Technical Report

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Abstract

Qatar's development, hot climate, and heavy dependence on bottled water have driven a stark increase in plastic waste, which places pressure on existing waste management systems and increasing the risk of long-term environmental damage, including plastic pollution in desert and marine ecosystems. This report evaluates which engineering interventions can most effectively improve plastic waste management in Qatar while remaining aligned with Qatar National Vision 2030 (QNV 2030).

Since field data were limited, we carried out a literature review of academic literature, government and industry reports, and international case studies. We traced the plastic life cycle in Qatar, identified key stakeholders, and reviewed five approaches to combat plastic pollutants being released: deposit return schemes (DRS), multi-stream recycling, advanced sorting and robotics, chemical recycling, and waste-to-energy (WtE).

We then assessed these options with a decision matrix aligned with QNV 2030 goals and refined the assessment using input from an industry mentor. Our findings show that two options stand out for Qatar: an incentive-based DRS for PET and metal beverage containers, and a stronger WtE role at the Domestic Solid Waste Management Center. DRS scored highest because it captures containers before they mix with other waste, allowing for high return and recycling rates, and can supply stock for establishing local circular chains.

WtE, using gasification technologies, offers a complementary route for residual plastics that are not economically recyclable, diverting them from landfill and generating electricity. Taken together, the results support a combined approach, in which DRS improves the quality and quantity of collected plastics and WtE manages the remaining fraction. This approach provides a practical short-term route to strengthen Qatar's plastic waste management system, reduce dependence on landfill, and limit the formation and leakage of microplastics into the environment.

Introduction

Qatar has environmental challenges, one of them being plastic waste, which has become a global menace. Qatar is a relatively small, developing, and prosperous economy and, consequently, has a higher than average plastic waste output for its population size. Municipal Solid Waste generated within the country is mostly from single-used plastic products, including, but not limited to, water and soft drink bottles, food containers, plastic shopping bags, and industrial plastic wraps. In spite of the increasing awareness, a considerable proportion of this waste is still being landfilled or littered, and when landfilled becomes a slow and permanent pollutant of the environment. In Balancing the environment with economic growth in Qatar, as envisaged in the Qatar National Vision 2030 (QNV 2030), Qatar's priorities include the need to minimize plastic generated waste.

Due to Qatar's population, climate, and water usage, there are even bigger problems. People depend on bottled water due to the extreme heat and water scarcity. This increases the demand for plastics. In addition, Qatar is Very Wealthy and Very Urban. Due to the fast pace and disposable culture, single-use plastics are very common. Moreover, the overall low participation and limited sorting of the household waste recycling system create obstacles to the sustainable management of waste. Consequently, the volume of plastic waste surpasses the capacity of waste management systems to handle it, and this enhances the level of plastic pollution in the landfills, thus amplifying the pollution risk of Qatar's deserts, and marine ecosystems.

The negative effects of plastic pollution go beyond just the environment. Poor waste management incurs increased municipal costs regarding the upkeep of landfills, strains Qatar's waste systems, and jeopardizes the Gulf's and Qatar's coastlines' marine and terrestrial ecosystems and cultures. There are also rising concerns regarding microplastics' risks to human health and animals. In light of the fact that Qatar intends to shift to a circular and resource efficient economy, for a growing economy that is also safe to the environment, Qatar should deal with plastic waste. This is also necessary to protect the health of the population.

In the last ten years in Qatar some valuable actions have been taken to address the issue of plastic waste through the establishment of recycling mu waste diversion programs, developing waste-to-energy technologies, and implementing single-use plastic regulations. However, these actions do not fully address the issue at hand. The next steps revolve around determining which solutions are most effective, feasible and scalable to Qatar's circumstances in regard to climate, climate, infrastructure, economy, and social behavior. Hence, the report analyzes a number of potential solutions to plastic waste and assesses these solutions against indicators that represent Qatar's desired state for the environment, technology potential, and sustainable future.

Methodology

Plastic waste is a major global issue, and to understand its impact in Qatar, we first needed to clearly define the specific problems the country faces. This allowed us to uncover potential blind spots in the current waste-management approach. Since we were unable to conduct field studies due to the nature of this problem, we relied primarily on publicly available information. Since there was already ample information, we were able to find all the relevant details, but at the same time, overloaded with its amount during our research. Our sources included academic research, government reports, news articles, and international publications, which helped us understand both the local situation and successful solutions implemented in other countries.

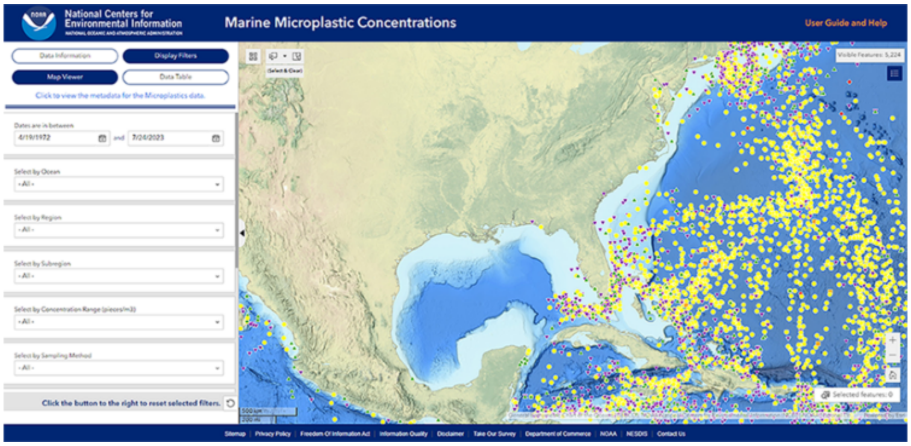
Our initial step was to gather as many potential solutions as possible, after which we refined the list and identified five solutions that could realistically be applied in Qatar. We began by assessing the plastic waste problem, examining how it affects people and how human activity contributes to it. We then identified the key stakeholders: members of the community affected by waste, authorities responsible for managing it, and the workers directly involved in waste handling. By tracking the plastic life cycle, we found that most plastic originates from households and ultimately ends up in landfills. This places a significant burden on available land and increases the financial costs of waste management.

Once the problem was clearly defined, we evaluated existing solutions in Qatar and abroad and assessed their effectiveness. To compare these solutions, we employed a decision matrix that was based on the priorities of the Qatar National Vision 2030, which serves as the main framework for sustainability in the country. The three criteria that aligned with the goals of QNV 2030 and were applicable to our solutions were feasibility, environmental impact, and cost-efficiency. Each solution was rated on a scale from 1 to 10 based on the challenges expected during implementation.

Through this process, we eliminated several options until only five remained. We also consulted Dr. Hanan, an industry professional, to validate our findings and provide expert insight. We presented a short memo that included a small problem statement as well as the solutions that we had in mind up until now with their evaluation based on the decision matrix. Our meeting with Dr. Hanan further helped us narrow the list to three solutions. Based on her recommendations, we changed the environmental impact criteria to the environmental and human impact, to have a broader scope and picked two solutions instead of one to combat the problem from two angles, collection and treatment.

Results

Our project assessed engineering interventions to reduce plastic waste from Qatar's environment, reducing plastic contamination. We began with five options identified in Memo 3: Deposit Return Schemes (DRS), multi-stream recycling, advanced sorting and robotics, chemical recycling, and waste-to-energy (WtE) [1-7]. Using a decision matrix that considered feasibility, impact on plastic pollution, and cost efficiency, and drawing on feedback from our industry mentor and instructor, we narrowed the scope to two options that are realistic for Qatar in the near term: (1) an incentive-based DRS for beverage containers and (2) WtE as a controlled methodology to deal with lacking plastic waste management [1][6].



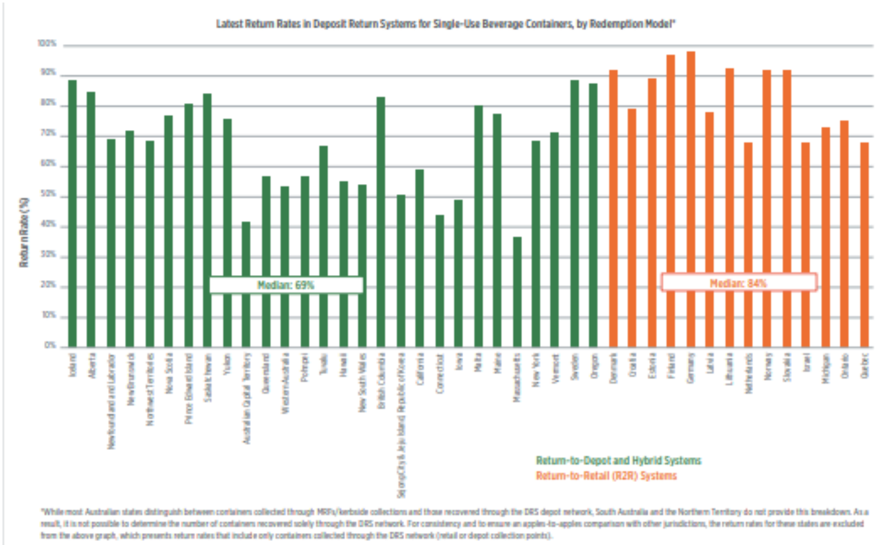
NOAA's National Centers for Environmental Information has created a database of existing datasets documenting microplastics in the world's oceans. [8]

1. Deposit Return Scheme (DRS) for Beverage Containers

The first solution is a DRS for single-use PET and metal beverage containers, building on pilot schemes run by retailers such as Al Meera and LuLu, where customers earn points or vouchers when they return bottles and cans through in-store machines [1]. In a full DRS, a small deposit is added to the purchase price and refunded when the empty container is returned, a mechanism documented in European systems [24][26]. Mature DRS programs such as Germany's report return rates of 98% for eligible drink containers, supported by a meaningful deposit and a dense network of return points [24][26].

For Qatar, this is important because studies show that plastic bottles and packaging form a major share of litter in the Gulf, and that plastics are present in both seawater and sediments along several parts of the coast [17][22]. By intercepting bottles at supermarkets and campuses before they enter mixed waste, landfills, or open dumping, a DRS reduces the volume of plastics being let out in the environment [11][17].

In our decision matrix, DRS received the highest overall score (26/30), driven by strong performance in feasibility and cost efficiency. infrastructure can be built on existing retail networks [1][2]. Concerns that DRS might increase beverage consumption were examined using international sales data and were not supported, as observed fluctuations remained within normal market ranges [2].



Latest Return Rates in Deposit Return Systems for Single-Use Beverage Containers, by Redemption Model [9]

2. Waste-to-Energy (WtE) as a Barrier for Residual Plastics

The second solution is to use WtE at Qatar's Domestic Solid Waste Management Center (DSWMC) in Mesaieed as a controlled barrier for plastics that are not captured by DRS or other recovery systems. The DSWMC is designed to treat about 2,300 tons of mixed domestic solid waste per day and combines mechanical sorting, composting, a 1,500 t/day incineration line, and a sanitary landfill, while generating tens of megawatts of electricity for the grid [15][18][6]. System-level assessments indicate that, when energy recovery is included, around 40% of plastic waste in Qatar is now recovered through recycling or WtE, and that the facility diverts roughly 95% of processed waste from landfill [12][20][22].

WtE does not remove particles already present in marine or terrestrial environments, but it does limit further fragmentation of residual microplastics by destroying them through controlled combustion or gasification [10][11][19]. This reduces the long-term stock of plastic items that would otherwise cause pollution in dumps, desert areas, or coastal zones [12][17][22]. In our decision matrix, WtE received a moderate overall score (19/30): feasibility is high because the plant operates at national scale, and cost efficiency is reasonable once capital costs are sunk [6]. The main drawback is that WtE converts plastics into CO_2 instead of retaining them in circular material loops, and over-reliance on incineration could reduce pressure to improve upstream prevention and recycling which can in turn be resolved using the process of gasification [10][13][14].

Analysis (WtE)

The feasibility of the Waste-to-Energy (WtE) technology is assessed on the basis of criteria such as feasibility, environmental sustainability, and cost-effectiveness, which were developed by the team during Project 1 and which were further perfected by the guidance of the mentor during Project 2. As reported by Memo 3, WtE technology is already operational to some extent in Qatar, and it is implemented by the Domestic Solid Waste Management Center (DSWMC) at Mesaieed, which is able to process 2,300 tons of waste on a daily basis by sorting, digestion, and an incineration plant having a capacity to burn 1,500 tons of waste daily. This is moderately to greatly feasible due to the built-in foundation which could further be developed on a wider scale. Another factor which gives a greater preference to WtE technology is said to support Qatar's National Vision 2030.

As far as the environment is concerned, WtE varies depending on the technology. In the case of conventional incineration, it has been proven to minimize the quantity of waste sent to landfills. According to Memo 3, the primary weakness of waste-to-energy incineration technology is the generation of CO_2. Gasification, which involves the exposure of waste materials to very high temperatures without the presence of any oxidation reaction to obtain syngas, is cited to act as a cleaner technology with greater possibilities of energy recovery.

In regards to cost efficiency, WtE is a medium-cost solution. Although it has a high capital cost due to the specialized infrastructure and technology, it also has a medium operational cost, which is compensated by the fact that it adds to the energy produced and fed into the national grid. Moreover, by dealing with non-recyclable plastics, WtE is an efficient supplement to sorting technology because it is able to process waste which will otherwise generate higher levels of plastic pollution. Thus, by working alongside a sorting solution, WtE is more efficient, and only the correctly separated waste is processed by the waste-to-energy solution. As has been made clear by this analysis, WtE is not only feasible but also environmentally astute when employing gasification, and it is cost-efficient.

Discussion(WtE)

From the analysis, it is recommended that WtE should be incorporated in the hybrid solution package along with DRS. Although DRS is beneficial regarding the sorting and collecting of recyclable plastics, it fails to account for the fate of the plastics which are either not recyclable or are contaminated. As clearly indicated by our mentor during our consultation, merely sorting waste does not 'solve' the waste issue but, rather, merely organizes it. In essence, WtE closes the gap by providing a sustainable mechanism to process the remaining stream of plastic waste, thereby preventing the collected plastic waste from ending up back in landfills.

A wider implementation of the WtE concept within the backdrop of Qatar will require coordinated efforts between the government (such as the Ministry of Municipality and the Ministry of Environment and Climate Change), industrial companies, and the existing waste management companies, including the DSWMC. The most important factor to keep in mind during the planning and design of the WtE installation is to arrange for it to utilize gasification and not incineration methods, which is relevant to the sustainable concern implicit within the technical report.

In financial terms, the WtE technology involves high capital costs. Nevertheless, when operational, it not only produces energy but also saves on landfill management costs.

Another factor to consider during implementation involves the social impacts. These should also be integrated into practice, as indicated during the evaluation of our decision matrix by the mentors.

In summary, WtE adds value to our overall solution by ensuring that the waste stream is not just sorted (through DRS) but also treated effectively and sustainably. By keeping non-recyclable plastics out of landfills, and generating power, WtE also satisfies the overall energy and environmental needs of the State of Qatar.

Analysis (DRS)

The Deposit Return Scheme(DRS) is assessed in terms of feasibility, environmental impact, and cost-effectiveness. DRS is seen as a practicable and achievable solution due to the simplicity of its mechanism. People return plastic bottles and are rewarded for it. This system doesn't need any extreme modifications in its current infrastructure therefore it can be implemented in retail stores and public collection points. As participation builds up, the system becomes more efficient and easier to manage in Qatar.

In the environmental sustainability aspect, DRS puts in an excellent performance. The early separation process reduces the amount of plastic entering landfills and cuts down the chance of plastics breaking down into microplastics. Furthermore, higher recycling rates mean that the overall environmental footprint of plastic consumption goes down.

When assessing cost efficiency, DRS falls into the category of medium cost. There are necessary investments in the reverse vending machines and maintenance of these machines. However, these costs are balanced by long-term gains, such as the value of clean recyclables and the decrease in landfill waste, which reduces maintenance and management costs. Over time, the system can generate steady economic returns while encouraging a consistent supply of recoverable plastics.

Overall, the analysis demonstrates that DRS has proven feasible, with significant environmental benefits and reasonable cost-effectiveness. Its strength over other sorting solutions is in capturing plastic at the earliest possible stage, before contamination. It is this aspect that makes DRS one of the best sorting solutions for improving recycling performance and minimizing plastic pollution.

Discussion (DRS)

Analysis indicates that DRS is an important component of the proposed integrated solution. Sorting technologies can facilitate separating waste after collection; however, these cannot completely deal with the problem of contamination. Once plastics are mixed with food waste or liquids, most of them become unsuitable for recycling. DRS addresses the problem by collecting bottles before they enter the general waste stream, ensuring that the recyclable plastics will remain clean and in good condition.

Introduction of DRS in Qatar is made even more functional by the fact that major retailers like Al Meera and Lulu Hypermarket have already started using the system. These early trials indicate that the public is getting used to the process and the basic operational framework is already being tested in real environments, making it easier to scale up DRS.

Nationally expanding DRS will similarly depend on cooperation between governments, retailers, and waste-management operators such as the Domestic Solid Waste Management Center (DSWMC). Government will determine the deposit value, design rules, and oversee system performance. Retailers will operate return points and DRS machine sites, while waste-management operators will deal with the plastics. Effective communication among them will be required for the system to function well.

Of course, one of the major reasons for success remains the motivation that consumers are given. There needs to be enough reward for them in order to participate continuously. Collection points should also be set up at accessible locations so the system is convenient to the public. Public awareness campaigns will also play a huge role; people need to know exactly how the system works and why it's important for them to participate if the nation is to meet its QNV 2030 sustainability goals.

Financial considerations are still taken into consideration as start up investment into DRS is necessary, but the long-term benefits associated with higher recycling rates and less dependency on landfills, make it a worthy solution. Overall, DRS minimizes contamination, improves efficiency in recycling, and supports cleaner environmental practices. When combined with WtE which can handle non-recyclable plastics, it establishes a balanced approach to long term sustainability.

Conclusion

In conclusion, addressing Qatar’s plastic waste management challenges is essential due to the country’s high waste-generation rate and heavy reliance on landfills. Effective waste management is crucial for protecting the environment, conserving resources, and ensuring long-term sustainability. The deposit return scheme (DRS) and waste-to-energy (WTE) solutions support the goals of Qatar National Vision 2030 by tackling plastic waste as both an environmental and an energy issue. These two solutions complement each other: DRS improves collection efficiency by incentivizing households and businesses to return plastics, while WTE provides a treatment pathway that reduces landfill dependence and generates usable energy. Although both systems require significant upfront investment, especially given their limited adoption in Qatar, their long-term benefits include reduced landfill costs, lower environmental impact, and the ability to feed energy back into the national grid, partially offsetting operational expenses. Successful implementation will require strong support, public participation, and scalable infrastructure. However, failing to act will intensify existing waste challenges and increase environmental and economic pressures in the future. By adopting both DRS and WTE, Qatar can take meaningful steps toward a more sustainable, efficient, and resilient waste-management system that aligns with its national vision for 2030 and beyond.

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