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ELECTRICITY GENERATION THROUGH MUNICIPAL SOLID WASTE IN SRI LANKA: DRIVERS AND BARRIERS

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ABSTRACT

The rapid increase in population and urbanisation has led to an increase in per capita consumption and the generation of waste. Thus, the need of having improved management strategies for Municipal Solid Waste (MSW) has aroused. Waste to Energy (WtE) was a concept that came up as a solution for waste management and as an ideal solution for energy crises as well. WtE is a process of generating energy mainly in terms of electricity and heat by giving MSW as the input where it will become the fuel for this process. Most countries like Denmark, England, Australia, etc. use this as a successful Municipal Solid Waste Management (MSWM) strategy and as a sustainable energy producing mechanism too. But, in Sri Lankan WtE has become unsuccessful in many instances due to the influence of barriers to implementing WtE mega-scale projects. Thus, this study aims to explore existing barriers in light of expanding WtE projects in Sri Lanka. In addition, it proposes strategies to mitigate those barriers. Data was collected through expert interviews and manual content analysis was used for data analysis. Some identified key barriers and strategies in the frame of political, economic, social, technological, legal, and environmental are lack of having government infrastructure, high initial investments, social burdens, lack of technical knowledge on WtE, disposal of bottom and fly ash as barriers and providing infrastructure by the government, introducing debt financing, social awareness, getting foreign technical experts, using bottom ash and fly ash to produce some necessary bi-products as strategies.

Keywords: *Barriers and Strategies; Drivers; Municipal Solid Waste (MSW); Municipal Solid Waste Management (MSWM); Sri Lanka; Waste to Energy (WtE).*

1. INTRODUCTION

Rapid urbanisation and human population expansion accelerate the capacity of Municipal Solid Waste (MSW) in urban areas in the global context and it will grow by 2.6 million tons per day by 2025 from 2012 (World Bank, 2012). The generation of MSW is considered an issue of global concern (Khajuria, et al., 2010), and MSW will prove to be one of the challenges ahead and thus contribute significantly to global warming and climate change (Li, et al., 2011). Thus, due to the adverse effects of MSW generation,

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Municipal Solid Waste Management (MSWM) becomes a key challenge. MSWM can be defined as the selection and implementation of appropriate technologies, techniques, and management programs to achieve the objectives and targets of waste management (Tanskanen, 2000). The main aim of MSWM systems is to safeguard environmental health and human by reducing the adverse effects of waste and seeking some beneficial consequences for it (Melosi, 2000). MSW is well known as a source of renewable energy due to its nature (wood or food) as a biomass material (Ryu, 2010). As one of the most common solutions, Waste to Energy (WtE) incineration helps to reduce landfill MSW (Monni, 2012). WtE technology can be seen as a great waste management strategy since it is not only utilising the recycling potential of degradable organic solid waste created by various activities but also offers renewable energy sources (Kothari, et al., 2010). WtE technologies can be addressed in the terms of thermal treatment technologies (incineration, pyrolysis, and gasification), biological treatment technologies (anaerobic digestion technologies), and biorefineries (waste to by-products) and landfill gas utilisation (Moya, et al., 2017).

WtE incineration is not only capable of dealing with the rapidly increasing amount of MSW, likely due to population growth, but can also meet energy demand by heat and electricity (Pavlas, et al., 2011). In this way, including MSW in an energy system will become active in pulling off the goals of a 20% reduction in CO2 emission and 20% renewable energy for the year 2020 (Munster and Meibom, 2011). Modern WtE installations convert the chemical energy embodied in MSW into heat and/ or electricity (Brunner and Rechberger, 2015). WtE technology can be seen as an effective industrial device to eliminate dangerous organic compounds, recover resources (Electricity) and materials and save landfill spaces (Vehlow, 2015). WtE plants are capable of destroying fully hazardous organic materials, eliminating risks due to pathogenic microorganisms and viruses, and storing both useful and harmful metals in certain fractions (Brunner and Rechberger, 2015). Currently, since there are plenty of waste management strategies, WtE technology can be seen as a successful process thus having several strategies, and many countries around the world already applying this technology.

In Sri Lanka MSW can be seen as a serious issue and haphasard disposal of solid waste accelerates this serious socioeconomic and environmental issue further and waste generation increased due to the rapid urbanisation, population growth, development, migration, and keep going with consumption pattern changes and industrialisation (Hikkaduwa, et al., 2015). Furthermore, the composition of solid waste collection through different councils is, 49.5% (1696 Mt) by municipal councils, 33.1% (1133 Mt) by Peradeniya sabha councils, and 17.4% (594.5 Mt) by urban councils. On average, in Sri Lanka, about 0.62 kg of solid waste is generated per day per person (Visvanathan and Trankler, 2003 cited by Chathumini, et al., 2019). At present MSWM, collection and treatment in Sri Lanka are not proceeding at an acceptable level due to incomplete collection of total generated solid waste by local authorities (Gunaruwan and Gunasekara, 2016). As a developing country, Sri Lanka is in a catastrophic situation on waste management due to the lack of a proper management strategy. As a solution Sri Lankan government recently approved the plan to construct the first WtE plant in the Karadiyana landfill (one of the waste dumping sites in Colombo) (Alwis, 2019). Thus, in Sri Lanka, the generation of electricity through this process took the lead and seems to be a trending and proper solution for MSW. the second WtE site under construction in Muthurajawela. The volume of MSW can be reduced after the functioning of these two sites while adding

20 megawatts of electricity to the national grid (Kamanthi, 2019). Furthermore, the author stated that WtE operations will be limited to these two projects since the government of Sri Lanka has decided not to extend WtE in Sri Lanka due to the moist condition of Sri Lankan waste which makes government incur additional Rs. 3000/= to produce electricity from one ton of waste. This is going to be a serious challenge for the government and this study focus on eliminating these challenges by investigating and proposing solutions while making the applicability of WtE in Sri Lanka at an optimum level.

Hence, this study aims to explore existing barriers in light of expanding WtE projects in Sri Lanka. The structure of the paper starts with the research methodology and is followed by research findings and discussion. Finally, the paper is concluded with conclusions and recommendations for this research.

2. RESEARCH METHODOLOGY

This study aims to explore existing barriers in light of expanding WtE projects in Sri Lanka. To achieve the research goal, this research requires more detailed qualitative and in-depth information. This research was therefore conducted under the qualitative approach, taking into account its advantages over the quantitative approach. Accordingly, the case study strategy was selected as one of the most appropriate tools for an in-depth analysis of this research. Since there are only 2 sites that will be going to function as WtE sites in Sri Lanka in near future have been selected under the case study approach in conducting data collection.

- Case A: The treatment plant would decrease the amount of waste transported to landfills by as much as 90% by volume and 80% by mass. A total of 83,000,000 kWh of electricity per year will be generated by the project and this is enough to meet the demands of 40,000 households. Furthermore, the plant will produce liquid and solid fertiliser with 40,000 tons per year an energy of 12 MW will be generated by this facility and the remaining electricity will be transmitted to the national grid (Ceylon Electricity Board) following the use of electricity for the plant consumption.
- Case B: This was implemented by private cooperation monitored by Megapolis and CEA (Central Environmental Authority). In the Colombo municipal sector, the project will recycle solid waste to produce a power of 11.5 Megawatts by transforming 500-700 MTs of MSW into electricity. Using the 700 metric tons of fresh waste from the Colombo municipal council district, this WtE power plant will run approximately 7,500 hours per year while automatically providing a waste disposal solution in Colombo. It provides the Colombo garbage clearing with a permanent solution and then offers the national grid with green energy.

Semi-structured interviews were conducted with experts who have experience in waste management and WtE sectors. Three (03) expert interviews were carried out with selected experts on WtE from each selected case. The details of the respondents are presented in Table 1.

The data was analysed using manual content analysis and data analysis techniques as there are only 02 mega-scale WtE projects available in Sri Lanka.

3. RESEARCH FINDINGS

This section consists of three sub-sections such as drivers for initiating a WtE mega-scale project in Sri Lanka, barriers for initiating a WtE mega-scale project in Sri Lanka, and suggested strategies to overcome the barriers to initiating WtE mega-scale projects in Sri Lanka.

Table 1: Details of Interviewees

Case	Code	Designation	Experience
Case A	RA-1	Chief technical officer	9
	RA-2	Manager - Regulatory Compliance and local affairs	10
	RA-3	Chief compliance officer	10
Case B	RB-1	Managing director	20
	RB-2	Site director	5
	RB-3	Deputy project director	12

3.1 DRIVERS FOR INITIATING A WTE MEGA-SCALE PROJECT IN SRI LANKA

Most the countries including developed and developing are using these WtE techniques to generate electricity and other energy sources like heat while giving a better solution to the garbage crisis as well. In the Sri Lankan context, most industries are tending to reuse their waste to generate electricity through small-scale WtE plants. Thus, apart from the traditional waste management options Sri Lankan government focused on substitutional waste management options. WtE was such a waste management option that came forward. With the use of case study facts, it can be demonstrated that in addition to the waste management issue there are some other drivers for implementing WtE mega-scale projects in Sri Lanka. The responses of the respondents that have been interviewed about the drivers that let them implement WtE projects in Sri Lanka are discussed below using the PESTLE analysis. Table 2 provides the responses given by the respondents on drivers for initiating WtE mega-scale projects in Sri Lanka.

Table 2: Responses on drivers for initiating WtE mega-scale projects in Sri Lanka

No	Drivers	Responses
	Political	
1	Need of reducing the increment of solid waste	6/6
2	Capable of extending landfill lifetime and energy recovery from waste	6/6
3	Elimination of public health-related issues associated with MSW	5/6
4	Having many side benefits instead of managing MSW	5/6
5	Strengthening public-private partnership goals	4/6
6	Tending towards green energy concepts	2/6
	Economic	
1	Deriving job opportunities in many fields due to having WtE projects	5/6
2	Generation of electricity and needful byproducts	5/6
3	Direct and indirect cost reductions in waste management	4/6
4	Creation of investment opportunities	4/6

No	Drivers	Responses
5	Reduce land scarcity by allowing minimum space for open dumping	3/6
6	Reduction of costs associated with public health and disasters due to poor waste management options	3/6
	Social	
1	Creation of new job opportunities	6/6
2	Public pressure	6/6
3	Increment in urbanisation and generation of waste	6/6
4	Mitigation of social externalities	4/6
5	The need for the general public to have a viable waste management solution	3/6
6	Social acceptance of technology	2/6
7	Supporting hand for electricity generation	1/6
	Technological	
1	Technological developments	6/6
2	Different energy recovery technologies are available for different types of waste	4/6
	Legal	
1	Complimentary legislations	3/6
	Environmental	
1	Negative impacts due to open dumping and landfilling	6/6
2	High dependency on imported coal in energy generation	5/6
3	Reduction of carbon dioxide emissions	5/6
4	Capacity to generate renewable energy sources due to having scarcity of available non-renewable energy sources	3/6
5	Environmental issues like climate changes	2/6

Political drivers: Accordingly, a major influencing driver towards the initiation of WtE mega-scale projects in Sri Lanka was the increment in the garbage disposal and open dumping. This was clarified by the RB-2 as "*the Sri Lankan government is facing huge problems with open dumping in different perspectives. For example, people died due to the collapsing of the Meethotamulla garbage pile, and the government has searched for a way to get rid of those stacks of waste"* So, the pressure built up by the general public towards the government has become a strong driving force towards WtE implementation. In addition, RA-2 stated that, "the *government also mainly focused on reducing public health-related issues that have happened as a result of open dumping*." Sri Lankan public especially around the Colombo area had to face several adverse effects of this open dumping like respiratory diseases, uncomfortable odour, and disasters (Meethotamulla pile collapse). In addition, adverse effects like aesthetic discomfort, and the use of large-scale lands for open dumping also happened. Thus, the elimination of such social externalities has become a key political driver. On the other hand, having additional benefits through WtE sites has been identified as another key driver. RA-1 stated that "*generation of electricity by giving MSW as the primary fuel is the main additional benefit except reducing MSW"* Within WtE plants they used MSW as the primary fuel for

generating electricity. So, this can be a solution to the energy crisis in Sri Lanka as well. Directors of both the projects have mentioned that they are going to deliver some amount of electricity to the national grid. "*Apart from generating electricity bottom ash from the incineration process can be used as a building material for construction projects like road constructions*" detailed by RB-1. This can be a critical advantage thus; Sri Lanka is going through large-scale development and construction projects. The responses of the respondents this was another critical political driver for initiating WtE mega-scale sites in Sri Lanka. It is also identified as a catalyst to tend more toward the sustainable alternatives to energy production because of the expenses that government has to bear to import coal.

Economic drivers: One of the main economic drivers was the creation of new large-scale investment opportunities in the Sri Lankan economic sector. Four out of six respondents mentioned, "*Sice the ca and case B WtE projects are establishing in large scale, this will affect positively on Sri Lankan economy as a considerable amount of money has been invested on these two projects."* Implementing these projects will open the path toward job opportunities in many fields. Further, RB-1 especially highlighted that a "*considerable amount of job opportunities will be coming into the action as these sites are comprising of a huge number of tasks and processes."* The reduction of cost components linked with typical waste management techniques that were followed by the Sri Lankan government also become an economic driver for WtE implementations. According to the respondents in both the cases, it is summarised that the "*Sri Lankan government has mainly followed open dumping for waste management. So, they have to bear a different type of costs in doing this like transportation costs, sorting costs, handling costs, etc."* Although the government followed daily there was poor management of waste because they were not able to reduce or eliminate the collected waste properly. As a result, the waste piles were created day by day. So, this has become an economic driver for WtE implementation. Most all the respondents have listed that, "*WtE is a process which is addressing the issue of waste while giving solutions to some other emerging issues as well*." Within this WtE process, MSW will be used as the input, and electricity and heat will be generated as the output. Since electricity can be generated through WtE this can be used as a process to address the energy crisis in Sri Lanka to some extent as well. An additional income will be created by selling the generated electricity to the national grid. If the waste was piled up, the government has to bear additional costs, and sometimes, they have to compensate the public as in the Meethotamulla situation. Through WtE it will reduce the waste and also generate electricity, through that creating additional income. In addition to that, the reduction of land scarcity has become one of the mentioned economic drivers. Open dumping will lead to inefficient waste management and land scarcity. By implementing WtE projects these waste piles can be removed and lands can be used for development projects to pull up money.

Social drivers: One of the key social drivers highlighted by all the respondents is "public pressure" for initiating WtE mega-scale sites in Sri Lanka. This driver has an interrelationship with all other drivers listed and discussed above.

Technical drivers: Although the WtE concept is still novel in Sri Lanka, both cases suggested that the main technical factor for the implementation of WtE projects was technological growth. The RA-1 explained, "*the non-availability of sufficient technologies was historically the biggest barrier for waste treatment, but WtE technology was gradually enhanced to the extent where most organic waste was both safely and*

efficiently incinerated to produce electricity". At present, there are many WtE technologies like incineration, gasification, anaerobic digestion, pyrolysis, etc. to generate electricity from waste. But, in the early stages, WtE has become unsuccessful due to having negative environmental impacts due to technical failures like emissions. According to the respondents these emissions and other negative environmental impacts have been controlled at present for safe generation of electricity from waste. RB-1 further added that "*there are emission control systems, fly ash control systems, bottom ash control systems, leachate treatment systems, wastewater treatment systems have been introduced to mitigate toxic emissions and negative environmental impacts*." Hence, the mentioned factors have become technical drivers for implementing WtE projects in Sri Lanka.

Legal drivers: As WtE is fresh in Sri Lanka, the respondents did not give favorable responses on the legal aspect because there is no separate legal framework established for the WtE sector. But Sri Lanka is now providing favourable regulations to promote the adoption of WtE in the Sri Lankan context.

Environmental drivers: Due to the environmental concerns caused by most of Sri Lanka's existing waste management activities, environmental drivers have also been a big force for the initiation of WtE mega-scale sites in Sri Lanka (For example; negative impacts due to open dumping and landfilling as discussed under social drivers). In addition, most of the respondents have mentioned the minimisation of air and water pollution as the main driver. Moreover, WtE which is having a very low level of emissions came forward instead of typical landfilling and open dumping. Although the respondents mentioned "High dependency on imported coal in energy generation" and "Capacity to generate renewable energy sources due to having scarcity of available non-renewable energy sources" as two different drivers, there is an interrelationship between those two drivers. Due to the scarcity of non-renewable energy sources like coal, people tend to generate sustainable renewable energy sources. Since coal can be identified as a scarce resource for generating energy it should be controlled and should move to generate renewable energy sources. Also, due to rapid population increment and urbanisation the generation of garbage never getting ends and can continuously supply the primary fuel in WtE sites to generate electricity. So, the above-mentioned factors are the ones that are mainly highlighted by the respondents in initiating WtE mega-scale projects in Sri Lanka as environmental drivers. However, the successful adoption of WtE plants is depending upon the proper identification of barriers to its implementation and proper strategies to overcome the identified barriers, thus the next section is discussing the barriers to implementing WtE projects in Sri Lanka.

3.2 BARRIERS TO INITIATING WTE MEGA-SCALE PROJECTS IN SRI LANKA

It is important to develop a clear understanding of the barriers that may arise through the implementation process to ensure the successful implementation of WtE projects and to decide on strategies to deal with such barriers if they arise. In the Sri Lankan context, barriers have been aroused from different perspectives. The results of the interviews revealed several obstacles faced by project participants through the PESTLE analysis, although the problems arising from the respondents of each case differ from the wording used, most of the problems seemed to be similar in the two cases. The initiation of WtE mega-scale sites in Sri Lanka has been influenced by barriers considerably. Table 3 provides the responses to barriers highlighted by the respondents.

Table 3: Responses on barriers to initiating WtE mega-scale projects in Sri Lanka

No	Barriers	Responses
	Political	
1	Lack of infrastructure from the government	6/6
2	Taxes on the machinery imported from other countries	6/6
3	Lack of awareness of the benefits of WtE projects	6/6
4	Burdens on gaining approvals for WtE project proposals	4/6
5	Political inertia of moving towards new mechanisms of MSWM from typical methods	3/6
6	Lack of national strategies	2/6
	Economic	
1	Need for high capital investment to initiate WtE projects	6/6
2	High operation and maintenance costs	6/6
3	Having long-run payback periods	6/6
4	Nature of the waste	4/6
5	High cost for EPC (Engineering, Procurement, and Construction) contractors	4/6
6	Projects are implemented through subordinates of real developers	2/6
	Social	
1	Segregation of waste: people show resistance to sorting their waste at home	6/6
2	Attitudes and habits of the general public	6/6
3	Having protests against the projects	4/6
4	Excessive noise during the construction phase	3/6
5	Odour and nuisance from the sites	3/6
6	Noise burdens along transportation routes to the sites	3/6
7	Sound pollution during the operational phase	3/6
	Technological	
1	Lack of expert knowledge on WtE technologies for such implementations	6/6
2	The high moisture content of waste available in Sri Lanka	4/6
3	Fewer technicians and their knowledge on performing operations and doing maintenance of WtE plants	6/6
4	Processing of hazardous substances	3/6
5	Segregation of waste	2/6
6	Poor maintenance activities performed on equipment	2/6
7	Availability of heavy metals	2/6
	Legal	
1	Absence of a regulatory framework	6/6
2	Difficulties in getting permissions and license	6/6
3	Difficulties in getting a power purchasing agreement from CEB	4/6

No	Barriers	Responses
4	The action laws and regulations of the national environment act	2/6
5	Absence of permitting protocol	2/6
	Environmental	
1	Disposal of fly ash and bottom ash	6/6
2	Controlling of leachate	6/6
3	Controlling air pollutants	6/6
4	Strict environmental regulations	4/6

Political Barriers: Respondents of both cases highlighted that, "*taxes imposed for imported items and machinery*" as the main political barrier, RA-3 mentioned that, "*as WtE is new to Sri Lanka, most of the equipment and related machinery have to be imported from other countries. So, the project developers are demotivated by the very high amount of taxes*" Similarly, all 3 respondents of case A highlighted that, since the government is not aware of the long-term advantages that can be gained through these types of projects it will demotivate the project developing parties in initiating WtE projects in Sri Lanka. In addition, RA-2 stated that "*typical political ideas are arising when concerning on this type of projects. They are only focussing on the high amount of capital budget for implementing this type of projects".* Furthermore, RA-3 mentioned that "*political people are not interested in focussing long term benefits of this kind of project*". Instead of calculating long-term benefits and cost savings, political people always focus on high capital budgets and show inertia regarding these types of projects. In addition, respondents from both the cases have mentioned that, the process that project developers have to follow on gaining required approvals to initiate a WtE mega-scale site and the lack of national base strategies for initiating these types of projects as they are modernist in Sri Lanka as political barriers as well.

Economic barriers: All revealed that the "*requirement of high capital investment is a critical economic barrier for WtE project implementation*". This is due to spending high costs on machinery and services that are required for implementing WtE projects. Highlighting the same fact, the RB-2 stated that, "a high cost has to be paid for EPC contractors for their service." This is since WtE is modernist in Sri Lanka the expert knowledge is lacking in this type of project. So, the service of EPC contractors who are responsible for designing and constructing WtE plants must be granted. In addition, RB-3 mentioned that "*the operation and maintenance phase will be contracted to some outside contractors who are delivering operation and maintenance services at high rates*". Moreover, the respondents pointed out that WtE projects are usually taking long-run payback periods to recover their capital investment. RB-3 explained that "in Sri Lanka, WtE projects have a poor return on investment when comparing with other countries which follow these projects due to the lower return from these projects." It was disclosed that CEB agreed to purchase the generating electricity from WtE sites at a very low rate per one unit. RA-2 stated that "usually WtE plants are working 24/7/365 leading to high operational costs." This is the main burden on covering capital costs within a short period. The nature of waste which are processed in WtE plants to generate electricity is an economic barrier in Sri Lanka. RA-1 mentioned that "*high moisture content of waste is a burden for incineration process*". Since Sri Lanka's waste composition consists of a high percentage of organic waste (high moisture content) they must be pre-treated before

sending for incineration. If not the efficiency of incineration will become less due to the partial burning of waste which is leading to inefficient electricity generation.

Social barriers: According to RB-1, many MSWM projects including WtE projects become failed due to the high influence of social barriers themselves. The main reason was the waste segregation problem. Case A identified this as a key barrier because it comprised of a hybrid plant consisting of an incinerator and an anaerobic digestion plant which required biodegradable and non-biodegradable waste separately. In addition to that, odour and nuisance from the sites are important social barriers. RB-3 stated that "*odour from the sites consists of some chemical compounds like ammonia (NH3) and hydrogen sulphide (H2S)*". As a result, this will create a bad odour combined with air pollution as well. Moreover, all the respondents highlighted that "*attitudes and habits of the general public towards social welfare*" are also a major social barrier. At this point, the typical philosophy of the Sri Lankan public is "not in my backyard" coming forward. People are just caring about themselves rather than considering social burdens. So, the push toward these types of projects becomes less. According to RA-2 and RB-3, "*public protests have a major impact on WtE projects in general as a social burden, but such issues have not been raised for our projects".* As per the RA-1, "the *main reason for these types of public protests against WtE projects due to less awareness of these types of projects and its long-term benefits*". So, the social barriers have much influence in initiating WtE sites in Sri Lanka.

Technical barriers: Since WtE is a modernist technology for Sri Lanka many technical issues are interrelated with the implementation of these types of projects. Deficiency in expert knowledge and specialisation in WtE was identified as one of the key technical barriers and RB-1 added that "*there are no trained or expert people for handling the operations and performing maintenance activities in WtE plants*". As a result of not having enough people for WtE operations and maintenance, the expected outcomes from WtE plants cannot be generated. Also, with poor maintenance of machinery and equipment, machine breakdowns, and machine wear and tear will appear frequently. As discussed in economic barriers, high moisture content and low calorific value in waste will cause inefficient energy output. With the case study results, it was identified the amount of energy that is released when 1Kg of waste is burnt in the presence of Oxygen (calorific value) available in Sri Lanka lies between 6500-7500 KJ/Kg (Kilo Joules per Kilogram). Segregation of waste which was identified as a social barrier before was identified as a technical barrier as well by RA-2 and RB-3. This is because MSW is comprised of heavy metals like mercury and hazardous materials like chemicals. If these are burnt inside an incinerator this will cause negative impacts. This fact was confirmed in both cases.

Legal barriers: All mentioned that the lack of a regulatory framework for WtE has become the key legal barrier, RB-3 mentioned that "*Sri Lanka is not delivering a separate regulatory framework for WtE projects, hence discouraging the project developers*". Also, RA-2 highlighted that "*getting approvals from government organisations for WtE projects has become a considerable barrier where several approvals have to be taken*". Apart from that getting the power purchasing agreement from CEB was also identified as a legal barrier. RB-1 stated that "*there are many requirements to be fulfilled to get power purchasing agreement like energy permit, letter of intent, grid connection permit, etc*". Moreover, RA-2 added that "*there are some regulations to be fulfilled like national*

environment act, provincial council, hazardous waste regulations, and local government ordinance".

Environmental barriers: One of the major environmental barriers identified was the generation of fly ash and bottom ash as alternatives. RA-1 mentioned that, "*the decomposition of fly ash and bottom ash is the main environmental impact from WtE sites*" and RB-1 added that, "*according to the estimations an amount of 5-6 MT/day of fly ash and 40-60 MT/day of bottom ash will be generated*". Moreover, both the cases highlighted the controlling of leachate which is identified as an environmental pollutant and an environmental-related barrier. The estimated amount of leachate per day will be 50-100 m3. According to the RA-3, "leachate is considered as an environmental pollutant which is causing groundwater contaminations and soil pollution." The respondents affirmed that there are air pollutants from WtE plants. This is due to the combustion process inside incinerators. As per the respondents of both cases, "strict environmental regulations" have become considerable environmental barriers as well.

Concluding, through the case studies twenty-eight (28) drivers and thirty-five (35) barriers were discussed. From both the literature findings and collected data, the magnitude of barrier forces seems to be greater than the driving forces. This is because Sri Lanka is still in its infant age in terms of WtE technologies and their adoption. But most of the respondents highlighted that due to the presence of well-built driving forces the applicability of WtE in electricity generation through MSW can be empowered by coming up with strategies to weaken the barrier forces. Hence, the next section is on suggested strategies to overcome the barriers identified.

3.3 SUGGESTED STRATEGIES TO OVERCOME THE BARRIERS TO INITIATING WTE MEGA-SCALE PROJECTS IN SRI LANKA

Drivers can themselves be the strategies for applicability of WtE in electricity generation through MSW in Sri Lanka. But separate strategies were discussed as suggested by the interviewees in terms of political, economic, social, technical, legal, and environmental as follows.

Political barriers: All the respondents highlighted the fact that the government of Sri Lanka should provide "incentives like tax downturns for the machinery and equipment that has to be imported for initiating WtE sites". Simultaneously all the required infrastructure like access roads, electricity, water, etc should be given. In addition, respondents proposed "a separate national base WtE initiation plan by implementing clear approval procedures". This should be achieved using an acceptable approach by convincing the government of the benefits of having WtE projects.

Economic barriers: The respondents suggested introducing debt financing as high capital investment is required. Through this, there will be more funders for a WtE project. Furthermore, guarantees can be given by the government. As an example, if CEB is willing to buy the electricity that is going to be generated through WtE sites then financial institutions will offer loans for project developers. The operation and maintenance costs can be reduced through proper maintenance and utilisation of the plants as per the respondents. As a solution for spending high costs for EPC contractors, Sri Lanka can find and train people within the country.

Social barriers: The best strategy that could be done as per the respondents is "having awareness programs to convince the public on the importance and long-term benefits that

can be obtained from initiating WtE projects". The main reasons for public protests against WtE projects can be mitigated by "facilitating proper waste storage within the sites, using better machinery were emitting less sound and vibrations, going for low noise designs like noise-proof buildings, using shortest routes for transportations and selecting sites in areas where having less volume of residents".

Technical barriers: Deficiency in expert knowledge in Sri Lanka for configuring and operating WtE sites was identified as one of the key technical barriers. The respondents provided a two-way strategy for this barrier. The respondents were therefore advised, "either to receive professional knowledge from foreign organisations or to implement a separate WtE module to local universities were conducting WtE related training programs as well". Waste should be stored inside a bunker for 6-7 days before sending for incineration to prevent the high moisture content and low calorific value, so the leachate that is coming from the waste will be eliminated and the moisture level will be reduced. To prevent burning hazardous waste inside the incinerators like e-waste, clinical waste, etc. the respondents suggested having agreements not to accept such types of waste. To solve the waste segregation, issue the respondents suggested that there should be more tough laws on waste segregation at the source.

Legal barriers: The key recommendation for resolving regulatory barriers was to provide an "approval system where all the approvals required for these types of projects can be obtained from one place". Through this, the approval process can be facilitated in an appropriate way where project developers will not get discouraged. Moreover, the respondents mentioned that there should have a proper regulatory framework with proper approval protocol.

Environmental barriers: It was proposed for bottom ash "to be used as a secondary aggregate in building sites or to dispose as an inert waste to a particular landfill or to be used in the manufacture of lightweight payment bricks". In terms of fly ash that could be accumulating using an ash silo. A proper leachate treatment plant can be installed within the site to solve the problem of leachate. Installation of a proper framework to monitor air pollution, monitoring system, measurement system for gas concentration, emission measurement system, and Flue Gas Desulfurization (FGD) systems have been proposed.

4. CONCLUSIONS

At present MSW has become a major crisis in Sri Lanka causing many negative impacts on the public as well as on the environment. This is due to the rapid generation of MSW as a result of the increasing population and urbanisation. Also, there is an imbalance in the demand and supply of electricity generation is one of the major issues in Sri Lanka. Thus, WtE is such a MSWM solution and it delivers alternative sources like electricity by addressing waste problems. It has been adopted in many countries already, but in the Sri Lankan context, this is still a newborn technology. Thus, to derive the adoption of WtE technology, mainly the drivers and barriers to such implementations have been identified. Even though the literature provides a smaller number of drivers (13) than the drivers that were highlighted through interviews (28) for the implementation of WtE projects under PESTLE analysis. However, through the case studies, thirty-five (35) barriers were identified which include twenty-one (21) new barriers. This study made a significant contribution to awareness by identifying how WtE projects in Sri Lanka can be successfully implemented as an efficient waste management strategy and renewable

energy generation technology. Moreover, the following recommendations have been suggested by the authors such as governments should promote the implementation of such projects by offering incentives and loan schemes as these are because expensive expenditure, "one roof system" that would enable the taking of all approvals at one location through the members of each company as necessary approvals and permits to consume more time and challenging, the WtE principles and their benefits be made known to the public through awareness campaigns.

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