Design Innovation To Tackle The Climate Change Problem.

By

Navin Chhetri (navin.chhetri@ue-germany.de),

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Supervised by:

Professor Johannes Kiessler & Professor Thomas Noller.

Abstract

This thesis seeks to explore the role of design innovation in tackling climate change and the gaps in design innovation in tackling climate change. Climate change is a complex, global, and multidimensional phenomenon requiring a multi-pronged approach. Research starts from an existing literature review of climate change, design innovation to address climate change, the impacts of climate change on human society and the environment, and mitigation and adaptation in the climate change context. Design innovation has emerged as an essential tool for addressing climate change. Research also covers sustainability and green design concepts and some design innovation solutions available. After examining the current state of design innovation in terms of climate change, the research identified crucial opportunities and gaps in design innovation as a solution to climate change.

The review, with the help of case studies, identified several critical gaps, including a lack of collaboration and integration between design and policy, the effectiveness of climate change innovation, the need to incorporate CCE (Climate Change Education) into educational curriculum designing, and the potential for the use of ML, AL, and intelligent manufacturing in the development of climate change solutions. The research results highlight that design innovation has the potential to combat climate change; however, there are some gaps which can reduce by increasing collaboration between design practitioners, government, educational institutes and policymakers. The wealth of knowledge disseminated in this review could inspire the global community and drive further to reduce the gaps in innovative design education and technologies to mitigate climate change and sustainably support human activities.

Keywords:

Climate change, Greenhouse Gases Design Innovation, Sustainability, Climate Change Policy, Climate change solutions, Adaptation, Mitigation, Climate change Education.

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1. Introduction

Design innovation has the potential to play a significant role in tackling climate change. As the world grapples with the devastating effects of climate change, research and development in the area of design innovation provide the opportunity to create solutions that can help reduce the impacts of global warming.[1] This thesis examines climate change as a growing concern and how practitioners can design innovation to address climate change by focusing on the current state of the field and its potential for the future.

1.1 Climate Change: A Growing Global Concern.

Climate change is a global phenomenon becoming increasingly more significant in our world, caused by human and natural influences.[2,3] It is a phenomenon that affects all aspects of life on Earth, from our ecosystems, economies and societies to our very health and well-being.[4] As the climate changes, so does the planet's ability to sustain life. In the Arctic, temperatures have risen significantly, melting sea ice and glaciers and disrupting traditional livelihoods for Indigenous Peoples. In the equatorial regions, extreme weather events such as floods, droughts, and hurricanes have become more frequent and intense, damaging infrastructure and crops. In the oceans, rising temperatures and acidification are causing coral bleaching and the death of marine species. In the mountains, melting snow and ice are resulting in changes to freshwater availability and increased risks of landslides and avalanches. All of these changes have a direct and profound impact on communities, from health risks to economic losses.[5]

The Earth's climate is an interconnected system that consists of four components: the atmosphere, hydrosphere, lithosphere, and biosphere.[6] As the climate changes, so too do each of these components. The Earth's atmosphere comprises several gases that trap heat and regulate the planet's temperature. As the

climate changes, the concentrations of these gases are affected, affecting the Earth's temperature.[7] The hydrosphere is the Earth's water cycle, which includes all the water in the oceans, rivers, lakes, ice, and atmosphere. Climate change affects the Earth's water cycle by raising temperatures, causing more water to evaporate. This increased evaporation leads to increased precipitation in some areas and decreased rainfall in others. The change in the rain, in turn, can cause increased flooding in some areas and droughts in others. Additionally, as warmer temperatures cause water to expand, sea levels rise, dramatically affecting coastal areas and leading to flooding, erosion, and habitat loss. The changing hydrosphere can also affect ocean circulation, leading to temperatures and current changes. These changes can negatively impact marine life, such as through coral bleaching and decreased biodiversity.[8] The Earth's lithosphere comprises the crust and upper mantle, and its surface is affected by climate change. Warmer temperatures can cause glaciers and ice sheets to melt, and rising sea levels can cause coastal flooding and coastal erosion in certain areas, damaging habitats and displacing people. Warmer temperatures can also cause more frequent and intense droughts, fires, and other extreme weather events. Water deficits can lead to poor crop yields, while fires can deplete air quality and destroy habitats. Extreme weather events can cause flooding, mudslides, and damage to infrastructure. These changes can affect ecosystems, people, and the economy.[9]

Climate change is dramatically affecting the biosphere, which refers to all living organisms on Earth. As temperatures increase, species struggle to adapt to their changing environments; many are forced to migrate to new habitats. This migration can cause a decrease in biodiversity, as species cannot find suitable habitats that provide the resources they need to survive. Climate change is also shifting the availability of specific resources, making it harder for species to obtain the food, water, and shelter they need. Additionally, some species may become vulnerable to new diseases or predation by invasive species. The loss of biodiversity

can create a ripple effect, as the loss of a single species can negatively impact the entire ecosystem.[10] Warmer temperatures can have several detrimental effects on human and animal health. As the climate warms, diseases typically found in warmer climates can spread to cooler climates due to an increased number of vectors, such as mosquitoes, that can carry and spread diseases. Additionally, many organisms, such as rodents, can thrive in warm temperatures and cause problems for humans and other species by spreading disease and competing with native species for resources. These organisms can also damage crops, leading to a decrease in food production and an increase in the cost of food.[11]

To effectively address the problem of climate change, it is essential to understand its causes and impacts.[3] Governments, businesses, and individuals all have a role in addressing this issue. Governments must develop policies to reduce greenhouse gas emissions and encourage the development of renewable energy sources.[12] Businesses must embrace practices that reduce their carbon footprint and invest in sustainable technologies.[13] Individuals must reduce their consumption of fossil fuels by switching to renewable energy sources such as solar or wind power or by utilising energy-efficient appliances and vehicles to reduce their energy consumption. Furthermore, individuals should adopt more sustainable lifestyles by reducing their overall energy usage, promoting energy conservation and efficiency, and investing in green technologies such as energy storage and home automation. They should also increase their use of public transportation and carpooling and purchase locally grown and produced foods to reduce their carbon footprint. Finally, individuals should reduce their waste production and practice recycling and composting to reduce their environmental impact.[14]

1.2 Design Innovation To Address Climate Change.

One way to minimise the effects of climate change is through design innovation, which can help to reduce the number of greenhouse gases released into

the atmosphere and create more sustainable and eco-friendly products and services.[15] Design innovation has become more widely utilised in academic and professional design circles over the last decade. Despite attempts from the modern theory of innovation in economics to make the link between design and innovation more tangible and to explain the significance of design in the innovation process, it is yet to adequately address the recent growth of design innovation in terms of terminology and conceptual understanding.[16]

Design innovation can help reduce the amount of carbon dioxide and other greenhouse gases released into the atmosphere by developing more sustainable and eco-friendly products and services.[17] It can be done in various ways, such as reducing the amount of energy required to produce a product, using renewable energy sources such as solar and wind to power products, or developing products that are more efficient and require less energy to operate.[12] By implementing these measures, businesses can help to reduce their overall carbon footprint and make their products and services more environmentally friendly.

Furthermore, design innovation can also be used to create products and services that can help adapt or mitigate climate change's effects. By designing strategies and products with sustainability in mind, companies can help to reduce their overall carbon footprint and create eco-friendly products.[18,19] AI-based design innovation can be used to evaluate and minimise emissions on a large and small scale which can be used to assess emission data from individual sources to identify areas where emissions can be reduced and to develop strategies for reducing emissions. AI-based design innovation can also be used to reduce the emission of greenhouse gases by developing new technologies for capturing and storing these gases. Additionally, AI-based design innovation can be used to establish processes for taking emissions out of the environment, such as by capturing and storing gases released from industrial processes. The world can reduce and remove environmental emissions with the help of AI-based design innovation, helping to reduce the impacts

of climate change.[20] Climate change is an urgent global issue, requiring unprecedented worldwide cooperation and innovation. By leveraging design innovation, solutions can be created that address the effects of climate change and mitigate its causes.

1. Literature Review

Literature research is an essential part of any research project, and a wide range of sources were consulted for this research project. Academic journals, books, conference proceedings, news and magazine articles, government publications, and websites were scoured to understand better the causes and effects of climate change and the potential solutions available. The literature review then explored the various ways that design can tackle the problem of climate change, such as using new technologies, sustainable design, and eco-friendly products and services. Additionally, the review looked into how design can encourage a cultural shift towards sustainable practices and behaviours, such as through persuasive design. This literature review provides a thorough overview of the current understanding of climate change and the potential design solutions that can be employed to tackle this issue.

2.1 Climate Change.

Climate change is a significant and lasting change in the statistical distribution of weather patterns over decades to millions of years. It is caused primarily by human activities such as burning fossil fuels, cutting down forests and altering land use patterns. These activities release large amounts of carbon dioxide and other greenhouse gases into the atmosphere, trap heat, and cause global warming. The effects of climate change include rising sea levels, increased ocean acidification, extreme weather events, and changes in ecosystems. Natural phenomena such as

volcanic eruptions, Earth's orbit variations, and ocean circulation changes can also play a role in climate change. However, these are relatively minor compared to the impacts of human activity.[3] Climate change results from an increased concentration of greenhouse gases (GHGs) in the atmosphere, primarily carbon dioxide, which releases from burning fossil fuels and other activities. When absorbed by the atmosphere, these gases trap heat, resulting in a higher average global temperature and a variety of other changes to the environment. Burning fossil fuels for energy, transportation, and industry is the most significant source of these emissions, accounting for the highest global GHG emissions. Other sources include land-use change, deforestation, livestock production, and the production and use of certain chemicals. As global GHG emissions continue to rise, the effects of climate change will continue to worsen.[21] The effects of climate change on the Earth's climate have wide-reaching impacts on humans. Rising sea levels can lead to flooding, the destruction of coastal areas, and the displacement of people who live in coastal communities. More extreme weather events, such as heat waves, droughts, and storms, can negatively impact infrastructure, economic activity, and human health due to the destruction of property, disruption of services, and increased illnesses and deaths. Changes in the abundance of plant and animal species can also have significant consequences, as some species may become extinct while others may become invasive and cause problems for people who rely on them for sustenance or economic activity. These changes can potentially cause significant disruptions to human life and activities.[22]

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for assessing climate change. The IPCC has concluded that human activities—particularly the burning the fossil fuels—are the primary driver of recent climate change. The panel has also concluded that the global average temperature is likely to rise by 1.5°C (2.7°F) by 2100 if current levels of greenhouse gas emissions continue.[23] The impacts of climate change are already being felt

around the world. Sea levels are rising, ocean temperatures are warming, and extreme weather events are becoming more frequent and intense. Climate change is also having an impact on the abundance and distribution of plant and animal species.[24] In response to the growing threat of climate change, countries have committed to limiting global warming to 2°C (3.6°F) above pre-industrial levels by the end of the century. To achieve the goal, governments are taking action to reduce emissions, increase energy efficiency, and develop clean energy sources.[25]

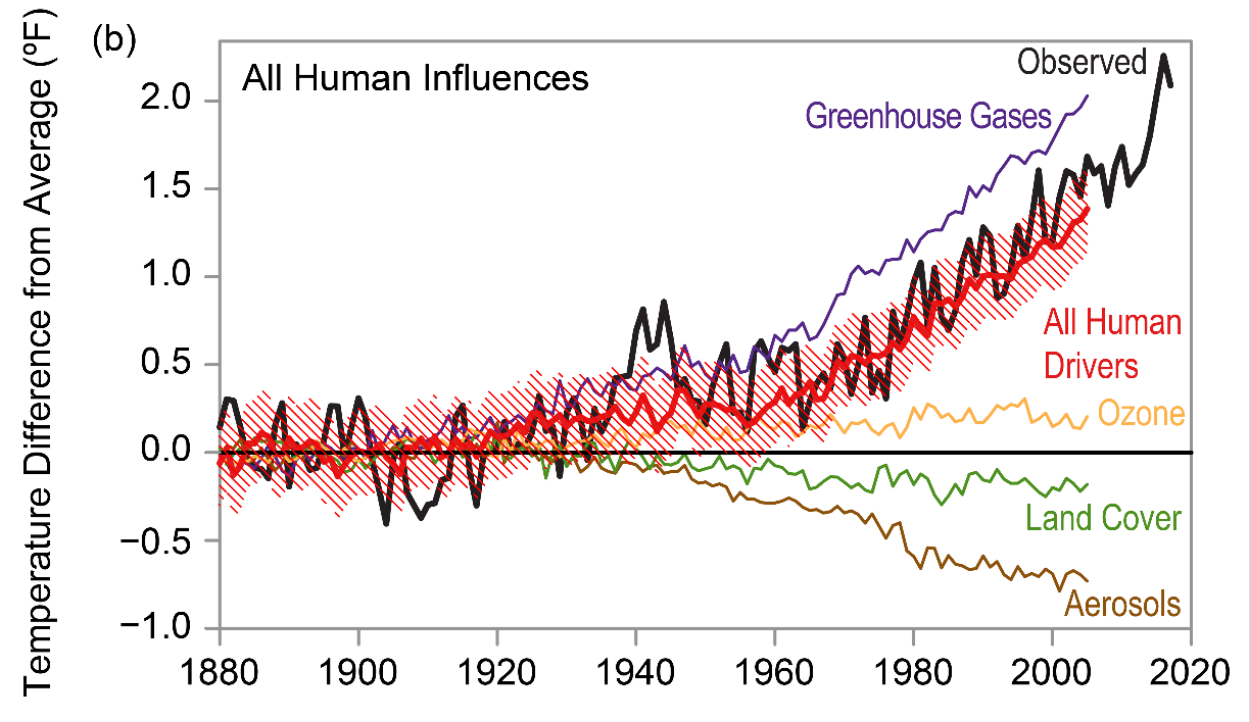

Figure 1: Human and natural factors influence the earth's climate, but the long-term trend observed over the past century can only be explained by the effect of human activities on climate.[F1]

2.2 Greenhouse Gases.

A greenhouse gas is a gas that absorbs and emits thermal radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. These gases include carbon dioxide (CO2), methane (CH4), nitrous oxide

(N2O), fluorinated gases (F-gases), and Ozone (O3). Greenhouse gases significantly affect the temperature of the Earth; too much emission of greenhouse gases warms the planet, while the reduction in emission helps to cool it.[26]

Since the start of the industrial revolution, the increase of greenhouse gases in the atmosphere Estimations suggest that carbon dioxide has increased by 40%, methane by 150%, and nitrous oxide by 20%, and human activities such as fossil fuel combustion and industrial processes have contributed to the emissions of man-made carbon dioxide, with half of all emissions being generated in the last 40 years. Global greenhouse gas emissions have plateaued or dropped from year to year but are once again accelerating, with a 1.6% increase in 2017 and a 2.7% increase in 2018.[27]

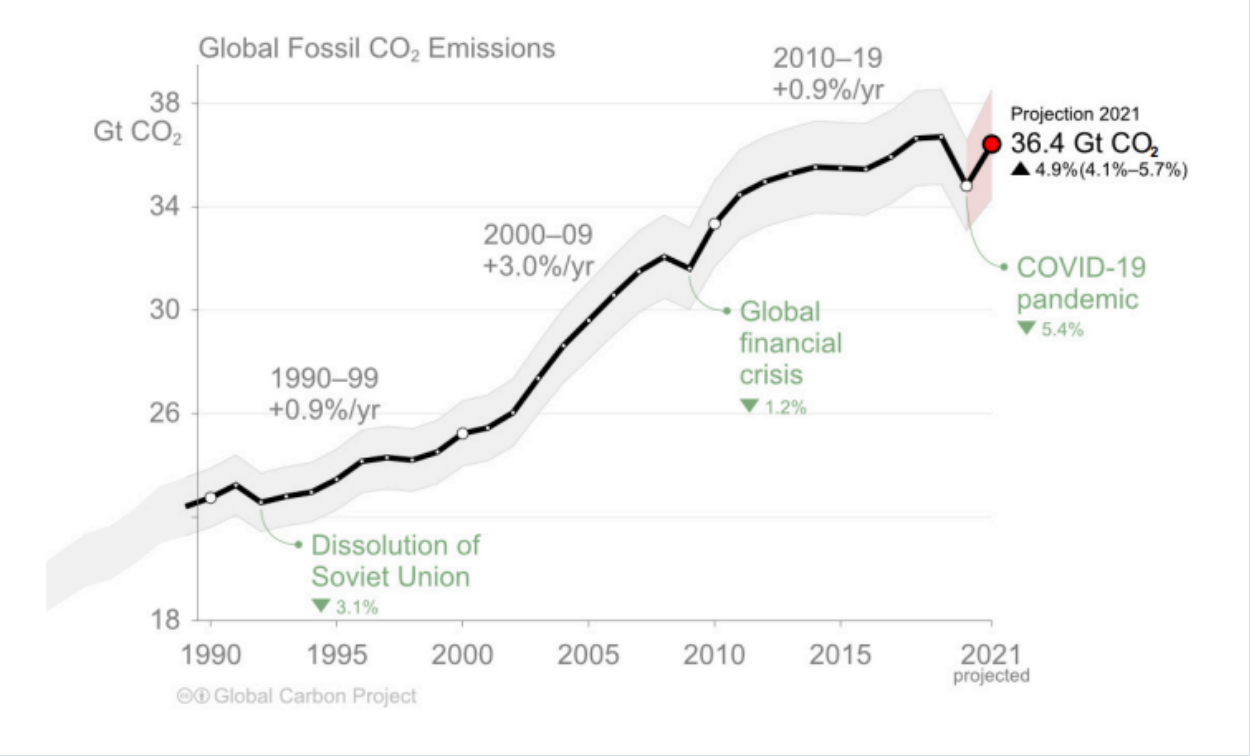

Figure 2: Global fossil CO2 emissions in 2021 are set to rebound by 4.9% after a record 5.4% drop in 2020. This follows a decade of strong and growing energy decarbonisation, which reduced emissions growth. [F2]

Greenhouse gases are transparent to sunlight but opaque to thermal infrared radiation. They allow sunlight to pass through the atmosphere to the Earth's surface, where it is absorbed and re-emitted as thermal infrared radiation. Greenhouse gases in the atmosphere trap some of this outgoing thermal infrared radiation and reflect it towards the surface, trapping heat and causing the Earth's average surface temperature to be higher than it would be in the absence of these gases.[28]

2.3 Impact Of Climate Change On Human And The Environment.

While the impacts of climate change are well-documented, the effects on humans, society, the economy and the environment are often less talked. But make no mistake; climate change has a profound and devastating impact on people's lives. [29]

> "*Climate change is a result of the greatest market failure the world has seen. The evidence on the seriousness of the risks from inaction or delayed action is now overwhelming. We risk damage on a scale larger than the two world wars of the last century. The problem is global and the response must be a collaboration on a global scale.*" Professor Lord Nicholas Stern.[30]

The economic impacts of climate change are also significant, as it is expected to cause a decrease in global crop yields, leading to higher food prices and a decrease in the availability of clean water.[31] Between 1980 and 2020, climate-related extremes caused economic losses totalling an estimated EUR 487 billion in the EU-27 Member States; these losses already average over EUR 12 billion per year.[32] The global economy could lose 10% of its total economic value by 2050 due to climate change, according to new research.[33] The social impacts of climate change are also significant. As the environment changes, people will be forced to relocate as the environment changes, leading to social and cultural displacement.[34] In addition, climate change is likely to cause health issues, particularly for vulnerable populations such as the elderly, children, and those with pre-existing health conditions. It is

projected that by the period 2030 to 2050, climate change could result in an estimated 250,000 more deaths each year due to malnutrition, malaria, diarrhoea, and heat-related issues.[29]

In many parts of the world, droughts are becoming more common and more intense. This is especially true in Africa, where the effects of climate change are being felt most keenly. Droughts can lead to food and water shortages, which can cause malnutrition, disease and even death.[35] Floods are another primary concern. As the planet warms and the ice caps melt, sea levels rise, making coastal areas increasingly at risk of flooding. And when floods do occur, they can destroy homes, disrupt communities and lead to loss of life.[36] Heatwaves are becoming more common and more intense as the planet warms. This can lead to heat-related illnesses such as heat stroke and can also put a strain on essential services such as power and water.[37] In many parts of the world, extremely high temperatures are posing a life-threatening risk to millions of individuals, as well as having a destructive effect on infrastructure and exacerbating food insecurity. Unfortunately, it is often the developing countries and those with limited financial resources who are suffering the most from the consequences of extreme heat yet have the fewest resources to deal with the situation.[38] Hurricanes are another potentially devastating consequence of climate change. As the oceans warm, hurricanes are becoming more intense and more destructive. And with more people living in coastal areas than ever, the risk to human life is increasing.[39]

The impacts of climate change are wide-ranging and far-reaching. But perhaps the most profound effect is on the most vulnerable people in the world – those who are least able to adapt to a changing climate. In the developing world, millions of people live in poverty and lack the resources to deal with the impacts of climate change. For them, climate change is a matter of life and death. And as the effects of climate change become severe, the number of people at risk will only increase.[40] If global warming surpasses 1.5°C (2.7°F), our options will become

severely limited. In some regions, if temperatures exceed 2°C (3.6°F), it will be impossible to adapt and reduce emissions. This important result highlights the need for fast and equitable action, including adequate funding, technology sharing, and strong political will. Collaboration and partnership are also essential for successful climate change adaptation and emissions reductions.[41]

2.4 Mitigation And Adaptation.

Climate change is a global issue caused by the long-term buildup of greenhouse gases in the atmosphere, resulting in higher temperatures worldwide. To address this problem there are two main strategies to address this problem: mitigation and adaptation.[42]

Mitigation is the process of reducing the number of greenhouse gases released into the atmosphere. This can be done through a variety of methods, including increasing energy efficiency and using renewable energy sources, reducing emissions from agriculture and land use, and transitioning to a low-carbon economy. Governments, businesses, and individuals can all take steps to reduce their emissions and help mitigate climate change.[43]

Adaptation is the process of adapting to a changing climate. This includes activities such as developing more resilient infrastructure, preparing for extreme weather events, and conserving water and other natural resources.[44] It also involves developing strategies to help vulnerable populations and ecosystems cope with the effects of climate change.[45]

The Intergovernmental Panel on Climate Change (IPCC) provides an overview of mitigation and adaptation strategies. The report states that mitigation can be achieved through a combination of technology-based and behavioural-based approaches, and it outlines a variety of mitigation strategies, such as increasing energy efficiency, reducing emissions from agriculture and land use, and transitioning

to a low-carbon economy. The report also outlines a variety of adaptation strategies, including preparing for extreme weather events, conserving water and other natural resources, and developing more resilient infrastructure.[46] The United Nations Framework Convention on Climate Change (UNFCCC) is another vital source of information on mitigation and adaptation. The UNFCCC provides an overview of climate change mitigation and adaptation strategies, as well as information on existing policies and initiatives.[47,48] The World Bank also provides a wealth of information on climate change mitigation and adaptation. The World Bank's Climate Change Knowledge Portal provides an overview of mitigation and adaptation strategies and outlines the various financing mechanisms available to support climate action.[49]

In addition to these resources, there are a variety of other open-sourced materials available for mitigation and adaptation. For example, the United Nations Environment Programme (UNEP) provides an overview of mitigation and adaptation strategies and outlines the various international initiatives and programs that support action on climate change.[50,51] The Global Climate Change Alliance (GCCA) also provides a variety of resources, including information on adaptation strategies, financing mechanisms, and existing initiatives. [52]

Overall, mitigation and adaptation are essential strategies for addressing climate change. Governments, businesses, and individuals all have a role to play in reducing emissions and helping vulnerable populations and ecosystems adapt to the impacts of climate change. Open-sourced materials, such as those provided by the IPCC, UNFCCC, World Bank, and UNEP, can help provide valuable information and support for these efforts.

2.5 Design Innovation As A Solution To Climate Change.

To mitigate the effects of climate change, it is essential to develop innovative technologies and strategies that can help to reduce emissions and increase energy efficiency. Design innovation can play a crucial role in helping to tackle climate change by providing new ways of thinking about reducing our environmental impact and creating more sustainable solutions.[1] This paper will explore how design innovation can help to address climate change and discuss the potential of design-led approaches to reduce emissions, increase energy efficiency, and create more sustainable products and services.[53]

2.5.1 Concept Of Design Thinking.

Design thinking is a human-centred approach to problem-solving that combines creative and analytical skills and methods. It is a process of exploring and understanding the needs of users and then using that knowledge to brainstorm and develop innovative solutions. Design thinking can be used to solve complex problems, create new products and services, and even improve existing ones.[54]

Design thinking is based on five key steps: empathise, define, ideate, prototype, and test. Empathizing involves gathering data and understanding the user's needs, goals, and motivations. Define consists of breaking down the problem into manageable chunks, which allows for more effective problem-solving. Ideate involves generating creative ideas and approaches to the problem. The prototype includes building and testing the solution to determine its effectiveness. A test concerns evaluating the design to determine if it meets the user's needs.[55]

Design thinking is becoming an increasingly popular approach to solving problems and creating innovative products and services. Companies such as Apple, Google, and IBM have all embraced design thinking to create better products and

services. Design thinking also has applications in education, food, and healthcare, among other opportunities.[56]

> "*Most people make the mistake of thinking design is what it looks like. People think it's this veneer – that the designers are handed this box and told, 'Make it look good!' That's not what we think design is. It's not just what it looks like and feels like. Design is how it works*." Steve Jobs.[57]

2.5.2 Innovation And Green Design Principles.

Innovation begins with a fresh concept. This could be a plan for a better product or service; it might be a more current approach to operating your business; it also could be an original business model. There are three main types of innovation: incremental, expansive, and disruptive. These can be applied to any aspect of a business, new or existing, and do not need to be groundbreaking.[58]

Following the principles of Sustainable Development, modern economic activities and lifestyles must be environmentally friendly, so Green Design must be incorporated into every step of the product's life cycle. Green design principles focus on reducing the environmental impacts of a product or service by the "*3R principles (Reduce, Reuse, Recycle)*", which are widely accepted as a means of achieving sustainable development but to expedite the progress of green growth, designers should adhere to the "*10R principles: Reduce, Reuse, Recycle, Renew, Recharge/Refill, Repair/Remedy, Re-manufacture/Recover, Replace/Replant, Re-clear/Refine and Remove.*" Reduce: reducing the number of materials used in the production and consumption of goods; reuse: finding new uses for existing products or materials; recycle: breaking down products and materials into their raw components to be reused in the production of new products or materials; renew: using renewable energy sources to power production and consumption activities; recharge/refill: refilling products and materials so they can be reused multiple times; repair/remedy: repairing products to extend their lifespan and reduce waste,

Re-manufacture/Recover: recovering components from used or damaged products to be used in the production of new products, Replace/Replant: replacing raw materials used in production with new materials from renewable sources, Re-clear/Refine: refining raw materials to improve their quality and reduce their environmental impact and Remove: removing products from the production process to reduce waste. By following the 10R principles, green design can be implemented from the outset and help to drive environmental progress. It is also the responsibility and obligation of today's designers to do so.[59]

Innovation and Green Design principles have helped us in the past and helped fight climate change, in the next sub-chapter, the research will examine how design innovation so far has been fruitful in tackling climate change.

2.5.3 Design Innovation Solutions And Climate Change.

The potential benefits of innovative design solutions for reducing emissions, increasing energy efficiency, and creating more sustainable products and services are well known. Now the research will explore some of the existing innovative design solutions that have successfully achieved these objectives. The paper will analyse the details of these existing solutions to see how they were successful and what elements could be adapted or implemented to create new and even more effective solutions. By doing so, the world can continue to reduce emissions, increase energy efficiency, and create more sustainable products and services.

- **Reducing Emissions.**

Design innovation can be used to reduce emissions by creating new technologies and strategies to replace existing, carbon-intensive processes. For example, by developing new and carbon-neutral forms of renewable energy sources such as wind, solar, geothermal, hydro, and biomass to reduce reliance on fossil fuels, [60] design innovation can create more carbon-neutral transportation systems

that use less energy.[61] Investing in research and development of new technologies to capture and store atmospheric carbon dioxide, CDR methods are a set of technologies that aim to remove atmospheric CO2. They are being researched to mitigate the greenhouse effect and avoid dangerous levels of climate change.[62] Additionally, design innovation can be used to create more efficient manufacturing processes that use fewer resources and produce less waste.[63]

- **Increasing Energy Efficiency**

Design innovation can also be used to increase energy efficiency by creating new, more efficient technologies.[64] This includes incorporating smarter building materials, insulation, and energy-efficient lighting and appliances to reduce energy consumption and reliance on fossil fuels, creating new materials and technologies that are more efficient at storing energy, such as solar panels or batteries.[65] Additionally, design innovation can be used to create new products, such as efficient energy storage,[66] energy-efficient lightings,[67] that use less energy and produce fewer emissions.

- **Creating Sustainable Products and Services.**

Design innovation can also be used to create new products and services that are tailored to meet the needs of a changing climate. This includes capturing and storing carbon dioxide from industrial and power plants for long-term storage,[68] utilising practices such as organic fertilisation, pest management, conservation tillage, and efficient energy and machinery used to reduce carbon dioxide emissions from farming,[69] utilising waste-to-energy technologies to convert waste materials into energy, as well as reducing waste production and implementing recycling and composting programs,[70] creating new products and services that are more sustainable and use fewer resources, low waste, such as renewable energy sources or alternative materials.[71] Additionally, design innovation can be used to create new

ways of living that are more sustainable, such as green buildings or alternative transportation systems.[72]

2. Methodology

The current climate crisis is an urgent issue that requires immediate and innovative solutions. The use of the secondary method for this paper provided a valuable and effective tool for research. Secondary research allowed me to understand the topic better, analyse existing data, and explore gaps and opportunities. Through the use of secondary data, the researcher was able to assess the validity of their research and examine the current state of design innovation in the context of climate change, identify gaps in current knowledge, and discuss the potential for further exploration. In addition, secondary research provided a reliable foundation of knowledge which was quickly accessible.

3.1 The Current State Of Design Innovation In The Context Of Climate Change.

Design innovation can refer to any type of new or improved design that seeks sustainability in any product or system.[73] This can include new materials, processes, technologies, or strategies for reducing energy use and emissions. The current state of design innovation in the context of climate change can be divided into two broad areas: technological advances,[74] and policy changes.[75]

Technological advances have been the primary driver of design innovation in the past few decades, as new materials, processes, and technologies have been developed to reduce the impact of climate change.[76] For example, new materials such as graphene and aerogel have been developed that are extremely lightweight and highly efficient in absorbing heat and light, making them ideal for use in

insulation and energy storage systems.[77] New processes such as 3D printing and nanotechnology have also been developed that allow for the rapid and inexpensive fabrication of complex products, increasing the efficiency of production and reducing the amount of energy required for manufacturing.[78] Lastly, new technologies such as solar energy, wind energy, and geothermal energy have been developed to provide renewable sources of energy that can reduce greenhouse gas emissions and improve the energy efficiency of existing products and systems.[79]

Policy changes have also been a major factor in driving design innovation in the context of climate change.[80] In recent years, governments around the world have enacted a variety of policies to reduce greenhouse gas emissions and promote more sustainable practices. These policies range from carbon taxes and emissions trading schemes to subsidies and incentives for developing and using renewable energy and energy efficiency technologies.[81] These policies have encouraged companies to develop more sustainable agricultural systems,[82] as well as to increase their investments in research and development of new technologies to reduce carbon emissions in the industry sector.[83]

Overall, the current state of design innovation in the context of climate change is encouraging.[84] Technological advances have allowed for the creation of new materials and processes that can reduce the environmental impact of products and systems,[85] while policy changes have encouraged companies to invest more in research and development and adopt more sustainable practices.[86] Additionally, the growing awareness of climate change has helped to drive more public and private investments in design innovation,[87] providing additional incentives for companies to create more sustainable products and systems.[88]

3.2 Gaps And Opportunities.

Design innovation has been a key component in addressing climate change, with the potential to create transformational solutions, from energy-efficient appliances to green infrastructure. However, certain gaps in design innovation concerning climate change must be addressed to maximise its effectiveness. Next, the paper examines some of the gaps and areas of opportunities that can be explored to integrate design innovation with climate change.

3.2.1 Lack of collaboration and integration between design and policy.

One key gap is the need for more collaboration and integration between design and policy. Even though the design is integral to the development of climate solutions, there needs to be more collaboration between design practitioners and policymakers.[89] It is possible that these solutions should be discussed or taken into consideration because of a lack of knowledge or interest on the part of policymakers. This leaves the potential for these solutions to be overlooked and for their potential positive effects to be unacknowledged. This means that the potential to make an impact on climate change through design solutions is being left untapped and under-utilized, leaving us with fewer options to help combat climate change.[90] This gap could be addressed through closer collaboration between design practitioners, policymakers, and researchers.

According to a report by the International Institute for Environment and Development (IIED), climate change adaptation policies are often not integrated with the design of cities and other built environments, leading to a lack of collaboration between the two and the need for greater action remains.[91]

- **Case Study 1. The Case Of The City Of Los Angeles.**

The National Resources Defense Council (NRDC) is a non-profit organisation that works to protect the environment and human health from the impacts of climate

change since 1970.[92] In 2020, NRDC worked to help the City of Los Angeles fight climate change through a variety of initiatives.[93] In 2018, the NRDC developed a "Los Angeles Shared-Mobility Climate And Equity Action Plan" to reduce greenhouse gas emissions and worked to create a more efficient, resilient, and equitable transport system by adopting clean energy and energy efficiency measures.[94]

Unfortunately, the NRDC's efforts to fight climate change in Los Angeles did not meet expectations. Limited resources, a lack of coordination with other stakeholders, and inadequate public engagement hampered the NRDC's initiatives. As a result, the City of Los Angeles' emissions has continued to increase despite the NRDC's efforts.[95]

- **Case Study 2. The Failure Of The European Union's Adaptation Strategy**

In recent years, the European Union has been striving to tackle the effects of climate change through various initiatives and policies.[96] The European Commission and the European Environment Agency (EEA) launched the European Climate Adaptation Platform (Climate-ADAPT) in March 2012 to help governments at all levels create plans for adapting to climate change. Additionally, a Copernicus climate change service is in the works to supplement existing services.[97] The European Environment Agency's 2019 report on the state of the environment has determined that Europe must take urgent action in the next ten years to reach its 2030 objectives. These objectives include reducing the rate of biodiversity loss, mitigating the effects of climate change, and curbing the overconsumption of natural resources. The report does express optimism, noting the increased awareness of the need for sustainability, technological advances, community initiatives, and EU action such as the European Green Deal.[98] In 2019, The European Green Deal pledged to allocate more than $100 billion for its Just Transition Mechanism (JTM) to finance the shift from carbon-intensive to low-carbon infrastructure.[99] A report argues that there are

still opportunities for design-led planning and climate change policy for effective policies of the European Union's adaptation strategy.[100]

Design innovation was expected to be a key component in Europe's fight against climate change. However, this has not lived up to expectations.[101] Design innovation has the potential to transform the way policies are crafted, implemented, and monitored. It can also provide new perspectives and insights into how best to address the climate crisis. Despite both EU and national climate policies highlighting the vulnerability of certain groups and the need for appropriate adaptation solutions, there is still very little in the way of practical implementation.[102]

- **Case Study 3. The Case Of Coastal Cities In The United States.**

The consequences of global warming have caused many changes in US coastal areas. Sea levels have risen, eroding shorelines, destroying wetlands and endangering built infrastructure. Hurricanes have become more powerful and frequent as Atlantic sea surface temperatures have risen. Water temperatures in certain regions have increased by 2°F, and the amount of runoff from landmass has increased, making the coastal waters more polluted with nitrogen, phosphorous and other pollutants. All of these factors come together in coastal areas, making them especially vulnerable to the effects of climate change.[103]

The Coastal and Marine Spatial Planning (CMSP) Program: The CMSP program was launched by the United States Government in 2009 to conserve and manage the ocean, coasts, and the Great Lakes. This program helps to reduce conflicts between different interests and to ensure that coastal and marine resources are used sustainably, identify areas that are most vulnerable to coastal hazards and climate change and also to ensure that activities such as fishing and shipping do not cause harm to the environment.[104] The National Ocean Policy: The National Ocean Policy was launched by the United States Government in 2010 to protect and conserve the ocean, coasts, and the Great Lakes. This policy was developed to

coordinate and streamline the many different federal and state actions related to the management and use of ocean and coastal areas. The policy focuses on promoting sustainable development, protecting marine ecosystems, and improving ocean governance.[105]

This case study examines how the lack of collaboration between urban planners, designers, and policymakers has resulted in inefficient strategies and policy solutions in coastal cities in the United States.[106] For example, Many coastal cities have implemented flood walls and other hardening measures to protect against the effects of sea level rise. However, these solutions often fail to take into account the long-term effects of climate change, such as erosion and shifting shorelines and can cause more harm than good.[107] Nuisance flooding is a type of coastal flooding that occurs when water levels rise above a certain threshold. It can cause a range of impacts, such as road closures, reduced stormwater drainage capacity, and damage to infrastructure not designed to withstand frequent inundation or exposure to salt water.[108] An article also supports urgent research needs in the United States with regard to improving the survivability and resilience of coastal communities as they face existential threats from climate change.[109]

3.2.2 Climate Change Innovation Vs Effectiveness.

Another area for improvement is in the evaluation of design solutions. To combat this, many innovative products have been designed over the years to help tackle climate change. [110] Unfortunately, not all of these products have been successful. Designers are often focused on creating innovative solutions, but they often need to assess the effectiveness of their solutions adequately.[111] The most recent data implies a discrepancy between research and practice in disseminating information about climate change. Practitioners need to utilise the available knowledge to its fullest potential, and researchers are not giving answers that would be most helpful to practitioners.[112] This can lead to ineffective or even

counterproductive outcomes. It is, therefore, important to include an evaluation component in the design process to ensure that solutions are practical and appropriate.

Four case studies of failed innovative products designed to tackle climate change:

- **Case Study 1: Plastiki**

Plastiki was an ambitious project launched in 2010 by inventor and environmentalist David de Rothschild.[113] The goal of the project was to bring attention to the issue of plastic pollution in the world's oceans by sailing a boat made of recycled plastic across the Pacific Ocean. The boat was made with 12,500 recycled PET bottles and was designed to be lightweight and eco-friendly.[114]

Unfortunately, the boat encountered numerous technical and logistical issues, which eventually led to the end of the journey in 2012.[115] The Plastiki project received a significant amount of media attention, but ultimately it was unsuccessful in its mission to raise awareness about ocean plastic pollution.[116]

- **Case Study 2: Carbon Capture Technology (CCT)**

CCT is a form of carbon capture and storage (CCS) is a 50-year-old technology which is designed to capture carbon dioxide emitted from power plants and other industrial sources. This technology has been in development for several decades but has yet to be widely adopted. The main issue with carbon capture technology is that it is expensive and energy intensive. Despite its extensive background, carbon capture is a difficult technology to use. An IEEFA study recently examined the capacity and performance of 13 key projects and discovered that 10 of them either did not work or did not display the capacities they should have, usually by a huge degree.[117] CCS also requires large amounts of space to store the captured carbon, which is not always available.[118] As a result, many companies have

abandoned their efforts to develop carbon capture technology, despite its potential to help mitigate climate change.[119]

- **Case Study 3: Solar Roadways In France**

Solar Roadways was an innovative project launched in 2014 by Scott and Julie Brusaw.[120] The idea was to replace existing asphalt roads with solar panels to generate electricity to power homes and businesses. The project was met with a great deal of enthusiasm, and the company was able to raise over $2 million in crowd-funding.[121]

Unfortunately, the project proved to be too ambitious, and the company could not deliver on its promises of generating enough electricity.[122] Similar projects in the United States faced the same consequences, adding to the failure of solar roadways.[123]

- **Case Study 4: Ocean Thermal Energy Conversion (OTEC)**

Ocean Thermal Energy Conversion (OTEC) is a form of renewable energy that utilises the temperature differences between warm surface water and cold deep ocean water to generate electricity.[124] OTEC has been studied and tested since the late 19th century and has been viewed as a promising and abundant energy source that could help meet the world's energy needs.[125] OTEC technology is much more than just electricity generation; it can generate a range of products. An onshore OTEC plant can be used to create electricity but also to develop other valuable items such as fresh water and hydrogen. These can be used for agricultural purposes and fuel, respectively.[126] Despite this, OTEC has not been developed commercially due to several challenges.

Economically, OTEC is expensive to build, maintain, and operate. It requires large amounts of capital to construct, and the operational costs are high due to the complexity of the technology and the need for expensive maintenance.[127]

Additionally, the high price of OTEC has prevented it from being built commercially, despite its remarkable potential as a renewable energy source.[128]

Technically, OTEC has several design and operational challenges. The majority of projects have not been advanced to commercial production due to the costly infrastructure requirements—particularly the wiring needed to connect the sea to the land—as well as the corrosive and hostile conditions of the ocean.[129] Additionally, the technology used to convert the heat from the ocean into electricity is still not efficient enough to be competitive with other forms of renewable energy.[130]

In conclusion, while many innovative products have been designed to tackle climate change, not all of them have been successful. The four case studies discussed in this chapter demonstrate that many of these products have encountered technical, logistical, and financial issues which have prevented them from achieving their goals.

3.2.3 Climate Change In Education Curriculum.

The next gap is the lack of integration of design thinking and climate change in higher education curriculum design. Higher education institutions have a responsibility to educate students about the causes and impacts of climate change and how to address them.[131]

While some schools have introduced courses on sustainable design or climate change, where approximately 47% of the 100 national curriculum frameworks reviewed contained no reference to climate change, the rest only briefly mentioned it. An evaluation of 20 countries' initiatives to communicate and teach about climate change revealed that most attention is given to primary and secondary education (90%). There is less focus on technical and vocational education and training (70%), higher education (70%) and teacher training (55%).[132] The UNESCO Global Education Monitoring Report for 2020 underlines the importance of education in

mitigating and adapting to climate change, yet many countries still fail to recognise the significance of CCE or invest in it adequately.[133] The paper will examine 3 case studies of the lack of integration of design thinking and climate change in the higher education curriculum.

- **Case Study 1: Climate Change Education In The United States**

Although climate change is one of the most pressing issues facing our planet today, the United States refused to sign the Paris agreement [134] and has been slow to integrate design thinking into climate change education.[135]

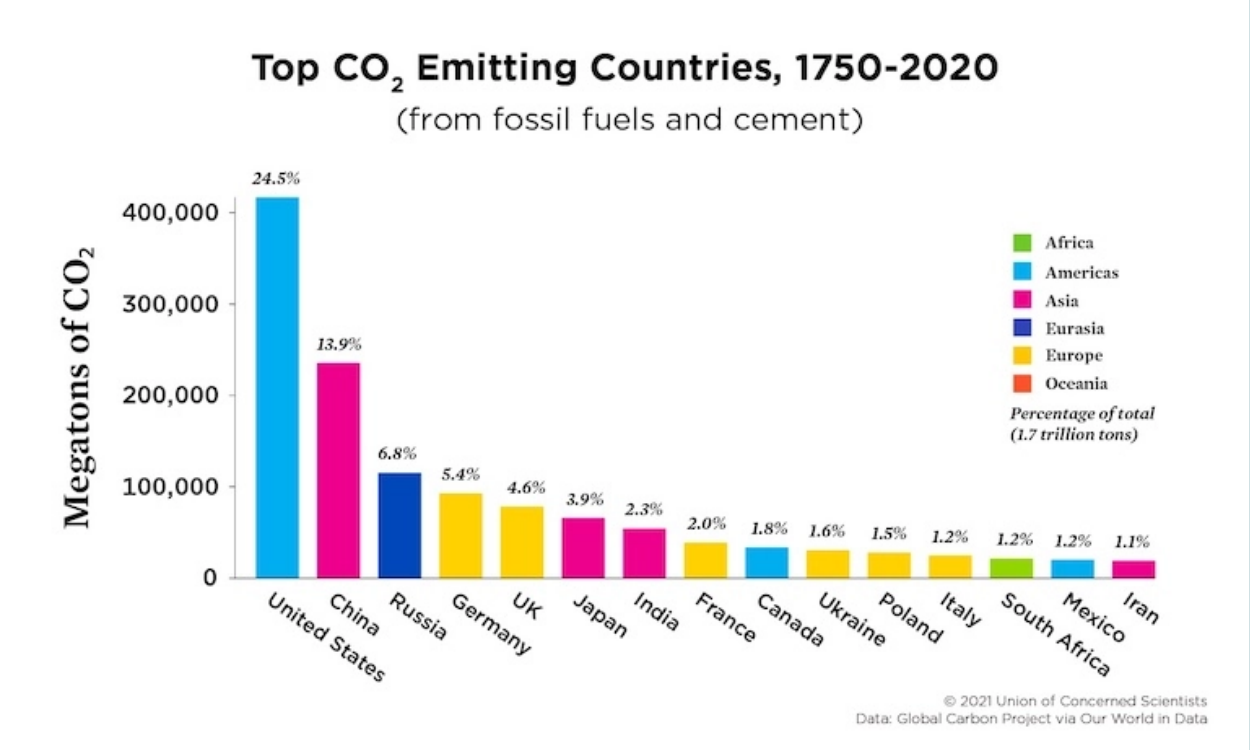

Figure 3: The new EDGAR report found that global carbon emissions for 2021 nearly bounced back to pre-pandemic levels. Image by Union of Concerned Scientists.[F3]

Despite this, only about a quarter of American schools have implemented climate change education into their curriculums. This is due to a few factors. Firstly,

there is a lack of adequately trained teachers who can effectively teach the subject. Additionally, there is opposition from sceptics who are sceptical of the science behind climate change and would rather not discuss it in schools. Despite this, a large majority of Americans are in favour of teaching climate change in school, suggesting that there is a disconnect between the general public and the decision-makers in the education sector. to address this issue effectively, more needs to be done to provide teachers with the necessary training and support to teach climate change and to ensure that those who oppose it are not able to influence the curriculum.[136] Although many universities in the US integrate research and education into their campus sustainability programs and initiatives, however, it is not part of the curriculum.[137] A nationwide survey of science teachers in the United States found that, while most spend some time discussing climate change in their courses, their lack of knowledge about the science and political factors behind it may limit their ability to teach the subject effectively.[138]

- **Case study 2: Climate Change Education In India**

Although India is one of the countries most affected by climate change, there has been a lack of integration of design thinking into climate change education. India is currently experiencing the effects of climate change, with increased droughts, floods, and extreme heat waves.[139] India ranked lowest among 180 countries in the World Economic Forum's Environmental Performance Index (EPI) 2022, which measures environmental health and sustainability.[140]

According to a survey conducted by UNESCO, only half of the 100 countries it reviewed had any mention of climate change in their national curriculum. In 2021, 95% of 58,000 primary and secondary teachers believed it was essential to teach climate change, although only 32% felt they could explain it concerning their local environment. Questions posed to 17,000 11-to-19-year-olds around the world

revealed that 70% of them could not explain climate change, had a limited understanding of its concepts, or were unaware of it in any way.[141]

At the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow in 2021, Prime Minister Modi highlighted the importance of including climate change adaptation policies in the school syllabus,[142] yet the National Council of Educational Research and Training (NCERT) recently removed chapters on climate change from the curriculum (Class 11: Greenhouse effect, Class 7: weather, climate and water and Class 9: the Indian monsoon). It was argued to be a measure to reduce students' workload; however, it was seen as a regressive move and showed a lack of consideration. After many teachers and activists expressed their disapproval, Education Minister announced that the omitted chapters would be re-included.[143] Unfortunately, India does not currently have a curriculum specifically on climate change, but topics like sustainability are explored in environmental studies. However, Institutions of higher learning in India have begun to recognise the advantages of green jobs and are working towards lessening the distinction between the climate-related skills that are in demand and those that are available.[144] Although several universities have also started providing specialised courses in areas [145] however, for a country where climate change has not been an extensive part of the education system till now will take some more time to integrate design innovation to tackle climate change.

- **Case study 3: Climate Change Education In African Nations.**

Africa is one of the regions most affected by climate change, yet there has been a lack of integration of design thinking into climate change education. The region is already experiencing the effects of climate change, with increased droughts, floods, and extreme heat waves.[146] The United Nations Environment Programme's (UNEP) Africa office is working to assist countries in the region in developing the necessary infrastructure to implement their Nationally Determined Contributions

(NDCs) to combat climate change. These NDCs are designed to meet critical socioeconomic objectives, such as food security, creating income and enterprise opportunities for the youth, and promoting economic growth.[147] Despite this, there is not much concentration on climate change education, and the majority of classrooms in Africa are not teaching students how to think critically and creatively about the problem.[148]

The research found that climate change literacy in Africa varies greatly from country to country, as well as within countries. Of 394 sub-national regions surveyed, 8% had a literacy rate lower than 20%, and only 2% scored higher than 80%. There can be a 33% difference between the highest and lowest climate change literacy rates in some countries. The average national climate change literacy rate in Africa is 37%.[149]

African nations must invest in resources and technology to properly integrate design innovation into climate change education. This investment will provide students with the opportunity to create sustainable solutions to the climate crisis while also helping to create an equitable and inclusive educational system.[150] Through the integration of design innovation into climate change education, African nations can help ensure that their citizens are armed with the knowledge and skills necessary to help protect their communities and the environment.[151] The lack of integration of design thinking and climate change into the higher education curriculum design is a significant issue that should be addressed. Without the necessary knowledge and skills to address the challenge, students are unlikely to develop the innovative solutions needed to tackle it.[152]

In conclusion, these three case studies from three different regions of the world demonstrate the need for the integration of design thinking and climate change in higher education curriculum design.

3.2.4 Use Of Artificial Intelligence.

Another area of exploration is the use of emerging technologies, such as artificial intelligence and digital fabrication, in the design of climate-friendly products and systems. While these technologies have the potential to improve the sustainability of design, there is a need to consider their potential impacts on the environment and the ethical implications of their use.[153] Despite the ongoing efforts to mitigate the effects of climate change, much more can be done, especially when it comes to leveraging the latest technologies such as machine learning, artificial intelligence (AI), and intelligent manufacturing, as they can be used to understand the effects of climate change better and to develop more effective solutions.[154]

Machine learning can be used to detect patterns and correlations in large datasets, making it possible to identify the factors that contribute to climate change and suggest solutions. AI can also be used to optimise energy efficiency, for example, by predicting when and how much energy should be used to reduce reliance on fossil fuels. [155]

In addition, intelligent manufacturing can be used to reduce energy consumption and greenhouse gas emissions. By using predictive analytics, it is possible to optimise production processes and reduce waste.[156] For example, intelligent manufacturing can be used to detect faults in production lines and to optimise the use of materials, thereby reducing the amount of energy required to operate the production line.[157] Furthermore, intelligent manufacturing can be used to develop more efficient products, such as those with lower energy consumption or lesser emissions.[158]

- **Case Study 1: AI & 3D printing can develop climate-friendly products.**

AI-driven design and fabrication techniques can be used to optimise manufacturing processes, providing cost savings and increased efficiency. These

techniques offer unprecedented customisation, allowing for the manufacture of products that are customised to individual customer needs, thereby reducing the need for mass manufacturing. Automated experimentation with AI-driven tools can also help to identify the best possible solutions for any given design problem. Additionally, AI-driven smart manufacturing technologies can be used to reduce energy-intensive manufacturing processes by providing real-time feedback on the process and allowing for more efficient use of resources. Such technologies can help to reduce the amount of energy used in the manufacturing process while also improving the quality and speed of production.[159] 3D printing has emerged as a viable alternative for manufacturers looking for ways to reduce their carbon footprint. By using 3D printing, manufacturers can produce lightweight, durable products with low-carbon materials that are more sustainable than traditional materials. This means that products can be made with fewer resources, resulting in a smaller environmental impact. 3D printing can also be used to create customised products that can be tailored to specific customer needs, leading to less waste and fewer emissions. Furthermore, lightweight, durable products made with low-carbon materials can be used in climate-friendly products that are designed to be energy efficient, have a long life span, and require minimal maintenance. This could lead to a more sustainable future for both businesses and the environment.[160]

- **Case Study 2: Using Machine Learning to Optimize Building Energy Efficiency.**

Buildings consume a large amount of energy from sources like electricity, natural gas and fuel oil to heat, cool, light and power the building. This energy consumption has a significant impact on the environment, contributing to climate change through the release of greenhouse gases. Improving the energy efficiency of existing buildings is a necessary step in the fight against climate change, as it reduces the amount of energy used and the emissions produced. This can be done by retrofitting buildings using energy-efficient materials and technologies, such as

insulation, high-efficiency windows and appliances, as well as renewable energy sources, such as solar panels and wind turbines. Additionally, reducing energy consumption through behaviour changes such as switching off lights and using energy-saving settings on appliances can also help reduce the building's energy consumption. Implementing these changes in existing buildings can help significantly reduce their energy consumption and emissions and thus contribute to the fight against climate change.[161] Optimising the energy efficiency of buildings is a challenging endeavour since there is a wide range of design and construction variables that need to be considered. These variables can include optimising the site's potential, energy use, water conservation variables, building space and material use, the placement of the HVAC systems, and the type of lighting fixtures. All of these variables can have a significant impact on the energy efficiency of a building, and they all need to be taken into account when designing and constructing a building to maximise its energy efficiency.[162]

Recently, researchers have turned to machine learning to address this problem. A team of researchers used a combination of machine learning algorithms to identify potential design improvements to existing buildings that would reduce their energy consumption.[163] The team analysed hundreds of thousands of design configurations to identify design elements that would significantly improve the energy efficiency of the building. This analysis included examining various building components, such as insulation, windows, shading devices, ventilation systems, and lighting. Additionally, the team also looked at energy consumption patterns and usage trends to determine how these elements could be best utilised to optimise the energy performance of the building. The team then used this data to inform a suite of design decisions that resulted in improved energy efficiency. These improvements included the use of higher-efficiency materials, such as insulated walls, windows, and doors; the installation of shading devices; the use of natural ventilation systems;

and the optimisation of lighting systems. The combination of these design elements resulted in a building that was more energy-efficient and cost-effective.[164]

Overall, these gaps in design innovation concerning climate change must be addressed for design solutions to be effective and equitable.

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3. Results

The results show that climate change is a global issue that affects human society and the environment in both direct and indirect ways, and design innovation can be a powerful tool for addressing climate change. The results of this thesis are as follows:

1. The integration of design thinking into policy and decision-making can create pathways to create more sustainable practices and products. This means governments, businesses, and other decision-makers can use design thinking to create policies that reduce emissions and encourage sustainable practices. Additionally, businesses can use design thinking to create products that reduce their environmental footprint and are more energy efficient. Design innovation also has the potential to create social change and innovation. By encouraging the public to be more aware of the impacts of climate change and by providing them with the knowledge and resources to take action, design innovation can create a more sustainable and socially conscious society. This can lead to more effective policy and decision-making that will help to tackle climate change.
2. To ensure the effective implementation of solutions to combat climate change, it is essential to reinforce collaboration between the design community and climate change policymakers. Designers and architects can play a key role in identifying innovative solutions for mitigating climate change, such as

designing energy-efficient buildings and urban spaces or creating new materials and technologies that can reduce our environmental impact. At the same time, policymakers must provide the necessary support and resources to ensure these solutions are implemented on a large scale. By working together, the design community and policymakers can develop effective strategies to address climate change and ensure the successful implementation of solutions.

3. Design innovation could help address the impacts of climate change on human society and the environment. Design innovation can create new ways of managing and using natural resources, such as water or soil, to reduce the strain on the environment. Additionally, design innovation could be used to create new products and services that promote sustainable living, such as energy-efficient appliances or public transportation systems. By utilising design innovation to develop these solutions, it is possible to reduce the impact that climate change has on human society and the environment.
4. Climate change education can help people understand the science behind climate change, the impacts it has on their lives, and how they can contribute to the solution. It can also help people understand the issue's scale and the urgency with which it needs to be addressed. Climate change education can also foster a sense of responsibility among individuals, communities, businesses, and governments, inspiring them to take action on climate change. Additionally, climate change education can inform policy-makers and foster public support for initiatives that are designed to reduce greenhouse gas emissions and build resilience to the impacts of climate change. Ultimately, effective climate change education is essential for ensuring that the right solutions are implemented and that the international community takes meaningful action to address climate change.
5. The use of machine learning, AI and intelligent manufacturing could be leveraged to create effective and efficient solutions to climate change.

Machine learning and AI can be used to analyse large datasets of climate data and identify patterns, allowing us to understand the effects of climate change better and create models to predict its future impact. AI can also be used to develop innovative solutions, such as autonomous drones and robots, to monitor and manage the environment. Intelligent manufacturing can be used to create energy-efficient buildings, appliances and transportation systems and to develop new renewable energy sources. By harnessing the power of these technologies, the world can work to reduce our impact on the environment and find sustainable solutions to climate change.

4. Discussion

Design Innovation is the process of creating new ideas, products, and services that can help reduce the effects of climate change. Designers are increasingly turning to Design Innovation to tackle climate change as it provides an opportunity to create effective and aesthetically pleasing solutions. Some of the most significant Design Innovation initiatives related to climate change include green building, energy efficiency, and renewable energy.

The impacts of climate change are far-reaching and are already being felt globally. Some of the most significant effects include extreme weather events, rising sea levels, and the spread of diseases. Extreme weather events, such as floods, droughts, and heat waves, have caused displacement, loss of life, and economic disruption. Rising sea levels have also caused displacement of populations, loss of land, and an increase in coastal flooding. The spread of diseases, such as malaria, has been linked to climate change due to warmer temperatures and increased rainfall.

One of the most promising solutions Climate change is Design Innovation. Design Innovation is the process of creating new ideas, products, and services that can help reduce the effects of climate change. Let us examine how design innovation can be used to create new solutions and technologies that are more sustainable and resilient to the impacts of climate change, as there are many opportunities available. Despite the potential of Design Innovation to address climate change, there are still several gaps in the current research and practice.

- **Lack of Collaboration and Integration between Design and Policy.**

A lack of collaboration and integration between design and policy limits the effectiveness of climate change solutions. Design and policy must be integrated to develop effective solutions which are both technically and socially feasible. By increasing collaboration between design practitioners and policymakers, considering the needs of low-income and marginalised communities, and evaluating the effectiveness of design solutions, designers can help create meaningful and impactful solutions to climate change

- **Climate Change Innovation vs Effectiveness.**

Although there is significant research and development in climate change innovation, there is still a lack of evidence to show that these solutions effectively reduce emissions and mitigate climate change. As the world continues to grapple with the issue of climate change, it is essential to learn from failed products and develop innovative solutions that are both effective and economically viable.

- **Climate Change in Education curriculum designing.**

Climate change is not adequately addressed in education curriculum design. This limits the number of students who are equipped with the skills and knowledge to develop effective solutions. Open-source references and links can be used to promote greater integration of these topics by providing students with a better

understanding of the science behind climate change and the role of design in addressing it. With the right resources and guidance, higher education institutions can ensure that their students are adequately equipped to tackle the challenges of climate change. Teachers need to be equipped with the tools to teach students about the issue in a way that is engaging and encourages them to think critically and creatively. This could be done by introducing design thinking activities into the curriculum, such as having students come up with innovative solutions to climate change or creating art projects that spread awareness about the issue.

- **Use of Machine Learning, AI and Intelligent Manufacturing.**

The literature review found that there is a lack of research on the use of machine learning, artificial intelligence and intelligent manufacturing to design climate change solutions. AI-driven technologies have the potential not only to help reduce carbon emissions but also to monitor the environment and help identify solutions for adapting to the changing climate.

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5. Conclusion

The research presented in this Master's thesis on Design Innovation to Address Climate Change has highlighted the need for a holistic approach to climate change. Through a comprehensive literature review, it has been established that climate change is a multifaceted issue with a wide range of impacts on human society and the environment.

The effects of climate change are becoming increasingly apparent around the world, and the world must take action now to mitigate its effects. Design innovation is a powerful tool for tackling climate change and can help to reduce emissions, increase energy efficiency, and create more sustainable products and services. By

using design-led approaches to address climate change, practitioners can create innovative solutions that are tailored to meet the needs of a changing climate. Design innovation can play a key role in helping to tackle climate change by providing new ways of thinking about how to reduce our environmental impact and create more sustainable solutions.

It has also been established that there are still several gaps and areas for further exploration, such as the lack of collaboration and integration between design and policy, the effectiveness of climate change innovation, the inclusion of climate change topics in educational curriculum designing, and the use of machine learning, AI and intelligent manufacturing.

Overall, the research conducted in this thesis has demonstrated that the gaps are areas of further exploration for design-led solutions to address climate change as well as the need for greater investment in education and research to ensure the effectiveness of climate change mitigation measures.

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University of Applied Sciences Europe
Iserlohn · Berlin · Hamburg

EIGENSTÄNDIGKEITSERKLÄRUNG / STATEMENT OF AUTHORSHIP

Chhetri
Name | Family Name

Navin
Vorname | First Name

24948500
Matrikelnummer | Student ID Number

Design Innovation To Tackle The Climate Change Problem.
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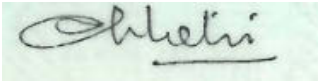

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