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INTERACTION BETWEEN WASTE MANAGEMENT AND ENERGY GENERATION SYSTEMS IN TERMS OF MATERIAL PROPERTIES AND ENVIRONMENTAL IMPACT IN THE EUROPEAN UNION

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ABSTRACT

This document is a product of my research on waste management structure in the European Union, focusing on Baltic countries precisely (Lithuania, Estonia and Latvia) [1]. Europe has experienced constant population growth from 1960 to 2020 (see Figure.1) [4, 5]. This continuous population growth and good lifestyle are significant factors for an increase in the energy consumption rate in Europe [6, 7]. High energy demands increase generated waste, which is why European countries need to develop a standard waste management structure to tackle this problem [10, 11].

According to my research, one of the most efficient ways of managing waste is to recycle and convert it into energy, such as electricity and fuel [12, 13]. This can be achieved by various waste treatment processes leading to energy generation. Moreover, recycling and refining waste are economically beneficial; this helps reduce waste by holding on to raw materials and resources reserved for an extended period before usage in production [14, 15].

This research paper reviews the correlation of energy-from-waste with the structural management of domestic solid waste. This study highlights divergent domestic waste management methods exercised in the Baltic countries and their economic impact [8, 9].

Keywords: Energy-from-waste, Anaerobic metabolism, Domestic Solid Waste, Waste Framework Directives, European Union, Waste Management, Landfilling waste, Packaging and Packaging Waste Directive.

Highlights

- To investigate and examine the energy production and waste management structures environmental impact in the European Union, focusing on the Baltic countries precisely.
- To review the procedure of the reuse of waste for energy production, likewise their contribution to the energy production system in the European Union.
- To evaluate the possibilities by which landfilled waste can be constantly used to generate energy and its environmental impact.
- To study the technological perspective of converting waste into valuable raw materials for energy production and its environmental impact.
- In reference to the listed tasks above, develop a technique that can provide an efficient waste management and energy production system.

1. INTRODUCTION

The waste management structure is crucial to our society and economy today. Many scientific pieces of research have shown that landfilled waste can be processed into biogas through an “anaerobic metabolism” [16]. Furthermore, incendiary destruction can be used in producing solid recuperate fuels, and organic materials derived from waste “biomass” can serve as an excellent renewable energy source [17].

Environmental-friendly raw material derived from landfilled waste benefits the economy and society [18]. These materials are more profitable because they lower energy and material costs in contrast to the derivation and production of such material in real nature [19].

European Union members have experienced constant population growth from 1960 to 2020, as outlined in Figure 1 [20].

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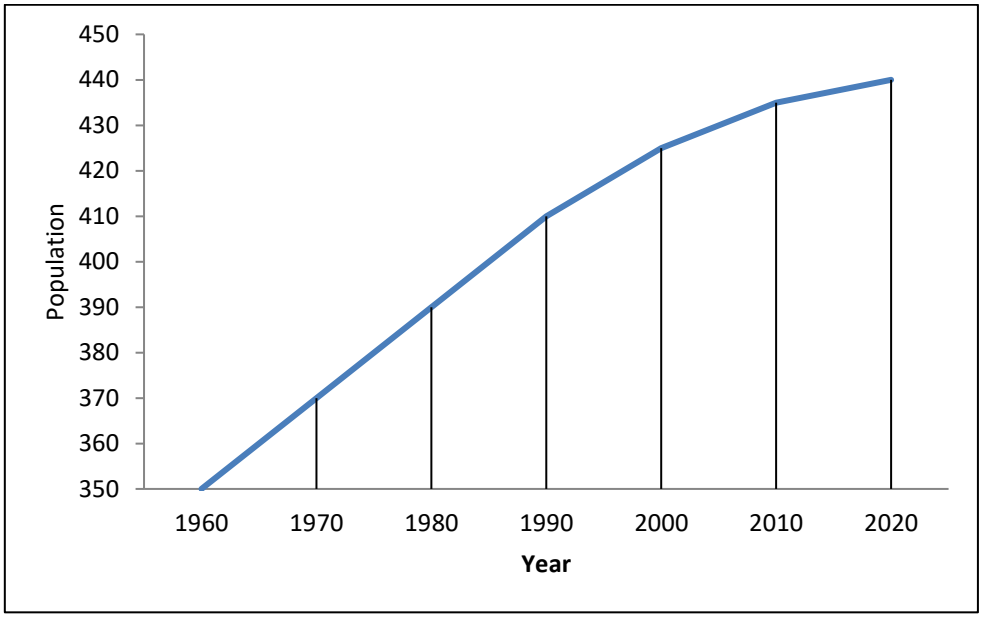

Figure 1. The European Union population, since 1960 till 2020

This continuous population growth and good lifestyle are significant factors for an increase in the rate of energy consumption in the European Union. [1]. According to my research, in 2020, the sum of waste generated in the European Union by commercial and household activities will be approximately 4812 kg per capita [2]. The fractional presentation of divergent commercial and household activities of generated waste in the European Union 2020 is outlined in Figure 2.

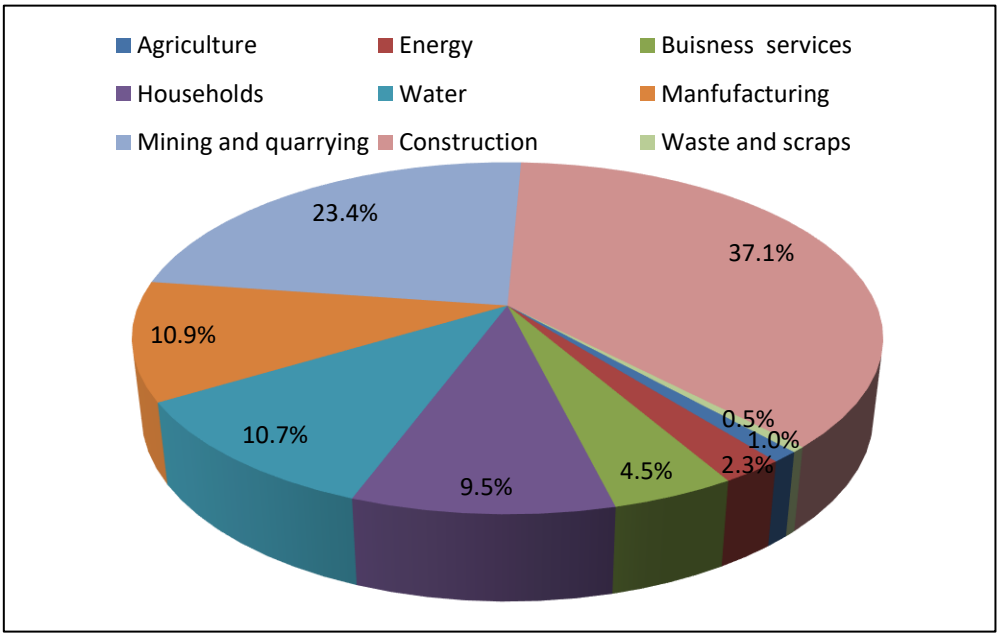

Figure 2. Waste products generated by commercial and household activities [1]

Finland is one of the European Union countries with the highest recorded value of generated waste, estimated at over 20.5 tons on average, this over four-time average (4.9 tons) waste generated per inhabitant of the European Union. Mineral wastes are composed of demolition [21], drilling, and mining and construction waste. Research has shown that in 2020, mineral waste was nearly 65% of waste generated in the European Union [1]. The amount of generated mineral waste varies across the European Union States [22], which may result from divergent commercial activities across the States. European Union States with a more significant fraction of mineral waste are considered to have carried out a lot of drilling and mining projects [23], evaluation and analyses of the generated waste are outlined in Figure 3.

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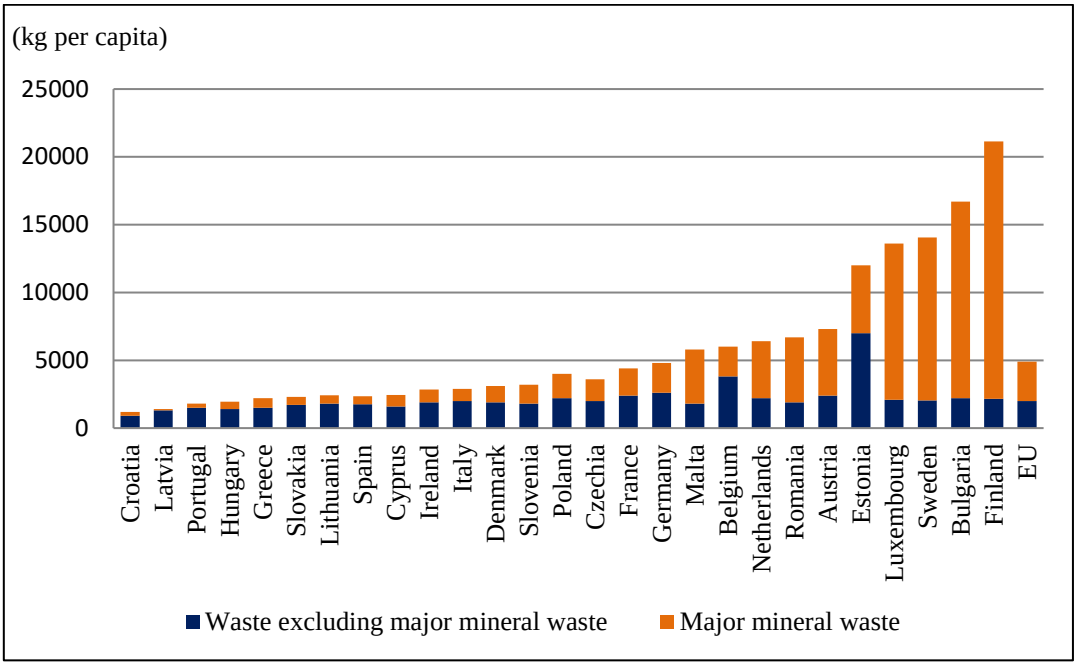

Figure 3. Waste generated in the European Union States, 2020 [1].

Keeping to the European Union solid waste management report, energy-from-waste, a form of renewable energy, will be one of the most suitable options to solve waste management challenges [24]. Education, gender, and pollution awareness are different criteria influencing waste management efficiency [2]. Citizens should be well educated about waste management procedures to actively participate in the process [25]. Introducing new policies and technology can sometimes be challenging for our society. Therefore, the government is responsible for educating its citizens with widespread information and mentorships. Waste management plays an urge role in human health and the environment, resulting in climate change, disease outbreaks, soil pollution, and air and water [2].

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2. METHODOLOGY

Generated wastes in the European Union have appreciated over the last decades in contempt of the existing waste management policies. An ineffectual waste-collection structure is a key factor influencing the recycling rate and its by-products [28]. According to reports, the illegal disposal of industrial and chemical pollutants that can cause environmental pollution needs to be better examined and considered [3].

The European Union Commission has evaluated precursory analysis of the implication of waste management, like reviewing the Waste Framework Directives [29]. Regarding these analyses in 2018, the European Union Commission implemented a systematic review of Industrial Emissions, Packaging Directives, Batteries Regulations and viable Eco-design product regulations. The European Union Commission is working towards the amendment of the Waste Frame Work Directives policy in 2023 [3]. This policy aims to ensure the general and viable management of industrial waste.

The European Union Commission aim to increase recycling and re-use of domestic waste by 65% in 2035. Concentrating on industrial waste, the Commission organized a workshop in 2020 to analyze obtainable principles of dealing with industrial waste. Moreover, the objectives of the Commission are to discuss and evaluate the most suitable methods for viable management of oil waste, collection of bio-waste, and waste prevention observation [30]. The outcome of the discussion and evaluation was finalized by the European Union Commission and European Economic Area [3].

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The concept of waste management in the European Union and its environmental impact

The European Union 2020 treated about 2030 million tons of waste, including imported wastes, but excludes the wastes exported from the European Union. The amount of waste transformed into energy [50], used for landfilling and recycled, grew to about 20% from 1110 million tons in 2010 to 1230 million tons in 2020, while the sum of waste disposal decreased over the years [1].

According to my research, domestic solid waste comprises different components, and some of these components can transform into a secondary raw material or a product. Waste Framework Directive Articles 6 (1) and (2) ruled out specific standards that should be considered during a waste recovery operation, and the idea of introducing waste recovery operation standards is to protect the environment and boost the economy [32].

Waste management strategies highlighted by the Waste Framework Directives are:

1. waste is required to be managed without causing environmental noise or odors;
2. waste is needed to be managed without endangering plants, soil, animals, air and water;
3. waste is needed to be managed without causing an environmental hazard or imperiling human health;
4. waste is required to be managed without affecting the public social lifestyle.

Hazardous waste is one of the most challenging risk factors to human health and its environment, thus, requires severe evaluation and control [33]. The Waste Framework Directives has established a strategy that investigates and keep account of waste generation to its disposal and recovery [3].

European Union standards regarding domestic solid waste management

According my research through published articles and papers, domestic solid waste management is regarded as waste from households and other channels like accommodation [26], food services, administration, health services, education and various activities which are related to nature [34]. In 2016 the European Union recorded, domestic solid waste only covers 10.5% of total waste generated. Notwithstanding, the local government needs to address this topic by empowering waste collection personnel and creating public awareness of the importance of domestic solid waste management [35]. 55% to 85% of domestic solid waste comes from households and the rest from commercial activities. Domestic solid wastes are complicated to recycle because they comprise plastic, wood, glass, batteries, oil wastes, paper, etc. [36].

Since domestic solid waste management is an important aspect of our society, the European Union has adopted peculiar legislation that ensures the recycling and re-use of domestic solid waste [37]. The domestic solid waste hierarchy is outlined in Figure 4.

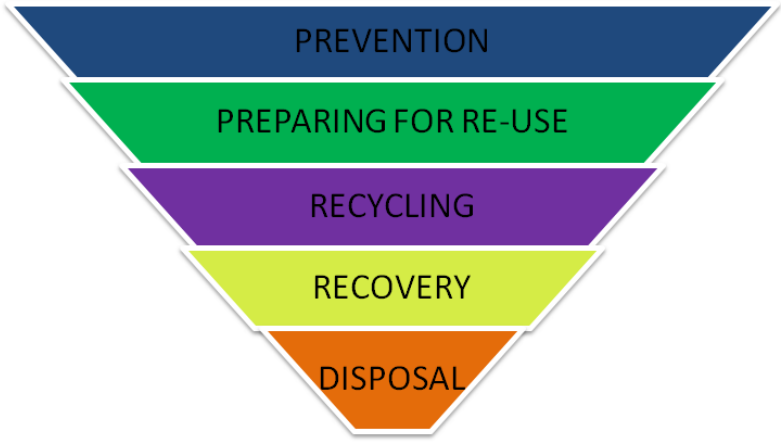

Figure 4. Domestic solid waste hierarchy

Waste Framework Directives 2008 revised version outlined protective measures for human health and it environment by ensuring the reduction of waste generated in the European Union States [38].

One of the laid down plans is to encourage separate collection of definite materials, thus simplifying the recycling process which will eventually improve the European Union economy.

In 2018 there is a revision to Packaging and Packaging Waste Directives which objectives to avoid the generation of packaging waste and its environmental influence [39, 59]. Furthermore, the European Commission endorsed the Circular Economy Package whose objective is to speed up the circular economy transaction by minimizing raw materials consumption and avoiding waste generation [40, 60]. The European Union legislative scheme for domestic solid waste management is outlined in Table 1.

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Table 1. The European Union legislative scheme for domestic solid waste management

Targets	2020	2025	2030	2035	Legislation
Hazardous waste		Set up separate collection schemes*			WFD
Bio-waste collection		Set up separate collection schemes**			WFD
Aluminum packaging recycling		50%	60%		PPWD
Domestic waste recycling	50%	55%	60%	65%	WFD
Ferrous metals packaging recycling		70%	80%		PPWD
Cardboard and Paper packaging recycling		75%	85%		PPWD
Glass packaging recycling		70%	75%		PPWD
Textile collection		Set up separate collection schemes			WFD
Domestic landfilling waste	Zero landfilling of separately collected waste			Maximum 10% of total generated waste	LD
Plastic bottles collection		77%	90%***		SUP

***Deadline is 2029, **Deadline 2023, *Deadline is 2022, Waste Framework Directive (WFD), Packaging and Packaging waste Directive (PPWD), Single-Use Plastic (SUP), Landfill Directive (LD).

Over the years, the European Union has established Strategies and Directives which oversee the legal interest of the State Members. European Member of States receives funding for domestic solid waste projects from European financial institutions like European project investment and reconstruction banks [41]. Waste management planning and regulation enforcement are mandates in ministries, regional administrative level and regional agencies across all the European States [42]. Municipalities and inter-municipality bodies are also responsible to ensure quality service for citizens through municipalities-owned waste management companies or by private companies through procurement. Across the European Union, different waste management bodies have been established to ensure quality domestic solid waste management services.

Structure of energy-from-waste processing technics

Multiple pieces of research have proven that poor domestic waste treatment can cause water, air and soil pollution. Therefore, the European Union has established legislation that will ensure the amount of biodegradable waste going into landfill is reduced by 55% in 2025 compared to 2000 [44].

Energy-from-waste is one of the factors that will boost waste reduction by transforming waste into renewable energy [43].

Energy-from-waste is a complex term that can describe different technologies and procedures. Transforming waste into energy benefits human health, the environment and our economy [45]. The scheme of energy-from-waste technologies regarding conversion processes is outlined in (Figure 5).

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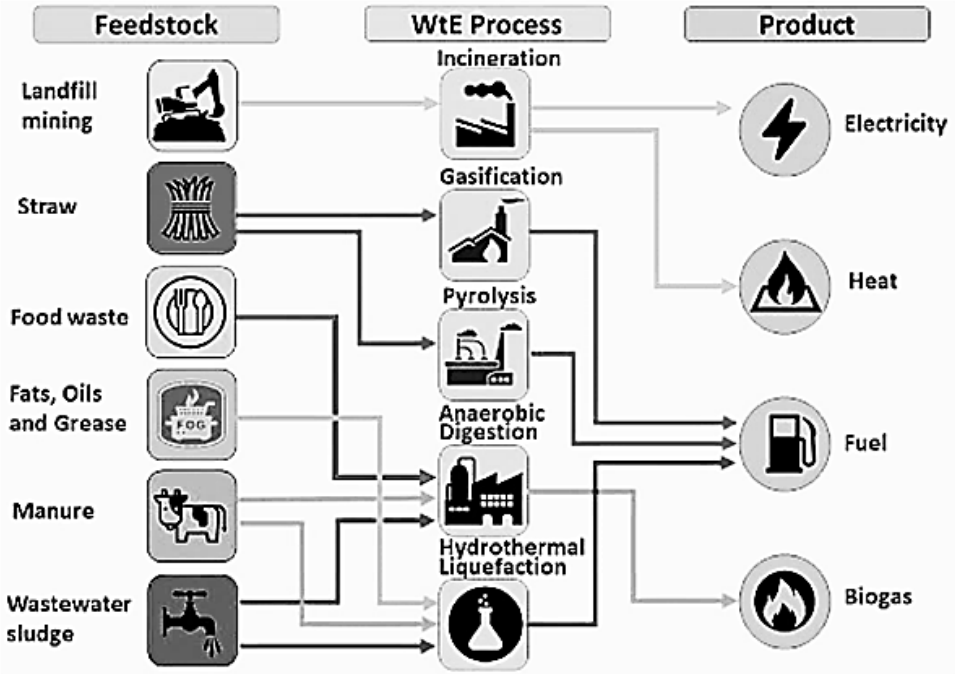

Figure 5. The scheme of energy-from-waste technologies in regards to conversion processes [51]

The suitable well-known technology to derive energy-from-waste is "Incineration". It is the absolute oxidation inside a waste stream of incendiary materials at a temperature over 850 °C (Figure 6) [46]. At temperatures between 500 to 1800 °C fragmental oxidation occurs, which decreases access to oxygen. During this process, syngas can congregate and be processed for various uses. One of the benefits of incineration is that it can be used to address different wastes.

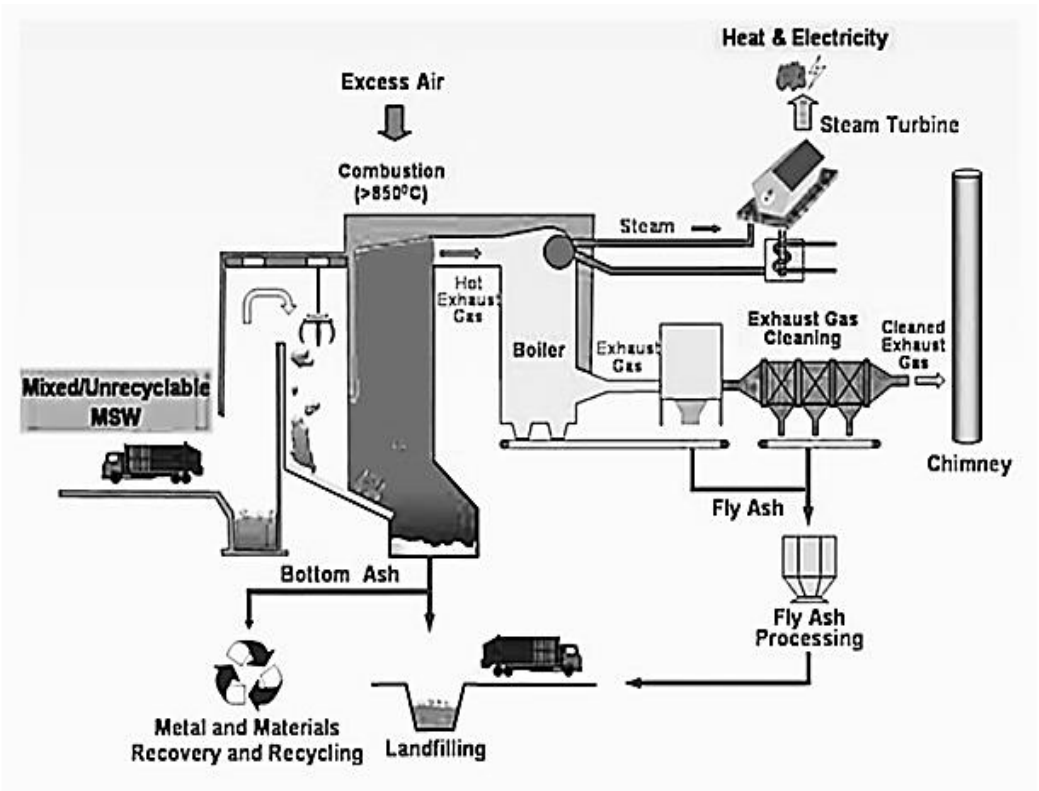

Figure 6. Energy-from-waste technological process [52]

Anaerobic metabolism is a unique process for attaining a circular economy, increasing bioenergy production and resource sustainability. The thermochemical conversion process by which bio-crude oil is obtained from biomass is called hydrothermal liquefaction [48]. Obtained bio-crude oil can be transformed into petroleum under the 4 to22 MPa pressure and at a temperature of 250 to 370 °C

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3. RESULTS

European Union's waste generation record was at its peak in 2020; approximately 170 million tons of manufacturing, 210 million tons of water service, and 195 million tons of household waste was recorded. Analyzing the data in (Table 2), in the gap between 2004-2020, the European Union households and water service waste appreciated by 180% and 12%, while manufacturing waste depreciated by 29%.

Table 2. Waste generated in the European Union disbarring extensive mineral waste product, 2004-2020 [1].

	2004	2006	2008	2010	2012	2014	2016	2018	2020	Change 2020/2004(%)
Households	174.1	179.2	181.6	186.0	180.7	175.9	181.4	186.1	195.9	12.5
Waste/water	75.1	83.3	98.9	129.9	155.0	180.7	196.9	208.5	211.0	180.4
Agriculture	62.3	56.7	45.5	20.2	20.4	17.7	19.7	19.4	20.9	-66.5
Mining and quarrying	10.4	7.1	10.0	7.9	7.5	7.7	6.9	8.1	7.5	-28.1
Manufacturing	239.9	225.8	216.8	190.5	176.4	175.9	178.9	180.0	170.7	-28.8
Construction	34.4	33.4	34.8	42.5	39.8	38.6	37.8	41.3	38.4	11.6
Energy	85.4	93.3	84.1	78.6	88.8	87.4	74.7	75.7	45.8	-46.4
Other sectors	97.7	111.2	88.8	102.3	88.9	85.1	88.5	94.1	90.6	-7.3
Total	**779.5**	**789.9**	**760.5**	**758.7**	**758.0**	**769.0**	**784.7**	**813.2**	**780.7**	**0.2**

Based on research analysis, the Baltic States (Lithuania, Estonia, and Latvia) in the space of 2005 to 2015 have overwhelming track records of waste recovery compared to other members of the European Union. Yearly, the significant amount of waste generated in the Baltic States has decreased [35, 49]. The waste statistics result shows that in 2014 amount of landfilled waste in Lithuania was nearly 80%, in Latvia 60% and in Estonia 8%. In 2014 Lithuania managed to reduce its waste disposal by 35% compared to the 2010 waste statistic result. After the Baltic States formally joined the European Union in 2004, a waste management system was established, which enabled the collection of waste separately for easy waste recovery [37, 49]. The Baltic States are among the nations that adopt waste incineration treatment methods [58]. The European Union, over the years, established two strategies for dealing with domestic solid waste; material recovery through incineration and material recovery through [8]. According to the 2015 European Union waste management report, Estonia generates a list of household waste compared to Lithuania and Latvia. Baltic State's domestic solid waste is below the European Union average of 476 kg/per capita [49].

Comparing the 2010 European Union waste statistic report to the recent 2020, Latvia takes the lead among the Baltic States in reducing generated waste, followed by Lithuania, while Estonia is the list (Figure 7). Despite all these waste management achievements in the Baltic States [49], there are plans to increase the efficiency of waste management systems across the States (Table 3).

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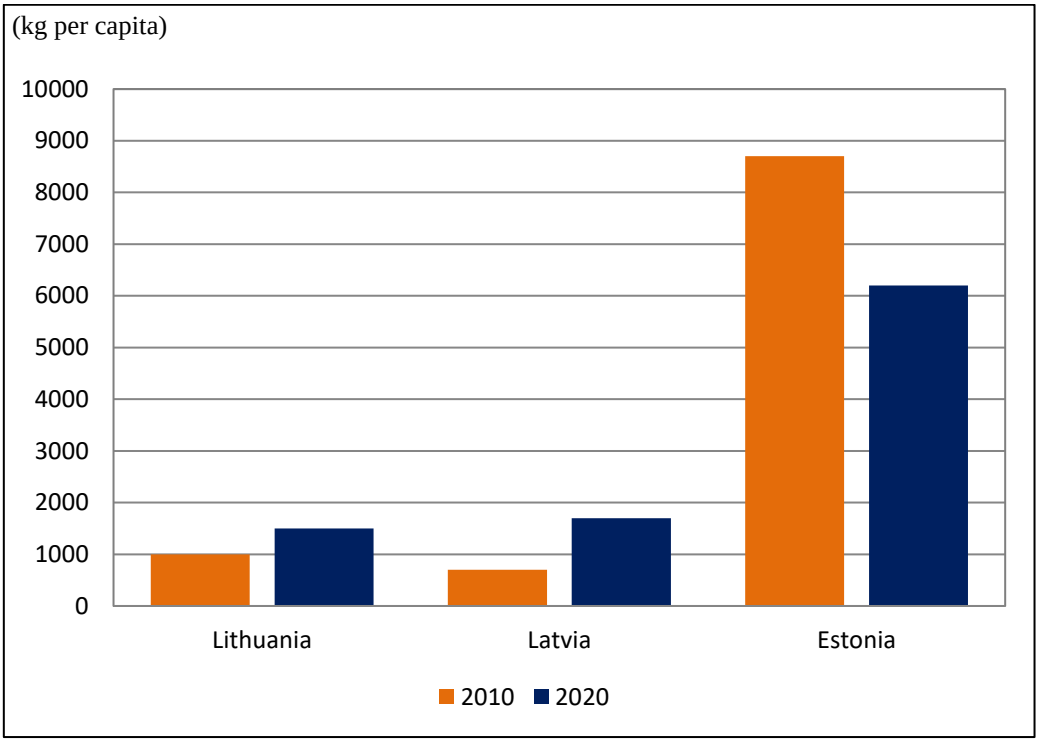

Figure 7. Baltic States waste generated reduction 2010-2020 [1]

Table 3. Baltic States future plans for waste management system

Baltic States	Plans for furniture waste	Plans for bio-waste		Plans for textile waste	Important Information
Estonia	x	✔		✔	According to European Union waste management publications, Estonia plans to upgrade its existing waste management system and reduce domestic solid wastes in 2023.
Latvia	✔	✔		✔	Latvian local governments in collaboration with waste management sector determine to prioritize separate collection of bio-degradable waste in 2023.
Lithuania	✔	✔		✔	- Lithuanian government has increased the number of containers for the collection of textile wastes. - Approximately €70 million European Union fund is allocated to waste recycling and re-use sector. - Lithuanian government is planning to provide urge waste collection site for citizen across municipalities to ensure proper collection of textile and furniture wastes by the of 2023

The Lithuanian government has amended its legislation on waste management taxes to make changes on recyclable and non-recyclable packaging tax and educate and encourage citizens to invest in waste management activities [8, 49]. Latvian and Estonian government have advanced their waste management system by preventing landfill waste and diverting European Union structural funds to eco-innovation and domestic waste management [9].

4. CONCLUSION

The European Union 2020 treated about 2030 million tons of waste, including imported wastes, but excludes the wastes exported from the European Union. The amount of waste transformed into energy, used for landfilling and recycled grew to about 20% from 1110 million tones 2010 to 1230 million tones 2020, while the sum of waste disposal decreased over the years [1, 50].

Considering waste management challenges in the European Union and the Baltic States, proper waste management regulation is one of the key factors that needs proper examination and consideration to run a waste-free economy [35, 57]. There is a need for urgent investment support for infrastructures and technologies that can enhance waste management. Municipalities across the European Union and the Baltic States need to create a monitoring establishment that can coordinate, standardize, regulate, and update databases on waste generation and management [49]. Provision of separate waste collection procedures and ensuring standard treatment technologies for each collected material sample is necessary.

Energy-from-waste has an urge role to play in the European Union waste management system [53, 54]; this means waste that cannot be recycled or prevented can be incinerated to produce heat and electricity, which can eventually be distributed to homes and industries [9, 46]. Energy-from-waste is one of the economically and environmentally safe methods of treating domestic waste.

Energy-from-waste plants can reduce landfilled waste by 85%, waste residue like metals can be refined, and sands residue can be used for road construction [8, 9].

The Baltic States have adopted the incinerated waste treatment method [55, 56], and many plans have been put in place to transform non-recyclable waste into energy. Latvia, Estonia and Lithuania are among the top countries in the European Union 2020 waste management report that successfully tackle waste management problems through the Energy-from-waste process [1].

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