recovery.

The availability of varying treatment processes also promotes a holistic and adaptable approach to waste management, addressing environmental, economic, and social considerations. This is only feasible due to the existence of efficient collection and segregation systems. The key characteristics of an effective waste collection system include systematic scheduling, widespread community participation, streamlined segregation practices, well-maintained infrastructure, and robust monitoring mechanisms. Collectively, these factors ensure the proper and sustainable management of diverse waste streams. This further highlights the significance of collaboration and stakeholder engagement, which have been a key strength in all benchmark countries. Programs such as EPR, industrial alliances with policymakers, and the involvement of NGOs and educational institutes, are all notable examples of the latter.

Recommendation 4: Strengthen civic engagement through dedicated initiatives, tailored awareness campaigns, and early development to foster a holistic behavioral change.

Waste management is an area that requires high civic engagement to achieve the desired objectives. Hence, all efforts in the benchmarks are reinforced by strong awareness campaigns emphasizing citizen responsibility for lower waste generation and higher resource utilization. Embedding these campaigns within the education system further strengthens their effects, ensuring that sustainable waste management practices become a behavioral trend among the wider population.

Exploring the Arabian Gulf region through the same lens, the benefits of administering and publishing a holistic vision/strategy on effective waste management are evident. Greater transparency helps in overcoming the challenges faced by the sector, further strengthening stakeholder engagement and collaboration. This limits the risk of the waste management landscape fragmenting, while also enhancing productive communication, thereby supporting the region's strive for achieving circular economies. Reflecting on investments and entrepreneurship, the aforementioned challenges can pose threats to the functional commercialization of waste management, thereby reducing market opportunities. This is valid despite the significant potential of waste management as an emerging market in the Arabian Gulf region, given the predominant reliance on landfills and the growing demand for alternative waste management facilities.

Recommendation 5: Foster a stable market for waste management through policy enhancements, gradual implementation, and private sector engagement to ensure environmental and fiscal sustainability.

The success of the benchmarks stemmed from the development of a stable market for waste management and ancillary services, which is currently still evolving in GCC countries. The feasibility of such solutions is associated with policy reforms but

can also be stimulated by key drivers such as the GCC countries' high human and financial capitals, which can be a fundamental enabler of investments, research and development, as well as innovative start-ups in waste management. Paving the way for various operational facilities, this can further complement the region's economic diversification visions.

Prevailing infrastructure gaps limit the effectiveness of certain policy measures; however, examining the benchmark countries illustrates that gradual implementation is crucial. Pilot phases, trials, and methodical evaluation from key stakeholders contribute to adopting feasible solutions at the appropriate time. While studying feasibility, countries can initiate construction of the required infrastructure, with a key target of engaging the private sector. Private sector engagement in the early stages is vital for the fiscal sustainability of the waste management sector. This ensures that countries do not adopt a welfare approach to waste management, which can be appealing to citizens but burdensome on the state in the long-term.

Yet, all these efforts require high levels of civic engagement, and significant behavioral changes at the grassroots level, which requires effective campaigning. Campaigning and education methodologies are not a "one-size fits all", with varying perceptions across each GCC country. Therefore, each public awareness initiative must be tailored to its target audiences. For example, Saudi Arabia's large youth demographic will resonate strongly with modern platforms such as social media influencers. On the other hand, the UAE's real-estate and construction sector requires a dedicated corporate campaign, which can potentially be reinforced with certain incentives.

Recommendation 6: Implement economic incentives to minimize waste generation, while focusing on addressing waste generation from source. For maximum effectiveness, economic levers must be tailored to regional social, economic, and environmental characteristics. Safeguards should be included that protect the living standards of low-income groups.

With the focus on waste minimization from source, all best practices include a form of an economic incentive to achieve this goal. Based on the “polluter should pay” principle, these incentives nudge citizens to reduce consumption and waste generation. By leveraging a proportional payment scheme, citizens are charged more when the amount of waste generated is higher. This allows for a deeper psychological penetration, steering public behavior towards waste reduction, specifically for priority waste streams. All benchmark countries have set priority waste streams, such as food waste, electric and electronic waste, and packaging, with specific strategies and regulations. Essentially, priority waste streams require specific treatment and handling processes to ensure achieving the highest levels of material/energy recovery and the lowest environmental impacts.

In line with international best practices, the GCC countries’ strategies must focus on leveraging economic incentives as a key policy tool to minimize waste generation from source, while also shielding various-income groups from the potentially adverse effects on purchasing power. This must be a high priority for GCC countries as it solves the problem from a demand-side perspective (i.e., demand for waste management facilities). Demand-side solutions provide a more sustainable approach to controlling consumption and protecting resources. As highlighted above, two of the benchmark countries (Singapore and Sweden) have built their waste management strategies in the past century on supply-side solutions. However, these countries have now shifted their perspective towards a zero-waste future by effectively managing waste generation from source. This indicates that while it is important to provide adequate waste management infrastructure, it is even more important to resolve the root cause of resource wastage, particularly with modern challenges of increased urbanization, population growth, climate change, and scarcity.

Economic levers applied in GCC countries must be tailored to the unique landscape of the region. With the region’s economic growth, higher disposable income can

lead to more tolerance for financial compromises instead of social or cultural ones. In other terms, paying relatively low fines or fees is more appealing to the public than sacrificing convenience, social status, or cultural values such as generosity and hospitality. It is inevitable to leverage economic incentives to propel environmentally-conscious behavior; however, it is equally important to assess their impact on hindering growth or weakening competition with imported products. This requires full-fledged cooperation between authorities, industry leaders, and civil society representatives to ensure the effectiveness of policy levers.

The urgency of waste management is derived from its nature as a cumulative problem, wherein delays in deploying effective solutions exacerbate the situation and increases the complexity of the problem. Having a late-mover advantage, GCC countries can utilize the policy and strategy changes made by leading countries to ensure the establishment of a sustainable waste management system. Figure (5.1) highlights the key pillars derived from best practices in waste management, which can contribute to shaping a holistic strategy for effective policies, optimized operations, and a healthy environment.

Figure 5.1. Key pillars derived from best practices in waste management



Source: Author

From acting as a key energy source to serving as a source of valuable materials through urban mining, waste has transformed into a valuable resource in an era marked with climate change and significant scarcity. Effective waste management is a key element in the global transition towards sustainability and equity. When assessing waste management strategies and prioritization in key developed countries, GCC countries have room for improvement in terms of both waste generation control and effective management strategies. This confers a late-mover advantage upon the region, taking the form of capitalizing on the best practices of pioneering countries, while simultaneously avoiding their mishaps.

On this basis, this study investigated the value chain of waste management in three renowned countries: South Korea, Singapore, and Sweden, taking into account various factors of importance to the GCC region. Several key pillars were extracted from the strategies and policies of these benchmark countries, reflecting the respective challenges and enablers within GCC countries. This includes a strategic policy tool leveraged by all benchmark countries, the economic incentive to reduce waste generation. While economic incentives are an inevitable approach for GCC countries to further develop their waste management systems, there are some considerations that might hinder the streamlining of this process.

First, the pricing mechanism must be thoroughly studied, through both quantitative and qualitative research. Lower prices may appeal to the public, thereby having minimum social impacts, however, they might also be ineffective in encouraging people towards waste reduction. On the other hand, higher prices will have a positive impact on consumption and waste reduction, but require some attention to the social factors, especially in a region with high welfare such as the Arabian Gulf. In addition, countries must factor in the income disparities between various social groups, to ensure that effective waste management does not become synonymous with climate injustice towards lower-income citizens or residents. The use of vouchers and other

in-kind transfers can help shield various income-groups from the adverse effects of such reforms on household purchasing power.

As emphasized above, effective waste management requires significant behavioral changes at the grassroots level, which needs to follow a gradual structure to ensure sustainability. For example, forcing Arabian Gulf households on a strict waste segregation system as an initial step will likely face significant challenges. Instead, the comingled collection system deployed in Singapore aligns perfectly with the cultural norms in the Arabian Gulf. In addition, establishing sorting facilities and ancillary markets allows for the creation of jobs, thereby progressively improving the psychological and social perceptions on the waste management sector. Stakeholder engagement and collaboration is pivotal in this stage for GCC countries.

Learning from best practices, the region must leverage its emerging markets, high demand trends, as well as its valuable human and financial capitals in developing innovative solutions tailored to the unique needs of each country. This includes incentivizing industries of priority waste streams, such as food or electronic waste, to collaborate in producing financially stable models of effective waste management. Stressing on the latter, this approach aligns with the economic reforms undertaken by GCC countries to alleviate public burdens and stimulate productivity.

6. Conclusion

The Arabian Gulf Countries are in the process of transitioning to a circular economy, which prioritizes effective waste management. This transition underscores the importance of implementing practices and strategies that minimize waste, maximize resource recovery, and ensure safe disposal. Effective waste management is characterized by enhanced environmental protection, increased public engagement, cost-effectiveness, and continuous improvement. While GCC countries have announced various initiatives targeting different stages of the waste management value chain, such as waste-to-energy plants and governance reforms, there remain disparities in governance and regulation that hinder collaboration and effectiveness.

The experiences of pioneering countries in effective waste management serve as a key tool for GCC countries to understand the intricacies of developing this sector. Notably, there is a need for implementing diverse waste treatment methods to address growing demands. Although GCC countries currently rely heavily on landfilling, there is significant potential to develop markets for various waste treatment facilities, necessitating investment in infrastructure and human capital. Centralized frameworks and policies are essential for standardizing waste management approaches while allowing for local adaptation.

Effective monitoring and reporting, alongside economic tools, are critical for minimizing waste generation and optimizing resource allocation. This reflects on the importance of stakeholder engagement, covering policymakers, industry, and civil society, which is vital for fiscal sustainability and innovation cultivation within the waste management sector. High levels of civic engagement are also crucial, supported by targeted awareness campaigns and policy incentives to promote sustainable behaviors. By leveraging their late mover advantage, GCC countries can learn from pioneering nations and develop effective, sustainable waste management systems tailored to their unique needs.

This study aims to serve as a stepping stone in the Arabian Gulf's sustainable transition, providing insights and recommendations for a more efficient and equitable waste management system. By highlighting the successes and challenges faced by benchmark countries, it lays the groundwork for tailored strategies that consider the unique socio-economic and cultural contexts of the GCC nations. Embracing a holistic approach, GCC countries can foster a sense of shared responsibility and commitment to sustainable waste management practices. This collective effort is essential for navigating the complexities of waste reduction and promoting a circular economy that minimizes environmental impact.

As the region embarks on its transformative journey, it is crucial to view waste not just as a challenge but as an opportunity for innovation, job creation, and long-term environmental preservation. By integrating these findings into policy frameworks and fostering a culture of environmental stewardship, GCC countries have the potential to create an effective and sustainable waste management landscape, contributing to global efforts in mitigating climate change and building a more resilient future.

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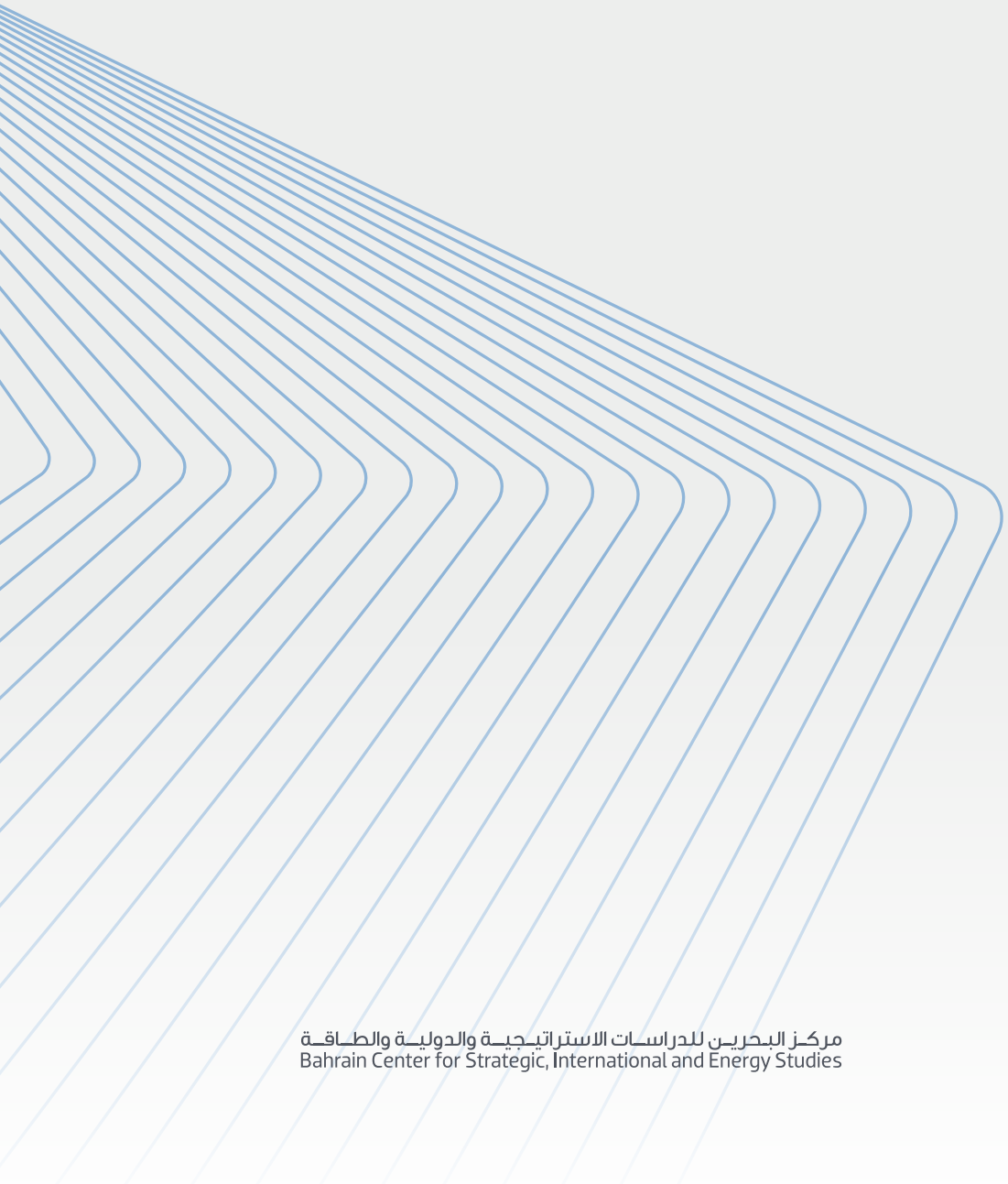
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