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REVIEW

Development of waste-to-energy through integrated sustainable waste management: the case of ABREN WtERT Brazil towards changing status quo in Brazil

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Abstract

In the context of circular economy, it is known that once waste is generated, it should be subject to proper treatment for recovering material or energy before being disposed. Many countries worldwide, especially developing countries such as Brazil, have been struggling to effectively apply sustainable waste management in municipalities and still rely on dumpsites and unsuitable landfills. Misinformation, a weak legal framework, lack of financial resources and poor infra-structure as well as pressure from organizations profiting from the expansion of landfills are some factors contributing to the preservation of the negative status quo: the "landfill culture". Material recovery, i.e., recycling and composting, is applied to less than 5% of Brazilian municipal waste, while 95% is disposed of in landfills or dumpsites. In this context, ABREN WtERT (Waste-to-Energy Research and Technology Council) Brazil was created in 2019 as the first permanent organization formed to promote the development of energy and material recovery from waste focused on the waste-to-energy (WTE) market. In this paper, the strategy proposed and implemented by the organization towards changing the status quo in Brazil through an integrated sustainable waste management approach is described. The proposed strategy integrates the concepts of Sustainability and Circular Economy for minimizing landfill disposal (avoiding methane emissions) and maximizing material/energy recovery. Among others, the approach focuses on changing the public opinion regarding thermal treatment facilities, mainly incinerators, which has been wrongly linked to pollution, excessive public expenditures and considered a harm to the recycling industry. The activities performed by ABREN include engaging public and private institutions, enhancing education, leading the publication of research and business studies, gathering industry members and academy experts, as well as creating strategic alliances with players around the globe. As a result, within a few years, major outcomes were achieved in Brazil, such as: (i) changes in the legal framework, (ii) launching of a specific public auction category for sponsoring electricity production from WTE facilities, and (iii) establishment of official targets for municipalities to decrease landfill disposal and increase recycling/biological treatment and energy recovery from thermal treatment. Among the national goals, it should be highlighted the target regarding the increase from zero to 994 MW of electricity production from municipal solid waste, which will require building dozens of new WTE facilities. Global outcomes are expected as well since Brazil is the seventh largest country of the globe and the most influential in Latin America. International and national business deals should thrive due to the need of operational skills and technology imports, and the avoidance of carbon emissions will positively reflect the world climate. In parallel, there is also potential for the academy to benefit from research projects and investments if the WTE national industry is to be developed in the long term.

Keywords Integrated Sustainable Waste Management (ISWM) · Waste-to-energy (WTE) · Municipal solid waste (MSW) · Energy recovery

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Introduction

One of the biggest problems in Latin America, particularly in Brazil, is the poor management of municipal solid waste (MSW), the consequences of which are countless damages to the environment and public health. More than 50 years behind in terms of waste management (compared with developed countries), Brazil still endorses outdated practices such as landfills as being environmentally appropriate. This is what the Brazilian National Solid Waste Policy (PNRS) establishes in Law no. 12.305 published in 2010 when defining landfills as "environmentally appropriate", whereas in practice, it is an outdated non-sustainable way of disposing MSW.

Brazil annually produces around 83 million tons of MSW, which corresponds to 390 kg per capita each year [1]. Not all MSW generated is collected. On average, 90% of the population accounts for waste collection services [2]. The general composition of the waste produced in Brazil is 45.3% organics, 16.8% plastics, 10.4% paper, 5.6% textiles/leather/rubber, 2.7% glass, 1.4% multi-layer packages, and 15.5% other [3]. Only 1.9 million tons of MSW are selectively collected per year in Brazil, out of which only 1.0 million tons are actually recycled [2]. Around 37 million tons of organic waste were subjected to composting in 2018 [3]. This means that only 4%–5% of Brazilian MSW (38 million tons out of 83 million tons generated) were subject to some sort of material recovery prior to final disposal. Energy recovery alternatives have also been timid, the majority applying biological treatment alternatives such as anaerobic digesters. The production of biogas in 2021 was 2.3 billion Nm^3/year [4] while the theoretical potential of production is estimated in 84.6 billion Nm^3/year [4]. More than 70% of the biogas volume generated in Brazil derives from sanitation, mostly landfills. The major biogas use is for electricity production, resulting in only 35 million Nm^3 of methane being produced in 2018 [3]. In 2018, the electricity generation from biogas was 751 GWh [3]. Meanwhile, energy recovery through thermal routes is non-existent for Brazilian MSW. Among the alternatives for the thermal treatment of all types of residues, including industrial and agricultural residues, are incineration, gasification, pyrolysis and co-combustion. As mentioned, none of those routes is applied for Brazilian MSW treatment on a large scale, even though there are operating facilities for co-combustion and incineration of industrial/agricultural/forestry residues. Regarding the lower heating value (LHV) of MSW in Brazil, the average range is 8–10 MJ/kg (1.900–2.400 kcal/kg) [5], which is enough to enable electricity production from incineration.

Municipalities are responsible for MSW collection and destination, and as observed from the above-mentioned paragraph, they rely almost exclusively on burying, with about 95% of the MSW being landfilled or dumped. There are actually three types of waste disposal sites: (i) dumps, (ii) unsanitary landfills and (iii) sanitary landfills. Dumps and unsanitary landfills are considered unsuitable due to the lack of barriers for fluid percolation/atmospheric emissions. In contrast, sanitary landfills are considered suitable for waste refuse because they present an engineering structure to minimize fluid emission/leakage (even though recent studies have demonstrated that actual technologies for avoiding atmospheric emissions from landfills are quite inefficient; biogas escape is estimated at 50% in USA landfills) [6]. In Brazil, the scenario is even more concerning; 60% of MSW destined for burying is disposed of in sanitary landfills, while 40% is disposed of in dumps or unsanitary landfills, which characterizes as an environmental crime. This illustrates the structural flaws in public policies that have resulted (and keep resulting) in irreversible environmental damages for the present and future generations.

ABREN is a non-profit Brazilian organization, meaning Association for Energy Recovery from Waste (acronym for ABREN in Portuguese). It was created in 2019 to tackle the obstacles hindering the development of the waste-to-energy (WTE) market in Brazil. By 2020, ABREN was selected to officially represent the Waste-to-Energy Research and Technology Council (WtERT) in Brazil, elevating WtERT Brazil to a new level. The same mission of the Global WtERT Council is adopted by WtERT Brazil, that is, "to identify and advance the best available waste-to-energy technologies for the recovery of energy or fuels from municipal solid wastes and other industrial, agricultural, and forestry residues" [7]. ABREN then becomes an organization including the body WtERT Brazil assigned to address Research and Development issues in alignment with academic interests. The incorporation of the Global WtERT Council's mission into ABREN's duty contributed significantly to its internationalization. ABREN has in 2022 a total of 48 associates, including large multi-national companies whose revenues add up to dozens of billions of dollars. ABREN has become one of the largest organizations in the waste sector in Brazil and Latin America, bringing together diversely skilled companies, scientists, engineers, and managers from industry, universities and government with the objective of advancing sustainable waste management worldwide [7]. Companies within the WTE sector, members of ABREN, operate as Project Developers, Technology Providers; Engineering, Procurement and Construction Contractors (EPC); Operation and Maintenance (O&M) Contractors, as well as in the area of Investment and Development, Trading and Engineering and Consulting. The accelerated expansion of ABREN is mainly due to the application of a strategy called Integrated Sustainable Waste Management (ISWM), which is a powerful environmental governance tool destined mainly to the development of public policies through the best waste management practices. More details are given about ISWM method in the next section.

Governance aspects usually explain how a society participates and performs complex tasks to achieve a common goal. In waste management, the governance must include diverse stakeholders who are intimately connected to the population's daily life. Good waste management governance has been proven to be crucial for human health and safety and for environmental protection. Observing the management of urban waste from the governance perspective provides transparency and solutions to solve problems about who is involved and who is responsible [8]. In order to provide virtuous waste management, developed countries have created several methods and technologies for waste generation reduction, waste treatment and to transform waste into useful products. According to Circular Economy concepts, reduction is a priority, that is, the generation of waste should be avoided, for example, through product and packaging design. Once generated, the reuse and recycling of materials should be prioritized, that is, in order to reincorporate them into production processes in industry and commerce. Biological recycling is also possible through the composting of organic material, which transforms waste into fertilizer to be used in agricultural/forestry processes. The next solution, includes efficient energy recovery, that is, the exploitation of the energy content existing in the waste material. Mostly combustion is applied as energy conversion route to transform the waste into electricity and/or heat. The combustion's inevitable undesired effect is the flue gases emission generated from it, which is why advanced flue gas treatment technology has been developed. The high-temperature combustion for electricity/heat generation should only take place in so-called WTE plants. By adopting such material and energy recovery methods, it is possible to avoid the deposit of waste in landfills, which often does not prevent liquid and gaseous emissions to the environment. It is important to highlight that, as mentioned, the prior steps in a virtuous waste management process are non-generation, reuse and recycling. Whenever none of those options is possible, the waste can be treated through biological recycling (material recovery from composting) and energy recovery (whether biological or through thermal routes). This is the so-called "Waste Hierarchy", which aims to prioritize (i) waste reduction, (ii) recycling, (iii) treatment by composting, (iv) energy recovery through WTE, and (v) final disposal of refuse (pretreated, non-reactive waste) in landfills. Such "waste management hierarchy" clearly prioritizes energy recovery in view of the disposal of MSW in sanitary landfills.

Although notable efforts have been made to include material recovery and increase recycling rates in developed countries, international experience has shown that it is not as effective as expected. Increasing recycling rates too much ends up being unattractive economically because the recycling process is expensive and the materials recovered may not be of interest for industrial/commercial use. Therefore, excessive recycling ends up being an inefficient waste management practice when the destination of the recovered materials is to thermal treatment facilities or, in the worst case, to landfills. Post-recycled MSW is estimated at 1.2 billion tons per year worldwide, of which only 0.2 billion (or 16.6%) is treated using WTE technologies. Furthermore, only 20% of landfilled MSW is disposed of in sanitary landfills, which are those that have mechanisms to reduce liquid and gaseous emissions to the environment [9]. Although landfills aim to protect surface waters and groundwater, and reduce the emission of greenhouse gases (GHG) into the atmosphere, thus being more desirable than open dumpsites, it is estimated that only 20% of the world's landfills are effectively sanitary and safe for the environment [9]. The 5th Report of the Intergovernmental Panel on Climate Change [10], notes that landfills equipped to capture methane, are actually able to capture, at best, only 50% of their GHG emissions. The necessary capital investment to implement a sanitary landfill with methane gas capture is 30% lower than a WTE plant, however, because of the higher electricity production, WTE plants are usually more economical over a 30-year life span or more [9].

Brazil still has a "culture of landfills", which is why ABREN WtERT Brazil has been working avidly towards developing a virtuous waste management policy in the country. It plays a crucial role in educating people, influencing decision makers and policymakers, engaging authorities and gathering industry stakeholders to foster the local WTE market in Brazil, aiming at addressing the social, environmental and economic consequences of current waste dumping and landfilling. Since very little environmental control is actually imposed on the existing "proper" landfills (not even leachate treatment is usually implemented), landfilling is tremendously cheaper than any other waste destination practice (as it is a disposal and not a treatment alternative). If adequate environmental strategies and economic charges were imposed on the landfilling of non-inert waste, as well as subsidies were given to better treatment methods, Brazil's current situation could definitely be overcome [11]. In developed countries and in China, landfills are being heavily criticized and progressively abandoned because they are the least efficient, their operation requires much land, and their environmental impacts are massive, especially regarding GHG emissions, while their liabilities remain long after they are shut down. Only recently have the costs of environmental liabilities from closed landfills been observed in Brazil. Moreover, in Brazil, many landfills have been built in environmentally protected areas, and are supposed to be destined for nature protection and preservation of native biodiversity. In 2018, the Brazilian Supreme Court effectively deliberated to forbid the expansion and implementation of new landfills in such areas, due to their ecological importance ("Unconstitutionality Direct Act" 4.903 [12]).

The adoption of WTE technology has been motivated both by the need to minimize landfill environmental externalities and by the need to increase the clean energy share. The last motive is explained by the fact that combustion of the MSW biogenic components is considered to generate clean energy since emission of biogenic carbon is offset by biomass growth. Over the last decade, WTE plants have been criticized by many people who emphasized their negative impacts on the environment and public health; however, the sophisticated Air Pollution Control (APC) systems have enabled WTE plants to perform the cleanest high-temperature industrial processes available today [13]. In conclusion, sustainable waste management including WTE technologies is crucial for achieving a circular economy and has become increasingly important to formulate a sustainable urban development agenda worldwide, especially in developing countries. This article intends to address conceptual theories that support ABREN's management and governance, as well as to show the results obtained in Brazil for the development of the WTE market derived from the application of ABREN WtERT Brazil's strategy.

ISWM in sustainable development

ISWM is a dynamic tool that encompasses several variable aspects required to the creation of public policies and institutional development. It also includes the strategy for developing integrated solutions for MSW handling and disposal. It starts with engaging stakeholders in the process, seeking to both minimizing the waste generation and maximizing the recovery of resources from the waste through the interaction with other systems and integration of different spaces such as public spaces, neighborhoods and residences. In addition to technical aspects, ISWM also acknowledges political and social facts as equally important in the MSW management process. ISWM assesses (i) physical components, such as energy collection, disposal, recycling and recovery, as well as (ii) governance aspects, such as inclusiveness of users and service providers, financial sustainability, coherent and solid institutions supported by proactive public policies [9].

The association of the term "integrated" in solid waste management first occurred in the 1970s [14], resulting in an exponential impact on the use of this term since then. It has become a standard term for several waste management academic research institutes since the year 2000.[1] The notion of "sustainable development" became globally relevant with the report "Our Common Future", published in 1987 by the United Nations World Commission of Environment and Development (WCED) [15]). Agenda 21 also stands out for its action plan for sustainable development, which was agreed upon at the United Nations Conference on Environment and Development, held in 1992 in Rio de Janeiro [16].

Three aspects inherent to sustainability (environmental, social and economic) are addressed from a holistic and systemic approach to the integrated and sustainable management of waste, with special emphasis on the spatial combination of MSW management, effluent treatment, energy production and food production facilities. Furthermore, ISWM must be addressed under three main dimensions translated into questions: (i) who?—this question focuses on stakeholders; (ii) what?—the scope should be designed, including in addition to the physical components of a waste system, the identification of various other planning and management issues that need to be addressed, such as strategic planning, public participation, financial management, etc.; and (iii) how?—question that addresses how strategic objectives and issues should be addressed, introducing a series of strategic political, institutional, social, financial, economic and technical aspects [16].

The stakeholder in this process is a person or organization that has an interest in the waste management process. Although stakeholders have different roles and interests in relation to waste management, the challenge of the ISWM process is precisely to get them to agree to cooperate and converge towards a common cause, which translates into improving the waste management system. Public consultations or hearings have proven to be an important instrument of public policy to seek clarification and consensus among interested parties.

The second dimension addresses the physical aspects and elements of the waste management system, referring to the way solid waste should be handled and where it should be destined. Particularly, the destination has great relevance regarding environmental issues, which is why environmental authorities in several countries have adopted the concept of waste management hierarchy, as shown in Fig. 1, which is also a cornerstone of the ISWM approach under the aspects of preference for the prevention and minimization of waste generation, recycling and other forms of material recovery [9].

Soil, population density, economic force and the importance the community places on sustainability are some of the main factors impacting the development of a waste management strategy. How the community prioritizes such factors is what leads different communities, regions and nations to manage their waste in such different ways. Waste hierarchy provides important general guidelines on how to prioritize the use of various waste management alternatives. The most

[1] The term "integrated" has become standard in the names of leading academic waste research centers such as 3R: Residual Resources Research, a Ph.D. research school in integrated resources and waste management at DTU, Denmark; Integrated Waste Management Center at Cranfield University, UK; Integrated Waste Systems from the Open University, United Kingdom; CSIR Centre for Integrated Waste Management, South Africa and the Center for Integrated Waste Management at the University at Buffalo, USA [14].

Fig. 1 Hierarchy of solid waste management. Source: [17]

successful waste management strategies recognize that the system must include all options to varying degrees. On the other hand, the most unsuccessful strategies rely entirely on the least preferable alternatives or set unrealistic goals of using only the most preferable ones, and the lack of planning associated with choosing only the most preferable option usually leads to an eventual overuse of the least preferable option. Therefore, the balanced approach, with an appropriate emphasis on hierarchy, has always been the most successful [18].

In the meantime, it is important to bear in mind that not all municipalities will be able to follow this hierarchy, due to practical or economic reasons, mainly in cases where WTE cannot reach a minimum affordably acceptable scale, which could then gather with neighboring municipalities. However, sanitary landfills implemented with effluent treatment and biogas recovery and valorization are a preferable solution to dumpsites, albeit palliative and temporary. As the most appropriate waste management solution varies from one region to another, a specific case study is necessary for each municipality [19] or a set of these in the form of a municipal waste management consortium.

ISWM third dimension comprises sustainability aspects that can be defined as principles or lenses through which the waste management system exists and can be evaluated, and how a new system or an expansion can be planned. For a new system or its expansion to be sustainable, all aspects inherent to it must be considered, including technical, environmental, economic-financial, sociocultural, institutional, legal, and political aspects [9].

The technical aspects are consistent with the implementation and maintenance of all waste management elements, including the equipment and facilities that are or should be used (planning), how and for what they were designed, the effectiveness of their operation in practice and how clean the city will be after its consistent implementation [9]. To make these aspects effective, the public administration must develop technical standards that deal with the various forms of recycling, composting and energy recovery, including existing procedures and technologies, with the purpose of guiding society and public and private managers on the implementation of such processes in the sustainable management of MSW.

Environmental aspects will focus on the impacts of waste management on soil, water and air, from the conservation of non-renewable resources, pollution control and preventive measures that will be adopted in relation to local public health [9]. In this regard, it is also important for the public administration to issue regulatory standards that can guide the way in which agents act, especially regarding the emission of GHG gases into the atmosphere and the protection of soil and water resources, under the technical aspects inherent to the environment and public health.

The economic-financial aspects are conceptualized with the issues inherent to the budget and cost accounting within the waste management system and its relationship with the regional, national and global economy. Specific items include: (i) privatization; (ii) cost recovery and reduction; (iii) environmental services impact on economic activities; (iv) the commodity business environment and how recycling infrastructures link to it; (v) efficiency of MSW management systems; (vi) macroeconomic dimensions of resource conservation and use; and (vii) revenue generation [9].

Sociocultural aspects include the influence of management and generation of waste culture in households, companies, industries and institutions, especially on how the community is involved in waste management and the relationships between groups and communities, according to age differences, gender, ethnic origin and social condition of workers involved in the waste chain [9]. To make this aspect effective, the adoption of broad institutional and educational advertising is suggested, focusing on preventive aspects related to the separation of materials for recycling processes, procedures and benefits inherent to the composting of the organic fraction, as well as the benefits of adopting WTE plants to replace landfills.

Social programs shall also be implemented to improve the working conditions of waste pickers, who could be deployed on different MSW management activities promoted by a municipality (under proper training and social assistance), allowing them to be integrated into recycling, composting or energy recovery processes. This can be included as a socio-environmental requirement in the permitting process of waste treatment projects, with integration of sorting plants for (clean) materials from separate collection, where recycling associations could benefit from the profits of materials sale, with working facilities being provided by the Concessionaire. Such an approach would require an (slightly) additional cost that could be afforded by

society through the payment of tariffs or waste management fees to support solving historic and persisting social problems in the waste sector.

Institutional aspects are related to political and social structures that manage and implement waste management under the aspects of distribution of functions and responsibilities, organizational structures involved in processes, procedures and methods involved, the available institutional capacities and the participation and involvement of the private sector. In this sense, planning becomes the main activity in relation to institutional and organizational aspects [9].

The legal and political aspects, as well as internal policies, address the boundary conditions in which waste management is established, according to goals and priorities, determination of roles and jurisdictions, the legal and institutional framework existing or being planned, as well as the basic decision-making processes [9].

WTE in the context of ISWM

ISWM proposes implementing plans that must be conceived in a systemic and holistic way, with action in the different stages of the management cycle, starting with efforts to minimize the generation of waste by rationalizing the collection processes and transport of waste, programs that promote the reuse, recycling, and energy recovery, as well as the final destination that must be devoted only to refuse, that is, the portion of the waste that remains after all efforts undertaken for economic use in the recycling and composting stages [20].

Based on these assumptions, it is relevant to observe that the sustainable management of MSW requires considerable effort to separate recyclables or compostable materials in the solid waste chain. These materials must be separated from the rest of the MSW at their origin, that is, at the generating source, the residences, companies, industries or institutions, which, once mixed with other types of waste, turns separation into a very expensive process and the value of materials (if any) decreases considerably. Responsible public authorities should educate the population about recyclable materials with greater demand since otherwise recyclable waste will end up in landfills or be subject to ungripped burning [9].

The ISWM approach does not expect MSW energy recovery through WTE plants to be carried out with waste destined to composting or recycling, as already exposed in the priorities of the waste hierarchy. Nor does it encourage the wastage and excessive production of MSW. In this context, the purpose is to dispose the waste which would otherwise be inevitably sent to landfills to the energy recovery processes in WTE plants.

In the Zero Waste concept, the priority becomes not only to recycle and recover energy from the waste, but also to change consumption and waste patterns in order to modify product design, production and distribution processes, with the ultimate goal of modifying the waste life cycle. Developing waste sustainable management systems to avoid, reduce, reuse, redesign, regenerate, recycle, repair, remanufacture, resell and redistribute waste resources has become a priority. Training programs in order to change behavioral patterns are considered long-term strategies, while implementing innovative industrial design and making efforts to change the legal framework and promoting the recycling industry are short-term strategies [9].

Without a doubt, ISWM's environmental, political and social focus must be to reduce and reuse waste through policies that can extend the useful life of products and make the population aware in all ways to modify their consumption patterns. This will provide great benefits in terms of sustainability. However, practice shows that recycling 100% of MSW is not possible, since a considerable part has high costs that would make the process unfeasible [21].

Material recycling and recovery methods are expensive and do not allow for the processing of all municipal waste. Filtering and separating waste is important, but only if it makes sense, and a proper cost-benefit analysis must be an integral part of the decision-making process. According to all sustainability pillars, energy recovery is preferable for refuse that cannot be effectively recovered and/or placed on the market. Indeed, WTE plants are a sustainable solution for developing countries (low income), which can be the first step to move up the waste treatment hierarchy [21].

As discussed, there is no doubt that communities must give high priority to waste reduction, reuse and recycling. However, there are economic and technological limits to these options, and there will be production of refuse, especially from recycling facilities. Therefore, what to do with such refuse? At this point, the waste hierarchy brings the preference of WTE plants to landfills, because once the landfills are saturated, conversions of new green areas into landfills would be necessary. In addition, a WTE plant treating MSW would be able to produce between 650 kWh and 800 kWh (kilowatt hours) of electricity per ton of MSW, while landfills with biogas captures extract an average of 65 kWh per ton, that is, a WTE plant has an energy efficiency at least ten times higher, not to mention that electricity generated from waste in a landfill environment is extracted slowly, over time, while it is generated immediately in a WTE plant [18].

In this context, some might claim that a new WTE plant will reduce the community's recycling rate. However, experience observed in developed countries shows that the exact opposite occurs. Communities willing to spend resources and efforts on recycling will soon realize that the properties of materials have technical and economic limits for

their recycling, requiring a final destination that cannot be other than a landfill or WTE, the latter being positioned at a higher scale in the waste management hierarchy. WTE plants allow the reduction of dependence on landfills, and as a result, electricity and steam are generated, and metals and minerals are recovered from the incineration process that would otherwise not be recovered. As mentioned, the countries with the highest recycling/composting rates are also the ones with higher use of WTE plants for waste treatment within the concept of an integrated MSW management [9].

For each ton of waste treated in a WTE plant, approximately 1.5 kg to 1.7 kg of CO_2 equivalent is expected to be avoided from landfill emissions in Brazil [22]. According to an ABREN study, implementing WTE plants only in the 28 most populated Brazilian metropolitan regions with more than 1 million inhabitants would have the potential to avoid the emission of about 60 million tons of CO_2 equivalent annually, or 1.8 billion CO_2 equivalent during 30 years of operation [23]. This is because landfills are an important source of methane, a powerful GHG that, according to the IPCC, has a global warming potential 80 times greater than that of CO_2 over a 20-year horizon (GWP20), or 34 times greater than that over a 100-year horizon (GWP100). Methane is currently considered the second largest driver of anthropogenic climate change [24].

According to current GHG inventories, landfills are the third largest source of anthropogenic methane in the world and in the USA [25]. However, new data suggest that landfill emissions and the opportunity to reduce them are huge. A series of recent studies employing direct measurement of methane plumes from landfills via leeward aircraft, have shown that measured emissions are on average more than double the modeled emissions reported in current GHG inventories [26]. Based on this growing set of data, methane emissions from landfills are comparable to methane emissions from the entire agricultural sector in the USA.[2] Although the State of California has implemented the most stringent landfill gas control regulations to date, a team of researchers from NASA and several American universities identified certain California landfills as "super emitters" of methane [27], even though it fully complies with the strict rules of the State.

[2] Total methane emissions in US landfills in 2019 accounted for 4.58 MMT CH_4, as reported in the US EPA (2021) [25]. On average, landfill emissions measured from recent data referenced here were 2.3 times higher than reported. Adjusting the US inventory with this factor yields total landfill emissions of 10.5 MMT CH_4. Total emissions from the agricultural sector, including enteric fermentation, manure management, rice cultivation and field burning of agricultural residues were 10.26 MMT CH_4.

According to the United Nations Environment Program (UNEP), "cutting methane is the strongest lever we have to slow climate change over the next 25 years." In the short term, reducing emissions of short-lived climate pollutants such as methane is more effective than reducing CO_2 [28]. The recently released IPCC 6th Assessment Report notes that methane reduction "stands out as an option that combines near and long-term gains in surface temperature and leads to air quality benefits by reducing surface ozone levels globally" [29].

It is important to note that even with the capture of methane for energy generation or biomethane production, the fugitive emissions still remain over the landfill massif, in addition to the inefficiency of flare burning, with percentages that can vary from 25% to 50% depending on the time of waste deposited and the efficiency of capture. That is, the initiatives of partial use of methane should be considered as palliative, that is, just a way of dealing with the environmental liabilities of existing landfills, and never an alternative for the adequate disposal of waste. It is essential to remember that the quality of waste management in developed countries is measured by the amount of waste diverted from landfills, which is why some countries have banned the disposal of MSW in landfills for over a decade.

It is also worth noting that Brazil signed a commitment at COP 26 to reduce methane emissions by 30% by 2030, which reinforces the need to reassess the inventory of anthropogenic methane emissions, including the landfills. Moreover, an adequate taxation of waste matter disposed in landfills is crucial to trigger the reduction of GHG emissions, which can only be achieved through the diversion of biodegradable waste from landfills, and a consequent absorption of such waste by the WTE plants, which are the best option today to reach this goal.

Below are listed some of the main benefits of WTE plants in terms of alternative final disposal (landfills) for MSW:

(a) WTE plants are subject to the strictest environmental law and are equipped with highly efficient flue gas treatment systems, with typical emission values between 50% and 75% below the limit values imposed by the European Directive 2010/75/EU. This Directive requires monitoring of the emission limits of over 20 components, while combustion plants with a thermal capacity greater than 50 MW only have 3 polluting components monitored. Brazilian Resolution SMA 79/2009 adopted by the richest State of Brazil, São Paulo, was based on such European Directive. Landfills are subject to minimal air emission regulations despite the emission of more than 170 pollutants and 46 air toxins, including 4 known carcinogens and 13 probable carcinogens [23].

(b) It has been observed from the experience of foreign countries that wherever WTE plants are implemented, higher recycling rates are achieved compared to places without WTE plants. In Brazil, an average recovery of 23 kg of recycled metals for each ton of waste treated in a WTE plant has been estimated. This means that implementing WTE plants in the 28 largest Brazilian metropolitan regions, with more than 1 million inhabitants, represents a potential recovery of more than 800,000 million tons of metals per year, which would otherwise be buried, since the majority of the waste is landfilled [23].

(c) WTE plants may be built close to urban centers, contrary to landfills, which are mostly built far away from the most populated locations. The WTE facilities provide a local solution to sustainably manage the MSW, allowing at least two types of savings: (i) MSW is expected to be transported fewer miles from households to the WTE plants than it would be if disposed in landfills; (ii) electricity generated in the WTE plants is expected to be distributed to the households also more easily than it would be if the regular eletricity sources are used (most of the generation plants are located very far away from consuming centers). In this context, applying WTE facilities to generate electricity close to urban centers can allow cutting costs from MSW transportation and from the use of the distribution network. Combining both savings, it is estimated from a study sponsored by ABREN WtERT Brazil that approximately 340 BRL/MWh (Brazilian Reais, which is equivalent to USD 68/MWh) could be saved by replacing landfills with WTE plants. On the other hand, when waste is disposed in landfills it is often transported by truck hundreds of miles before being buried, contributing to the emission of GHG produced by burning fossil fuels.

(d) The top 13 countries with 25% or more of their MSW being destined for WTE plants are also among the top 16 countries in the World Economic Forum's Health and Wellbeing Index. Based on data from studies by the International Solid Waste Association (ISWA [30]), the environmental and health care costs associated with dumpsites and landfills in Brazil are estimated at a range between USD 3–5 billions [31]. Among the 28 largest metropolitan regions of Brazil, with more than 1 million inhabitants, it would be possible to save the equivalent of about BRL 2.5 billion per year, or BRL 75 billion in 30 years [23].

(e) A study conducted by the European Commission showed that the energy recovery of 10,000 tons of waste can create up to 40 jobs [32]. During the high job demand season of a WTE plant construction phase (usually lasts about 36 months), up to hundreds of direct employees can be hired. In the operating phase, a medium-sized WTE plant can employ over 100 direct permanent jobs for the thirty years of the plant existence (plus the indirect ones). On the other hand, for every 10,000 tons of waste disposed in landfills, it is estimated that only about 10 jobs are created.

ABREN WtERT Brazil's journey in recent years

In March 2021, ABREN and WtERT Brazil participated in the first day of Energy from Waste Conference, a renowned annual event that usually takes place in London, UK, and that brings together the world's leading experts in the WTE field. Due to the COVID-19 pandemic the conference was held online, presenting an overview of the expectations for the development of the Brazilian market to the world, raising great interest in the international players by the country's recent achievements.

In May 2021, ABREN held its second annual event, the 2nd Waste to Energy Forum. The event took place in two days with strong participation of multiple players, accounting with great support from the industry, significant presence of the Federal and State government representatives. Several large associations that corroborate with the organization's mission consolidated the Coalition for Waste to Energy ("Coalizão Valorização Energética de Resíduos"), gathering for the first time important associations of the waste management sector such as ABIMAQ, SINDESAM, ABEMI, ABGD, SOBRATEMA, ANIP, COGEN and CERVBRASIL. Important authorities were present: the event opened with a speech by the Vice President of the Federative Republic of Brazil, Hamilton Mourão, as well as the Brazilian Minister of Mines and Energy, Bento Albuquerque.

In October 2021, ABREN participated in the most important event in the Brazilian electricity sector, a conference called "Meeting for players in the energy industry" ("ENASE"), promoted by Informa Markets and the Brazilian Energy Channel. The congress brought up the debate about "The Electrification and Decarbonization of the Economy Through the Sector's View", presenting the WTE projects currently ongoing in Brazil, in addition to highlights about the Brazilian potential market and suggestions for public policies to encourage waste management growth.

ABREN has entered into a partnership with Messe München Brazil, which is responsible for organizing the IFAT fair, which is the largest sanitation fair in the world, held biannually in countries like Germany, China, India, Turkey and South Africa. Another two important events took place in Brazil: the "Waste Sanitation" and the "Energy Recovery Forum". Both accounted with participation of important authorities from the Brazilian National Water

and Sanitation Agency ("ANA") and the Federal Government, in addition to the presence of companies in the waste and sanitation sector and experts talking about the impacts and perspective of the Brazilian New Legal Framework for Sanitation.

As per a request from ABREN, the Ministry of Regional Development (MDR) created a working group with periodic meetings to discuss the WTE projects being developed in Brazil, with the participation of other sectoral entities, the Ministry of Mines and Energy ("MME"), the Ministry of the Environment ("MMA") and the Energy Research Company of Brazil ("EPE"). EPE is quite an important player because their studies base the audit pricing of different electricity sources. Those audits are organized by the Federal Government and engage about 70% of the electricity production market in Brazil. They orchestrate the energy demand/supply in the country with the purpose of commercializing electricity through concessions of 20–30 years. The meeting was especially important because it was a broad inter-ministerial debate and confirmed the interest of the Federal Government in not only changing the Brazilian electrical matrix, but also opening space and shedding light on the challenge and opportunity of the WTE sector in Brazil.

Within the scope of the private sector, ABREN presented great development, approximation and promotion of the entry of global companies in the sector into the Brazilian market, such as Hitachi Zozen Inova, Babcock & Wilcox, Veolia, Rambol, Sutco, Solvay, Sacyr, Lhoist and Toyo Setal (Mitsui Group). The movement indicated the success of the policies and actions implemented with the contribution of ABREN, as well as the confidence that the sector is finally moving and offering opportunities in a safe and concrete way. As of 2021, ABREN also started to represent the majority of the Refused Derived Fuel (RDF) sector, gathering companies that process 80% of all RDF destined for co-combustion in Brazil, as well as manufacturers of machinery and equipment for this segment, which currently has a replacement of 31% of pet coke for the production of clinker used in the manufacture of cement in Brazil.

In addition to sector representation, one of ABREN's main activities is legal security and the reduction of bureaucracy in its sector. Still in line with the Environmental, Social and Governance (ESG) agenda and the decarbonization movement of the global economy, the president of ABREN, Yuri Schmitke, joined forces with Marco Tsuyama in a special participation in the work "Legal and Regulatory Paths for Decarbonization in Brazil", the result of the thesis of doctorate of Dr. Cácia Pimentel, defended by Columbia University in New York.

Along with other representatives of the waste and sanitation sector, ABREN's representatives delivered to the Brazilian Minister of the Environment, Joaquim Álvaro Pereira Leite, a Manifest in favor of reducing GHG in the waste management sector for COP26 in Glasgow.

One of the great results of ABREN's work in 2021 was the feasibility of the first auction of energy derived exclusively from MSW, at an initial cap price of 639 BRL/MWh (around USD121.00/MWh), allowing the feasibility of the first WTE project in Brazil in Barueri, São Paulo, awaited since 2012. The auction's sales agreement was placed to provide 20 MW of electricity from the WTE Barueri for 20 years at a price of approximately USD 104.00. This was a great achievement for the Brazilian business sector because it was the first auction considering the energy recovery from MSW, opening new perspectives for the waste management sector in Brazil. Hopefully it will contribute to increase the development of business opportunities, ventures and international investments in the WTE sector in the country.

One of the major outcomes achieved by ABREN is its contribution to a technical study within the scope of the public consultation for the National Solid Waste Plan (PLANARES), which is such an important document containing guiding instructions and goals leading to strategies being implemented in accordance with the National Solid Waste Policy (PNRS). The PNRS was established in 2010 but it was lacking a supplementary guideline with especific goals and targets for the waste management sector, which is the PLANARES. ABREN WtERT Brazil has been advocating for greater recycling, composting and energy recovery from MSW based on the ISWM method, that is, respecting the above-mentioned waste management hierarchy. After twelve years from the publishing of PNRS, the awaited PLANARES was finally approved through Brazil's Federal Decree No. 11,043/2022. It establishes a goal to implement 994 MW_e of installed electrical power by the year 2040 in Brazil. This is enough to supply 27 million residences with electricity MMA [3]. This target is equivalent to a total of 50 plants of 20 MW_e of installed power, or 3 WTE plants of 20 MW installed per year until 2040 [23].

In 2021, ABREN partnered with an education institution called Getúlio Vargas Foundation (FGV), which is the most renowned business university in Brazil. Together, they launched the first MBA program in the country on Treatment and Energy Recovery from Waste. This was the first course dedicated exclusively to the business of energy recovery from MSW in Brazil. The course aimed to train students, company managers, and interested people on how to develop business plans for thermal and biological waste treatment plants. ABREN participated in creating the discipline summary and material content, selecting professors, advertising and marketing the course. The classes successfully started in August 2021, and were attended by highly qualified professionals, opening up space for future continuation of instruction programs and education of the open public regarding WTE disciplines.

In May 2022, ABREN, invited by the Suisse Consulate, participated in the Carbon Global Market Congress about Decarbonization and Green Investments which took place in Rio de Janeiro, Brazil, promoted by the Brazilian Environment Ministry in partnership with Petrobras, Brazilian Bank and Central Bank. It discussed alternatives for carbon credit market, the presentation of corporate strategies, projects and successful cases of green business, with a focus on innovation and sustainability. ABREN WtERT Brazil conducted a presentation about the importance of developing the WTE sector in Brazil, reinforced by the recent publication of PLANARES (one month prior to the event).

In June 2022, ABREN held the 3rd Waste to Energy Forum in the city of São Paulo, Brazil, which had the opening of the President of the Brazilian National Water and Sanitation Agency ("ANA"), the Director of the National Bank for Development ("BNDES"), in addition to the presence of representatives from several Brazilian organizations from the engineering, construction, recycling, mining, energy, machinery, and other sectors: ABIMAQ, ABEMI, INESFA, ABGD, COGEN, SOBRATEMA, ANIP, CERVBRASIL, ABEAMA, among others important associations. In conclusion, major lessons drawn from ABREN's journey include that to improve waste management and enhance WTE industry, it is necessary to directly tackle the problems identified. Efforts should be made to combat fake news, change the legal framework, pressure public authorities to create/change public policies, create national targets, establish goals for specific sectors, increase knowledge, gather institutions, etc. Those have been shown to be efficient measures proposed and applied.

Major outcomes achieved in Brazil

Since its creation in 2019, ABREN has been participating avidly in the promotion of important events and dissemination of crucial information about the WTE sector in Brazil. It has published more than 400 articles in the Brazilian press, including newspapers, digital media, TV interviews, congresses, and academic journals. The importance of ABREN WtERT Brazil's strong presence in a wide variety of sectors has contributed to a turning point towards improving waste management practices in Brazil, influencing companies, public authorities, organized civil society and the general public. This is a very important practice in Brazil due to the lack of knowledge involving advanced technology in the sanitary and waste valorization sectors. It has contributed to creating valuable awareness of the waste problem among decision makers and policymakers, collaborating to foster the improvement of sanitation and the implementation of better waste management practices.

Based on data collection, meetings with companies and public entities, as well as an analysis of the Brazilian scenario, ABREN WtERT Brazil developed a basic text for the Bill 924/2022, which provides for the National Waste-to-Energy Program (PNRE). It proposed measures to encourage Brazilian municipalities to bid for plants that use MSW to generate electricity. The Bill was published in the Brazilian Chamber of Deputies on the same date that the Federal Government launched important programs to enhance waste management, sanitation and recycling. Such programs include the National Solid Waste Plan (PLANARES) and the Recicla + (translates as "Recycle plus") through the Brazilian Federal Decrees No. 11,043/22 and No. 11,044/22, respectively. The PNRE text complements the national guidelines and encourages the energy recovery of the non-recyclable fraction of solid waste, in addition to encouraging, financing and promoting the structuring of bidding processes for municipal waste management concessions.

The Bill aims to expand the generation of clean and renewable energy through solid waste in the Brazilian energy matrix. Moreover, it intends to expand and guarantee the participation of workers from recycling cooperatives in WTE projects, seeking cooperation with the private sector and enabling the structuring of municipal concessions of WTE systems. The purpose of developing technical criteria to assess the reduction of GHG emissions and the respective pricing of carbon credits for WTE plants also stands out, in addition to promoting research and development of national solid WTE technologies.

Some highlights of Bill 924/2022:

(a) It creates the self-production and distributed generation regimes from WTE plants, with the option of joint bidding for the WTE plant with electric urban mobility and waste collection by electric trucks that will be supplied directly at the WTE plant;
(b) It establishes the possibility of contractual cooperation between the State and the municipalities for a joint contract with WTE plant operators, in which the municipality can participate in the auction to sell electricity in advance before bidding for the municipal concession;
(c) It creates programs and regulations for the production, processing, trade, import and export of RDF;
(d) It proposes targets for the reduction of bio-waste in landfills, with 25% in 2026, 50% in 2031 and 75% in 2036, under penalty of budgetary restrictions or loss of incentives by municipalities that do not adopt the measures or do not justify their technical or economic infeasibility;
(e) It exempts from manufacture tax (IPI) for the acquisition of machinery, equipment, appliances and instruments intended for WTE, and proposes exemption from social taxes (in Brazil called "PIS/PASEP" and "COFINS") on the purchase and sale of waste,

electricity, biofuels or other inputs resulting from the WTE process, co-combustion and RDF;

(f) It defines mandatory requirements and deadlines for carrying out technical and economic feasibility studies for each municipality (with more than 200,000 inhabitants), individually or in consortia. It is imperative to ascertain the best waste treatment practices that can be implemented in these regions, which generally have population density and complexity to find new areas close to the city for the construction of landfills.

The creation of the PNRE will bring an important contribution for Brazil to evolve in this regard. The measures listed by the Bill are expected to reduce damage to public health and the environment through the adoption of energy recovery technologies, in addition to using the best practices of sustainable and integrated waste management throughout the national territory, when evaluating the best technologies available and appropriate to local and regional realities. The actual status of the Bill 924/2022 is that it is awaiting for approval by the Brazilian Chamber of Deputies and later by the Federal Senate.

Brazil currently has approximately 15 projects of WTE plants under development. The most advanced ones are as follows:

(a) WTE Mauá: the technology used for incineration furnace is moving grate. The plant will be built in the City of Mauá, in Sao Paulo province, with 80 MW of installed electric power capacity to treat 3000 t/d of MSW from the urban area of São Paulo, which is currently disposed of in a landfill in the city of Mauá, São Paulo. The project has an environmental permit (LP) issued and meets the conditions to participate in the new energy auctions;

(b) WTE Consimares: the technology used for incineration furnace is with a moving grate. The plant will be built in the metropolitan region of Campinas, in the city of Nova Odessa, in the province of São Paulo, with 20 MW of installed power capacity to treat 700 t/d of MSW that is currently disposed of in landfills. The project has an environmental permit issued and meets the conditions to participate in new energy auctions;

(c) WTE Caju: the technology used for incineration furnace is moving grate. The plant will be built in the metropolitan region of Rio de Janeiro with 31 MW of installed power capacity to treat 1300 t/d of MSW. The municipal waste is currently disposed of in the Seropedica landfill located in the urban area of Rio de Janeiro. The project has an environmental permit issued and meets the conditions to participate in the new energy auctions;

(d) WTE Brasília: the project integrates manual and mechanical sorting, biological treatment, and thermal treatment of residual waste through incineration in a grate moving furnace, among others, with a capacity to treat around 700,000 t/a of waste, which today is disposed of in the sanitary landfill in Samambaia, in the capital of Brazil, Distrito Federal. It has not yet started its environmental permitting process and is currently preparing for the tender.

A study has been developed to estimate the capital investment necessary to treat urban waste from the 28 largest cities of Brazil. It represents 58% of all urban waste generated in the country, encompassing 28 metropolitan regions with more than 1 million inhabitants. The CAPEX investments are estimated at 80 billion BRL (around 16 billion USD of 2022), including over 270 facilities, among which are 94 WTE plants, 95 refuse derived fuel production units and 85 biogas production units, excluding recycling facilities and landfill gas to energy power plants. This scenario represents over 46 million tons of MSW treated each year; which represents, in terms of mass, 62% destined for WTE, 21% for refuse derived fuel production, 11% for biogas production and 6% for recycling, with only 4% going to landfills. Regarding direct jobs, it is estimated that it represents 15,000 new positions and 63 million tons of equivalent CO_2 avoided [23].

ABREN has promoted a diversity of business model instruments to implement WTE plants, and all of them follow the municipal concession contract regime in order to guarantee the payment of the gate fee for the MSW management service. However, to guarantee financing, the need arises for the early and long-term sale of the electric energy generated by the plant. The first option currently existing, which resulted in the engagement of URE Barueri, was through regulated new energy auctions held by the Ministry of Mines and Energy.

Another model that tends to be effective is the self-production regime, where the generator can supply energy to public buildings, public lighting, and electric vehicles, provided they are all for the same company. Since there is a tax exemption in the self-production regime, this model allows for increased attractiveness, but there is the complexity of dialoguing with other public services and rendering the project with the same company feasible in a bidding process held by the municipality.

Another possibility is charging for the MSW management service provided by the municipalities directly on consumers' bills, e.g. water and/or electricity bills. This enables the balance of the project and the apportionment of costs to the consumer, in addition to improving compliance of the service in view of the possibility of a cut in the supply of water or electricity to the consumer. With this

model, WTE plants become more competitive with other thermal sources in Brazil, and may participate in capacity auctions within the scope of the Brazilian Ministry of Mines and Energy.

How ABREN WtERT Brazil's actions may influence other countries

ABREN WtERT Brazil institutional actions demonstrate the effectiveness of the application of the ISWM strategy in different fields: technical, economical, financial, environmental, legal, regulatory, political, social, and communicational. This is because the methodology has a holistic and multidisciplinary structure aiming at changing the actual reality of a country, which is the use of landfilling/dumping as destination for almost totality of its MSW without any treatment.

Despite its short existence, the organization has been able to gather important players under such different perspectives, managing to have today 48 associated companies, standing out as one of the largest entities in the waste management sector in South America. Among the key actions ABREN WtERT-Brazil has taken, it can be hightlighted the important pressure and significant contributions within the scope of public administration. In particular, acting towards changing the legal framework were directly made in the Brazilian National Congress using the ISWM approach in order to drive Public Authorities to adopt the best sustainable and integrated practices in waste management. Because of particular reluctancy observed in the country from groups involved with recycling and from those benefiting from the maintenance of the status quo, the approach had to be given emphasis on the fact that the intended energy recovery aims to be applied only tothe non-recyclable portion of the MSW, as designed in the ISWM method.

In conclusion, the creation of national associations and their effective performance in other countries in Latin America and other continents where WTE plants do not exist yet or where there is a certain stagnation, as it is the case with the United States, tends to leverage more WTE projects. With the effective use of ISWM in all political, institutional, and social spheres, it has become possible to seek the support of the society for the development of the best sustainable and integrated MSW management practices. The Brazilian example clearly corroborates the effectiveness of ISWM in this sense.

Conclusions

The generation of MSW has been a major problem and challenge for humanity, especially since the industrial revolution, when countries began to produce a multitude of consuming goods. This problem has worsened even more in recent years, with the increase in the production of non-durable and disposable items. Fortunately, technology has allowed to transform MSW into a valuable resource and an opportunity for the implementation of a circular economy in the world. ABREN WtERT Brazil's strategy applied successfully in Brazil includes aligning technology expertise with various political and social practices to be taken as crucial pillars for those who seek to make the energy and material recovery of the waste a reality.

The ISWM strategy has proved to be an excellent public policy tool to ensure effectiveness in sustainable waste management and in terms of environmental governance. In the Brazilian context, several obstacles still need to be removed for an adequate final destination of MSW, essentially due to the fact that Brazil sends 96.1% of its waste to landfills and almost nothing is sent to energy and material recovery processes. A huge energy potential is wasted; at the same time, it raises the risk of contamination of water resources and allows GHG emissions into the atmosphere. Important measures to significantly prevent climate change are expected and energy recovery from MSW has been shown to be one of the ways to fulfill the goals for mitigating global warming.

Assessing all aspects inherent to the waste management is not an easy task, but it is essential for the success of environmental management policies. Pursuing sustainable development is a must today and the inclusion of WTE plants in the circular economy is the only way to ensure effective treatment of the waste, avoiding contamination of natural resources. Moreover, it must be clear that landfilling does not compete with WTE because it is not a treatment alternative (landfilling), as it does not guarantee the accomplishment of circular economy at all. On the contrary, MSW burying is a risk to the protection of the environment and represents a liability to present and future generations. Landfilling has to be abandoned in the world as much as possible, reducing its use for disposal of refuse no longer treatable otherwise, that is, after worn-out all other possible recycling, biological and thermal treatment alternatives. This is the only way of eliminating the environmental externalities inherent to the putrefaction of organic waste underground, causing methane emissions and increasing global warming, such as that actually promoted by landfills and dumpsites.

With this, it can be concluded that the measures that must be adopted by all countries should be to encourage the implementation of WTE plants, which are sanitation facilities with the benefit of allowing energy generation at a short-distance from urban centers. They consists of thermoelectrical systems allowing to recover energy from the waste through a combustion process. WTE plants provide and adequate alternative for treating the waste as well as the generation of significant amounts of energy (electricity, steam and/or heat), managing to eliminate more than 95% of the MSW

mass that would otherwise cause environmental and health problems when disposed in landfills, including: (i) contamination of aquifer sources with leachate; (ii) GHG emissions into the atmosphere; (iii) use of huge areas near or within the cities; and (iv) need for a new landfill every 10 a or 20 a.

Whenever WTE is not adopted waste ends up being landfilled, which is the most primitive way of dealing with MSW and still used today by 80% of the global population. Even sanitary landfills present a major risk to the environment and humans, such as those resulting from leachate that contaminates surface and groundwater (through fissures) due to precipitation and earth movement, or else due to, as said, methane emissions into the atmosphere, hindering the achievement of the goals for combating global warming

ABREN's work reinforced by WtERT Brazil undertaken various governance practices, gathering important players in the field and within public and private institutions, enhancing education and knowledge on the subject throughout the country. The application of the ISWM strategy in the last three years in Brazil has shown great improvements. Namely, the Brazilian legal framework has started to change and national goals for increasing energy generation from WTE have been stablished. Public policies together with a comprehensive national movement including academia, private and public institutions towards an historic change to a better waste management system, especially with the use of energy recovery plants in the metropolitan regions, are in progress now in the country. The outcomes of such hard work include the development of the firsts WTE projects in progress, and greater substitution of fossil fuel by RDF in the manufacture of cement. Brazil will experience great outcomes in the upcoming years by the effective implementation of better sustainable and integrated waste management practices thanks to a collective effort initiated by ABREN WtERT Brazil, its members and supporters. The organization goals were developed and are based on the ISWM approach, which can also be adopted by other markets in South America and other countries which are struggling to make the WTE business thrive in a national context.

Declarations

Conflict of interest The authors do not have any conflict of interests with the members of the Editorial Board Members.

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