



The Development of Sustainable Construction in the European Union: Exploring Benefits and Challenges.

Submitted to Davis Gibbs, MSc

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Vienna, January 30th, 2024

Affidavit

I declare that I have authored this thesis independently, that I have not used other than the declared sources and resources, further I have explicitly indicated all materials which have been quoted either literally or by content from the sources used.

The thesis was not submitted or published elsewhere.

Gregor Aichbichler, 30.01.2024

Abstract

Sustainability has become a common word in recent years and for a good reason. Global warming is noticeably affecting the environment and creating challenges, extreme weather, rising temperatures and water levels are the results of global warming.

In the European Union the construction industry is a vital contributor to economic activity, infrastructure, and employment, additionally with all this activity the sector is a large emission contributor. The topic of sustainability and shifting to new and more resource-efficient methods is becoming globally important and recommended in the construction industry. Raising people's awareness of the issue and the possibilities of sustainable construction for designing buildings, to renovating existing buildings, is essential to start a shift towards a net-zero building stock.

The objective of this thesis is to examine how sustainability influences the construction sector. The paper will also display to what extent Germany is a positive benchmark in the European Union, by adopting sustainable strategies and incentivizing them in the construction sector. Through literature research and review, the paper will provide the reader with a general understanding and insights on the topic. Furthermore, six qualitative email interview participants were identified across the European Union which work in the construction sector or in a construction-related industry. The conducted Interviews provided the researcher with more profound understanding of the matter. The valuable insights and perspectives of the experts were analyzed and in combination with the researched literature, served to answer the proposed research questions and raise general awareness of the topic.

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List of Abbreviations

BIPV/T – Building-integrated photovoltaic/thermal
CO₂ – Carbon Dioxide
EED – Energy Efficiency Directive
EPBD – Energy Performance of Buildings Directive
EU – European Union
GmbH – Gesellschaft mit beschränkter Haftung
GDP – Gross Domestic Product
ISO – International Organization for Standardization
OECD – Organization for Economic Co-operation and Development
PVT – Photovoltaic thermal collectors
SDGs – Sustainable Development Goals

1 Introduction

1.1 Background Information

The term climate change describes a long-lasting change of weather conditions over the entire earth and poses a threat, that has embarked to set pressure onto numerous sectors. The topic has become a familiar term over the past years and its consequences are bound to have a strong effect on the entire population and future generations (Abbass et al., 2022).

In the past years a noticeable increase in the adoption of eco-friendly methods across various industries could be observed, this surge aimed to both contribute to the society and environment, utilizing sustainable frameworks targeting both organizations and the broader society. (Jung & Kim, 2023, p.1). Reports suggest that six years ago the construction industry was responsible for 36% of energy consumption and 39% of CO₂ emissions on a global scale, marking this industry as a crucial sector to reach climate goals (Petkov et al., 2023, p.1). Ensuring new building projects are being built efficient and renewable, while taking advantage of sustainable practices during the construction phase and tackling challenges with existing buildings that are expected to still stand in 2050 are core aspects that demand consideration within the construction sector (Petkov et al., 2023, p.1).

According to the World Bank, emissions created by the construction industry must be lowered by 36% in order to meet the objectives of the Paris agreement to restrict global warming to below 2°C. In a fast-evolving world with a growing population, the construction sector has grown into a crucial industry for implementing new policies to mitigate environmental damage in the building process (Matemilola & Muraina, 2023).

The European Union does not exempt from this, the construction sector in the EU is accountable for 42% of the total consumption of energy. More apparent the building sector in the EU was responsible for 30% of the water consumption and waste production, created 35% of the greenhouse gases and finally consumed more than 50% of extracted materials. These large figures result from the various phases construction must go through. Starting with the extraction of the raw materials, following with the manufacturing of the finished goods for the construction, to the construction itself where heavy machinery must be used over a long period of time, to finally the maintenance and the operation of the finished building. For this reason, the EU has implemented several policies and legislation on constructions and buildings which will be further elaborated in the literature review (Kylili & Fokaides, 2017).

Analyzing the economic benefits of building sustainable, a case study from Norway proposes that energy savings of 30-40% can be achieved during the lifetime of the building by tolerating an additional cost of 7-10% in the process of construction, making it interesting in financial and environmental terms (Christensen et al., 2018, p.276).

1.2 Aim of the Study

The objective of this thesis is to identify the most effective practices and strategies adopted in the construction sector in the European Union to mitigate environmental damage and support sustainability. Additionally, the aim is to particularly identify the policies and legislation introduced on an EU-level and their implementation in Germany. This will clarify the importance of climate preservation and display strategies of reaching emission reductions, by implementing effective practices in the supply of raw materials, construction phase and running phase of buildings. The specific policies and legislations from the European Union for construction in its member states can be found, but a lack of scientific information of its implementation was established. Therefore, the thesis should clarify, how and if the policies and legislation are implemented, further it should identify the environmental and financial benefits if implemented. The data will be visualized in graphs and tables in order to determine relationships and patterns. Verified through literature research and conducted expert interviews in the field. The compromised outcomes and data will clearly provide a recommendation and conclusion on sustainable construction and should trigger a better understanding and interest for the readers on the matter.

1.3 Research Question

The aim of this research is to raise awareness of the primary sustainability practices and strategies in the construction industry and their effect on environment and economy, specifically with a geographic and political scope in the European Union. Furthermore, the study will evaluate the adaptation of sustainable policies in Germany. The research questions established for the study aim to shed light and increase awareness for the previously mentioned aspects. Additionally, the research focusses on contributing valuable knowledge to inform future policy makers, adapt industry practices and enhance the understanding of sustainability in economic and environmental terms, with European construction as context. The spotlight on the German construction will showcase an interesting example, due to its general activity in the construction sector and its position as a positive benchmark for other European Union member states.

RQ1. What are the primary sustainability practices and strategies adopted in the construction sector in the European Union?

RQ2. What sustainability policies in the construction sector are adopted in Germany?

RQ3. How do these strategies affect the environment and economic systems in Germany?

2 Literature Review

2.1 Climate change

Rise of the sea-level and extreme weather are results from climate change. This phenomenon is noticeable in Europe. By the year 2100 annual deaths in Europe could increase to 152.000 compared to the 3.000 that were observed in the recent past.

Mainly because of stronger and more frequent occurring heatwaves and extreme weather.

Most effected by extreme coastal storms will be cities located by the sea (Laino & Iglesias, 2023).

Climate change is to some degree a natural phenomenon, since for example natural fluctuations in solar radiation and tectonic shifts affected earth's temperature both warming and cooling it. But at the root of the problem is the greenhouse effect, which is strongly influenced by human activity, especially since the industrial revolution. Compared to the natural level the process of global warming is happening much too rapid in the past decades (Turrentine, 2022).

This rapid increase of temperature is illustrated in Figure 1 and showcases the immense increase over the next decades for an ongoing high emission scenario.

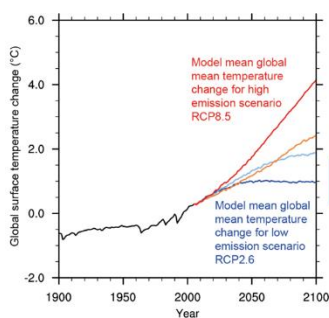


Figure 1. Future temperature changes

Published by the United States Environmental Protection Agency, April 2020

Reaching the Paris Agreement is an important target to mitigate climate change to well below 2 degrees Celsius. The net zero concept is an important and efficient approach for governments and industries to reach given temperature objectives. But without specific temperature targets its focus shifts to an engineered balancing of emissions. Hence the net zero concept should be paired with cumulative accounting of emissions to achieve the targets of the Paris Agreement (Kuriakose et al., 2022).

The construction sector has various highly energy consuming phases, making it one of the main polluting sectors and therefore a pivotal industry to implement working net zero concepts (Ahmed et al., 2021).

2.1.1 Sustainability (Three Pillar Model of Sustainable Development)

Currently humanity is facing numerous challenges, which are felt on a global scale, especially ones related to sustainability. Implementing sustainable practices has become a critical goal in the 21st century. Numerous frameworks were firstly introduced in the 1970's with further interest growing over the years. The frameworks are helpful on a broad scale for many stakeholders and create measures for various characteristics of sustainability (Candelaria et al., 2023).

Defining sustainability in broad terms should let the present generation satisfy their needs without diminishing the chance of future generations to do so. This desire affects both humanity and all kinds of corporations and should include social, environmental, and economic aspects (Baxter & Chipulu, 2023).

Social sustainability addresses mainly problems like poverty, equity, and human justice. Tackling these issues could provide the affected population with a better life and build a lasting sustainable future (Razia & Abu Bakar Ah, 2023). However, this does not serve as the focal point of this study and for the most part will remain outside of the study's scope.

Environmental sustainability is considered a focal point due to its centrality influencing our life on earth. Greenhouse gas emissions, waste and water management, degradation and pollution are all part of environmental sustainability and display its urgency and complexity (Hognestad et al., 2022).

Economic sustainability is a less familiar term and often underrepresented. Economic sustainability has the goal of guaranteeing organizational endurance, through a risk-averse strategy that prefers sustainable approaches. It covers a broad range of various management functions, for example procurement, logistics, production, and marketing (Gleißner et al., 2022).

2.1.2 Sustainable Development Goals (SDGs)

Developed by the United Nations in 2015 with the assistance of its member states, the sustainable development goals or SDGs are a global initiative to action with the goal to end poverty, protect earth and ensure both peace and prosperity for all people to enjoy. The model includes 17 sustainable development goals, 169 targets and 231 indicators which all serve to evaluate the efforts undertaken, to reduce global challenges. The 17 SDG's have strong positive synergies, this means if one sustainable development goal is successfully reached this could benefit various other goals simultaneously (Surman & Böcskei, 2023).

The 17 SDGs may be split into three categories social, economic, and environmental; they all recognize and utilize that an action in one area will affect outcomes in others. But countries have committed to prioritize states that are currently furthest behind on reaching the desired goals. This desire can only be achieved by utilizing technology, financial resources, and creativity from all of humankind (United Nations Development Programme, 2023).

Considering that the construction sector has a vast impact on the environment, society, and economy, it naturally has a big impact on the progress of the sustainable development goals. More specifically Goubran (2019) has discovered that 17% of the SDGs are directly influenced by the construction sector and that the achievement of SDGs 6 (clean water and sanitation), 7 (affordable and clean energy) and 11 (sustainable cities and communities) are mostly dependent on the construction sector to be achieved (Opoku et al., 2022)

A Danish study has identified that a shortage of resources, knowledge, tools, and time are the main barriers for implementing SDGs in construction. Providing practical knowledge with case studies and displaying best practices, would significantly benefit the implementation of SDGs in construction projects (Gade & Selman, 2023).

2.2 The Construction sector in the European Union

The Construction industry is of great importance across the world, it creates the infrastructure and buildings needed by the public. Furthermore, it has an enormous impact on the employment rate, the construction sector provides 18 million direct jobs within the European Union. The value chain of construction starts with suppliers responsible for raw materials and parts, the next step is general construction and manufacturing, followed by engineering and architecture responsible for design and cost, lastly the overall responsibility of maintenance and operating of the finished construction project (European Commission, 2016).

On a global scale the industry is considered a primary resource consumer amounting to 50% of the total raw materials and more than three billion tons. This demonstrates both its positive sides like creation of employment and contribution to a large amount of economic activity, but additionally also illustrates its potential for negative externalities for the environment, for example pollution of air, water and soil or creation of a significant amount of waste (Guerra & Leite, 2021).

With these factors in mind this social and economic growth industry has a potential to apply a circular economy approach, this would include increasing the application of recycled materials, reducing waste on the numerous stages of the construction cycle, and adopting environmentally beneficial technologies (Dsilva et al., 2023).

2.2.1 Construction policies in the European Union

Building policies in the European Union have been under development since the 1990s, due to the European Commission, construction standards and policies have progressively improved. Financial solutions, renewable energy and the indoor environmental quality were targeted. The main policymakers and legislators aimed to transform the European construction sector are the following, the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED) and the Renewable Energy Directive (Fabbri et al., 2020).

The initial version of the Energy Performance of Buildings Directive was introduced in 2002 and was revised and updated over the following years. EU member states are encouraged to regard the standards, especially from the EPBD list, which aims to enhance the performance of buildings in the European Union. The EPBD provides five generalized standards (The Energy Performance of Buildings Directive, 2018).

- ISO 52000-1 is a EPB standard providing a general framework for systematically evaluating the energy performance of a building.
- ISO 52003-1 explains the relationship between EPB indicators and the EPB requirements and EPB ratings.
- ISO 52010-1 consists of mechanisms to evaluate the climatic data needed as common input.
- ISO 52016-1 grants methods to determine internal temperatures and energy needs for cooling and heating buildings.
- ISO 52018-1 gives a summary of the indicators enabling specific EPB requirements at the level of energy needs and building fabrics.

Since construction is a high energy consumer the Energy Efficiency Directive and its policies play a major role in the sector. Energy efficiency was given legal power to require member states to consider energy efficiency across multiple aspects of planning and investment decisions. Energy management systems will be obligatory for large enterprises. High efficiency heating and cooling systems should gradually ensure decarbonization. Finally financing policies will play an important role, due to innovative green financing schemes (*The energy efficiency directive, 2023*).

The Renewable Energy directive came into effect in 2018 setting a binding renewable energy target of 32%. It aims with its policies to maintain EU's status as a leader in renewable energy and should assist meeting the emission reduction commitments of the Paris Agreement. This directly influences the building sector especially in transport and heating and cooling (*Renewable energy directive, 2018*).

2.2.2 Practices and Strategies in the construction sector

Construction strategies and practices sometimes fall short in terms of the different stages. Which can be separated in preventive strategies which entails the initial stages, like designing and the planning of a construction project, followed by management strategies which start in the subsequent stage and include management, operation and finally also demolition and decommission of buildings (Eberhardt et al., 2020).

Construction may be classified into various types for example it can be residential, commercial, or public. All types start off with the preventive strategy of designing and planning, which involves initial investment, operation logistics and scheduling of milestones and other planning aspects. Acquiring building materials or raw materials requires the right civil engineering strategies. The aspect of storage

and in-time supply is crucial for timing and success of the project. This involves transportation in terms of routing and assignment problems, which become a major part of the planning stage (Sarker et al., 2012).

Management strategies firstly involve the buildings maintenance which is the effort to keep, improve or restore the building, this aspect is crucial to sustain an overall standard for the performance, safety, and value of a building. The success of maintenance relies on efficient cost assessment and budget allocation and can be divided into hard and soft services. Hard services include technical tasks for example heating, cooling, and ventilation. Soft services on the other hand involve janitorial services like waste management or cleaning services (Puķīte & Geipele, 2017).

Finally, after its useful period we arrive at the last stage of construction, which is the demolition or dismantling of a building. A building can also be deconstructed which means that through careful and strategic methods valuable elements of buildings can be re-used. Pre-planning is the first step before demolition, followed by conducting a study of the different parameters through building surveying and structural surveying. After the required planning and preparation, the demolition is carried out in general with a top-down method, the method can vary based on the condition and architectural attributes (Rathi & Khandve, 2014).

2.2.3 Environmental impact of the construction sector in the European Union

In numerous buildings in the European Union energy efficiency is practically zero. This is because more than 220 million buildings which represents around 8% of the entire EU building stock, is aged 21 years or more and 95% of them are approximated to still be standing in 2050. These buildings rely on heating methods that use fossil fuels and therefore would provide great opportunities to save energy, when changed to renewable energy sources. Currently the rate for energy renovation sits around 1% where it should be three times higher, at 3% EU's energy and climate targets would be more achievable. This would lower as previously indicated the overall energy consumption of the EU construction sector which is 42% of the total consumption and the greenhouse gas emissions which is 35% (Sáez-de-Guinoa et al., 2022).

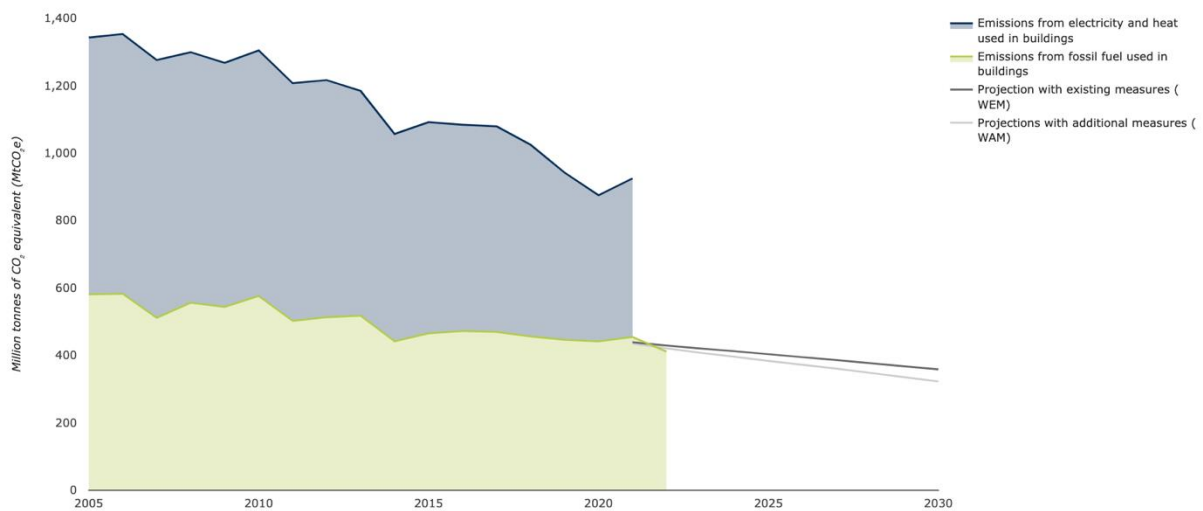


Figure 2. Greenhouse gas emissions from energy use in Buildings in Europe

Published by the European Environment Agency, October 2023

As seen in Figure 2 the building sector is a vital contributor to greenhouse gas emissions. But through improvements to buildings such as insulation and renewable heating and cooling methods, estimates for the coming years indicate a slight decrease in emissions. However, the projected decline is not enough to meet the overall targets (European Environment Agency, 2023). The concept of shifting from a linear economy to a circular economy by extending material cycles and reusing materials would be crucial to reduce the environmental effect of the construction sector (Illankoon & Vithanage, 2023).

2.2.4 Economic Impact of the construction sector in the European Union

The construction sector has evolved into a major contributor to the economy, employment, and infrastructure of Europe. Forecasts project growth in the sector, as of 2022 the European construction sector attained a value of \$2,62 trillion (Grigorenko, 2023).

To further illustrate the economic importance of the construction industry, Figure 3 displays the proportion of the gross domestic product share of the construction business compared to the total gross domestic product of the European Union. Considering the enormous economy and various sectors of the European Union, 12% represents a significant proportion and marks the great importance of the construction sector for the EU.

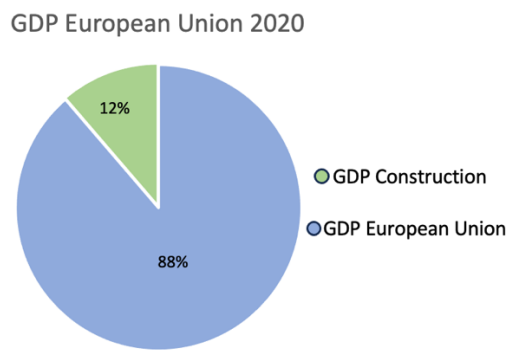


Figure 3. European Union GDP

Created by the Author, November 15, 2023; data source: Statista Research Department

To put the percentages in numbers, according to Statista the total gross domestic product of the European Union in the year 2020 was 13,471 trillion euros (McEvoy, 2023) and the 12% proportion of the construction sector which includes construction of buildings, civil engineering and specialized construction amounted to 1,715 trillion euros in the year 2020 (Statista Research Department, 2023). Analyzing the construction sector in terms of employment opportunities it is important to point out that the sector seeks employees from low, to medium, to high skilled individuals.

Due to an ageing and decreasing workforce a labor shortage in the EU is expected in the future. The more developed countries in the EU satisfy their shortage of a lower skilled workforce in construction, with migrated workers mainly from southern and eastern Europe. This creates a workforce shortage in their own countries, and they must rely on recruiting third-country nationals.

On the other hand, construction also requires some of the most skilled workers for complex projects. Labor shortages are not easy to predict, requirements vary over time, but with a growing trend of the construction industry it is likely that EU member states will continue if not increase to feel labor shortages in construction on all levels of skill (Brucker Juricic et al., 2021).

2.2.5 The supply chain of the construction sector

The supply chain of the construction sector is complex and consists mainly of upstream products this means a lot of the activities are related to the sourcing and transportation of raw materials, needed in the manufacturing process. In the European Union almost 60% of the annual output of the

construction industry is achieved through other economic activities. The value chain of construction can be distinguished into three main sets of activities.

Firstly, the supply and transport of materials and equipment for construction. This includes external industries that extract raw materials. These raw materials are processed by manufacturing industries into useable building products. Additionally heavy machinery must be produced and provided for the construction sector by other industries, including earthmoving, road making, concrete mixing and lifting machines.

Secondly all aspects of the on-site procedure of the construction which includes the execution of the project and various preparations to insure efficiency and safety of the building activities.

Thirdly the construction services, which is the design phase of construction that requires civil, structural, and building engineering. Lastly, in the using phase of the building operational services like managing and maintenance are required to optimize the life cycle of the project (Reinstaller, 2016).

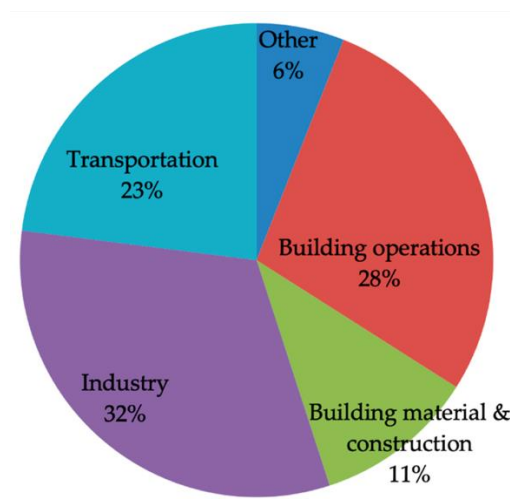


Figure 4. Global CO2 emission by sectors

Published by the Environmental Technology Division, September 10, 2020

Figure 4 further illustrates the contribution of the carbon emissions by individual sectors and showcases that various parts of the supply chain contribute to the increasingly large outflows of carbon dioxide. Carbon dioxide is proven to contribute to global warming as it increases the natural

greenhouse effect, trapping heat in the atmosphere and therefore warming up the planet (Ahmed Ali et al., 2020).

2.3 Environmental and economic impact of the construction sector in Germany

The construction industry in Germany is immensely important to its economy and employment rate. With a market size in 2022 of 493 billion, which is a considerable chunk of the total German GDP and approximately 2 million people being employed in the building sector (Federal Ministry of the Interior and Community, 2022).

This is further visualized in Table 1 which indicates the value of the construction industry as a share of the gross domestic product. It is very visible in the table that the construction industry is progressively gaining a bigger share of the whole domestic product, underlining the importance of the sector to the German economy.

	2007	2012	2016	2020	2022
Share of GDP in %	3.9	4.5	4.7	5.4	6

Table 1. Value of the construction industry as a share of the gross domestic product in Germany

Created by the Author, January 29, 2024; data source: Statista Research Department

For the first time since 2009 the construction sector is predicted to decline in 2024, this is due to the current interest rate environment, which makes financing new projects more expensive. This economic downturn has likely nothing to do with sustainable measures (Wagner & Sims, 2024).

The market is shared by many competitors, the 29 leading construction firms in Germany only accounted for 10.3% of the overall revenue generated by the sector in 2021. The three biggest players are Strabag with 1,19% of the market share and Züblin and Zech with a share less than one percent. It is interesting to note that Strabag which by some margin has a larger share, is an Austrian listed company (Statista Research Department, 2023).

This information leads to the conclusion that Germany does not exempt from the fact that its construction sector plays an important role to reduce the emission of greenhouse gases to the atmosphere. The German building sector has set the goal of greenhouse gas neutral buildings by the year 2045 to mitigate climate change effects.

As of now the German construction sector is accountable for 40% of the entire CO₂ emissions produced in the country. Furthermore, the sector generated 209 million tons of construction and demolition waste, which indicates the potential the sector has for optimizing and recycling material (Krause & Hafner, 2022).

2.3.1 Implementation of sustainable policies in the German building sector.

Germany has been proactive in developing sustainable policies to act as a positive benchmark in the European Union. Germany has developed strong environmental frameworks (Organisation for Economic Co-operation and Development, 2012).

These efforts are visible over the years, since the greenhouse gas emissions emitted by the construction industry in Germany where nearly cut in half from 1990 to 2019. But in order to bring the sector to a greenhouse gas neutral state the emissions must drop further. For this reason, Germany is implementing policies and incentives to further promote efficiency in all buildings and the usage of renewable energy.

Not only the initial phase of constructing is important to implement sustainable design, but the whole lifecycle of a building. For this reason, Germany has implemented a tax relief of 20% for energy-efficient renovations since January 2020. This includes replacing heating systems, insulating roofs and walls and fitting new windows.

To help funding sustainable design and renovation, low-interest loans, and repayment grants of up to 40% for buying, building and renovating energy efficient buildings, have been introduced since 2020. In 2021 funding of up to 20% for individual renovation measures were introduced.

Germany like other European Union states, suffers from an old building stock. Around 3 million residential buildings were built before 1977 before first regulations on energy saving and thermal insulation were introduced. This marks a great potential for renovating external walls and replacing heating systems, saving energy and money. Since 2020 heating systems running on fossil fuels are worthwhile to be replaced in Germany. As the State has introduced a replacement premium of up to 45% for building owners that replace their fossil fuel heating system for a more energy efficient system.

Additionally, from 2026 onwards the installation of oil heating systems will be no longer permitted in Germany (Federal Government of Germany, 2020).

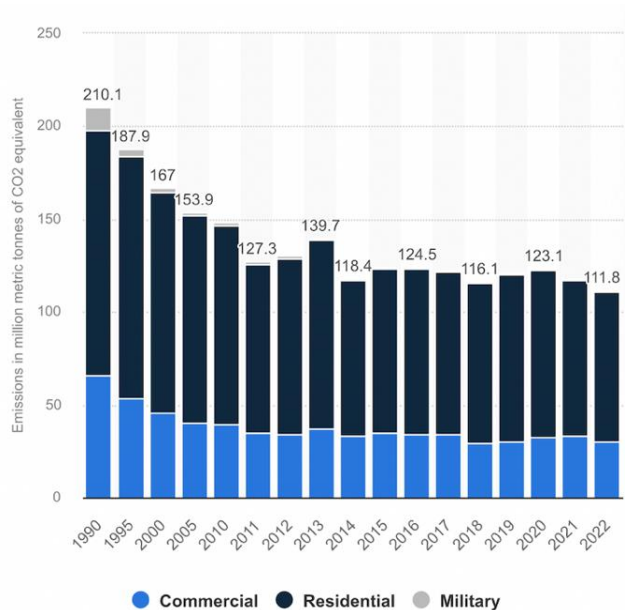


Figure 5. Greenhouse gas emissions of the building sector in Germany

Published by the Statista Research Department, June 19, 2023

Figure 5 displays the effectiveness of the German policies and strategies in the construction sector and proves its position as a positive benchmark. During the last three decades, the greenhouse gas emissions emitted by its construction sector were reduced from 210 million metric tons to 112 million metric tons in 2022 (Statista Research Department, 2023).

2.4 Sustainable construction and forms

Constructing sustainably has become increasingly important over the past years and can be defined as managing a healthy and responsible built environment while efficiently using resources and respecting ecological principles. The international organization for economic co-operation and development short OECD has identified five objectives for sustainable construction which are as follows. Construction should be resource and energy efficient which can reduce greenhouse gas emissions. The prevention of pollution is an objective identified by the OECD this includes indoor quality of air and noise pollution. The next objective is the harmonization with the environment which includes environmental assessment, and the last objective is to integrate systemic approaches like environmental management systems (Zabihi et al., 2012)

The construction industry is experiencing increasing demand for efficient sustainable practices and forms, driven by the environmental concerns, and enforced by government regulations. This trend intends to reduce climate impact, enhance quality of life and conserve resources. Even though innovation plays a significant role in the sector to maintain competitiveness and meet customer needs, the construction sector displays a slower adoption of new technologies and methods compared to other industries (Van Nguyen, 2023).

The following part of the paper will elaborate on different forms of sustainable designs and implementations in the construction industry.

2.4.2 Solar Energy

In the European Union since 2021 there is a strong aim for net-zero concepts in new buildings, this means that the energy consumed by the building while operating does not exceed the on-site production of renewable energy. To achieve this goal solar energy remains the most used and favorite renewable energy source. In order to best utilize solar energy, it is highly recommendable to have an energy efficient building in place in terms of technologies, building quality, and building envelope or insulation. Generally solar collectors can be divided into three categories.

Starting with photovoltaic which has a high efficiency and can be integrated at a low cost, photovoltaic systems will use sunlight to generate electricity. Disadvantages of photovoltaic are limited placement options mainly only on the roof of a building and they are generally considered aesthetically unpleasing.

The second category is thermal flat plates which are also available at low cost, compared to photovoltaic they harvest sunlight to generate heat. Disadvantages of thermal systems are fluid leakages and similarly to photovoltaic systems they are aesthetically unpleasing.

Lastly combining the two previous systems creates a PVT system or photovoltaic + thermal system. This type of solar energy system will produce electricity through sunlight on the first layer of the panel and on the back a thermal exchanger will extract heat from the panel. The generated heat will be used for heating and hot water and the electricity for either cooling or general use.

This system is very efficient but comes with the drawbacks of the other systems which is aesthetics and fluid leaks (Shirinbakhsh & Harvey, 2023). To avoid aesthetical disputes and to exploit the maximum space for solar energy, an increased interest in integrating photovoltaic cells in the building components could be observed in recent years. An example would be including photovoltaic cells into roof tiles. Building components with integrated photovoltaic are a great way of generating electricity but also serve as an envelope for the construction (Alim et al., 2020).

The most efficient method is to combine building integrated photovoltaic and thermal systems or BIPV/T, these are directly implemented in the structure of a building and can replace conventional building materials. BIPV/T collectors will produce both electricity and heat, making these systems highly attractive for domestic construction sectors but also interesting for other commercial sectors (Abdelrazik et al., 2022).

2.4.3 Plant-covered buildings

Direct greening of buildings is steadily securing popularity because of its positive effect on internal air temperature paired with its low implementation cost. The most widely used plants are *Parthenocissus tricuspidata*, *Hedera helix* and *Pileostegia viburnoides* which are high-climbing plants that can vertically cover buildings and efficiently reduce air temperatures during the daytime in the summer by at least one degree Celsius. The *Hedera helix* is the most effective plant when it comes to the cooling effect with internal reduction by up to seven degrees Celsius on a model building.

But the plants also help during the winter months in terms of insulation, dense vertical greening increases the external wall temperature in the winter by up to three degrees which also increases the internal air temperature (Thomsit-Ireland et al., 2020). Additionally, one can also consider roof greening which can be implemented with positive results in urban areas.

Urban areas are experiencing higher air and surface temperatures compared to rural areas, this occurs because of biological surface areas which have a cooling effect are replaced with concrete or stone which oppositely have a heating effect in the summer. Biologically active surfaces evaporate water in the soil when temperatures rise and therefore reduce the pace of how quickly temperatures rise, additionally plants provide shade. The established benefits of green roofs are therefore the ability to reduce heat and absorption of solar radiation (Suszanowicz & Kolasa Więcek, 2019).

2.4.4 Cool roofs

Similar to green roofs, cool roofs can decrease the surface temperature of roofs and therefore the internal air temperature of buildings, reducing the cooling load. The advantages of cool roofs in warm climate zones for both rural and urban areas are positive, the effect of cool roofs in mixed and cold climate areas are not necessarily beneficial, because the heating efforts in colder months may exceed the benefits of the cooling savings. But a study in the Netherlands found that with a light roof reflectivity of 0.6-0.7 on an industrial building, cooling savings of 73% were measured with only a 5% heating penalty, looking at these statistics one could argue that the savings in cooling outweighs the additional heating efforts needed. One of the most extensive studies of 236 commercial buildings in US cities found that all location except for remote sites in Alaska yield net annual savings (Tzempelikos & Lee, 2021).

Implementing the mentioned coatings with high thermal emissivity and solar reflectance is an effective strategy to lower energy consumptions of buildings and promote sustainability. Mixed climate areas like the European Union would already profit from the implementation of cool roofs. The higher the solar radiation the higher the benefits, this suggests that the benefits cool roofs provide will increase the further south they are installed in the European Union (Kolokotroni et al., 2018).

2.4.5 Biodegradable and low emitting materials

The traditional cement used to create concrete in the construction industry is one of the highest contributors to its carbon footprint. With an urban expansion and population growth demands for cement is rising (Althoey et al., 2023).

Reducing cement consumption and replacing it with alternatives is necessary to minimize the emissions of the construction sector (Milling et al., 2020). Green concrete is a concept that replace the common cement with pozzolanic materials which is produced using less energy.

Results demonstrate that the use of low calcium fly ash and silica fume as a cement replacement proves to be an effective choice to lower the use of cement and thus promote sustainability (Mehran et al., 2022).

Replacing cement with 20-35% of fly ash provides dual benefits as it reduces the energy needs in the production process of concrete and lowers the need for raw materials. Using these pozzolanic by-

products from industrial processes enhance the strength of the concrete and its durability while reducing CO2 emissions.

Another alternative for an environmentally friendly cement replacement is limestone calcined clay, which is a combination of limestone and clay and requires lower temperatures when manufactured into concrete compared to traditional cement, therefore reducing the energy consumption (Althoey et al., 2023).

The entire life cycle of a construction project is important to achieve the goal of sustainability and a working circular economy. Using biodegradable materials is an efficient method to achieve these goals. The first biodegradable material that can be utilized either for internal or external purposes is cork, which is a great acoustic insulator, waterproof and the harvesting process is entirely renewable (Thorns, 2018).

Secondly bamboo can be used as a renewable and biodegradable material in construction projects. Bamboo has a solid fiber and has compared to concrete a stronger compressive strength, it can be used to build roof trusses, walls, flooring, scaffolding or as a foundation (Yadav & Mathur, 2021).

Lastly the use of timber or simply wood in construction is a renewable and biodegradable approach that emits by far less carbon dioxide compared to steel and concrete and has the same use spectrum in many aspects. Timber construction is a growing market because of its affordability and significantly shorter time to construct (Ghobadi & Sepasgozar, 2023).

2.5 Strategies of Sustainable Construction adopted in the EU and Germany

The European Union influences national technical regulations aiming to integrate construction methods that protect the environment. But the construction sector is subject to national regulations by the individual member state, the regional and local authorities have significant power to enforce regulations.

Germany's federal government created a framework for incorporating sustainability in all phases of a building's lifecycle, from planning to operation. This framework serves as a comprehensive tool for private and public construction projects and includes project specific guidelines, principles, and recommendations for the operation of buildings. The guidelines are broken down into four core parts.

The first part outlines the foundational principles for sustainable building practices which are applicable for both the private and the public sector, furthermore the part emphasizes the assessment of lifecycle sustainability. The second part defines sustainable planning for new and refurbishment projects focusing on long-term goals. The third part aims to offer guidance for property managers and owners to optimize the operation of buildings in order to ensure the requirements for sustainable operation are fulfilled throughout the life cycle of a project. The last and fourth part specializes in sustainable refurbishment strategies for existing buildings considering their unique requirements. These guidelines are supported by annexes that offer practical tools and documents for successful implementation of the strategies (BMUB, 2016).

3 Methodology

3.1 Study design

The methodology chapter illustrates the used research design, sampling, and any limitations of this thesis. The study design needs to be adequate for the specific research in order to effectively answer the research questions (Ranganathan, 2019).

The methodology chapter will illustrate the techniques used in the thesis to gather applicable qualitative data. The research design can be described and interpreted as a framework, or the set of procedures utilized to gather and analyze data to solve a specific research problem. The selection of a research method strongly depends on the question asked and the objective of the research. The chosen design for a study is critical to ensure the credibility of its findings (Ranganathan & Aggarwal, 2018).

In general, three distinctive forms of research designs exist, which are qualitative, quantitative, and mixed methods. This thesis exploits a qualitative research approach (Strijker et al., 2020).

3.1.1 Qualitative Research

Qualitative data collection is conducted by being observational and making use of open-ended approaches, like interviews to collect data and then employ nonstatistical methods for the analysis.

This technique provides in depth perspectives of the individuals being interviewed and authentic answers that add to the depth of the research. The interviewee was free to express themselves to their personal preference or liking. Qualitative research is also holistic meaning that the interviewer aims to understand the entire system or picture (Forman et al., 2008).

This thesis implemented a qualitative research design utilizing the concept of open-ended interviews to gather in-depth understanding of the topic sustainable construction in the European Union. This in-depth understanding was achieved by addressing adequate questions to professionals involved in the construction industry. Interviewing the participants was not only for gathering information about sustainability in the construction sector, but recognized the component of human experience and allowed the participant to express subjective views on the topic (Dunwoodie et al., 2022).

Sustainability in the construction sector could be a major lever to reduce the impact of climate change as this industry is the biggest consumer of raw materials and a key contributor to greenhouse gases and therefore climate change.

Transforming the sector with innovative solutions that improve the efficiency of buildings both in the construction phase and in the maintaining phase is a leap forward to reduce the emission output of the branch. This can be achieved with the right mindset of the people involved in the industry, the open-ended interviews conducted in this qualitative research provide insights on the mindset and opinions of individuals that are directly involved in the construction industry and showcases their view on the matter (Giesekam et al., 2018).

3.1.2 Interviews

This thesis explored sustainability in the construction sector limited to the European Union, a qualitative approach was chosen in the form of conducting interviews with selected professionals. These interviews illustrated their experience and point of view on the topic, by answering open-ended questions with the flexibility of using their own words. For this research, asynchronous email interviews were chosen, which is an online exchange between the researcher and participant, the data received was not shared between other participants. The anonymity and intimacy for the participant to conduct the interview from their preferred surroundings provides them with comfort and sufficient time to answer the questions.

Asynchronous emails offer various benefits, particularly in terms of cost and efficiency. It is more economical than face-to-face interviews, especially when considering geographical distances. Email interviews also streamline the process of transcribing and organizing data received from the interviews. Furthermore, anonymity may increase participation as participants feel more comfortable sharing sensitive information. In terms of data quality, email interviews can provide the researcher with rich, structured, and explicit responses.

Despite the benefits of asynchronous email interviews, they yield some challenges. Establishing a rapport with participants without personally interacting with participants requires a different approach, often a more detailed and emphatic communication. Additionally email interviews require a basic level of technical skills and internet access for both the participant and researcher. Furthermore, it is crucial to ensure clarity in question phrasing to avoid miscommunication and to guarantee and maintain informed consent with the participants (Ratislavová & Ratislav, 2014).

3.2 Sampling

The sample is a key element of a research in order to establish a scope of a study and furthermore, a sample is a subset of the population and represents the entire population that is analyzed. The method of sampling and the size of the sample strongly correlates with the studies purpose, generalization approach, and method. Both qualitative and quantitative methods may use varying sample sizes based on several factors. Quantitative research samples should fulfill statistical requirements for generalization which usually requires a larger sample size (Cash et al., 2022).

While qualitative research on the other hand is effective with a small sample size (Hennink & Kaiser, 2021).

Both probability sampling and non-probability sampling can be utilized to draw a sample, probability sampling uses mathematical rules to guarantee equal chances for participants to be included in a sample and is commonly used in quantitative research. While non-probability sampling can be split into purposive sampling which is a purposeful selection, quota sampling which is based on a stratified quota and convenience sampling which is based on availability (Cash et al., 2022).

This thesis applied a non-probability convenience sampling method, which allowed a not costly and simple strategy for the sampling process (Stratton, 2021).

A relevant sample of professionals for the researched industry was identified and contacted based on availability, these individuals are either directly involved in the construction sector such as developers and engineers or indirectly involved in the construction sector such as property managers and energy solution experts. The sample was chosen with the assistance of friends and family and therefore matches the traits of convenience sampling, participants were chosen based on availability and convenience for the researcher (Stratton, 2021). A total of six participants were identified and asked for their consent to participate in an asynchronous interview.

3.3 Interview questions

The formation of effective and targeted interview questions was critical to identify useful insights and facts about the researched topic, sustainable construction. Due to the broad scope and different action points of the sustainable construction industry, ten interview questions were created specifically for this matter. The interview questions were designed to identify interviewees position and experience in the first two questions.

The following eight questions aimed to shed light on the individual perspectives of the interviewee, identify hurdles in the implementation and integration of sustainable methods in the construction sector, express personal opinions on sustainable projects, communicate advice for stakeholders, and a personal look into the future of the sector. Refer to Appendix 1 for the interview guide.

The open-ended answers provided a rich set of data and findings that assisted to answer the research questions of the thesis. Furthermore, the output of the interview has the potential to identify the current state of sustainable construction in the European Union and the future progress that needs to be achieved in order to guide the construction sector into a more sustainable future. The process of interviewing took place between 05.12.2023 - 12.01.2024 and the conducted interviews are attached with the original answers in the appendices.

3.4 Limitations of the Research

The thesis aimed to showcase the existing sustainability practices and strategies in the construction sector of the European Union and their implementation and effect. A non-probability convenience sampling approach was used to conduct interviews that provide insights and personal experiences, while rich in detail this approach encountered several limitations. Since participants are selected not

on a random basis, but based on convenience and accessibility the finding is potentially not generalizable to a broader population.

The selection method may be subjected to sampling biases as this approach could highlight specific perspectives, while neglecting others (Golzar et al., 2022). Additionally, asynchronous email interviews do offer flexibility for the interviewee, but create limitations for the researcher. Establishing a relationship with the participant is challenging and the interview is limited to the participants ability to use a digital medium. As real time clarification is not possible in this format, misunderstandings of the questions must be considered and are crucial to be minimized by creating straight forward questions, preferably not double-barreled (Ratislavová & Ratislav, 2014).

Lastly both time and financial constraints were identified as a limitation to the research this is due to the fact that the thesis is authored by a student that is restricted to time and financial limitations.

4 Analysis and Results

The analysis and results chapter aimed to investigate the conducted email interviews and examine the various answers collected through the different open-ended questions asked. The interviewees gave their informed consent to participate in the asynchronous email interviews and for the results to be used anonymously and solely for this thesis. Because there were no set answers to the questions and no set length, the participants had the flexibility of answering the questions to their preferences in all aspects, this provided a broad range of different answers. All ten answers of the six interviewees were analyzed to understand perspectives and experiences of the participants and check for similarities and for differences in order to make adequate recommendations.

4.1 Question 1

What Company do you work for?

The first question of the interview was an informational question, “What company do you work for?”. This initial question was asked to gather information about the interviewee’s professional affiliation or occupation. The answers from the participants revealed that there is an adequate variety of different companies included in the sample which allows the thesis to draw more generalizable findings.

There were two participants which revealed they work for a construction firm, the first one being respondent five working for Strabag, which is one of the largest European construction firms, that also has one of the largest shares of the German construction sector. The fourth respondent also in the construction sector is an employee of the Kollitsch Immobilien GmbH, which is a smaller construction firm but still has a considerable size for a firm operating solely in Austria.

The third respondent specializes in modernizing and expanding existing buildings and works for a real estate developer. The first respondent is an employee of an Austrian battery storage firm which aims to stabilize the power grid through innovative solutions. The second respondent gathered his experience in a large privately held real estate management firm, that operates across Europe in the UK, France, Germany, Poland, and Rumania. Lastly, respondent six who works for Swiss family-owned firm that operates in diverse industries such as construction, real estate, Internet of Things or IoT for the built world and specialized engineering.

4.2 Question 2

What is your current position and years of experience?

For the second question, the participants were asked what their current position in the firm is and how many years of experience they have. This question supported the understanding, of the participants responsibilities and capabilities, it also helped to assess the interviewees level of expertise which is directly influenced by their experience in the field. This marks an important question as the position and years of experience may influence the opinions of the participants.

The years of experience between the participants varied between two years and thirty-five years of professional experience, this great difference may have an impact on the understanding of sustainable practices and the adaptability of undergoing changes. Sustainability is a dynamic field and professionals with a longer experience in the field may have already gathered experience in adapting to new trends but could also be more resistant to change compared to younger participants.

The participants also show a great variety of different positions, which influences the expertise and responsibilities of the participants and indicates at which stage of the construction phase they are involved. With a deputy manager that gathered hands on experience in renovation projects and

implementing innovative technologies, to a senior function lead in sustainability that has great experience in driving sustainable change within an organization and may often be involved in the planning phase of projects. Furthermore, to a senior non-executive director of a real estate management firm that manages and maintains existing buildings, to the chief of staff of a construction and engineering firm.

The position variation is large, but the participants have one thing in common, which is they all have an influence on the construction sector and the ability to collectively move into a more sustainable future.

4.3 Question 3

From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?

The third question examines the perspective of the participant on the key challenges that the construction industry faces in implementing sustainable practices and is the first field specific question. All six respondents recognized and acknowledged challenges for implementing sustainable practices in construction. The third, fourth and the sixth respondent identified the upfront cost of sustainable materials to be a challenge while the fourth respondent also mentioned the maintenance of quality as a challenge when using sustainable alternatives.

Respondents one, five and six agree that regulatory and policy issues mark a significant hurdle when it comes to implementing sustainable practices. Both respondent five and six also agree that a lack of standardization and automation is a challenge which affects the process efficiency and the rate of adoption of sustainable practices. Respondent six further elaborated that transformation takes time especially in the construction sector due to its complexity and regulations among other factors. Additionally respondent number five identified missing technology, such as large excavating machinery, powered in a sustainable way as a challenge and that the public sector as a client imposes constraints as their contracts do not offer flexibility for the firm.

On the contrary there are some disparities when it comes to the key challenges, as respondent one identifies, despite the growing awareness, some technical barriers in implementing and integrating sustainable practices and respondent five identified missing innovation as a challenge to adapt to a full sustainable strategy.

On the other hand, respondent six does not see missing technology as the biggest barrier and emphasizes on well-established and cost-effective measures which can be implemented now. The respondent offered evidence using a study they conducted with Terrascope, which shows a significant reduction of up to 50% of CO₂ emissions when using post-tensioning technology in building slabs and up to 73% when combined with recycled materials.

Each participant brought a unique perspective based on their role in the sector and identified key challenges of the construction industry, while there is consensus on significant challenges, some opinions differed from each other, when it came to technology.

4.4 Question 4

Could you share your insights on the current state of sustainable construction practices?

The fourth question asked the interviewee to share their insights on the current state of sustainable construction practices. Analyzing the current trends based on the insights of professionals, helped to reveal current trends, and makes the thesis more practically applicable.

All six respondents provided their insights on the current state of sustainable construction practices. Respondents two, three and six pointed out an evolving trend in the adoption of sustainable practices with an increasing focus on eco-friendly materials, minimizing the ecological footprint of buildings and increased priority and pressure on adopting sustainable construction practices in the last three to four years. Respondent six further elaborated that many industry stakeholders are pulling in the same direction in the context of sustainability, as demand for both transparency and clearly defined, actionable targets is increasing.

Both respondent five and six indicated the usefulness of certificates, such as green building certificates for example, which promote net zero carbon buildings. Respondent five gave furthermore insights about a basic certificate they developed in collaboration with the German society for sustainable building which proofs sustainability in the construction process and includes social and ecological aspects, meanwhile being used to certify large projects in Germany. Additionally, the respondent also highlighted that ratings and governance currently play a significant role in sustainability practices.

Only respondent one discussed the aspect of integrating energy storage systems and smart grids as a current practice and shared positive experience of incorporating smart home systems to monitor and control energy consumption and the use of photovoltaic systems to improve the energy efficiency of constructions. Respondent six also uniquely identified a trend in the market results, in the form of green premiums, which affects prices, occupancy, and financing costs in a positive way.

The respondents all shared their unique insights with some participants mentioning similar observations and others identifying distinctive insights. Overall, there were no contradicting opinions identified between the responses.

4.5 Question 5

From your experience, what role do regulations and policies play in influencing sustainable construction strategies?

The fifth question of the interview sought to examine what role regulations and policies play in influencing sustainable construction strategies, based on the respondent's experiences. Policies and regulations play an important role in the context of sustainable construction because generally they have the ability to pose a barrier or the potential to accelerate sustainable practices. All the respondents answered the question from their own experience and all six collectively agreed that both regulations and policies play a vital and significant role in influencing sustainable construction strategies, though the opinions and the examples given to why, differ from the respondents.

Respondent one identifies politics as a hurdle, in the context of missing flexibility in order to react efficiently and timely to advancing technological developments and to obligations they have to customers.

Respondent two is of the opinion that regulations need to catch up with the requirement of using less carbon intensive materials. Respondent four also identified a need for regulations and policies to catch up, because firms are bound to these rules and therefore are unable to undertake certain approaches. Respondent three describes that the regulations and policies set a minimum standard and help in the adoption of sustainable materials and technology, though they become a challenge if they are outdated. Respondent five explained that regulations and policies have a significant impact to their firm and elaborated with an example.

The annual report of Strabag must be written within the corporate sustainability reporting directive framework, this requires the firm to establish new data collection systems to gather this information and various energy efficiency laws for Germany, Austria and other European Union countries are changing rapidly, the firms must comply to these regulations, which can be challenging in some cases.

Respondents six went more into detail with an example, respondent six explained the significant importance of policies like the “Renovation Wave”, which was introduced in Europe in 2020 and aims to renovate up to 35 million buildings and create up to 160.000 green jobs. This policy could reduce emissions, since maintaining and renovating existing buildings is by far more environmentally friendly compared to emissions generated when building new structures.

The respondents highlighted the importance of regulations and policies from different angles, but all respondents agree that they have a big impact on their overall strategies.

4.6 Question 6

How do you see the integration of innovative technologies impacting sustainable construction?

Question six asked the interviewee how they see the integration of innovative technologies impacting sustainable construction. There is an agreement between respondents one, three, four, five and six that innovative technologies are enablers to a more sustainable and efficient construction environment, respondent two explains that there could be an extra cost to use innovative technologies, yet it is vital to utilize and promote best practices in sustainability.

Respondent five further describes a lack of innovative construction machinery in terms of being powered by renewable energy and explains the importance of innovations for data collection and robotics in the construction process.

Respondent three points out how technologies like smart building technologies, utilization of renewable energies und using renewable building materials can minimize energy consumption and increase efficiency.

Similar to respondent three, respondent one places great importance on utilizing innovative technologies like photovoltaic systems, but also emphasizes on the potential of battery storage

systems that collect energy during production and uses the excess produced energy when production is not possible.

Respondent six, explained that a simultaneous integration of sustainable design techniques, material improvements driven by efficient, automated, and digitized processes and products have the ability to provide synergies and accelerate progress.

All respondents recognize the importance of evolving technologies and innovations, to grant the emergence of new sustainable methods. Respondent six stressed that synergies between different phases, can accelerate progress and respondent one and three pointed out the importance of innovative renewable energy sources, for production and efficient management.

4.7 Question 7

Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?

For question seven the Interviewees were asked to highlight in their opinion specific examples of successful projects built in the European Union that should be used as an example for future projects. All the respondents identified an example of a successful sustainable project, but there was no overlap in the answer, there was one common factor, four respondents provided an example in which the company they work for was involved.

Respondent one gave an energy power plant they built in Austria as a standout example as it serves as a model for integrating energy storage solutions into the energy infrastructure, another example the respondent gave is the SolarCity in Linz, which is designed to maximize sunlight to generate energy, reducing the dependence on traditional sources.

Respondent four shortly identified the AvantGardens as a successful example which is a project the Kollitsch GmbH is planning. The fifth respondent provided a quarry built by Strabag in Saalfelden as an example of a successful sustainable project. The quarry is located at an altitude of 1.500 meters where material is broken down and must be transported, this is done using a conveyor belt. The sheer weight of the material generates energy as it utilizes gravitation forcing it down the belt.

Respondent six highlighted two examples, the first one being a shopping mall called Max Stoja in Croatia, in which one of Tectus' affiliated franchises was able to offer an alternative design. By using post-tensioning technology for the slabs, which resulted in a thinner and lighter structure, but also lowered the use of concrete and therefore 33.5% CO₂ emissions, additionally 120 days of the construction time was shaved off, while reducing the construction budget. This example serves for a win-win situation using technology readily available at this point in time. Another building designed for ultra-low energy consumption is the Powerhouse Telemark in Norway which exemplifies a carbon negative design utilizing a holistic approach.

Similarly to the Max Stoja shopping mall example, respondent two also gave an example of using tensioned steel cables, to reduce the need for cement, as an example Heathrow's Terminal 5 was chosen, which successfully utilized this technology. Lastly respondent three pointed out the Vauban district in Freiburg, which combines sustainability and community living, displaying what sustainable urban development could potentially look like.

All respondents introduced interesting examples of successful projects that utilized a sustainable approach. The diverse answers show that there are numerous examples, which can be further used and applied on future projects.

4.8 Question 8

In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?

The eighth question to the participants of the interview was to answer in their opinion how important the collaboration between different stakeholders is to promote sustainable construction initiatives. Without any exemption all respondents initiated the answer with expressing how vital and important collaboration with different stakeholder is to reach objectives.

Furthermore, respondent five and six both pointed out that collaboration is key in granting and improving a circular economy and to find good solutions together along the entire value chain. Respondent six further adds that the earlier in the design and planning phase sustainability considerations are incorporated the bigger the benefit is, most effectively this can be achieved with the united efforts of the involved stakeholders.

Respondents one and three agree, that collaboration between stakeholders enables the exchange of knowledge and experience of effective and innovative solutions, that promote sustainable initiatives. The common denominator of all respondents was that collaboration between stakeholders is crucial to achieve sustainable objectives.

4.9 Question 9

From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?

The ninth question asked the participants from a practical standpoint what advice they would give contractors and policymakers looking to enhance sustainability in projects.

The answers from respondents one, four and five stood out because they both established the same advice to policymakers. The public sector is somewhat ambivalent and contradicts itself, in the case of respondent one, a partner proposed and applied for a sustainable project to produce wind power, but it took seven years for the approval, at the point of approval, the specific wind turbine was outdated, and the application progress had to be reinstated.

The fourth respondent suggests that regulations and policies should be evaluated. Respondent five explains that the public sector designs laws to maximize sustainability and recycling rates, but when it issues contracts as a public client, they aim for cost reduction and therefore do not allow the achievable recycling rates and applications of sustainability.

The second respondent highlights the importance of having a clear-cut objective and well-defined timeline for completion, additionally the respondent recommends continuing using best practices and latest sustainable materials.

The third respondent proposes to invest in education and training to enhance awareness and skills in sustainable design, building and implementation, additionally the respondent emphasizes on the importance of incentives and flexibility to facilitate the adoption of new technologies.

Respondent one additionally recommends introducing pilot projects, which could test new technologies and based on the effectiveness, recommend, or reject the technology. Lastly respondent

six advises to use a holistic view of assets and infrastructure across the entire lifetime, this increases the resilience of a structure and furthermore there is a financial and regulatory imperative of adopting such approaches. Each of the respondents provided specific advice, especially to the policymakers to better facilitate sustainable approaches.

4.10 Question 10

Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of the practices to mitigate environmental deterioration?

The tenth and last question of the interview questioned the interviewee's what they envision as the future of sustainable construction and how important they perceive the implementation of these practices to mitigate environmental deterioration.

The respondents are aware that the construction industry must move towards a more sustainable future and expressed their opinion on the future of the sector. Respondent one suggested that the industry must adapt and integrate sustainable methods to reduce the ecological footprint, this is important for the environment but also for social and economic sustainability.

The second respondent envisions the future to have a more rigorous application of low emitting materials in construction, this can be achieved on a regulatory or self-imposed basis. Respondent three emphasizes if construction firms do not adopt to innovative technologies and increase the use of sustainable materials, they could miss out on a trend which could lead to projects being rejected and deals being lost.

The cradle-to-cradle method which is a development paradigm that aims to increase eco-effectiveness (Toxopeus et al., 2015), was proposed to be more used in the future by respondent four. As mentioned previously respondent five envisions the term of cycle to play an important role in the future, considering what happens at the end of the life cycle of a structure, furthermore the respondent sees climate resilience, energy storage and renewable energy as important points for the future.

Finishing with the sixth respondent, which summarizes previous points made. The respondent points out that sustainable considerations are already high on the agenda and industry stakeholder can gain competitive advantage by showing leadership in this field. This ongoing shift could lead to a more

sustainable construction environment. The responses clearly show the intention of professionals in the field to further increase and implement sustainability in their projects.

4.11 Conclusion of Interviews

The interview participants proved with their knowledge and assessments that sustainability in the construction sector is an apparent and present topic and there is clearly a shift towards a more innovation driven future and willingness to apply materials with the least carbon footprint. The responses further revealed that regulations and policies can pose a hurdle for the implementation of sustainable approaches. But on the other hand, regulations and policies could and should move more towards the direction of being enablers of sustainable approaches.

The perceived issue of too high upfront costs was mentioned by multiple participants, but there were also solutions provided towards the policymakers, which was to start incentivizing the initial steps towards a sustainable project more heavily. Respondent six added to this matter that when sustainable designs are implemented at the earliest stage, the benefits are maximized.

There was a general agreement that innovation enables the shift towards a more sustainable future, for this reason investments towards innovative technologies will increase sustainable alternatives and therefore enable a more balanced interaction with the environment, ensuring a viable long-term solution to the environment and economy.

For the present and the future of the construction industry the topic of circular economy was highlighted, especially in the construction sector, closing the loop by recycling and reusing materials to minimize the need for new material is an effective method to reduce environmental impact. Additionally, a holistic view was identified as crucial for the future, which envelops the principles of a circular economy but considers a wider range of factors.

In conclusion the participants of the interview shared personal insights, assumptions and recommendations which greatly benefited the researched topic. The intention of a shift towards a more sustainable construction industry was observed and recommendations to stakeholders were expressed. The combination of the findings, have the potential to transform the construction industry towards a more sustainable future.

5 Discussion

This chapter of the thesis intends to answer the proposed research questions, by combining all the relevant findings of the research conducted. The relevant information was identified in the literature reviewed by initially analyzing the challenges that arise from climate change and further delving deep into the specific impact the construction sector has on the environment and economy of the European Union. Furthermore, the literature review identified the most common forms of sustainable construction and their impact.

Lastly the policies and strategies adopted in the European Union and in Germany were discussed. The gained knowledge was broadened by questioning experts in the field specific questions in an email interview to further gain insights and knowledge which is challenging to identify through literature research.

5.1 First research question

What are the primary sustainability practices and strategies adopted in the construction sector in the European Union?

Throughout the thesis multiple sustainable practices and strategies in the construction sector were discussed. Generally, the research found that construction can be classified as either residential, commercial, or public, of which all start with the preventive strategy which entails the designing and planning of a construction project (Sarker et al.,2012).

The designing and planning phase is also the start of the circular economy strategy which intends to increase the use of recycled materials and therefore reduce the generated waste on numerous stages in the construction (Dsilva et al.,2023), as respondent six identified this could potentially close the loop and minimize or even eliminate the need for newly sourced materials.

If reusing materials in the initial phase of construction is not an option, the research found that using biodegradable and low emitting materials is also an alternative to lower the emissions generated during the construction process. Reducing the use of cement which is notorious for being a carbon intense material can be achieved by replacing common cement with pozzolanic materials which requires less energy in the production (Mehran et al.,2022).

Respondent two and six identified another strategy to reduce the need for concrete and steel beams, the application of post-tensioning technology for the slabs which can significantly reduce the use of concrete while providing numerous other benefits in terms of cost, weight, and construction time.

The second stage is the management strategy of a construct which includes management, operation, and demolition (Eberhardt et al., 2020). In this stage diverse sustainable practices can be implemented and applied, the first one being solar energy which is also the most used renewable energy source for buildings. Solar panels can be installed on any construct and generally transform sunlight into usable energy.

This can be combined with a battery storage system to manage produced energy as efficient as possible (Shirinbakhsh & Harvey, 2023). For managing in-door climate, the strategy of plant-covered buildings and cool roofs was discussed. Plant-covered buildings lower in-door temperatures by utilizing high climbing plants to vertically cover the building, which protects the walls from direct sunlight and therefore reduces the in-door temperature on warm days (Thormsitt-Ireland et al., 2020). Cool roofs reduce the surface temperature on roofs, by implementing coatings with solar reflectance, this can reduce the internal temperature of buildings and reduce the need for air-conditioning in warmer climate zones (Kolokotroni et al., 2018).

Respondent six further clarified that the European Union recently sees an evolving trend in the adoption of sustainable practices, certificates were developed to proof sustainability in construction projects. Additionally, because of increasing demand in transparency and clearly defined and actionable targets, stakeholders are pulling in the same direction in the context of sustainability strategies.

5.2 Second research question

What sustainability policies in the construction sector are adopted in Germany?

Germany serves as a positive benchmark in the European Union, as the country has generally proved to be proactive in adopting numerous sustainable policies and furthermore incentivizing them. The country has developed strong environmental frameworks (Organisation for Economic Co-operation and Development, 2012).

Respondent five from Strabag, which is one of the three biggest constructors in Germany has questioned the policies of the public sector in some cases. The respondent explained that the public sector as a public client can be somewhat ambivalent, since laws are designed to maximize sustainability, but when the public client issues contracts, they aim for cost reduction, which subsequently reduces the possibility to utilize the full potential of sustainable methods. The respondent further added positive development in Germany with the introduction of a certificate by the German society for sustainable building, which is a basic certificate for construction sites and proofs sustainability in the building process. This certificate includes social aspects, but also ecological components, like resource conservation, waste handling, and occupational safety, which go further than the normal requirements.

The policies proposed to the public are beneficial, since in January 2020 a tax relief of 20% for energy-efficient renovation was implemented. Furthermore, in 2020, Germany introduced low-interest loans and repayment grant of up to 40% for buying, building, and renovating energy efficient buildings. Additionally in 2021 funding of up to 20% for individual renovation measures were introduced (Federal Government of Germany, 2020).

This issue of new policies effectively counters the obstacle of the old building stock in Germany. Around 3 million residential buildings are older than 47 years which was before first regulations on energy saving and thermal regulations were introduced. In order to improve the efficiency of these old buildings, especially in terms of heating systems which mainly run on fossil fuel heating systems, the state has introduced a replacement premium of up to 45% (Federal Government of Germany, 2020)

Respondent six also discussed the issue of old buildings and infrastructures in Europe, which have great potential to enhance efficiency by retrofitting them. On an EU level the “Renovation Wave” announced to renovate up to 35 million buildings and with that create up to 160.000 green jobs. The combined efforts of the policies are visible in the achieved reduction of greenhouse gas emissions by the construction industry in Germany, in the past years.

5.3 Third research question

How do these strategies affect the environment and economic systems in Germany?

The research found that the construction industry has a sizeable impact on both economy and environment on a global scale. Germany is no exception; its construction industry is immensely

important to the economy and environment. The market size of the German construction industry in 2022 was 493 billion which marks an important contributor to Germany's total GDP of 3.867 billion and provided employment to approximately 2 million individuals (Federal Ministry of the Interior and Community, 2022).

The sector is accountable for 40% of the entire CO₂ emissions produced in the country and furthermore generated 209 million tons of construction and demolition waste (Krause & Hafner, 2022). The construction sector shows resilience in economic terms and has been growing since the financial crisis, demonstrating that the sustainable strategies have no negative consequences on the economic aspects of the construction sector (Wagner & Sims, 2024). On the contrary as respondent six indicated, there is a wave to retrofit the old building stock of Europe. Germany has a substantial number of old buildings and the process of renovating these buildings, has the potential to create numerous green jobs.

The effectiveness of the strategies imposed by Germany shows in the last three decades, as the greenhouse gas emissions emitted by the construction sector specifically, was reduced from 210 million metric tons in 1990 to nearly half in 2022 (Statista Research Department, 2023). These numbers prove the claim of respondent six, which pointed out that sustainable considerations are already high on the agenda and industry stakeholders can gain competitive advantage by showing leadership in this field. Additionally, the respondent gave insights on the positive affects alternative designs can have. Following the strategy of implementing innovative and new designs can have both economic and environmental benefits and its use should be promoted, when possible, to the public and the private sector. Respondent five indicated the strategy of circular economy could further positively affect the German construction sector in the future, by considering what happens at the end of the life cycle of a building.

6 Conclusion

This concluding chapter of the thesis will examine the main outcomes of the analyzed topic of sustainable construction in the European Union. The thesis aimed to identify various practices and strategies adopted in the sector and display its most effective implementation. Furthermore, policies and regulations introduced on a European Union level and their implementation and effect on an example member-state, in this case Germany were analyzed. The reader should gain awareness and a

general knowledge through the information provided in the thesis. Since the construction sector is one of the largest energy consumers and polluters, it is vital to find solutions to decrease the impact of the sector in order to reduce the ongoing challenge of climate change (Guerra & Leite, 2021). The conducted literature review discussed the topic from various relevant angles.

Furthermore, the researcher conducted six expert interviews, utilizing asynchronous email interviews to gather relevant data, the participants received ten open-ended questions in which they could express their insights and opinions on the matter.

The literature research revealed the problem and challenges of climate change, which is the rise of the sea-level and extreme weather. Unfortunately, this phenomenon is becoming more noticeable, because of the greenhouse effect which is strongly influenced by human activity (Laino & Iglesias, 2023).

Construction is a highly energy consuming and greenhouse gas emitting sector and therefore a main contributor to the greenhouse effect, making it a pivotal industry to implement working net zero concepts. To counter the negative effects of the industry, policies and regulations are introduced, for example energy management systems will be obligatory for large enterprises, innovative and efficient heating and cooling systems aim to gradually ensure decarbonization.

Furthermore, financing and incentivizing will also play an important role to implement sustainable strategies on new projects and to renovate the old building stock to enhance efficiency. Different forms of sustainability in the construction industry were discussed and highlighted in the literature research. Lastly even though the European Union influences regulations that protect the environment, the construction sector is subject to national regulations by the individual member state (BMUB, 2016). This points out the impact that the political stakeholders have with their policies and regulations on the construction sector.

Especially in the interviews it became apparent that the regulations and policies have great influence on the firms involved in the construction industry. The six interviewees were chosen because of their relevant connection to the construction sector. Three of the participants work directly in the construction sector and the other three participants are involved in the construction sector. It became clear in the first topic specific question, that all participants are aware of the importance of sustainability especially in the highly energy consuming sector of construction.

The open-ended questions revealed multiple similarities between the participants, as they identified that there is a clear shift towards a more innovation driven future and the willingness to apply materials with the least carbon footprint. Additionally, the responses further identified the impact the political stakeholders have in either creating hurdles by being ambivalent or inflexible. But also, how regulations and policies can promote sustainability through incentivizing sustainable projects and investing in education and training to enhance awareness and skills in sustainable design, building and implementation.

6.1 Recommendations

Both the conducted literature research and the expert interviews have discussed numerous aspects of the construction sector, especially in the context of sustainability. This part of the thesis summarized the key findings and aimed to propose recommendations based on these findings, to both the political and organizational stakeholders of the construction industry.

6.2 Key findings

Especially in recent years an increased adoption of sustainable practices in the European Union was observed, with increased focus on eco-friendly materials and innovative technologies, which both minimize the ecological footprint of buildings. Through these efforts, statistics have identified that the emission contribution of the construction sector is declining in the past years. However, the decline is not enough to meet the overall targets of the Paris agreement which aims to limit global warming (European Environment Agency, 2023).

Because the activity of the construction sector is crucial in economic terms, various strategies that promote sustainability without limiting the construction activity were discussed. As respondent six indicated the earlier sustainable methods are integrated into the planning process of a construction project the greater the benefits. But considering the entire life cycle of a construct is also crucial, as this allows a circular economy, which reduces waste production on many different stages of the construction cycle and increases efficiency by adopting environmental beneficial technologies (Dsilva et al., 2023).

These technologies can vary from the use of sustainable machinery in the building process, to the substitution of traditional high emitting materials by low emitting materials, to using renewable energy and battery storage systems for the management phase of a building, to renovating and modernizing existing structures to lastly the deconstruction of buildings and the importance of reusing materials where possible, which enables a circular economy. It is important to note that the construction sector seeks employees from low, to medium, to highly skilled and trained individuals. Especially for complicated applications of sustainable methods the need for experienced and trained professionals is a requirement. The effectiveness of sustainable measures is shown to be true in the statistics of the decline of emissions in the construction sector of Germany (Statista Research Department, 2023).

6.3 Political Stakeholders

Politics have great influence on the adoption of sustainable approaches in the construction sector due to the proposed regulations and policies. Regulations and policies have the potential to be accelerators of sustainability, but they can also be an immense hurdle and prevent sustainable approaches to be both implementable and feasible.

The literature review provides information on various policies and regulations that were introduced both on a European level and in Germany. On the European level the main entities covering building policies are the EPBD, EED and the Renewable Energy Directive. The individual states create their own policies and regulations, to which firms are bound to. The politics aim to maximize sustainability in the construction sector and have multiple levers to do so, the thesis mainly discussed frameworks, awareness, subsidies, and tax reliefs (The energy efficiency directive, 2023)

Through the conducted interviews with professionals in the construction sector, greater insights were collected in terms of political influence on the construction industry and the following recommendations to political stakeholders were established. To further increase the availability of skilled and experienced workers in the construction market, training and education is necessary. Requirements in construction vary over time, but with a growing trend of sustainable methods in the construction sector, the need for experts in this field will grow (Brucker Juricic et al., 2021). Respondent three suggests that political stakeholders should invest in education and training to enhance awareness and skills in sustainable design, building, and implementation.

Another recommendation from respondent one was the introduction of pilot projects which could test latest technologies and based on the findings on the effectiveness and best implementation, recommend or reject the technology. Furthermore, an evaluation of regulations and policies was suggested by respondent one, to ensure flexibility in the possible areas and to avoid constraints where they are not necessary.

Lastly respondent five highlighted the importance, that political stakeholders follow the sustainable approaches proposed by them, themselves. When issuing contracts as a public client they should aim to maximize sustainability in the project, instead of minimizing cost, even though the upfront cost maybe increased, looking at the entire life cycle of a construct, the benefits will outweigh the initial cost.

6.4 Organizational Stakeholders

Respondent two highlighted that sustainable construction is not only imposed on a regulatory level but also self-imposed, this is where the organizational stakeholders must show responsibility and future orientated approaches. Respondent six advises to use a holistic view of assets and infrastructure across the entire lifetime, this approach has the potential to increase the resilience of a structure and additionally there are financial and regulatory imperatives when following a holistic approach.

Furthermore, also organizational stakeholders should take responsibility when it comes to educating and training workers, with the adequate attitude firms could take the matter into their own hands and promote training in the field of sustainable construction.

Lastly respondent six advised that by researching and implementing sustainable approaches early in the planning phase organizations could benefit from a shorter construction time paired with lower costs and lower emissions generated. Furthermore, their constructed buildings are not subject to lower valuations in the future due to inefficiency. The shift towards a more sustainable construction industry has various benefits as mentioned throughout the thesis and should be considered by all stakeholders.

6.5 Future research implications

The research methodology was central for this research and provided valuable insights and point of views from professionals in the relevant field.

For the future, the topic of sustainability is of utmost importance and should be prioritized in all possible aspects. Since the construction sector has a vast potential to reduce emissions, it is essential for industry stakeholders to adopt greener construction practices and aim for a circular economy in order to lower the carbon footprint associated with the construction industry. The research additionally identified through the literature research and the interviews, various economic benefits both on a regulatory level through incentives and tax reliefs and on cost saving throughout the project by utilizing sustainable approaches.

The thesis can serve as a foundation for future research on the topic of sustainability in the construction sector and the insights collected through the conducted research could contribute to the academic field offering fresh perspectives and preliminary findings. Additionally, the thesis highlighted the current state of sustainable construction and challenges which points out where further research, investments and innovations are required.

6.6 Limitations

Lastly it is important to note that the thesis as a whole is subject to limitations, since this is an undergraduate thesis there may be a limited scope and depth to the research as the researcher was facing constraints like time, resources and level of expertise. The sample included six participants in the field, which provided the researcher with their opinion on the matter, the results may not lead to generalizable findings as individuals can be biased because of various factors.

In summary the topic was analyzed through different lenses, and all contributed to answer the research questions effectively and to the best of the researcher's ability considering all relevant limitations.

Lastly the geographical limitations must be considered as the research was conducted with a focus on the European Union, as a consequence the findings may not be globally accurate.

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Appendices

Appendix 1 Interview Guide

Dear Participant,

my name is Gregor Aichbichler, and I am currently enrolled at Modul University in Vienna pursuing my bachelor's degree for international management. For my thesis I am conducting expert interviews as part of my qualitative research which is focused on sustainability practices in the construction sector, specifically in the European Union. The interview will be conducted depending on the preference of the interviewee either via email, videocall or in person. A set of two demographic and eight open-ended questions will reveal the position and experience of the interviewee and the knowledge and assumptions towards the topic of sustainable construction. By conducting the interview, the participant will provide important insights which will significantly help to make adequate recommendations, the collected information will be evaluated anonymously and will exclusively be used for this thesis. The collected data will solely be processed by the author of the thesis and deleted after the analysis to ensure anonymity.

By participating in this Interview, I willingly consent to the interview data being collected, processed, and stored anonymously solely for the purpose of this research project. I confirm the decision to participate in this research was voluntary.

For further concerns or questions feel free to contact me at any time via my personal E-Mail address: gm.aichbichler@gmail.com

Please answer the following questions truthfully and to the best of your ability.

1. What company do you work for?
2. What is your current position and years of experience?
3. From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?
4. Could you share your insights on the current state of sustainable construction practices?
5. From your experience, what role do regulations and policies play in influencing sustainable construction strategies?
6. How do you see the integration of innovative technologies impacting sustainable construction?
7. Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?

8. In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?
9. From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?
10. Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of these practices to mitigate environmental deterioration?

Your participation is very much appreciated and an important contribution to the thesis.

Appendix 2 Respondent 1

Please answer the following questions truthfully and to the best of your ability.

1. What company do you work for?

I work at an energy company specializing in developing and implementing battery storage systems. Our focus is on supporting and stabilizing the power grid, especially through innovative energy storage solutions. We recently built the largest energy storage power plant in Austria, a sign of our ambitions and capabilities in this sector.

2. What is your current position and years of experience?

I've been a project manager in the energy industry for two years. My experience is shaped by the challenges and successes we had in building the energy storage power plant. This project gave me deep insights into the complexity and importance of energy storage solutions in modern energy infrastructure.

3. From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?

The construction industry faces challenges in implementing sustainable practices. A key issue is building energy efficiently. It's a constant challenge to design and build buildings with minimal energy consumption. Another problem is integrating renewable energy. Despite growing awareness of the need for renewable energy, there are still technical and regulatory barriers that make full integration difficult. Also, the lack of efficient energy storage solutions is an obstacle that limits the ability to optimally use renewable energy sources. Efficient in the sense of a power community of several households. The storage possibility is basically there, but authorities and especially politics put a stop to it.

4. Could you share your insights on the current state of sustainable construction practices?

From my experience, energy storage and smart grids are crucial for the future of sustainable building. Battery storage systems play an important role to optimize energy efficiency and facilitating the integration of renewable energies. Smart home systems are also important as they help monitor and control energy consumption in real time. Furthermore, the use of photovoltaic systems is another component to improve the energy efficiency of buildings.

5. From your experience, what role do regulations and policies play in influencing sustainable construction strategies?

As mentioned in question 3, I see the biggest hurdle in politics and authorities. For example, we also install photovoltaic systems and have been waiting for 4 months for feedback regarding subsidies and the possibility of feeding into the grid. This delay is frustrating for us, as we can't move forward and potentially lose customers and their trust in the technology. Regulations and guidelines are crucial for setting standards for energy efficiency and the use of renewable energies. They promote innovations in these areas and ensure that new buildings and renovation projects meet certain standards. However, it is important that these regulations are flexible enough to adapt to rapidly advancing technological developments.

6. How do you see the integration of innovative technologies impacting sustainable construction?

The integration of innovative technologies is key to more sustainable building practices. Battery storage systems are particularly important as they allow for more efficient use and storage of energy. Smart home systems and photovoltaic systems are other examples of technologies that influence and advance sustainable building. During the day, the batteries charge with the photovoltaic system, and in the evening, the stored energy is used. These technologies enable more efficient use of energy, reduce the CO2 footprint, and especially provide some security against blackouts.

7. Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?

A standout example of a successful sustainable building project is the energy storage power plant we built in Austria. It serves as a model for integrating energy storage technologies into the energy infrastructure. Additionally, SolarCity in Linz is a model for integrating solar energy into urban architecture. The buildings are designed to maximize sunlight for energy generation, reducing dependence on traditional energy sources.

8. In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?

Collaboration between different stakeholders is essential. Close cooperation between energy companies, construction companies, governments, and other stakeholders is necessary to implement sustainable building practices. This collaboration allows for sharing knowledge, efficient use of resources, and developing innovative solutions.

9. From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?

My advice to construction companies and policymakers is to invest in research and development to advance innovations in energy efficiency and renewable energies. It's also important to promote partnerships with energy companies to integrate modern energy storage solutions into construction projects. Additionally, pilot projects should be encouraged to test new technologies and demonstrate their effectiveness. Above all, politics should focus on facilitating and speeding up processes, not spending so much time on bureaucratic matters. For example, it took 7 years to get approval for a wind farm of a partner, and after approval, it had to be reapplied for because the technology of the specified wind turbines was outdated. Politics contradict itself here, as on one hand, everything is supposed to be "GREEN," but not enough is done to achieve it.

10. Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of these practices to mitigate environmental deterioration?

I see the future of sustainable building as crucial for tackling the challenges of climate change. The industry must adapt and integrate innovative solutions to minimize the ecological footprint and create environmentally friendly cities. Implementing these practices is not only

important for the environment but also for the economic and social sustainability of our societies.

Your participation is very much appreciated and an important contribution to the thesis.

Appendix 3 Respondent 2

Please answer the following questions truthfully and to the best of your ability.

1. What company do you work for?

A real estate management firm that operates in the UK, France, Germany, Romania, and Poland

2. What is your current position and years of experience?

Senior non-executive director, 35 years.

3. From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?

The application of energy saving systems such as solar panels or wind turbines and the use and amount of material being used, like cement and steel.

4. Could you share your insights on the current state of sustainable construction practices?

We are only at the beginning of the realization of the carbon used in the production of these materials and the way they are transported.

5. From your experience, what role do regulations and policies play in influencing sustainable construction strategies?

I believe that rules and regulations need to catch up with the need to use less carbon intensive materials.

6. How do you see the integration of innovative technologies impacting sustainable construction?

There could potentially be an extra cost to use innovative technologies to reduce the carbon footprint. On the other hand, it is vital to promote best practices in sustainability.

7. Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?

The use of tensioned steel cables to replace steel beams in the construction of buildings. These steel cables reduce the need for cement by 50%. Heathrow's Terminal 5 could serve as a successful example of a building that utilizes tensioned steel cables.

8. In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?

I think it is vital and essential that all collaborators agree on the pricing and research needed to achieve a sustainable result.

9. From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?

To have a clear-cut objective and a well-defined timeline for completion. To continue researching best practices in construction and use of the latest sustainable materials.

10. Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of these practices to mitigate environmental deterioration?

The future will be a more rigorous application of seeking materials with the least carbon footprint and the way which they are brought together for the construction.
This could either be regulatory or self-imposed.

Your participation is very much appreciated and an important contribution to the thesis.

Appendix 4 Respondent 3

Please answer the following questions truthfully and to the best of your ability.

1. What company do you work for?

I work for a real estate developer specializing in renovating and expanding existing buildings. Our company is known for modernizing historical and old buildings.

2. What is your current position and years of experience?

I am currently the deputy manager and have been in this role for five years. My experience includes leading renovation projects, developing sustainable construction strategies, and implementing innovative technologies in our building projects.

3. From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?

The construction industry faces many challenges in implementing sustainable practices. These include higher costs for sustainable materials and technologies, complexity, and a lack of expertise in sustainable building.

4. Could you share your insights on the current state of sustainable construction practices?

Sustainable building has evolved in recent years. The focus is increasingly on efficiency, using eco-friendly materials, and minimizing the ecological footprint of buildings. We also see a trend towards long-term planning that considers the lifecycle costs and impacts of building.

5. From your experience, what role do regulations and policies play in influencing sustainable construction strategies?

Regulations and guidelines play a crucial role in implementing and executing sustainable building strategies. They set minimum standards and help in the adoption of eco-friendly materials and technologies. However, they can also be a challenge if they are outdated and thus hinder innovation.

6. How do you see the integration of innovative technologies impacting sustainable construction?

In order to build and design sustainably innovation is a necessity. This includes smart building technologies for more efficient building management and the utilization of renewable energies. Additionally, using sustainable and renewable building materials can have a large positive impact. These technologies help minimize energy consumption and reduce the environmental impact of buildings.

7. Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?

A successful example of a sustainable building in the EU is the Vauban district in Freiburg, which combines sustainability and community living, showing what sustainable urban development could look like.

8. In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?

Engagement between stakeholders is vital to achieve progress. It allows for the exchange of knowledge, experience, development, and implementation of effective and efficient building strategies. Cooperation between governments, construction companies, environmental organizations, and the local community is essential for the success of building initiatives that are sustainable.

9. From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?

My advice would be to invest in education and training to enhance awareness and skills in sustainable design, building and implementation. It's also important to create financial incentives for sustainable practices and increase flexibility in regulations to facilitate adaptation to new technologies and methods.

10. Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of these practices to mitigate environmental deterioration?

Implementing sustainable practices is crucial to minimize the ecological footprint and address the challenges of climate change. Construction companies need to adapt their approach now because if they don't invest in innovative technologies and sustainable materials, they may miss the trend and therefore lose a significant number of deals as non-sustainable building projects could potentially be rejected.

Your participation is very much appreciated and an important contribution to the thesis.

Appendix 5 Respondent 4

Please answer the following questions truthfully and to the best of your ability.

1. What company do you work for?

Kollitsch Immobilien GmbH

2. What is your current position and years of experience?

Position: market analysis; experience: solicitor; project development; acquisitions

3. From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?

Cost factor plays an important role and quality maintenance.

4. Could you share your insights on the current state of sustainable construction practices?

That our sustainable projects get certified through (e.g. klimaaktiv).

5. From your experience, what role do regulations and policies play in influencing sustainable construction strategies?

Sustainability can only be achieved in combination with the applicable policies, regarding this there is need to catch up in my opinion, as the construction firms are bind to construction policies and therefore some approaches cannot be undertaken.

6. How do you see the integration of innovative technologies impacting sustainable construction?

Sustainable strategies will be achieved and implemented in the future trough new innovations.

7. Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?

AvantGardens (by Kollitsch, project is in the planning phase)

8. In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?

Collaboration between stakeholders and partners is crucial in promoting sustainable initiatives.

9. From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?

Evaluate regulations and policies.

10. Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of these practices to mitigate environmental deterioration?

Taking advantage of the ‚Cradle to Cradle‘ method as well as creating an indigenous building feature.

Your participation is very much appreciated and an important contribution to the thesis.

Appendix 6 Respondent 5

Please answer the following questions truthfully and to the best of your ability.

1. What company do you work for?

Strabag

2. What is your current position and years of experience?

Senior function lead in sustainability management for three years at Strabag and started 12 years ago in consulting.

3. From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?

The problem is that standardization and normalization are not yet at the necessary level. Currently, the focus is on process standardization, which means that a certain process must be followed. For Strabag the main client is the public sector, which provides us with fixed contracts, some contracts even specify the suppliers and the exact products that must be used. This means that we do not have much influence in some cases. In our own project we do have the ability to influence.

Additionally, a major challenge is that certain products do not yet exist on the market. For example, large excavating construction machinery that is powered with alternative energy.

4. Could you share your insights on the current state of sustainable construction practices?

Ratings and governances play an important role on the topic of sustainability. Strabag for instance has developed an important component, we have worked with the DGNB which is the German society for sustainable building to develop a basic certificate for construction sites, which proofs sustainability in the building process.

This includes social aspects, but also ecological components such as resource conservation, waste handling, and occupational safety, which go further than normal requirements. Large projects in Germany are meanwhile certified on this basis.

5. From your experience, what role do regulations and policies play in influencing sustainable construction strategies?

Regulations and policies have a significant impact on our strategies which we see in deferent areas. For example, the CSRD or corporate sustainability reporting directive is just now coming into effect which means we must write the 2024 annual report within the CSRD framework, which requires more data to be disclosed and of course this is sometimes a challenge as we have to set up data collection systems to gather this information.

Furthermore, various energy efficiency laws for Germany, Austria and other EU countries are changing quite rapidly and we must comply to these regulations, which can be a significant challenge.

6. How do you see the integration of innovative technologies impacting sustainable construction?

We are reliant on the emergence of innovations, as already mentioned earlier, we cannot operate our construction machinery fully on renewable energy because this technology does not yet exist. Thus, we are dependent on innovations in this sector, also for data collection and robotics innovation play a crucial role for us.

7. Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?

For example, Strabag has a quarry in Saalfelden which is located at 1.500 meters. Material is broken down and must be transported, which is done with a conveyor belt. The weight of the stones and material generates energy utilizing gravitation forcing it down the conveyor belt.

8. In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?

Collaboration is of great relevance and importance because construction projects are very cost intensive and involve a large set of contributors. It is important to work together from the planning phase through to the execution. A circular economy is only possible if different stakeholders are involved and finding good solutions together along the entire value chain is very important.

9. From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?

The public sector or regulator is somewhat ambivalent, when the public sector designs laws they aim to maximize sustainability and recycling rates, but when it issues contracts as a public client, they aim for cost reductions and therefore limit recycling rates. Objectives and regulations must be put into practice also by the public sector. Policymakers must work on standardization, normalization and certification and furthermore raise awareness which is lacking.

10. Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of these practices to mitigate environmental deterioration?

We need to think more in terms of cycle, in the initial planning phase we need to consider what happens at the end of the life cycle, the question of how we can reuse the materials has to be asked.

Another big point is climate resilience, efficiency of buildings should be prioritized over appearance.

Energy storage can also be utilized, store excess renewable energy in storage systems to be used when production is not possible, this would increase the efficiency of buildings.

Your participation is very much appreciated and an important contribution to the thesis.

Appendix 7 Respondent 6

Please answer the following questions truthfully and to the best of your ability.

1. What company do you work for?

Tectus Group, a Swiss family-owned multinational operating in diverse industries and geographies, including construction, real estate, IoT for the built world and specialized engineering.

2. What is your current position and years of experience?

Chief of Staff – over 15 years work experience.

3. From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?

Industry, environmental and regulatory factors all present challenges and opportunities in implementing sustainable practices in construction. Among the challenges are:

a – **Adoption** transformations take time, and the construction industry has tended to be slow to change due to complexity and regulation among other factors. This can be seen in the example of the construction industry historically having one of the lowest levels of digitization according to McKinsey Global Institute's industry digitization index, though this is now beginning to change rapidly and become a priority now.

b – **lack of standardization and automation** – built world construction is often managed on an ad-hoc, individualized project basis slowing productivity and efficiency gains which also impact emissions slow progress. Offsite and modular construction are good examples of opportunities to overcome this challenge.

b – **Short term thinking + upfront cost** fragmented players and margin pressure towards the tail end of the value chain means education on adopting a holistic life-time view on assets value and longevity, which strongly promote sustainable practices, take time.

c- **Regulation** while regulations have enormous potential to accelerate built world decarbonization, they are not always ideally structured or creating the right incentives. For example, emphasis has been placed on minimizing operational carbon emissions, allowing much progress to be made, while regulation on embodied carbon is lagging despite embodied carbon emissions now making up approximately 50% of a new building's lifetime carbon footprint the majority of which is made upfront.

d - **greenwashing** has at times made it difficult for stakeholders to understand where and how much real progress is being made, while it is encouraging to see pushback and with more data and specificity on measurement and decarbonization plans, the effect can be minimized.

Technology I do not see as the biggest barrier as there are a number of well-established and cost-effective measures which can and should be immediately implemented, as well as promising new complementary technologies which will become increasingly available and affordable in the coming decade. For example, a recent study we conducted with Terrascope on applying established post-tensioning technology in building slabs demonstrated a substantial 50%+ reduction in CO2 emissions versus conventional construction techniques, growing to 73% when combined with recycled materials.

4. Could you share your insights on the current state of sustainable construction practices?

I feel the priority and pressure on adopting sustainable construction practices in construction has intensified in the last 3-4 years with many industry stakeholders pulling in the same direction, from investors and asset owners to regulators, consumers and employees each increasingly demanding both transparency and clearly defined, actionable targets.

In developing countries especially, the combination of technology, regulation, green building certificates and standards and market awareness is seeing many new projects which push the envelope on net zero carbon buildings and combining green construction practices, while there is more to be done to make this mainstream and especially to incorporating embodied carbon considerations in a simple and meaningful way.

We start to see the market results in the form of both green premiums where sale and rental prices are higher and occupancy rates and financing costs lower for green certified buildings as compared with non-, green-certified buildings.

5. From your experience, what role do regulations and policies play in influencing sustainable construction strategies?

As mentioned earlier, I see they have a vital role to play in accelerating the adoption of sustainable technologies as well as processes and importantly also a sustainability mindset in both design and life cycle thinking.

A good example is the pivotal role of maintenance, repair and retrofit technologies in sustainable construction. Studies have shown it can take over 50 years to recoup the upfront emissions generating in building a new structure rather than maintaining, retrofitting and an existing building. In Europe we have a huge stock of buildings and infrastructure which are reaching a certain age where inspection and maintenance for longevity and retrofitting for energy efficiency are becoming a priority. The EU Green “Renovation Wave” announced in 2020, which aimed to renovate up to 35 million buildings and create up to 160,000 green jobs in the construction sector is a policy example which supports this.

Viewed from the other side, with construction and operation of the built environment responsible for around 40% energy related CO₂ emissions, meeting the Paris climate goals will only be possible with significant policy and action in the built environment sector.

6. How do you see the integration of innovative technologies impacting sustainable construction?

Innovation in terms of technology as well as processes are important enablers for the built environment to become more sustainable and efficient. Simultaneous integration of novel sustainable design techniques, material improvements, and productivity driven by efficient, automated, and digitized processes and products can provide synergies and accelerate progress.

7. Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?

One good example on the embodied carbon side is the Max Stoja shopping mall project in Croatia, in which one of Tectus' affiliated franchisees BBR Adria was able to offer an alternative design using post-tensioning technology for the slabs which resulted not only in thinner and lighter structures using less concrete but contributed to a 33.5% lower CO2 while shaving 120 days of the construction time and reduced construction budget ([see p.91](#)). For me this exemplifies it is not always a trade-off between time/cost and sustainability but can be a win-win and using technologies readily available today.

Another project exemplifying a holistic approach to de-carbonization is the Powerhouse Telemark in Norway. It is a carbon negative building designed for ultra-low energy but also with sustainable design and materials and innovative technologies such that it will produce more energy than it will consume over its lifetime including its construction and demolition – this would be true net zero.

8. In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?

I think collaboration can be hugely beneficial, there are lot of solutions already available which can have an impact, while combining them and co-operating along the value chain can amplify the impact. It is well documented that the early in the design and planning phase sustainability considerations are incorporated the bigger the impact can be and this is where governments, green building councils, asset owners, designers, architects and engineers all the way to pensions funds and tenants who invest in and occupy real estate can incorporate this mindset upfront.

On an operational level another important area where collaboration is key is in improving circularity, recycling and reuse of structures and materials where the interfaces need to function cost-effectively and be scaled into an ecosystem.

Here again I would highlight the importance of common standards and transparency as the foundation for measurement and target setting that will facilitate collaboration and progress (ideally across Scope 1-3 emissions).

9. From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?

A holistic view of assets and infrastructure across their lifetime should be the starting point for policy development as well as project design and implementation. This means considering not only the environmental footprint but also the resilience of assets for maximum longevity and NPV, both are most effective when engaging at the earliest stages of asset planning and decision making. There is a regulatory as well as financial imperative to adopt more sustainable construction practices and to monitor and maintain our existing infrastructure stock, most of which will still be around in 2050.

10. Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of these practices to mitigate environmental deterioration?

I've already covered this in my previous responses, but I would summarize that incorporating sustainability considerations into construction is already high on the agenda of many industry stakeholders as well as society at large and can be a source of competitive advantage for those who can show leadership in this field, as well as having a positive effect in terms of financial risk and profile and contributing to responsibly growing and maintaining the built world. In all I expect to see an acceleration (albeit unevenly) of implementation of sustainable construction practices.

Your participation is very much appreciated and an important contribution to the thesis.

Appendix 8 Interview Questions

Interview Question	Purpose of the Question	Source
What company do you work for?	To identify the professional background of the participant.	Created by author.
What is your current position and years of experience?	To establish the credibility and depth of the respondent's experience which may influence their opinions.	Created by author.
From your perspective, what are the key challenges that the construction industry faces in implementing sustainable practices?	To identify specific obstacles that professionals in the sector encounter when aiming to include sustainable approaches in projects.	Created by author.
Could you share your insights on the current state of sustainable construction practices?	To gather first-hand experience on the present sustainable practices.	Created by author.
From your experience, what role do regulations and policies play in influencing sustainable construction strategies?	To gain knowledge and understand the impact of regulatory frameworks on sustainable construction practices.	Created by author.
How do you see the integration of innovative technologies impacting sustainable construction?	To explore the potential of new technologies in advancing sustainability in construction.	Created by author.
Could you highlight in your opinion specific examples of successful sustainable construction projects in the European Union that should be used as an example for future projects?	To gather information on exemplary projects in the EU that may serve as benchmarks in the industry.	Created by author.
In your opinion, how important is collaboration between different stakeholders in promoting sustainable construction initiatives?	To assess the cooperative efforts being taken to create sustainable projects.	Created by author.
From a practical standpoint, what advice would you give to contractors and policymakers looking to enhance sustainability in projects?	To solicit strategies for sustainability that can be implemented by industry and policy actors.	Created by author.

Looking ahead, what do you envision as the future of sustainable construction and how important do you perceive the implementation of these practices to mitigate environmental deterioration?	To capture predictions from experts on the future of sustainable construction and its importance in addressing environmental concerns.	Created by author.
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Table 2. Interview Questions

Created by Author, January 31, 2024