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IMPLEMENTATION OF THE CIRCULAR ECONOMY INTO ARCHITECTURE MULTIFUNCTIONAL CENTER AND MUSEUM OF THE APOCALYPSE IN ICELAND

RINGMAJANDUSE RAKENDAMINE ARHITEKTUURIS
MULTIFUNKTSIONAALNE KESKUS JA MAAILMALÕPU MUUSEUM ISLANDIL

Master thesis

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ABSTRACT

Climate change and environmental problems over recent decades are beginning to affect all the inhabitants of the planet in the especially strong way, and more and more scientists today are calculating how soon resources will run out due to their excessive consumption. The process of shifting to more environmentally sustainable development has been underway for a long time, but such processes have not been effective enough or involve numerous difficulties. The proposed new economic model for rounding the chains of material flows, called the circular economy, may well be one of the possible options for solving existing environmental and resource problems.

The main goal of this master's thesis is to analyse the possibilities for introducing a circular economy into architecture. To this end, not only strategic decisions and practical opportunities and efficiency were analysed, but also the general context of the circular economy model, which aims to create a new business model and move away from the logic of the traditional linear economy.

In the theoretical part, first, an overview is given of documents and policies of the European Union aimed at introducing a circular economy into the existing economic model, and, in particular, into the construction sector. Potential practical solutions were identified, highlighting currently existing examples. The new economic model was also considered in the context of implementation in the urban space and rural area, which is especially important for the practical part.

Secondly, the research analyses the Icelandic approach to implementing a circular economy in architecture through the study of documents and interviews with the scientists who compiled these documents.

Based on a theoretical study, the objective of this master's thesis in architecture is to create a multifunctional centre combined with a museum of apocalypse in the Myvatn region, Iceland.

Keywords: Circular economy, Recycling, Upcycling, Ecology, architecture, master's thesis, social hub, rural area, 5R, pollution, Iceland, Myvatn, community centre, museum, Apocalypse, business-model, material flow.

ANNOTATSIOON

Viimastel aastakümnetel esilekerkinud kliimamuutused ja keskkonnaprobleemid hakkavad märkimisväärselt mõjutama kõiki planeedi elanikke ning üha enam teadlasi on välja arvutanud, millal täpsemalt võivad ressursid liigse tarbimise tõttu otsa saada. Keskkonnasäästlikumale arengule üleminek kui protsess on kestnud juba pikemat aega, kuid sellised arengud ei ole olnud piisavalt tõhusad või on kaasa toonud arvukalt raskusi. Lõputöö raames välja pakutud uus majandusmudel materjalivoogude ahelate ümardamiseks, mida nimetatakse ringmajanduseks, võib olla üks võimalikest valikutest olemasolevate keskkonna- ja ressursiprobleemide lahendamisel.

Käesoleva magistritöö põhieesmärk on analüüsida võimalusi ringmajanduse rakendamiseks arhitektuuris. Selleks ei ole analüüsitud mitte ainult strateegilisi otsuseid ja praktilisi võimalusi ning efektiivsust, vaid ka ringmajanduse mudeli üldist konteksti, mille eesmärk on luua uus ärimudel ja eemalduda traditsioonilise lineaarmajanduse loogikast.

Teoreetilises osas antakse esmalt ülevaade Euroopa Liidu poliitikast ja dokumentidest, mis on suunatud ringmajanduse kohaldamisele olemasolevasse majandusmudelisse ja eelkõige ehitussektorisse. Määrati kindlaks ja selgitati võimalikud praktilised lahendused, tuues välja praegu olemasolevaid näiteid. Uut majandusmudelit käsitleti ka linnaruumis ja maapiirkonnas rakendamise kontekstis, mis on eriti oluline töö praktilise osa jaoks.

Teiseks analüüsitakse lõputöös Islandi lähenemist ringmajanduse rakendamisele arhitektuuris, mille raames töötati läbi teemat puudutavad dokumendid ning viidi läbi intervjuud teadlastega ja spetsialistidega.

Antud (arhitektuurialase) magistritöö eesmärk on teoreetilisele uuringule tuginedes luua Islandile Myvatni regiooni multifunktsionaalne keskus koos apokalüpsise muuseumiga.

Võtmesõnad: ringmajandus, taaskasutus, ümbertöötlemine, ökoloogia, arhitektuur, magistritöö, sotsiaalkeskus, maapiirkond, 5R, reostus, Island, Myvatn, rahvamaja, muuseum, apokalüpsis, ärimudel, materjalivoog.

PREFACE

This master's thesis was prepared as part of the integrated studies in the field of architecture at Tallinn University of Technology, Faculty of Engineering.

I would like to thank everyone who contributed to the completion of this master's thesis. I thank my supervisor Jaan Kuusemets for the inspirational advices, honest and high-quality criticism and support in my master's thesis.

All my friends, especially Anna Solts, Marta Volchek and Jelena Kazak were very helpful in preparing this thesis, providing a lot of advice and feedback.

In addition, I thank my family, whose support was very important throughout the process.

CONTENTS

INTRODUCTION

1.1 Problem setting

1.1.1 What we have – linear economy

The modern capitalist model of the economy has contributed to a rise in the standard of living of a large number of people, but this was achieved through the use of a huge amount of natural and social resources. On the one hand, it led to huge environmental problems in terms of pollution, destruction of biodiversity, climate change, and, on the other hand, to an incredible level of economic inequality, which is only worsening under the yoke of economic crises. The economic model used in many countries is based on linearity and the logic of «Create - Use - Discard», which considers the environment as an almost endless source of resources, and, in the same way, a free and endless landfill [1].

1.1.2 A consequence of the linear model

Such an unprecedented attitude towards the environment is progressively leading to the depletion of natural resources, terrible pollution, and global climate change. However, it is hard to imagine what the consequences would be if the energy and material flows continued to grow exponentially. Such consequences are certainly difficult to predict, but they would inevitably have catastrophic consequences for the level of quality of life on earth for the whole humanity. All of the above generate the need for changes in the general economic concept of a linear economy, which has been formed over the centuries.

1.2 Main thesis

The main thesis of the study is the assertion that 'Implementation of a circular economy with creation of a multifunctional center in region Myvatn in Iceland would increase the regional sustainability and reduce the ecological footprint of Iceland'.

This research paper also seeks answers to the following questions:

- What are the principles of the circular economy in the built environment?
- What methods and strategies can be used to successfully implement circular economy in an architecture?
- What are the main features of sustainable building in Iceland?

1.3 Work content and methodology

The master's thesis is the creative research overlooking the opportunities for the introduction of the circular economy in the construction sector and its impact on architecture; in addition, it offers its own architectural and design solution in a sparsely populated region of Iceland, in rural areas.

In the course of the work, various research methods were used. The theoretical part of the dissertation is based on the overview of diverse thematic literature and profile studies, scientific articles, analysis of existing projects, as well as interviews with scientists from the University of Iceland related to this topic. Among other things, a considerable emphasis was placed on the characteristics and the analysis of the situation in the construction sector in Iceland with the introduction of the circular economy in the construction sector in Iceland.

1.4 Work structure

This master's thesis consists of the two parts – theoretical research and design solution. The theoretical part is further divided into two main parts: The study of the circular economy in architecture in general; and Specific features in Iceland. Thus, the theoretical part provides an overview of the scope of the problem and the current approach to solving these problems through the analysis of various studies, strategies, policies and pilot projects related to the topic of work. In the second part, i.e., in the practical part, an architectural and design solution is presented – a local multifunctional centre with museum of Apocalypse in Iceland in the Lake Myvatn region which is currently being created.

THEORETICAL PART

2.1 Pollution

2.1.1 Types and main sources of environmental pollution

The author of the thesis introduces pollution of the environment, which also means the natural environment and the biosphere, is an increase in the content of physical, chemical, or biological reagents that are not typical for this environment, and the presence of which leads to negative consequences [2].

The studies conducted lead to the conclusion that humanity is already facing global climate and environmental change due to human activities [3]. Pollution of the oceans with plastic and oil products has already reached incredible proportions, and both the inhabitants of the sea and the entire ecosystem on the whole are under threat. An enormous number of industries and cars emit a huge amount of carbon dioxide into the atmosphere every day, increasing the impact of the greenhouse effect. And the massive garbage patches that result from human activity are often simply stored on the surface, causing soil pollution, increasing its erosion and reducing its fertility.

The main types of pollution are classified according to the sources of environmental pollution [4]:

- Biological
- Chemical
- Physical
- Mechanical

The biological environmental pollution is caused by living organisms or anthropogenic factors. The latter generate a change in the natural chemical composition of the environment by adding other chemicals that are not characteristic of this environment. In the third place, there are physical environmental characteristics that change, such as thermal or radiation pollution, as well as noise and other types of radiation. The third type of pollution is also associated with human activities and waste emissions into the biosphere.

All types of pollution can be singular, exist together or transform from one to another.

Figure 1. Used computers (Peter Essick/foundation for deep ecology)

Figure 2. Coal Power plant (Jason Hawkes/foundation for deep ecology)

2.1.2 Water pollution

Although it may seem that there is an abundance of clean water on earth, in terms of percentage, only 3% of the fresh water supply in the world remains unpolluted [2]. Sadly, this does not prevent humanity from polluting water with oil products, wastewater, chemically resistant substances, synthetic fertilizers and other substances and methods [5].

Polluted water contains a large amount of xenobiotics – substances that are not characteristic of the human or animal body. If such water enters the food chain, it can lead to serious food poisoning and the death of all participants in the chain. Wastewater, which contains detergents, food residues, small household waste and waste, in turn, contributes to the formation of new pathogens that, when in contact with the human body, cause various diseases.

A massive volume of unrecycled plastic waste also litters the world's oceans, and by 2100, more than half of the world's marine species may be on the verge of extinction [6]. Often, such rubbish is carried away by sea currents away from land, and its disposal becomes even more problematic. This is how the Great Pacific Garbage Patch has already formed - an accumulation of debris from the North Pacific Ocean with an area of about a million square kilometres [7].

2.1.3 Soil pollution

Soil is an important part of human life. Humans receive the main share of their food from the soil - from cereals to fruits and vegetables. To continue normal agriculture, it is necessary to maintain the balance of available soils at the level of the normal water cycle. However, pollution has already caused almost a third of the Earth's land cover to be eroded, and if the relevant measures are not taken, more than 90 percent of the planet's soil cover is expected to be degraded by 2050 [8].

Soil pollution is the ingress of toxic materials into it, and, besides, rubbish, which negatively affects the groundwater cycle. The main sources of soil pollution are [9]:

- Industrial enterprises
- Transport
- Agriculture and pesticides
- Nuclear energy and power stations
- Residential buildings

In the case of residential buildings, soil pollution is due to garbage that is stored in landfills. Burning waste irrevocably spoils the soil, polluting the entire environment.

Toxic substances, heavy metals and chemical compounds are emitted at industrial enterprises. This leads to man-made pollution of the soil and affects living beings.

Transp ort emissions of hydrocarbon nitric oxide and other compounds affect food chains by entering the soil. They reach a person through food. Ploughing, pesticides, and fertilizers also lead to desertification and soil erosion.

2.1.4 Air pollution

After the beginning of industrialization, the atmosphere of the Earth began to be enriched with dangerous impurities. And since the gaseous shell of the Earth protects the planet from radiation, affects the climate and the Earth's thermal background, such pollution negatively affects all ecological processes.

Thermal power plants, burning a large amount of fuel, provide a person with electricity, light, and heat, but emit a large amount of carbon dioxide, dust, and soot into the environment. By reacting with substances already present in the atmosphere, even more toxic compounds are formed.

In industrial areas, the air is often different from the forest. It is also driven by air pollution and industrial emissions.

Of course, the use of all kinds of filters has already begun, the transition to more environmentally-friendly energy sources, but this is not enough. By 2050, the world population is expected to increase by 2 billion people, from 7.7 billion to 9.7 billion, and this may lead to an increase in resource consumption [10].

Figure 3. Mexico City (Pablo Lopez Luz/foundation for deep ecology)

2.2 Damage and warning

In November 1992, some 1,700 leading scientists from around the world issued a call that human activity and the use of then-modern practices had an extremely negative impact on the environment, threatening the future of human society. This manifesto demanded a fundamental change in attitude towards nature in order to avoid the ecological clashes which are unavoidable if the current practices are not stopped. The authors of this declaration feared for the destruction of the Earth's ecosystem, lack of resources and planetary stress due to overpopulation [11].

However, the use of natural resources and energy has not decreased, but rather increased, due to a growth in the world's population by 2 billion people compared to 1992, which leads to the even more urgent demand for changes to avoid exceeding planetary boundaries [12].

25 years later, in 2017, scientists repeated their warning with a second consortium of 15,000 scientists, where they also analysed humanity's response to the first warning. Thus, it was found that since 1992, except for the stabilization of the stratospheric ozone layer, humanity has not made sufficient progress in the overall solution of the envisaged environmental problems. New trajectories for potentially catastrophic climate change have also been identified due to rising greenhouse gas emissions from fossil fuel burning, deforestation and agricultural production. These factors have raised particular concern in society [13].

Thanks to all of the above, in recent decades, many studies have been aimed at exploring opportunities to reduce greenhouse gas emissions and reduce the number of resources consumed. Consequently, this led to the concept of recycling used materials and reusing resources, however, the effectiveness of these methods was not so progressive, since the cost of recycled materials was often higher, and their quality often left much to be desired.

Figure 4. Great Pacific Garbage Patch (AFP or licensors Nov 2017)

Figure 5. Polluyion in Bangladesh (Hasasn/foundation for deep ecology)

Figure 6. River pollution (Lu Guang/foundation for deep ecology)

Figure 7. Tar sands Alberta Canada (Lentz/foundation for deep ecology)

Figure 8. Black Friday in Idaho (Oswald/foundation for deep ecology)

Figure 9. Industrial agriculture (Bertrand/foundation for deep ecology)

Figure 10. Vancouver Island (Lentz/foundation for deep ecology)

Figure 11. Tires in Nevada (Dancer/foundation for deep ecology)

Figure 12. Tar sands (Lentz/foundation for deep ecology)

2.3 Circular economy

2.3.1 Concept of circular economy

A much more efficient way to conserve resources and reuse them for different purposes is described by the concept of a circular economy. The concept of a circular economy is defined as a regenerative system in which resource input and waste, emissions and energy leakage are minimized by slowing down, closing and narrowing material and energy cycles [14]. All this can be achieved through sustainable design, technical support, maintenance, repair, reuse and recycling [15]. The new idea could contribute to stronger social involvement in environmental issues, creating a balanced economic environment, minimizing environmental problems for the benefit of future generations. This concept, first proposed back in 1966 in a book by Kenneth Boulding [16], has recently gained popularity due to the exponential growth of scientific publications on this topic.

2.3.2 Circular economy and architecture

Architecture, together with construction, also plays an important role in the context of the ecological footprint. Thus, it was revealed that the construction industry consumes huge natural resources and produces a huge amount of solid waste around the world. For example, according to the new Circular Economy Action Plan published by the European Commission, it accounts for about 50% of all recoverable materials and over 35% of total waste generation in Europe. And greenhouse gas emissions from the extraction of raw materials, construction and renovation of buildings are estimated at 5-12% of total European CO2 emissions.

To achieve the concept of zero waste and minimize the consumption of resources, it is necessary to introduce circular economy technology, which would help in increasing the efficiency of the use of materials and would help to reduce emissions by more than 80%, which is extremely important in the context of global economic problems [17].

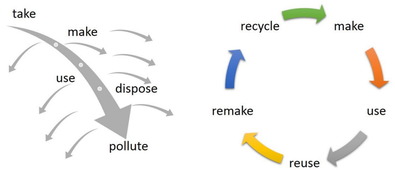


Figure 13. Linear versus circular economy. Image via Wikimedia Commons

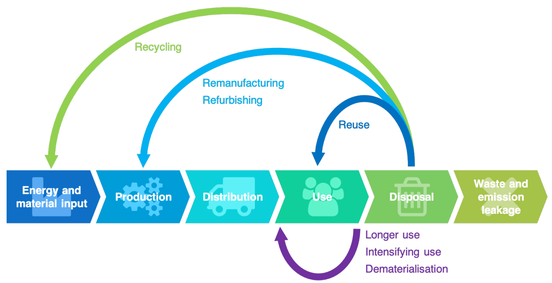


Figure 14. An illustration of the Circular Economy concept. Image via Wikimedia Commons

2.3.3 What are the principles of the circular economy in the built environment?

The circular economy is a strategy aimed to gradually separate economic activity from the consumption of scarce resources and design a secondary life for waste.

In April 2018, the European Commission officially opened a two-year level testing phase for companies seeking to introduce circular thinking logic and implement circular economy technology. The European approach to assessing and reporting on the sustainability and durability of buildings throughout the life of the building emerged [17].

In February 2020, the European Commission released a new paper on the Circular Economy in Architecture: The Circular Economy – Building Design Principles paper. In their report, they highlighted key actions to implement the principle [18]:

- Sustainability

The need to plan the life of the building and its structural elements as the entire, with the preferred use of building systems that incorporate circular economy thinking with ease of maintenance.

- Adaptivity

Preventing premature demolition of a building by taking into account possible future changes, and extending its lifespan through the ability to change its purpose through adaptation, replacement and reconstruction.

- Waste reduction

Promoting circular thinking in building materials by pre-thinking about reusing resources and facilitating high-quality waste management. This proposal includes the following ideas:

o Reuse of resources and materials - retaining most of the value of the material and recovering it by the end of the building's life.

o Proper component design - use of various construction methods for recovery and reuse opportunities to avoid degrading cycles.

This document is aimed at different actors involved in the construction sector. Among them: architects, engineers and designers, building managers and owners, building users, as well as manufacturers of building materials, disassembly and demolition companies, investors, developers, insurance companies, governments, regulators and local authorities.

An equally important document adopted by the European Commission in 2020 is the "Circular Economy Action Plan" [17], which is one of the key blocks of the European Union under the new sustainable development program – the European Green Deal [19].

On March 30, 2022, the European Commission adopted the package of measures proposed in this plan, in particular, the "Proposal for the revision of the Construction Products Regulation", which implies the revision and improvement of European standards, which in the current regulation are not suitable for the implementation of the broader priorities of "The Green Deal Policy in Europe". Under the new regulation, environmental information on recycled building materials will be made more accessible by accelerating digital adoption. These are, in fact, the first steps in creating a common database of recycled or already used materials [20].

The Commission is also launching a new comprehensive Sustainable Built Environment Strategy aimed at realizing the environmental benefits of improved material efficiency [21].

In addition to the strategies developed by the EU, there are various funds that also develop different concepts of strategic decisions. For example, the ReSOLVE framework developed by McKinsey is a key result of a study by the Ellen MacArthur Foundation, an international leader in the field of analytics, whose activities are aimed at actively supporting the transition to a circular economy [22]. The work Circular Economy in the Built Environment [23] outlined six actions to move towards a circular economy:

- Regenerate

Safeguarding, restoring and increasing the resilience of ecosystems, returning valuable biological nutrients safely to the biosphere

- Share

Pooling the usage of assets and its reuse

- Optimise

Prolonging an asset's life, decreasing resource usage and implementing reverse logistics

- Loop

Remanufacturing and refurbishing products and components, recycling materials

- Virtualize

Replacing physical products, services and locations with virtual services, delivering services remotely

- Exchange

Using alternative material inputs, replacing them with renewable energy and material sources, replacing traditional solutions and product-centric delivery models with advanced technology and new service-centric ones.

Figure 15. From Principles to Practices Realising the value of circular economy (Ellen MacArthur Foundation, 2022)

2.3.4 How to implement a circular economy in the built environment?

An equally interesting study was conducted by a group of scientists from the National Taiwan University. So, studying the strategies of the Ellen MacArthur Foundation, they proposed their alternative structure of the waste hierarchy and created a strategy of the 5R principles - Rethink, Reduce, Reuse, Repair, Recycle with examples of implementation in the construction industry. Based on this, they compared Taiwan and the Netherlands circular economy pilot projects and developed 30 circular economy practices to help future project stakeholders understand what are the key practices related to circular economy [24]. Examples were also offered of how emissions and waste reductions could be achieved in practice.

In another article [25], listing on 10 principles for applying the circular economy in architecture, Olivia Bartolini did her own analysis and compiled a fairly simple list of 10 main ways, and also gave good examples of their use:

- The Use of Glass as an Exterior Finish

The use of glass as a facade design is associated, first of all, with a relatively simple and affordable opportunity to update it. And the transformation of old buildings with glass is especially effective and reduces the ecological footprint.

- Remanufacturing

Also known as «value-added manufacturing», it is essentially the restoration of a product to its original specifications. Many companies are already beginning to consider repairing worn parts of their original product. In the context of building materials, for example, recycled wood can be recovered and reused.

- Cradle-to-Cradle Fabrication

Cradle-to-cradle design is a biomimetic approach to product and system design that models human industry on natural processes, where materials are seen as nutrients circulating in a healthy, safe metabolism. The idea was put forth by architect William McDonough in his 2002 book Cradle to Cradle: Rethinking How We Make Things [26].

- Glass Wool Insulation

Glass wool is an insulating material made from tiny fibres of glass laid in a wool-like texture. When creating this material, many tiny air pockets are formed in it, which provide excellent thermal insulation properties that can be used to create lightweight structures. Easy transportability and installation are also a good feature in favour of this product. Its main raw material is glass, which can be recycled and recycled.

- Pay-Per-Lux

This technology, but rather a business model, was also described in an article by the Ellen MacArthur Foundation [27]. This new idea was developed by Philips Lighting (now Signify), a lighting expert. So, she proposed a business model according to which the customer and the developer do not purchase lighting equipment, but the lighting service itself from the company with a daily monthly fee - Lighting as a Service (LaaS). According to this business model, the Signify is interested in producing high quality, reliable and modular equipment that lasts much longer, thus saving resources used in production. In addition, since lighting is often professionally managed using artificial intelligence and the Internet of Things, the system works more efficiently, resulting in significant energy savings. Efficient systems management has already led to an overall reduction in energy consumption of 55-35% as a result of installing LED lighting, and another 20% thanks to the Signify optimization process.

- Furniture Re-Usability

In the United States alone, 15 million tons of furniture are thrown away every year and only 2% is returned for recycling. At the same time, a quarter of a million people move in or out every year in a city like New York. The actual potential of the used furniture market is estimated at $10 billion a year. In fact, the same business models are now being offered as with lighting, when the consumer does not buy furniture, but uses it as a service, which, after the expiration of the contract, is taken by the manufacturer to provide it to a new tenant. Of course, in this case, the furniture undergoes restoration and repair, which is the main idea of the circular economy.

- Modularity

Demand for office furniture is growing rapidly – by 2024 the industry will be valued at US$100 billion [25]. The production of office furniture requires a lot of materials and energy, and after a fairly short period of use, almost all furniture is thrown away. In this way, resources are wasted. Dutch office furniture creation company Ahrens offers its customers a similar business model, office furniture as a service (FAAS), in which customers pay a monthly fee and return the furniture when they no longer need it.

- The Possibilities of Post-Consumer Glass Concrete

Reinforced concrete is a fairly long-existing material for building load-bearing structures, but it has significant drawbacks. Reinforced steel begins to corrode over time, worsening its properties and destroying concrete. To avoid this, a new glass fibre reinforced material (GRC) was invented. Glass fibre concrete panels are non-combustible, stable and durable, and the reinforcement does not rust.

- Circular Building

William Macdonald, the pioneer of the Cradle-to-Cradle strategy, has often stated that there is a problem with materials in the wrong place. In other words, it happens that materials that can be used in construction are often difficult to find. Villa Welpeloo is a home and art studio designed and built in 2005 by Superuse Studios. What makes this building unique is that 60% of the home is made up of materials were collected from the area, and Superuse has adopted a new yet affordable strategy to source these raw materials. They collaborated with Google Earth Planet to efficiently search for materials.

- Product Passports

The Maersk shipbuilding company has developed the Cradle-to-Cradle Passport. This idea includes an online database to create a detailed inventory that can be used to identify and recycle ship components to a higher quality than ever before.

2.3.5 Circular economy as a business strategy

However, it is worth noting that the circular economy is not only a waste management strategy or a design strategy, choosing the right and recycled materials, but rather a general business strategy that will not work without a financial incentive. It is important to show the owner that it is profitable to take apart the components at the end of the building's life and reuse them. Also, a large number of innovations, such as modularity or the introduction of green energy, will not be effective without attention to social aspects. A circular economy will not work without the active participation of people.

Thus, the circular economy is not just a 5R strategy, but a much more complex concept presenting numerous ramifications that involve paradigm shifts in how urban environments are designed.

One of the key steps in developing a circular economy is to involve people in the design and management of their communities. Cities are major consumers and major producers of greenhouse gas emissions. Thus, cities already consume about 75% of raw materials, and according to forecasts, by 2050 the demand for raw materials will double. Urban communities play a key role in developing circular economy models [28].

Further, the research will consider examples of the introduction of a circular economy in the context of urban design.

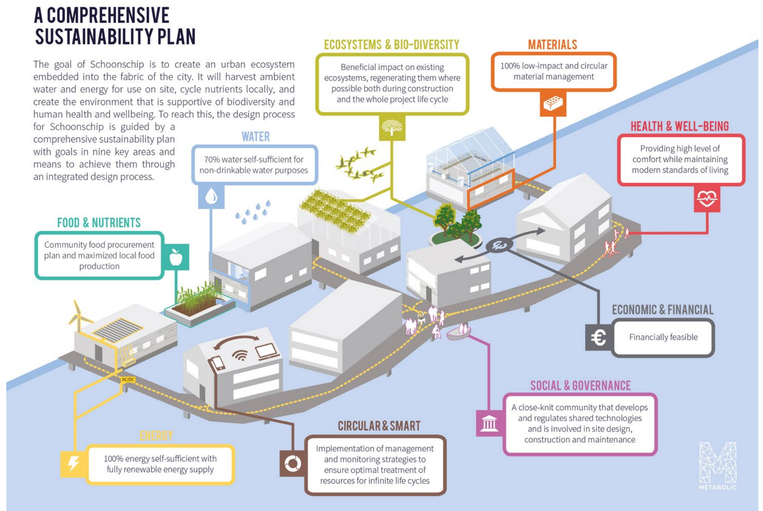


Figure 16. Schoonschip by Space&Matter. (Courtesy of Space & Matter)

2.3.6 Circular Economy in urban design

Cities are already leading the fight against climate change and laying the groundwork for a circular economy, creating additional opportunities for climate change mitigation. Creating new circular economy strategies may require a city to understand how waste is managed. An important aspect is the involvement of private financial stakeholders to create a new local economic fabric, with an emphasis on ecological balance.

Thus, the city of Prague became a pioneer in this area, which in 2019 analysed local material flows, carbon emissions in connection with the local economy and identified the main sectors of the economy in which the introduction of a circular economy would be most effective. This has resulted in the creation of reuse hotspots where discarded products such as furniture, household appliances, food and household waste are treated. By processing food waste, biomethane is produced, which can be used as a fuel for transportation, and the remains of the bio substance are introduced into the agricultural industry and sent to agricultural land around the city.

In addition to the regulation of material flow and products, as well as waste management, it is important for the urban community to pay attention to their own self-sufficiency. This implies attention to the independent production of energy, food and participation of the community and, in particular, residents, in all these policies.

A good example is the Schoonschip floating district project in Amsterdam. It was developed by Space and Matter. In this project, the principles of the circular economy were introduced at the level of the neighbourhood, with the allocation of profits. The project consists of 46 residential buildings with about 100 people living in 30 water areas connected by a jetty. The main feature of the project is sustainable energy supply, water supply and waste disposal systems, which are managed by the local community. Thus, a network of solar panels helps residents to exchange energy among themselves, and water treatment technologies extract energy and nutrients from wastewater. To promote the local solution and share their experience, the local community created a website detailing various aspects of their neighbourhood. The project showed that involving people in the design and management of their communities is one of the key steps in the development of a circular economy, which was described above [29].

Another firm, Valentino Gareri Architects, has developed its project of a village model with the introduction of a circular economy [30]. Their concept proposes the creation of a community for 200 people with co-working and cohabitation with its own system of agriculture, water and energy networks. The main idea of the concept is the transformation of inorganic materials into new products or other resources, like the reuse points in Prague.

The transition to a fully closed economy is a complex process based on a general change in the linear economy. As shown in these examples, small communities, cities and creators of urban space, can take on the main burden of changing the way the economy in the region by changing and transforming urban space, expanding their knowledge and introducing a new circular economy [31].

Figure 17. Schoonschip by Space&Matter. (Alan Jensen)

Figure 18. Prototype for Circular Economy Village In Australia. (Valentino Gareri Atelier)

2.3.7 Circular Economy in rural area

The idea of reducing consumption of resources, reducing carbon emissions, and reusing resources is especially important for small, closed communities that are far from the main centres of trade. For example, rural areas and island nations face a number of challenges related to their long-term sustainability. Various solutions to improve the situation at the local and regional levels would help ensure the efficiency of reuse of resources in different waste streams, involve society in these processes, and, additionally, raise the value of regional products [32].

A group of scientists from Italy, in their research on the prospects for the introduction of a circular economy, found out that the emerging circulation processes need to be combined into existing nodes and create new networks with local initiatives, where residents could also be involved. Thus, they propose the creation of a model of local rural hubs, in which interested communities would search for innovative solutions for the economic and social development of the region. Such a model in marginalized rural areas should also have the goal of promoting social farming – farming that could bring local people together. The main idea of such farming is to open new markets for local enterprises and multifunctionality

Inter alia, the paper identified the key features of this rural hub for successful development:

- Activating - expanding business opportunities through the introduction of innovative technologies, training and creating events to increase social cohesion.
- Ecosystem for social innovations - adding value to the local rural economy through interaction with local authorities and local companies.
- Community connectivity - the development of services in the region to strengthen local economic and production chains and a sense of identity.

However, these changes need to be implemented in a way that prevents the innovative approach from adapting to the current regime. This requires a clear formation of the main objectives of the concept of a circular economy to the countryside, supported by the introduction of innovations. Only in this way will a positive change, and not a decrease in the efficiency of the existing system, be ensured.

Figure 19. Rural area sketch (Google search)

2.3.8 Remote areas with high import

Furthermore, remote island states like Iceland, New Zealand and Japan are typical examples, since they have to import the bulk of the resources to their own islands, and after using them, process them themselves or use expensive transportation to dispose of waste by distant partners. Perhaps, one of the best examples is Iceland, an island nation in the North Atlantic Ocean that was one of the poorest regions in Europe as far back as the early 20th century. Now Iceland is one of the richest countries, with one of the highest levels of human development. Various events have led Iceland towards the gradual development of a modern innovative society. It might seem that virtually endless fish stocks, large supplies of clean water, and geothermal energy used to generate cheap and renewable electricity lead the way to prosperity in Iceland, but there is a danger that these and other factors could be overshadowed by high ecological footprint if Iceland, which is more than the European average [33]. Indeed, Iceland has become an innovative society that is always looking for new technologies and exploits available resources wisely for different purposes [34].

Let’s take a closer look at Iceland as it hopes to become a shining example of sustainable development with the introduction of new environmental practices and a circular economy.

Figure 20. Rural area sketch (Google search)

Figure 21. Iceland (US department of State)

2.4 Iceland

2.4.1 History

It is a small northern island country located between the North Atlantic and the Arctic Ocean. With a population of less than 333,000, it is the most sparsely populated country in Europe. Most of Iceland's population lives in and around the capital Reykjavik.

Iceland was first settled in 874 AD, when the Norwegian chieftain Ingolf Arnarson became the island's first permanent settler. In the following centuries they were followed by Norwegian colonists, as well as settlers from other Scandinavian countries. Iceland was ruled by Norway and Denmark from 1262 to 1814 and became a republic in 1944.

Iceland has relatively low taxes, but retains the Scandinavian welfare system, which provides universal health care and higher education for its citizens. Iceland is run almost entirely on renewable energy thanks to its geothermal source, and its main industries are fishing, agriculture and tourism.

2.4.2 Culture

Thanks to centuries of isolation, Icelandic culture is distinct from other Scandinavian countries, despite the fact that Icelandic culture is based on the Scandinavian national heritage. A prime example of this is Icelandic, which remains the closest to Old Norse of all the Scandinavian languages. Since most Icelanders are descendants of Germanic and Gaelic settlers, Icelandic is a North Germanic language that is also closely related to the Faroese and West Norse dialects.

The cultural heritage of Iceland includes classic literary works such as the medieval Icelandic sagas, which are set during the period of the settlement of Iceland. The best known of these are Njala's saga about an epic blood feud, as well as the Greenlanding saga and Eirik's saga, describing the discovery and settlement of Greenland and Vinland.

2.4.3 Geography

The geography of Iceland is extremely diverse and unusual. Geologically, Iceland is located on the Mid-Atlantic Ridge, along which oceanic crust spreads, forming new oceanic crust. Iceland was formed as a result of rifting and as a result of volcanism along the ridge. Due to this, the island is volcanically and geologically active. On the territory of the island there is a large number of active volcanoes, geysers and hot springs. Due to the constant movement of the lithospheric plates on the island, volcanic eruptions and earthquakes occur about once every five years. Volcanic eruptions sometimes occur not only on the island of Iceland itself, but also on the bottom of the ocean off its coast, as well as on small islands. The volcanic eruption with the unpronounceable name of Eyjafjallajökull in 2010 disrupted air traffic in Northern Europe as the large amount of volcanic ash and dust was thrown out, which spread far beyond Iceland.

The area of the entire country is 103,000 km2, 62.7% of which is treeless tundra. Iceland's coastline is indented by many fjords, around which most of the country's population centres are located, but the interior of the country is cold and sparsely populated. It consists of untouched sand and lava fields, mountains and glaciers, and many glacial rivers flow into the sea through the lowlands near the coast.

2.4.4 Climate

Despite the fact that Iceland is located in close proximity to the Arctic Circle, the climate here is temperate and humid due to the warm Atlantic currents of the Gulf Stream. It can be described as a subarctic marine. But at the same time, a cold maritime climate prevails throughout Iceland, since the weather on this island in the North Atlantic Ocean is formed not only by a warm current, but also by the polar Arctic ice. Being closer to continental Europe than to the North American mainland, Iceland is considered part of Europe despite the fact that its closest territory is actually Greenland.

2.4.5 Tourism

Iceland is also a popular tourist destination in northern Europe, mainly because of its unique and untouched nature. Whale safaris, hot springs, and glacier hikes are available here. Active tourism with lots of hiking trails is also a popular part of tourism in Iceland. The most famous and popular tourist routes in Iceland are the golden circle of Iceland, which runs through the central and southern parts of the island, and the Diamond Ring, a tourist route in the north of Iceland. The availability of these routes, as well as their popularity, is due to the construction of the main ring road in Iceland, 1322 kilometres long. Also, the growth of tourism has contributed to modern technology, the availability of the Internet and social networks, which distribute magnificent photographs of unique places.

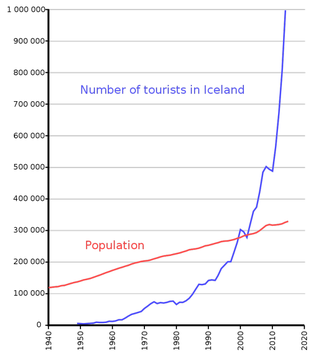


Figure 21. Tourism in Iceland. Image via Wikimedia Commons

Also, thanks to the Icelandic apocalyptic scenery, various world-famous sci-fi films and fantasy series such as Interstellar, Game of Thrones, Star Wars: The Force Awakens and others were filmed here. Many fans also travel to Iceland to visit the filming locations of their favourite films.

The number of tourists in Iceland is growing at an incredible pace. Thus, in the early 80s the number of tourists did not exceed 80,000 people a year, and at the beginning of this century, the annual number of visitors for the first time exceeded the total resident population and amounted to about 300,000 people. A few years later, Iceland began to experience a tourism boom, which peaked in 2019, the year before the COVID-19 pandemic. More than two million people visited Iceland in 2019. About 30% of this number visited the Lake Myvatn region [35].

Figure 22. Islandic Landscapes (The Ultimate Guide to Lake Myvatn)

2.4.6 Architecture

The architecture of Iceland has been largely influenced by its harsh and cold climate, long polar nights, almost complete absence of vegetation, snowy winters and icy winds. Under such conditions, the first architecture was aimed not at elegance and beauty, as was the case in Italy in the middle of the 15th century, but at functionality and heat preservation. Due to the sparse vegetation, peat and turf, which was in abundance here, became the first building material. Stone and wood were also used in construction, but wood quickly became scarce due to its use both as a material for creating labour products, vehicles, and as a fuel for heating houses. Stone, on the other hand, became the dominant building material, but its physical properties meant that the first houses, without proper insulation, retained heat very poorly. To solve this problem, peat with turf was used, whose heat resistance properties appeared to be better.

Hence, traditional peat houses, covered with turf on top, provided sufficient thermal insulation to keep warm inside, and in summer they protected well from rain and the hot sun. The foundation of such houses consisted of large stones, and the wooden frame took on the main burden of peat. Sod was planted on the gable roofs, which helped to keep warm. Such a building had few additional details - a wooden door and a small window – all to keep warm.

As a rule, the houses were about 17 meters long and about 6 meters wide. The interior was not divided into rooms but was one single space with a hearth in the centre for better space heating. There were no bedrooms as such, and the hosts slept on the benches around the hearth in the common large space of the hall.

In such «long houses» the inhabitants of the island lived until the middle of the 18th century. Later, due to urbanization and the growth of cities, new requirements were adopted, therefore, a new architectural solution arose associated with the construction of stone houses. Consequently, in the centre of Reykjavik, streets with stone houses built according to the designs of Danish architects began to appear. Due to the growth of trade, new materials appeared and opportunities for building houses widened. Iceland started to import wood, tuff, basalt, metal. Thanks to both cultural and geological proximity and the similarity of Iceland with the Scandinavian countries, as well as new imported materials, more and more new houses were constructed, similar in architecture to the traditional houses of the Scandinavian countries. However, the climate still had its influence, and the new houses continued to be highly functional, utilitarian and simple, without architectural frills. The reason behind – keep house warm and economise.

Since the beginning of the 20th century, Icelandic cities embarked on the path of transformation, when new, modern forms, structures, materials and construction methods arrived. Four- and five-story houses became commonplace for Reykjavik, new public houses were built from reinforced concrete. After Iceland gained independence at the end of World War II, a building boom began here. World architecture with its experience burst into Iceland though not replacing the traditional architecture [36].

Figure 23. Traditional Islandic houses with sod rood (The Ultimate Guide to Iceland)

Figure 24. Hverfjall in region Myvatn (The Ultimate Guide to Iceland)

Figure 25. Waterfall gullfoss (The Ultimate Guide to Iceland)

2.4.7 Myvatn region

Myvatn is the northern region of Iceland, home to some of the country's most impressive natural wonders, such as the Dettifoss waterfall, which is considered to be the largest and most powerful waterfall in Europe, and the Hverfjall volcanic structure. Considered the capital of Iceland's northern lights, Myvatn is also home to Iceland's fourth largest lake in Iceland - Lake Myvatn, which covers an area of 36.5 square kilometres and is home to a variety of birds and wildlife [37]. Mývatn is a legally protected conservation area.

Forming part of the Diamond Circle, a popular tourist route in northern Iceland, Lake Mývatn and its hilly and tundra surroundings are an idyllic place for birdwatching or fishing, relaxing in natural hot springs, and exploring the eerily beautiful Dimmuborgir lava fortress [38]. There is an abundance of hiking trails, bus tours and lots of other activities. Of course, one of the most spectacular sights is the northern lights themselves, which are most often seen in the northern region of Iceland [39].

Tourists spent an average of 6.4 nights in Iceland in August 2019 [35]. The creation of a museum in the region could increase the length of stay of tourists in the region and, consequently, improve local economic performance. In addition, the museum could act as a tourist centre of the region, which might become be the main information point of the region.

2.4.8 Landscape integration

The Myvatn region is a sparsely populated and remote rural area, and its landscape is extremely unique with special natural conditions, which is highly appreciated by tourists.

Remote buildings in rural areas influence the rural landscape, which can be a fundamental factor in creating the overall typology of the area. As single buildings are small and scattered, they do not create a common or coherent new landscape, but only deprive it of its original specification, almost completely destroying the natural beauty.

The impact of rural buildings on the landscape varies depending on the size of the building, the choice of materials and design. There are two main areas of interaction between architecture and landscape in rural areas. In the first case, a large significant dominant element is created, which takes on an important role, for example, a huge farm, a silo. In another case, the building merges with the landscape, abandoning its dominant role.

Determining the character of the landscape is also essential to guide the integration of the building into the landscape. It is necessary to note here that traditional buildings, which are, in fact, immediately integrated into the environment, thanks to the constant presence of man, give the landscape intangible values, such as identity values. Historical architecture in Iceland is a good example of this integration - small houses recessed into the soil, houses well-integrated into the landscape due to climatic conditions have strongly influenced the identity of the countryside in Iceland for many centuries [40].

Thus, the local hilly and tundra landscape of the Myvatn region will not tolerate strong and dominant forms of glass and concrete, which in turn calls for an integrated building into the landscape with the possible use of traditional features of Icelandic historical architecture, such as sod roofs. In this case, the historical natural landscape with historical identity will be preserved.

Figure 26. Lofoten Opera hotel (arquitecturaviva.com)

2.4.9 Development of the region

Negotiations are currently underway in Iceland to merge the two local nearby municipalities of Skútustaðahreppur and Thingeyjarsveit into one with the new name Þingeyjarsveit, which was chosen by popular vote on April 26, 2022 [41]. Both leaders of the two regions, the commissions for unification, and local residents, whose opinion matters, take part in the negotiations. The regions have a population of 399 and 852 respectively, and the new combined municipality will be the largest in Iceland, covering about 12,000 of Iceland's 103,000 square kilometres. The Commission for the Merger of the Two Regions, which has been set up, has already created a project for the Merger of the Two Regions, which provides a clear and neutral picture of what a merged municipality might look like, highlights the main advantages and disadvantages of the merger, to make it easier for voters to take a stand on the merger. The new commission also takes into account the future development of the new region, with an emphasis on environmental issues and sustainable development.

As the region develops, there will be a need to create a sustainable environment aiming to avoid pollution of the Lake Myvatn region and protect the environment in the region. For this development of the new united region, it is planned to introduce new circular economy technologies with zero CO2 emissions and reuse of materials. It means, the region will strive to become one of the world's brightest examples of sustainable development. The Skútustaðahreppur Council strives to be an example for other municipalities in Iceland by demonstrating how its actions contribute to reducing carbon emissions.

All in all, in this research, it is especially important to raise the question of potential strategies for introducing a circular economy into the architecture of the Icelandic region, taking into account the peculiarities of construction in Iceland and the study of material flow, which will be discussed further.

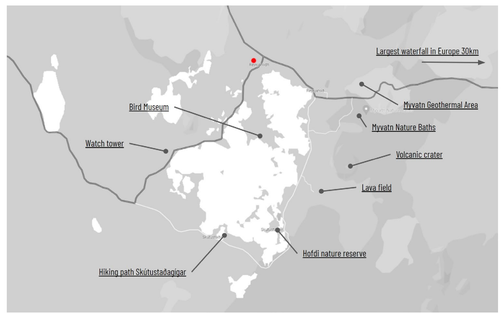


Figure 27. Attraction points around Myvatn Lake

Figure 28. New municipality Þingeyjarsveit

2.5 Circular economy in Iceland

2.5.1 Features of sustainable building in Iceland and material flow

On 12 December 2020, at the Climate Ambition Summit, Iceland announced that the country will raise its ambition from its currently promised 40 percent emission reduction by 2030 to 55 percent or more, working together to achieve this expanded target with other European states [42]. This document sets the general direction for Iceland on the issue of carbon neutrality.

The updated Climate Action Plan was published in June 2020 and includes 48 mitigation measures across sectors to meet net emission reduction commitments. The Action Plan specifically states that it is intended to achieve greater net emission reductions than are strictly required under current international commitments of Iceland, prior to the official announcement of the expanded ambition on 12 December 2020. Climate Action Plan [43].

Iceland has the Icelandic Green Building Council, which is a member of the World Green Building Council and which works to raise environmental awareness and green action planning, and make lobby authorities to pass laws that will steer the market in a more sustainable direction [44]. The work was based on the three core principles of the Ellen MacArthur Foundation, which were discussed earlier in this research paper: durability, adaptability, and waste reduction. The council is currently developing state-of-the-art eco-certification systems and EPD, an environmental product declaration system that will contain verified product information about its environmental impact during the product life cycle and sets standards for carbon-neutral building in Iceland.

In March 2022, the Green Building Council of Iceland released a new document - Roadmap for Greener Building 2030 [45]. The paper assessed annual emissions from the construction sector and sets new targets and action plans to reduce emissions by 2030. Thus, in this document, proposals for measures to reduce emissions in the construction sector were divided into six groups. It was suggested that all groups interact with environmental incentives, circular economy, research and innovation. Each of the groups has its own specific goals, according to the action plan:

- Construction Materials

Creation of a common database, increasing the competitiveness of environmentally friendly building materials.

- Construction site

Improving energy exchange at the construction site

- Usage

Reduce building energy consumption, improve building maintenance, educate occupants to promote green home use

- End of life

Improving the correctness of the assessment of the life cycle of the building, processing of construction waste on site, reusing of construction waste.

- Organization and design

Life cycle analysis, creation and development of environmental certificates

- Emission estimates

Estimates of emissions in the current year, assessment of the effects of emissions from groups 1-5

The documents described above show the involvement of Iceland in solving real environmental problems on a par with other European states. The development of modern information systems and the change in the general linear concept of the economy is the main key to the introduction of a circular economy.

Figure 29. Cover of Iceland's climate action plan (Government of Iceland Government of Iceland)

2.5.2 Interview

The strategies for introducing a circular economy into the construction sector in Iceland have been described above, but it is also worth considering the specifics of building in Iceland and the challenges that both researchers and developers face. Hence, for example, as mentioned above, many building materials are imported to Iceland [46], and construction waste is exported to other countries, as well as the almost complete absence of forests and harsh climatic conditions with high humidity, which negatively affects the durability of materials, are a particular challenge for effective implementation of the circular economy.

Seeking to obtain more objective and accurate information about the current state of affairs, as well as to identify real opportunities for introducing new technologies into the practical part and the correct choice of material, the author of the study contacted Áróra Árnadóttir - Managing Director of the Green Building Council Iceland, responsible for changing the built environment of Iceland in an environmentally-friendly way; and Sigríður Ósk Bjarnadóttir, Associate Professor at the University of Iceland teaching Housing Construction and Material Science.

The author of the dissertation set five key interview questions regarding the implementation of the circular economy in an architectural project in Iceland:

- What are the specifics of building a carbon-neutral building in Iceland?

- How to use the material passport correctly and how effective and common is it in Iceland?

- How to take care of the recycling of the building material after its use?

- How strong is the influence of the Icelandic environment on the maintenance of the building?

- And how the costs on a maintenance of a building in Iceland can be reduced?

Professor Sigríður Ósk Bjarnadóttir answered the questions in writing, and with Áróra Árnadóttir the author held an online meeting.

During the interview, it was confirmed that building codes in many cases discourage the use of previously used and recycled materials. According to Sigríður Ósk Bjarnadóttir, windows, for example, cannot be reused because modern CE (European conformity mark) certification standards do not cover reused materials. As it was written above, when reviewing the documents of the European Union on the integration of the circular economy, work on changing European standards is already underway.

The absence of a common database on the plausible use of previously used materials was also confirmed. As a result, designers and architects in Iceland are essentially unaware of what materials are available in recycling centres and their reuse is complicated. The same is true for the material passport, which is not used in Iceland. Although BM Valla has begun to include passports on their finished products. Anyway, this is only the beginning.

Another issue reported by Sigríður Ósk Bjarnadóttir is the uncertainty of a carbon neutral building for Iceland. Nevertheless, the work on this issue is currently in progress at the Icelandic Green Building Council. Besides, work is underway to solve the problems of structural integrity of structural elements, with the help of which it is possible to disassemble and use the optimal round house later.

The choice of construction material must be approached in the most responsible manner. In this way, a lot of resources are spent on importing wood, and since the climatic conditions are far from being favourable, its use is questionable, though this issue can be completely solved by the correct placement of waterproofing. Moreover, it is much more effective to use a local substitute wood such as CLT - Cross laminated timber. On the other hand, CLT in Iceland is produced on a limited scale, which cannot cover the entire demand for material in Iceland. This material definitely has future and new forest plantations are already underway in Iceland, which, for natural reasons, will not be ready for use until 10 years from now.

CLT is manufactured in Iceland by Límtré Vírnet, with plants located within 100 kilometres of Reykjavik. To meet the market demand, Limtre Virnet started selling and importing steel frame houses as early as 2000. This was the company's response to the increased demand for various solutions in the Icelandic market. In addition to supplying steel and/or wood frame buildings, the company offers a specially trained contractor who takes care of the installation on the construction site. Límtré Vírnet ehf is by far the largest steel forming company in Iceland and has the widest range of individual products in this area. It is also the only producer of glued laminated lumber and sandwich panels in Iceland. The company has very good relationships in the construction industry and sells materials to retailers, building contractors and individuals [47].

It was also found out that BM Valla is developing new technologies for the creation of carbon-neutral cement. BM Valla was founded in 1956 and for many years was at the forefront of Icelandic industrial companies and played a leading role in providing services to the Icelandic construction market. The company owns a concrete plant that serves the metropolitan area and its surroundings. There is a slab plant, as well as a small-scale production, which produces, for example, prefabricated garden blocks and other products. Let us mention here that BM Valla has a large fleet of concrete mixer trucks, plenty of concrete pumps and uses excellent raw materials in the entire production. Its latest developments in footprint reduction are expected to provide Iceland, by 2030, with a new cement technology that captures and stores carbon during production, further helping to reduce its carbon footprint [48].

In addition to above, Iceland has its own local production of stone insulation wool, which can be used as insulation in construction. Therefore, when transporting it, additional resources are not spent. Steinull hf manufactures mineral fibre insulation materials. The plant began production in 1985, and its capacities allow to produce 10,000 tons of high-quality insulation per year. The production of mineral wool is carried out on a single line with a width of 1.8 m using electric smelting. The raw material is mainly local basalt sand and crushed seashells, including a proportionately small amount of dust-binding oil and other ingredients. The fibre itself consists primarily of silicon oxide with a number of other metal oxides. It is bio-soluble and the temperature limit is over 1000°C. Not only is the raw material derived from renewable resources, but the electricity used in the melting and curing ovens is derived from natural sources: hydroelectricity and geothermal energy, neither of which emit CO2 in their production. Due to the smelting method used, the exhaust gas emissions from the manufacturing plant are negligible even when compared to conventional insulation installations. Icerock's unique properties as a stone-based mineral wool come from the use of electric smelting instead of the more conventional coke-fired stone wool cupola found elsewhere in the world [49].

When introducing a building into the landscape, the need to take into account the mode of this integration occurs. Thus, Áróra Árnadóttir proposed to use construction equipment powered by electricity, which is produced by geothermal sources. This will help reduce construction CO2 emissions by more than 10%.

Additionally, the interviews revealed the prerequisite for involving local residents in order to fully integrate the circular economy into the region. Therefore, instead of traditional processing centres, an Upcycling Centre was offered, in which products would not be dismantled for materials, but could be restored to their original products. This might help to get rid of the extra costs of transporting garbage.

Figure 30. Construction joint done by Límtré Vírnet (limtrevirnet.is)

2.5.3 Interview results

After a conversation with scientists, it became clear that, today, the full implementation of the circular economy in Iceland is hampered by the absence, of the necessary information base in the first place. Accordingly, it is difficult for architects and designers when designing to find and use reclaimed materials in the project. It is almost impossible to know about their presence, quality and quantity.

In addition to this, the creation of a round house is hampered by the inconsistency of the existing regulations with the standard, which, with its prohibitions, excludes the option of using certain products in construction. The lack of a common database and of material passport makes it difficult to indicate and pre-calculate the cost of processing building materials after the completion of its operation.

However, the required development and improvement of standards to improve the current situation is already underway and there are already local raw material suppliers in Iceland ready to work in an environmentally-friendly direction.

The author assumes that more favourable conditions for the active use of the studied technologies and the economy may arise in 3-5 years, when a correct and working infrastructure is created to round off material flows.

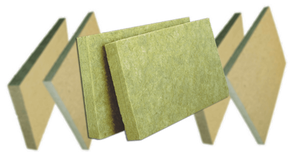


Figure 31. Mineral-fiber wool by Steinull (steinull.is)

2.6 Case study

Furthermore, the author of the study explored some excellent projects related to the creation of a recycling centre and a museum that fit seamlessly into the landscape. Both examples have been built and are functioning, hence it is possible to analyse their effectiveness. The first project - Sydhavns Recycling and Upcycling Center in Copenhagen, Denmark [50], and the second – a museum complex created in the Biesbosch National Park in the Netherlands.

2.6.1 Sydhavns Recycling Center

The centre was designed by the Danish architectural firm BiG and built in 2018. In this development project, circular economy technology is introduced, where, likewise, the centre is engaged in the recycling, recovery and reuse of materials in the city.

The architecture of the building represents a hollow hill around crater used to sort goods for recycle. This is done to reduce the spread of noise and possible odours in the area. On the outside it appears like a small green mound. On top of this hill there is a public space with fitness centres, jogging tracks and picnic areas. It turns out that a processing centre is buried in vegetation, offering curious citizens to look «inside», enjoying daily physical exercises.

Inside, the building houses a waste sorting site, a store and warehouse for refurbished items, a recycling centre, a testing laboratory, a workshop and auditoriums for seminars and courses.

As stated on the official website of the centre, there are seminars, debates and educational events to teach children how to sort waste and restore materials. In the test lab, a team of entrepreneurs develop new products and circular business ideas while conserving resources, which is the core strategy of the circular economy. Thus, this project also implements the involvement of people in the business model of the circular economy [51]. On their Facebook page, a popular social networking site, the centre constantly posts photos of their products, which can be easily purchased [52]. Judging by the large number of subscribers, as well as constant posts with building materials and restored things, the centre is successfully functioning.

Figure 32. Sydhavn recycle center (ugeavisen.dk)

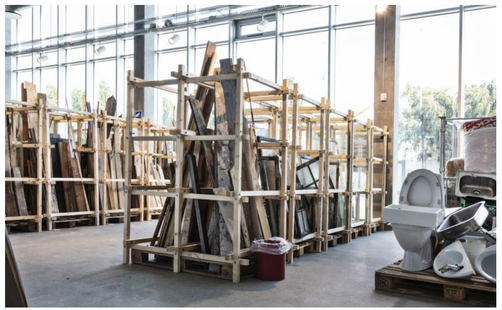


Figure 33. Material shop in Sydhavn recycle center (sydhavngenbrugscenter.kk.dk)

2.6.2 Biesbosch Museum Island

In 2015-2016, Studio Marco Vermeulen reset the Biesbosch Museum, which was outdated and did not actually attract visitors. The museum has been completely refurbished, including getting a café and a temporary exhibition in the new wing, a visitor centre for information about the national park. The creation of a new green roof, which also improves the insulating properties of the structure, added environmental value to the building, while the introduction of new techniques, such as wastewater treatment or the use of heat-resistant glass, reduced energy consumption.

The renovated museum has become the starting point for exploring the national park. The new museum, with its unique forms, has become a virtual piece of land art with a sustainable design and embedded technologies that help minimize energy consumption [53].

Furthermore, it is worth noting that the new site began to act not only as an exhibition site, but also as a cultural and educational centre [54]. It boasts educational activities for children, and visitors can better immerse themselves in the region's culture by taking a boat cruise on the reservoir. There is a small library and a restaurant.

The creation of a cultural and educational centre is of the utmost importance in the context of a modern museum. While retaining their primary purpose of collecting, preserving, and exhibiting, contemporary museums are turning towards the community. As a result, they become the centres of the region, developing local culture, maintaining local identity. Besides, museums today are developing in the direction of communities, offering a space for finding innovative solutions to contemporary social problems and conflicts. At the local level, museums can also contribute to solving global problems. As centres of communities, museums improve the dialogue of cultures by involving local residents [55]. Today, the museums transform into local cultural hubs.

Figure 35. Biesbosch Museum Island (Ronald Tilleman)

Figure 34. Biesbosch Museum Island (Ronald Tilleman)

Figure 34. Biesbosch Museum Island (Ronald Tilleman)

2.7 CONCLUSION OF THEORETICAL PART

The global environmental problems in focus of scientific community in recent years, the excessive consumption of resources and the threat of disruption of resource flows due to recent escalation of the political situation have a negative impact on the stable development and future of Europe and require immediate action by European states in order to change the traditional linear economy and round off the use of resources. All these features can be offered by the circular economy.

The study showed the prospects of the proposed economy, possible strategies for its application, as well as gave an overview of the current green course of the European Union and the proposed policies, the development of which is currently ongoing. The paper discusses the principles and possible methods for introducing a circular economy into architecture and the built environment, such as the creation of a material passport, Cradle-to-Cradle Fabrication to reduce waste, and modular design for building adaptability and durability. Although the general change in the concept of the economy and the rounding of the material flow goes far beyond the correct choice of materials and their recovery, the circular economy is still considered as a general business model. Next, the work describes the social opportunities associated with the involvement of citizens in environmentally sustainable development and their cohesion in solving global problems. Pilot projects to improve the urban environment, which are already showing their effectiveness, were cited as an example.

In Iceland, as in other remote regions and rural areas, the application of the methods being studied to solve environmental problems is especially relevant in the context of sustainable building, since most materials and resources are currently imported, and waste is exported. Such an excessive transfer of resources is not rational, and the demand is rising to use the materials available on site with maximum efficiency.

A review of the current situation and interviews with the scientists showed that although the technology of the circular economy is regenerative and promising in its idea, its widespread implementation in the architecture of Iceland and the European Union on the whole is limited due to problems. These include outdated standards that do not allow certain refurbished products to be certified, and therefore limit their use. The lack of a correct information infrastructure, complicating the situation, hinders our ways to easy and understandable information about the available recovered materials. Admittedly, the possibilities for the restoration and use of materials at the end of the building's service life are also difficult.

The EU and Iceland are already developing many strategies and documents aimed at solving the above and other problems associated with the introduction of a circular economy, though it will take time to develop and revise existing standards. The author believes that this may take at least a couple of years.

To sum up, due to the lack of development and lack of clarity in the future technological possibilities for recycling and recovery of material, the application of the circular economy in the architecture of Iceland today is limited. Nevertheless, choosing carbon-neutral and durable island-produced materials and getting people involved in the design and management of communities still may have a positive impact.

Further research can be aimed at studying the existing barriers to the implementation of the circular economy and their solutions.

Figure 35. Mood 4:20AM

PRACTICAL PART AND SOLUTION

3.1 Design strategy, baseline

Existing environmental problems require urgent changes in attitude towards nature. The implementation of a circular economy is one of the possible solutions to the existing problems. This is especially important for Iceland, where most of the materials and products are imported and additional resources are spent on this extra transportation.

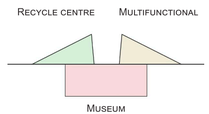
As new municipality of Iceland - Þingeyjarsveit move towards being an example of a sustainable carbon-neutral development with implementation of a circular economy for a whole world, recycle centre with local rural hub will be in high demand.

The aim of this master's thesis project is to create a multifunctional centre with recycle possibilities and museum of the Apocalypse in rulal area of Myvatn region.

The initial task of the design solution is based on the initial data of the International Architectural Competition Iceland lake Myvatn community house [56]. The organizers of the competition provided the location and site plan with the landscape, photographs from the site. Waste sorting containers are currently present at the proposed construction site.

3.2 Site responce

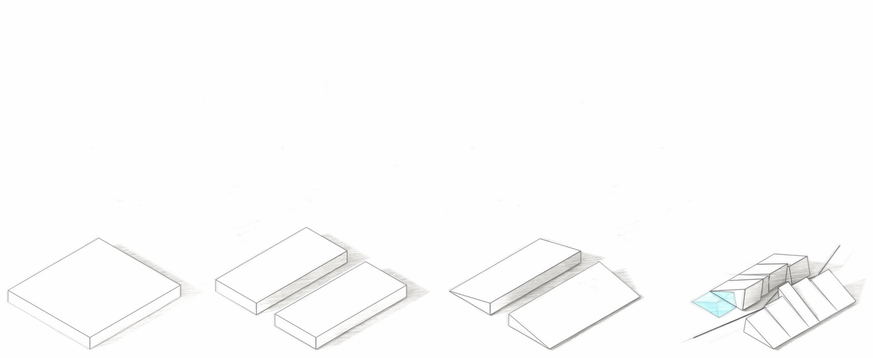
The Myvatn region with picturesque and untouched nature, as follows from the theoretical part, is sparsely populated, and it has a large number of natural attractions that are high valued by tourists. Thanks to this, the region is visited by many tourists who get here either by personal transport, campers, or by tourist buses, or in the summer by bicycles. The nearest settlement from the proposed development site is five kilometres away. There is currently no house within a kilometre radius. However, the district also lacks a major tourist centre, making it difficult to get to know the region.



3.3 Concept

The main idea and concept of the building was based on the geology of Iceland. So, Iceland is located on two lithospheric plates that move in different directions. This causes the geological activity of Iceland and the presence of a large number of volcanoes and hot springs. The movement of the soil in different directions also may create a geological fault, which can later transform into a rift valley, which also abound in Iceland. So, the shape of the building consists of two blocks that convey the feeling of a valley with a depression in the centre and hills on opposite sides. Due to erosion, the resulting rift valleys are usually not ideal: they are broken, and the highlands at the edges have a different height. This is also reflected in the project, through the different heights of the walls and their varied slope in the central part of the building. Due to this, there is an asymmetrical open space in the centre - an atrium, protected from the influence of the wind.

During the analysis of the terrain, a distant height was noticed, which rose in the south above the horizon. Thus, the central line of the open space in the middle was rotated to this height to create a particularly prominent perspective, which can be noticed from the centre of the complex.



3.4 Landscape

In order not to disturb the natural landscapes and the overall harmony of the region, it was decided to integrate the building into the landscape and hide all the main details of the infrastructure. Too smooth forms could make the museum inconspicuous, which would not call for a visit. It was decided to create more prominent and angular forms against the background of the hilly terrain using sod roofs, which are typical of traditional Icelandic architecture. This is how the idea was born to create an essentially land art object in a remote area.

All external infrastructure was hidden - the main parking was moved to the underground floor, the waste sorting section was covered with a sod roof, and the bus parking was made as inconspicuous as possible to eliminate contrasts between multi-coloured buses and the general dark tone of the building. Bicycle parking is available.

The integration of the building into the landscape also made it possible to isolate the dirty area of the building with waste sorting, to provide protection from noise, vibration, and smells. Part of the building with a museum for guests of the region and an open workspace for locals is a clean area of the building.

3.5 Plan solution

The division of the building into two blocks made it possible to functionally divide the building and place the museum on the underground floor.

On the ground floor, on the left side of the building, there is a waste sorting and recycling area, a workshop for the recovery of materials and products, as well as a used goods store, second hand store. All three zones are open and create a common area for sorting, recovery and sale of materials and used products. Entry for personal vehicles, trucks and technical vehicles to the waste sorting area is provided.

Also in this part of the building is a public/shared greenhouse using recycled organic waste for the soil. Nearby is a cafe that could offer fresh produce from the greenhouse on its menu. The height of the ceiling made it possible to expand the cafe to a small second floor.

The presence of a depot and storage room is determined by the competition program. So, the depot has technical trucks for cleaning roads from snow and search engines, and the storage room has a public purpose for storing household utensils by local residents.

On the right side of the building are open workspaces, office space intended for the administration of the museum and local residents, exploring the possibilities of implement the circular economy into the region. There is also an exit from the museum, next to which is a book store and an auditorium for social events and educational lectures. The central staircase connects the museum to the ground floor and underground parking for 120 cars.

At the centre of the atrium, located in the centre of the complex, between the two blocks, there are gaps in the floor with views to the first floor, where the main staircase leads. There is the main entrance to the museum, which should be used by tourists arriving by bus and bicycles. On the underground floor, in addition to the museum and the reception and cloakroom, there are classrooms, multimedia room, museum storage and technical rooms for the geothermal heating system.

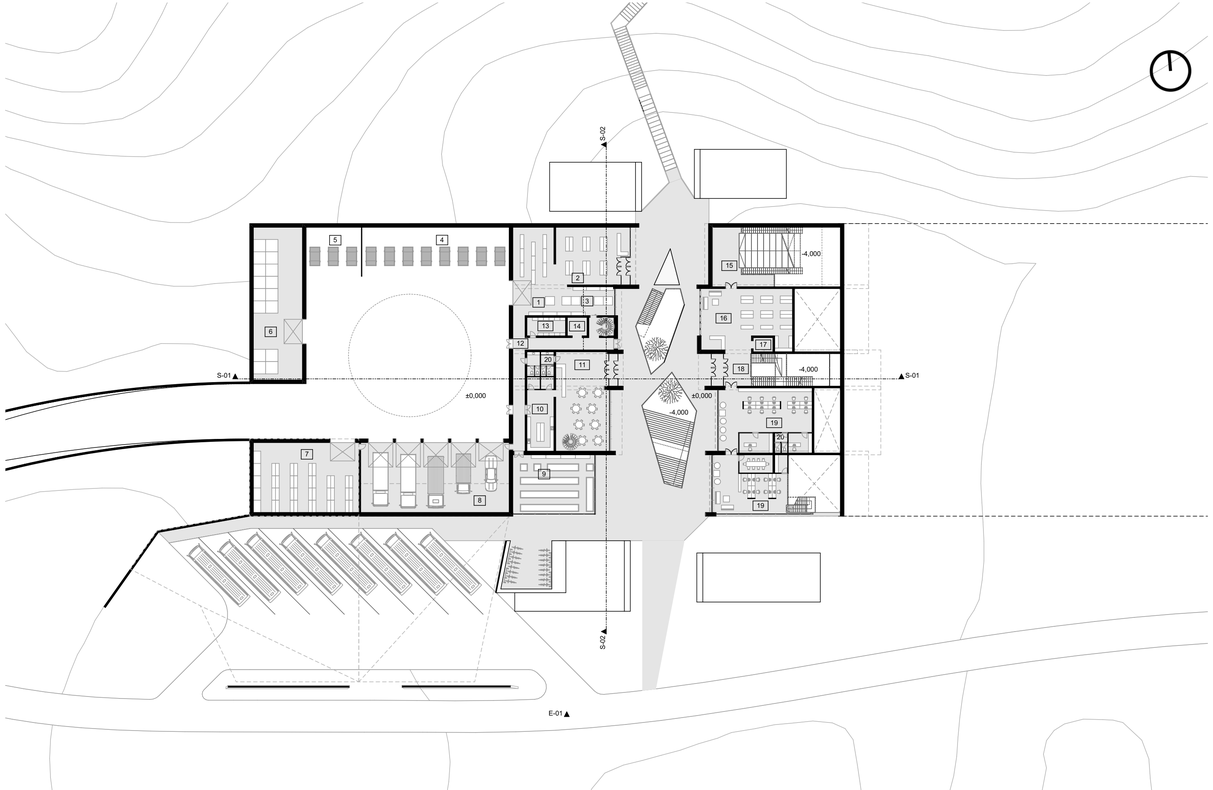
Site plan **M1:1000**

Area program

Zone Number	Zone Name	Measured Area
Ground Floor 0		
1	Waste management zone	121,6
2	Secondhand store	113,1
3	Workshop	44,2
4	Waste collection zone	192
5	Org. waste collection zone	70,4
6	Features for recycling	199,2
7	Storage	196,1
8	Depo	275,9
9	Greenhouse	126
10	Kitchen	53,6
11	Cafe	136,1
12	Walkway	86,3
13	Staff room	18,9
14	Cargo lift	9,6
15	Auditorium	175,2
16	Book store	144,7
17	Lift	7,4
18	Enterway	22,8
19	Open workspace	115,6
19	Open workspace	154,6
20	Restrooms	6,8
20	Restrooms	17,6

Zone Number	Zone Name	Measured Area
Underground Floor -1		
14	Cargo lift	9,6
15	Auditorium	103,8
17	Lift	7,4
18	Enterway	89,3
19	Open workspace	155,1
20	Restrooms	6,2
20	Restrooms	35,4
21	Wardrobe	51,6
22	Lobby and reception	110,9
23	Exhibition hall	600,2
24	Tehno room	24,6
24	Tehno room	78,7
25	Museum storage	145,4
26	Study room	92,2
27	Multimedia room	79,5
28	Staff storage	41,8
First Floor 1		
11	Cafe	74
25	Offices	49,2
	Total area	4 042,6 m²

Ground floor 0 plan **M1:500**



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11	Cafe	74
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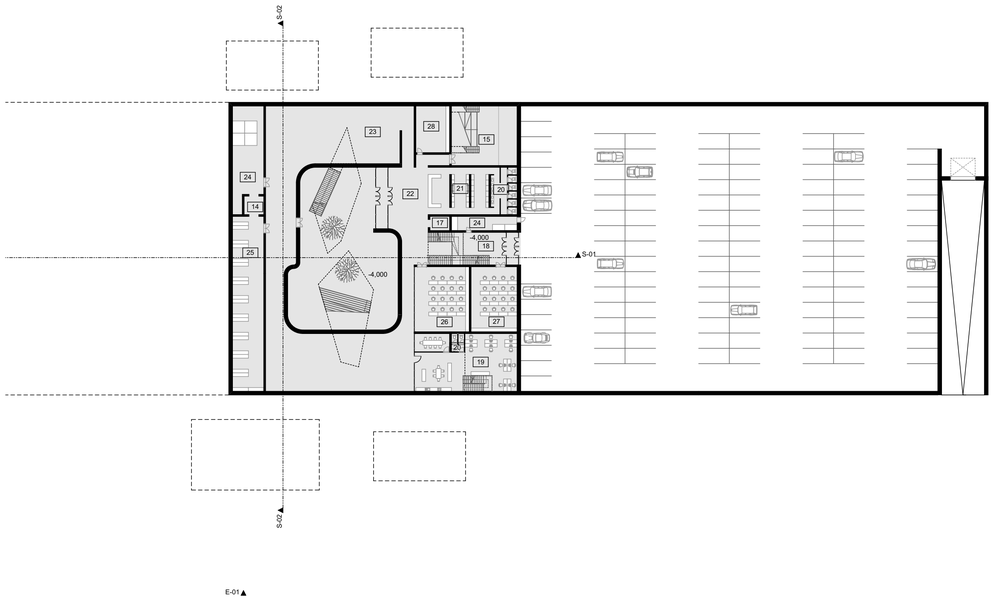
	Total area	4 042,6 m²

Underground floor -1 plan

M1:500



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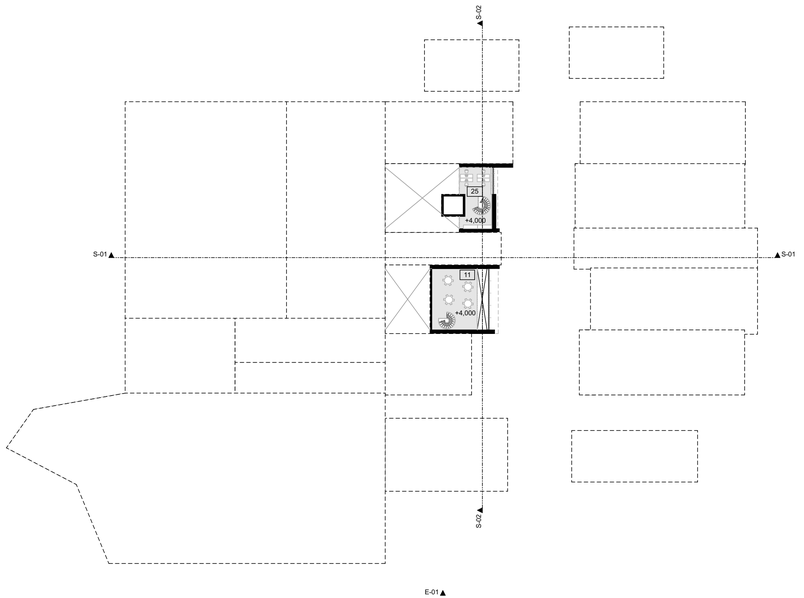
First floor 1 plan

M1:500



3.6 Museum

The idea for the Apocalypse Museum came primarily from the Icelandic landscape. Its desolate, grey hills create an apocalyptic picture, not familiar to our planet, and the feeling of the last nuclear war is reflected in the small craters of Icelandic volcanoes. So in the museum it is possible to create an exposition of 20 possible scenarios of the apocalypse.

Secondly, the theme of the apocalypse is closely connected with environmental problems. The Museum of the Apocalypse should talk about the threats associated with the environment and lead the visitor to the question of how the current situation can be corrected and what needs to be done for this. There are no such museums in the world yet, and Iceland could be a good location for such a museum.

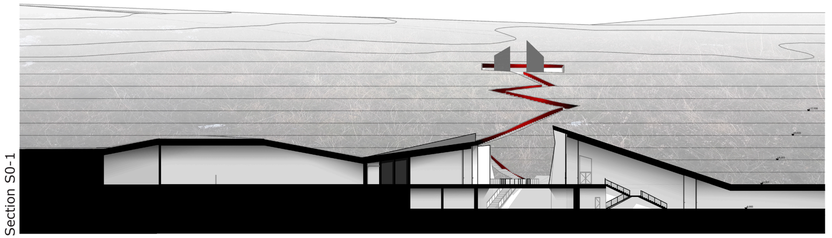
Going down the gap in the centre of the complex, the visitor finds himself in a dimly lit atmospheric room with dried trees, creating an oppressive feeling of the end of the world. Here is the main entrance to the reception. Movement in the museum takes place in a circle, the formulation of the problem of the future of ecology should occur during the inspection of the museum exposition.

According to the idea, after getting acquainted with the museum, the visitor goes up the stairs to the first floor and enters the book store. Going out into the street, he watches through the windows how the sorting is going on and sees a direct solution to the problem posed by the museum. He is also lured to the observation deck with Unity Path. According to the concept, during the ascent to the observation deck, the visitor should feel unity with nature, as well as understand the value of local virgin landscapes, which additionally creates a sense of involvement and responsibility for environmental problems.

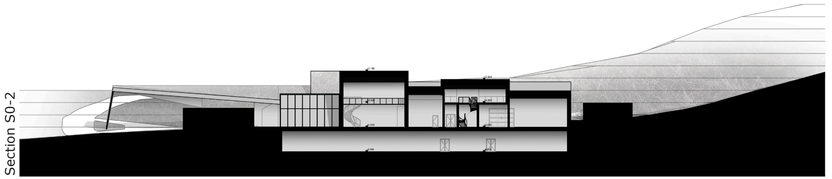
3.7 Circular economy

The very creation of a multifunctional centre in a sparsely populated region of Iceland with a processing centre is already a big step towards implementation of a circular economy into the rural area. In addition to the general purpose of the building, Icelandic materials were chosen for the finishing, such as basalt stone, which is abundant in Iceland, a glass façade, and stone wool, also produced in Iceland.

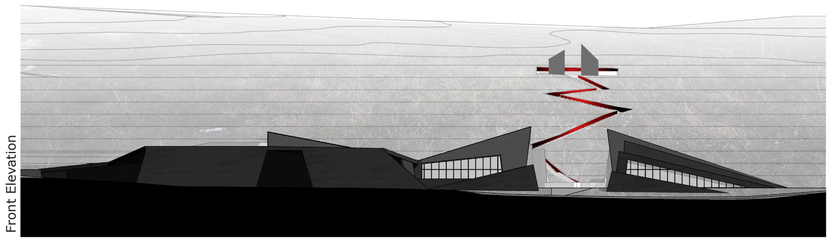
Section S0-1



Section S0-2



Front Elevation



3.8 Thesis conclusion

At the rate at which humanity is being consumed today, the world's consumption of materials already exceeds what the planet can provide. More importantly, the UN has declared a climate crisis. It is time to rethink how we design, build and use. We need new thinking in creating architecture that takes into account environmental factors.

The rural area must move towards a circular economy and use its citizens to find an opportunity to make a difference.

The thesis proposes that it is by developing circular commons and local recycling, caring of using local materials in design and exploring avenues to nudge the public that the vision of circular economy and promise of zero waste can be achieved.

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Appendix

Interviewer: Ervin Golvih

Interviewee: Sigríður Ósk Bjarnadóttir, Associate Professor at the University of Iceland teaching Housing Construction and Material Science.

- What are the features of the material flow in Iceland and how to implement a circular economy into a new building? As I wrote above, the recycling centre would include facilities for sorting, recycling, and redistributing materials and waste and an exchange point for already used items, to leave materials in the region and prevent their extra transportation. Besides, I am planning a greenhouse for organic waste recycling.

I am not sure what you are referring to here.

I have been looking into the implementation of the circular economy into the design and construction of buildings. There are a few issues in Iceland. First off, building regulations hamper the use of repurposed materials in many cases. Windows, for example, cannot be reused as the regulation is written now because then the CE-certification does not cover the second use. Although I disagree with the regulation here; consideration must be taken of the age of the building material, its previous use, its maintenance and wear, etc. Some slack must be given. But as the regulation is written, it is very tough for building materials that require a CE certification to be reused. Currently, there is no database or even collection hub for building materials that have been discarded. Essentially designers don’t know what is available, its condition, etc.

Another issue is the design of structures to be reused later. The optimal circular house would be constructed with elements that can be dismantled and used again later. Here we have to tackle all sorts of issues regarding the structural integrity of structural elements. This is an ongoing project that I am working on.

- What are the specifics of building a carbon-neutral building in Iceland? For example, as I understood, almost all the wood material is imported to Iceland, so, its transportation creates additional environmental impact, and it is necessary to use local materials. I thought, maybe in this situation, lava bricks could be a great solution.

As of now, a carbon-neutral building has not been defined for Icelandic conditions. I know this work is ongoing with the Icelandic Green Building Council. We do have some benchmarks; you can check out byggjumgraenniframtid.is.

- How to use the material passport correctly and how effective and common is it in Iceland? How to take care of the recycling of the building material after its use?

Well, if I use lava bricks, for example, then it would be nice to get to know, that this is a correct and durable material with recycling possibilities after its life.

There are no material passports that I know of in Iceland. In? BM Vallá one of the concrete manufacturers has started to include the passports on their pre-fab products.

- How strong is the influence of the Icelandic environment on the maintenance of the building? And how could its costs be reduced? The high humidity of Iceland adversely affects the life of the wood material, and it needs additional maintenance – you have to choose material wisely.

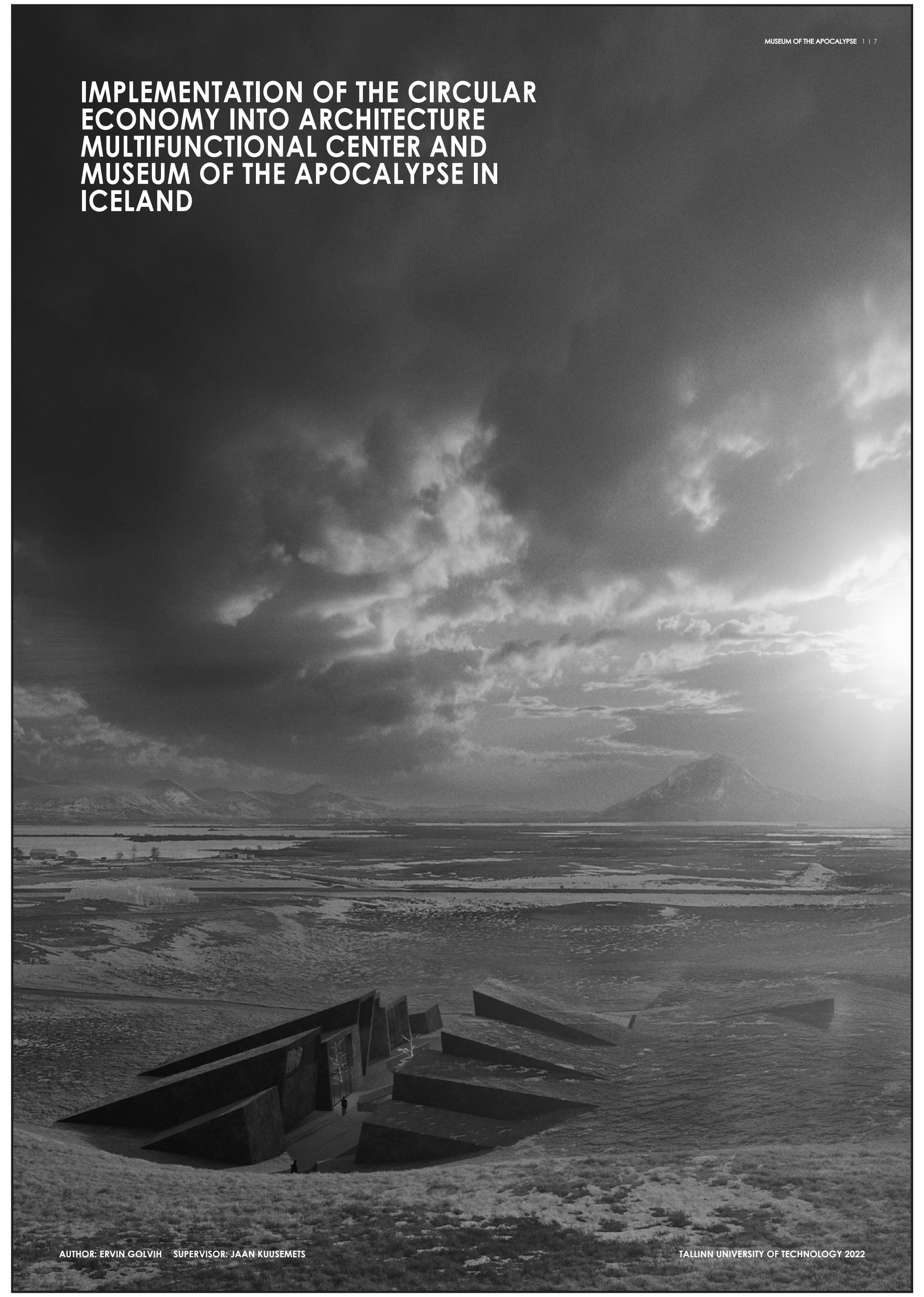
Yes, correct. The materials must be chosen wisely, and the construction phase is of particular importance. For example, when constructing with CLT, the construction site should be covered with tarp to ensure the excess moisture is not trapped in the building materials (this may lead to degradation/decay/mold). Unfortunately, most contractors do not ensure this type of protective environment for construction. When designing, we can use Life cycle costing to ensure correct materials are chosen that reduce maintenance over the life cycle of the building. LCCs are becoming more popular in design now.

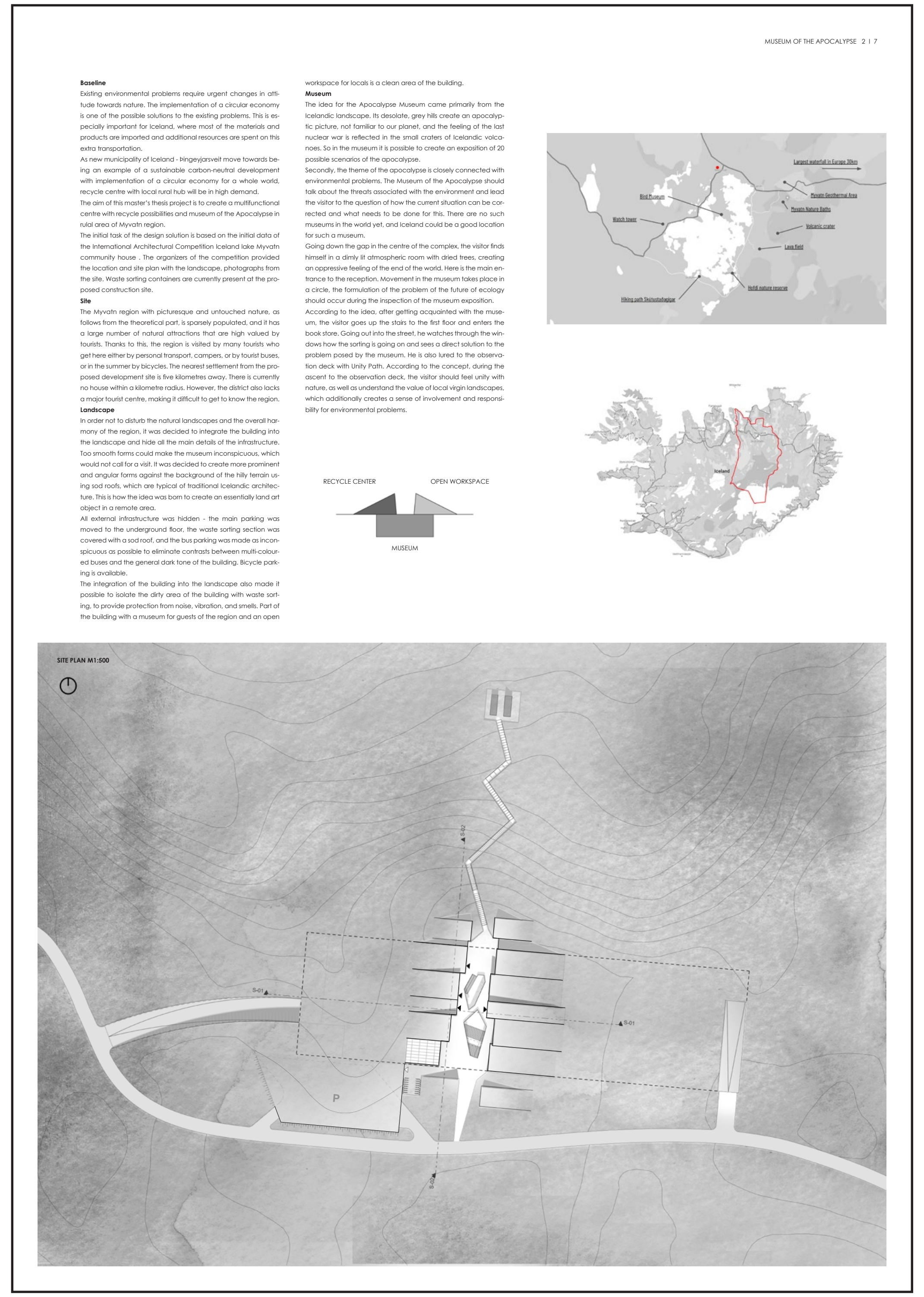
- Could you, please, recommend some documents or web pages related to the circular economy in Iceland?

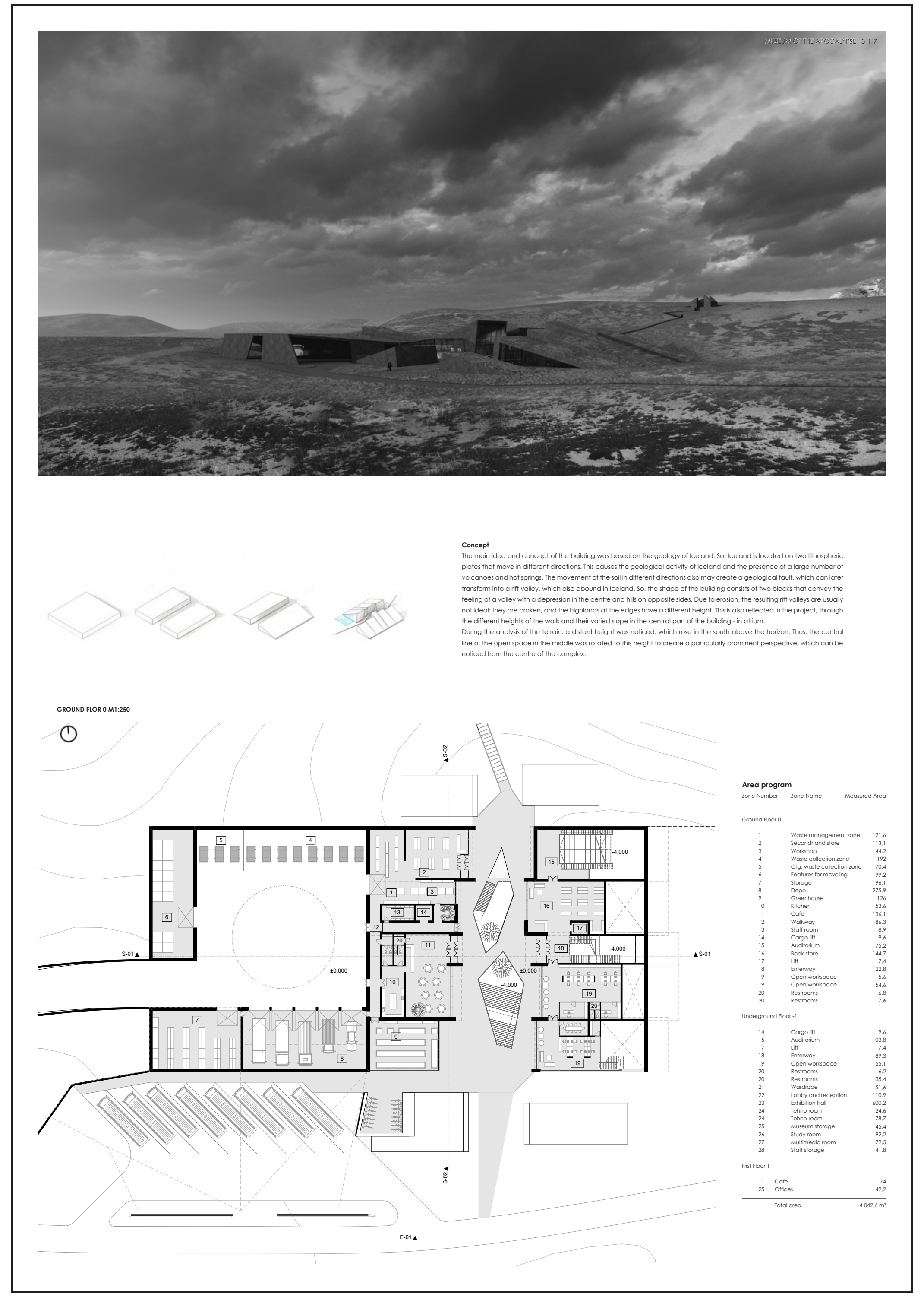
graennibyggd.is – Icelandic Green Building Council, has at least one pamphlet on the circular economy: https://cfb5f439-74b6-493e-a7fd-f59376383508.filesusr.com/ugd/54e708_c2be38b586b14a26a65551888bba0f5d.pdf

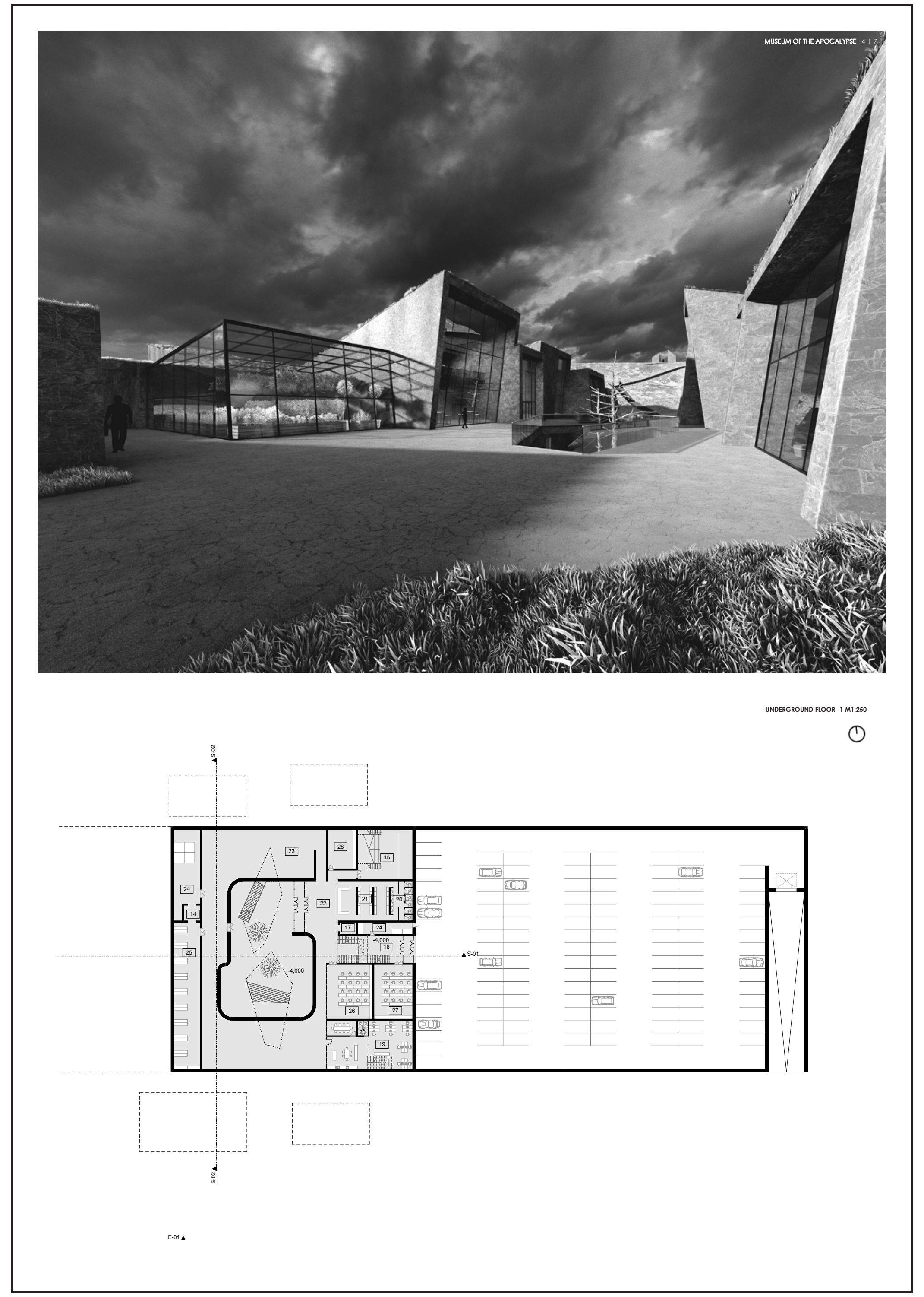
Byggjumgraenniframtid.is – status on carbon emissions in Iceland from construction, first assessment: https://byggjumgraenniframtid.is/wp-content/uploads/2022/02/Vegvisir-ad-vistvaenni-mannvirkjagerd.-I.-hluti.pdf

POSTERS


IMPLEMENTATION OF THE CIRCULAR ECONOMY INTO ARCHITECTURE MULTIFUNCTIONAL CENTER AND MUSEUM OF THE APOCALYPSE IN ICELAND
AUTHOR: ERVIN GOLVIH
SUPERVISOR: JAAN KUUSEMETS
TALLINN UNIVERSITY OF TECHNOLOGY 2022



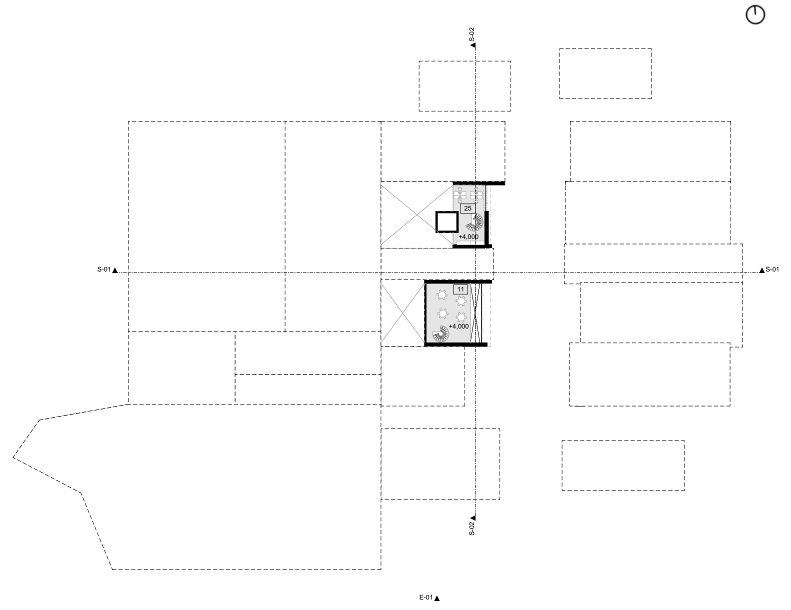


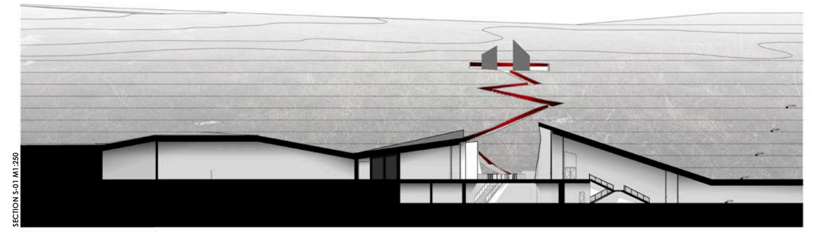


FIRST FLOOR 1 M1:250

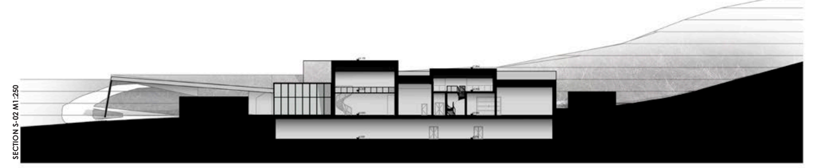
Area program

Zone Number	Zone Name	Measured Area
Ground Floor 0		
1	Waste management zone	121,6
2	Secondhand store	113,1
3	Workshop	44,2
4	Waste collection zone	192
5	Org. waste collection zone	70,4
6	Features for recycling	199,2
7	Storage	196,1
8	Depo	275,9
9	Greenhouse	126
10	Kitchen	53,6
11	Cafe	136,1
12	Walkway	86,3
13	Staff room	18,9
14	Cargo lift	9,6
15	Auditorium	175,2
16	Book store	144,7
17	Lift	7,4
18	Enterway	22,8
19	Open workspace	115,6
19	Open workspace	154,6
20	Restrooms	6,8
20	Restrooms	17,6
Underground Floor -1		
14	Cargo lift	9,6
15	Auditorium	103,8
17	Lift	7,4
18	Enterway	89,3
19	Open workspace	155,1
20	Restrooms	6,2
20	Restrooms	35,4
21	Wardrobe	51,6
22	Lobby and reception	110,9
23	Exhibition hall	600,2
24	Tehno room	24,6
24	Tehno room	78,7
25	Museum storage	145,4
26	Study room	92,2
27	Multimedia room	79,5
28	Staff storage	41,8
First Floor 1		
11	Cafe	74
25	Offices	49,2
	Total area	4 042,6 m²





SECTION S-01 M1:250



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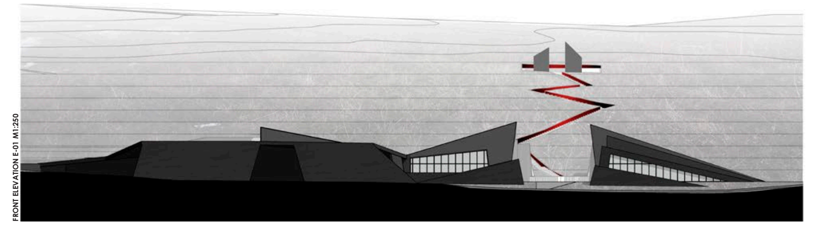

FRONT ELEVATION E-01 M1:250