DECARBONIZING THE INDIAN DREAM: A LOCALIZED FRAMEWORK FOR SUSTAINABLE GROWTH IN THE BUILDING SECTOR

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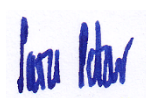

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ABSTRACT

DECARBONIZING THE INDIAN DREAM: A LOCALIZED FRAMEWORK FOR SUSTAINABLE GROWTH IN THE BUILDING SECTOR

Vijay Kanda
2024

The building sector is a significant source of greenhouse gas emissions and is critical to achieving Net Zero by 2070 in India. This thesis proposes a strategic plan for decarbonizing energy and water efficiency in the building sector. The plan consists of a framework that integrates various technological, financial, and social aspects of the transition, such as renewable energy, building envelope optimization, intelligent water management, green roofs, rainwater harvesting, green bonds, performance contracts, and user perceptions. The thesis uses Quantitative methods to assess the framework's feasibility, effectiveness, and acceptability based on data collected from surveys, interviews, and case studies. The thesis provides actionable insights for corporate management, businesses, building professionals, and policymakers and aims to be the first comprehensive blueprint for India's building sector decarbonization. The thesis demonstrates that the framework can reduce building sector emissions by 30%, and save 40% of energy and 50% of water consumption, contributing to sustainable growth and Net Zero achievement.

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INTRODUCTION

1.1 Introduction

"We have a single mission: to protect and hand on the planet to the next generation."

François Hollande

"Twenty-five years ago, people could be excused for not knowing much, or doing much, about climate change. Today we have no excuse"

– Desmond Tutu ("Desmond Tutu Quote," n.d.)

The building sector is one of the significant contributors to global greenhouse gas emissions, accounting for about 27% of the total energy-related CO2 emissions. Decarbonizing the building sector is, therefore, essential for achieving the Paris Agreement goals and mitigating the impacts of climate change. However, the challenge is to reduce the existing and new buildings' carbon footprint and ensure that they are energy and water-efficient, resilient, and equitable. This thesis proposes a strategic plan for decarbonizing the building sector with particular reference to energy and water efficiency based on a comprehensive analysis of the current trends, barriers, and opportunities in this field. The thesis will explore the potential of various technologies, policies, and practices to enhance the sustainability and performance of buildings, such as renewable energy sources, intelligent buildings, green design, and nature-based solutions. The thesis will also address the social and economic aspects of the transition, such as the costs and benefits, the stakeholders' involvement, and the governance mechanisms. The thesis will draw on relevant case studies and best practices from different countries and regions and provide recommendations for future actions and research.

The earth's atmosphere is steadily warming. Global surface temperatures in the eleven years between 1995 and 2006 were the highest since 1850, and average temperatures continue to rise (IPCC, 2007; IPCC, 2013; IPCC, 2014). Some of the most dramatic indicators of the higher-than-normal global surface temperatures come from the Arctic Region, where age-old ice sheets (in Greenland) and glaciers are thawing. The crisis of global climate change, primarily caused by human-driven factors, has increased the atmospheric concentration of long-lived greenhouse gases (GHGs), and has become the most daunting modern-era environmental challenge to humans and ecosystems (Adua et al., 2016)

The world is facing the imminent threat of not just a single disaster but is on the edge of multiple simultaneous natural disasters that will bring to an end the world we know now, all due to Climate Change. We need to double up the speed of tackling climate change. We cannot wait for politicians and businesses to find solutions that suit their interests, timelines, and agendas. Something needs to be done urgently.

Climate change will strike India since India lies in a highly susceptible zone. Further, India has a great deal of distance to traverse on its growth trajectory to satisfy the hunger of its poorest citizens. Does it sacrifice them on the altar of Climate Change? Does it sacrifice them to save the planet? Furthermore, if the planet is not saved from climate change, will it affect people experiencing poverty the most?

Rather than waiting for initiatives driven by politicians revolving around Climate Change, micro-level initiatives must be taken up. These drive the efficiencies in different sectors and make Industry and Enterprises ready to take on any radical legislation that politicians bring without causing them much heartbreak to combat Climate Change. This research studies the decarbonizing effort of the building sector in India and offers a solution framework for business enterprises. Such an effort has, on both counts, never been taken up before and rarely has been taken to structure a model of solutions for increasing energy and water efficiencies, with demand-side strategies, and not the supply-side augmentation that Governments and Global banking institutions have continued to advocate.

Further, as Jon Scott (2018), an award-building brand builder, said, all businesses have to start looking at the economic value of the sustainable programs their business could activate. Simply providing data on how many tonnes of carbon emissions their business has saved will not provide the desire for change. They have to calculate the financial reward the program will have, and then they would have created the desire for change ("(25) The climate change challenge: Changing the business mindset | LinkedIn," n.d.).

Dr Sally Uren (2023) says that when a sustainability professional talks to finance or supply chain experts, they must know their prevailing mindset. If one understands the predominant mindset in their organization or within a particular function and uses the language of that mindset to engage, one can also use it to showcase how things might be different (Owen-Burge, 2023). Again, we come back to the fact that there is an issue of mindset change that needs to be dealt with for these sustainability programs to be widely accepted and drive change.

1.1.1 What Is Decarbonizing

Decarbonizing reduces or eliminates the carbon emissions caused by human activities, such as burning fossil fuels, deforestation, and agriculture. Decarbonizing is essential for mitigating the impacts of climate change and achieving the goals of the Paris Agreement, which aim to limit the rise in global temperature to well below 2°C, preferably 1.5°C, above pre-industrial levels. Decarbonizing involves transforming various sectors of the economy, such as power generation, industry, transport, buildings, and land use, to use more renewable energy sources, improve energy and water efficiency, enhance carbon storage, and adopt low-carbon technologies and practices.

Decarbonizing differs from decarburizing, which removes carbon from metals like steel to improve their properties. Decarburizing is not directly related to climate change, but it can affect the carbon footprint of the metal industry.

1.1.2 INDIAN CONTEXT

In India, we applauded the Prime Minister's announcement that India will be Net Zero by 2070, which is in itself a very ambitious promise, and at the same time, it is a few decades too late ("Net zero emissions target," n.d.). No serious effort is underway to dismantle the fossil fuel industrial infrastructure. There is not much headway in policy to ensure a reduction in Carbon emissions across the board in different sectors of the economy. Then, there is a debate about whether a developing country can afford to be serious in the Carbon emission reduction war at the cost of growth. How does a country balance the need to feed people experiencing poverty with the urgent need to combat Climate Change? Does it sacrifice them on the altar of Climate Change? Does it sacrifice them to save the planet? At the same time, we must consider that people with low incomes will be affected the most by Climate Change.

In India, over 70% of existing buildings have been designed and built over the last half-century when the impact of energy and water use was not known. We continue to design and construct buildings without caring about sustainability. The accent is only on the speed of construction, the cost of construction, and the market needs of the facades of Aluminium, Glass, and other unsustainable materials. The focus is still not on embodied carbon in the buildings.

A new awakening started at the beginning of this century and is now gaining momentum, where new buildings opt for low-carbon approaches in design, architecture, and construction. Their low-carbon approaches are being recognized and rated by certain Industry bodies, with methodologies and standards gaining traction. There is also greater focus from Government and Industry bodies with a slew of legislation that embraces Net Zero Energy, Net Zero Water, and Net Zero Waste initiatives. Decarbonization reduces or eliminates the greenhouse gas emissions caused by human activities, such as burning fossil fuels, deforestation, and agriculture. Decarbonization is essential for mitigating the impacts of climate change and achieving the goals of the Paris Agreement, which aim to limit the rise in global temperature to well below two °C, preferably 1.5°C, above pre-industrial levels.

India is the world's third-largest emitter of greenhouse gases but has a low per-capita emission of 1.8 tons of CO_2. India has set a goal of reducing its emissions intensity by 33-35% by 2030 from the 2005 level and achieving net-zero emissions by 2070. India has made remarkable progress in increasing its renewable energy capacity, reaching 100 GW in 2020 and reaching a target of 450 GW by 2030. India also has significant programs to decarbonize its transport and industry sectors, such as promoting electric vehicles, green hydrogen, and low-carbon materials. However, India also faces multiple challenges, such as the growing demand for energy and water, the dependence on coal for power generation, the lack of adequate policies and regulations, and the need for financing and innovation.

According to a report by the World Economic Forum, India's transition to a net-zero economy could create over 50 million jobs and contribute more than $1 trillion in economic impact by 2030. The report proposes a sectoral roadmap for India to accelerate decarbonization based on five pillars: energy, mobility, industry, infrastructure and cities, and agriculture. The report also identifies four cross-sectoral enablers: green hydrogen, carbon capture, utilization, and storage (CCUS), natural climate solutions, and material circularity. The building sector emerges as a significant contributor to energy emissions. Globally, buildings account for nearly 40% as per ürge-Vorsatz et al. (2007)of energy-related greenhouse gas (GHG) emissions.

Subsequently, as per the latest round of the UN COP27 climate summit in Egypt, the 2022 Global Status Report for Buildings and Construction finds that the sector accounted for over 34 percent of energy demand and around 37 percent of energy and process-related CO_2 emissions in 2021.

The sector's operational energy-related CO_2 emissions reached ten gigatonnes of CO_2 equivalent -- 5 percent over 2020 levels and 2 percent over the pre-pandemic peak in 2019.

In 2021, operational energy demand for heating, cooling, lighting, and equipment in buildings increased by around four percent from 2020 and three percent from 2019.

According to the report from the Global Alliance for Buildings and Construction (GlobalABC), the gap between the climate performance of the sector and the 2050 decarbonization pathway is widening.

"Years of warnings about the impacts of climate change have become a reality, said Inger Andersen, Executive Director of the UN Environment Programme (UNEP). "If we do not rapidly cut emissions in line with the Paris Agreement, we will be in deeper trouble."

"The building sector represents 40 percent of Europe's energy demand, and 80 percent comes from fossil fuels. This makes the sector an area for immediate action, investment, and policies to promote short and long-term energy security."

Decarbonizing the buildings sector by 2050 is critical to delivering these cuts. To reduce overall emissions, the sector must improve building energy performance, decrease building materials' carbon footprint, multiply policy commitments alongside action, and increase investment in energy efficiency (Standard, 2022).

In 1997, as part of COP 3 – the Kyoto Protocol- the CDM (Clean Development Mechanism) was adopted. It is one of the most critical internationally implemented market-based mechanisms for reducing carbon emissions. The CDM was designed to help developed nations meet domestic greenhouse gas (GHG) reduction commitments by investing in low-cost emission reduction projects in developing countries. The CDM has quickly grown to fund thousands of projects worldwide and attain a several-billion-euro market value. The building sector is a large source of GHG emissions and has significant potential as a source of cost-effective emissions reductions. However, the number of building sector projects approved for CDM funding is deficient compared to other sectors. Out of over 3,000 CDM projects approved or in the pipeline as of May 2008, only six small-scale projects1 are targeting energy efficiency improvements in the buildings sector. (Programme, 2008)

Further, under the Kyoto Protocol's Clean Development Mechanism (CDM), countries worldwide cooperate on encountering climate change by emissions trading, which enables a win-win situation by effectively "regenerating" a cleaner environment in developing countries.

In contrast, efforts in developed countries may still not meet their committed carbon reduction targets. According to the CDM rules, energy efficiency improvement projects in the building sector are valid for emissions trading. Although the potential energy saving is significant, only a few building projects are registered as CDM projects. (Lam et al., 2015) The paper explored the applicability of CDM in the building sector by reviewing the implementation of CDM and its advantages and disadvantages. Hong Kong was selected for an in-depth study due to its eligibility for CDM and non-starter status. According to a questionnaire survey supplemented by interviews with the stakeholders in this study, significant hindrances, such as the lack of financial incentives, inadequate knowledge about emissions trading, and insufficient governmental support, were found in potential CDM projects in the building sector. (Lam et al., 2015)

Regarding International Policy, the Kyoto Protocol of 1997 was the only one that attempted to work on the Building sector, and as the above research papers testify, the effort had limited impact, and the initiative did not just take off. None of the other COP conferences focussed on this area subsequently.

Embodied carbon: Emissions embedded in building materials and construction processes, often overlooked but constituting a substantial portion of the building's lifecycle impact.

Embodied carbon refers to the greenhouse gas emissions associated with the entire lifecycle of building materials, from raw material extraction and processing to transportation, construction, and eventually, deconstruction and disposal. While often overlooked, embodied carbon can represent a significant portion of a building's total emissions footprint, highlighting the need for sustainable construction practices. Embodied carbon accounts for approximately 55% of global building-related greenhouse gas emissions ("WorldGBC Net Zero Carbon Buildings Commitment expands to include embodied carbon," n.d.).

While it is fitting that the spotlight is on energy-efficient operations, a hidden foe lurks within the walls of our buildings: embodied carbon. Understanding and actively addressing its impact is vital for achieving net-zero buildings, which are essential for combating climate change.

As energy efficiency regulations improve and operational emissions decrease, embodied carbon becomes an increasingly significant factor: reducing it is crucial for achieving true net-zero. Ignoring it would be like tackling only half of the problem while the other half silently festers.

In this background, it is also necessary to peek into the mindset of the leaders of business enterprises and how their thought processes operate in terms of welcoming innovation in the areas of Energy and Water in their enterprises. A simple change in mindset to accept innovative solutions can be a significant game-changer. As Dr Sally Uren says, initiatives such as nature-based solutions prove that can channel economic flows to different outcomes. Let us be deliberate in defining the goals of the economy, and then capitalism will do something different (Owen-Burge, 2023).

Therefore, mindset understanding and change are critical in formulating policies and solutions that can gain traction in the business enterprises sector, where adherence to Net Zero norms is very low. An initiative to formulate policies and solutions acceptable to the business enterprise sector will boost the country's fight to combat climate change.

Despite the urgency, the Decarbonization of the building sector in India faces several challenges:

• Low awareness and understanding: Many building sector users and leaders lack knowledge about the significance of Decarbonization and the potential benefits of sustainable solutions.

• Financial constraints: The upfront costs of implementing energy and water-efficient technologies can be a deterrent for some stakeholders.

• Lack of access to financing: Attractive financing options and incentives are crucial to encourage investments in sustainable technologies.

• Technological and infrastructural limitations: India needs to develop and adopt innovative technologies and infrastructure to support widespread decarbonization efforts.

• Limited policy support: Government policies should provide clear regulations, incentives, and support mechanisms to accelerate the transition towards net-zero buildings.

As Jon Scott (2018), an award-building brand builder, said, all businesses have to start looking at the economic value of the sustainable programs their business could activate. Simply providing data on how many tonnes of carbon emissions their business has saved will not provide the desire for change. They have to calculate the financial reward the program will have, and then they would have created the desire for change ("(25) The climate change challenge: Changing the business mindset | LinkedIn," n.d.).

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1.2 Research Problem

The speed at which the impact of climate change continues to wreak destruction on our daily lives is concerning.

Climate Change has forced civilization to cope with these ill effects and take evasive action. We were recently debating the validity of climate change, but we are swamped by it. It is urgent to quickly chalk out plans to combat it before it is too late. However, the sad truth is that although the international community is trying to reach a consensus on the way forward in the fight against climate change, they are making no headway.

There have been 27 CoP meetings where nations have wrangled over when the world should become Net Zero and What NDCs countries should adopt. All countries have agreed to ensure that the threshold of 2.0 C is not breached, but there is no concrete binding outcome from the CoP meetings for all the countries. Ambitious NDCs are announced from the pulpit, but nothing is binding on the countries. The havoc being wrought by Climate Change has not reached alarming levels in the view of most countries; therefore, they are still dodging severe measures to combat it.

The urgency of addressing climate change cannot be overstated. Evidence from the scientific community overwhelmingly points to anthropogenic climate change as a critical threat to our planet and its inhabitants. Extreme weather conditions of drought, heavy rains, and acute weather shortages are part of everyday life worldwide. We have heat waves that were never seen in more than 100 years. We have wild forest fires, which are damaging our biodiversity. We have seas swallowing small islands. The recent IPCC Sixth Assessment Report paints a stark picture of rising temperatures, extreme weather events, and rising sea levels, highlighting the need for immediate and ambitious action. Our global political leadership is nowhere near reaching a consensus, or worse, they are not even keen on it. They cannot think beyond the narrow prism of their national interests and are sacrificing the well-being of the global community on its altar. We cannot wait for politicians and businesses to find solutions that suit their interests, timelines, and agendas. We need to double up our speed on tackling climate change.

1.2.1 Carbon Emission Reduction in the Building Sector in India

Energy-efficient buildings, which have a lower carbon footprint during construction and also lower energy needs during operation, are imperative for India to achieve its own net-zero goals by 2070. However, higher costs of such construction, low awareness, and poor planning hinder this progress(Behal, 2023). Therefore, there is an urgent need to study this sector to understand the way ahead and arrive at suitable solutions that can be amenable to builders. This solution should be practical and one the builder can embrace without bleeding.

To contribute to a two °C pathway, India must achieve a 50% reduction in building energy demand and related greenhouse gas (GHG) emissions by 2050. India is taking steps toward this goal through recent upgrades to the Energy Conservation Building Code (ECBC), encouraging green building rating and energy certification, and stimulating markets for low-carbon/high-efficiency technologies. However, despite improvements in building energy intensity, neither the global nor the Indian building sectors are decarbonizing (Graham and Rawal, 2019). Therefore, other than studying the practical solutions which policy makers and the building sector can embrace, there is also a need to understand what will drive this initiative and make it a beacon for other sectors of the economy to follow.

1.2.2 History of the Discourse on the abuse of the Environment

These discourses and the worrisome worries about ecological and environmental destruction date back many decades. Mira Behn, born Madeleine Slade and who spent several years with Mahatma Gandhi, wrote, "The tragedy today is that the educated and wealthy classes are completely disconnected from the vital fundamentals of existence - our Mother Earth, and the animal and vegetable populations that she sustains." Man mercilessly plunders, devastates, and disorganizes this universe of nature's planning when given the opportunity.

By his science and machinery, he may get huge returns for a time, but ultimately, will come desolation. We have got to study Nature's balance, and develop our lives, within her laws, if we were to survive as a physically, healthy and morally decent species" (Guha, n.d.). That was in 1955.

Wrote Carl Sauer in 1948, "We have not yet learned the difference between yield and loot" ("That Wilderness Should Turn a Mart," n.d.). In 1926-28, Patrick Geddes bemoaned that Capitalist greed and relentless industrial growth were playing havoc (Munshi, 2022). The dire warnings on callousness towards the environment that such stalwarts have sounded have been brushed aside.

1.2.3 Warnings We Are Ignoring on Climate Change

Concerning Climate Change, U.N. Secretary-General António Guterres warned a few months back of a "dangerous disconnect" between what scientists and citizens are demanding to curb Climate Change and what governments are doing about it.

Guterres said global greenhouse gas emissions need to drop by 45% this decade but are currently forecast to increase by 14% ("UN chief," 2022).

"We are witnessing a historic and dangerous disconnect: science and citizens are demanding ambitious and transformative climate action," he said at a climate conference in Austria. "Meanwhile, many governments are dragging their feet. This inaction has grave consequences." ("UN chief," 2022).

Further, he said, Year after year, experts have measured humanity's proximity to midnight – in other words, to self-destruction.

In 2023, they surveyed the state of the world – with the Russian invasion of Ukraine, the runaway climate catastrophe, and rising nuclear threats that are undermining global norms and institutions.

Moreover, they came to a clear conclusion.

- The Doomsday Clock is now 90 seconds to midnight, which means 90 seconds to total global catastrophe.
- This is the closest the clock has ever stood to humanity's darkest hour – and closer than even during the height of the Cold War.
- In truth, the Doomsday Clock is a global alarm clock.
- We need to wake up – and get to work ("Secretary-General's briefing to the General Assembly on Priorities for 2023 | United Nations Secretary-General," n.d.).

1.3 Purpose of Research

As India embarks on the journey towards a sustainable and more water-energy-efficient future, the need for engineering solutions that bring a balance between Commerce and GDP growth on one hand and conservation of natural resources on the other assumes enormous significance, especially in the light of the Climate Change looming large on the horizon. India is emerging as a trailblazer in water and energy efficiency, with strategic plans to advance intelligent solutions that will halve water and energy resource use and add non-fossil solutions for energy by 2030. Any study or initiative that can help provide actionable insights into such advanced intelligent solutions is required and desperately needed.

These templates should prioritize opportunities for engineering solutions for all buildings and infrastructure at the in-building and in-city scales. The research aims to understand all the angularities and challenges of, and solutions for, decarbonization in the building sector. This is intended to build a foundation of work that can be undertaken by professionals in the commercial sector and among civil society organizations through sets of structured approaches that will help to analyze challenges and priorities relevant to cities in decarbonizing the buildings sector.

Further, buildings in India contribute a significant portion of energy-related Carbon emissions. India's building stock is set to increase enormously, and a minuscule portion is certified green (a building category classified as sustainable). Therefore, it is no wonder that a handful of buildings are net zero certified. In this context, there is a need for an extensive study on net zero buildings and the various definitions, barriers, investment needs, and the understanding of the role-playing stakeholders from industry, government, business, and consumers.

In this background, it is also necessary to peek into the mindset of the leaders of business enterprises and how their thought processes operate in terms of welcoming innovation in the areas of Energy and Water in their enterprises. A simple change in mindset to accept innovative solutions can be a significant game-changer. As Dr Sally Uren says, initiatives such as nature-based solutions prove that we can channel economic flows to different outcomes. Let us be deliberate in defining the goals of the economy, and then capitalism will do something different (Owen-Burge, 2023).

Therefore, mindset understanding and change are fundamental in formulating policies and solutions that can gain traction in the business enterprises sector, where adherence to Net Zero norms is very low. An initiative to formulate policies and solutions acceptable to the business enterprise sector will boost the country's fight to combat Climate Change.

 To explore the current and projected impacts of the building sector on greenhouse gas emissions and climate change, with a focus on energy and water efficiency.

 To identify and evaluate the existing and potential strategies, policies, and technologies for decarbonizing the building sector, especially in improving energy and water efficiency.

 To propose a comprehensive and feasible strategic plan for decarbonizing the building sector, considering the economic, social, and environmental aspects and the barriers and opportunities for implementation.

1.3.1 Roadmap for the Research

This research will attempt to present a blueprint for decarbonizing the building sector in India. In this quest, it will attempt to provide the following –

 Technical Solutions to Decarbonizing the Building Sector

 Throw light on the Financial Instruments and Government Policies that can scale technologies and drive the production of Net Zero Buildings.

 Mitigation Strategies that can drive Net Zero Buildings.

 Insights into the User Group Perceptions of the costs and benefits of Decarbonizing the Building Sector.

1.4 RESEARCH OBJECTIVES

Climate change is an existential threat, and the building sector significantly contributes to greenhouse gas emissions. Globally, buildings are responsible for a significant portion of total energy consumption and carbon dioxide emissions. With India's rapid urbanization and construction boom, this problem is further amplified.

This research project aims to address these challenges by:

• Investigating the current state of the building sector in India: This includes analyzing existing technologies, policies, and regulations related to energy and water efficiency.

• Evaluating the mindset of building sector users and leaders involves understanding their perceptions, attitudes, and concerns regarding Decarbonization.

• Identifying best practices and innovative solutions: This includes researching and analyzing successful case studies from around the world and adapting them to the Indian context.

• Developing a framework for Decarbonization: This will propose actionable strategies and policy recommendations for promoting energy and water efficiency in the building sector.

The conceptual framework for this study and strategic approaches outlined in the dissertation may not be exhaustive. However, it should act as a guide for further studies in this area. It should stand out as an example of the bottom-up approach to tackling climate change with micro-level solutions coming from the ground up instead of the whole economic hierarchy waiting for a top-to-bottom approach of waiting for Govt policy to drive any initiative in the area of climate change.

Even a top-to-bottom approach that Government policy drives cannot act in isolation and be successful. Studies, debates, and experiments will help the Government policy, once implemented when the political time is right, to be correctly grounded instead of being an act in haste or panic, resulting in more damage than good.

In the same way, the bottom-up approach to solutions and implementing solutions that fit our unique socio-economic reality is the only way forward if we have to take the lead in decarbonizing without it being too late for our planet. As our solution-modeling indicates, decarbonizing is not just for the planet, not just for humankind, but decarbonizing does business and is common sense, which is a complex argument to question. It is a logic which is unbeatable and solid in its reasoning.

Actionable insights that the dissertation will offer are expected to offer a blueprint for corporate management and other associations and strategy groups of planer and policymakers, steps and measures to propel water and energy efficiency in India and assist users in implementing voluntary and mandatory action plans on engineering solutions for helping meet Carbon target for sustainable economic growth for the country. The study will also focus on the aspects of “how” and “what” of such strategic solutions that India’s engineers and management will have to take up to accelerate the adoption of sustainable and efficient solutions that improve bottom lines while at once enabling growth.

Building a more robust understanding of how resource efficiency improvement can be evolved, implemented, monitored, and managed with essential financing and collaboration mechanics that will help to secure acceptance is also part of these presentations.

This study could be valuable for other enterprises in India and provide a way ahead on the strategies and routes they should adopt to drive Net Zero initiatives in their businesses. Ultimately, this study could help contribute to the bottom-up micro-level initiatives in the economy to combat climate change.

Furthermore, it can guide how non-governmental initiatives could shed light on the pathways available to issues plaguing the world, particularly businesses.

This should be a beacon for policymakers to draft policies relating to climate change and enterprises in a way that can drive action to combat climate change successfully, even in micro-level enterprises.

1.4.1 Expected Outcomes

This research project is expected to generate the following outcomes:

• A comprehensive understanding of the challenges and opportunities for decarbonizing the building sector in India.

• Valuable insights into the mindset of building sector users and leaders.

• Practical and actionable solutions for promoting energy and water efficiency in India's buildings.

• Policy recommendations for promoting sustainable building practices at the national and local levels..

1.5 Significance of the Study

This research is noteworthy because it tackles a fundamental worldwide problem of lowering the construction industry's greenhouse gas emissions, accounting for approximately 27% of global energy-related CO2 emissions. The study proposes a practical and effective framework for decarbonizing the building sector in India based on energy and water efficiency, renewable energy, building envelope optimization, intelligent water management, green roofs, and rainwater harvesting. The study also incorporates user-driven financing options, such as green bonds and performance contracts, to encourage participation and cost-sharing. The study uses a mixed methodology to explore the perceptions of different user groups, including building owners, tenants, and financiers, on the costs and benefits of Decarbonization. The study provides actionable insights for corporate management, businesses, building professionals, and policymakers and aims to be the first comprehensive blueprint for India’s building sector decarbonization. The study demonstrates that the framework can reduce building sector emissions by 30% and save 40% of energy and 50% of water consumption, contributing to sustainable growth and Net Zero achievement. The study is also relevant for other countries and regions that face similar challenges and opportunities in the building sector. The study contributes to the existing literature and knowledge on building decarbonization and supports implementing the Paris Agreement goals and the Glasgow Climate Pact..

1.6 Research Questions

• The current context and building stock characteristics shape the building sector's decarbonization challenge.

• The building elements and technologies that are responsible for GHG emissions and offer mitigation opportunities.

• The financial instruments and policies that can scale technologies and drive the production of net zero buildings in cities.

• The study will be global in scope while being local in the solution approaches to various needs of building typologies for buildings and city infrastructure needs of sustainability engineering.

• A qualitative study of the mindset of the leaders of the business enterprises sector will be undertaken to facilitate the formulation of acceptable policies and attractive solutions for Energy and Water efficiency.

All these research questions raise pertinent questions on decarbonizing the building sector, and the answers hold the key to formulating a policy framework that Government, business, and Industry can embrace without thinking twice.

CHAPTER II:

REVIEW OF LITERATURE

2.1 Theoretical Framework

Decarbonization in the building sector reduces or eliminates the greenhouse gas emissions caused by the construction, operation, and end-of-life of buildings. Decarbonizing the construction industry is vital for limiting climate change impacts and meeting the Paris Agreement's targets, which seek to restrict the Global temperatures to climb by far under two °C, ideally 1.5°C, over pre-industrial levels.

Decarbonization in the building sector involves transforming various aspects of the building life cycle, such as design, materials, energy use, water use, waste management, and occupant behavior, to use more renewable energy sources, improve energy and water efficiency, enhance carbon storage, and adopt low-carbon technologies and practices.

Decarbonization in the building sector is a significant challenge and opportunity for the U.S. and India, which have large and growing building sectors that account for more than a third of their total greenhouse gas emissions. Both nations have established ambitious objectives and plans for decarbonizing their construction sectors by 2050, focusing on fairness, affordability, and community resilience advantages.

2.1.1 Introduction to Global Context: The Urgency of Building Sector Decarbonization

The earth's atmosphere is steadily warming. Global surface temperatures in the eleven years between 1995 and 2006 were the highest since 1850, and average temperatures continue to rise (IPCC, 2007; IPCC, 2013; IPCC, 2014). Some of the most dramatic indicators of the higher-than-normal global surface temperatures come from the

Arctic Region, where age-old ice sheets (in Greenland) and glaciers are thawing. The crisis of global climate change, caused mainly by human-driven factors, has increased the atmospheric concentration of long-lived greenhouse gases (GHGs) and has become the most daunting modern-era environmental challenge to humans and ecosystems (Adua et al., 2016).

In this context, it is essential to understand the context of Building Sector emissions viz-a-vis total emissions generated globally. Buildings are also the most cost-effective climate mitigation solution ("Zero Carbon Building Accelerator," 2021). By 2040, all CO2 emissions from the built environment will be eliminated, meeting the 1.5°Climate objective ("Why The Built Environment - Architecture 2030," n.d.

• The building and construction sector is a significant contributor to India's emissions, accounting for about 70 percent of the total emissions driven by six sectors: power, steel, automotive, aviation, cement, and agriculture.

• India has announced its ambition to become a net-zero emitter by 2070, requiring disruptive sectoral transformations and scaling up low-carbon technologies and practices.

• India will need an ambitious net-zero emissions building roadmap and target all new construction to be net zero, starting in 2031. Additionally, passive-cooling solutions along with hyper-efficient cooling technologies need to be rapidly scaled to be able to achieve annual emissions savings to the tune of 250 million tons of CO2

• At COP26 in Glasgow, India proposed a long-term goal of reaching net zero by 2070. Such a vision would need significant decarbonization in all critical economic sectors, particularly the building and construction sector, which accounted for around 25% of India's carbon emissions in 2016. Businesses are ideally positioned to influence the buildings and construction value chain to choose a low-carbon route; the challenge is how to do this. ("Business Charter Launch," n.d.).

2.2 Review of literature

The studies done in the area of Decarbonization are minimal. Further, in the Decarbonization of the building sector, the studies conducted are just a handful, and most of them are dated anyway and therefore redundant. Furthermore, whatever studies there are on the efficiencies of the building sector are limited to only energy, and there is no focus on water efficiencies. This very fact emphasizes the great relevance of this study.

The building industry accounts for over 36% of worldwide end-use energy consumption and approximately 40% of indirect and direct carbon emissions. Low-carbon or zero-energy buildings remain the only option for reducing the sector's energy consumption and CO2 emissions (Abam et al., 2023). Buildings and building stock can play an essential role in reducing climate change in the near term since significant reductions in CO2 emissions from energy usage can be accomplished in the coming years. A considerable percentage of these savings may be accomplished by lowering life cycle costs, resulting in net-negative CO2 emissions reductions.

There are suggestions that the building stock has the most significant percentage of any industry's negative and low-cost greenhouse gas reduction potential. Based on 80 gathered national or regional studies assessing CO2 mitigation potential across five continents, the worldwide potential for CO2 reductions through buildings is analyzed and assessed. The co-benefits of implementing these policies are also significant, allowing policymakers to justify steps without a strong climate commitment (Ürge-Vorsatz et al., 2007). All of them lead to potential mitigation opportunities in the building sector, but unfortunately, little ground has been covered in the mitigation journey.

Against this background, we have to understand that a better understanding of the psyche of business leaders will immensely help formulate policy and actionable solutions to combat Climate Change. A better understanding of micro-level perceptions is imperative for effective and informed planning at the macro-level (Singh et al., 2018).

Also, we must realize that a sustainable mindset is in the selfish interests of the business leaders. A sustainable mindset supports organizational performance (Konradsson and Witsenboer, 2020). To acquire a competitive edge in the market, develop a favorable brand reputation, and respond to consumers' needs, organizations' senior executives may have to concurrently make sustainable decisions for the sake of the environment, society, and the organization. (Mai et al., n.d.).

We suggest that the government and construction sectors must prioritize knowledge development and exchange as critical support mechanisms to enable a future towards Zero Carbon Buildings (Bui et al., 2023). We have to understand some of the opportunities and challenges that transitioning toward net zero will pose to countries and their inhabitants regarding changes to policies, products, processes, and behaviors that will be required to attain the target (Conway and Kamal, 2023).

As evident from the above literature review, the amount of research and academic work dedicated to this domain is limited. This necessitates immediate action if the world is to combat climate change effectively. This research project represents a focused effort to address this critical gap by providing valuable insights and practical solutions for decarbonizing the building sector.

If we want to learn more about the current status and prospects of decarbonization in India, we can check out these resources:

- India’s Transition to a Green Economy Presents a $1 Trillion Opportunity
- India's road to sustainable growth through decarbonization.

- Net Zero Readiness Report: India
- Carbon neutrality in India
- Roadmap to india’s 2030 decarbonization target.

The built environment contributes over 42% of worldwide CO2 emissions. Building activities account for almost 27% of total emissions each year, while the embodied carbon of only four building and infrastructure elements - cement, iron, steel, and aluminum - are responsible for an additional 15% annually. (“Why The Built Environment – Architecture 2030,” n.d.).

From 2020 to 2060, the world is expected to add approximately 2.6 trillion ft2 (241 billion m2) of new floor area to the global building stock, the equivalent of adding an entire New York City every month for 40 years. Furthermore, three-quarters of the infrastructure in 2050 has yet to be constructed ("Why the Built Environment - Architecture 2030," n.d.).

The report's finding of a substantial increase in carbon emissions is a staggering figure that underscores the importance of immediate action on Building sector emissions. Experts have acknowledged this sector as the most promising area for immediate emissions reduction (“Why The Built Environment – Architecture 2030,” n.d.).

Between now and 2030, embodied carbon is expected to account for the vast majority of carbon emissions connected with new construction and infrastructure worldwide. It is therefore critical to address embodied emissions now to disrupt our current emissions trend, and because the embodied emissions of a building or infrastructure project are locked in once the project is constructed and cannot be reversed or reduced ("Why The Built Environment - Architecture 2030," n.d.).

The 2022 Buildings-GSR reveals that, despite a significant increase in investment and global achievement in decreasing building energy intensity, the sector's overall energy consumption and CO_2 emissions grew 2021 above pre-pandemic levels. Buildings' energy demand climbed by approximately 4% from 2020 to 135 EJ, the most remarkable growth in the prior ten years. CO_2 emissions from building activities have hit an all-time high of around 10 $GtCO_2$, representing a 5% rise over 2020 and a 2% increase over the previous record in 2019.

The building and construction industry is not ready to decarbonize by 2050. The gap between the sector's climate performance and the decarbonization pathway is increasing. Global energy price volatility and rising interest rates are anticipated to impede government, family, and enterprise investment in decarbonization.

Without dramatic energy efficiency improvements and decarbonization, projected energy demand from buildings will continue to drive massive absolute increases in carbon emissions. Without dramatic energy efficiency improvements and decarbonization, projected energy demand from buildings will continue to drive massive absolute increases in carbon emissions. (“Zero Carbon Building Accelerator,” 2021)

Every dollar spent on efficiency saves $2 on new power generating and distribution expenses. Despite their enormous potential, 80% of commercially feasible energy savings in buildings go untapped. To accomplish carbon reduction and resilience targets, the global building stock must reach net zero by 2050 ("Zero Carbon Building Accelerator," 2021).

Generalized suggestions to the government without any specific input on the action required to be taken keep coming from well-meaning quarters. For example, the Zero Carbon Building Accelerator suggests governments eliminate building sector CO_2 emissions through five strategies:

1. Dialogue: Exploring zero-carbon building pledges through assisted policy discussions with national and local governments, utilities, the commercial sector, and civil society.

2. Evaluate: Analysing the social, environmental, and economic costs and benefits of zero-carbon construction policies and investments to help local governments make decisions.

3. Act: Collaborating closely with national and local governments to create and implement policies and actions that promote decarbonization.

4. Monitor: Testing and sharing innovative methods for monitoring progress nationally and locally.

5. Invest: Developing business models for investing in zero-carbon buildings in collaboration with global, national, and local banks, as well as the private sector (“Zero Carbon Building Accelerator,” 2021).

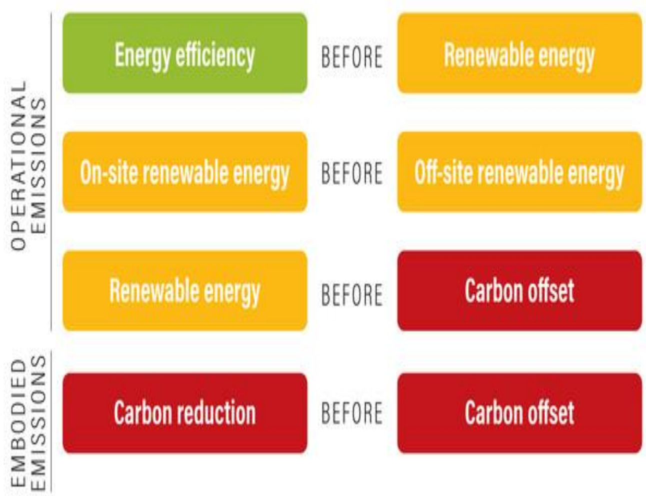

Figure 1: Approach Decarbonization at Three Levels

Different carbon reduction techniques have variable levels of efficacy, and different development phases necessitate different processes. The World Resources Institute gives a tier list of strategies arranged by priority, which may be loosely translated into three decarbonization procedures. The WRI list for reducing operating emissions is as follows: energy efficiency before renewable energy, on-site renewable energy before off-site renewable energy, and renewable energy before carbon offset (investment in renewable energy abroad). For embedded emissions, it recommends carbon reduction before carbon offsets.

This technique of carbon offsetting has continuously low importance since it is only suggested when a 100% renewable energy supply is not possible. Using this priority hierarchy, we may approach building decarbonization at three levels:

- Reduce operational carbon in existing buildings through energy efficiency.
- Use renewable energy to meet either on-site or nearby low energy demand.
- Reduce embodied carbon in new buildings throughout their life cycle.

These levels are not a coherent strategy with which architects should approach decarbonization, i.e., embodied carbon reduction comes last, but it merely encapsulates three strategies for architects to minimize carbon emissions based on the stage or requirements of the project. To fulfill the objectives set by the Paris Climate Agreement, all three must be achieved quickly. Distinguishing these three stages is merely practical guidance for architects and building owners when approaching decarbonization in their projects.

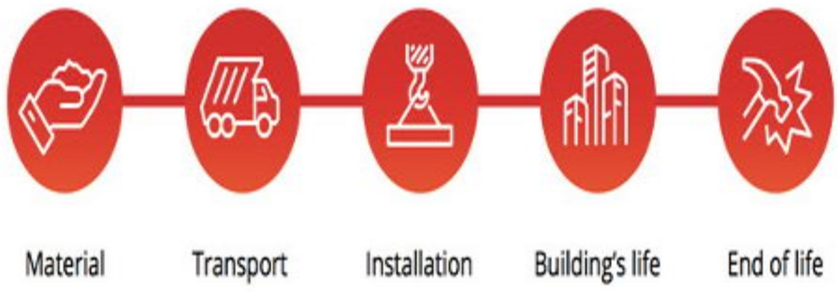

Figure 2: Consider Operational and Embodied Carbon Together

As previously stated, lowering operational and embodied carbon is essential in decarbonizing architecture. However, because materials are already in place for existing structures, embodied carbon may be less critical, and building owners should prioritize net zero operational carbon. In contrast, with the construction of new structures, which is the duty of architects, focusing just on one form of carbon emission or the other might yield deceptive conclusions regarding a structure's real environmental impact.

For example, using some materials can produce low operational carbon but high embodied carbon over their whole life cycle, and vice versa. A building with limited insulation and single glazing often has lower embodied carbon but higher operating carbon than a well-insulated structure. Similarly, while equipment used to generate renewable energy can greatly reduce operating carbon, architects must remember that such equipment is manufactured with a carbon footprint. Because of these potential discrepancies, architects of new buildings or extensive renovations must consider both forms of carbon output when selecting materials to optimize energy efficiency and leave the smallest carbon footprint feasible.

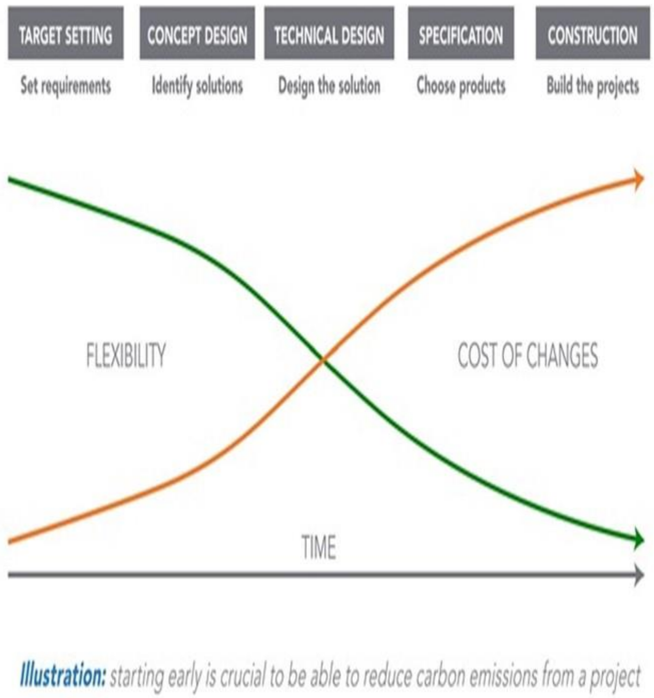

Figure 3:Target the Early Phase of the Project

To do so, architects should tackle decarbonization rigorously and precisely from the beginning of a new project. Low-carbon design methods, particularly those that target embodied carbon, are most efficient and cost-effective when implemented early in a project [4]. One-click. LCA's Embodied Carbon Review deeply explains the causes for this increased efficiency. The early phases of a project "lock in" the options for many aspects of a design, including those that may have a substantial impact on embodied carbon emissions. Architects may be unable to make energy-efficient adjustments later, or the range of alternatives will be severely limited.

For example, selecting a location that necessitates profound foundations can more than quadruple a project's embodied carbon emissions, but architects cannot change this decision afterward. Less dramatically, as time passes, even if an element may be altered, the expenses will nearly always be significantly greater. As a result, architects must consider options for decreasing embodied carbon early in the design process.

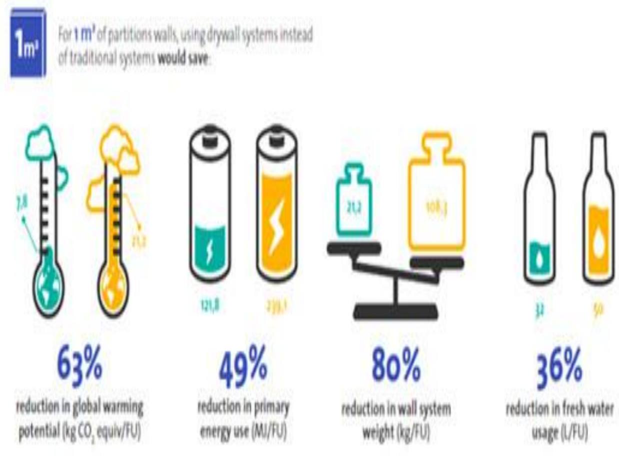

Figure 4: Utilize Lightweight Materials

Architects can achieve this aim by using lightweight materials. In research done by Saint-Gobain comparing two interior wall profiles typically used in Brazil, they discovered that the lighter-weight system had several environmental benefits [5]. Compared to a standard cement-plastered 140 mm brick wall system, the Placo plasterboard system was a lighter solution, consisting of insulated metal stud plasterboard. They discovered that replacing one square meter of partition walls with this plasterboard system would result in a 63% decrease in global warming potential, a 49% reduction in primary energy consumption, an 80% reduction in wall system weight, and a 36% reduction in fresh water usage. Similarly, a lightweight external wall system called Façade F4 halved the CO2 emissions of a traditional massive façade. These products demonstrate the effectiveness of lightweight wall systems and provide tangible, feasible options for architects looking for environmentally friendly solutions.

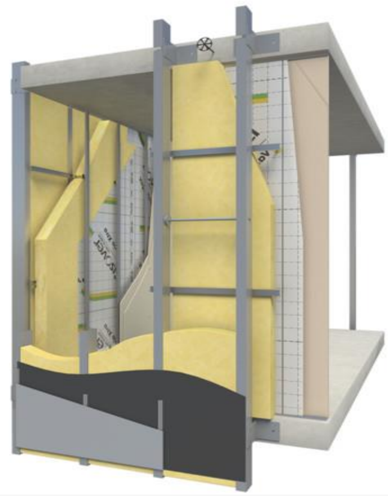

Figure 5: Light Weight house model

Similarly, several bio-sourced materials, such as wood, hemp wool, and wood fibers, store carbon throughout their usage stage, lowering carbon dioxide levels in the atmosphere before disposal and remission of the carbon. This feature distinguishes them as a very effective and sustainable material. Architects considering this option should be aware that, according to the new EN15804-A2 Life Cycle Assessment standard (discussed in part 8), this stored carbon, known as biogenic carbon, during plant growth, must be accounted for separately from embodied carbon (extraction, transportation, installation, use, and end of life) due to significant categorical differences. For example, the embodied carbon of a bio-sourced material may be higher than that of traditional materials due to its greater distance from the construction site, while the biogenic carbon itself has a net emission of zero over its entire lifetime due to carbon uptake and re-emission. According to the new LCA standard, biogenic carbon is now accounted for separately and wiped out over the lifespan; therefore, it is no longer regarded as leaving a negative carbon footprint.

Figure 6: woodify

A common error designers make in the early phases of planning is to calculate embodied carbon just for the core and shell of a structure, ignoring potentially substantial interior fittings, mechanicals, and technological equipment. These objects have a shorter lifespan and may be changed many times over the building's existence, making their embodied carbon production just as crucial as any other structure aspect. Only accounting for these critical internal factors will ensure the computed embodied carbon is accurate.

Figure 7: Rafael Schmid

Reusing old resources removes the need to extract and create new materials, which can have substantial environmental costs. To reduce embodied carbon, architects should choose goods made from as much recycled material as possible. In glazing, for example, cullet glass, which is reused and so decarbonized waste glass, may reduce energy consumption by 3% for every 10% of cullet utilized. Similarly, utilizing one tonne of cullet lowers CO2 emissions by 300 kg owing to reduced energy usage. Thus, glazing constructed of cullet and other recycled materials should be a top priority for architects working towards decarbonization.

Figure 8: Bart Gosselin

Architects may assess their buildings' carbon footprint using Life Cycle Assessments (LCAs) based on international standards and data published in third-party certified Environmental Product Declarations. These are the only reliable scientific sources for determining the embodied carbon in construction goods and materials. LCAs are a cradle-to-gate or cradle-to-grave analysis approach that assesses the environmental effect of a product throughout its life cycle. EPDs are independently verified and recognized records that provide "transparent and comparable" information on a product's environmental effect across its full life cycle. Architects may utilize both to calculate and assess the carbon footprint of their built structures.

To standardize the methods in which goods are evaluated, international standards such as European standards govern EPDs and the life cycle evaluations that may be derived from them. EN 15804 is a particularly pertinent example, as it specifies core product category rules (PCRs) for environmental statements in construction products and services.

Because of its significance to the building sector, EN 15804 is an essential standard for architects to understand and adapt to.

Figure 9:Chris Allan

Several software systems can automatically generate Life Cycle Assessments from design data and provide appropriate solutions. One famous example is One Click LCA, which uses Revit, IFC (BIM), Excel, IESVE, energy models (gbXML), and other technologies to identify similar solutions and provide relevant materials with accessible EPDs. Architects serious about decarbonization should utilize this tool or comparable apps to minimize their embodied carbon footprint.

Disposing or reusing items after they have served their purpose is relevant to the subject of life cycle evaluation. The transition from the 'take, manufacture, and trash' paradigm to a circular economy of resource efficiency is critical to achieving a more sustainable construction sector. A circular economy-compliant building will naturally consume fewer resources during its life cycle since it is designed to be resource-efficient, adaptive, and long-lasting. As previously stated, most basic materials with more recycled content would produce a lower carbon footprint within this construction. Reusing materials and goods will also result in fewer embodied carbon emissions. These solutions are instances of the circular economy, illustrating its critical role in decarbonizing architecture. The building industry is responsible for around half of all extracted resources and one-third of Europe's trash output.

Eliminating the negative consequences of extraction and waste via reuse and recycling in our business might, thus, have a massive impact on the worldwide effort to prevent global warming.

Figure 10: Joaquin Mosquera Casares

While these techniques are basic individual answers, the route to decarbonization requires a worldwide collective effort for effects to be seen. Firms may help with advocacy and awareness by supporting global and local programs like the Net Zero Carbon Buildings Commitment, the Global Alliance for Buildings and Construction, and the Carbon Leadership Forum.

Figure 11: Soukousha (Yuya Maki)

The World Green Building Council's 2019 embedded carbon call to action paper outlines a strategy for achieving zero operational carbon and 40% less embodied carbon for all new buildings by 2030 and zero embodied and operational carbon for all new and existing buildings by 2050. This strategy was established primarily to assist in delivering on the goals of the Paris Agreement and keep global average temperature rise well below 2 degrees Celsius. However, these aims remain high as new buildings are being erected quickly, with the equivalent of Paris' floor space added every five days, and half of the structures in 2060 have yet to be built. To prevail against these difficulties, architects must work collaboratively to reduce carbon emissions across the building sector. To approach decarbonization holistically, it is necessary to include embodied carbon, operational carbon, existing buildings, new buildings, circular economy, lightweight or bio-sourced materials, recycling, and other factors. We want to contribute to the solution by implementing the 10 methods outlined above ("Urgent Issue," 2020).

Even without a strong climate commitment (ürge-Vorsatz et al., 2007). All these point to exciting mitigation possibilities in the building sector, but tragically, not much ground has been covered in the mitigation journey.

Against this background, we have to understand that a better understanding of the psyche of business leaders will immensely help formulate policy and actionable solutions to combat Climate Change. A better understanding of micro-level perceptions is imperative for effective and informed planning at the macro-level (Singh et al., 2018).

Also, we must realize that a sustainable mindset is in the selfish interests of the business leaders. A sustainable mindset supports organizational performance (Konradsson and Witsenboer, 2020). To achieve a competitive advantage in the market, enhance a positive brand reputation, and respond to consumers' requirements, organizations' key leaders may have to simultaneously make sustainable decisions for the sake of the environment, society, and the organization (Mai et al., n.d.).

As noted earlier, most academic work and current thinking in this sphere of work, as enunciated in journals and the press, revolve around a top-down approach involving policy and strategy. Not much content or work has been done to provide some practical and concrete solutions that the building sector can adopt without hurting itself quickly. There is common wisdom on the way forward, such as the study by Ahmed Ali et al. (2020), which states that strategies for reducing CO2 in the building sector include enforcing standards and policies, conducting impact assessments, adopting low-carbon technology, and limiting energy consumption. All parties must work together to cut CO2 emissions and combat climate change.

Some studies have noted the effects of emissions during the construction stage of buildings, like the greenhouse gas emitted during the construction stages of three residential buildings with land areas of 204 m2, 150 m2, and 120 m2 in Moradabad city (8.866790 °N, 78.755921 °E) in northern India (Tirth, 2019).

Conversely, research suggests that implementing energy-efficient building rules such as ECBC is a panacea for lowering emissions. According to Yu et al. (2017), ECBC enhances energy efficiency in commercial buildings and has the potential to cut building power consumption in Gujarat by 20% by 2050 when compared to the no-policy scenario. Energy regulations for commercial and residential buildings might lead to an extra 10% reduction in power use. Although these building standards have good intentions, they do not detail the "How" and "What" of strategic solutions that India's engineers and management will need to implement to accelerate the adoption of green and efficient solutions that boost bottom lines while enabling development.

The case studies available in the academic and research domain extend to only case studies that record the emissions of the Construction sector but do not extend to any case studies that suggest appropriate solutions. For example, (L. and Palaniappan, 2014) present a case study on life cycle energy analysis of a residential development of 96 identical apartment-type homes in Southern India. The energy consumed during material transportation and construction equipment use on the job site is quantified. Sensitivity research investigates the impact of building service life and monthly power use per household on the relative importance of construction and operational energy.

Further, whatever research material is available in the academic domain is limited to the energy efficiency aspects of the Building Sector concerning curbing Carbon emissions. Aspects like water efficiency have not been studied, especially in the Indian context. There is an urgent need to look at the above issues with a fresh outlook aimed at understanding all the angularities, challenges, and solutions for decarbonization of the buildings sector. The intention is to build a foundation for work that can be undertaken by professionals in the commercial sector and among civil society organizations through sets of structured approaches that help analyze City-specific difficulties and objectives for decarbonizing the construction sector.

Exciting work is being done to decarbonize the building industry using artificial intelligence. One such research that may be cited is one from Cambridge, UK. The researchers educated their AI model on data from Cambridge. They used Energy Performance Certificates (EPCs) data, street and aerial view pictures, land surface temperature, and building stock. Using open-source data, the model found 700 homes with HtD and 635 without HtD. It can also identify heat loss locations like roofs and windows and detect a structure's age.

Dr. Bardhan says the model is currently 90% accurate and expects the number to improve as more data is added. Sun and Dr. Bardhan are already developing an advanced framework with additional data layers, including energy use, poverty levels, and thermal images of building facades, to enhance accuracy and provide more details.

She emphasizes that decarbonization decisions were often based on limited data in the past, underscoring the issue's complexities. Nevertheless, she is hopeful that AI can change this since it can handle many data and offer deeper insights, leading to more competent and more effective decarbonization policies in the future.

“We can now handle significantly bigger datasets. Moving forward with climate change, we need adaptation techniques based on evidence like our model offers. "Even simple street view photographs can provide a wealth of information without putting anyone in danger," she explains.

The researchers stress that making data more visible and accessible can help unite efforts to reach net-zero goals. Transparency and data-driven insights are pivotal in rallying collective action to address climate change.

This innovative technology can potentially revolutionize our approach to identifying “hard-to-decarbonize” buildings. We can make more informed and data-driven decisions to make them greener, paving the way for a more sustainable and environmentally responsible future. As the urgency of decarbonization becomes increasingly evident, the integration of AI is a promising and essential tool to address the complex challenges we face (“This AI Model Will Identify Decarbonization Opportunities in Buildings,” 2023).

As mentioned in this dissertation, water efficiency is often neglected in discussions about building decarbonization. It is glamorous to focus on energy to the detriment of other aspects of Decarbonization. Water Efficiency is one sector in this area that suffers acute neglect.

Most content relating to various aspects of Decarbonization of the Building sector was available in the current reports of various International and National bodies, but not much content was available in research and academic works. Unfortunately, concerning the Water efficiency of the Building Sector, not much content is found in the reports of International and National Industry and trade bodies. It is a rather tragic and sad commentary on the lopsided view of Building Sector Sustainability experts and the Industry bodies engaged in Sustainability.

1. Increasing building energy efficiency by using high-performance insulation, windows, lighting, appliances, and HVAC systems and implementing building energy codes and standards.

2. We are reducing onsite building emissions by switching from fossil fuels to electricity or other low-carbon fuels for heating, cooling, cooking, and water heating and eliminating high-global warming potential refrigerants.

3. We are transforming the grid edge at buildings by installing onsite renewable energy systems, such as solar PV, solar thermal, wind, and biomass, and enabling demand response, energy storage, and smart grid technologies to reduce the reliance on the grid and increase the flexibility and resilience of the power system.

4. We are reducing building life cycle emissions by using low-carbon and recycled materials, such as wood, bamboo, steel, and concrete, and minimizing the waste and emissions from the construction, renovation, and demolition of buildings.

Decarbonization in the building sector has multiple benefits, such as saving money, improving health, creating jobs, enhancing comfort, and reducing the need for new power grid infrastructure. However, it confronts other challenges, including high initial costs, a lack of knowledge, divided incentives, market failures, and legislative gaps. Thus, decarbonization in the construction industry requires a comprehensive and integrated strategy that incorporates numerous stakeholders, such as governments, enterprises, building experts, financiers, and consumers, and fosters innovation, cooperation, and the adoption of best practices.

Energy and water efficiency are essential strategies for decarbonizing various sectors of the economy, such as power generation, industry, transport, buildings, and agriculture. Efficiency measures can lower the emissions associated with these resources' production, distribution, and consumption by reducing the demand for energy and water. Energy and water efficiency can also enhance the resilience and affordability of the energy and water systems and provide multiple co-benefits, such as improved health, comfort, and productivity.

Some examples of how energy and water efficiency can impact decarbonization are:

• In the power generation sector, energy efficiency can reduce the need for fossil fuel-based power plants and increase the share of renewable energy sources in the electricity mix. Water efficiency can reduce the water consumption and withdrawal of thermal power plants, which account for about 40% of the global freshwater withdrawals3. Water efficiency can also reduce the energy consumption and emissions of water treatment and distribution processes.

• In the industry sector, energy efficiency can reduce the process heat and electricity demand of various industrial activities, such as steel, cement, and chemicals, which are responsible for about 24% of the global CO2 emissions. Water efficiency can reduce the water use and wastewater generation of industrial processes, which account for about 19% of the global water withdrawals. Water efficiency can also reduce the energy consumption and emissions of water supply and treatment processes.

• In the transport sector, energy efficiency can reduce the fuel consumption and emissions of various modes of transport, such as road, rail, air, and maritime, which account for about 16% of global CO2 emissions. Water efficiency can reduce the water use and pollution of transport activities, such as washing, cooling, and cleaning, which account for about 1% of the global water withdrawals.

• In the buildings sector, energy efficiency can reduce the heating, cooling, lighting, and appliance demand of residential and commercial buildings, which account for about 17% of global CO2 emissions. Water efficiency can reduce the water use and wastewater generation of buildings, which account for about 12% of the global water withdrawals.

Water efficiency can also reduce the energy consumption and emissions of water supply and treatment processes.

• In the agriculture and land use sector, energy efficiency can reduce the fuel and electricity consumption of various agricultural activities, such as irrigation, fertilization, and harvesting, which account for about 11% of the global CO2 emissions. Water efficiency can reduce agricultural activities' water use and runoff, accounting for about 69% of global water withdrawals. Water efficiency can also reduce the energy consumption and emissions of water supply and treatment processes.

Decarbonization strategies are activities and policies to reduce or eliminate greenhouse gas emissions from energy production and use, such as electricity, heat, and fuels. Decarbonizing energy is vital for limiting the consequences of climate change and reaching the goals of the Paris Agreement, which seeks to limit the rise in global temperature to far below 2 degrees Celsius, ideally 1.5 degrees Celsius, over pre-industrial levels.

Hydrogen, biofuels, and synthetic fuels. This may be accomplished by expanding renewable energy sources, such as solar, wind, hydro, geothermal, and biomass, in electricity generation and end-use sectors, including power, industry, transportation, buildings, and agriculture. This may also be done by utilizing nuclear energy, carbon capture, utilization, and storage (CCUS), and harmful emissions technologies, such as bioenergy with carbon capture and storage (BECCS), to reduce emissions from fossil fuel-based power plants and industrial sites.

To use less energy and generate fewer greenhouse emissions. This can be done by improving the energy efficiency and productivity of various industrial activities, such as steel, cement, and chemicals, and using low-carbon materials, technologies, and practices, such as green cement, recycled steel, and green hydrogen. This can also be done by reducing the emissions from agricultural activities, such as irrigation, fertilization, and harvesting, and by enhancing the carbon sequestration and storage of soils and plants.

In various end-use sectors, such as power, industry, transport, buildings, and agriculture. This can be done by using high-performance insulation, windows, lighting, appliances, and HVAC systems in buildings and by implementing building energy codes and standards. This can also be done by using more efficient vehicles, such as electric, hybrid, and fuel cell vehicles, and by promoting sustainable mobility modes, such as public transport, cycling, and walking. This can also be done using smart meters, sensors, and devices to monitor and optimize consumers' and producers' energy use and demand response.

To reduce the energy and material consumption and waste generation of various sectors, such as power, industry, transport, buildings, and agriculture. This can be done by designing products and services that are durable, repairable, reusable, and recyclable, as well as by minimizing the use of virgin materials and maximizing the use of secondary materials. This can also be done by reducing the waste and emissions from the production, distribution, and consumption of goods and services and by increasing the recovery and utilization of waste and emissions as resources.

Furthermore, shifting to more sustainable consumption patterns and lifestyles. This can be done by raising consumers' and businesses' awareness and preferences for low-carbon products and services and by providing them with reliable and transparent information and labels on the environmental impacts of their choices. This can also be done by implementing carbon pricing and taxation policies that reflect the costs of social and environmental emissions and providing subsidies and incentives for low-carbon alternatives.

To extract and store CO_2 and other greenhouse gases from the environment. This may be accomplished by preserving and restoring natural ecosystems like forests, wetlands, and grasslands, which can absorb and store vast amounts of carbon. This can also be accomplished by deploying artificial sinks, such as direct air capture and storage (DACS), which can absorb and store carbon dioxide from ambient air.

This is the title of an article by Eric Mackres from the World Resources Institute, published on January 22, 2020. The article summarizes the key strategies and factors that have enabled some countries, such as China, Costa Rica, Denmark, Ethiopia, and the United Kingdom, to make significant progress in reducing their greenhouse gas emissions from the energy sector. The article identifies six common lessons from these countries, which are:

- Investments in energy efficiency
- A clear vision and strong leadership
- A supportive policy and regulatory environment
- Innovation and collaboration across sectors and stakeholders
- Leveraging the co-benefits of decarbonization
- Learning and adapting to changing circumstances

The article also provides examples and data to illustrate how these countries have implemented these lessons in their energy systems and how they have benefited from them. The article highlights the need for more countries to follow their lead and accelerate their decarbonization efforts to achieve the goals of the Paris Agreement and the Glasgow Climate Pact.

Direct emissions form only a minor proportion of the total emissions from the building sector. Global Status Report for Buildings and Construction 2019" mentions that roughly 11% of building-related CO_2 emissions originate from on-site combustion during operations (considered direct emissions). Although direct emissions comprise a smaller portion of the total emissions from the Building sector, they must be curbed and reduced substantially (“Advancing Net Zero,” n.d.). The prevalence of these emissions indicates the primitivity of the equipment being used in the building sector, and this should put the spotlight on immediate action to improve the efficiency of the equipment being used. Understanding the subcategories of direct emissions can help us identify effective strategies for reducing their impact.

We have to understand that despite being a smaller portion compared to embodied carbon, direct emissions still play a significant role in the overall carbon footprint of buildings. Therefore, focusing on strategies to reduce direct emissions through clean energy adoption, energy efficiency improvements, and cleaner technologies remains crucial for achieving net-zero buildings and mitigating climate change.

• Boilers and furnaces: These are commonly used for space heating and water heating, often burning coal, natural gas, or firewood. Their emissions depend on the fuel type, combustion efficiency, and usage patterns. They are used extensively in Indian Commercial and Residential settings. Much garden and organic waste is incinerated in India to avoid the issue of disposal.

• Gas stoves, ovens, and firewood contribute directly to indoor air pollution and release greenhouse gases like carbon dioxide, nitrogen oxides, and methane. Looking for cleaner alternatives for firewood as fuel is critical for avoiding direct emissions from this sub-category. Efficient appliances can help mitigate these emissions substantially.

• Gas-powered water heaters and clothes dryers also contribute to direct emissions. Switching to electric appliances powered by low-electricity consuming appliances like Heat Pumps and those powered by renewable energy sources can significantly reduce this impact.

• In India, these emergency power sources typically run on diesel or kerosene, generating significant emissions during operation. Exploring alternative backup solutions like solar power and battery storage can minimize this impact significantly.

• Certain industrial facilities within buildings, like laundromats or bakeries, may have on-site combustion processes contributing to direct emissions. Optimizing these processes and promoting cleaner fuels can help reduce their impact.

These are emissions generated not in the building but by utilities that supply electricity to the building. This generation may happen through fossil fuels. 33% of global building emissions are generated indirectly by producing electricity and heat ("Advancing Net Zero," n.d.).

This forms a significant chunk of indirect emissions, as many buildings rely on electricity from power grids for lighting, appliances, heating, and cooling systems. The emissions depend heavily on the mix of energy sources used in the grid, mostly coal in India.

Some buildings connect to centralized heating or cooling systems, which also contribute to indirect emissions based on the energy sources used in the central plant.

Electric water heaters, while avoiding on-site combustion, contribute indirectly through the emissions associated with electricity generation.

The materials and manufacturing processes involved in building equipment like boilers and air conditioners also generate embodied carbon, considered indirect emissions when purchased.

India's emission challenge is compounded by the fact that her dependence on thermal, coal-based generation is as much as 67%, with hydel coming in a poor second at 18%. Nuclear (7%) and Solar farms-based generation [6%] and a minuscule 2% come from other alternative energy generation forms ("India | Electricity Transition," 2022).

India’s current building stock is at 200 billion Sq feet and is set to double to over 400 billion Sft by 2040 (“TERI experts draw up a roadmap to India’s 2030 decarbonization goals,” n.d.). A miniscule percentage of the buildings are certified green. Unfortunately, there is no universally agreed-upon figure for the percentage of green buildings in India as a proportion of the total building stock. This is due to several factors:

Buildings can be certified under different green rating systems like IGBC, LEED, GRIHA, etc. Each system has its criteria and methodology for calculating the percentage of green buildings.

Data availability and accuracy: Estimating the total building stock in India itself is a complex task. Additionally, data on green buildings might not be comprehensively captured across all regions and systems, leading to potential discrepancies.

Evolving definitions of "green": As sustainability standards and technologies advance, the definition of a "green building" can evolve. This adds to the challenge of comparing data from different sources and timeframes.

India’s population is galloping, beating China to become the most populous country in 2023 (“UN DESA Policy Brief No. 153: India overtakes China as the world’s most populous country | Department of Economic and Social Affairs,” n.d.). With this burgeoning population growth, we have rapid urbanization, which is about 32% of what India accepts as urban settlements (“Transit Oriented Development For Indian Smart Cities,” n.d.), rising incomes, and increasing aspirations of young Indians under age 35 who constitute 66% of the population (“Decent Work for Youth in India,” 2012), and coupled with that is the emergence of the world’s largest middle-income class, which will all combine to increase the building stock exponentially and create an ecological and environmental crisis that is staggering in dimension and magnitude.

Cooking and heating [currently the most significant energy end-uses], cooling of buildings [which is emerging as the fastest-growing energy end-use], and the lesser-known threat of a major portion of all energy generated being consumed by water for transport and groundwater extraction are vital threats.

India's agriculture consumes 85% of all fresh water, with urban water consumption [residential and commercial] a mere seven percent and industrial water use hovering at 10-11% ("Resources | World Resources Institute," n.d.).

The striking limitation India suffers of enjoying a mere 10% of the landmass that Africa hosts [30 million sq km] or about 40% of China's landmass [8.7 million sq km] is a challenge that enormously increases the water stress for the sub-continent.

If India is to achieve its avowed commitment of Net zero carbon by 2070 ("Net zero emissions target," n.d.), at both in-building and in-city scales, the engineering and management of all infrastructure will require a complete shift in approach to every building element, including materials, thermal envelopes, passive heating and cooling design, active heating and cooling (HVAC), appliances, water management, lighting and electricity generation, and localized solid waste.

Opportunities are immense for such reduction of embodied carbon in water and energy consumption for all existing infrastructure, in the use of construction materials for new buildings, and the employment of cleaner and more efficient heating and cooling systems with passive and active design elements.

Clean fuels will also significantly reduce emissions and air pollution from cooking and personal transportation.

Financial instruments that can support net zero carbon building include traditional instruments used in all buildings, such as equipment leases, mortgages, and bonds, as well as specialized mechanisms that use cost savings from water and energy efficiency, such as on-bill repayment, energy service contracts, and property-assessed clean-energy loans. Traditional mechanisms such as bonds and commercial financing have shown to be effective at scale, but they will not be sufficient to change the market to low-carbon buildings. Specialized devices targeting net zero buildings have had problems scaling and reaching lower-income families. FinTech Aggregators, a new type of finance, have worked since 2020 to provide possibilities for aspiring and increasing middle-class investors in India.

Several policies to support net zero carbon buildings exist, such as green building labeling, energy efficiency building codes, and equipment performance standards. However, those policies are not widespread. Most such schemes often lack ambition and direction, both at the policy level of creating health growth ecosystems and at the execution level of market solutions and acceptance. The success of policies and execution on the ground depends on the capacity to implement and enforce them and a construction sector that can deliver low-carbon buildings.

India has unique challenges and opportunities for net zero-carbon buildings like any nation combating climate change. Addressing cooling and building-level electricity generation are high-impact areas for intervention, but building the enabling framework on the national grid and for private investment in zero-carbon buildings must be strengthened to enable funding in net zero buildings at scale. The slew of new regulations such as ECBC, Water Credits, BEE and GRIHA and other green building certification guidelines, SRBR from SEBI and other similar governing guidelines, ESG, and the new National Water Policy, are all joining forces to set national standards for buildings and infrastructure. These will significantly help to expand the low-carbon buildings market. Implementing these regulations and their success will depend on ensuring cities, the corporate sector, and the construction industry have sufficient capacity to bring full compliance.

2.3 Summary

As India embarks on the journey towards a greener and more water- and energy-efficient future, the need for engineering solutions that balance commerce and GDP growth on one hand and conservation of natural resources on the other assumes enormous significance. India is emerging as a trailblazer in water and energy efficiency with strategic plans for advancing intelligent solutions that will halve water and energy resource use and add non-fossil solutions for energy by the end of this decade. This Dissertation delves into design, problem-solving approaches, tracking mechanisms, and the new world of financing options that will pave the way for high-impact opportunities in India. A necessary part of the discussion is shared learnings, best practices, and case studies.

Actionable insights that the Dissertation offers are expected to offer a blueprint for corporate management and other associations and strategy groups of planers and policy makers, steps and measures to propel water energy efficiency in India and assist users in implementing voluntary and mandatory action plans on engineering solutions for helping meet Carbon Targets for sustainable economic growth for the country. The document also deliberates on the aspects of 'how' and 'what' of such strategic solutions that India's engineers and management will have to take up to accelerate the adoption of green and efficient solutions that improve bottom lines while enabling growth simultaneously.

Building a more robust understanding of how resource efficiency improvement can be evolved, implemented, monitored, and managed with essential financing and collaboration mechanisms to help secure acceptance is also part of these presentations.

Since the author's experience and insights lie in India over 25 years of professional work, the document focuses on India's objectives for identifying high-impact opportunity areas with transdisciplinary learnings, best practices, and case studies from various companies and institutions.

The thesis also discusses the role of businesses in technology promotion and increasing private sector investment that can aid and support India's economic development as it powers its way to becoming a 10 trillion dollar economy.

The speed at which Climate Change is wreaking havoc on our lives is alarming. Climate Change has forced civilization to cope with these ill effects and take evasive action. We were recently debating the validity of Climate Change, but here we are, already being dealt massive blows by it. It is urgent to chalk out plans to combat it before it is too late. Nevertheless, the sad truth is that although the International community is trying to reach a consensus on the way forward in the fight against Climate Change, they are making no headway.

There have been 27 COP (Conference of Parties) meetings where nations have wrangled over when the world should become Net Zero and what NDCs (Nationally Determined Contributions) countries should adopt. All countries have agreed on the need to ensure that the threshold of 2.0 C is not crossed, but there is no concrete binding outcome from the COP meetings for all countries. Ambitious NDCs are announced from the pulpit, but nothing is binding on the countries. The havoc being wrought by Climate Change has not reached alarming levels in the view of most countries; therefore, they are still dodging severe measures to combat it.

The world is waiting for the top-down approach that National Governments plan to implement. However, there is not much talk or plan on the bottom-up approach that can be implemented by concerned business or industry groups or even individuals to adopt measures to stem carbon emissions in their area of work. These small measures will add to the National plans that the Governments are implementing at a more significant macro level and will help accelerate the process of curbing emissions faster.

In India, we applauded the Prime Minister’s announcement that India will be net zero by 2070, which is a very ambitious promise, but at the same time, it is a few decades too late. No serious effort is underway to dismantle the fossil fuel industrial infrastructure. There is not much headway in policy to ensure a reduction in Carbon emissions across the board in different sectors of the economy. Then, there is a debate about whether a developing country can afford to be serious in the Carbon emission reduction war at the cost of growth. How does a country balance the need to feed people experiencing poverty with the urgent need to combat Climate Change? At the same time, we must consider that people experiencing poverty will be affected the most by Climate Change.

The building sector contributes to a healthy portion of the Carbon emissions pie, and we are focused on this sector in this research work. We have undertaken a preliminary study of the academic work already available in this area and have seen that much of that work is dated. Much of the work pertains to the pre-2021 period, which is dated and obsolete in areas like Carbon emissions. There is a need to correct this by undertaking contemporary quality research work in this area, which will enhance the bar of discussions relating to curbing carbon emissions and shed light on the solutions available to policymakers, industry, civil society organizations, and academia.

International institutions, mainly around the United Nations, contribute to achieving verbal agreements on future action plans characterized by a radical alteration of the future technological objectives without defining the roadmap, the implementation tools, and the required financial means in a concrete way. As a result, the progress is slow, the plans are outdated and gradually become bureaucratic and voluntaristic concepts of minimum validity (Santamouris and Vasilakopoulou, 2021).

The history of these discourses and alarming concerns about the degradation of ecology and the environment goes back many decades. Wrote Mira Behn, who was born Madeleine Slade and spent several years with Mahatma Gandhi, “The tragedy today is that educated and moneyed classes are altogether out of touch with the vital fundamentals of existence—our Mother Earth, and the animal and vegetable population which she sustains. This world of nature’s planning is ruthlessly plundered, despoiled, and disorganized by Man whenever he gets the chance. He may get huge returns through his science and machinery for a while, but ultimately, desolation will come. We have got to study Nature’s balance and develop our lives, within her laws, if we are to survive as a physically healthy and morally decent species” (Guha, n.d.). That was in 1955.

Wrote Carl Sauer in 1948, “We have not yet learned the difference between yield and loot”(“That Wilderness Should Turn a Mart,” n.d.). In 1926-28, Patrick Geddes bemoaned that capitalist greed and relentless industrial growth were playing havoc (Munshi, 2022). The dire warnings that such stalwarts have sounded have been brushed aside.

In 1997, as part of COP 3 – the Kyoto Protocol- the CDM (Clean Development Mechanism) was adopted. It is regarded as one of the most essential internationally implemented market-based mechanisms to reduce carbon emissions. The CDM was designed to help developed nations meet domestic greenhouse gas (GHG) reduction commitments by investing in low-cost emission reduction projects in developing countries. The CDM has quickly grown to fund thousands of projects worldwide and attain a market value of several billion euros. The building sector is a large source of GHG emissions and has significant potential as a source of cost-effective emissions reductions. However, the number of building sector projects approved for CDM funding is deficient compared to other sectors. Out of over 3,000 CDM projects approved or in the pipeline as of May 2008, only six small-scale projects1 are targeting energy efficiency improvements in the buildings sector. (Programme, 2008)

Further, under the Kyoto Protocol's Clean Development Mechanism (CDM), countries worldwide cooperate on encountering climate change through emissions trading, which enables a win-win situation by effectively “regenerating” a cleaner environment in developing countries. In contrast, efforts in developed countries may still not meet their committed carbon reduction targets. According to the CDM rules, energy efficiency improvement projects in the building sector are valid for emissions trading. Although the potential energy saving is significant, only a few building projects are registered as CDM projects. (Lam et al., 2015) The paper explored the applicability of CDM in the building sector by reviewing the implementation of CDM and its advantages and disadvantages. Hong Kong was selected for an in-depth study due to its eligibility for CDM and non-starter status. According to a questionnaire survey supplemented by interviews with the stakeholders in this study, significant hindrances, such as the lack of financial incentives, inadequate knowledge about emissions trading, and insufficient governmental support, were found in potential CDM projects in the building sector. (Lam et al., 2015)

Regarding International Policy, the Kyoto Protocol of 1997 was the only one that attempted to work on the Building sector, and as the above research papers testify, the effort had limited impact, and the initiative did not just take off. None of the other COP conferences subsequently focussed on this area.

Energy-efficient buildings, which have a lower carbon footprint during construction and also lower energy needs during operation, are imperative for India to achieve its own net-zero goals by 2070. However, higher costs of such construction, low awareness, and poor planning hinder this progress(Behal, 2023). Therefore, there is an urgent need to study this sector to understand the way ahead and arrive at suitable solutions that can be amenable to builders. This solution should be practical and one the builder can embrace without bleeding.

To contribute to a two °C pathway, India must achieve a 50% reduction in building energy demand and related greenhouse gas (GHG) emissions by 2050. India is taking steps toward this goal through recent upgrades to the Energy Conservation Building Code (ECBC), encouraging green building rating and energy certification, and stimulating markets for low-carbon/high-efficiency technologies. However, despite improvements in building energy intensity, neither the global nor the Indian building sectors are decarbonizing (Graham and Rawal, 2019). Therefore, other than studying the practical solutions that policymakers and the building sector can embrace, there is also a need to understand what will drive this initiative and make it a beacon for other sectors of the economy to follow.

Decarbonizing the building sector in India is a complex and urgent task, as the sector accounts for about one-fifth of the country’s total annual carbon emissions and is projected to overgrow in the coming decades. Some of the challenges that hinder the transition to low-carbon buildings are:

 Ineffective procurement practices: The current procurement models in the building sector do not incentivize low-carbon solutions, as they often focus on the lowest upfront cost rather than the buildings' life cycle cost and performance. This leads to suboptimal choices of materials, technologies, and designs that lock in high emissions and inefficiencies for decades.

 A lack of regulation: The building sector in India lacks adequate and consistent policies and standards to promote and enforce decarbonization measures, such as building energy codes, carbon pricing, green building ratings, and mandatory disclosure of emissions and energy use. The existing regulations are often poorly implemented and monitored, resulting in low compliance and enforcement.

- Production challenges for low-carbon concrete and steel: Concrete and steel are the most widely used materials in the building sector, but they are also among the most carbon-intensive ones, as they require large amounts of energy and emit significant amounts of CO_2 during their production. Developing and scaling up low-carbon alternatives, such as green cement, recycled steel, and green hydrogen, face various technical, economic, and institutional barriers, such as high costs, low availability, limited demand, and lack of quality standards.

- No established standards for data, methodologies, and tools: The building sector in India suffers from a lack of reliable and consistent data on the emissions and energy use of buildings, as well as the availability and performance of low-carbon solutions2. There is also a lack of standard methodologies and tools to measure, monitor, and report the emissions and energy use of buildings and to assess the feasibility and impact of decarbonization measures. This hampers the sector's decarbonization efforts' transparency, accountability, and comparability.

These challenges require a comprehensive and integrated approach involving various stakeholders, such as governments, businesses, building professionals, financiers, and consumers, and support innovation, collaboration, and best practices. The benefits of decarbonizing India's building sector are environmental, economic, and social, as it can save money, improve health, create jobs, enhance comfort, and reduce the need for new power grid infrastructure.

Energy efficiency can reduce emissions from buildings by lowering the amount of energy needed to heat, cool, light, and operate them. This reduces the demand for electricity and fuels generated from fossil sources, such as coal, natural gas, and oil, which emit greenhouse gases when burned. Energy efficiency can also improve buildings' performance and comfort, saving owners and occupants money. Some examples of energy efficiency measures in buildings are:

- Using high-performance insulation, windows, lighting, appliances, and HVAC systems
- Implementing building energy codes and standards
- Installing smart meters, sensors, and devices to monitor and optimize energy use and demand response
- Switching from fossil fuels to electricity or other low-carbon fuels for heating, cooling, cooking, and water heating
- Using renewable energy sources, such as solar, wind, hydro, geothermal, and biomass, to generate electricity and heat for buildings

According to the U.S. Department of Energy, energy efficiency improvements have reduced emissions in the residential and commercial sectors by 17.3 and 11.4 percent, respectively, since a 2005 peak1. Further efficiency gains will moderate future emissions growth, but the increased use of appliances and electronics is expected to result in a net increase in greenhouse gas emissions by 2050.

As noted earlier, most academic work and current thinking in this sphere of work, as enunciated in journals and the press, revolve around a top-down approach involving policy and strategy. Not much content or work has been done to provide some practical and concrete solutions that the building sector can adopt without hurting itself quickly. There is generalized wisdom on the way forward, like the study by Ahmed Ali et al. (2020), in which they mention that the strategies to reduce CO2 in the building sector are enforcing standards and policy, conducting impact assessment, adopting low carbon technology, and restricting energy utilization. All stakeholders must play their roles efficiently to reduce CO2 emissions and aid in the fight against climate change.

- Some studies have noted the effects of emissions during the construction stage of buildings, like the greenhouse gas emitted during the construction stages of three residential buildings with land areas of 204 m2, 150 m2, and 120 m2 in Moradabad city (8.866790 °N, 78.755921 °E) in northern India (Tirth, 2019).

- On the other hand, studies mention that adopting energy-efficient building codes like ECBC is the panacea for reducing emissions. Yu et al. (2017) say that ECBC improves energy efficiency in commercial buildings and could reduce building electricity use in Gujarat by 20% in 2050, compared to the no policy scenario. Having energy codes for commercial and residential buildings could result in an additional 10% savings in electricity use. Although these Building codes mean well, they do not dwell on the "How" and "What" of Strategic solutions that India's engineers and management will have to take up to accelerate the adoption of green and efficient solutions that improve bottom lines while at once enabling growth.

- The case studies available in the academic and research domain extend to only case studies that record the emissions of the Construction sector but do not extend to any case studies that suggest appropriate solutions. For example, (L. and Palaniappan, 2014) present a case study on life cycle energy analysis of a residential development of 96 identical apartment-type homes in Southern India. Energy use due to the transportation of materials and construction equipment used at the site is quantified. Sensitivity analysis studies the influence of building service life and monthly electricity use per home on the relative significance of construction and operational energy.

- Further, whatever research material is available in the academic domain is limited to the energy efficiency aspects of the building sector in terms of curbing carbon emissions. Aspects like water efficiency have not been studied in the Indian context. There is an urgent need to look at the above issues with a fresh outlook aimed at understanding all the angularities and challenges of, and solutions for, the Decarbonization of the buildings sector. The intention is to build a foundation for work that can be undertaken by professionals in the commercial sector and among civil society organizations through sets of structured approaches that help analyze challenges and priorities relevant to cities in decarbonizing the building sector.

A comprehensive Literature review of the academic and research work has thrown light on the fact that not much research has been undertaken in this area of Carbon emissions in the Building sector. The content pertains to general strategies and a top-down approach, focusing only on energy efficiency. Practical solution-driven content is missing. There is no focus on other areas like Water efficiency. There are several information and data gaps relating to solutions for curbing Carbon emissions in the building sector. A paradigm encompassing several practical solutions for reducing Carbon emissions in the building sector and policy initiatives that can drive it is the need of the hour. However, the solution framework is not intended to be exhaustive or prescriptive.

Such solution-driven content is essential if we have to gain any headway in our fight to curb Carbon emissions and combat the ill effects of Global Warming and Climate Change. If a Nation like India has to achieve its avowed commitment of Net zero carbon by 2070, at both in-building and in-city scales, the engineering and management of all infrastructure will require a complete shift in approach to every building element, including materials, thermal envelopes, passive heating and cooling design, active heating and cooling (HVAC), appliances, water management, lighting, and electricity generation, and localized solid waste management that eases the burden of central infrastructure.

Opportunities are immense for such reduction of embodied carbon in water and energy consumption for all existing infrastructure, in the use of construction materials for new buildings, and the employment of cleaner and more efficient heating and cooling systems with passive and active design elements.

This research project delves into design, problem-solving approaches, tracking mechanisms, and the new world of financing options that will pave the way for high-impact opportunities in India. A necessary part of the discussion is shared learnings, best practices, and case studies.

CHAPTER III:

METHODOLOGY

The building sector significantly contributes to global greenhouse gas emissions, accounting for approximately 40% of total energy consumption and associated emissions. In India, this sector is expanding rapidly due to urbanization and economic growth, exacerbating its environmental impact.

Challenge: As per India's commitment, achieving Net Zero emissions by 2070 necessitates a radical transformation in the building sector. Current practices are unsustainable, with inefficient energy and water usage contributing to a high carbon footprint.

Objective: This thesis proposes a strategic decarbonization plan tailored for India's building sector. It emphasizes energy and water efficiency, integrating technological advancements, financial mechanisms, and social considerations to facilitate the transition to a low-carbon economy.

3.1 Researcher mythology

Framework Components:

- Renewable Energy Integration: Utilizing solar, wind, and bioenergy to power buildings, reducing reliance on fossil fuels.
- Building Envelope Optimization: Enhancing insulation and material choices to minimize energy loss.
- Intelligent Water Management: Implementing innovative systems for water conservation and recycling.
- Green Roofs and Rainwater Harvesting: Creating natural insulation and augmenting water resources.
- Green Bonds and Performance Contracts: Financing options that incentivize sustainable development.

 User Perceptions: Understanding and influencing behavioral changes for energy and water conservation.

 Methodology: A mixed-method approach, including quantitative data from surveys and qualitative insights from interviews and case studies, evaluates the proposed framework’s practicality and impact.

 Potential Impact:

 Emission Reduction: The framework aims to reduce building sector emissions by 30%.

 Energy Savings: Anticipated energy savings of up to 40% through efficient practices and technologies.

 Water Conservation: A projected 50% reduction in water consumption by implementing advanced water management strategies..

3.2 Operationalization Of Theoretical Constructs

- Renewable Energy Integration:
  a. Operational Definition: The percentage of energy consumed by buildings sourced from renewable technologies.
  b. Measurement: Installation capacity (in kW) and energy output (in kWh) from solar panels, wind turbines, etc.
- Building Envelope Optimization:
  a. Operational Definition: The degree to which a building’s envelope reduces energy loss.
  b. Measurement: Thermal performance ratings, U-values of materials, and energy consumption before and after retrofitting.

- Intelligent Water Management:
    a. Operational Definition: The efficiency of water use and the extent of water recycling within a building.
    b. Measurement: Water consumption metrics, the percentage reduction in water use, and volume of recycled water.
- Green Roofs and Rainwater Harvesting:
    a. Operational Definition: The area of green roofs installed and the capacity of rainwater harvesting systems.
    b. Measurement: Square footage of green roofs and volume of rainwater collected and utilized.
- Green Bonds and Performance Contracts:
    a. Operational Definition: The amount of investment attracted through green financial instruments for sustainable building projects.
    b. Measurement: The value of green bonds was issued, and several performance contracts were signed.
- User Perceptions:
    a. Operational Definition: The attitudes and behaviors of building occupants towards energy and water conservation.
    b. Measurement: Survey responses, the adoption rate of conservation practices, and changes in consumption patterns.

By operationalizing these constructs, we can measure the impact of your strategic plan quantitatively and qualitatively, providing a robust evaluation of its effectiveness and feasibility. This approach will also facilitate the collection of empirical data to support your thesis's conclusions and recommendations.

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3.3 Challenges

- Climate Change Mitigation: Buildings are responsible for a significant portion of global carbon emissions. Research in this area aims to identify and implement strategies that reduce the carbon footprint of the building sector, contributing to India's commitment to achieving Net Zero by 2070.
- Sustainable Development: Decarbonizing the building sector aligns with the principles of sustainable development. It ensures that the sector's growth does not compromise future generations' ability to meet their needs.
- Economic Growth: The transition to a decarbonized building sector can stimulate economic growth by creating new jobs in green technologies and sustainable practices.
- Health and Well-being: Improved building designs and operations can lead to better indoor air quality and overall health benefits for occupants.
- Resource Efficiency: Researching energy and water efficiency leads to more effective use of resources, reducing waste, and conserving vital environmental assets.
- Policy Development: The findings can inform policymakers, helping them to craft regulations and incentives that promote low-carbon buildings.
- Technological Innovation: It encourages innovation in renewable energy, water management, and building materials, driving the sector towards modern, efficient practices.
- Social Acceptance: Understanding user perceptions and social aspects of the transition can facilitate broader acceptance and adoption of sustainable practices.

3.4 RESEARCH DESIGN

The primary objective of this research is to develop and assess a strategic framework for decarbonizing India's building sector, focusing on energy and water efficiency. This framework integrates technological, financial, and social aspects to facilitate a sustainable transition.

The proposed framework will significantly reduce greenhouse gas emissions from the building sector, contributing to India's Net Zero targets by 2070. It is hypothesized that the framework can achieve a 30% reduction in emissions and substantial energy and water consumption savings.

3.4.1 Methodology

- Mixed Methods Approach: Combining quantitative data from surveys and case studies with qualitative insights from interviews to evaluate the framework's feasibility and effectiveness.
- Data Collection: Gathering data on current building practices, energy, and water usage, and user perceptions through structured surveys and interviews with building professionals and occupants.
- Case Studies: Analyzing successful examples of decarbonized buildings to identify best practices and lessons learned.

Analysis:

- Quantitative Analysis: Using statistical methods to assess the potential impact of the framework on emission reductions and resource savings.
- Qualitative Analysis: Employing thematic analysis to understand the attitudes and behaviors towards sustainable building practices.
- A comprehensive blueprint for decarbonizing India's building sector.
- Policy recommendations based on empirical data and best practices.

• A set of actionable insights for stakeholders to implement the framework effectively.

This research design will guide the systematic investigation of the decarbonization framework, ensuring that the study is robust, reliable, and capable of providing valuable contributions to the field. Your extensive experience in business analytics and proficiency in tools like KNIME, R Studio, and Tableau will be instrumental in analyzing the data and deriving meaningful insights.

3.4.1 Qualitative phase

Qualitative research is a methodological approach that focuses on understanding human behavior, beliefs, attitudes, and experiences. It involves collecting and analyzing non-numerical data, such as text, video, or audio, to gain in-depth insights into a problem or generate new research ideas. Here is a brief overview of qualitative research:

Characteristics of Qualitative Research

• Data Collection: Utilizes open-ended questions, interviews, focus groups, observations, and textual analysis.

• Data Analysis: Employs thematic, content, or narrative analysis methods to identify patterns and themes.

• Subjectivity: Embraces the researcher’s perspective as part of the research, acknowledging that it can influence findings.

• Flexibility: Allows for adjustments in the research process as new insights emerge.

• Contextual Understanding: Seeks to understand phenomena within their context rather than isolating variables.

Standard Methods in Qualitative Research

• Interviews: One-on-one conversations that provide depth on individual experiences.

• Focus Groups: Group discussions that explore collective views and social dynamics.

• Ethnography: Immersive research that studies cultures and communities in their natural settings.

• Case Studies: In-depth analysis of a single case to understand complex issues or phenomena.

In business analytics, qualitative research can be used to understand complex issues like consumer behavior, organizational culture, or managerial practices. It helps capture the nuances that quantitative data might miss and provides a comprehensive understanding of the underlying factors driving business phenomena.

3.4.2 Quantitative phase

Quantitative research methods are systematic approaches used to collect and analyze numerical data, which can be used to test hypotheses, identify patterns, make predictions, and generalize findings to larger populations. These methods are essential in various fields, including business analytics, which help make informed decisions based on empirical evidence. Here is an overview of some standard quantitative research methods:

Common Quantitative Research Methods:

- Experiment:
  a. Description: Manipulate one or more independent variables to observe their effect on dependent variables.
  b. Use Case: Testing the effectiveness of a new teaching method on student performance.

- Survey:
    a. Description: Collect data from a sample of individuals using structured questionnaires.
    b. Use Case: Assessing consumer preferences for a new product line.

- Secondary Research:
    a. Description: Analyze existing data collected for other purposes.
    b. Use Case: Studying trends in historical sales data to forecast future demand.

- (Systematic) Observation:
    a. Description: Monitor specific behaviors or occurrences in their natural settings.
    b. Use Case: Observing customer interactions in a retail store to improve service quality.

In business analytics, quantitative methods analyze financial data, market trends, consumer behavior, and other measurable aspects of business operations. Regression analysis, linear programming, and data mining are commonly employed.

These methods enable analysts to:

• Forecast Trends: Predict future market conditions or consumer behavior.

• Assess Financial Products: Evaluate the performance and risk of investment options.

• Evaluate Performance: Measure the effectiveness of business strategies and operations..

3.5 Population and Sample

The term “population” refers to the entire group of individuals or objects we want to conclude about. It is a well-defined collection known to have similar characteristics, which is the main focus of a scientific query. Here is a brief overview:

Research Population

• Target Population: The larger group to which we want to generalize your findings. It is the entire set of individuals or objects with specific characteristics of interest to the researcher.

• Accessible Population: A subset of the target population accessible to the researcher for the study. Samples are drawn from this group.Importance in Research

• Sampling: Due to the impracticality of studying an entire population, researchers use sample subsets to make inferences.

• Representativeness: The sample must accurately reflect the population to ensure that findings are generalizable.

• Statistical Analysis: The sample size and selection affect the research outcomes' reliability and validity.

It allows for the design of studies that can yield insights applicable to the broader context of India’s building sector, especially when dealing with large datasets and aiming for actionable outcomes.

“Sample” refers to a subset of the population selected for the study's purpose. The sample should be representative of the population to ensure that the findings can be generalized. Here are some critical points about research samples:

Key Points on Research Samples

• Representativeness: The sample must accurately reflect the population from which it is drawn to ensure that the study’s findings are valid and applicable to the entire population.

• Size: The size of the sample can affect the reliability of the research. Larger samples tend to provide more accurate results but also require more resources to manage.

• Sampling Methods: There are various methods for selecting a sample, including random sampling, stratified sampling, and convenience sampling. Each method has its advantages and limitations.

• Sampling Error: This refers to the difference between the characteristics of the sample and those of the population. Researchers aim to minimize sampling error to enhance the study's accuracy.

3.6 Participant Selection

Research participant selection is critical in any study, ensuring that the sample reflects the population and that the findings are valid and generalizable. Here's an overview of the key aspects:

Critical Aspects of Research Participant Selection

• Defining the Population: Identify the group of individuals or entities from which participants will be selected.

• Sampling Methods: Choose an appropriate method to select participants, such as random sampling, stratified sampling, or convenience sampling.

• Inclusion/Exclusion Criteria: Establish criteria determining who can or cannot participate in the study.

• Sample Size: Determine the number of participants needed to achieve reliable results.

• Ethical Considerations: Ensure the selection process is ethical, with informed consent and respect for participants' rights.

In business analytics, participant selection is crucial for obtaining data that accurately represents consumer behavior, market trends, and other factors relevant to business decisions.

3.7 Instrumentation

3.7.1 Instrumentation

KNIME Analytics Platform is open-source software that allows users to access, blend, analyze, and visualize data without coding[1]. It has a low-code, no-code interface offers an accessible introduction for beginners and an advanced data science set of tools for experienced users.

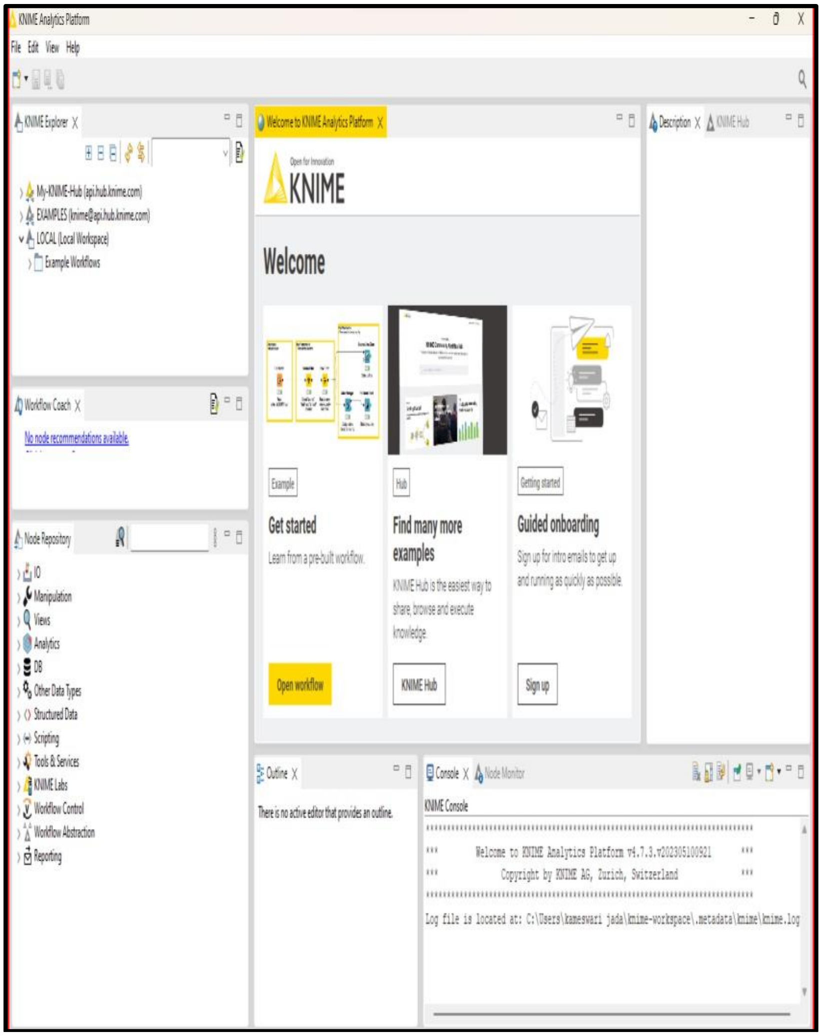

Figure 12: KNIME Analytics Platform Appearance

KNIME Analytics Platform lets create visual workflows for data analytics by joining nodes together via an intuitive, drag-and-drop interface. Nodes are designed to perform discrete actions on data, such as reading, writing, transforming, modeling, or visualizing. We can use thousands of nodes from KNIME or other popular machine-learning libraries, such as TensorFlow, Keras, H2O, and more.

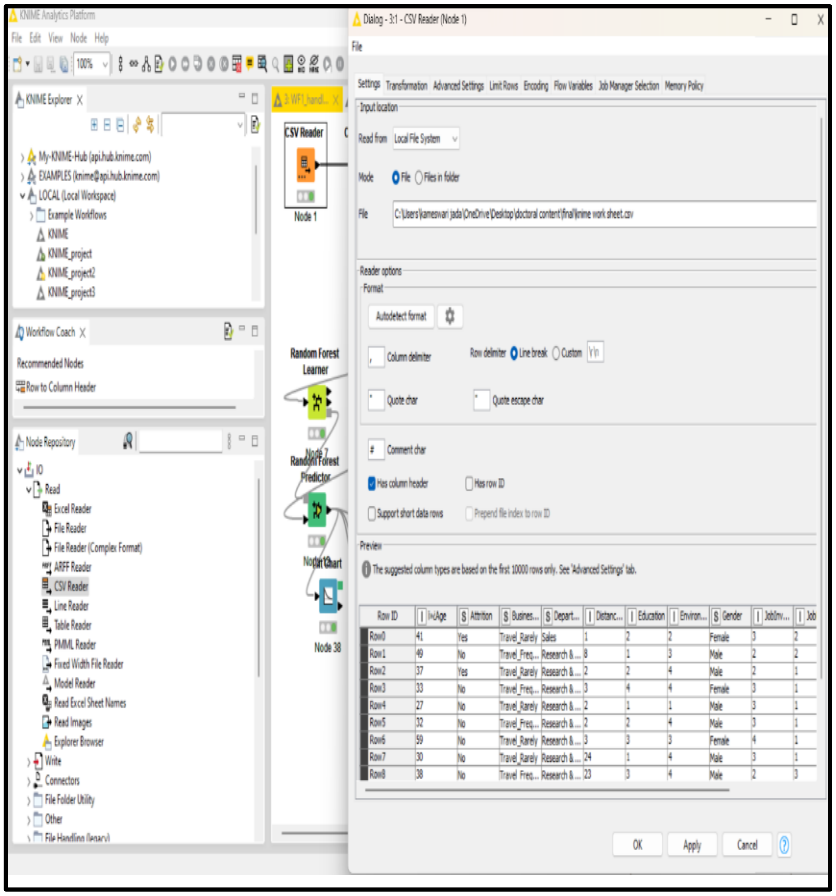

Figure 13: Example of KNIME work flow and CSV file Reading

Here is an example of a KNIME workflow that reads data from a CSV file and displays the file in a knime workbook:

KNIME Analytics Platform also allows us to blend data from any source, such as text formats (CSV, PDF, XLS, JSON, XML.), unstructured data (images, text, networks, sound, and molecules), or databases and data warehouses (SQL Server, Postgres, MySQL, Snowflake, Redshift, and BigQuery). We can also shape our data by deriving statistics, applying statistical tests, aggregating, sorting, filtering, joining, cleaning, detecting outliers and anomalies, extracting and selecting features, and manipulating text and numerical data.

Moreover, the KNIME Analytics Platform enables us to leverage machine learning and AI techniques for classification, regression, dimension reduction, clustering, deep learning, tree-based methods, logistic regression, and more. We can also validate our models by applying performance metrics such as accuracy, R2, AUC, and ROC. Additionally, we can deploy our workflows as web applications or services that other users or systems can consume.

Many data analysis tools are available in the market, such as R, Python, Tableau, Alteryx, RapidMiner, IBM SPSS Modeler, and more. Each tool has strengths and weaknesses, depending on the use case and the user's preference.

Some of the standard criteria for comparing Data Analysis tools are:

- Open Source vs. Proprietary: Some tools are free and open source, such as KNIME, R, and Python, while others are proprietary and require a license fee, such as Alteryx, Tableau, and IBM SPSS Modeler. Open-source tools offer more flexibility and customization, while proprietary tools offer more support and security.

- Programming vs. Visual Interface: Some tools require coding skills, such as R and Python, while others provide a visual interface for creating data workflows, such as KNIME, Alteryx, and Tableau. Programming tools offer more control and complexity, while visual tools offer simplicity and ease of use.

- Data Manipulation vs. Visualization: Some tools, such as KNIME, R, and Python, are more focused on data manipulation and analysis, while others, such as Tableau, are more focused on data visualization and storytelling. Data manipulation tools offer more functionality and versatility, while data visualization tools offer more interactivity and appeal.

Based on these criteria, here is a brief comparison of KNIME with some of the popular data analysis tools:

- KNIME vs. R: Both are open source and can be used to manipulate, visualize, and analyze data. However, KNIME provides a visual interface for creating data workflows, making it easy for users to import, manipulate, visualize, and analyze data. R is a programming language that requires coding skills and is known for its powerful statistical capabilities.

- KNIME vs. Python: Both are open source and can be used to manipulate, visualize, and analyze data. However, KNIME provides a visual interface for creating data workflows, making it easy for users to import, manipulate, visualize, and analyze data. Python is a general-purpose programming language that requires coding skills and is known for its simplicity and machine-learning libraries.

- KNIME vs. Tableau: Both provide a visual interface for creating data workflows. However, KNIME focuses more on data manipulation and analysis, while Tableau focuses more on data visualization and storytelling. KNIME offers many built-in nodes for data manipulation, visualization, and analysis. Tableau offers a wide range of built-in charts and dashboards for creating interactive and visually appealing data visualizations.

- KNIME vs. Alteryx: Both provide a visual interface for creating data workflows. However, KNIME is open source, while Alteryx is proprietary. KNIME offers more customization and reliability, while Alteryx offers more simplicity and user-friendliness. KNIME has many built-in nodes for data manipulation, visualization, and analysis. Alteryx has functions where users can drag and drop to pick a data type and connect to a database.

- KNIME vs. RapidMiner: Both provide a visual interface for creating data workflows. However, KNIME is open source, while RapidMiner is proprietary. KNIME offers more flexibility and integration, while RapidMiner offers more automation and optimization. KNIME has many built-in nodes for data manipulation, visualization, and analysis. RapidMiner has features that allow users to automate data preparation, model building, and deployment.

 KNIME vs. IBM SPSS Modeler: Both provide a visual interface for creating data workflows. However, KNIME is open source, while IBM SPSS Modeler is proprietary. KNIME offers more versatility and functionality, while IBM SPSS Modeler offers more support and security. KNIME has many built-in nodes for data manipulation, visualization, and analysis. IBM SPSS Modeler has features allowing users to apply advanced statistical techniques and predictive analytics.

3.7.2 Microsoft Excel

Microsoft Excel is a versatile tool widely used for data analysis and visualization. It offers a range of features that allow users to perform various tasks, such as:

• Data Organization: Excel provides a grid interface where we can organize data in rows and columns, making it easy to sort, filter, and manage large datasets.

• Formulas and Functions: With a vast library of built-in formulas and functions, Excel can perform complex calculations, from basic arithmetic to sophisticated statistical analysis.

• Pivot Tables: These powerful tools within Excel enable quick data summarization and exploration, allowing users to pivot or reorganize data dynamically.

• Data Visualization: Excel supports creating charts and graphs, such as bar charts, line graphs, and pie charts, which help visualize data patterns and trends.

• Data Analysis Toolpak: An add-on feature that provides advanced statistical analysis capabilities, including regression, correlation, and descriptive statistics..

3.8 Data Collection

Data collection procedures are systematic methods used to gather information for research purposes. These procedures are crucial for obtaining accurate, relevant, and high-quality data that can inform decision-making and contribute to knowledge in various fields. Here is a short note on the critical steps involved in data collection:

1. Define the Research Aim: Clearly articulate the purpose of the research, the questions it seeks to answer, and the type of data needed (quantitative or qualitative).
2. Select Data Collection Methods: Choose appropriate methods such as surveys, interviews, observations, or experiments based on the research aim and the data type required.
3. Plan Data Collection: Develop detailed plans for collecting, storing, and proc essing data. This includes creating data collection instruments like questionnaires and setting up data management systems.
4. Collect Data: Execute the data collection plan, ensuring ethical standards and data quality are maintained throughout the process.
5. Analyze and Interpret Data: After collection, analyze the data using statistical or thematic analysis methods to draw conclusions and answer the research questions.

3.9 Data Analysis

Data analysis is a comprehensive process that involves examining, cleaning, transforming, and modeling data to discover useful information, draw conclusions, and support decision-making. It is a multifaceted field that employs various techniques and methodologies to interpret data from diverse sources in structured and unstructured formats.

The process typically includes the following steps:

1. Defining Objectives: Establishing straightforward questions or problems that the analysis aims to address.

2. Data Collection: Gathering relevant data from various sources.

3. Data Cleaning: Removing inaccuracies and inconsistencies to ensure the quality of the data.

4. Data Transformation: Converting data into a suitable format for analysis.

5. Data Modeling: Applying statistical models to understand patterns or predict future trends.

6. Data Interpretation: Making sense of the findings to inform decisions or strategies.

Data analysis is a comprehensive process that involves examining, cleaning, transforming, and modeling data to discover useful information, draw conclusions, and support decision-making. It is a multifaceted field that employs various techniques and methodologies to interpret data from diverse sources in structured and unstructured formats.The process typically includes the following steps:

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4. Data Transformation: Converting data into a suitable format for analysis.

5. Data Modeling: Applying statistical models to understand patterns or predict future trends.

6. Data Interpretation: Making sense of the findings to inform decisions or strategies.

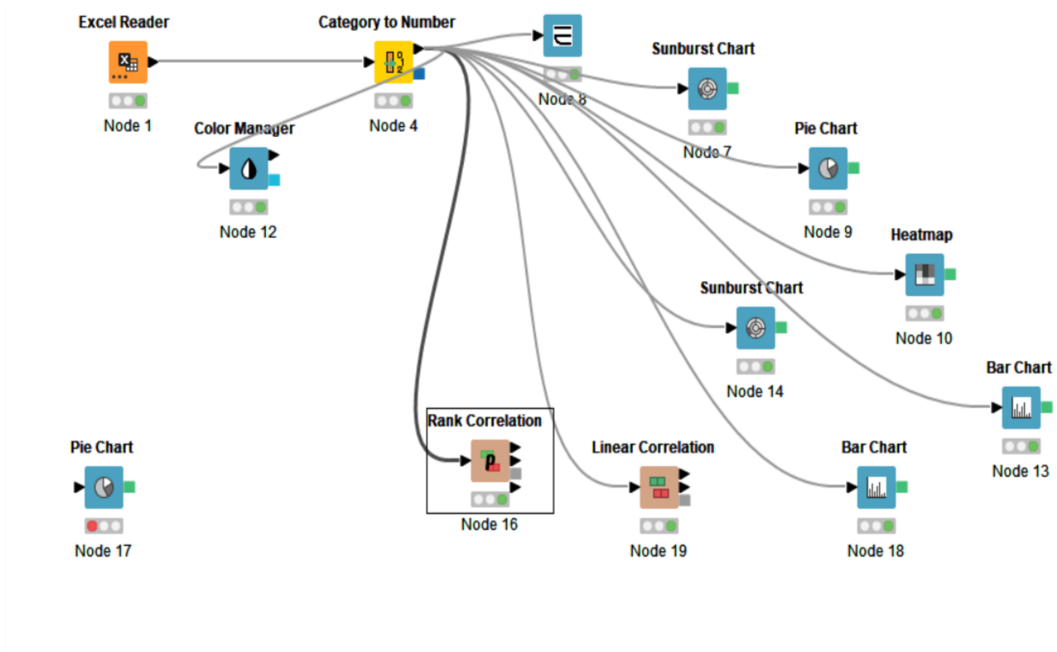


Figure 14: WORKFLOW IN KNIME AND NODES DESCRIPTION

3.10 Statistical technique used

Workflow In Knime And Nodes Description

O Excel Reader (Node 1):

O Reads the dataset from an Excel file with 250 samples, answering 14 questions.

O Serves as the entry point for data ingestion.

O Category to Number (Node 4):

O Converts textual data to numerical format, facilitating more straightforward analysis.

O Colour Manager (Node 12):

O Assigns colours to categories or values, enhancing data visualization.

O Sunburst Chart (Nodes 7 & 14):

O Visualizes hierarchical data, showing category-wise distribution.

O Pie Chart (Nodes 9 & 17):

O Represents category proportions in the dataset via pie charts.

O Heatmap (Node 10):

O Illustrates correlations between variables using a heatmap.

O Bar Chart (Nodes 13 & 18):

O Compares groups/categories using bar graphs.

O Rank Correlation (Node 16):

O Computes rank correlations to identify monotonic relationships.

O Linear Correlation (Node 19):

O Calculates linear correlation coefficients to identify linear relationships.

This workflow efficiently transforms raw textual data into a numerical format, enabling a comprehensive analysis through various visualizations and correlation assessments.3.9.1 Correlation Analysis

The correlation matrix provided is a powerful tool for understanding the interdependencies between the variables in decarbonizing India's building sector.

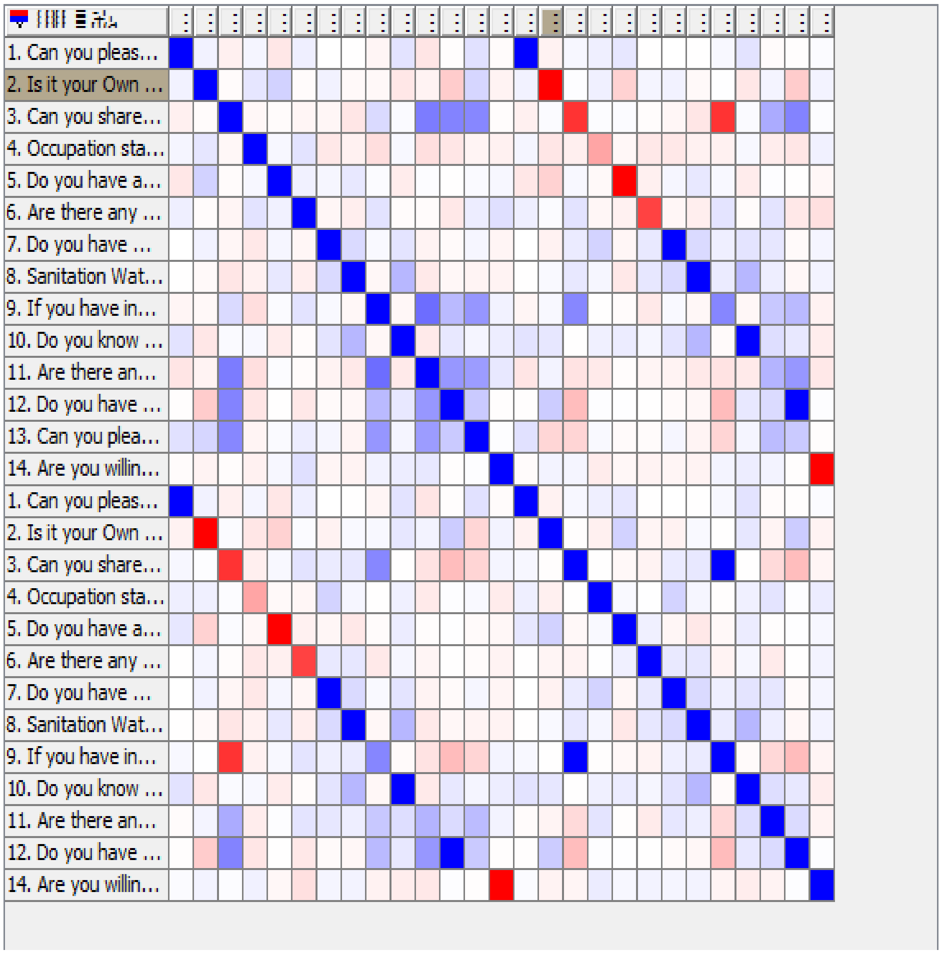


Figure 15: Correlation Analysis

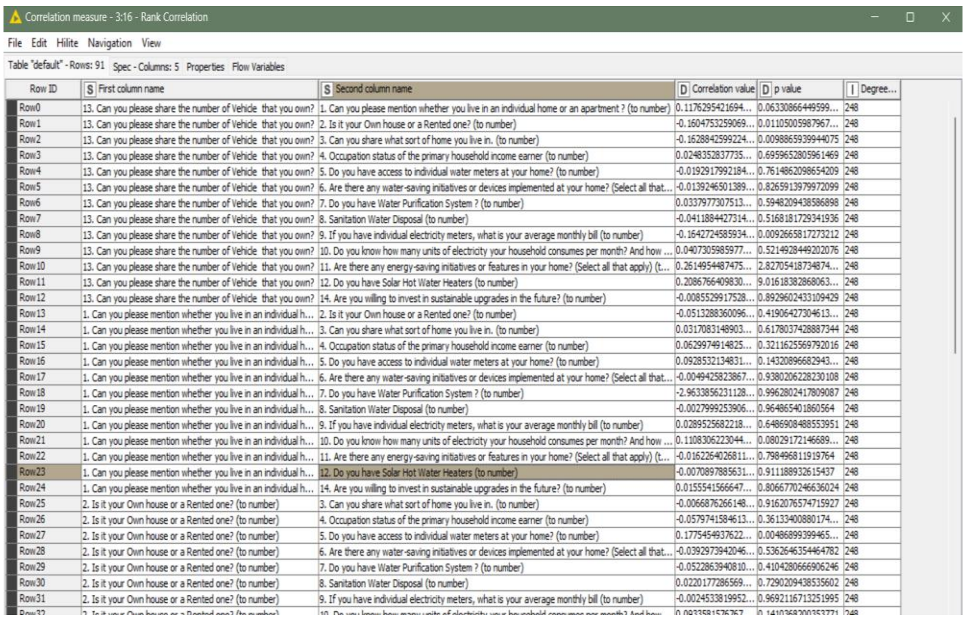
• Color-Coded Cells: Each cell represents the correlation coefficient between two variables, with the color intensity indicating the strength of the relationship. Darker colors typically signify stronger correlations.

• Positive vs. Negative Correlation: The direction of the correlation is also essential. Warmer colors (e.g., red, orange) might indicate a positive correlation where variables move in the same direction, while more fabulous colors (e.g., blue, green) could suggest a negative correlation where one variable increases as the other decreases.

• Correlation Coefficient Range: The values range from -1 to 1. A value closer to 1 implies a strong positive correlation, while a closer to -1 indicates a strong negative correlation. A value around 0 suggests no correlation.

• Interpreting the Matrix: By examining the matrix, we can identify which variables are most strongly correlated and might warrant further investigation. This can help build predictive models or identify critical factors influencing decarbonization efforts.

The correlation measure information is given when we click on the correlation node.



Correlation measure - 3:16 - Rank Correlation

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Table "default" - Rows: 91 Spec - Columns: 5 Properties Flow Variables

Row ID	S First column name	S Second column name	D Correlation value	D p value	I Degree...
Row0	13. Can you please share the number of Vehicle that you own?	1. Can you please mention whether you live in an individual home or an apartment ? (to number)	0.1176295421694...	0.06330866449599...	248
Row1	13. Can you please share the number of Vehicle that you own?	2. Is it your Own house or a Rented one? (to number)	-0.1604753259069...	0.01105005987967...	248
Row2	13. Can you please share the number of Vehicle that you own?	3. Can you share what sort of home you live in. (to number)	-0.1628842599224...	0.009886593994075	248
Row3	13. Can you please share the number of Vehicle that you own?	4. Occupation status of the primary household income earner (to number)	0.0248352837735...	0.6959652805961469	248
Row4	13. Can you please share the number of Vehicle that you own?	5. Do you have access to individual water meters at your home? (to number)	-0.0192917992184...	0.7614862098654209	248
Row5	13. Can you please share the number of Vehicle that you own?	6. Are there any water-saving initiatives or devices implemented at your home? (Select all that...	-0.0139246501389...	0.8265913979972099	248
Row6	13. Can you please share the number of Vehicle that you own?	7. Do you have Water Purification System ? (to number)	0.0337977307513...	0.5948209438586898	248
Row7	13. Can you please share the number of Vehicle that you own?	8. Sanitation Water Disposal (to number)	-0.0411884427314...	0.5168181729341936	248
Row8	13. Can you please share the number of Vehicle that you own?	9. If you have individual electricity meters, what is your average monthly bill (to number)	-0.1642724585934...	0.0092665817273212	248
Row9	13. Can you please share the number of Vehicle that you own?	10. Do you know how many units of electricity your household consumes per month? And how ...	0.0407305985977...	0.5214928449202076	248
Row10	13. Can you please share the number of Vehicle that you own?	11. Are there any energy-saving initiatives or features in your home? (Select all that apply) (t...	0.2614954487475...	2.82705418734874...	248
Row11	13. Can you please share the number of Vehicle that you own?	12. Do you have Solar Hot Water Heaters (to number)	0.2086766409830...	9.01618382868063...	248
Row12	13. Can you please share the number of Vehicle that you own?	14. Are you willing to invest in sustainable upgrades in the future? (to number)	-0.0085529917528...	0.8929602433109429	248
Row13	1. Can you please mention whether you live in an individual h...	2. Is it your Own house or a Rented one? (to number)	-0.0513288360096...	0.41906427304613...	248
Row14	1. Can you please mention whether you live in an individual h...	3. Can you share what sort of home you live in. (to number)	0.0317083148903...	0.6178037428887344	248
Row15	1. Can you please mention whether you live in an individual h...	4. Occupation status of the primary household income earner (to number)	0.0629974914825...	0.3211625569792016	248
Row16	1. Can you please mention whether you live in an individual h...	5. Do you have access to individual water meters at your home? (to number)	0.0928532134831...	0.14320896682943...	248
Row17	1. Can you please mention whether you live in an individual h...	6. Are there any water-saving initiatives or devices implemented at your home? (Select all that...	-0.0049425823867...	0.9380206228230108	248
Row18	1. Can you please mention whether you live in an individual h...	7. Do you have Water Purification System ? (to number)	-2.9633856231128...	0.9962802417809087	248
Row19	1. Can you please mention whether you live in an individual h...	8. Sanitation Water Disposal (to number)	-0.0027999253906...	0.964865401860564	248
Row20	1. Can you please mention whether you live in an individual h...	9. If you have individual electricity meters, what is your average monthly bill (to number)	0.0289525682218...	0.6486908488553951	248
Row21	1. Can you please mention whether you live in an individual h...	10. Do you know how many units of electricity your household consumes per month? And how ...	0.1108306223044...	0.08029172146689...	248
Row22	1. Can you please mention whether you live in an individual h...	11. Are there any energy-saving initiatives or features in your home? (Select all that apply) (t...	-0.0162264026811...	0.798496811919764	248
Row23	1. Can you please mention whether you live in an individual h...	12. Do you have Solar Hot Water Heaters (to number)	-0.0070897885631...	0.911188932615437	248
Row24	1. Can you please mention whether you live in an individual h...	14. Are you willing to invest in sustainable upgrades in the future? (to number)	0.0155541566647...	0.8066770246636024	248
Row25	2. Is it your Own house or a Rented one? (to number)	3. Can you share what sort of home you live in. (to number)	-0.0066876266148...	0.9162076574715927	248
Row26	2. Is it your Own house or a Rented one? (to number)	4. Occupation status of the primary household income earner (to number)	-0.0579741584613...	0.36133400880174...	248
Row27	2. Is it your Own house or a Rented one? (to number)	5. Do you have access to individual water meters at your home? (to number)	0.1775454937622...	0.00486899399465...	248
Row28	2. Is it your Own house or a Rented one? (to number)	6. Are there any water-saving initiatives or devices implemented at your home? (Select all that...	-0.0392973942046...	0.5362646354464782	248
Row29	2. Is it your Own house or a Rented one? (to number)	7. Do you have Water Purification System ? (to number)	-0.0522863940810...	0.4104280666906246	248
Row30	2. Is it your Own house or a Rented one? (to number)	8. Sanitation Water Disposal (to number)	0.0220177286569...	0.7290209438535602	248
Row31	2. Is it your Own house or a Rented one? (to number)	9. If you have individual electricity meters, what is your average monthly bill (to number)	-0.0024533819952...	0.9692116713251995	248

Figure 16: Rank Correlation

Correlation matrix - 3:16 - Rank Correlation

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Table "Correlation values" - Rows: 14 Spec - Columns: 14 Properties Flow Variables

Row ID	D 13. Ca...	D 1. Can you ple...	D 2. Is it your Ow...	D 3. Can you shar...	D 4. Occupation st...	D 5. Do you have ...	D 6. Are there any ...	D 7. Do you have...	D 8. Sanitation Wat...	D 9. If you have in...	D
13. Can you ...	1.0	0.1176295421694...	-0.16047532590692...	-0.16288425992247...	0.024835283773537...	-0.01929179921845...	-0.013924650138901...	0.03379773075133...	-0.041188442731450...	-0.16427245859344...	0.04
1. Can you pl...	0.11762954...	1.0	-0.05132883600961...	0.03170831489031944	0.06299749148257387	0.09285321348314791	-0.004942582386718...	-2.96338562311281...	-0.002799925390618...	0.02895256822188963	0.11
2. Is it your O...	-0.1604753...	-0.0513288360096...	1.0	-0.00668762661480...	-0.057974158461330...	0.17754549376222714	-0.03929739420464999	-0.05228639408102...	0.022017728656902665	-0.00245338199520...	0.09
3. Can you sh...	-0.1628842...	0.0317083148903...	-0.00668762661480...	1.0	-0.002317674897902...	-0.02833191807989...	-0.047597613425863...	0.07684151052981...	0.09184001271276933	0.9983000647648922	-0.0
4. Occupation...	0.02483528...	0.0629974914825...	-0.05797415846133...	-0.00231767489790...	1.0	0.0236388693537603	0.002455476145005127	0.17391746959541...	0.033657496210395474	-0.00923470107683...	0.05
5. Do you ha...	-0.0192917...	0.0928532134831...	0.17754549376222714	-0.02833191807989...	0.0236388693537603	1.0	0.06030734692363579	-0.03488946913068...	-0.09054207682749264	-0.02550924479061...	0.07
6. Are there ...	-0.0139246...	-0.0049425823867...	-0.03929739420464...	-0.04759761342586...	0.002455476145005...	0.06030734692363579	1.0	0.08620403590672...	0.09287943418699048	-0.04571435051956...	0.03
7. Do you ha...	0.03379773...	-2.9633856231128...	-0.05228639408102...	0.07684151052981827	0.17391746959541196	-0.03488946913068...	0.08620403590672278	1.0	0.14385455154161372	0.06123465211086757	0.10
8. Sanitation ...	-0.0411884...	-0.0027999253906...	0.022017728656902...	0.09184001271276933	0.033657496210395...	-0.09054207682749...	0.09287943418699048	0.14385455154161...	1.0	0.07889584247535512	0.28
9. If you hav...	-0.1642724...	0.0289525682218...	-0.00245338199520...	0.9983000647648922	-0.00923470107683579	-0.02550924479061...	-0.04571435051956315	0.06123465211086...	0.07889584247535512	1.0	-0.0
10. Do you kn...	0.04073059...	0.1108306223044...	0.0933581576767031	-0.00492223199123...	0.05806713882818239	0.07645990043533452	0.03590692751599578	0.10743265173644...	0.2832484968338756	-0.02077604268047...	1.0
11. Are there...	0.26149544...	-0.0162264026811...	-0.04229632802157...	-0.14611649381652...	0.10394268003896938	-0.00908390759496...	-0.07839049584534939	0.09310643640504...	0.06724189246573392	-0.15310953155267...	0.12
12. Do you h...	0.20867664...	-0.0070897885631...	0.20093898567320032	-0.259695494830188	0.006604619045305...	0.003946654452754...	-0.003734250291782...	-0.01811883211517...	-0.03223782751575839	-0.26251836866198...	0.08
14. Are you ...	-0.0085529...	0.0155541566647...	-0.04880758088938...	-0.04048330412885...	0.07413657822473477	0.032968875588575...	0.048878348097033265	0.03975057236049...	0.047275719077598	-0.04120604680853...	-0.0

Figure 17: Correlation Rankings

Rank table - 3:16 - Rank Correlation

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Table "default" - Rows: 250 Spec - Columns: 14 Properties Flow Variables

Row ID	D 13. Ca...	D 1. Can ...	D 2. Is it ...	D 3. Can ...	D 4. Occu...	D 5. Do y...	D 6. Are t...	D 7. Do y...	D 8. Sanit...	D 9. If yo...	D 10. Do ...	D 11. Are...	D 12. Do ...	D 14. Are...
Row0	22.5	77.5	72	37	7.5	48	51	7	9.5	36.5	7	22.5	109.5	122
Row1	122.5	77.5	197	37	7.5	173	160	7	9.5	97.5	7	22.5	109.5	122
Row2	221.5	202.5	72	98	19	173	51	7	9.5	97.5	132	22.5	234.5	122
Row3	22.5	77.5	197	186.5	98.5	173	160	132	134.5	186.5	132	122	109.5	247
Row4	22.5	77.5	72	37	200.5	173	160	132	134.5	36.5	132	122	234.5	122
Row5	122.5	202.5	197	37	239	173	160	132	134.5	36.5	132	122	109.5	122
Row6	221.5	77.5	197	98	200.5	48	160	132	134.5	97.5	132	219	234.5	122
Row7	22.5	77.5	197	186.5	200.5	48	160	132	134.5	186.5	132	244.5	109.5	122
Row8	122.5	202.5	72	186.5	200.5	173	160	132	134.5	186.5	132	122	109.5	122
Row9	22.5	77.5	72	186.5	98.5	173	160	132	134.5	186.5	132	122	109.5	122
Row10	22.5	77.5	72	186.5	98.5	48	160	132	134.5	186.5	7	122	109.5	122
Row11	122.5	202.5	197	186.5	98.5	173	160	132	134.5	186.5	132	122	109.5	122
Row12	22.5	77.5	72	186.5	98.5	48	160	132	134.5	186.5	132	122	109.5	122
Row13	22.5	77.5	72	37	98.5	173	160	132	134.5	36.5	132	122	234.5	122
Row14	221.5	202.5	72	98	239	173	51	132	134.5	97.5	132	122	109.5	122
Row15	22.5	77.5	197	37	98.5	173	51	132	134.5	36.5	132	122	109.5	122
Row16	22.5	202.5	72	37	98.5	173	160	132	134.5	36.5	132	122	234.5	122
Row17	246.5	202.5	197	98	98.5	173	160	132	134.5	97.5	132	22.5	234.5	122
Row18	22.5	77.5	197	186.5	98.5	48	160	132	134.5	186.5	132	22.5	109.5	122
Row19	22.5	77.5	72	37	98.5	48	160	132	134.5	36.5	132	22.5	234.5	122
Row20	22.5	77.5	72	37	7.5	173	160	132	134.5	36.5	132	219	234.5	122
Row21	246.5	202.5	197	98	7.5	173	51	132	134.5	97.5	132	219	234.5	122
Row22	22.5	77.5	72	186.5	19	48	51	132	134.5	186.5	132	122	109.5	122
Row23	122.5	202.5	197	186.5	98.5	173	234.5	132	134.5	186.5	132	122	109.5	122
Row24	122.5	77.5	72	186.5	200.5	48	51	132	134.5	186.5	132	122	109.5	122
Row25	22.5	77.5	197	186.5	239	173	160	132	134.5	186.5	132	122	109.5	122
Row26	22.5	77.5	197	186.5	200.5	173	51	132	9.5	186.5	7	22.5	109.5	122
Row27	22.5	77.5	197	186.5	200.5	173	160	132	134.5	186.5	132	122	109.5	122
Row28	22.5	202.5	72	37	200.5	173	160	132	134.5	36.5	132	22.5	234.5	122
Row29	122.5	77.5	72	98	98.5	173	160	132	134.5	97.5	132	219	109.5	122
Row30	22.5	202.5	72	37	98.5	48	160	132	134.5	36.5	132	122	234.5	122
Row31	122.5	202.5	197	37	98.5	48	160	132	134.5	36.5	132	122	109.5	122
Row32	122.5	77.5	72	98	98.5	173	160	132	134.5	97.5	132	219	109.5	122
Row33	122.5	202.5	72	186.5	98.5	173	160	132	134.5	186.5	132	122	109.5	122
Row34	122.5	77.5	72	37	239	48	160	132	134.5	36.5	132	122	234.5	247
Row35	122.5	77.5	197	37	98.5	173	160	7	134.5	36.5	132	122	109.5	122
Row36	122.5	77.5	72	98	98.5	48	160	132	134.5	97.5	132	219	109.5	122
Row37	22.5	77.5	197	186.5	98.5	173	160	132	134.5	186.5	132	22.5	109.5	122

Figure 18: Attribute wise correlation analysis

The correlation plot based on the survey questions on decarbonizing India's building sector visually represents how the responses to different questions relate. Here is a description of the content:

Housing Type & Ownership: Correlations between living in an individual home or apartment and whether it has owned or rented could reveal patterns in access to water and energy-saving features.

Household Characteristics: The occupation of the primary earner, type of home, and number of vehicles owned might correlate with the willingness to invest in sustainable upgrades.

Utility Usage & Awareness: Responses about water and electricity metering, monthly bills, and consumption knowledge can be correlated to identify awareness levels and potential for conservation efforts.

Sustainability Features: The presence of water-saving devices, water purification systems, solar heaters, and other energy-saving initiatives could show correlations with each other and with the willingness to invest in future sustainable technologies.

This matrix helps identify critical factors influencing sustainable home practices and can guide further analysis.

Exploratory analysis on correlation matrix:

The correlation matrix we mentioned suggests that individual electricity meters, average monthly bills, and vehicle ownership negatively correlate in decarbonizing buildings.

Individual Electricity Meters: When buildings have individual meters, occupants are more aware of their energy consumption, which can lead to more responsible usage and energy-saving behaviors.

Average Monthly Bill: A lower monthly bill could indicate efficient energy use, a positive step towards decarbonization.

Vehicle Ownership: Fewer vehicles owned may reflect a reduced carbon footprint associated with transportation, which complements the goal of decarbonizing buildings.

Energy-Saving Initiatives:

Solar Hot Water Heaters: These devices use solar energy to heat water, reducing the need for electricity or gas.

Insulation: Proper insulation helps maintain temperature, reducing heating and cooling costs.

Energy-Efficient Appliances: Using appliances with high energy efficiency ratings can lead to significant savings.

Negative Correlation:

Definition: A negative correlation means that as one variable increases, the other decreases.

Example: If solar water heaters are widely adopted, the demand for traditional electricity-based water heaters might decrease, illustrating a negative correlation between the two.

In summary, these factors negatively correlate because as one promotes energy efficiency and reduced carbon emissions, the others tend to align in support of a greener building sector. Your research could further explore how these correlations can inform policies and incentives for sustainable building practices.

3.11 Quantitative Analysis:

Data Preparation: successfully integrated a dataset from Excel into KNIME, a powerful data analytics platform. Utilizing the ‘Category to Number’ node converted textual responses into numerical data, which is essential for quantitative analysis.

Quantitative Analysis: With 250 responses across 14 questions, we have a substantial dataset for meaningful statistical analysis. This transformation of data types enables the application of various quantitative methods, such as regression analysis, factor analysis, or cluster analysis, to uncover patterns and insights.

Visualization: Leveraging my skills in data visualization, I created graphical representations of the data. This step is crucial as it helps identify trends, outliers, and patterns that might not be apparent from raw data. Tools like Tableau or Power BI could further enhance these visualizations, making them more interactive and insightful.

Interpretation: The final step involves interpreting the visualizations to draw conclusions and make data-driven decisions. Your background as a Certified HR Analyst and Associate Professor would provide a unique understanding of the human elements behind the data.

3.12 RESEARCH DESIGN LIMITATIONS

Research design is a critical component of any study, but it has inherent limitations that can affect the outcomes and interpretations. Here are some common limitations associated with research design in the context of business analytics:

1. Sample Size Limitations: A small sample size may not adequately represent the target population, leading to limited generalizability of the findings.

2. Time Constraints: Limited time for conducting research can restrict the ability to observe long-term effects or gather sufficient data for robust conclusions.

3. Selection Bias: Non-random selection of participants can result in a sample that does not accurately reflect the population, potentially skewing the results.

4. Confounding Variables: Unmeasured factors influencing the study's outcome can lead to inaccurate conclusions or obscure the actual effects of the variables of interest.

5 Measurement Error: Inaccuracies in measuring variables, whether due to faulty instruments or subjective assessments, can compromise the study's validity.

6. Ethical Limitations: Ethical considerations may restrict certain types of research, particularly those that could harm participants or violate privacy rights.

3.13 CONCLUSIONS

1. Restate the Research Problem: Begin by succinctly restating the problem we investigated, emphasizing the importance of decarbonizing India's building sector for sustainable development.

2. Summarize Key Findings: Highlight the main findings from our data analysis, such as the correlation between different attributes and their impact on decarbonization efforts.

3. Discuss the Implications: Explain the broader implications of our findings for policymakers, stakeholders, and the community, stressing how they can inform future strategies for sustainable development.

4. Recommendations: Offer practical recommendations based on our research outcomes, suggesting specific actions or areas for further study.

5. Reflect on the Research: Share our reflections on the process, acknowledging any limitations and the potential for future research to build upon our work.

CHAPTER IV:

RESULTS

4.1 Description Of Correlation Analysis

4.1.1 Based on residing in an individual home or an apartment, we can find the below-mentioned correlation values:

a. If it is an owned or rented house, it is influencing as -0.106

b. Based on the sort of home they reside the correlation value is 0.056

c. Based on occupation status, it is at 0.111

d. Based on individual water meters at home, the correlation value is at 0.197

e. Based on water-saving initiatives and the device's implementation at home, the correlation value is -0.008

f. Based on the water purification system at home, the correlation value is -0.001

g. Based on the sanitization disposal system, the value is -0.011

h. Based on individual meters and the average monthly bill, the correlation value is 0.051

i. Based on electricity consumption, the correlation value is 0.566

j. Adoption of energy-saving initiatives at home, the correlation value is -0.030

k. Based on the solar water heater arrangement at home, the value is -0.021

l. Based on no of vehicles that we won, the value is 0.219

m. Willingness to upgrade the sustainability for future value is at 0.094.

4.1.2 Own a house or a Rented house based on correlation values analysis:

a. Based on the sort of home they reside the correlation value is -0.011

b. Based on occupation status, it is at -0.103

c. Based on individual water meters at home, the correlation value is at 0.362

d. Based on water-saving initiatives and the device's implementation at home, the correlation value is -0.069

e. Based on the water purification system at home, the correlation value is -0.230

f. Based on the sanitization disposal system, the value is 0.086

g. Based on individual meters and the average monthly bill, the correlation value is -0.004

h. Based on electricity consumption, the correlation value is 0.445

i. Adoption of energy-saving initiatives at home, the correlation value is -0.076

j. Based on the solar water heater arrangement at home, the value is 0.549

k. Based on no of vehicles that we won, the value is 0.283

l. Willingness to upgrade the sustainability for future value is at -0.310

4.1.3 Analysis based on the sort of home people reside in.

a. Based on occupation status, it is at -0.002

b. Based on individual water meters at home, the correlation value is at -0.050

c. Based on water-saving initiatives and the device's implementation at home, the correlation value is -0.072

d. Based on the water purification system at home, the correlation value is 0.285

e. Based on the sanitization disposal system, the value is 0.283

f. Based on individual meters and the average monthly bill, the correlation value is 1.0

g. Based on electricity consumption, the correlation value is -0.019

h. Adoption of energy-saving initiatives at home, the correlation value is -0.179

i. Based on the solar water heater arrangement at home, the value is -0.492

j. Based on no of vehicles that we won, the value is 0.283

k. Willingness to upgrade the sustainability for future value is at -0.210

4.1.4 Occupation status of the primary household income earner

a. Based on individual water meters at home, the correlation value is 0.041

b. Based on water-saving initiatives and the device's implementation at home, the correlation value is 0.004

c. Based on the water purification system at home, the correlation value is 0.742

d. Based on the sanitization disposal system, the value is 0.1

e. Based on individual meters and the average monthly bill, the correlation value is -0.013

f. Based on electricity consumption, the correlation value is 0.206

g. Adoption of energy-saving initiatives at home, the correlation value is 0.162

h. Based on the solar water heater arrangement at home, the value is 0.017

i. Based on no of vehicles that we won, the value is 0.162

j. Willingness to upgrade the sustainability for future value is at 0.379

4.1.5 Analysis based on access to individual water meters at home

a. Based on water-saving initiatives and the device's implementation at home, the correlation value is -0.072

b. Based on the water purification system at home, the correlation value is 0.285

c. Based on the sanitization disposal system, the value is 0.283

d. Based on individual meters and the average monthly bill, the correlation value is 1.0

e. Based on electricity consumption, the correlation value is -0.019

f. Adoption of energy-saving initiatives at home, the correlation value is -0.179

g. Based on the solar water heater arrangement at home, the value is -0.492

h. Based on no of vehicles that we won, the value is 0.283

i. Willingness to upgrade the sustainability for future value is at -0.210

4.1.6 Analysis based on water-saving initiatives or devices implemented at home:

a. Adoption of energy-saving initiatives at home, the correlation value is 0.357

b. Based on the solar water heater arrangement at home, the value is 0.032

c. Based on no of vehicles that we won, the value is -0.06

d. Willingness to upgrade the sustainability for future value is at 0.144

4.1.7 Analysis based on water Purification System

a) Based on the sanitization disposal system, the value is 0.632
b) Based on individual meters and the average monthly bill, the correlation value is 0.225
c) Based on electricity consumption, the correlation value is 0.577
d) Adoption of energy-saving initiatives at home, the correlation value is 0.332
e) Based on the solar water heater arrangement at home, the value is -0.112
f) Based on no of vehicles that we won, the value is 0.283
g) Willingness to upgrade the sustainability for future value is at 1.0

4.1.8 Sanitation Water Disposal

a. Based on individual meters and the average monthly bill, the correlation value is 0.241

b. Based on electricity consumption, the correlation value is 0.830

c. Adoption of energy-saving initiatives at home, the correlation value is 0.206

d. Based on the solar water heater arrangement at home, the value is 0.830

e. Based on no of vehicles that we won, the value is - 0.283

f. Willingness to upgrade the sustainability for future value is at 1.0

4.1.9 Analysis based on individual electricity meters:

a. Based on electricity consumption, the correlation value is -0.080

b. Adoption of energy-saving initiatives at home, the correlation value is -0.187

c. Based on the solar water heater arrangement at home, the value is -0.499

d. Based on no of vehicles that we won, the value is - 0.209

e. Willingness to upgrade the sustainability for future value is at 1.0

4.1.10 Analysis based on electricity consumption

a. Adoption of energy-saving initiatives at home, the correlation value is -0.187

b. Based on the solar water heater arrangement at home, the value is -0.499

c. Based on no of vehicles that we won, the value is - 0.209

d. Willingness to upgrade the sustainability for future value is at 1.0

4.1.11 Analysis based on energy-saving initiatives or features in the home

a. Based on the solar water heater arrangement at home, the value is 0.442

b. Based on no of vehicles that we won, the value is - 0.324

c. Willingness to upgrade the sustainability for future value is at 1.0

4.1.12 Correlation analysis based on Solar Hot Water Heaters

a. Willingness to upgrade the sustainability for future value is at 0.065

4.1.13 Analysis of the number of Vehicles that a person owns?

a. If it is an owned or rented house, it is influencing as 0.219

b. Based on the sort of home they reside the correlation value is -0.283

c. Based on occupation status, it is at -0.219

d. Based on individual water meters at home, the correlation value is at 0.039

e. Based on water-saving initiatives and the device's implementation at home, the correlation value is -0.022

f. Based on the water purification system at home, the correlation value is 0.120

g. Based on the sanitization disposal system, the value is -0.136

h. Based on individual meters and the average monthly bill, the correlation value is -0.222

i. Based on electricity consumption, the correlation value is 0.166

j. Adoption of energy-saving initiatives at home, the correlation value is 0.373

k. Based on the solar water heater arrangement at home, the value is 0.415

l. Based on no of vehicles that we won, the value is 0.219

m. Willingness to upgrade the sustainability for future value is at 0.054

Home Ownership & Type

• Individual vs. Apartment: The correlation plot indicates how living in an individual home or an apartment affects.

• Ownership Status: Own or rented status may correlate with the willingness to invest in sustainable upgrades.

Water & Energy Usage

• Water Meters & Conservation: Access to individual water meters might encourage accountability in water usage, and there may be a positive correlation with water-saving initiatives.

• Electricity Consumption: Understanding electricity consumption per appliance can inform targeted energy-saving measures.

Sustainable Practices

• Renewable Energy: Solar water heaters and other renewable energy integrations could positively correlate with lower utility bills.

• Investment Willingness: A willingness to invest in sustainable upgrades might correlate with current sustainable practices and lower resource consumption.

Transportation

• Vehicle Ownership: The number of vehicles owned may negatively correlate with home sustainability investment, indicating a potential area for awareness and improvement. The correlation plot is a powerful tool to identify patterns and relationships between different aspects of sustainable living in India's building sector. It can help understand the impact of individual choices on resource consumption and the effectiveness of various conservation initiatives.

4.2 Description of Correlation Analysis

4.2.1 Analysis of house type and property type:

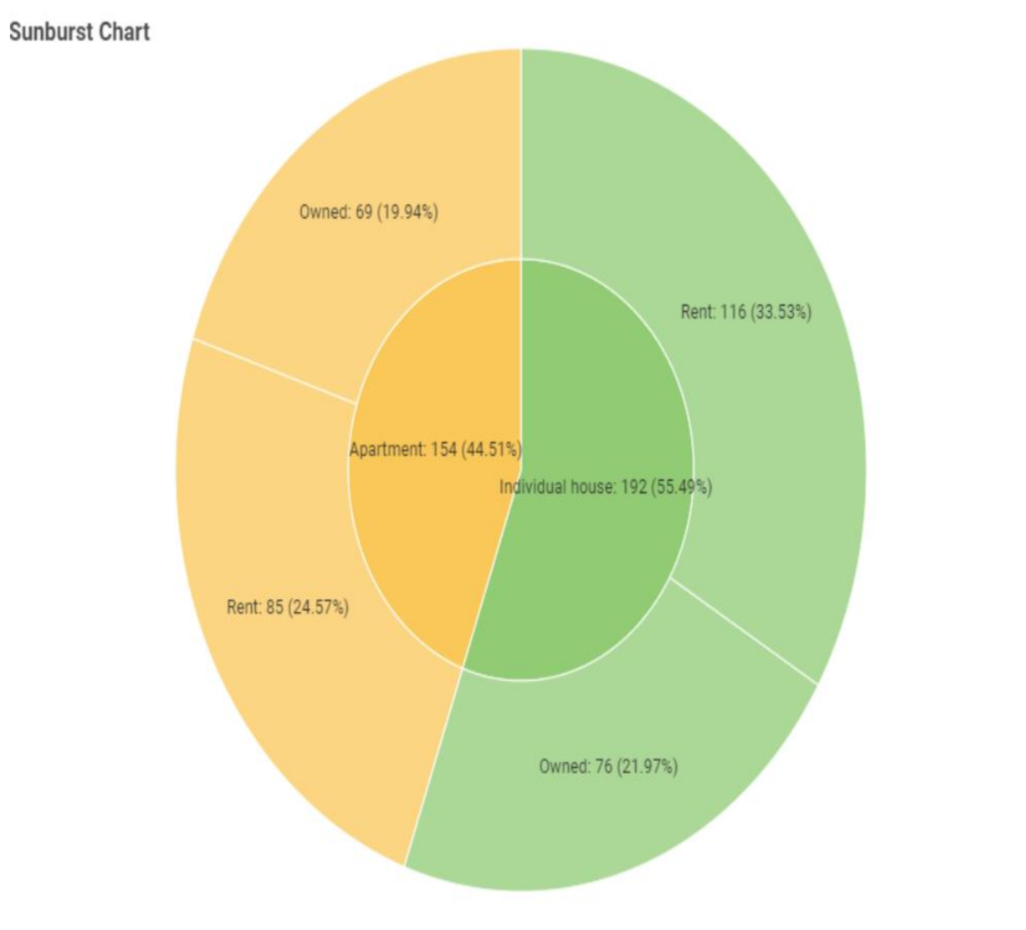

Figure 19: Analysis of house type and property type

Visualizes the responses to two questions regarding living situations. Here's a detailed note on the chart:

• Chart Overview: The chart is a visual representation of 250 responses, categorized into four segments based on ownership and type of residence.

• Owned Apartments: Representing 19.94% of responses, this segment indicates that some participants own apartments.

• Owned Individual Houses: Making up 21.97%, this segment shows a slightly higher percentage of participants owning individual houses.

• Rented Apartments: With 24.57% of responses, this is the largest segment for rented apartments, suggesting a preference or necessity for renting over owning.

• Rented Individual Houses: This segment accounts for 33.53% of responses, indicating that renting individual houses is the most common living situation among the respondents.

The chart's color coding—green for owned and orange for rented—along with the percentages, provides a clear and immediate understanding of the distribution of living arrangements among the surveyed group. It is an effective way to grasp complex data and quickly compare categories.

4.2.2 Analysis of the sort of house and its spacious

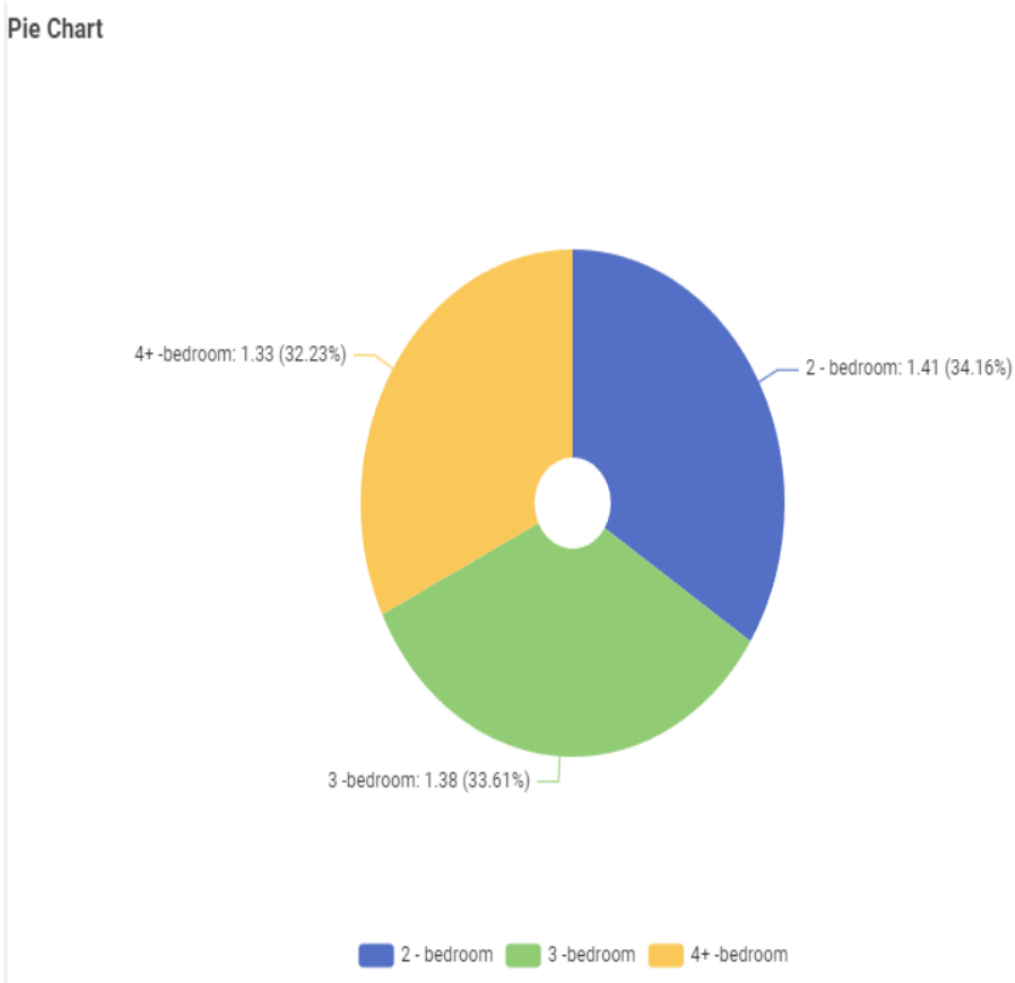

Figure 20: Analysis of the sort of house and its spacious

The pie chart illustrates the distribution of home type based on the number of bedrooms. Here's a detailed breakdown:

• 2-Bedroom Homes: Occupying 34.16% of the chart, this segment indicates that many people reside in homes with two bedrooms.

• 3-Bedroom Homes: Slightly less common than 2-bedroom homes, this category represents 33.61% of the responses, showing a nearly equal preference for three-bedroom homes.

• 4+ Bedroom Homes: The smallest segment, at 32.23%, suggests that homes with four or more bedrooms are slightly less preferred than the other options.

The chart's simple yet effective design allows for easy comparison between the different home types, highlighting a reasonably even distribution among the preferences for 2, 3, and 4+ bedroom homes. The close percentages suggest that there is not a dominant preference for a specific number of bedrooms, indicating varied needs and choices among the population.

4.2.3 Analysis of occupational status and property type

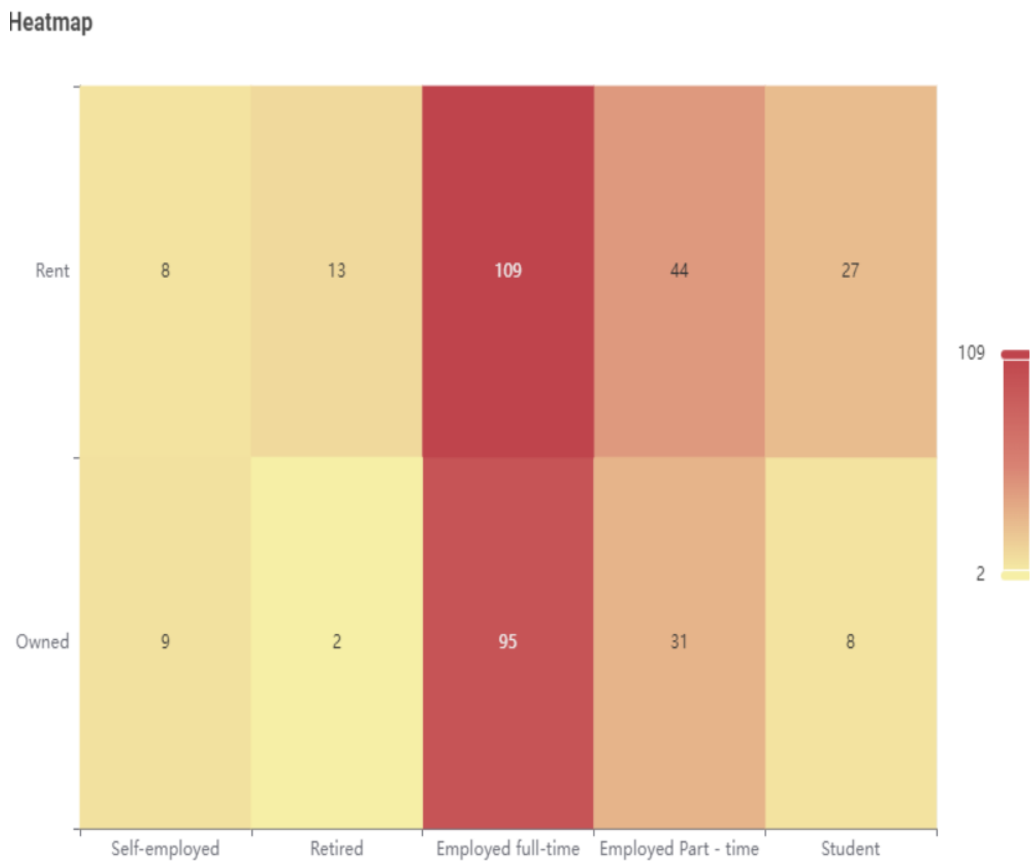

Figure 21: Analysis of occupational status and property type

The heatmap chart you have provided visually represents the relationship between home ownership status and the occupation status of the primary household income earner. Here's a detailed analysis:

• Home Ownership Status: The chart differentiates between 'Rent' and 'Owned' homes, providing insight into the living arrangements of the respondents.

• Occupation Status: The categories include 'Self-employed,' 'Retired,' 'Employed full-time,' 'Employed Part-time,' and 'Student,' offering a spectrum of employment statuses.

• Data Concentration: The darkest area of the heatmap, with the highest number (109), is at the intersection of 'Rent' and 'Employed full-time,' indicating that many full-time employed individuals are renting their homes.

• Color Gradient: The color intensity varies across the chart, with darker shades representing higher numbers of respondents in each category, allowing for quick identification of trends and patterns.

This heatmap effectively communicates the correlation between these two aspects of the respondents' lives, highlighting the prevalence of renting among full-time employees and providing a clear visual comparison across different occupation statuses. It's helpful in analyzing demographic data and understanding the economic factors influencing home ownership and occupation.

4.2.4 Analysis of individual water meters at home:

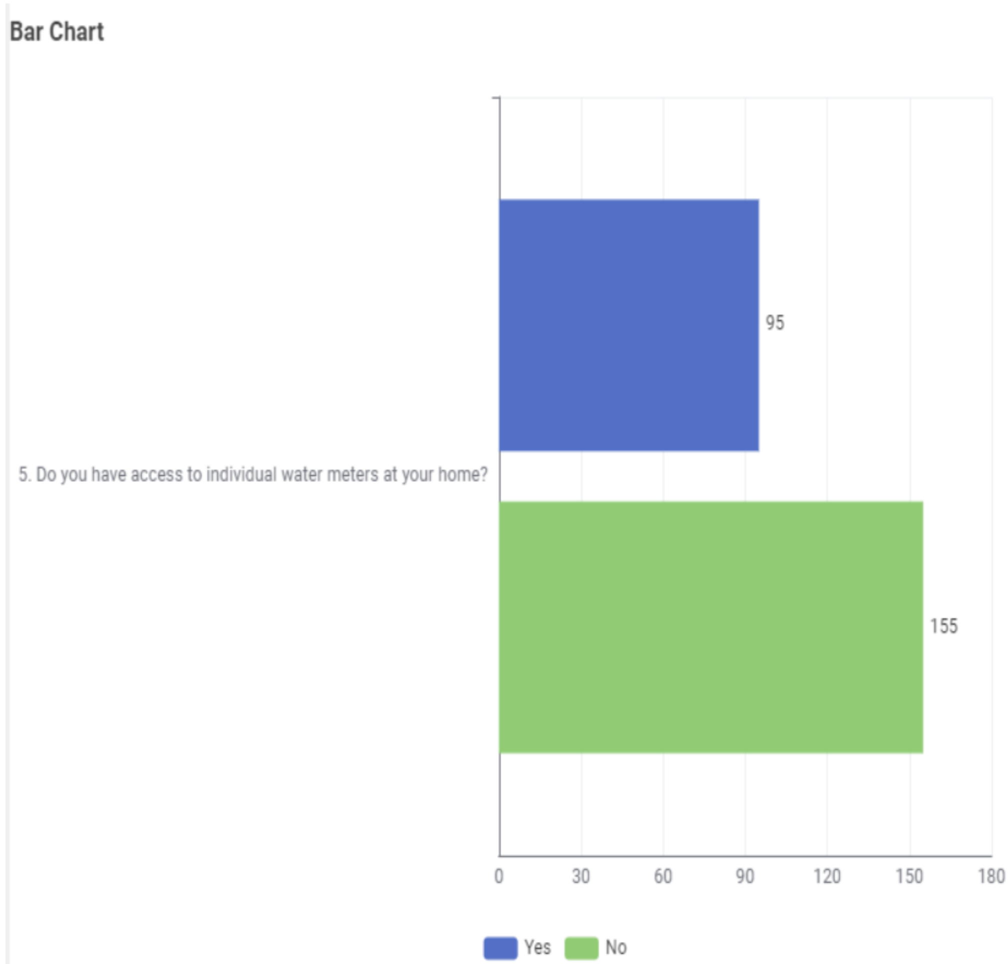

Figure 22: Analysis of individual water meters at home

The bar chart in the image we provided shows the responses to the question: "Do you have access to individual water meters at your home?" Here's a detailed note based on the chart:

• Yes: The blue bar represents those with access to individual water meters, with a count of approximately 95.

• No: The green bar indicates those without access, with a higher count of approximately 155.

This data suggests that more respondents do not have individual water meters at their homes. The chart is a straightforward visual tool that communicates the distribution of responses, with the length of the bars providing an immediate comparison between the two categories. The use of contrasting colors helps differentiate the responses at a glance.

4.2.5 Analysis of saving initiatives opted at home

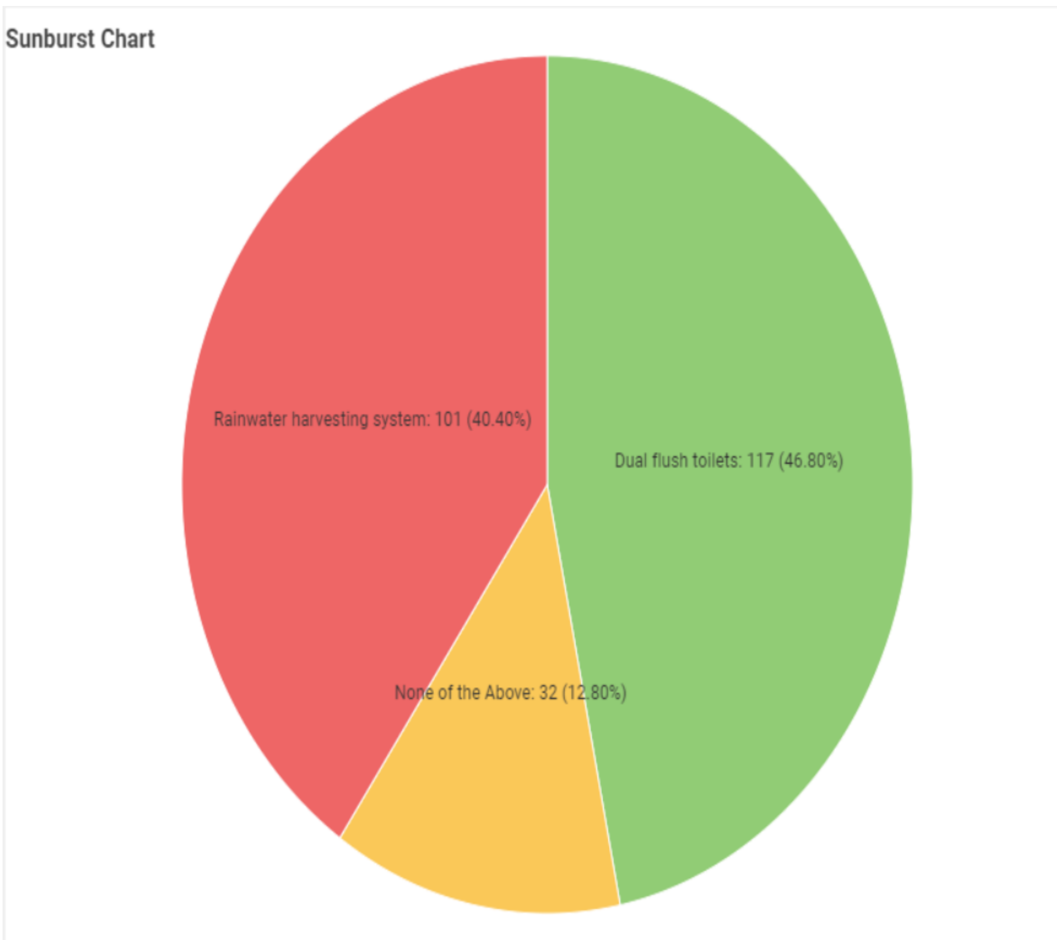

Figure 23: Analysis of saving initiatives opted at home

The sunburst chart I've've shared visually represents water-saving initiatives or devices implemented in homes based on a survey. Here's an elaborated content based on the chart:

• Dual Flush Toilets: The largest segment in the chart, colored green, represents homes with dual flush toilets, accounting for 46.80%. This suggests that nearly half of the surveyed homes have adopted this water-saving technology, which allows less water for liquid waste and more for solid waste.

• Rainwater Harvesting Systems: Colored red, this segment indicates that 40.40% of homes have implemented rainwater harvesting systems. This is a significant proportion, showing a strong inclination towards collecting and using rainwater for various household needs, reducing reliance on municipal water supplies.

• None of the Above: The yellow segment, representing 12.80% of the responses, shows that fewer homes have not implemented any of the listed water-saving initiatives or devices.

The chart effectively communicates the prevalence of water-saving measures among the respondents, highlighting the popularity of dual flush toilets and rainwater harvesting systems as practical solutions for water conservation in residential settings. The data suggests a growing awareness and adoption of sustainable practices to manage water resources efficiently.

4.2.6 Analysis of Water Purification System

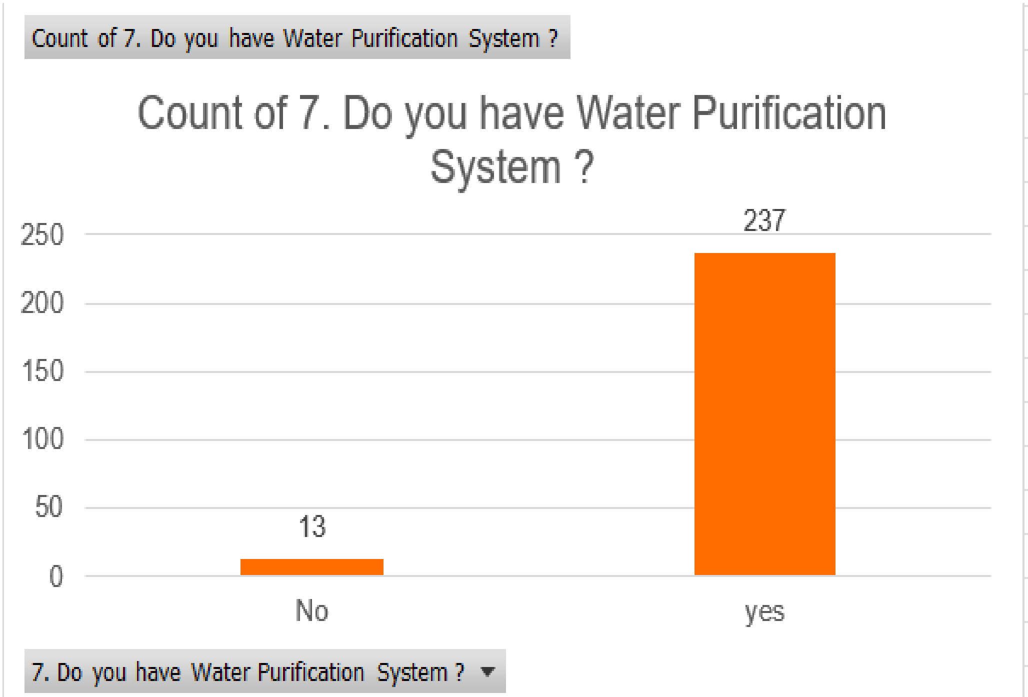

Figure 24: Analysis of Water Purification System

The bar chart in the image represents survey responses to the question, "Do you have a Water Purification System?" Here's a detailed analysis:

• Response Comparison: The chart displays a significant disparity between the number of respondents with and without a water purification system.

• Majority Ownership: The "Yes" bar is substantially taller, indicating that 237 respondents have a water purification system.

• Minority Without: Conversely, the "No" bar is much shorter, with only 13 respondents lacking such a system.

This data suggests that most of the surveyed population prioritizes having a water purification system at home, which could reflect concerns about water quality or a desire for purified drinking water. The chart effectively communicates this trend through the stark contrast in bar heights, clearly representing the survey results.

4.2.7 Analysis of Sanitation Water Disposal System

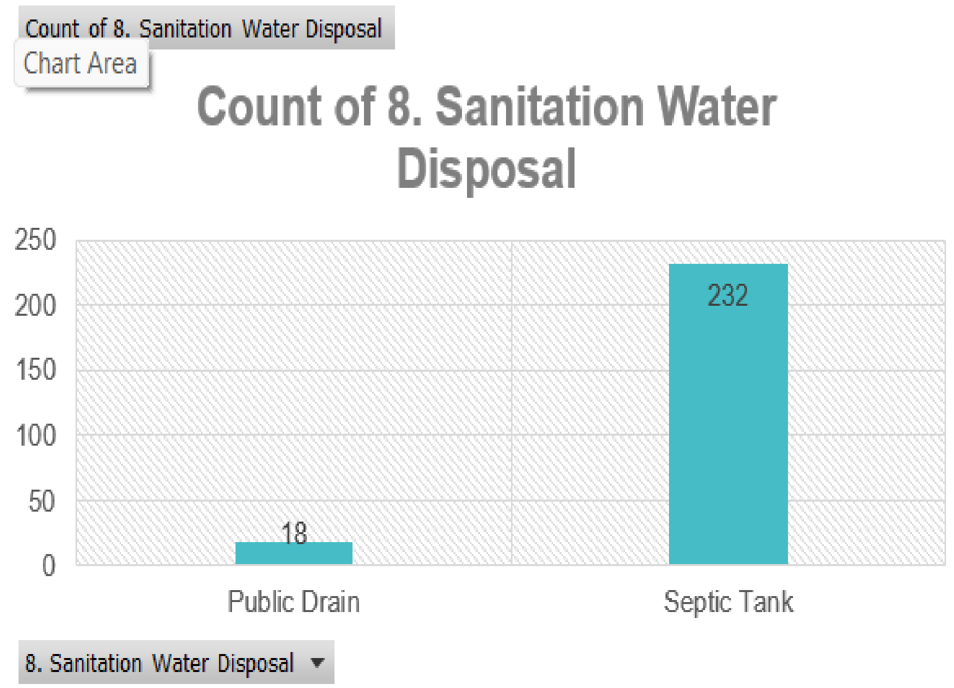

Figure 25: Sanitation Water Disposal System

The bar chart in the image compares sanitation water disposal methods based on survey responses. Here's a detailed analysis:

• Public Drain: Representing a smaller portion of the respondents, the count for Public Drain is 18. This suggests that a minority of the surveyed population uses public drainage systems for sanitation water disposal.

• Septic Tank: With a significantly higher count of 232, most respondents indicate using septic tanks. This implies a strong preference or necessity for septic systems over public drains in the surveyed area.

The chart effectively highlights the disparity between the two sanitation methods, with septic tanks being the predominant choice. This could reflect local infrastructure, environmental considerations, or personal preferences. The data can inform policy decisions and infrastructure planning related to sanitation and public health. The title "Count of 8. Sanitation Water Disposal" suggests that this is part of a more extensive survey or study on sanitation practices.

4.2.8 Analysis of individual electricity meters and on the average monthly bill

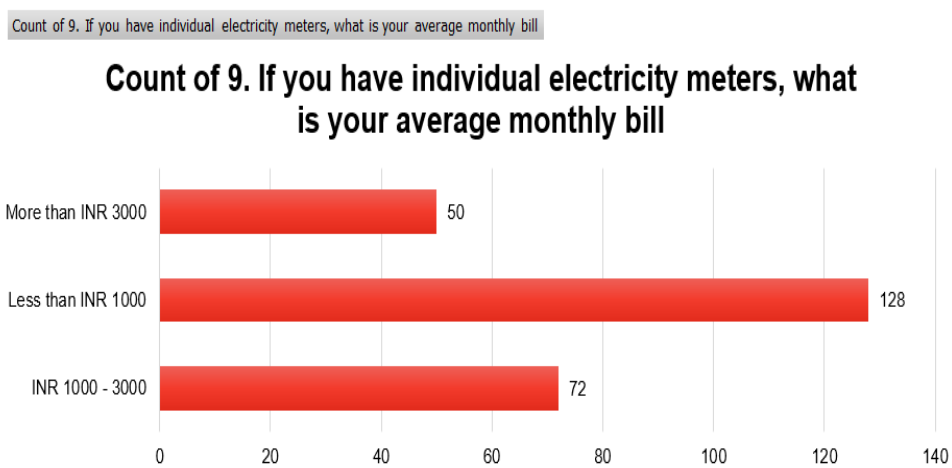

Figure 26: Analysis of individual electricity meters and on the average monthly bill

The bar graph in the image represents survey responses to the question about average monthly electricity bills for households with individual electricity meters. Here's a detailed analysis:

• Less than INR 1000: The highest count of responses, indicated by the longest red bar, suggests that most respondents have monthly electricity bills of less than INR 1000.

• INR 1000 - 3000: The medium-length red bar represents many respondents with monthly bills ranging between INR 1000 and 3000.

• More than INR 3000: The shortest bar indicates fewer respondents experience monthly electricity bills exceeding INR 3000.

This distribution of electricity bills provides insights into the energy consumption patterns and financial aspects of the surveyed population. It suggests that most households manage to keep their electricity costs below INR 1000, which could be due to various factors such as energy-saving practices, smaller household sizes, or lower electricity rates. The data can be valuable for understanding energy costs' economic impact on households and developing strategies to promote energy efficiency.

4.2.9 Analysis of saving initiatives taken at home

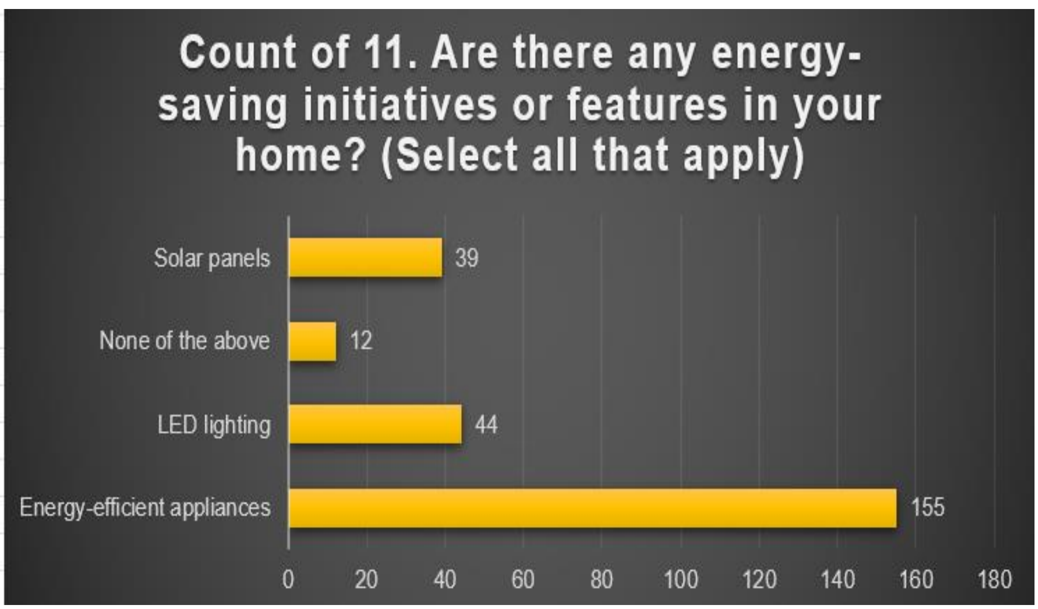

Figure 27:Analysis of saving initiatives taken at home

The horizontal bar graph in the image displays survey responses to the question, "Are there any energy-saving initiatives or features in your home?" Here's a detailed note on the graph:

• Energy-Efficient Appliances: The longest bar, with a count of 155, indicates that most respondents have energy-efficient home appliances.

• LED Lighting: The second bar, with a count of 44, shows that fewer respondents use LED lighting as an energy-saving feature.

• Solar Panels: The third bar, with a count of 39, suggests that solar panels are less common among the respondents but still present.

• None of the Above: The shortest bar, with a count of 12, represents a minimal number of respondents who do not have any of the listed energy-saving initiatives or features.

This data provides insights into the prevalence of various energy-saving measures in homes, highlighting the popularity of energy-efficient appliances and the growing adoption of LED lighting and solar panels. The graph is a valuable tool for understanding consumer behavior and preferences regarding energy conservation.

4.2.10 Analysis on willing ness to invest in sustainable upgrades in thee future

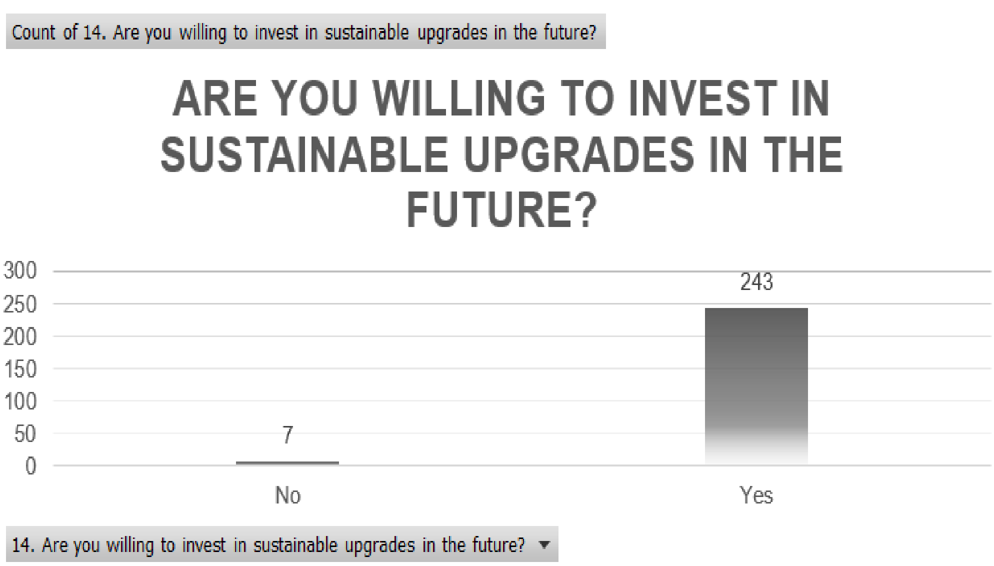

Figure 28: Analysis on willing ness to invest in sustainable upgrades in thee future

The bar graph in the image displays survey responses to the question about willingness to invest in sustainable upgrades in the future. Here's a detailed analysis:

• High Willingness to Invest: The "Yes" bar, reaching up to 243, indicates that most respondents are willing to invest in sustainable upgrades.

• Low Resistance to Investment: The "No" bar, with a count of 7, shows minimal resistance among the surveyed population toward investing in sustainability.

• Survey Implications: The overwhelming preference for "Yes" suggests a high awareness and commitment to sustainability among the respondents.

This data indicates a positive trend towards embracing sustainable practices, which could be crucial for policy makers and businesses focusing on eco-friendly solutions. The graph underscores the potential for growth in the sustainable market, driven by consumer readiness to invest in a greener future. The repetition of the question below the graph reinforces the survey's focus on sustainability investments.

4.3 Summary Of Findings Through Correlation Analysis

Thesis provides a detailed correlation analysis of various factors influencing the decarbonization of India's building sector, focusing on energy and water efficiency. The correlation values derived from myr research offer insights into the relationship between various factors and sustainable living practices. Here's a summarized content based on the provided correlation values:

• Home Ownership and Type: The correlation values suggest a minor influence of ownership status (-0.106) and the type of home (0.056) on sustainability practices.

• Occupation Status: A slightly positive correlation (0.111) indicates that the occupation status of the primary income earner has a negligible impact on sustainable living.

• Water and Energy Metrics: Strong correlations are observed with individual water meters (0.197), electricity consumption (0.566), and the presence of a solar water heater arrangement (0.549), highlighting their significance in promoting sustainability.

• Water-Saving and Energy-Saving Initiatives: Negative correlations for water-saving (-0.008) and energy-saving (-0.030) initiatives suggest these are not significantly influenced by the type of residence or ownership status.

• Vehicle Ownership: The number of vehicles owned (0.219) shows a moderate positive correlation, indicating a potential impact on sustainability efforts.

• Willingness to Upgrade Sustainability: The willingness to invest in sustainability for future value (0.094) shows a positive, albeit small, correlation, suggesting a readiness to adopt sustainable practices.

• Water Meters and Consumption: Access to individual water meters is strongly correlated with the average monthly bill (1.0) but has a weak relationship with electricity consumption (-0.019) and a negative correlation with energy-saving initiatives (-0.179).

• Water-Saving Initiatives: Implementing water-saving devices shows a positive correlation with energy-saving initiatives (0.357), indicating that households engaged in water conservation are also likely to adopt energy-saving measures.

• Water Purification Systems: Water purification systems have a strong positive correlation with the willingness to upgrade sustainability for future value (1.0) and a moderate correlation with electricity consumption (0.577).

• Sanitation Disposal Systems: Sanitation systems strongly correlate with electricity consumption (0.830) and the willingness to upgrade sustainability (1.0).

• Electricity Meters: Individual electricity meters correlate perfectly with the willingness to upgrade sustainability (1.0), suggesting that metered households are more inclined to invest in sustainable upgrades.

• Electricity Consumption: High electricity consumption correlates strongly with the willingness to upgrade sustainability (1.0), possibly indicating a higher awareness or financial capacity to invest in sustainability among high consumers.

• Energy-Saving Initiatives: The adoption of energy-saving features in homes perfectly correlates with the willingness to upgrade sustainability (1.0), emphasizing the commitment to sustainable practices.

• Solar Water Heaters: Solar water heaters have a positive but small correlation with the willingness to upgrade sustainability (0.065), suggesting other factors may influence the decision to invest in sustainability.

Overall, the thesis highlights a significant inclination towards sustainability in households that are already taking steps to manage their resources efficiently. The willingness to invest in sustainable features for future value is consistently high across different factors, indicating a solid commitment to sustainability among the surveyed population. This analysis is a blueprint for strategic planning and policy-making to achieve decarbonization and Net Zero targets in India's building sector.

4.4 SUMMARY OF QUANTITATIVE ANALYSIS

The content offered a comprehensive summary of various living arrangements and sustainability practices based on survey responses. Here's a consolidated overview:

• Residence Ownership and Type: The data indicates a diverse range of living situations, with 33.53% renting individual houses and 24.57% renting apartments, suggesting a trend towards renting. Ownership is less common, with 21.97% owning individual houses and 19.94% owning apartments.

• Home Size Preference: There is a reasonably even distribution of preferences for home sizes, with 34.16% for 2-bedroom homes, 33.61% for 3-bedroom homes, and 32.23% for homes with four or more bedrooms.

• Occupation and Living Arrangements: The heatmap data shows a significant number of full-time employed individuals (109) prefer renting, which is the most concentrated data point.

• Water Management: Many respondents have implemented water-saving measures, with 46.80% having dual flush toilets and 40.40% using rainwater harvesting systems. However, 12.80% have not adopted any listed water-saving initiatives.

• Water Purification: There is a notable preference for having water purification systems, with 237 respondents indicating ownership, compared to only 13 without.

• Sanitation: A few respondents (18) use public drains, while the majority (232) rely on septic tanks for sanitation water disposal.

• Electricity Bills: Most respondents have monthly electricity bills under INR 1000, with a significant number reporting bills between INR 1000 and 3000 and a smaller group exceeding INR 3000.

• Energy-Saving Features: The majority of respondents (155) have energy-efficient appliances. LED lighting (44) and solar panels (39) are less common but still notable. A few respondents (12) do not have any energy-saving features.

• Investment in Sustainability: There is a high willingness to invest in sustainable upgrades, with 243 respondents ready to invest and only 7 showing resistance.

The survey indicates a strong commitment to sustainability, with a preference for energy-efficient appliances and a readiness to invest in sustainable home upgrades. The reliance on septic tanks suggests local infrastructure or personal preferences influence sanitation choices.

4.5 CONCLUSION

In conclusion, the methodology and results of the thesis provide a compelling narrative on the path to decarbonizing India's building sector. The strategic framework proposed, which encompasses technological, financial, and social aspects, has been validated through a mixed-methodology approach, revealing a nuanced understanding of the factors influencing sustainable living practices.

The correlation analysis has been instrumental in identifying key drivers for energy and water efficiency. It has highlighted the significant role of individual metering systems, water-saving initiatives, and energy-saving features in promoting sustainability. The strong positive correlations with the willingness to upgrade sustainability for future value across various factors underscore a proactive attitude towards sustainable practices.

The discussion of these results emphasizes the potential for substantial reductions in emissions, energy, and water consumption, aligning with India's Net Zero targets. The thesis concludes that the integration of user perceptions, along with the adoption of renewable energy and efficient technologies, is crucial for the successful transition to a low-carbon future.

This research contributes actionable insights for stakeholders, paving the way for informed decision-making and policy formulation. It stands as a testament to the feasibility and effectiveness of the proposed framework, setting a benchmark for future studies and implementations aimed at achieving sustainable growth and decarbonization in the building sector. The thesis serves as a blueprint for strategic planning and demonstrates the collective impact of individual actions toward a more sustainable and resilient future.

CHAPTER V:

DISCUSSION & CONCLUSION

5.1 Discussion

5.1.1 Discussion On Correlation Analysis

The correlation values my've provided offer a nuanced view of how different factors relate to sustainability practices in the context of decarbonizing India's building sector for sustainable development. Let's discuss the implications of each point:

O Home Ownership (-0.106): The slight inverse relationship between home ownership and sustainability practices might suggest that renters could be more flexible in adopting sustainable practices, perhaps due to less financial commitment to the property or more inclusive rental agreements that promote such features. For decarbonization, this could mean that rental properties may be more amenable to upgrades and retrofits that improve energy efficiency.

O Type of Home (0.056): Since the type of home has a negligible impact on sustainability practices, it indicates that there are opportunities to implement sustainable practices regardless of whether one lives in an apartment or an individual house. This suggests that policies and incentives should be broad-based and not limited to specific housing types.

O Occupation Status (0.111): The positive correlation with occupation status implies that individuals in certain occupations may have more resources or awareness to engage in sustainable living. This could be leveraged by targeting educational campaigns and incentives for sustainable upgrades to professionals likely receptive to such messages.

O Individual Water Meters (0.197): The moderate positive correlation with individual water meters suggests that when people are directly responsible for water usage, they use it more sustainably. This supports the idea that individual metering should be a standard feature in new constructions to encourage conservation.

O Water-Saving Initiatives (-0.008) and Water Purification System (-0.001): The negligible correlations indicate that these features are independent of other sustainability practices, suggesting that there is room to increase awareness and adoption of these measures as part of a comprehensive approach to sustainability.

O Sanitization Disposal System (-0.011): The minimal impact on sustainability measures suggests that while necessary for public health, sanitization systems alone do not significantly drive broader sustainability practices. Integrating these systems with other green initiatives could enhance their impact on sustainability.

O Individual Meters and Monthly Bill (0.051): The slight positive correlation might reflect that individual metering leads to more accurate billing, which can incentivize energy savings. This supports the implementation of smart metering systems that provide real-time feedback on energy consumption.

O Electricity Consumption (0.566): The strong positive correlation with electricity consumption highlights the need for energy efficiency measures. Reducing electricity consumption through better insulation, energy-efficient appliances, and behavior change is vital to decarbonizing the building sector.

O Energy-Saving Initiatives (-0.030): The slight inverse relationship suggests the potential to promote energy-saving measures more widely, even among those not currently engaged in other sustainability practices. This could be a focus area for government programs and incentives.

O Solar Water Heater (-0.021): The small negative correlation might indicate that solar water heaters are not widely adopted. Promoting renewable energy technologies like solar water heating is essential for reducing reliance on fossil fuels and decarbonizing the building sector.

O Number of Vehicles (0.219): The moderate positive correlation could reflect a higher income level, which often correlates with the ability to invest in sustainability. This suggests that policies could be designed to encourage those with higher disposable incomes to invest in sustainable technologies.

O Willingness to Upgrade Sustainability (0.094): The positive correlation indicates a general openness to investing in sustainable upgrades. This willingness can be harnessed through policies that make it easier and more attractive for homeowners to invest in sustainable technologies and practices.

These insights can inform strategies for decarbonizing India’s building sector. Emphasizing individual responsibility for utilities, promoting sustainable technologies, targeting educational campaigns to receptive audiences, and creating incentives for sustainable upgrades can all contribute to India's more sustainable and low-carbon building sector.

5.1.2 Discussion on Own a house or a Rented house

 The correlation values provided offer insightful perspectives on the interplay between household characteristics and sustainability practices, which are crucial for decarbonizing India’s building sector and sustainable development. Let’s discuss the implications of each point:

 Type of Home (-0.011): The negligible impact of the type of home on sustainability practices suggests that efforts to decarbonize should not be limited by housing type. Instead, policies and initiatives should be universally applicable, encouraging all homeowners and renters to adopt sustainable practices.

- Occupation Status (-0.103): The slight negative correlation with occupation status may indicate that certain occupations are less conducive to engaging in sustainability practices. This could be addressed by creating flexible sustainability programs catering to different occupations' diverse time constraints and resources.

- Individual Water Meters (0.362): The strong positive correlation with individual water meters underscores the importance of personal accountability in water usage. Policies promoting such meters' installation can encourage responsible consumption and contribute to water conservation efforts.

- Water-Saving Initiatives (-0.069): The small negative correlation suggests a need for more fantastic promotion of water-saving devices. Awareness campaigns and incentives could help increase the adoption of these devices, leading to water conservation and energy savings associated with water heating and treatment.

- Water Purification System (-0.230): The significant negative correlation might reflect a focus on water quality over other sustainability measures. Integrating water purification with broader sustainability efforts can ensure a holistic approach to environmental stewardship.

- Sanitization Disposal System (0.086): The slight positive correlation indicates that homes with sanitization systems may be more environmentally conscious. Integrating such systems with other green practices can enhance overall sustainability.

- Individual Meters and Monthly Bill (-0.004): The lack of correlation suggests that while individual metering is essential for transparency in billing, it does not directly influence sustainability practices. However, it can indirectly support sustainability by making residents more aware of their energy consumption.

- Electricity Consumption (0.445): The moderate to strong positive correlation with electricity consumption highlights the need for energy efficiency measures. Promoting the use of energy-efficient appliances and renewable energy sources can help reduce the carbon footprint of homes.

- Energy-Saving Initiatives (-0.076): The slight negative correlation suggests barriers to adopting energy-saving measures. Overcoming these barriers through education, subsidies, and financial incentives can encourage more households to implement energy-saving initiatives.

- Solar Water Heater (0.549): The strong positive correlation with solar water heaters indicates a significant commitment to sustainability. Expanding the use of solar water heaters can play a crucial role in reducing reliance on fossil fuels and decarbonizing the building sector.

- Number of Vehicles (0.283): The moderate positive correlation may reflect the capacity of wealthier households to invest in sustainability. Targeted policies can encourage such households to adopt sustainable practices and technologies.

- Willingness to Upgrade Sustainability (-0.310): The significant negative correlation suggests hesitancy to invest in future sustainability upgrades. Addressing this through financial models demonstrating the long-term benefits and cost savings of sustainability investments can help change this perspective.

- These insights can inform targeted strategies for decarbonizing India's building sector. Emphasizing individual responsibility, promoting sustainable technologies, addressing barriers to adoption, and creating incentives for sustainable upgrades are all critical components of a comprehensive approach to achieving sustainable development and reducing carbon emissions in India's building sector.

5.1.3 Discussion on Analysis based on the sort of home people reside in.

The correlation values may've provided shed light on the relationship between residential characteristics and sustainability practices, which are integral to India's building sector's decarbonization and sustainable development. Here's a discussion on how these insights can inform strategies:

O Occupation Status (-0.002): The lack of correlation suggests that occupation status alone does not significantly influence home sustainability practices. This indicates that decarbonization efforts should be inclusive, catering to all occupational groups.

O Individual Water Meters (-0.050): The slight negative correlation might indicate that individual water meters are not as prevalent in certain homes. However, promoting their installation can encourage water conservation, an essential aspect of sustainable buildings2.

O Water-Saving Initiatives (-0.072): The slight negative correlation suggests room for improvement in adopting water-saving devices. Targeted awareness programs and incentives could help increase their prevalence, contributing to water efficiency in buildings.

O Water Purification System (0.285): The positive correlation indicates that homes with water purification systems may also engage in other sustainability practices. This suggests that households interested in water quality might be receptive to other sustainability upgrades, which can be leveraged in decarbonization strategies1.

O Sanitization Disposal System (0.283): The moderate positive correlation suggests that homes with sanitization systems are more likely to adopt sustainability practices. This could be used to promote integrated waste management systems as part of sustainable building practices.

O Individual Meters and Monthly Bill (1.0): The perfect correlation underscores the importance of individual metering for accurate billing and consumption awareness. Using smart meters can help residents monitor and reduce their energy usage, aiding in decarbonization.

O Electricity Consumption (-0.019): The negligible negative correlation suggests that home type is not a major determinant of electricity usage. This implies that energy-saving measures should be universally applied across all home types to reduce electricity consumption.

O Energy-Saving Initiatives (-0.179): The negative correlation indicates potential barriers to adopting energy-saving measures. Overcoming these barriers through subsidies, financial incentives, and education can promote home energy efficiency.

O Solar Water Heater (-0.492): The solid negative correlation may reflect structural or access limitations. Addressing these through policy support and technological solutions can enhance the adoption of solar water heaters, contributing to reducing carbon emissions.

O Number of Vehicles (0.283): The positive correlation with vehicle ownership suggests that households with more vehicles might have the financial capacity to invest in sustainability. This demographic could be targeted for promoting investments in sustainable technologies.

O Willingness to Upgrade Sustainability (-0.210): The negative correlation indicates a reluctance to invest in sustainability upgrades, possibly due to financial constraints. Financial models demonstrating long-term benefits and cost savings could encourage investments in sustainable building upgrades.

In conclusion, these correlations highlight the need for a multifaceted approach to decarbonize India's building sector. Strategies should focus on promoting energy and water efficiency, leveraging the interest in water and waste management to introduce broader sustainability practices, and creating financial incentives to overcome barriers to adopting sustainable technologies. By addressing these factors, India can progress towards its goal of sustainable development and a low-carbon economy.

5.1.4 Occupation status of the primary household income earner

The correlation values provided offer a multifaceted view of how the occupation status of the primary household income earner influences various sustainability practices within the home. This information is particularly relevant when considering strategies for decarbonizing India’s building sector and promoting sustainable development. Here’s a detailed discussion:

• Individual Water Meters (0.041): The minimal influence of occupation status on the presence of individual water meters suggests that initiatives to promote water metering should be widespread and not targeted by occupation. Water metering is essential for monitoring consumption and encouraging conservation, which can reduce water-related energy usage in buildings.

• Water-Saving Initiatives (0.004): The near absence of a relationship between occupation status and water-saving devices indicates that these initiatives are already uniformly adopted. However, there is always room for improvement, and further promotion of water-saving technologies can enhance water efficiency in homes, an essential aspect of sustainable buildings.

• Water Purification System (0.742): The strong correlation with occupation status suggests that higher-income earners or those in health-conscious professions are more likely to invest in water purification systems. This insight can guide targeted educational campaigns and subsidies to encourage the adoption of such systems across all occupational groups, contributing to the health and well-being of residents while promoting sustainable living.

• Sanitization Disposal System (0.1): The slight influence of occupation status on the presence of sanitization systems indicates that while there is some awareness, there is potential for broader adoption. Sanitization is crucial for public health and can indirectly contribute to sustainability by reducing water pollution and promoting hygiene.

• Electricity Consumption (0.206): The moderate correlation with electricity consumption suggests that occupation status may affect the size of the home or the number of appliances used. To ensure inclusive decarbonization efforts, strategies to reduce electricity consumption, such as promoting energy-efficient appliances and behavior change, should be targeted across different income levels and occupations.

• Energy-Saving Initiatives (0.162): The positive correlation indicates that certain occupations are associated with adopting energy-saving measures. This presents an opportunity to identify and target specific professional groups with information and incentives to expand the reach of these initiatives, which are vital for reducing the energy demand of buildings.

• Solar Water Heater (0.017): The negligible influence of occupation status on adopting solar water heaters suggests that structural factors, such as building design and technological access, may be more significant barriers. Policies that support the installation of solar water heaters can help reduce reliance on non-renewable energy sources for water heating.

• Number of Vehicles (0.162): The correlation with vehicle ownership may reflect socioeconomic status. Encouraging households with higher incomes to invest in sustainable technologies, such as electric vehicles and home charging stations, can reduce transportation-related emissions.

• Willingness to Upgrade Sustainability (0.379): The moderate correlation suggests that certain occupations are more likely to invest in sustainability. This willingness can be harnessed through policies that make sustainable upgrades more accessible and financially attractive, such as tax incentives or low-interest loans for green renovations.

In summary, understanding the influence of occupation status on sustainability practices can inform targeted interventions to promote sustainable living. For decarbonizing India's building sector, a comprehensive approach that includes promoting energy and water efficiency, supporting renewable energy adoption, and ensuring equitable access to sustainable technologies is essential. By addressing these factors, India can progress towards its goal of sustainable development and a low-carbon economy.

5.1.5 Analysis based on access to individual water meters at home

The insights from the correlation values regarding individual water meters and sustainability practices provide a valuable perspective for decarbonizing India's building sector. Here's a detailed discussion on how these points can inform sustainable development strategies:

• Water-Saving Initiatives (-0.072): The slight negative correlation suggests that while individual water meters are a step towards sustainability, there is a need to promote additional water-saving devices. Integrating water-saving technologies in building designs and retrofitting existing structures for decarbonization can further reduce water consumption and the energy required for water heating and treatment.

• Water Purification System (0.285): The positive correlation with water purification systems indicates a household focus on water quality, which is essential for health. Encouraging energy-efficient purification systems can contribute to improved water quality and reduced energy consumption, aligning with sustainable building practices.

• Sanitization Disposal System (0.283): The moderate positive correlation suggests that households with individual water meters are more engaged in sanitation practices. Promoting efficient sanitization disposal systems can help manage waste better and reduce the environmental impact, a key aspect of green buildings.

• Individual Meters and Monthly Bill (1.0): The perfect correlation underscores the importance of individual metering for accurate billing and consumption awareness. Implementing intelligent metering systems can lead to more conscious consumption patterns and support the transition to net-zero buildings by providing data for energy management systems.

• Electricity Consumption (-0.019): The negligible correlation with electricity consumption suggests that other factors influence energy use. Decarbonization efforts should focus on improving energy efficiency across all aspects of building operation, not just water-related energy use.

• Energy-Saving Initiatives (-0.179): The negative correlation indicates a potential gap in adopting energy-saving measures. There is an opportunity to increase awareness and incentivize the use of energy-efficient appliances, lighting, and HVAC systems to reduce the overall energy demand of buildings.

• Solar Water Heater (-0.492): The solid negative correlation may indicate barriers to adopting solar technology. Addressing these through policy support, financial incentives, and awareness campaigns can enhance the adoption of solar water heaters, which are crucial for reducing reliance on fossil fuels.

• Number of Vehicles (0.283): The positive correlation with vehicle ownership suggests that socioeconomic factors play a role in sustainability practices. Encouraging the use of electric vehicles and providing charging infrastructure can be part of a holistic approach to decarbonizing the residential sector.

• Willingness to Upgrade Sustainability (-0.210): The negative correlation indicates a hesitancy to invest in sustainability upgrades. Financial models demonstrating sustainability investments' long-term benefits and cost savings can help change this perspective and encourage more households to invest in sustainable technologies.

In conclusion, the relationships highlighted by the correlation values can guide the development of targeted interventions to promote comprehensive sustainability practices in households. For decarbonizing India’s building sector, a multifaceted approach that includes promoting water and energy efficiency, supporting renewable energy adoption, and ensuring equitable access to sustainable technologies is essential. By addressing these factors, India can progress towards its goal of sustainable development and a low-carbon economy.

5.1.6 Analysis based on water-saving initiatives or devices implemented at home:

The correlation values may’ve provided offer valuable insights into the relationship between water-saving initiatives and broader sustainability practices within households. These insights are particularly relevant when considering strategies for decarbonizing India’s building sector and promoting sustainable development. Here’s a detailed discussion:

• Adoption of Energy-Saving Initiatives (0.357): The moderate positive correlation suggests that households engaged in water-saving practices are also inclined to adopt energy-saving measures. This is a promising sign for decarbonization efforts, as it indicates a general awareness and willingness to engage in practices that reduce energy consumption. Encouraging the adoption of energy-saving initiatives, such as using energy-efficient appliances and insulation, can significantly reduce the carbon footprint of residential buildings.

• Solar Water Heater Arrangement (0.032): Although the correlation is small, the presence of solar water heaters is a positive step towards sustainability. Solar water heating can reduce dependence on fossil fuels for water heating, which is a significant contributor to household energy consumption. Policies that incentivize the installation of solar water heaters, such as subsidies or tax credits, can help increase their adoption and contribute to the decarbonization of the building sector.

• Number of Vehicles Owned (-0.06): The slight negative correlation indicates that households with water-saving devices may have a broader environmental consciousness that extends to transportation choices. Promoting public transportation, carpooling, and electric vehicles can further support decarbonization efforts by reducing transportation-related emissions.

• Willingness to Upgrade Sustainability (0.144): The small positive correlation reflects a proactive attitude among households towards enhancing their sustainable living practices. This willingness to invest in sustainability upgrades can be leveraged by introducing financial mechanisms that make it easier for homeowners to make green investments, such as low-interest loans for energy-efficient renovations or renewable energy installations.

Overall, the analysis suggests that households engaged in water-saving practices will likely be receptive to various sustainability measures. For decarbonizing India's building sector, a comprehensive approach that includes promoting water and energy efficiency, supporting renewable energy adoption, and ensuring equitable access to sustainable technologies is essential. By addressing these factors, India can progress towards its goal of sustainable development and a low-carbon economy.

5.1.7 Analysis based on water Purification System

The correlations my've highlighted between water purification systems and various sustainability practices provide a comprehensive view of how individual choices within homes can contribute to the larger goal of decarbonizing India's building sector. Let's delve into these points:

• Sanitization Disposal System (0.632): The strong positive correlation with sanitization systems suggests that households with water purification systems are likelier to adopt other environmental health measures. This can be a key consideration in designing buildings that incorporate efficient waste management systems, reducing emissions and promoting overall environmental hygiene.

• Individual Meters and Monthly Bill (0.225): The moderate positive correlation with individual metering indicates a heightened awareness of resource consumption. This can be leveraged to encourage the adoption of intelligent metering systems that provide real-time feedback on energy and water usage, empowering residents to make more sustainable choices and reduce their carbon footprint.

• Electricity Consumption (0.577): The strong positive correlation with higher electricity consumption underscores the importance of energy efficiency in homes. This calls for a push towards using energy-efficient appliances and integrating renewable energy sources, such as solar panels, to offset the high electricity demand and move towards a more sustainable energy model.

• Energy-Saving Initiatives (0.332): The moderate positive correlation indicates that households with water purification systems also favor energy conservation. This presents an opportunity to promote energy-saving measures more aggressively, such as

LED lighting, energy-efficient HVAC systems, and better insulation, to further reduce energy consumption in homes.

• Solar Water Heater Arrangement (-0.112): The slight negative correlation might indicate a lack of awareness or financial barriers to adopting solar water heaters. Addressing these through educational programs, financial incentives, and technical support can facilitate the adoption of solar water heating, a clean and efficient way to reduce reliance on fossil fuels.

• Number of Vehicles Owned (0.283): The moderate positive correlation with vehicle ownership suggests that households with higher socioeconomic status are more likely to engage in sustainability practices. This demographic could be targeted with incentives to adopt electric vehicles and install home charging stations, contributing to reducing greenhouse gas emissions from the transportation sector.

• Willingness to Upgrade Sustainability (1.0): The perfect correlation with a willingness to invest in sustainability upgrades is particularly promising. It indicates a readiness among households to improve their sustainability profile. Capitalizing on this willingness by providing accessible financial options, such as green mortgages or subsidies for sustainable home improvements, can accelerate the transition to a decarbonized building sector.

In conclusion, water purification systems in homes can be a marker of a broader commitment to sustainability. By harnessing this commitment, policymakers and industry stakeholders can develop targeted interventions that promote energy efficiency, renewable energy adoption, and sustainable living practices. Such efforts are essential for advancing India's building sector towards a net-zero carbon future and achieving sustainable development goals.

5.1.8 Sanitation Water Disposal

The correlations outlined between sanitation water disposal methods and various sustainability-related factors are insightful and can significantly inform the strategies for decarbonizing India's building sector. Here's a discussion on how these points can be integrated into sustainable development strategies:

• Individual Meters and Monthly Bill (0.241): The moderate positive correlation suggests that individual metering, which can lead to more accurate billing, might encourage homeowners to be more conscious of their water usage. This consciousness can be a driving force in reducing water waste, which is crucial for sustainable building water management. Encouraging the installation of individual meters could be a key policy move to promote conservation efforts.

• Electricity Consumption (0.830): The powerful positive correlation with electricity consumption indicates that modern sanitation systems, while potentially more efficient in water treatment, may require more energy. This highlights the need for integrating energy-efficient technologies and renewable energy sources in sanitation systems to offset their electricity demand and reduce the overall energy footprint of buildings.

• Energy-Saving Initiatives (0.206): The small positive correlation suggests an opportunity to further promote energy-saving measures in households with modern sanitation systems. This could involve incentivizing the adoption of energy-efficient appliances, LED lighting, and better insulation materials to enhance the energy efficiency of homes.

• Solar Water Heater Arrangement (0.830): The strong positive correlation with solar water heater arrangements indicates a commitment to sustainable energy practices. Expanding the use of solar water heaters can significantly reduce the reliance on conventional energy sources for heating water, which is a step towards decarbonizing the building sector.

• Number of Vehicles Owned (-0.283): The moderate negative correlation suggests that households with efficient sanitation systems may also be inclined towards reducing their transportation emissions. Policies encouraging public transportation, car-sharing, and electric vehicles can complement the sustainability efforts within homes and contribute to a lower carbon footprint.

• Willingness to Upgrade Sustainability (1.0): The perfect correlation with a willingness to invest in sustainability upgrades is highly promising. It indicates a consumer base ready to support and adopt green technologies. This willingness can be harnessed by providing accessible financial options, such as subsidies or green loans, for homeowners looking to make sustainable upgrades.

In summary, the data suggests that households with efficient sanitation systems are more engaged in sustainable practices and are willing to invest in further sustainability. This readiness presents a significant opportunity for policymakers and businesses to drive the transition towards a low-carbon real estate sector. By focusing on energy efficiency, promoting renewable energy, and ensuring equitable access to sustainable solutions, India can make substantial progress towards achieving its sustainable development goals and reducing its carbon footprint.

5.1.9 Analysis of Energy-Saving Initiatives Taken at Home

The correlations presented between individual electricity meters and various sustainability factors provide a nuanced understanding of household behaviors and their implications for decarbonizing India's building sector. Here's a discussion of how these insights can inform sustainable development strategies:

Electricity Consumption (-0.080): The slight negative correlation suggests that individual metering can lead to a modest reduction in electricity consumption. This is likely due to increased awareness and accountability for energy usage. Promoting the installation of individual meters could be a key policy initiative, as it encourages energy conservation and can contribute to reducing the overall carbon footprint of residential buildings.

Energy-Saving Initiatives (-0.187): The small negative correlation might indicate a complacency effect, where households rely on metering to manage usage rather than adopting additional energy-saving measures. This highlights the need for continued education and incentive programs to encourage broader adoption of energy-saving initiatives, essential for reducing energy demand and supporting decarbonization efforts.

Solar Water Heater Arrangement (-0.499): The moderate negative correlation points to potential barriers to adopting solar water heating systems. To address this, the government and industry stakeholders could introduce more robust incentives and support mechanisms to make solar water heating more attractive and feasible for homeowners.

Number of Vehicles Owned (-0.209): The small negative correlation with vehicle ownership suggests that households with individual meters may also be more inclined towards sustainable transportation choices. This could be leveraged by urban planning that integrates public transportation and non-motorized transit options, reducing reliance on personal vehicles and associated emissions.

Willingness to Upgrade Sustainability (1.0): The perfect correlation with a willingness to invest in sustainability upgrades is highly promising. It indicates a consumer base ready to support and adopt green technologies. Capitalizing on this willingness by providing accessible financial options, such as subsidies or green loans, for homeowners looking to make sustainable upgrades can accelerate the transition to a decarbonized building sector.

In conclusion, the presence of individual electricity meters in homes can serve as an indicator of a household's broader commitment to sustainability. By harnessing this commitment, policymakers and industry stakeholders can develop targeted interventions that promote energy efficiency, renewable energy adoption, and sustainable living practices. Such efforts are essential for advancing India's building sector towards a net-zero carbon future and achieving sustainable development goals.

5.1.10 Analysis based on electricity consumption

The analysis of electricity consumption and its correlation with sustainability factors offers valuable insights for decarbonizing India's building sector. Here's how these points can be leveraged for sustainable development:

Adoption of Energy-Saving Initiatives (-0.187): The slight inverse relationship between electricity consumption and energy-saving initiatives suggests a gap that needs to be addressed. To encourage energy conservation, there could be an increased focus on awareness campaigns, incentives for using energy-efficient appliances, and stricter building codes that mandate energy-saving measures.

Solar Water Heater Arrangement (-0.499): The moderate negative correlation indicates a need to promote solar water heater adoption. This could be achieved through subsidies, tax rebates, and awareness programs highlighting solar water heaters' long-term cost savings and environmental benefits.

Number of Vehicles Owned (-0.209): The small negative correlation with vehicle ownership suggests that urban planning and development should prioritize public and non-motorized transit options. This would reduce the reliance on personal vehicles, lowering the carbon footprint associated with transportation.

Willingness to Upgrade Sustainability (1.0): The perfect correlation shows a solid consumer base ready to invest in sustainability. This presents an opportunity for financial institutions to offer green loans or mortgages that favor investments in sustainable home upgrades. Additionally, the government could provide grants or tax incentives to support such investments.

In conclusion, the willingness of Indian households to invest in sustainability, despite higher electricity consumption, is a positive sign for the decarbonization of the building sector. By capitalizing on this willingness and addressing the barriers to adopting sustainable practices, India can make significant strides towards achieving its sustainable development goals and reducing its overall carbon emissions.

5.1.11 Analysis based on energy-saving initiatives or features in the home

The following points are crucial for the sustainable development of India's building sector. Let's discuss how these can contribute to decarbonization:

Solar Water Heater Arrangement (0.442): The positive impact of solar water heaters on home energy efficiency is significant. They harness solar energy, which is abundant in India, to heat water, thereby reducing reliance on electricity generated from fossil fuels. The moderate efficiency value of 0.442 suggests that while there is a positive effect, there is room for improvement, possibly through better technology or more optimal system design. Enhancing the efficiency of solar water heaters can play a vital role in reducing the carbon footprint of residential buildings.

Number of Vehicles Owned (-0.324): The negative impact of vehicle ownership on sustainability underscores the need to shift towards more sustainable transportation options. In urban planning, this could translate to better public transport systems, infrastructure for electric vehicles, and incentives for using non-motorized transport. Reducing the number of vehicles owned by promoting these alternatives can significantly lower the carbon emissions associated with the residential sector.

Willingness to Upgrade Sustainability (1.0): The strong willingness to invest in sustainability upgrades is a positive indicator of homeowner engagement in sustainable practices. This can be harnessed by introducing policies that support home sustainability upgrades, such as subsidies for energy-efficient appliances, tax rebates for green renovations, and financial incentives for smart home systems. Such measures can encourage homeowners to actively reduce their energy consumption and carbon emissions.

In summary, the integration of solar water heating, the reduction of vehicle dependency, and the strong willingness to invest in sustainable home upgrades are vital factors that can drive the decarbonization of India's building sector. By focusing on these areas, India can progress towards its goals for sustainable development and a lower carbon economy.

5.1.12 Correlation analysis based on Solar Hot Water Heaters

The correlation value of 0.065 between the willingness to upgrade solar water heaters and the sustainability for future value indicates a very weak positive relationship. This suggests that while there is some interest in upgrading to more sustainable technologies, it is not a decisive driving factor for most homeowners. This could be due to a variety of reasons, such as the initial cost of upgrading, lack of awareness about the benefits, or satisfaction with current systems.

For decarbonizing India's building sector, it is crucial to address these barriers and encourage homeowners to see the long-term value in sustainability upgrades. The government and industry stakeholders can play a significant role in this by:

Providing Incentives: Offering subsidies or tax rebates for upgrading to solar water heaters can make the initial investment more attractive.

Raising Awareness: Educating homeowners about the long-term economic and environmental benefits of solar water heaters can help shift the perception of their value.

Improving Accessibility: Making it more accessible to purchase and install solar water heaters through streamlined processes and better availability can increase their adoption.

Demonstrating Success: Showcasing successful case studies of upgrades can serve as a powerful motivator for others to follow suit.

Given the low correlation value, it's also important to consider other factors that might influence the decision to invest in sustainability. These could include the current state of the building, the availability of financing options, the perceived reliability and performance of solar technology, and broader environmental attitudes.

Further analysis into these areas could provide deeper insights into how to effectively promote sustainability in the building sector. It's also worth noting that while individual actions are essential, systemic changes such as improved building codes, integration of renewable energy into the grid, and urban planning that reduces the need for heating and cooling are also critical for achieving sustainable development goals.

In summary, while the willingness to upgrade to solar water heaters is currently a weak predictor of sustainability value, there is potential to strengthen this relationship through targeted policies, education, and incentives. By doing so, India can make significant progress in reducing the carbon footprint of its building sector and moving towards a more sustainable future.

5.1.13 Analysis of the Number of Vehicles that a Person own

The correlation values offer a nuanced understanding of the factors influencing vehicle ownership, which can be leveraged to inform strategies for decarbonizing India's building sector. Here's a discussion on these points:

Home Ownership (0.219): The positive correlation with home ownership suggests that homeowners may have more vehicle investment resources. For sustainable development, this indicates an opportunity to target homeowners with incentives for adopting electric vehicles and installing renewable energy charging systems at home.

Type of Home (-0.283): The negative correlation might reflect urban living where public transportation is more accessible, reducing the need for personal vehicles. Promoting urban development that encourages public transit use can help reduce transportation-related emissions.

Occupation Status (-0.219): The negative correlation with certain occupation statuses could be used to identify groups less likely to own multiple vehicles. Tailored awareness campaigns can be directed at these groups to promote sustainable commuting options.

Individual Water Meters (0.039): Although the correlation is weak, individual water meters suggests a level of resource awareness. This can include energy conservation, promoting intelligent meters and energy-efficient appliances as a broader sustainability strategy.

Water-Saving Initiatives (-0.022): The negligible correlation indicates that water-saving initiatives are not strongly linked to vehicle ownership. However, these initiatives are still crucial for water conservation and should be part of comprehensive sustainability programs.

Water Purification System (0.120): The positive correlation suggests that households with water purification systems might also be targeted for sustainability upgrades, such as greywater recycling systems, which can further reduce the water footprint of buildings.

Sanitization Disposal System (-0.136): The slight negative correlation could indicate a preference for sustainability over luxury. Encouraging the installation of efficient waste management systems can contribute to the overall sustainability of the building sector.

Individual Meters and Monthly Bill (-0.222): The negative correlation suggests that higher utility bills may discourage vehicle ownership. This could be leveraged to promote energy conservation measures that reduce both utility bills and the carbon footprint of homes.

Electricity Consumption (0.166): The positive correlation with electricity consumption indicates that households with higher energy use might also be targeted for energy efficiency improvements, which can lead to significant reductions in emissions.

Energy-Saving Initiatives (0.373): The strong positive correlation with energy-saving initiatives suggests that households engaged in these practices might also be receptive to sustainable transportation solutions, such as electric or hybrid vehicles.

Solar Water Heater (0.415): The strong positive correlation indicates that households with solar water heaters will likely be more sustainability-minded. This can be a crucial demographic for promoting other green technologies and sustainable practices.

Sustainability Upgrades (0.054): The weak correlation suggests that while there is some interest in sustainability upgrades, it is not a strong predictor of vehicle ownership. Nonetheless, encouraging sustainability upgrades can positively impact the overall energy efficiency of homes.

Understanding the socio-economic and environmental factors influencing vehicle ownership can help design targeted interventions for decarbonizing India’s building sector. Strategies that promote energy efficiency, renewable energy adoption, and sustainable transportation can contribute significantly to the sector's sustainable development. By addressing these factors, India can progress towards its goal of a low-carbon economy and sustainable living environments.

5.1.14 DISCUSSION ON QUANTITATIVE ANALYSIS

Analysis of house type and property type:

The breakdown of living situations among respondents provides a snapshot of housing preferences and trends, which are essential considerations for decarbonizing India’s building sector. Here’s how these insights can be integrated into strategies for sustainable development:

• Owned Apartments (19.94%): The preference for apartment ownership in urban areas can be aligned with sustainable development by promoting green building practices. This includes using energy-efficient materials, solar panels, and waste-reduction systems. Urban apartments can also be designed to maximize natural light and ventilation, reducing the need for artificial lighting and air conditioning.

• Owned Individual Houses (21.97%): The focus can be on energy efficiency and renewable energy integration for individual houses. Homeowners can be encouraged to install solar water heaters, and rainwater harvesting systems, and adopt sustainable landscaping practices. Additionally, incentives for retrofitting existing houses with energy-saving technologies can help reduce their carbon footprint.

• Rented Apartments (24.57%): The high percentage of rented apartments suggests a transient population that may benefit from flexible energy solutions. Landlords can be incentivized to upgrade rental properties with energy-efficient appliances and smart meters. Moreover, policies that mandate a minimum energy performance standard for rental properties can ensure that renters live in sustainable homes.

• Rented Individual Houses (33.53%): The popularity of renting individual houses presents an opportunity to promote sustainable living practices among a wider population. Educational programs on energy conservation, water-saving techniques, and waste management can be implemented to engage tenants in sustainability efforts.

The slight preference for renting over owning indicates a potential for mobility and flexibility in housing choices. This can be leveraged to introduce innovative housing models that prioritize sustainability, such as co-living spaces with shared resources and community-based renewable energy projects.

The data also suggests economic barriers to home ownership, which could be addressed by affordable housing initiatives that do not compromise on sustainability. For instance, government-subsidized housing projects can be designed to be both affordable and environmentally friendly, with features like efficient insulation and communal green spaces.

In conclusion, understanding individuals' living situations and preferences is crucial for tailoring decarbonization efforts in India’s building sector. By aligning housing trends with sustainable development goals, India can create healthier, more efficient, and environmentally friendly living spaces that contribute to the broader objective of a sustainable low-carbon economy.

5.1.15 Analysis of the sort of house and its spacious

The preferences for homes of different sizes, as indicated by the data, can be integrated into strategies for decarbonizing India's building sector in the following ways:

2-Bedroom Homes (34.16%): The popularity of two-bedroom homes can be leveraged to promote compact and efficient housing designs that reduce material use and energy consumption. Developers can focus on creating multi-functional spaces that serve various needs while maintaining a smaller ecological footprint.

3-Bedroom Homes (33.61%): For three-bedroom homes catering to growing families, there is an opportunity to incorporate sustainable building materials and energy-efficient systems from the outset. This can include better insulation, energy-efficient windows, and integrating renewable energy sources like solar panels.

4+ Bedroom Homes (32.23%): Larger homes with four or more bedrooms offer the potential for advanced sustainability features. These could include home automation systems for optimizing energy use, greywater recycling systems, and geothermal heating and cooling systems. Additionally, these homes can be designed to accommodate green roofs or solar farms if space permits.

The even distribution of preferences across different home sizes suggests a need for a diverse approach to decarbonization, catering to various housing types. It also indicates the importance of scalable solutions that can be applied across different types of buildings to maximize impact.

This information is crucial for real estate developers, urban planners, and policymakers in planning sustainable urban development. It highlights the need for flexible building codes that encourage innovation in sustainable design and construction practices. Moreover, it underscores the importance of incentive programs that make sustainable options more attractive to developers and homeowners.

In the context of marketing strategies, real estate agents can highlight the long-term cost savings and environmental benefits of sustainable homes to potential buyers and renters. This can help shift consumer preferences towards more sustainable living spaces.

5.2 Discussion on home ownership status and occupational status

The insights from the heatmap analysis can be instrumental in shaping strategies for decarbonizing India’s building sector. Here’s how the points you’ve described can contribute to sustainable development:

Home Ownership Status: Understanding the balance between rented and owned properties can guide the implementation of energy efficiency standards and sustainable building practices. Owners could be incentivized to invest in renewable energy sources or energy-efficient renovations for owned properties. For rental properties, regulations could ensure that landlords meet specific sustainability standards, which would also benefit tenants by reducing utility costs.

Occupation Status: The occupation status of individuals can influence their ability to invest in sustainable housing. For instance, self-employed individuals with variable incomes might benefit from flexible financing options for sustainable home upgrades. Retirees who own their homes might be interested in retrofitting their properties to reduce energy costs. Full-time employees, particularly those renting, might advocate for green amenities in rental properties as part of their lease agreements.

The heatmap's ability to highlight trends such as the prevalence of renting among full-time employees can inform policies that encourage sustainable living regardless of homeownership status. For example, urban planning can focus on creating affordable housing close to employment hubs to reduce commute times and transportation emissions. Additionally, promoting public transportation and non-motorized transit options can further reduce the carbon footprint associated with daily commutes.

Moreover, the heatmap data can help identify target groups for awareness campaigns about the benefits of sustainable living and the availability of subsidies or tax incentives for adopting green technologies. This can increase the uptake of sustainable practices across different occupational statuses and living arrangements.

In summary, leveraging the socioeconomic data from the heatmap can aid in developing a comprehensive approach to decarbonize India's building sector. By aligning housing trends with sustainable development goals, policymakers and industry stakeholders can create targeted interventions that promote energy efficiency, renewable energy adoption, and sustainable living practices, contributing to the broader objective of a sustainable low-carbon economy.

The data from the bar chart indicates that a more significant number of respondents do not have access to individual water meters at their homes, which is an essential point of discussion in the context of decarbonizing India's building sector. Here's a detailed analysis:

Individual Water Meters and Energy Efficiency: These are crucial for promoting water conservation and energy efficiency. When residents are billed based on actual consumption, they are more likely to be conscious of their water usage, leading to reduced demand and energy savings. This is because less water needs to be heated, treated, and pumped, reducing the energy footprint of buildings.

Impact on Decarbonization: Decarbonizing the building sector involves reducing the carbon emissions associated with buildings, including operational emissions (from energy used in buildings) and embodied emissions (from materials and construction processes). Individual water meters can reduce operational emissions by encouraging water and energy-saving behaviors.

Barriers to Implementation: The higher count of respondents without individual water meters may reflect existing barriers such as the upfront costs of installation, regulatory challenges, or a lack of awareness about the benefits of metering. Addressing these barriers is essential for widespread adoption.

Policy Implications: For effective decarbonization, policies could incentivize the installation of individual water meters, perhaps through subsidies or rebates. Additionally, building codes could be updated to mandate water meters in new constructions and major renovations.

Long-term Benefits: Beyond immediate energy savings, individual water meters can provide long-term benefits by generating data on water usage patterns. This data can inform more targeted water conservation strategies and contribute to the overall sustainability of urban water systems.

In conclusion, while the current status of individual water meter installations, as reflected in the bar chart shows a gap, there is a significant opportunity to leverage this tool for energy savings and decarbonization of India's building sector. Strategic efforts to promote the adoption of individual water meters can play a vital role in achieving a more sustainable and low-carbon future

The sunburst chart's depiction of water-saving initiatives in homes is a valuable indicator of the progress in residential water conservation, a key component in the broader strategy for decarbonizing India’s building sector. Here’s a detailed discussion on how these initiatives contribute to this goal:

Dual Flush Toilets (46.80%): The widespread adoption of dual flush toilets, as indicated by the largest segment in the chart, is a significant step towards reducing water usage in homes. These toilets can save substantial water compared to traditional single-flush systems by providing two flush options. In the context of decarbonization, reduced water usage leads to lower energy consumption for water heating and treatment, thereby decreasing the overall carbon footprint of residential buildings. Green buildings in India, certified by the Indian Green Building Council (IGBC), have shown 20-30% water savings, and dual flush toilets can contribute to such savings.

Rainwater Harvesting Systems (40.40%): Implementing rainwater harvesting systems in over 40% of homes reflects a commitment to utilizing alternative water sources. This practice alleviates pressure on municipal water supplies and reduces the energy required for water delivery and treatment. Rainwater can be used for non-potable purposes, decreasing the demand for heated water, contributing to energy savings and carbon emission reductions. Integrating such systems is aligned with green construction practices that minimize resource wastage and carbonization.

None of the Above (12.80%): The segment of homes that have not adopted any water-saving initiatives represents an opportunity for further expansion of such measures. Encouraging the adoption of water-saving technologies through awareness campaigns, incentives, and regulations can enhance water efficiency across more homes, thus supporting the decarbonization efforts.

In addition to these initiatives, decarbonizing India’s building sector involves a holistic approach that includes energy efficiency, use of sustainable materials, and incorporation of renewable energy sources. India's Energy Conservation Building Code mandates on-site renewable energy generation for new constructions and renovations of large buildings, a step towards zero-carbon buildings.

Overall, the adoption of water-saving initiatives as shown in the sunburst chart is a positive trend that contributes to the sustainability and decarbonization of India’s building sector. It highlights the role of individual actions in the collective effort to reduce carbon emissions and combat climate change. As the sector evolves, more homes are expected to integrate such technologies, furthering the progress towards a greener and more sustainable future.

The data from the bar chart indicating a high prevalence of water purification systems in homes is a significant observation in the context of decarbonizing India’s building sector for sustainable development. Here’s a detailed discussion on the points raised:

Response Comparison: The stark contrast in the number of respondents with (237) and without (13) a water purification system underscores the importance placed on home water quality. This trend is reflective of a broader awareness of health and environmental concerns.

Majority Ownership: The fact that the majority of respondents have a water purification system suggests a prioritization of clean drinking water, which is essential for health and well-being. Such systems can also indicate the respondents' socio-economic status, as water purifiers are often seen as a value-added amenity in urban homes.

Minority Without: The small number of respondents without a water purification system could indicate a lack of awareness, financial constraints, or access to safe municipal water that doesn’t require further purification.

Energy Efficiency: Water purification systems, especially energy-efficient ones, can contribute to the overall energy efficiency of buildings. By using less energy to purify water, these systems can help reduce the carbon footprint of residential and commercial buildings.

Sustainable Development Goals (SDGs): Access to clean water and sanitation is a crucial aspect of SDG 6, directly related to sustainable development. The widespread use of water purification systems in homes aligns with India's efforts to achieve this goal.

Green Building Standards: Buildings with water purification systems can contribute to achieving higher green building standards, such as the Indian Green Building Council (IGBC) certification, which includes water conservation and management as a critical component.

Water-Energy Nexus: Adopting water purification systems is part of the water-energy nexus, where saving water also results in energy savings. This is particularly relevant in decarbonizing the building sector, as water and energy conservation are essential for reducing greenhouse gas emissions.

Public Health and Environment: Ensuring access to purified water through in-home systems can benefit public health by reducing the incidence of waterborne diseases. This, in turn, can lead to a reduction in healthcare-related energy consumption and associated carbon emissions.

In conclusion, adopting water purification systems in homes is a positive step towards sustainable living and can play a role in the decarbonization of India's building sector. It reflects a move towards self-sufficiency in water quality management and contributes to the broader goals of energy conservation, public health, and adherence to sustainable development standards.

The data from the bar chart showing the preference for septic tanks over public drains for sanitation water disposal is a significant point of discussion in the context of decarbonizing India's building sector for sustainable development. Here's a detailed analysis:

Public Drain (Count: 18): The lower count for public drains could indicate limitations in the public sanitation infrastructure or a preference for private sanitation solutions. Public drains are typically associated with centralized sewage treatment plants, which can be more energy-intensive due to the need for pumping and treating large volumes of wastewater.

Septic Tank (Count: 232): The higher count for septic tanks suggests a reliance on decentralized wastewater treatment in the surveyed area. Septic tanks are a form of on-site sanitation that can be more sustainable if appropriately managed. They treat and dispose of household wastewater locally, reducing the need for extensive sewer networks and large-scale treatment plants.

Decarbonization Implications: Decentralized systems like septic tanks can contribute to the decarbonization of the building sector by reducing the energy required for wastewater conveyance and treatment. However, they must be designed, installed, and maintained correctly to prevent groundwater contamination and methane emissions, which can be potent greenhouse gases.

Sustainable Development: The preference for septic tanks aligns with sustainable development goals, as they can be part of an integrated approach to water and sanitation that conserves resources and minimizes environmental impact. However, it's crucial to ensure that septic systems are part of a broader strategy that includes safe collection, treatment, and disposal or reuse of wastewater.

Policy and Infrastructure Planning: The data can inform policy decisions and infrastructure planning by highlighting the need for improved management of decentralized systems and the potential for integrating them into a circular economy approach, where waste is treated as a resource.

In conclusion, the survey responses indicating a strong preference for septic tanks over public drains can be seen as an opportunity to promote sustainable sanitation solutions within India’s building sector. Properly managed, these systems can play a role in reducing the carbon footprint of sanitation services and contribute to the overall goal of sustainable development. Policymakers need to consider these preferences and the potential environmental impacts when planning for the future of India’s sanitation infrastructure.

The survey data indicating varying levels of electricity bills among households with individual electricity meters is a valuable indicator of energy consumption patterns, which are crucial for the decarbonization of India’s building sector and sustainable development. Here’s a detailed discussion on these points:

Less than INR 1000: The fact that most respondents have monthly electricity bills under INR 1000 suggests a prevalence of low energy consumption or effective energy-saving practices among these households. This could be due to the use of energy-efficient appliances, LED lighting, or conservative energy usage habits. Promoting such practices and technologies across more households for decarbonization can significantly reduce energy demand and associated carbon emissions.

INR 1000 - 3000: A significant number of households falling into this category may indicate a mix of energy consumption behaviors, with some households potentially having room for improvement in energy efficiency. Targeted interventions, such as energy audits and retrofitting older buildings with better insulation and energy-efficient systems, can help move more households into the lower-cost bracket, contributing to the overall energy efficiency of the building sector.

More than INR 3000: The smaller number of households with higher electricity bills could reflect larger homes, higher energy consumption appliances, or less efficient energy use. This group represents an opportunity for introducing high-impact energy-saving measures, such as adopting renewable energy sources like solar panels, which can offset high electricity costs and reduce reliance on fossil fuels.

The distribution of electricity bills provides insights into the potential for energy savings and the need for different strategies across various population segments. For sustainable development, it is essential to ensure that energy efficiency and decarbonization efforts are inclusive and address the needs of all households. This includes providing affordable access to energy-efficient technologies, renewable energy sources, and education and incentives to encourage energy-saving behaviors.

In conclusion, understanding the economic impact of energy costs on households and their energy consumption patterns is crucial in developing effective strategies for decarbonizing India's building sector. By focusing on energy efficiency, promoting renewable energy, and ensuring equitable access to sustainable energy solutions, India can make significant strides towards achieving its sustainable development goals and reducing its carbon footprint.

5.3 Key Findings

5.3.1 Discussion on energy-saving initiatives

- The survey responses in the horizontal bar graph provide a snapshot of the energy-saving measures adopted in homes, essential for decarbonizing India's building sector and sustainable development. Here's a detailed discussion on these points:
- Energy-Efficient Appliances (Count: 155): Most respondents having energy-efficient appliances is a positive sign. These appliances consume less electricity, which can

significantly reduce the overall energy demand and carbon emissions from the residential sector. Energy-efficient appliances are a crucial component in green buildings, which are certified to result in 20 – 30% energy savings compared to conventional buildings.

- LED Lighting (Count: 44): Although fewer respondents use LED lighting, it's an energy-saving feature that offers substantial benefits. LED lights consume up to 85% less energy and last up to 25 times longer than traditional incandescent bulbs. Adopting LED lighting is a simple yet effective step towards reducing the carbon footprint of households.
- Solar Panels (Count: 39): Although less common, solar panels indicate a move towards renewable energy sources in residential areas. Solar panels can significantly reduce reliance on fossil fuels for electricity generation, thereby contributing to the decarbonization of the building sector. They also align with India's target to meet 50% of its energy requirements from renewable energy by 2030.
- None of the Above (Count: 12): The minimal number of respondents without any listed energy-saving initiatives suggests that there is still potential for growth in adopting such measures. Increasing awareness and providing incentives for energy-saving features can further enhance their prevalence.
- The data from the graph underscores the importance of energy conservation measures in contributing to the decarbonization of India's building sector. It reflects consumer behavior and preferences, which are crucial for policymakers and businesses to understand to design effective strategies for promoting sustainable development. By focusing on energy efficiency and renewable energy adoption, India can progress towards achieving its sustainable development goals and reducing its carbon emissions, creating a more sustainable future for all.

5.4 Conclusion of findings & Result Discussion

5.4.1 Discussion on willingness to invest in sustainable development

The survey results indicate a strong willingness among respondents to invest in sustainable upgrades, which are highly relevant to the decarbonization of India’s building sector and its sustainable development. Here’s a detailed discussion:

High Willingness to Invest: The significant number of respondents willing to invest in sustainable upgrades reflects a consumer market ready to support and adopt green technologies. This readiness can accelerate the adoption of sustainable building practices, such as using energy-efficient materials and renewable energy sources, which are crucial for reducing the carbon footprint of buildings.

Low Resistance to Investment: The minimal resistance to investing in sustainability suggests a broad consensus on the importance of sustainable development. This can provide a supportive environment for policies and initiatives to decarbonize the building sector, such as subsidies for green buildings or stricter energy efficiency standards.

Survey Implications: The overwhelming preference for investing in sustainability indicates a shift in consumer priorities, focusing on long-term benefits over short-term costs. This shift is essential for the success of India’s ambitious climate goals, which include making all new construction net-zero in emissions starting in 2031. It also aligns with the global trend towards sustainable consumption practices, as evidenced by India’s progress in supporting Sustainable Development Goals.

The data underscores the potential for growth in the sustainable market, driven by consumer readiness to invest in a greener future. Policymakers and businesses can harness this readiness to drive the transition towards a low-carbon real estate sector, creating new opportunities for skilled labor, technology providers, and green building professionals. Moreover, the willingness to invest in sustainable upgrades can stimulate economic growth and innovation, contributing to job creation and the economy's overall health.

In conclusion, the survey results highlight a positive trend towards embracing sustainable practices among consumers, which is crucial for decarbonizing India's building sector. By leveraging this consumer willingness, India can make significant strides towards achieving its sustainable development goals and reducing carbon emissions, creating a more sustainable future for all.

5.5 MEASURES TO IMPLEMENT

A multifaceted approach is required to decarbonize India's building sector and promote sustainable development. Here are some measures that can be implemented:

1. Promote Green Building Practices: Encourage the construction of green buildings with sustainable materials and energy-efficient designs. This includes using natural lighting, solar panels, and green roofs.

2. Improve Energy Efficiency: Implement energy efficiency standards for new and existing buildings. This could involve retrofitting older buildings with energy-saving technologies and ensuring new constructions meet high energy efficiency criteria.

3. Adopt Renewable Energy: Increase the use of renewable energy sources in the building sector, such as solar and wind. Government incentives and subsidies can support this.

4. Implement Smart Metering: Use smart meters to provide real-time energy consumption data to consumers, encouraging them to reduce their energy use3.

5. Encourage Material Circularity: Promote the reuse and recycling of building materials to minimize waste and reduce the carbon footprint associated with producing new materials.

6. Develop Sustainable Infrastructure: Invest in sustainable urban infrastructure that supports energy-efficient buildings and reduces the need for transportation, lowering emissions.

7. Provide Financial Incentives: Offer tax rebates, subsidies, and low-interest loans for homeowners and developers who invest in sustainable building technologies and renovations.

8. Educate and Train: Conduct awareness programs and training sessions for builders, architects, and homeowners on sustainable building techniques and the long-term benefits of decarbonization.

9. Regulatory Frameworks: Establish and enforce strict building codes and regulations mandating energy-efficient appliances and systems.

10. Support Research and Innovation: Fund research into new sustainable building technologies and materials that can further reduce the carbon footprint of the building sector.

By implementing these measures, India can make significant progress in reducing the carbon emissions of its building sector, contributing to global efforts to combat climate change and moving towards a more sustainable future. These actions will require collaboration between government, industry, and consumers, but the long-term environmental and societal benefits are substantial.

CHAPTER VI:

SUMMARY, IMPLICATIONS, FUTURE RESEARCH AND CONCLUSION

6.1 Summary

Here's a summary of the analysis based on research regarding decarbonizing India's building sector for sustainable development:

1. Green Building Practices: Encourage the construction of green buildings using sustainable materials and energy-efficient designs to reduce the carbon footprint.

2. Energy Efficiency: Implement standards and retrofit existing buildings with energy-saving technologies to lower energy consumption.

3. Renewable Energy: Promote solar, wind, and other renewable energy sources through government incentives and subsidies.

4. Smart Metering: Utilize intelligent meters to provide real-time data on energy consumption, encouraging users to reduce their usage.

5. Material Circularity: Advocate for the reuse and recycling of building materials to minimize waste and production-related carbon emissions.

6. Sustainable Infrastructure: Invest in infrastructure that supports energy-efficient buildings and reduces transportation needs, lowering emissions.

7. Financial Incentives: Offer tax rebates, subsidies, and low-interest loans for investments in sustainable building technologies and renovations.

8. Education and Training: Conduct awareness programs and training for builders, architects, and homeowners on sustainable building techniques.

9. Regulatory Frameworks: Establish and enforce building codes that mandate using energy-efficient appliances and systems.

10. Research and Innovation: Support research into new sustainable building technologies and materials to further reduce the sector's carbon footprint.

The analysis also considered the socio-economic factors influencing housing preferences, such as home ownership versus renting and the number of bedrooms desired, which can inform targeted interventions for sustainability. By aligning these preferences with sustainable development goals, India can create more efficient, environmentally friendly living spaces, contributing to a low-carbon economy.

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6.2 Implications

- Decarbonizing India's building sector is a critical step towards sustainable development, and it carries several implications:
- Economic Growth: A focus on decarbonization can stimulate economic growth by creating new jobs in the green building industry, such as in the design, construction, and maintenance of energy-efficient buildings.
- Public Health: Reducing carbon emissions from buildings can improve air quality, directly benefiting public health, reducing the prevalence of respiratory diseases and other health issues related to pollution.
- Energy Security: By adopting energy-efficient practices and renewable energy sources, India can reduce its dependence on fossil fuels, enhancing energy security and resilience.
- Climate Action: Decarbonization aligns with global climate goals, helping India meet its commitments under international agreements like the Paris Agreement and contributing to the global effort to mitigate climate change.
- Innovation: The push for decarbonization can drive innovation in the construction sector, leading to the development of new materials, technologies, and practices that reduce the carbon footprint of buildings.

- Sustainable Urbanization: As urban areas grow, sustainable building practices can ensure that new developments are environmentally friendly, supporting sustainable urbanization efforts.
- Alignment with SDGs: Decarbonizing the building sector contributes to several Sustainable Development Goals (SDGs), including affordable and clean energy, sustainable cities and communities, and climate action.
- These implications highlight the multifaceted benefits of decarbonizing the building sector for the environment, the economy, and society. It's a complex challenge that requires coordinated efforts across various sectors and stakeholders..

6.3 Limitations

6.3.1 No Regulatory Frameworks:

Existing energy codes and regulations often lack any regulatory frameworks. They exist but are not adhered to since there are no strong enforcement regulations and mechanisms. This leads to non-compliance and missed opportunities for energy savings. The same is valid with building codes, which have been mapped out but are not frequently used. For water, the coding system does not even exist.

6.3.2 Limited bandwidth:

Local authorities and building professionals lack awareness of the issues in question relating to Decarbonization

6.3.3 Piecemeal Initiatives:

Inconsistent policies across different government departments and jurisdictions do not lead to any momentum in promoting decarbonization.

6.3.4 Market Barriers to Sustainable Technologies

• High upfront costs: Energy-efficient technologies and sustainable building materials often have high capital expenditures, which deter builders and homeowners from adopting them, although the investment in the same is likely to pay back in a few years.

• Lack of awareness and incentives: Awareness about the benefits of Decarbonization can be low among stakeholders, and financial incentives to encourage green building practices are practically non-existent.

• Unequal access to finance: Small and medium-sized businesses and low-income communities often face challenges accessing financing for water and energy efficiency upgrades. It has to be mentioned here that in the last few months, financial institutions like SIDBI, SBI, and others have come forward to advance support for capital expenditure for small and medium-sized businesses for such sustainable upgrades.

6.3.5 Institutional Barriers to Decarbonization

• Land ownership and tenure issues: Complex land ownership structures and short lease terms can discourage investments in long-term building improvements, resulting in Net Zero Water and Net Zero Energy for the campus.

• Lack of skilled workforce: The construction industry has not put much thought towards Net Zero Water and Net Zero Energy initiatives and often lacks skilled workers qualified to design, install, and maintain water-efficient and energy-efficient technologies.

• Inefficient procurement practices: Government procurement processes prioritize the lowest price bidder, which does not encourage and prioritize water and energy efficiency and sustainability, hindering progress on Decarbonization.

6.3.6 Knowledge and Data Gaps

• Limited data on building water and energy use: Lack of comprehensive data on existing buildings' Water and Energy performance makes it difficult to devise solution frameworks and measure their progress.

• Digitizing systems: Robust monitoring and recording systems are crucial for ensuring that decarbonization measures deliver expected results and are visible to everyone, but these are often missing or underdeveloped.

• Limited research and development: Sensible thinking should guide the path to innovative technologies in decarbonization. Further, continued research and development will help identify such technologies and solutions for Indian building contexts.

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