TALLINN UNIVERSITY OF TECHNOLOGY

SCHOOL OF ENGINEERING

Environmental Engineering & Management

BUILDING INFORMATION MODELING FOR THE SUSTAINABLE CONSTRUCTION PRACTICES: ENERGY EFFICIENCY, RESOURCE OPTIMISATION, AND EFFICIENT FACILITY MANAGEMENT IN BUILDINGS.

JÄTKUSUUTLIKU EHITISE INFOMUDEL: ENERGIATÕHUSUS, RESSURSIKASUTUSE OPTIMEERIMINE JA HOONETE EHITUSELEMENTIDE HALDAMINE.

MASTER THESIS

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Tallinn 2021

(*On the reverse side of title page*)

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THESIS TASK

Student: MUHAMMAD FAIZAN (EABM195428)

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main specialty: Environmental Engineering & Management

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Thesis topic:

IN ENGLISH: Building Information Modeling For The Sustainable Construction Practices: Energy Efficiency, Resource Optimisation, And Efficient Facility Management In Buildings.

IN ESTONIAN: Jätkusuutliku Ehitise Infomudel: Energiatõhusus, Ressursikasutuse Optimeerimine Ja Hoonete Ehituselementide Haldamine.

Thesis main objectives:

1. To assess the Environmental and sustainability aspects of construction sector.
2. To evaluate effectiveness of Building information modeling tools for the sustainable construction practices.
3. To analyze household building sector of Estonia, and comparative analysis between the Baltic states regarding greenhoouse gas emissions, and energy consumptions from the residential sector.

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Literature review	February 2021
2.	Designing and circulating of the BIM survey questionnaire	March 2012
3.	Analysis of responses and finalising the thesis	May 2021

Language: English **Deadline for submission of thesis:** "......."........2021….a

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BIM	Building Information Modeling
AEC	Architecture, Engineering & Construction
GBC EESTI	Green Building Council Estonia
LEED	Leadership in Energy and Environmental Design
BREEAM	Building Research Establishment Environmental Assessment Method
Mt CO2	Millions of Tons of carbon dioxide

1. Introduction

Rapid growth in the Human population is surging demand for housing and enlargement of infrastructure. Accordingly, Increased demand leads the construction industry to grow rapidly on a universal scale[1]. In addition, Economic growth is driven by the infrastructure that increases productive capacity and adds value to the standard of life[2].

To meet the demand for infrastructure, the construction industry is undergoing steady expansion. The construction volume in Estonia has also been increased in the last two decades. According to the report from statistics Estonia, the volume was increased by 18% only in 2018 and the total cost of the construction activities was calculated to be around 3 billion euros. However, most of the dwellings were completed in Harju county mainly in the capital. Furthermore, in 2019 only In Tallinn about 1900 permits were issued for the construction of new dwellings, and it was 2% more than the previous year[3].

The Construction industry is a major driver for the economy. However, on the other side also a major contributor to carbon emissions[4]. Consequently, causing baneful impacts on the environment. The detrimental impacts of construction activities arise from all stages of the project. These impacts come from the beginning stage which includes site cleaning, throughout construction activities, operational phase, and even from the demolition phase, hence covering all the lifecycle impacts[4]. Furthermore, the main concern is global warming. According to the Environmental protection agency (EPA), the Construction sector is the third-largest sector which contributes more to the emissions of greenhouse gases with about 25% of all industry-related emissions. When considering the impacts on Environment; around 50% of greenhouse gases, 41% of waste in cities, and about 25% of air pollution is caused by the construction of residential or commercial dwellings[5]. In addition, the other important aspect is sustainability. According to the report by the world economic forum, the industry is also the largest consumer of natural resources, Natural resources are being used abundantly, and a lot of waste is being produced in the end by both construction and demolition, ultimately resulting in excessive consumption of non-renewable resources[6].

The idea of sustainable construction was developed in the 19th century however it started to progress in the early 20th century[7]. Several titles express the definition of sustainability in the construction sector such as green building, sustainable design, eco-friendly design, integrated design, and intelligent building. Although, there are several barriers to the implementation of sustainable construction practices. However, This study aims to identify environmental impacts of the construction sector, to analyze the effectiveness of Building Information modeling as a tool for sustainable construction processes. In addition, to identify the barriers in the adoption of BIM-based modeling both in Estonia and worldwide. Furthermore, to analyze green building certification activities in the Baltic region (Estonia, Latvia, and Lithuania). Lastly, comparative analysis will be done to analyze energy consumption and respective carbon emissions from the household sector in the Baltic countries.

2. Literature Review

2.1. Concept of sustainable development

The concept of sustainability came in the 18th century when Adam Smith, a famous economist, highlighted the matter of evolution, and later in the 19th century, Malthus a the famous classical economist also addressed the same concept, and highlighted the idea of sustainable development, while after that the importance of clean air, water, and renewable resources was emphasized by neoclassical economic theory [8], [9]. However, about 30 years ago in 1987, the modern concept was presented, Which is, Sustainability means fulfilling the demand of the present-day without compromising the needs of future generations [10].

2.1.1. Goals of Sustainable development

In 2015, Member states of the united nation came closer to address the agenda of Global goals, mainly known as the sustainable development goals (SDGs), The focus of SDGs goals is to ensure the protection of the planet, end penury, and make sure that all humans will be ensured peace and prosperity by 2030. There is a set of seventeen goals to address the economic, political, and environmental issues. However, Goal-11 is more relevant to this study, and it aims to make human settlements more resilient and safer.

According to the facts provided by the United nation, at present time, about three and half billion people are residing in cities, and it is expected that the number will grow steadily, and more than 60% of people will be living in urban areas by 2030, Even though urban areas occupy only 2% of Earth´s land, but on the other hand responsible for more energy consumption and carbon emissions[11]. Furthermore, increased urbanization also increasing the demand for utilities. Therefore, technological innovation and rapid actions are needed to balance the development with sustainable goals.

The concept of Sustainable development forecasts the continuous progress of society without compromising on today's standard of life. It is proposed that complete development be understood through the sustainable development paradigm, which strives for environmental management, corporate social responsibility, and economic solutions by abandoning the consumer society. According to this viewpoint, sustainable development consists of three constituents termed Environmental, Societal, and economic. Figure 1 is demonstrating the link between these parameters.

Figure 1. Parameters of Sustainability [12]

2.1.2. Environmental Sustainability

Ensuring future generations a better world in terms of balanced ecology and protected natural systems is termed environmental sustainability[13]. In addition, the sustainability of natural resources relies on their capability to resumption themselves. For instance, evaporation and precipitation in the water cycle. However, the important is to ensure the quality of this water cycle for future generations. In consequence, human activities such as wastewater, disturbance of ecology in natural water bodies due to agricultural pesticides disturb the sustainable water cycle. In one way, environmental sustainability means passing all those resources to future generations without destruction. Therefore, while consuming natural resources, it is essential to maintain their resumption level, and also to control the contamination[14]. The study conducted by Hoskara has highlighted the areas which require attention for achieving sustainability goals;

- Preservation of ancient and cultural surroundings.
- Ensuring less distress to the environment and habitats.
- Sustainable consumption of renewable resources.
- Concept of saving in case of non-renewable resources.
- Protection of the marine environment, and
- Conservation of diversity and aliveness on the planet[15].

2.1.3. Economic Sustainability

In today's modern economic model, It is considered that buying power of people determines the economic activity of certain societies, and thus assumed that the Gross national product (GNP) is the main contributor for the people. Considering this model, progress is relying on the extent of consumption and production of goods. But if we consider the environmental aspect, the aforesaid concept needs limitless resources. Nonetheless, according to reality, these resources are limited and they are reducing steadily due to the excessive utilization all across the globe. Contrastingly, this is not the only concern. The other concern is the generated waste and the associated impact of waste on the environment. Economical sustainability is one of the essential components of sustainable development. In addition, In the economic process, ecological susceptibilities should also be considered seriously, and therefore it is essential to set a balance between production-consumption[16].

According to the global urban development organization [17], sustainable Economic development has 4 major elements, which global urban development (GUD) describes as the Four Greens:

- **Green opportunities**- Expansion of markets and development of businesses by creating employment and income opportunities for sustainable development.
- **Green Savings**- Cost can be cut down by efficient use of renewable resources, by minimizing waste, and by promoting 3R's concept.
- **Green Places**- Building green infrastructure, and protecting the natural build environment for the communities.
- **Green Talent**- More investment and funds for the educational and research centers.

2.2. Sustainability in Construction Sector

People require many structures to sustain their lives during civilization. During the building, service, and maintenance of these facilities, as well as their decommissioning, they trigger a slew of environmental issues. Buildings, which use a lot of energy and natural resources, contribute to climate change by influencing the quality of air and water in cities[18]. Buildings use 45 percent of global energy and 50 percent of global water[19]. According to 2010 data, also When looking at environmental effects, buildings are responsible for 23 percent of air pollution, 50 percent of greenhouse gas production, 40 percent of water pollution, and 50 percent of solid waste in cities[20]. Changes in the application will significantly reduce the environmental issues caused by the construction industry. Aside from the most obvious or observable impact of industry on the environment, its socio-economic effects also have significant negative consequences[21].

The construction industry's heavy use of natural resources, solid and liquid wastes, and gas pollution at the end of construction and demolition operations have a substantial negative effect on the environment. Consumption of nonrenewable energy, depletion of ecological diversity, degradation of forest lands, loss of agricultural areas, contamination of air, water, and soil, deterioration of natural green areas, and global warming are just a few of the negative consequences.

Otherwise, lasting solutions to issues created by building sector operations are not identified, and conservation and economic development are not seen as feasible. In this stage, the concepts of "sustainable architecture" and "sustainable construction," which serve a comprehensive approach to the subject by deciding values, techniques, and methods, become prominent for solving environmental problems caused by dwellings.

2.3. Environmental impacts of Construction Sector

Any construction initiative meant to promote people's standard of living has both beneficial and detrimental effects. The construction project should be structured in such a way that it has the greatest positive effect on the economy and the minimal negative impact on the environment[22]. Early prediction of the environmental consequences of construction can help to promote the environmental performance of construction projects and civil works. The building is likely to damage the vulnerable ecosystem due to the negative effects of construction. This includes environmental scarcity, lack of ecological diversity due to raw material production, landfill issues due to waste generation, lower job productivity, detrimental human health due to inadequate indoor air quality, global warming, acid rain, and smog caused by pollution, and so on[23]. Ecosystems, natural capital, and societal impacts are the three categories of environmental impacts that need to be discussed[24].

2.3.1. Energy Use, Global Warming, and Climate Change

The Earth has warmed by around 0.5 degrees Celsius in the last century[25]. There is convincing proof that this is due to a rise in the amounts of specific trace greenhouse gas emissions. The most significant of these is carbon dioxide, which is emitted when fossil fuels are burned to generate electricity. Global energy consumption, as well as related carbon dioxide emissions, has been increasingly growing over the last few decades. The primary customers are the developed economies, which possess living conditions to which emerging economies strive. The effects of persistent increases in energy consumption are highly damaging. As means of having the issue under the balance, developing countries should boost their energy efficiency. Construction-related energy usage accounts for nearly half of all national energy consumption in the United Kingdom. The use of fossil-fuel-derived energy in the manufacturing of materials, during the construction period, and by the occupants or consumers of the building or structure during its lifespan produces large volumes of CO_2. Though it is not the main effect of the so-called greenhouse gas emissions, it is the most abundant. Changes in building methods may be expected as a result of these changes in the climate[26].

2.3.2. Resource depletion, waste, and recycling

The building industry consumes a lot of energy. Materials come from a variety of origins and vendors, and waste minimization is a special challenge. Although many of the items used are similar to most sites, the irregular nature of construction limits the practical scale of recycling. Besides that, considering the products' long existence, their subsequent destruction or reconstruction may generate substantial waste for landfill sites if not re-used.

Construction often has a significant environmental effect due to its energy use, which is both direct and reflected in the resources used. The vast majority of goods used require a significant amount of energy to move. Considering both direct and embodied energy into account, the building sector consumes about 4.5 percent of the national total. As a result of this energy usage, construction produces over 40 million tons of carbon dioxide, which causes global warming through the greenhouse effect[25]. Acid gases and nitrogen oxides (NO2) are formed as well, leading to acid rain and photochemical smog. The connections between water and energy are increasingly getting clearer. Energy generation needs a lot more water for cooling, and a shortage of water has also resulted in power outages where nuclear power plants have been closed amid drought conditions.

Large amounts of waste are generated during the construction period, but particularly at the end of a building's life. The building phase itself produces a large amount of pollution. Many of this waste can be avoided on-site, but ignorance of design specifications, inadequate content, measurements, late deviations, over-ordering, and other factors all add to waste[21].

2.3.3. Pollution and hazardous substances in the natural and built environment

There is a wide range of definitions of emissions: pollution from the built environment (sewage, waste, etc.), contamination from goods and products during manufacturing, pollution and dangers created by the storage and use of materials or by the site itself; and other buildings as well as practices relating to operations. The design and installation stages include material specification and the use of plants, procedures, and techniques. The majority often affect the natural ecosystem, whether on green fields or primarily planned sites. Any of these operations creates a threat of contaminants being incorporated into the atmosphere that may impact on-site staff, the neighborhood, or local land, water, and air quality. In the organizational process of production, similar impacts can arise.

Human beings spend nearly 90% of their time in buildings in the developing world. They are subject to a lot of contaminants because of the furnishing and finishes they use. Other activities that occur inside the building affect their physiological and psychological responses. Building architecture and construction are increasingly necessitating aggressive steps to ensure that residents' health and general well-being are maintained.

Since the consequences of a weak internal climate are long-term and, with a few exceptions, not immediately life-threatening, they are often ignored. Furthermore, the factors have not been precisely identified, so remedies are not apparent. In the United Kingdom, this has resulted in a refusal to take the problem seriously. Since there has been little study, there is confusion about the factors, and quantitative evidence is scarce.

2.3.4. Planning, Land-use, and conservation

There are many environmental concerns related to the relationship between land use, infrastructure, and the construction industry. Any project undertaken by the building industry necessitates the approval of a planning application.

Developments and resource mining for the building industry can seriously damage habitats on unique sites. To conserve biodiversity, nevertheless, a wide variety of nature conservation programs and area designations have been created.

Construction work has a substantial effect on transportation flows. Quarrying activities will put a significant strain on the local road network and neighboring uses. Furthermore, completed projects and their interactions with other land uses will affect travel proclivity and mode preference. These variables, in turn, may affect the amount of energy used, as well as the amount of pollution and emissions generated.

The interaction of the constructed and natural ecosystems has a direct influence on the hydrological system. The cumulative impact of urbanization and rural intensification has overwhelmed the land's ability to withstand unusually high amounts of rainfall. About the same time, because of global climate change, rainfall has become more extreme, localized, and unpredictable.

Construction-related energy use, covering both direct and indirect operations, is estimated to account for approximately half of the total national energy consumption[27]. Since the location of projects undertaken by the client and constructed by the construction industry is primarily governed by established planning processes, land use planning may contribute to energy consumption through the arrangement and location of buildings. Even then, legislation cannot guarantee the development's effectiveness in interacting with, and the acceptability of the way it modifies and communicates with, the underlying natural and built environment.

Although the above description provides a valuable context for discussing the problems, few of them can be regarded in isolation, and particular attention must be given to the various relationships and interdependencies that occur between:

- The media of air, water, and land.
- The internal and external environment.
- The effects of such actions on a local, international, and global scale.
- Behavioral changes and other secondary impacts.

Some of the interrelationships are presented in figure 2.

ISSUE	Energy use, global warming and climate change	Resources, waste and recycling	Pollution and Hazardous substances	Internal environment
Planning, land-use and conservation	• Transport implications • Sea level rise • Overheating • Increased UHI effect • Passive heating/cooling • Thermal standards for refurbished buildings • Urban form and configuration • Flooding • Biodiversity • Water quality	• Minerals extraction • Disposal of spoil • Recycling derelict land • Re-use of existing buildings • Resources used for major infrastructure projects	• Pollution effect of built environment • Waste disposal • Maintenance of environmental quality objectives • Ecosystem conservation • Biodiversity conservation • Contaminated land register • Estate maintenance • Pesticides etc.	• Orientation daylight and passive heating • Rn-222 • Electromagnetic radiation
Internal environment	• Energy use, heating, appliances etc. • Flooding • Thermal efficiency • Reduced ventilation rates/less occupant control	• Gas from recycled sites • Reduced off-gassing from recycled products	• Indoor pollution/ Off-gassing from materials • Effect on pollution levels of reduced ventilation rates • Smoking • Noise from external and Internal environment • External air quality • Rn-222 and landfill gases	
Pollution and hazardous substances	• Energy related greenhouse gases • Other greenhouse gases • Ozone depletion • Ozone creation • Acidification • Ecotoxicity • Wastes and pollution from power generation	• Pollution during manufacture • Waste production • Pollution of primary resource • Recycling contaminated land		
Resources, waste and recycling	• Energy in transport • Energy in recycling • Use of sustainable resources (e.g. timber)			

Figure 2. Interrelationships between the built environment and environmental issues[28].

2.4. Building Information modeling (BIM) in the Construction industry

Construction expenses, low-carbon footprints, environmentally sustainable constructions, greenhouses, social responsibility, natural ecologies, and healthcare are all challenges that the construction industry faces. BIM (Building Information Modeling) is among the ways to change the way projects are maintained, designed, and built.

2.4.1. Technology of BIM

A Building Information Model (BIM) is a 3D project model that connects architecture, planning, installation, and service, as seen in figure 3[29].

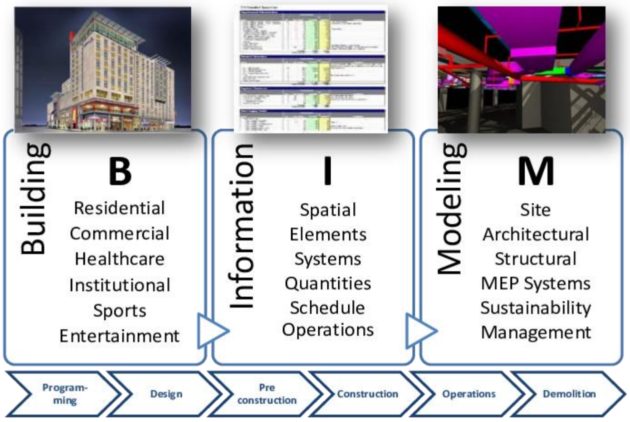

Figure 3. Schematic representation of BIM model.

The BIM methodology is composed of all three processes: control, direction, and project monitoring, and facilities management. The 4D, 5D, 6D, and 7D stage are core aspects of energy conservation, functional safety, and sustainability of buildings and infrastructure, the last two being crucial without ignoring the supervision or the control and the administration of building and future installation maintenance (See Table 1) [30].

Table 1. Dimensions, properties, and aspects to be developed in the Building Information Modeling.

Dimensions BIM	Properties	Developed aspects
2D	2D Basic Documentation	✓ Traditional two-dimensional (2D) plans Lines, planes images
3D	3D three-dimensional model	✓ Graphic documentation in three dimensions (3D) ✓ Special geometric information ✓ Objects with properties 3D ✓ visualization of the project
4D	Programming the Execution Plan (Deadlines)	✓ Simulation of Project phases ✓ Installations Simulation ✓ Design of the execution Plan
5D	Planning, Monitoring, and Cost Control	✓ Budget estimate of expenses ✓ Measurements of materials and labor ✓ Analysis of operating costs
6D	Sustainability and energy efficiency	✓ Energy analysis ✓ Envelope variations and interactions ✓ Analysis of simulations and energy-efficient and environmentally sustainable proposals
7D	Facility Management	✓ BIM Life Cycle Analysis (LCA) Strategies ✓ BIM as-built ✓ Building Operations and Maintenance Plan Model ✓ Logistical Control of the Project

2.4.2. Building Information Modeling and Sustainable construction practices

At the moment, sustainable development faces numerous challenges around the world, including the inability to organize total life-cycle data and perform data analysis to share with project partners[31]. BIM can retain and monitor data on energy use in building projects, as well as provide comprehensive workflow data during building projects. As a result, by using the BIM framework, users can conveniently import, extract, search, or turn content. BIM technology, by visual characteristics, can alleviate these constraints while still achieving energy-saving goals.

Many scholars have published several studies of construction projects, combining BIM with sustainability assessment methods, including potentially significant benefits in integrating BIM technology and construction sustainability. Numerous research articles on the convergence of BIM and sustainable development have been conducted over the last twenty years. Timothy (2018), for instance, examined the major obstacles experienced by construction stakeholders in their efforts to incorporate BIM and sustainable activities into building projects. The three major hindrances are market reluctance to transition from conventional working methods, a lengthy cycle of adaptation to new technology, and a lack of knowledge of the systems and workflows needed for BIM and sustainability[32]. Gao (2019) conducted a study on the application of BIM technologies and the building energy model, which was used during the design process of energy-efficient buildings[33]. The building energy model, which was used during the design process of energy-efficient buildings. Kota (2014) focused on using BIM technology with a day-lighting simulation in sustainable construction and measured performance based on a simulation study with BIM technology in sustainable construction[34]. Lu (2017) examined the use of BIM for sustainable development over the life cycle of a building project[35]. Antwi (2017) researched the understanding of actual implementations of BIM technology in sustainable building from the standpoint of sustainable design and discovered that the BIM application can save construction costs while increasing productivity level[36].

2.4.3. Building Information Modeling (BIM) and Energy efficiency

Building construction has been significantly influenced by the rise of global environmental issues, as well as the development in analytical technologies and methods. Building developers are constantly being pushed to improve their design's energy efficiency. Multidisciplinary simulation-based optimization can be used to assist designers in finding further design options and making educated decisions to reach a high degree of energy efficiency. Since setting up a building model for multi-objective design optimization is so complicated, there is a strong demand for innovative modeling and simulation tools, such as BIM, to be used and integrated[37].

BIM-based Building Performance Analysis (BPA) offers a helpful way to reduce the amount of data needed for simulation software while still ensuring the data is delivered consistently through multiple modelers. Under the BIM model, information including zoning, design, internal load, and schedule for thermal efficiency and energy analysis could be conveniently described[38].

Autodesk Revit's daylighting rendering offers an excellent lighting visualization for a general comprehension of interior lighting without the use of artificial lighting. As a result, the distribution of electric lighting will be configured to help the dark areas where there is inadequate lighting efficiently and reasonably [38].

A case study was conducted by Francisco and others, where they applied BIM methodology to Hospital Building and analyzed energy consumption considering Interior Lighting and Daylight. The Building is a Diagnoses and Treatment center, and it is in Jaén, Spain. The Figure 4 gives the general view of the exterior of the hospital building.

Figure 4. General View of the Hospital[39].

The case study analyzed different energy improvement options, and the options were analyzed individually and jointly, utilizing BIM-based simulation tools. Based on the application of different options, the results are presented below figure 5.

Improvement	**Scenario Name**	**Consumption (kWh/(m^2 year)).**	**Energy Saving (kWh/(m^2 year)).**
Existing building	*Existing building*	*259.11*	-
Air conditioning system	HVAC	198.02	61.09
LED Lighting system	LED Lighting	232.31	26.8
Windows glass	Window Glass	250.45	8.66
Lighting control system	Daylighting and Occ.C.	252.16	6.95
Efficient electrical power	Plug Load	244.57	14.54
Photovoltaic panels	PV—Panels	241.10	18.01
Simulated global improvement	**Energy Saving Package**	**138.17**	**120.94**

Figure 5. Results achieved from different energy-saving options[39].

The Above table illustrates the energy consumption of the existing hospital building. And in the next rows, all the improvements are mentioned along with their energy requirements. With the proposed improvement it was observed that 47% of energy-saving was found as compared to the existing energy demand, i.e., reducing consumption from a

50 years-old hospital, with the consequent minimization in carbon emissions, which translates into more sustainable buildings[39]. The below graph in figure 6 shows the results.

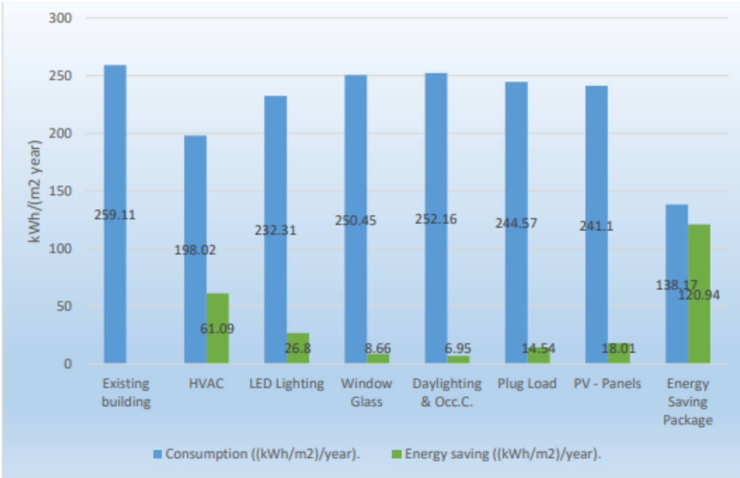

Figure 6. Graph with different scenarios analyzed in building[39].

Building Information Modeling (BIM) improves building and construction performance. The multi-dimensional and interdisciplinary features demonstrate a new pre-estimation and coordination concept for AEC project execution and management. BIM provides groundbreaking modeling and animation techniques for the entire lifecycle, from planning to final process and management, in comparison to traditional 2D drawing methods. Its reliable and stable production not only means a reduction in project waste and energy savings during the construction process, but it also means long-term operation and management with high energy efficiency[38].

2.4.4. Building Energy Performance Certifications

Energy efficiency certification allows individual buildings – whether private, industrial, or public – to be rated for how effective (or inefficient) they are in comparison to the amount of energy used to provide consumers with desired levels of quality and functionality[40]. Several parameters determine the degree of efficiency in the buildings including; Design specifications in building, climate conditions, construction techniques, sourcing of materials, heating, ventilation, cooling, and all those requirements which support the functions of the dwelling[40]. Certification considers a building´s components and analyzes them individually rather than just considering it the sum of different components[40]. However, Building energy certification normally consists of three main stages: The analysis of the energy performance of a building, rating of building energy performance and issuance of a certificate, and coordination with stakeholders by publishing certificate.

Globally there are different actions taken regarding the recognization of the energy performance of the buildings. However, the EU proposed the energy performance directive

(EPBD) in 2002, and member states were provided time till 2006 to transpose these requirements in their national policies. Energy performance building Directive (EPBD) has four main sets of requirements;

- A common model for analyzing the energy efficiency of buildings.
- Minimum energy standards for newly constructed dwellings and also for the buildings that need substantial rehabilitation.
- Development of systems for the certification of newly constructed and existing buildings.
- Regular Inspection of building operating units (Air-conditioning, ventilation, and heating) and their regular upgradation[40].

However, this study will analyze LEEDS, BREAM certified projects in Estonia, and the Baltics. The overview of the mentioned certifications will be presented in the following section;

2.4.4.1. LEEDS

LEED (Leadership in Energy and Environmental Design) is the world's most common eco-building ranking system. LEED, which is accessible for almost all building forms, offers a platform for sustainable, fully efficient, and cost-effective sustainable building[41]. Furthermore, LEED provides the following building certifications;

1) Green Classroom Professional
2) TRUE advisor (GBCI)
3) EDGE Expert (GBCI)
4) Parksmart Advisor (GBCI)
5) Green Rater

In addition, LEED certification is globally recognized for high performance green buildings. There are about 52,329 LEED certified activities worldwilde[41]. The below figure 7 provides the overview of LEED certification activities.

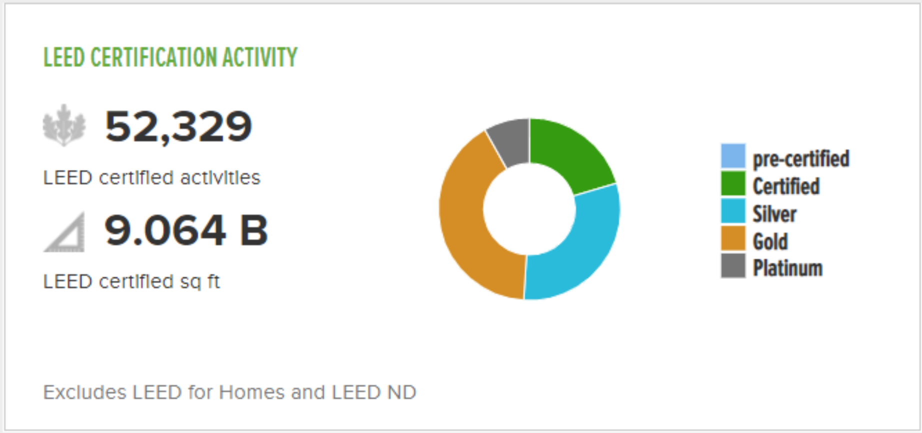

Figure 7. LEED Certified activities[42].

2.4.4.1.1. *LEED Activities in Estonia*

In addition, The below figure gives an overview of LEED Certified activities in Estonia. As shown in below figure 8, there are 29 LEED-certified activities in Estonia which cover around 3.102 M LEED-certified sq ft. Furthermore, Figure 9 gives an overview of cumulative activity count by the year for Estonia. Lastly, figure 10 gives the overview of Project certifications at buildings, and it can be seen that about 56% of activities are for newly designed and construction activities and about 43% are for existing Buildings retrofit.

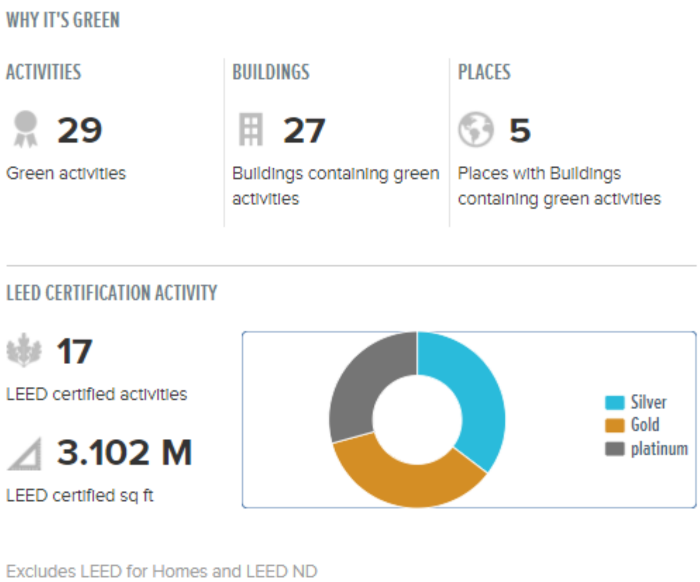

Figure 8. LEED Certified activities in Estonia[43].

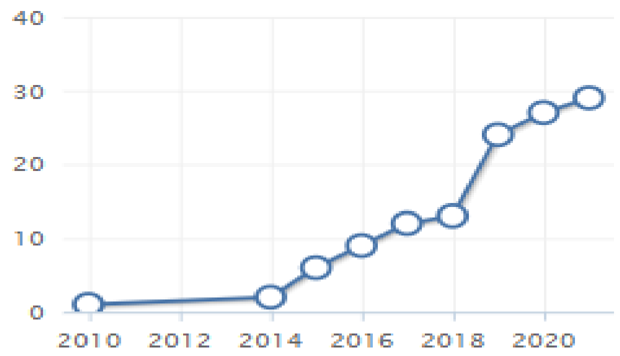

Figure 9. Commulative activity count by year[43].

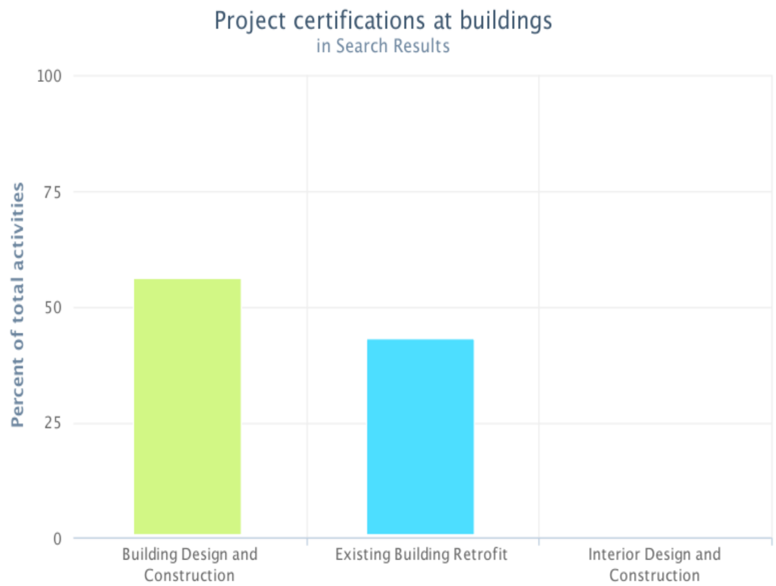

Figure 10. Project Certifications at buildings in Estonia[43].

2.4.4.1.2. LEED Activities in Latvia

This section provides an overview of LEED certification in Latvia. The below data in figure 11 shows that there are 12 Green activities in Latvia spaning over 11 buildings which cover around 502.992 sq ft area. Furthermore, Figure 12 gives the overview of cumulative activity count by the year for Latvia. Lastly, figure 13 gives the overview of Project certifications at buildings, and it can be seen that about 66% of activities are for newly designed and construction activities and about 33% are for existing Buildings retrofit.

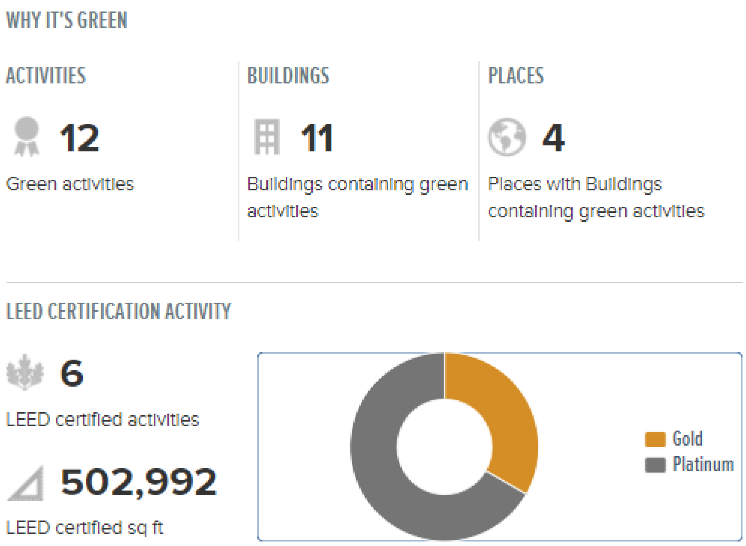

Figure 11. LEED Certified activities in Latvia[44].

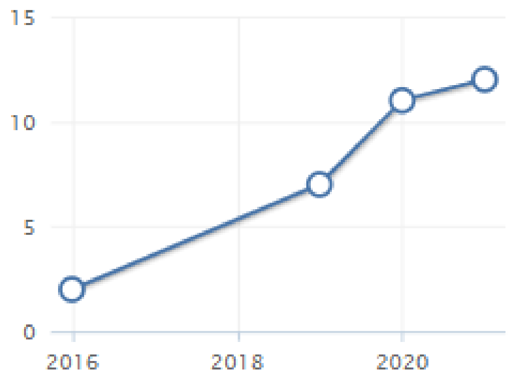

Figure 12. Coomulative activity count in Latvia by year[44].

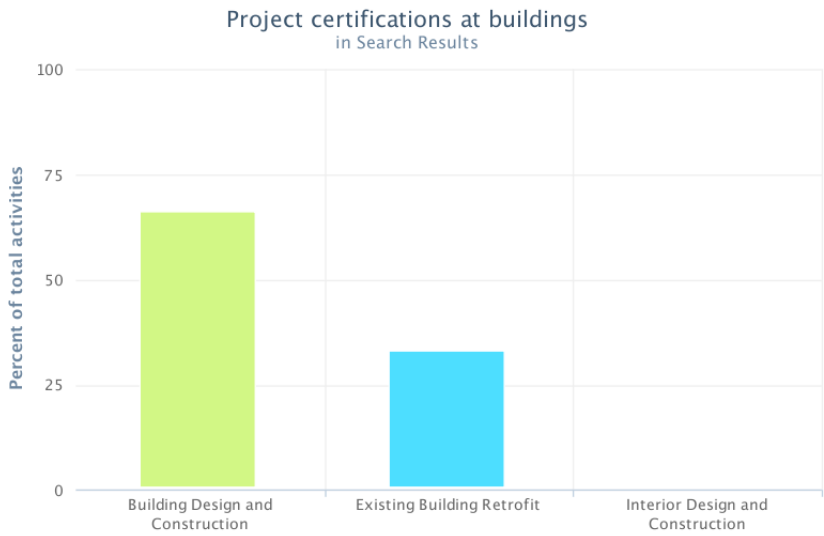

Figure 13 Project certification at Buildings in Latvia[44].

2.4.4.1.3. LEED Activities in Lithuania

This section provides an overview of LEED certification in Lithuania. The below data in figure 14 shows that there are 18 Green activities in Latvia spaning over 17 buildings which cover around 2.436M sq ft area. Furthermore, Figure 15 gives an overview of cumulative activity count by the year for Lithuania. Lastly, figure 16 gives the overview of Project certifications at buildings, and it can be seen that about 38% of activities are for newly designed and construction activities and about 61% are for existing Buildings retrofit.

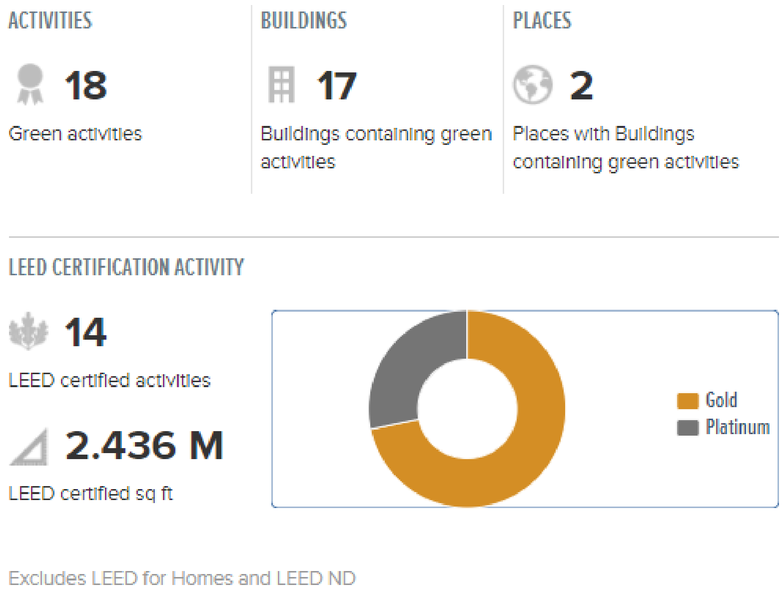

Figure 14. LEED certified activities in Lithuania[44].

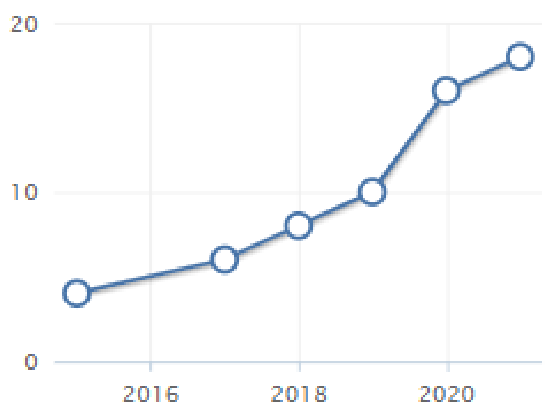

Figure 15. Coomulative activity count in Lithuania by year[44].

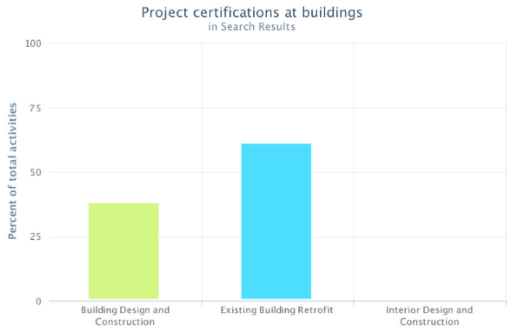

Figure 16. Project certification at Buildings in Lithuania[44].

2.4.4.2. BREEAM

BREEAM (Building Research Establishment Environmental Assessment Method) is an international certification scheme that offers impartial third-party certification of the environmental performance of individual buildings, municipalities, and public works projects[45]. BREEAM assesses long-term efficiency in a variety of categories ranging from energy to biodiversity[45]. Any of these categories covers the most important considerations, such as low impact construction and carbon emissions reduction; design resilience and adaptability; climate change adaptation; and ecological benefit and biodiversity conservation. The main of BREEAM certification is a six-star rating system, and it presents the performance of the project and its stakeholders[45].

BREEAM is spread over 89 countries, has provided over 594,011 certificates, and there are about 2.3 Million registered buildings. The below figure 17 gives the overview of BREEAM certifications, and it can be seen that more certified assessments exist in the EU region.

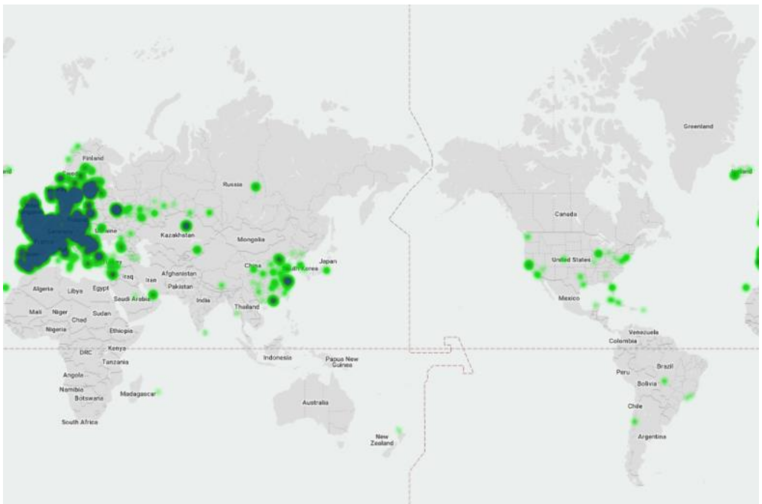

Figure 17. BREEAM certified assessments (Global)[46].

2.4.4.2.1. BREEAM Activities in Estonia

There are 13 certification schemes in Estonia for 12 different buildings which are certified by BREEAM. However, 10 buildings are from Tallinn and the rest two are located in Loo. Furthermore, Kaubanduskeskus Rocca al Mare is a highly scored BREEAM building in Estonia with an overall score of 64.50%. The below table 2 presents the BREEAM certified projects in Estonia[46].

Table 2. BREEAM Certified Buildings in Estonia[46].

S.no	Building/ Assest name	Score	Rating	Town
1	Aiandi 13	56.00%	Very Good	Tallinn
2	Akadeemia tee 15B	56.90%	Very Good	Tallinn
3	City Plaza	25.20%	Pass	Tallinn
4	City Plaza	42.60%	Good	Tallinn
5	Hilton Tallinn Park	56.10%	Very Good	Tallinn
6	Kadrioru Ärikeskus	37.00%	Pass	Tallinn
7	Kaubanduskeskus Rocca al Mare	64.50%	Very Good	Tallinn
8	Lasnamäe Bauhof	56.20%	Very Good	Tallinn
9	Metro Plaza	56.20%	Very Good	Tallinn
10	Niidu tee 1	49.50%	Good	Loo
11	Niidu tee 3	50.40%	Good	Loo
12	Sõpruse Ärimaja	56.80%	Very Good	Tallinn
13	Ülemiste Shopping Center	52.90%	Good	Tallinn

2.4.4.2.2. BREEAM Activities in Latvia and Lithuania

There are 25 certification schemes in Latvia for 19 different buildings which are certified by BREEAM. However, There are 64 certification schemes in Lithuania for about 40 buildings that are certified by BREEAM[46].

Furthermore, the sustainability assessment conducted by Laura, Irene, and others focused on new residential projects in the Baltic region. For which nine new residential projects were selected for the sustainability assessment-Three dwellings from each capital of Latvia, Lithuania, and Estonia. Furthermore, the study conducted three different sustainability dimensions which included- Environmental, Social, and economic sustainability dimensions. Buildings were named from A1-A9 (Where A1-A3= Lithuania, A4-A5= Latvia, and A7-A9= Estonia). The study revealed that among all nine projects no project was leading in all sustainability aspects, each project, however, has its strengths[47]. Overall, the SAW approach showed that the Estonian project A9 (Meerhof 2.0) held the highest ranking in all aspects of sustainability. Furthermore, Estonian Project A8 (Vibu 4/2) held 3rd place[47]. However, the study concluded that sustainability analysis should consider all the aspects of sustainability i.e., Environmental, social, and economical[47]. It was also added that there should be multi-criteria assessments as currently used tools only focuses on environmental aspects. The below figure 18 gives an overview of the sustainability rankings of chosen projects.

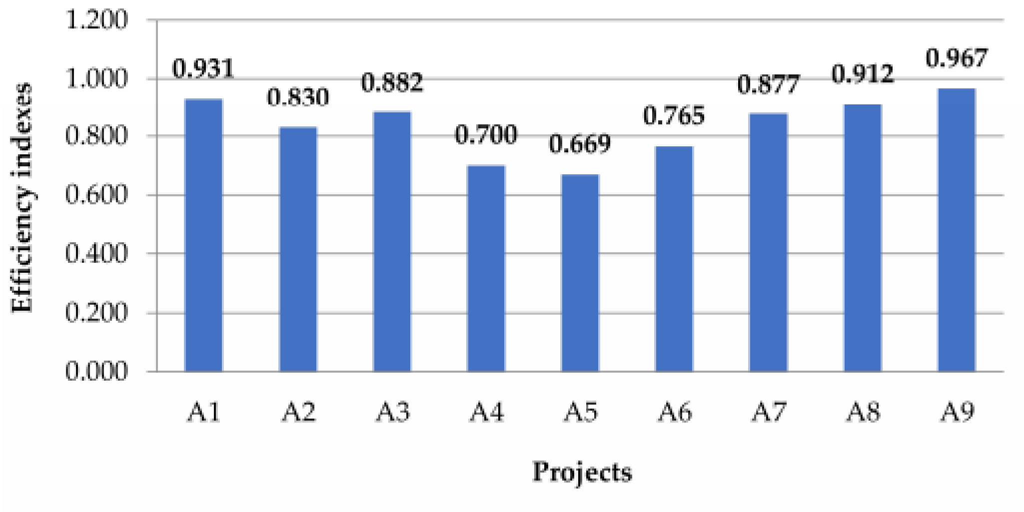

Figure 18. Overall Sustainability ranking of the Projects[47].

Furthermore, there is a concern that green building certifications can be expensive. However, statistics presented by the Estonian green building council show that certified buildings have a higher sales demand, better staff productivity, lesser communal expenses, and an eco-friendly environment. Furthermore, it is stated that if the mechanism is properly executed, Lifecycle costs can often be much lower. Since certification increases the design and maintenance process, construction costs can be lower or slightly higher, based on the building owner's preferences and the extent of modifications. Lastly, to support the claims GBC Eesti presents the data of certified projects in the below table 3.

Table 3 Green building benefits (Estonian buildings case studies[48].

Project	***Certification***	***Cost during design and construction.***	***Property Value***	***Operational Cost savings (15 years)***	***Net gain (+) or loss (-)***
Adamsoni 27	NQS Eesti Breeam NC 2013	€ 11,220 € 19,870	€ 62,170	€ 17,111	€ 48,191
Ulemiste retail centre	Breeam 2009	+0,85% total	€2,140,000*		+€1,840,000*
Navigator offices	Leed	+3% total			
Estonian Opera House	Breeam (In Use)	€ 3,900			
Estonian National Library	Breeam (In Use)	€ 4,200			
TM8 Commercial	Breeam (In Use)	€ 3,750	+€42,000*		+€38,250*

Furthermore, the Green Building Council (GBI) also presented the benefits of green building certifications from statistics and studies, The below table 4 summarizes the data.

Table 4 Benefits of Green Building Certifications[48].

Benefit	***Percent (%) Increase***	***Percent (%) Decrease***
Sales value	21%	
Staff Sick Days Per year		2.88
Energy Usage		50%
Water Usage		40%
Waste		70%
Rental income	18%	
Staff Productivity	7%	
Water Usage		35%

2.5. Building Information modeling and resource efficiency

Building materials have usually been sourced from raw material supplies that are comparatively abundant and unlikely to be depleted soon. However, raw material extraction and quarrying may have negative environmental consequences such as ground and grasslands disruption, as well as pollution. In addition, several materials need careful attention. Modern building materials like steel, aluminum, and polymeric materials require extensive extraction and processing techniques, which have environmental consequences. Building materials account for roughly half of all materials used worldwide, as well as a similar proportion of all waste produced[49].

Pullen and others reviewed case studies and identified the ways to minimize the consumption of resources in the design and construction of buildings. Furthermore, presented the hierarchy of actions to reduce the consumption of materials. The below figure 19 presents the hierarchy.

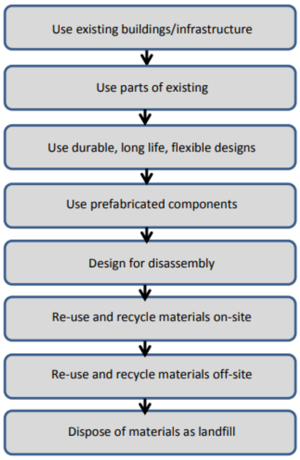

Figure 19. Hierarchy for minimizing the impact of resources in construction[49].

If we consider the above hierarchy and current BIM applications then there are several actions that can be supported by the application of BIM for sustainable construction.

There are major advantages in the project construction process by using BIM in 4D and 5D. Through synchronizing the building schedule with design templates, early coordination between the design and construction teams can be achieved, allowing faults to be found before construction and reducing the rate of rework. Due to the removal of rework, massive labor infrastructure, materials, and energy consumption may be reduced, resulting in significant cost savings. In addition, sourcing and execution of project resources will be coordinated with the concept model and development process to promote LEAN building techniques[38].

2.6. Building Information modeling and facility management in buildings

The use of BIM technology in the operational phase of a building’s lifecycle is taking hold as building owners look for potential opportunities to take advantage of BIM and increase the efficiency of their facility's activities. Following the success of BIM in design and construction, there is increasing interest in how the digital asset knowledge contained in building models from design and construct programs can be better used throughout the building's operating life.

Ammar evaluated the application of BIM ongoing building operations throughout a Building`s lifecycle. Furthermore, the case study was done on James cook university's biosecurity building (Townsville, Queensland, Australia). All new building schemes at the university have been designed, constructed, and operated using BIM[50].

JCU recognized the need for a BIM-enabled architecture and continuous data management process after starting with a CAD/paper-based project management and handover process. JCU took care of data from the design production stage to handover by implementing new technology, systems, and specifications, ensuring that they had access to the data they wanted, where they needed it, and in a format, they could use[50].

The University used the improved availability of space data to boost operating efficiencies and rationalize the University's constructed footprint at the operations level[50].

At James Cook University, the use of BIM to promote asset management has had a huge effect. The ability to create visualizations within the framework of the university has enhanced overall interaction with the University population, although greater collaboration between disciplines has resulted in fewer delays[50]. In addition, The most significant improvement, as a result of the case study data collection and review, has been in operations, where increased visibility of building asset data has simplified operations, vastly improved data quality among operating units, and helped foster understanding of FM activities within the campus[50]. The technologies of BIM have been adopted by James Cook University to strengthen organizational decision-making and strategy activities. The University's 10-year growth plans, "Strategic Asset Management Strategy," "Activity-Based Cost Modeling," and numerous space rationalization programs have all benefited from BIM results[50].

Figure 20. James Cook University Biosecurity Building[50].

2.7. Household Energy Consumption in the Baltic Region

The scope of the study also involves a comparative analysis of household energy consumption in the Baltic region: Estonia, Latvia, and Lithuania. The below tables (4-6) show the energy data of baltic states sector-wise. The data is taken from the EU website, and it covers from 2010 to 2019.

The overall data for all baltic states shows that there is not much difference in terms of household (%) share in beginning in 2010. However, the tables show that there´s an almost continuous decrease in a percent (%) share for all three states. But the trend for Latvia and Lithuania shows that the percent share for the household sector is declining. However, for Estonia, it is increased by almost 1% for 2019 as compared to the previous year (2018). Lastly, as can be seen, the percent household share for Estonia (33.6%) is higher in 2019, as compared to Latvia and Lithuania (26.5% and 30.2%, respectively). Tables 5-7 gives the overview;

Table 5. Energy by Sector (%) Data of Estonia[51].

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Final Energy by sector [%]										
Industry	20.0%	21.7%	20.2%	22.6%	20.0%	19.5%	16.4%	16.5%	16.9%	16.4%
Transport	26.2%	26.7%	26.7%	26.0%	26.7%	27.6%	27.8%	28.6%	28.8%	29.4%
Households	35.7%	33.4%	34.2%	32.8%	32.0%	31.2%	33.3%	33.5%	32.6%	33.6%
Services	14.8%	14.4%	14.9%	14.7%	16.5%	16.9%	17.8%	16.6%	17.0%	16.5%
Agriculture and Fishing	3.3%	3.9%	3.9%	3.9%	4.7%	4.8%	4.7%	4.7%	4.3%	4.0%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%

Table 6. Energy by Sector (%) Data of Lithuania[51].

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Final Energy by sector [%]										
Industry	20.0%	21.4%	22.1%	22.0%	21.5%	20.6%	19.8%	20.4%	20.2%	20.4%
Transport	31.5%	31.4%	31.2%	31.9%	34.6%	36.6%	37.3%	37.4%	38.1%	39.4%
Households	33.5%	32.4%	31.7%	31.1%	29.2%	28.4%	28.6%	27.8%	27.7%	26.5%
Services	12.6%	12.4%	12.6%	12.6%	12.2%	12.0%	12.0%	12.1%	11.9%	11.5%
Agriculture and Fishing	2.3%	2.3%	2.3%	2.3%	2.2%	2.1%	2.1%	2.1%	2.0%	2.1%
Other	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.2%	0.2%	0.1%	0.2%

Table 7. Energy by Sector (%) Data of Latvia[51].

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Final Energy by sector [%]										
Industry	19.3%	19.9%	21.2%	20.6%	21.0%	21.4%	20.3%	20.5%	22.3%	21.7%
Transport	27.1%	25.7%	23.8%	25.2%	26.0%	28.2%	28.0%	27.9%	27.5%	28.1%
Households	34.7%	35.4%	35.2%	34.0%	32.8%	30.0%	30.9%	30.9%	30.6%	30.2%
Services	14.9%	14.8%	15.9%	16.1%	16.1%	15.9%	16.0%	15.7%	14.7%	14.5%
Agriculture and Fishing	3.9%	4.1%	3.8%	4.2%	4.1%	4.4%	4.8%	5.0%	4.7%	5.3%
Other	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%

2.8. Greenhouse gas emissions from residential sector in Baltics

Similarly, emissions from the household sector in Baltic states are reviewed in this study. As seen in the below table, it can be observed Greenhouse gas emissions (Mt CO2) from the residential sector in the Baltic region. The data is taken from the EU website, and it covers from 2009 to 2018 (10 Years). In addition, as can be seen below table 7 that from 2009, there were more emissions in Latvia and Lithuania, and till the end of 2018, they have increased slightly. However, for Estonia, the trend is different and a slight decline can be seen for the year 2018. The below table 8 gives an overview of Greenhouse emissions.

Table 8. Greenhouse gas emissions [Mt CO2] from Residential Sector in Baltics[51].

Greenhouse gas emissions [Mt CO2] from Residential Sector										
Country	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Estonia	0.19	0.20	0.20	0.21	0.19	0.19	0.18	0.18	0.18	0.17
Latvia	0.45	0.54	0.49	0.46	0.44	0.44	0.42	0.45	0.46	0.47
Lithuania	0.64	0.76	0.75	0.74	0.70	0.64	0.59	0.68	0.75	0.79

2.9. Building Information modeling (BIM) and construction Policy

Since the building sector is highly decentralized and governed by strict regulations, the government's push, as the primary client of public construction projects, is critical for BIM acceptance. BIM policies range from a firm mandate of BIM in all publicly procured projects through legislation changes, where necessary, to provide financial and organizational aid down to low-level encouragement and support. Finland, Singapore, Australia, Korea, the United States, and the United Kingdom are at the forefront of BIM policy development globally[52]. The government and its subsidiary authorities have played a crucial role in promoting and promoting BIM adoption in these countries, but they have taken somewhat different approaches. Singapore made it mandatory to send construction papers for public construction projects through an internet portal called "Corenet" as early as 2004[53]. Similarly in Finland, Since 2007, public authorities have mandated the use of digital building models for all public projects with a budget exceeding one million euros[54]. Moreover, national regulatory landlords in the United States, such as the General Service Administration (GSA) and the US Army Corps of Engineers (USACE), have also regulated the use of BIM approaches for project implementation[55]. Another noteworthy example is from British construction policy, which began in 2011, with the stated goal of cutting costs and lowering the carbon footprint of construction projects by the use of BIM approaches and technology[56].

Many other European countries have already initiated efforts to introduce BIM in the construction sector. These countries include Netherlands, Finland, and Norway[52]. In 2014, France initiated its “plan de transition numérique du bâtiment” with significant investments to support the transition towards digital technologies. In Germany, the Ministry of Transport released a BIM Roadmap in 2015, stating that from 2020 onwards, all federal building programs must use BIM approaches. In Spain, an advisory committee was formed in 2015, and a draft timetable was created, with BIM being recommended in public sector projects by March 2018, mandatory in public building projects by December 2018, and mandatory in infrastructure projects by July 2019. In addition, Austria and Switzerland have begun working on BIM standardization in depth[52].

Apart from Singapore, the most advanced countries in Asia in terms of BIM adoption are South Korea, China, and Japan. Korea has a long history of BIM implementation, with the first BIM roadmap being released in 2010. The first BIM recommendations were released in 2011 and have been revised on a regular basis since then[52]. China, on the other hand, began developing BIM rules and criteria in 2001, The "Outline of Development of Construction Industry Informatization (2011–2015)" published by the Ministry of Housing and Urban-Rural Development (MOHURD) in 2011 stressed BIM as a key technology to help and boost the construction industry. In Japan, Building projects are referred to as BIM, whereas civil engineering projects are referred to as "construction or civil information modeling (CIM)" or "construction information modeling (CIM)" for both the building and civil engineering fields[52]. Meanwhile, The UK's visionary efforts heavily shape and motivate Australia's BIM deployment plan. The "National Building Information Modeling Initiative (NBI)" paper, released in 2012, outlined a roadmap for "the oriented implementation of BIM and associated emerging technology and processes for the Australian built environment sector."

3. Research Methodology

3.1. Overview

Th focus of this study is to identify barriers & opportunities in the adoption of BIM into the concepts of sustainable construction practices, the focus is the entire lifespan of the building project but mainly covering energy consumption and facility management part. Literature review and relevant studies have shown how digitalization of the construction industry or how the adoption of BIM can aid in achieving sustainability goals. However, this study is mainly focusing to take the current overview of the construction industry in terms of efficient building design in terms of energy efficiency, sustainable construction practices, and facility management during the operational phase of building. A survey was generated and circulated throughout the Construction industry professionals to gather information regarding their opinion on the adoption of BIM for efficient building design, and sustainable construction practices. As a result, the survey's goals were defined as 1) to analyze the role of BIM for achieving sustainability goals in the construction sector; 2) To analyze the present trend and role of BIM in the construction industry; 3) To gather the information that how building energy analysis are carried out in construction industry; 4) To identify challenges in adoption of BIM-based energy modeling; 5) to get an opinion of professionals regarding the effectiveness of BIM-based modeling for all stages of building development; 6) and lastly to get an overview of professionals opinion on adoption of BIM as a part of construction policy.

The second stage was to deliver the survey form. Accordingly, a google form was developed, and it was sent to construction professionals both in Estonia and globally. The questionnaire survey was delivered to professionals by email, LinkedIn, and through personal contacts. The third part was to analyze the collected information. The below chart in (figure 21) represents the research methodology process.

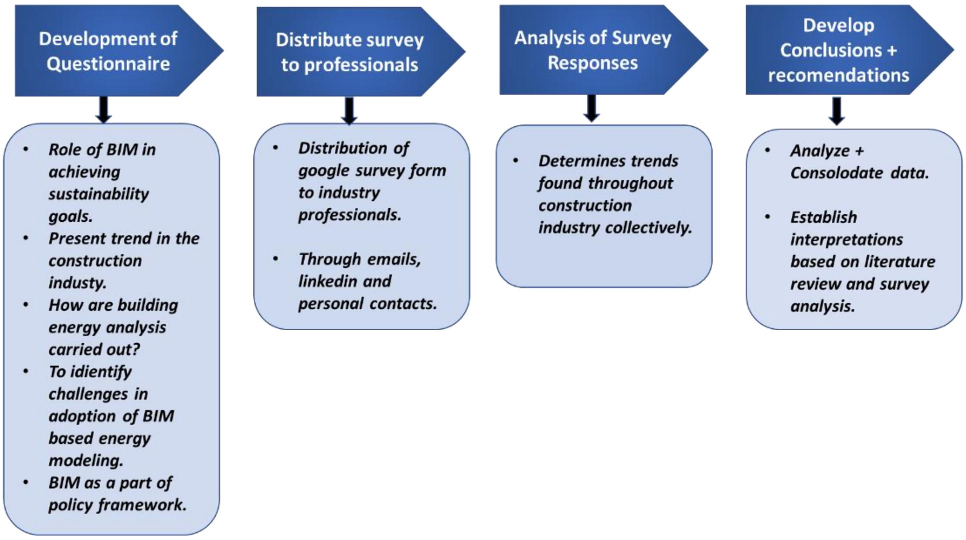

Figure 21. Research Methodology Process.

3.2. Survey Questionnaire Design

The questionnaire had two parts, one part was intended to get the demographic information of the respondents and the second part consisted of main questions related to the adoption of BIM for sustainable practices.

In order to satisfy the study objectives, Professionals were contacted who are working on active building projects. A total of 62 construction professionals took part in the survey over the course of two months beginning in February 2021. Initially, it was intended to take a survey within Estonia but considering the volume of responses, it was widened globally. The demographic information of respondents is presented in

3.2.1. Demographic Information of Respondents

This section of the report will present the demographic information of the respondents. The survey was including questions related to; Current job title, resident country, job sector/Expertise, and professional experience in the construction industry. The below table 9 gives the overview of current job title of survey respondents.

Table 9. Demographic Information of respondents.

Current Job title of survey respondents						
Project Manager	**BIM Cordinator**	**Project Director**	**Planning Engineer**	**Design Engineer**	**Project Engineer**	**Others**
15	8	5	6	5	12	11
24.19%	12.90%	8.06%	9.67%	8.06%	19.35%	17.74%

The second question was related to the resident country of respondents. In the study respondents from Estonia, Finland, Middle East, Canada, Luxembourg, United Kingdom, Norway, Germany, Italy, Denmark, United States, Nepal and Pakistan took part in the survey. However, for achieving the outcomes of the study responses are divided into two parts i.e., Responses from Estonia and Global. The below chart in figure 22 represents the outcomes, and it can be seen that about 22 (36%) responses were from Estonia and around 40 (64%) globally.

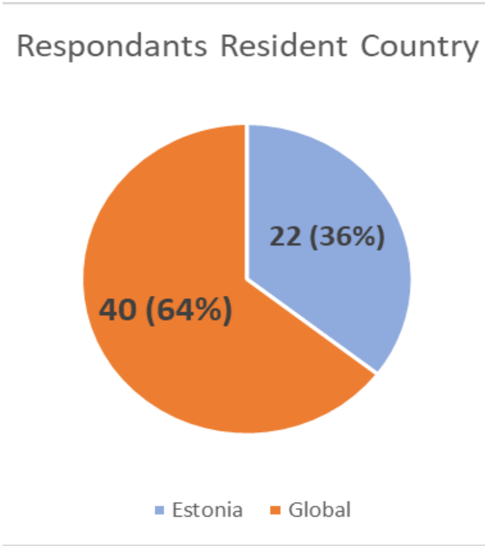

Figure 22. Respondents country distribution.

The third question was intended to know the job sector/ Expertise of the respondents. The options were Planning, Design, Procurement, Construction, Consultation, and others. The Below chart in figure 23 represents the information regarding the expertise of respondents.

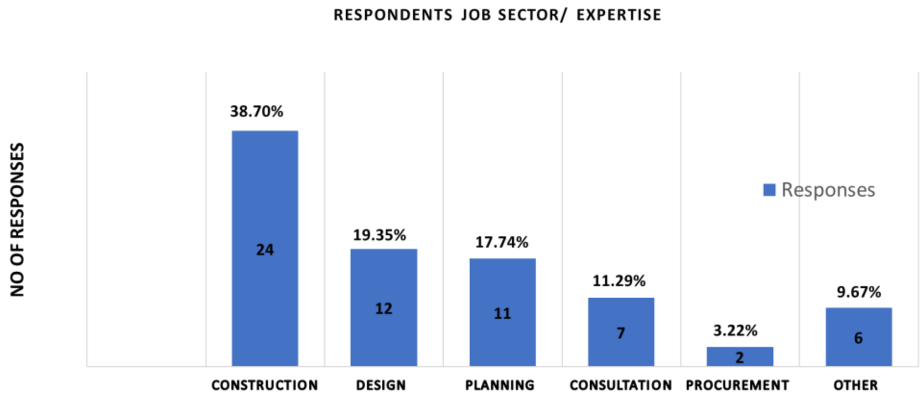

Figure 23. Job sector/Expertise of the respondents.

The last question for demographic information was related to the professional experience of the respondents. The below table 10 summerizes the professional experience of the respondents.

Table 10. Professional Experience of Respondents.

Experience (Years)

0-5	5-15	15-20	More than 20
51.61%	22.58%	17.74%	8.06%

3.3. Building Information Modeling and sustainability

Following part 1, the second part of the questionnaire was considered to capture the respondent's opinion on implementation, effectiveness, barriers in the adoption of Building information modeling (BIM) for sustainable construction practices. In total 9 questions were targetting the use of BIM for the sustainability goals.

Question 2.1: Do you think that BIM can play an important role in achieving sustainability (i.e. Energy efficiency, Waste reduction, resource optimization) in the construction sector?- This question was used as a means to understand professional's opinion on the application of BIM for achieving sustainability in the construction sector. The question was marked with a scale from 1-5 where (1=Strongly disagree, 2= Rather Disagree, 3= Neutral, 4= Rather agree, 5= Strongly agree)

Question 2.2: What role does BIM have in your company/ organization?- The purpose of this question was to identify the usage of BIM software in the construction industry. As literature has shown that digitilizing can help construction to achieve sustainability goals. However, the main role can be different within organizations, i.e., Project visualization, energy modeling, material optimization, and so on.

Question 2.3: How the building energy analysis is carried out in your company/organization?- This question was aimed to analyze that how building energy analysis is carried out in the construction industry both in Estonia and globally. Since literature suggests that BIM-based energy modeling can be more effective to enhance sustainable design and construction activities than the conventional energy analysis tools.

Question 2.4: Which of the following building performance analysis software has been utilized by your company/organization in one form or another, If any?- This question was included to figure out what specific types of environmental applications are being used to undertake to build energy analysis. Most of the listed software options in question are designed to have compatibility with BIM software.

Question 2.5: What is the main challenge in adopting BIM-based energy modeling in your company/organization, If any?- This question was asked in order to access current barriers in the implementation of BIM-based modeling for efficient energy design, and for overall construction processes. Additionally, the purpose is to identify barriers and to provide recommendations based on the analysis outcome.

Question 2.6: In which stage of the building development, BIM-based energy modeling can be more effective?- This question aimed to analyze the effectiveness of BIM-based energy modeling in a specific stage of building development, i.e., Energy performance analysis in the early design stage, Improved life cycle cost analysis, and monitoring actual building performance during the operational phase. The aim was to analyze the opinion of professionals.

Question 2.7: In your opinion, How do you rate current BIM packages in terms of their effectiveness in reducing carbon footprint and optimizing the energy consumption of a building?- The question is also designed to analyze the opinion of Construction industry professionals regarding current BIM packages in terms of their effectiveness in reducing carbon footprint and optimizing the energy needs. It was again a rating-based question, marked with a scale from 1-5 where (1=Highly ineffective, 2= Rather ineffective, 3= Neutral, 4= Rather effective, 5= Highly effective). The question was designed to analyze how energy analyses are carried out and what is the opinion of professionals regarding the adoption of BIM for sustainable building practices.

Question 2.8: In your opinion, do you consider that adoption of BIM can support asset/facility management more efficiently during the operation & Maintenance (O&M) phase of the building?- As is discussed in the literature part that BIM-based facility management is an effective tool during the operation & Management phase of building. Scale-based question with a scale of 1-5 where (1=Strongly disagree, 2= Rather Disagree, 3= Neutral, 4= Rather agree, 5= Strongly agree), aiming to analyze professionals opinion regarding the adoption of BIM for the effective asset/facility management.

Question 2.9: In your opinion, Do you think that adoption of BIM software should be mandatory by the regulatory bodies (Government/ Building Control Bodies BCB)?- As is discussed in the literature review part that some countries and respective building control bodies have made it mandatory to adopt BIM for the building development processes. Scale-based question with a scale of 1-5 where (1=Strongly disagree, 2= Rather Disagree, 3= Neutral, 4= Rather agree, 5= Strongly agree), aiming to analyze the opinion of professionals regarding the adoption of BIM as a part of Construction policy to aid sustainable building development.

4. Survey Results

At the time of the survey's closure, 62 respondents had visited the link and had submitted a response. Initially, it was targeted to achieve 100 samples. However, due to time constraints, and also the findings continue to provide similar trends. Therefore, it was restricted only to 62 responses. The survey questionnaire findings are presented in the following section.

4.1. Question 2.1

As mentioned in the previous section, the question aimed to analyze the opinion of professionals regarding making construction activities more sustainable. As shown in the below graph majority of the respondents believe that sustainability can be achieved through the application of BIM, and BIM can aid in making buildings energy efficient, can help in the reduction of construction waste during construction, and can also be effective for the optimization of resources. As shown in the below graph in figure 24, about 46.8% and 43.5% of the respondents agree or strongly agree respectively. Additionally 3.2% and 1.6%, strongly disagree or just disagree with the opinion. Lastly, 4.8% have a neutral opinion of the statement.

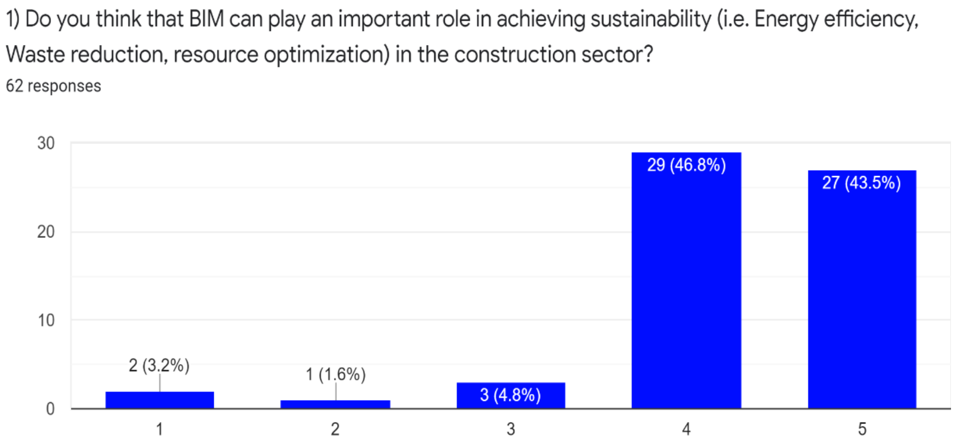

Figure 24. Question 2.1: Role of BIM in achieving Sustainability.

4.2. Question 2.2

Four emerging BIM model categories, according to Taylor et al. (2010), are thoroughly implemented in existing practices: Project visualization, For efficient energy modeling, resource optimization, and project management[57]. Question 2.2 is designed to understand the main application of BIM in the construction industry. As presented in the below graph in figure 25, the majority of the respondents use BIM as a tool for project visualization and project management (69.4% and 61.3%, respectively). Furthermore, only 17.7% of the respondents use BIM for energy analysis and resource optimization respectively. Lastly, 9.67% have other applications.

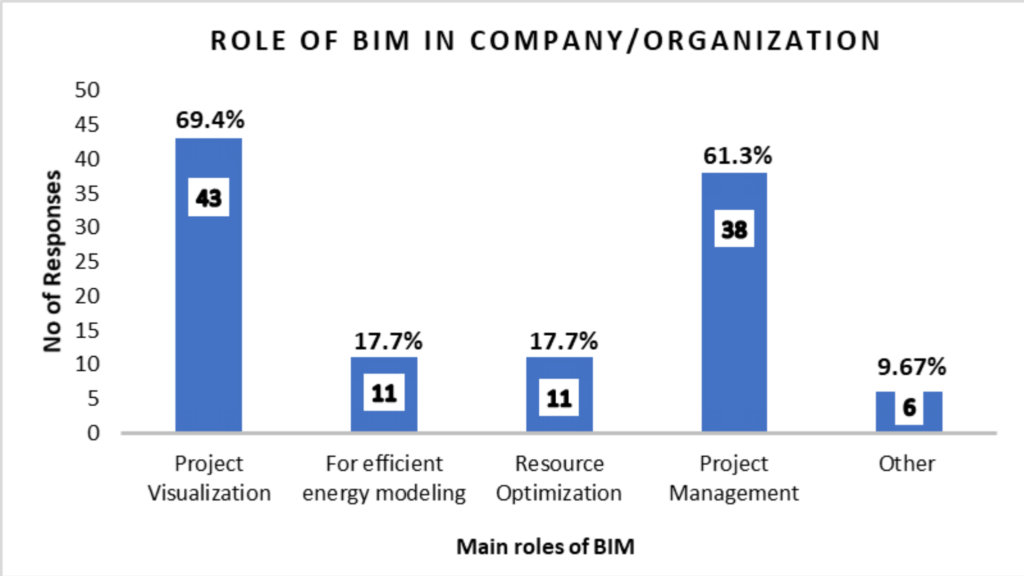

Figure 25. Question 2.2: Main applications/role of BIM in respondent´s organizations.

4.3. Question 2.3

As presented in the literature review, BIM-based modeling can be effective for efficient energy designs. It is found to be effective not only during the design phase but also during the operational stage. However, in response to this question, the below pie chart in figure 26 shows that 61% of the professionals are applying Conventional methods for energy analysis, and about 26% are carrying energy analysis with BIM.

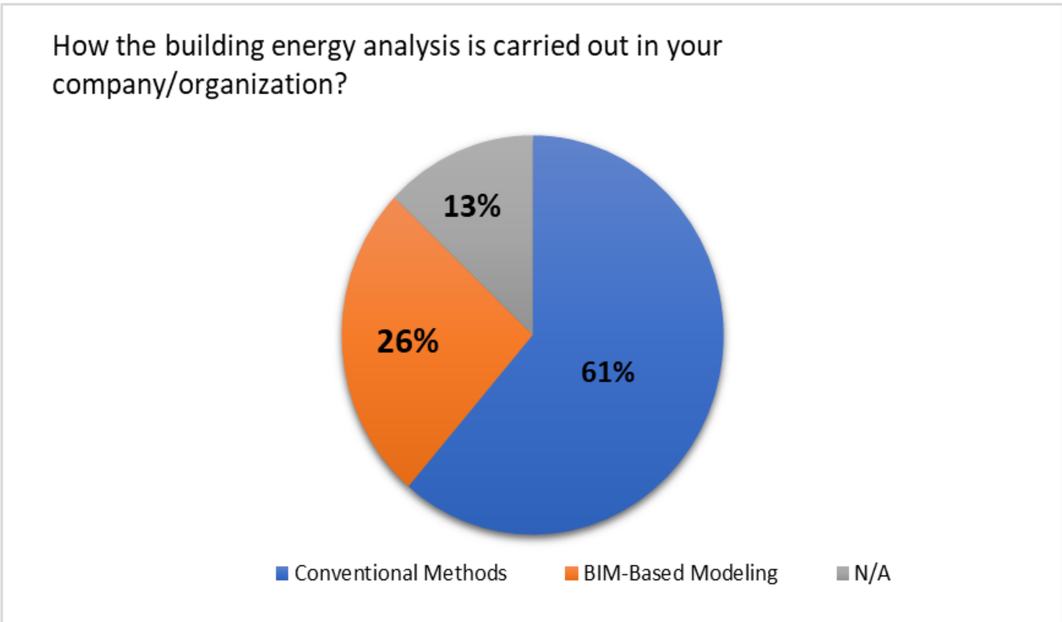

Figure 26. Question 2.3: Methods of Energy analysis in construction sector.

4.4. Question 2.4

The provision of building efficiency analysis software that is specifically linked to BIM allows for the analysis of designs in order to construct more sustainable structures. The aim of

Question 2.4 is to find out what forms of building performance analysis software are used in the construction sector. As shown in the below graph in figure 27, about 75.8% of the respondents are not utilizing within their organization. In addition, there is other software which is being utilized. However, of the listed products, Green building studio held the highest responses at 7 (11.3%).

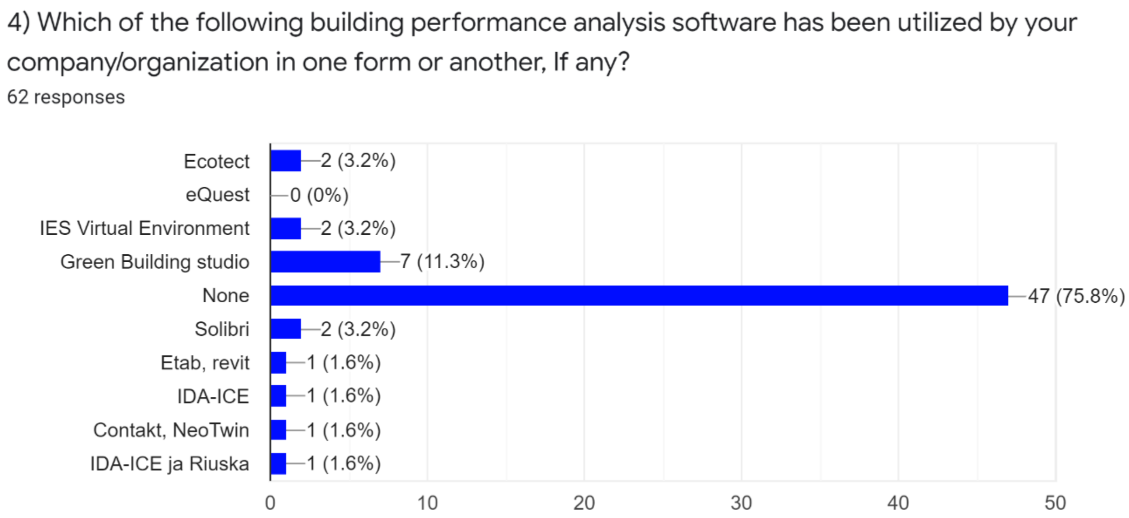

Figure 27. Question 2.4: Building Performance analysis softwares.

4.5. Question 2.5

Question 2.5 was intended to analyze the main challenge in adopting BIM-Based energy modeling in companies/organizations. As seen in the below chart in figure 28, it can be observed that 68% of the respondents believe that substantial investment in software is the main challenge. In addition, 25% of the respondents believe that lack of the trained staff is a challenge. Lastly, 7% responded that BIM-based modeling is inefficient.

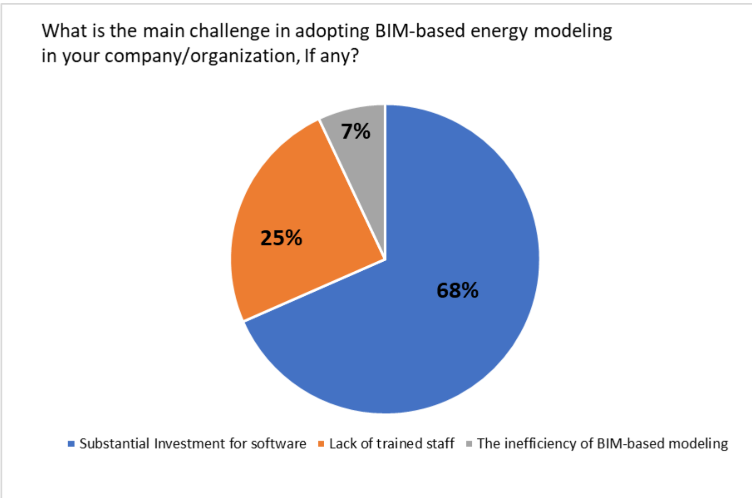

Figure 28. Question 2.5: Challenges in adopting BIM-based energy modeling.

4.6. Question 2.6

This question referred to the respondent's point of view regarding the effectiveness of BIM-based energy modeling during the specific stage of building development. Which includes; Energy performance analysis in the early design stage, Improved life cycle analysis, and Monitoring actual building performance during the operational phase. The below chart in figure 29 shows that about 75.8% of respondents think that BIM-based energy modeling is effective in all listed stages of building development. In addition, 12.9% of respondents regarded energy performance analysis in the early design stage as being the more effective. Lastly, 8.1% and 3.2% of respondents regarded improved life cycle cost analysis and monitoring actual building performance during the operational phase, respectively.

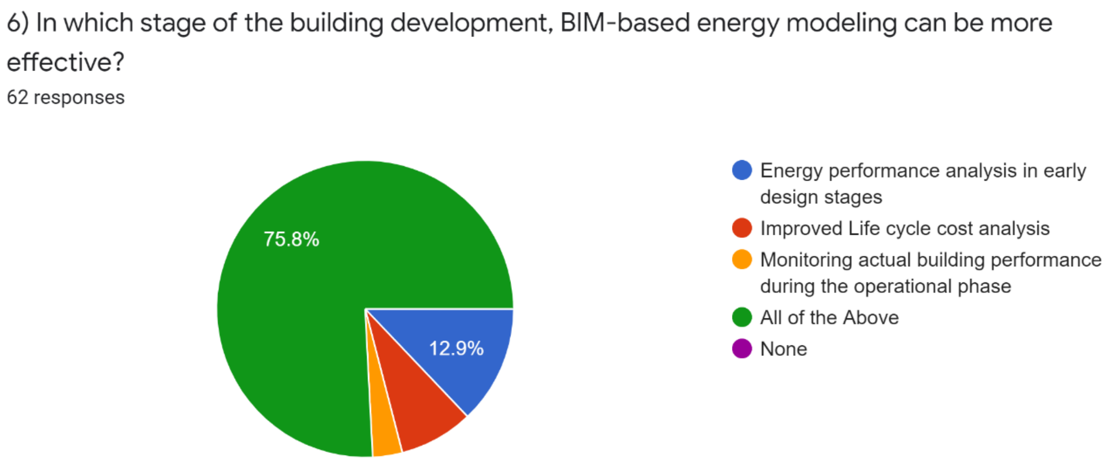

Figure 29. Question 2.6: Effectiveness of BIM-based energy modeling for specific stages.

4.7. Question 2.7

Question 2.7 refers to the respondent's point of view on rating BIM packages in terms of their effectiveness in reducing carbon footprint and optimizing the energy consumption of the building. As can be seen in the below graph in figure 30, about nearly 60% of the respondents strongly agreed or somewhat agreed to the statement (30.6% and 29%, respectively). On the other side, only 3.2% somewhat disagreed with the statement. Lastly, 37% have a neutral opinion.

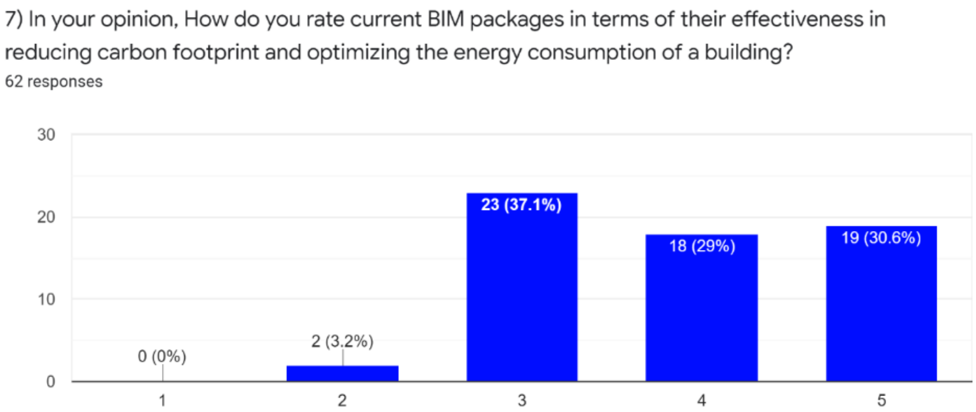

Figure 30. Question 2.7: Effectiveness of BIM packages in reducing carbon footprint and optimized energy consumption in buildings.

4.8. Question 2.8

Similar to Question 2.7, this question is also scale-based and refers to a professional`s opinion on efficient asset/ facility management during the operation & Maintenance (O&M) Phase of the building. The below graph in figure 31 shows that overall about 86% of the respondents agree that being can be effective for efficient asset/facility management. Where 29% strongly agree with the statement, and about 56% somewhat agree. However, nearly 13% of the respondents have a neutral opinion. However, only about 1.6% of respondents contradict the statement.

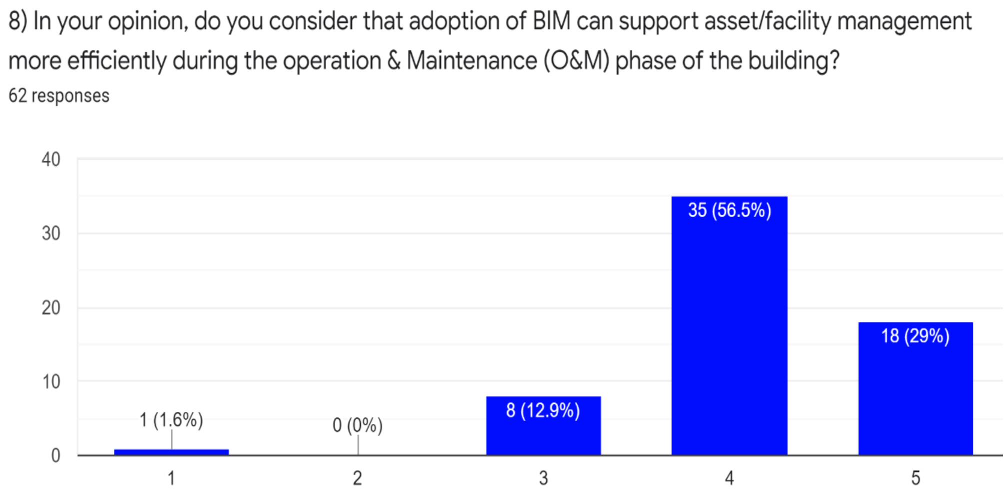

Figure 31. Question 2.8: Role of BIM for the assest/ Facility management.

4.9. Question 2.9

Identical to the previous 2 questions, the Last question aims to analyze respondent's opinions on the adoption of BIM software as mandatory by the regulatory bodies. In response to the statement, about 38.7% of respondents have a strong opinion that BIM should be a part of the policy framework. Whereas, about 42% somewhat agree with the statement. Furthermore, about 16% have neutral views. Lastly, only 3.2% believe that BIM should not be a part of the Policy (Figure 32).

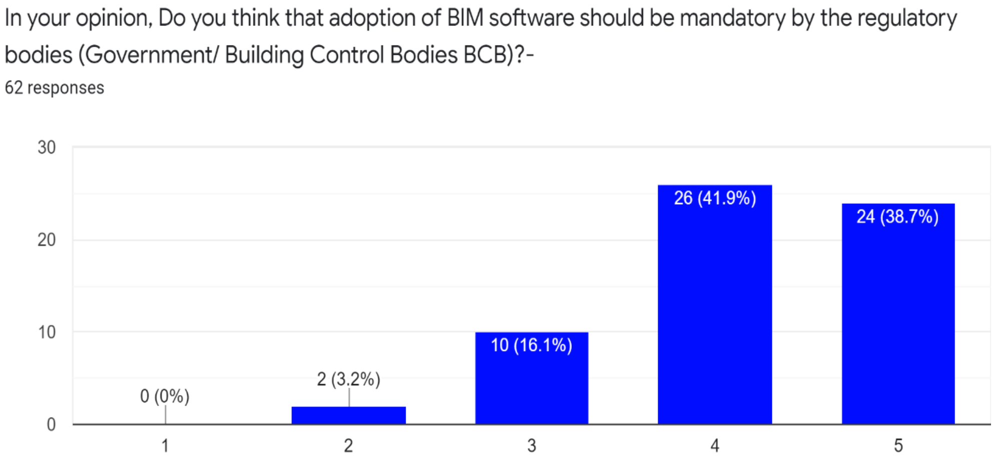

Figure 32. Question 2.9: Adoption of BIM in policy framework.

5. Analysis of Survey Responses

This section aims to analyze the survey results in detail. Generally, survey questions were based on the following aspects:

- BIM & sustainable building development
- BIM-based energy modeling
- BIM & efficient Asset/facility management
- BIM & construction policy framework

The below table summarizes the survey results. Table 11 summarizes the survey results (Global) and Table 12 for Estonia.

Table 11. Summery of the Survey Results (Global).

Questions	*Responses*				
BIM & its potential to achieve sustainability	Strongly disagree 3.20%	disagree 1.60%	Neutral 4.80%	Agree 46.80%	Strongly agree 43.50%
Main role of BIM in organizations	Project Visualization 69.40%	Efficient energy modeling 17.70%	Resource Optimization 17.70%	Project Management 61.30%	Other 9.67%
Building energy analysis in AEC Industry	Conventional Methods 61%	BIM-Based Modeling 26%		N/A 13%	
Building performance analysis softwares	Green Building Studio 11.30%	Ecotect/ IES Virtual Environment 3.20%	Solibri 2%	None 75.80%	Other 6.40%
Challenges in BIM-Based Energy analysis	Substaintial investment for software 68%	Lack if trained staff 25%	BIM is inefficient 7%		
Effectiveness of BIM-based modeling in specifc stage	Energy analysis in early design stage 12.90%	Improved life cycle cost analysis 8.10%	Analysis in Operational stage 3.20%		All options 75.60%
Effectiveness of BIM packages for energy analysis	Highly Ineffective 0%	Ineffective 3.20%	Neutral 37.10%	effective 29%	Highly effective 30.60%
BIM & efficient Asset/facility management	Strongly disagree 1.60%	disagree 0%	Neutral 12.90%	Agree 56.50%	Strongly agree 29%
BIM & construction policy framework	Strongly disagree 0%	disagree 3.20%	Neutral 16.10%	Agree 41.90%	Strongly agree 38.70%

Table 12. Summerized survey Results (Responses from Estonia).

Questions	*Summerized Result (Estonia)*				
BIM & its potential to achieve sustainability	Strongly disagree 0.00%	disagree 0.00%	Neutral 0.00%	Agree 59.00%	Strongly agree 41.00%
Main role of BIM in organizations	Project Visualization 90.90%	Efficient energy modeling 22.72%	Resource Optimization 22.72%	Project Management 68.18%	Other 9.09%
Building energy analysis in AEC Industry	Conventional Methods 53%	BIM-Based Modeling 33%		N/A 14%	
Building performance analysis softwares	Green Building Studio 14.00%	Ecotect/ IES Virtual Environment 0.00%	Solibri 14%	None 63.00%	Other 9.00%
Challenges in BIM-Based Energy analysis	Substaintial investment for software 12%	Lack if trained staff 82%	BIM is inefficient 6%		
Effectiveness of BIM-based modeling in specifc stage	Energy analysis in early design stage 14.00%	Improved life cycle cost analysis 4.00%	Analysis in Operational stage 5.00%		All options 77.00%
Effectiveness of BIM packages for energy analysis	Highly Ineffective 0%	Ineffective 5.00%	Neutral 36.00%	effective 18%	Highly effective 41.00%
BIM & efficient Asset/facility management	Strongly disagree 1.60%	disagree 4%	Neutral 9.00%	Agree 74.00%	Strongly agree 13%
BIM & construction policy framework	Strongly disagree 0%	disagree 0.00%	Neutral 14.00%	Agree 50.00%	Strongly agree 36.00%

5.1. BIM & sustainable building development

As presented in the literature review, many scholars have published several studies of construction projects, combining BIM with sustainability assessment methods, including potentially significant benefits in integrating BIM technology and construction sustainability. Furthermore, the survey results as shown in table 3, BIM can play an important role in efficient energy modeling. Furthermore, it can be effective for construction waste reduction by up to 15% by allowing design reviews in the early design stages[58]. In addition, in response to question 2.2 of a survey, As can be seen in table 3, nearly 70% say they are using BIM for project visualization, and 61% for project management within their organization. Hence, in this regard, BIM can play a vital role in effective project coordination, and project visualization through BIM can aid in design reviews.

In addition, Table 8 summarizes the survey results from Estonia, and in response to question 2.1; the response is similar as compared to the global responses. About 41% of the respondents strongly agree that BIM can be an effective tool for making the construction sector sustainable. However, 59% rather agree with the statement. In response to question 2.2; The numbers are different as compared to global responses. The results show that about 90% of the respondents responded that BIM is being utilized in their organization for Project visualization purposes, and 68.18% responded that for project management within their organization.

5.2. BIM-based energy modeling

Energy efficiency is also one of the key aspects to make the building sector more sustainable and literature review has shown that BIM can be an effective tool for efficient energy modeling. Therefore, this study has mainly focused on energy efficiency in buildings. As shown in the table, survey results show that nearly 61% of respondents answered that they are using conventional methods for energy analysis. Furthermore, if we consider question 2.2, it can be seen that only about 17.7% of respondents answered that in their organizations they are using BIM for the energy analysis. Accordingly, in question 2.4, there were some building analysis software listed, which are certified by LEEDS, US Energy department, Rochester Institute, etc. However, as presented in the survey results, more than 75% of the respondents mentioned that they are not using any of the mentioned software. ,

Furthermore, as can be seen in Table 8. Greenhouse gas emissions [Mt CO2] from Residential Sector in Baltics[51].; about 53% of the respondents from Estonia responded that they are using conventional methods for energy analysis, and only about 33% responded that they are doing BIM-based energy modeling. Similarly, if we consider question 2.2, it can be observed that only about 22.72% of the organizations are using

BIM for energy analysis. Similarly, for question 2.4 which referred to some energy analysis tools, and about 63% of respondents answered that they are not utilizing the listed software for energy analysis.

Furthermore, question 2.6, aimed to identify key challenges in adopting BIM-based energy modeling in the construction sector. As can be seen in the table, 68% of respondents mentioned BIM requires substantial investment. However, in response to the mentioned question, only 7% believe that BIM is inefficient. However, regarding challenges in adopting BIM, the results for Estonia are different as compared to global responses, about 82% of the respondents answered `lack of trained staff´ is a major barrier in adopting BIM in their organizations, and only about 12% answered that BIM requires substantial investment. Lastly, as we have discussed that in response to question 2.7, respondents both from Estonia and globally agreed that BIM can be an effective tool for reducing carbon footprint. Therefore, if we summarized all responses, it can be said that BIM can play an important role in making the construction sector more sustainable.

5.3. BIM & efficient Asset/facility management

The use of BIM technology in the operational phase of a building's lifecycle is taking hold as building owners look for potential opportunities to take advantage of BIM and increase the efficiency of their facility's activities. As shown in table 10, more than 75% of the respondents mentioned that BIM can be effective for all stages of building design. Furthermore, the Literature review has presented case studies, where BIM is being applied in the Operational and maintenance phase of the building. Similarly, question 2.8, also shown that 56.5% of the respondents agree too that BIM can be an effective tool for the efficient management of facilities.

In Estonia, in response to the above question regarding asset management; Likewise, about 74% rather agreed and 13% strongly agreed that BIM can play a vital role in efficient facilities management.

5.4. BIM & construction policy framework

As Literature review has shown that different countries have made different approaches to make their construction sector more digitalized. However, survey results have shown that most applications are on project management, and for project visualization. But in response to question 2.9, Most professionals in the construction sector believe that BIM should be a part of construction policies. However, at the same time, its usage should not only be limited to only the design and construction stage, expanding it to the operational & maintenance phase should be made mandatory.

In Estonia, in response to question 2.9; about 86% rather agreed or strongly agreed (50% and 36%, respectively) that BIM should be a part of the policy framework.

5.5. Comparative analysis: Green Building construction in Baltic Region

The literature review has provided a comprehensive overview of LEED and BREEAM Certifications. This section will provide the analysis based on the presented data. As it can be seen the below figure gives the overview of LEED and BREEAM certification activities in Estonia. It can be observed that there are more LEED Certifications in Estonia (27), followed by 18 and 12 both in Lithuania and Latvia, respectively. However, if we consider BREEAM certifications, the data shows that Lithuania has more BREEAM certified activities for the green building certifications followed by 25 in Latvia and 13 in Estonia. The below graph in fig 33 provides the graphical view of statistical data.

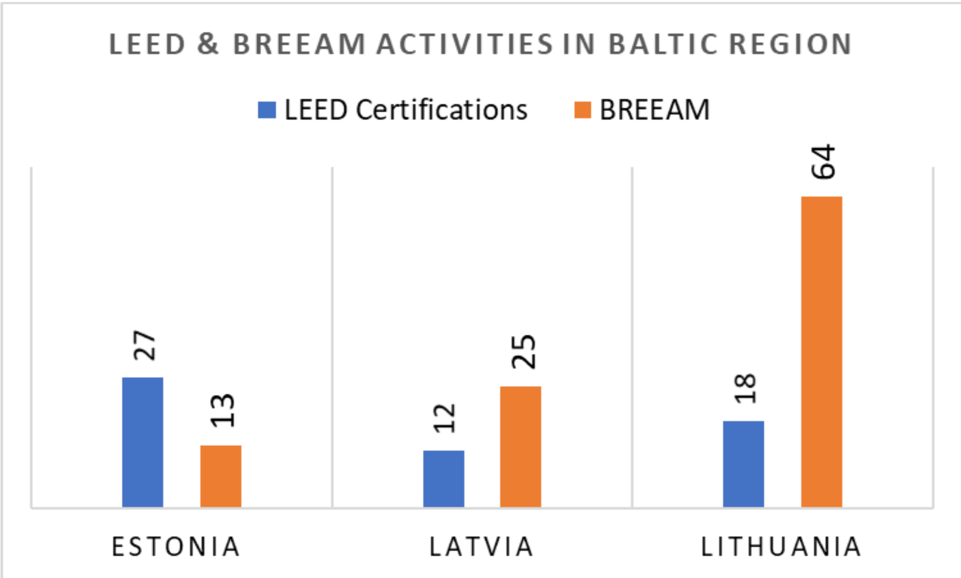

Figure 33. LEED & BREEAM Certifications in Baltic region.

In the literature review from Figure 18 , it was observed that the Estonian project (A9) held the highest place in sustainability assessment analysis, followed by the Lithuanian building (A1) which held the second-ranking. However, this section will provide some analysis based on the greenhouse gas emissions (MT CO2) from residential buildings in the Baltic countries (Estonia, Latvia, and Lithuania). The below chart in figure 34 showed that there are lesser greenhouse gas emissions from the Estonian residential sector from 2009-2018. However, Lithuania showed the highest greenhouse gas emissions and it can be observed there is a continuous rise in trend from 2009-2018. Similarly, Latvian stats are in middle, However, there is no significant rise in 2018 as compared to 2009. In Addition, the Estonian household sector showed a significant decline in 2018. However, Per capita emissions can be different, But still, the decline in emissions in the Estonian household sector is noticeable, and a significant indication of green building operations.

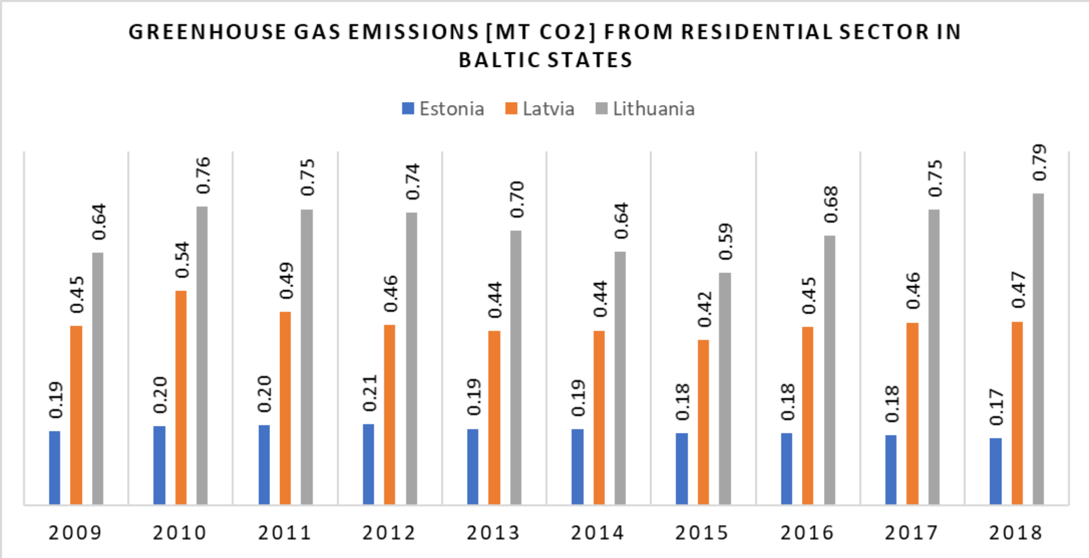

Figure 34. Green house gas emission from residential sector in Baltic region.

Furthermore, The below section presents the energy usage in percent by household sector in the Baltic region. It can be observed in the below (table 12) that all the baltic countries managed to reduce their annual energy consumption in the household sector from 2010-2019. However, The below graph in figure 35 shows that consumption in Lithuania decreased significantly in 2019 (26.5%) as compared to 2010 (33.5%).

Table 13. Final Energy usage in the Baltic region (2010-2019)[51].

Final Energy [%] usage in the baltic region										
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Estonia	35.7%	33.4%	34.2%	32.8%	32.0%	31.2%	33.3%	33.5%	32.6%	33.6%
Latvia	34.7%	35.4%	35.2%	34.0%	32.8%	30.0%	30.9%	30.9%	30.6%	30.2%
Lithuania	33.5%	32.4%	31.7%	31.1%	29.2%	28.4%	28.6%	27.8%	27.7%	26.5%

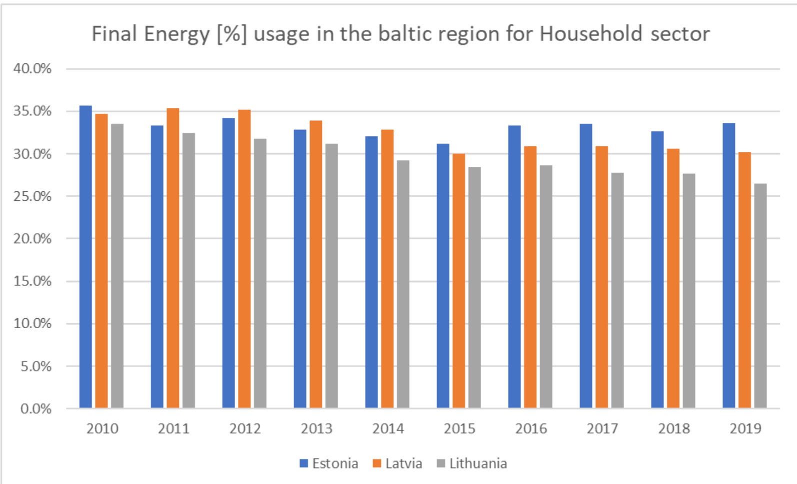

Figure 35. Final Energy usage in the Baltic region (2010-2019).

The below graph in figure 36 gives the trend of energy consumption in percentage (%) by the residential sector in the Baltic region (Estonia, Latvia, Lithuania).

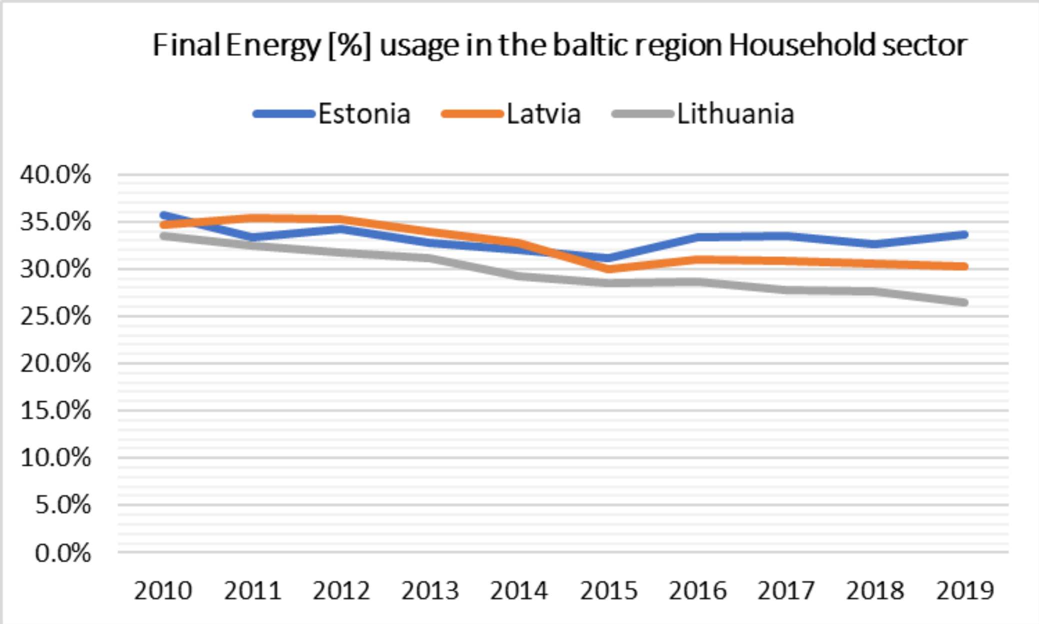

Figure 36. Final Energy usage in the Baltic region (Trend Graph).

SUMMARY

This study focused on the environmental impacts of the construction sector, and the utilization of Building Information Modeling (BIM) as a tool for sustainable construction activities, efficient building designs, and the efficient management of assets/Facilities management both in Estonia and globally. The study sought the opinions of construction professionals on BIM-Based analysis through the survey. In addition, through the literature review; a comparative analysis was done for the Baltics states (Estonia, Latvia, Lithuania) regarding Green building certifications and the energy consumption for the residential sector.

The survey results showed that the majority of the construction professionals both in Estonia and worldwide have an opinion that BIM can be an effective tool for making the construction sector sustainable. The study further found that the main applications of BIM both in Estonia and global are; project visualization and project management. However, efficient energy modeling and resource efficiency are secondary applications. The study also revealed that energy analysis is mostly being done through conventional analysis methods/tools. Furthermore, the study also identified the key barriers in the adoption of BIM-based energy modeling. The survey results showed that lack of trained staff is one of the main barriers in the adoption of BIM-based analysis in the Estonian construction industry. However, analysis for global responses shows substantial investment for the software is the main barrier. In addition, survey analysis showed that BIM-based modeling can be effective for all stages of building development. Moreover, construction professionals also believed that current BIM packages are reliable for analysis, and they can be utilized for efficient asset/facility management in buildings. Lastly, AEC professionals both in Estonia and worldwide agree that BIM should be a part of the construction policy framework.

Furthermore, for the comparative analysis in the Baltic region, analysis of data showed that Estonia has the least greenhouse gas emissions from the residential sector as compared to Latvia and Lithuania. Although, when it comes to energy consumption, the residential sector in Estonia consumed more energy in 2019 (33.6%) as compared to Latvia and Lithuania (30.2% and 26.5%, respectively). In addition, the study also analyzed Green building certifications. Literature review (Table 4) showed that green building certifications have several benefits: energy, waste and utility efficiency, more sales value, rental income, and staff productivity. In addition, through real project analysis, literature revealed that Green certifications are cost-effective. Furthermore, comparative analysis of data for the baltic states showed that Estonia has more LEED-certified activities in the Baltic region. However, it has lesser BREEAM certifications (13) as compared to Latvia and Lithuania (25 and 64, respectively). Anyhow, one of the case studies for the baltic countries

ranked Estonian projects more eco-friendly, the study also revealed that green buildings certifications neglect some sustainability aspects: Social and Economical.

Finally, the evaluation of this study based on survey results and literature review is that Building information modeling (BIM) can be an effective tool, and can play an important role in minimizing the carbon footprint from the construction sector. However, the construction industry is mostly utilizing it for project visualization and project management. On the other side, energy analyses both in Estonia and globally are carried out through conventional methods. However, the case studies revealed that BIM-based modeling is more effective. Therefore, It is essential to widen the applications of BIM, and it should also be utilized for efficient energy analysis, and resource optimization. Lastly, there should be a certain frame of policies regarding the adoption of BIM in AEC industry. In addition, regarding the comparative analysis, green building certifications should be promoted as literature showed that it is cost-effective. However, still, only green building certifications are not enough, there should be certain analysis methods to cover all aspects of sustainability i.e., Environmental, Social, and Economic.

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