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INVESTIGATING THE STATE OF GREEN SOFTWARE ENGINEERING IN ZIMBABWE: A CASE STUDY OF TANO DIGITAL SOLUTIONS.

BY

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A DISSERTATION/THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELORS IN SOFTWARE ENGINEERING IN THE COLLEGE OF ENGINEERING AND APPLIED SCIENCES

2024

ABSTRACT

This research sought to investigate the state of Green Software Engineering in Zimbabwe , with a case study of a local IT firm TANO Digital Solutions.The research involved case study of university students at Africa University who were presented with a survey which is the main data collection instrument . Data collected was analysed and presented to offer a platform for comparison with existing literature so as to validate the study's findings. Results highlighted the lack of understanding Zimbabweans have in relation to the concept of Sustainability and the digital industry. Cultural and Socio-Economic factors including implementation costs , lack of awareness and inadequate training impact the implementation of Green software engineering in Zimbabwe.The study is concluded by recommendations to various stakeholders on their individual responsibilities of ensuring sustainability.

Key Words: E-Waste; Green Software Engineering(GSE); Sustainability

DECLARATION PAGE

I declare that this dissertation is my original work except where sources have been cited and acknowledged. The work has never been submitted, nor will it ever be submitted to another university for the award of a degree

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ACKNOWLEDGEMENT

Firstly, I would like to thank my supervisor Mr Makambwa for his patience and guidance throughout the process of this dissertation and his assistance in selecting a topic to the successful completion of the research.

DEDICATION

I dedicate this project to my family and friends, through their everyday help and inspiration as I pursued this. I would also want to thank my parents Mr & Mrs Mahachi, and University Lecturers. I would not have made it without your encouragement and financial support and understanding during my period of study, and all those who stood by me to make it up to the end.

LIST OF ACRONYMS AND ABBREVIATIONS

CFE	Carbon-free energy
SDG	Sustainable Development Goal
VMs	Virtual Machines
SDLC	Software Development Life Cycle
CSR	Corporate Social Responsibility
GSE	Green Software Engineering
E-Waste	Electronic Waste
CO2	Carbon Dioxide
UN	United Nations

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CHAPTER 1 INTRODUCTION

1.1 Introduction

The research is aimed at assessing the state and current application of environmentally sustainable software engineering practices within the African region. Due to the increase in demand within the software engineering field, it has become of paramount importance to acknowledge the environmental impact of the software development process. Sustainable development refers to resource use for meeting the needs of humans while taking into account the ecological, economic, and societal impacts. Software indirectly affects the environment by controlling the hardware it runs on, but there has been some recent effort to create green and sustainable software, including designing tailored software processes to assist all necessary stakeholders in producing sustainable Software products.

Naumann et al proposed the GREEN SOFT approach for sustainable software development, the four-part framework aims to assist software developers, administrators, and users create, manage, and utilize green software. Software itself in modern day is used to optimize the energy usage and resource over-consumption within IT industries. Therefore, instead of focusing on curating “Greener” software's, a shift from the general view can be made in which Software can be used to monitor and assess whether resources are being used efficiently. Through this exploratory research, we dive deeper into the concept of sustainable practices as we look to draw further attention to the measures being taken to ensure “GREEN” software engineering through-out the African continent.

1.2 Background Study

The name ‘Software Engineering’ was proposed in 1969 at a NATO conference to discuss software development problems, large software systems were late, did not deliver the functionality needed by their users, cost was more than expected, and were unreliable. Nigeria, Kenya, Egypt, and South Africa, for example, have emerged as booming digital centers with a pool of highly qualified and experienced engineers. With an estimated 690,000 software developers, Africa has a rapidly increasing digital talent pool that is expected to rise dramatically in the coming years. The development of a local software industry can therefore lead to many positive externalities and is a necessity if African countries are to adapt software technology to suit local needs. "Software production is nowadays an industry, essential for the growth of the economies of the developing countries and the launching of programs to promote strong and indigenous software industries is a priority task." (Fialkowski 1990).

Some of the environmental implications of software development are high energy consumption. This is because developing, maintaining, and using software requires a considerable amount of energy. This energy is often derived from nonrenewable sources like fossil fuels such as coal, which contribute to carbon emissions and global warming. The indirect environmental impact of software development extends to the extraction of raw materials and the manufacturing processes required to build the physical infrastructure for instance servers, computers, networking equipment that software development and deployment rely on. Raw materials involved range from copper, silicon and lithium for the racks of servers, to the aluminum, steel and concrete of

the actual buildings. These activities contribute to habitat destruction, pollution, and greenhouse gas emissions.

In addition, the disposal of electronic trash resulting from old or obsolete software and hardware poses a substantial environmental risk. As electronics sales in African countries increase rapidly, so does the emergence of e-waste, which is driven by foreign trade and domestic consumption. In 2019, Africa created 2.9 million Tonnes of e-waste, equivalent to 2.5 kg per person. Although Africa has the world's second lowest per capita e-waste creation, more than 60% of it comes from imports. Electronic garbage includes hazardous chemicals and toxins that may damage the environment, and improper disposal of such material can cause toxification of water bodies, and landfills on land. Furthermore, Energy consumption from software creation and usage produces carbon emissions, which contribute to climate change. In fact, the software industry currently accounts for 2% to 3% of global emissions, according to the UN very close to that associated with the aviation industry.

The production of computer gear and the cooling of servers need a large quantity of water. Without getting too technical a data center is a building that connects computer equipment and infrastructure to store, process, and disseminate information. Given that data centers rely on power, they must be kept cold to avoid overheating and disrupting services. As a result, technology-related companies require some form of cooling equipment for their data centers, and in most situations, water cooling towers are utilized to guarantee that these centers are properly cooled. According to estimates, depending on the size of the data center, between 5 and 20

million liters of water are required every day, which is roughly equivalent to what a small town may consume. These statistics and knowledge available on the African software development scene, has given a more eminent reason for “Green Software Engineering” adoption.

Green software engineering is an emerging discipline with principles and competencies to define, develop, and run sustainable software applications. It is expected that the green software engineering will ultimately result in applications that are more sustainable whilst still efficient not only for businesses but for engineers and developers that interact with these products on a regular basis too. The increased demand is one that cannot be ignored, leading to the notion that the next wave of sustainable software technology innovation is most likely to be driven by Africa itself. Various African nations have taken note of the innovation and have swiftly embraced renewable energy and other environmentally friendly alternatives, advancing over older technology. Additionally, it will seek to identify opportunities for innovation and collaboration to further promote sustainability in software development, In the African context, where issues of energy access, resource scarcity, and environmental degradation are prevalent. In this study an examination of existing literature and research related to green software engineering will be further explored, including the identification of environmentally harmful practices in software development and the exploration of potential solutions and best strategies for reducing the environmental impact.

1.2 Statement of the problem

Green software engineering seeks to recognize the potential practices within the software development process that have a negative environmental impact and identify methods to mitigate the effects of the process. This includes analyzing the energy consumption, carbon footprint, and electronic waste generated by software applications, IT Companies and various other technologies. Additionally, the aim is to highlight the lack of widespread adoption of sustainable practices in software engineering and the potential consequences for the environment.

Although green software engineering will significantly help reduce business costs as well as carbon emissions, for software developers this concept may be difficult to implement. This is due to the nature of some of the software applications, they may have less access to competing resources in a bid to maintain sustainability. Maintenance and updating of theses software's may prove difficult in the long run especially for complex systems, and the introduction of green software engineering in IT companies may require that these software developers train and advance their technical skills. However other stakeholders such as IT managers and environmental experts may not find common ground, due to the misalignment between priorities. Environmental experts will value more sustainable approaches rather than economical or profitable strategies in reference to software development. I team managers as well as business owners would be more reluctant to adopt green software engineering especially if it would have a negative impact on sales and profits as well as software efficiency. Rather the software industry needs to promote collaborations and partnerships that support sustainability and environmental impact awareness.

A lack of understanding among ICT experts concerning green ICT's contribution to environmental sustainability slows its adoption. Technology adoption is one of the mature areas of research in information systems. Carr (1999) has defined technology adoption as the 'stage of selecting a technology for use by an individual or an organization'. Initially, technology adoption in African nations is critical to their overall growth. Organizations and governments spend heavily on development that has potential to offer significant benefits and a significant change in the consumers' lifestyles. However, expenditures may not generate results if the innovations are not adopted by the intended users even in industries for instance Education, healthcare, agriculture, and governance that rely heavily on technology. Technology transfer or diffusion of new technologies between countries is very quick, but dissemination within a nation takes much time. Diffusion Of Innovation proposes that communication has a significant impact on social development within a society Diffusion refers to how an innovation spreads through a social system over time. The model by E.M. Rogers (1962) included four key components invention, communication channels, time, and social system which influence the spread of a new idea

Green Software Engineering offers various potential advantages by creating much-needed jobs through the emergence of new firms and industries that develop and trade these technologies. However, Hankel, Heimeriks, and Lago (2019) argue that organizations must overcome specific impediments to guarantee that those potential advantages are realized. Furthermore, a lack of awareness about organizational and environmental rules provides a barrier to implementing the productivity-enhancing benefits of green ICT. In developing countries such as South Africa, a huge proportion of the population lack knowledge about and skills in ICT.

Lastly, governments and policymakers play a role in the implementation of green software engineering. Without sustainable software development carbon emissions would still remain at an all-time high, electronic waste will continue to increase and the constant demand for energy will have to be met by the depleting natural resources. As a way to mitigate these negative impacts policymakers can introduce by laws and policies that makes purchasing non sustainable software more expensive forcing reluctant businesses, engineers and appropriate stakeholders to go green

1.3 Research Objectives

1. Examine the current state of Software development methodologies utilized by African tech-companies.
2. Assess the potential role communication plays in facilitating knowledge dissemination on the concept of "Green Software Engineering" channels, social networks, and governments.
3. Evaluate the effectiveness of African Government intervention and policy making in promoting software implementation.
4. Investigate the impact of implementing green software engineering practices on the environment and the potential Economic benefits.
5. Identify potential barriers (such as technical skills) that would hinder the adoption of green software engineering in the African technology sector.

1.4 Research Questions

1. What is the state and impact of current Software development methodologies in Africa, and possible “Green” approaches that could be introduced to mitigate the negative impact?

2. How do the energy consumption patterns of software development in African countries contribute to environmental challenges, and what sustainable practices can be implemented to address these issues?

3. What may hinder the effective adoption of green software engineering practices within Zimbabwe. States the various methodologies and software models that may assist in overcoming adoption barriers?

4. How can the integration of renewable energy sources and energy-efficient technologies in software development contribute to environmental sustainability in African countries?

5. What roles does the society and relevant stakeholders have in ensuring that the software technologies they use assist in promoting sustainability in their nation.?

6. How do cultural and socio-economic factors impact the implementation of green software engineering practices in Zimbabwe, and how can these factors be addressed to promote sustainable technology development?

7. What are the potential economic and environmental benefits of transitioning to sustainable software development practices in Zimbabwe, and how can these benefits be measured and communicated to stakeholders?

1.4 Assumptions/Hypothesis

1. The implementation of green software engineering practices will lead to a reduction in the environmental impact of software development processes.

2. Sustainable practices in software engineering will contribute to improved energy efficiency and reduced electronic waste generation.

3. Organizations that prioritize green software engineering will experience long-term cost savings and enhanced environmental sustainability.

4. It is the sole responsibility of Tech Companies and software engineers to ensure and uphold green software development guidelines.

1.5 Significance of the study

The particular significance of this study lies in the potential to address environmental sustainability challenges while promoting technological advancement. Africa is experiencing rapid growth in the technology sector, and the adoption of green software engineering practices can contribute to the development whilst mitigating the environmental impact of this growth. The growing demand to go green whether in the development process or implementation, focuses on minimizing the carbon footprint by optimizing the use of computational resources and reducing energy consumption. has come about due to Additionally, the study's findings, conclusions and recommendations can provide valuable guideline to other African countries looking to invest into sustainable technology infrastructure while minimizing ecological harm.

Moreover, the implementation of green software engineering practices will strategically align with global efforts to combat climate change and promote sustainable development, thereby positioning Africa as a leader in environmentally conscious technological innovation.

1.6 Delimitation of the study

The research on green software engineering may include the focus on specific geographical regions within Africa, such as urban centers or specific countries, rather than providing a comprehensive analysis of the entire continent. In addition, attention will be drawn to the methodologies and tools during all stages of the software development process. The durability and longevity of whichever of the software's will not be taken into consideration. To add on, an investigation will be undertaken to identify areas of improvement and amendments to be made to the software engineering processes to ensure sustainability or “Green Software”. The study will take into case tech companies within the Southern African region, in which the interviewees belong to. Conclusion will be drawn from their opinions and views but is of paramount importance to establish that the perception of sustainability could vary from company to company or merely countries.

1.7 Limitation of the study

There may be some possible limitations in this study on green software engineering that may encompass factors such as potential challenges in obtaining comprehensive data on environmental impact within the African context. Another limitation that is present is the sample size is smaller as we are drawing conclusions from a tech company in Zimbabwe, it will be difficult to identify significant relationships in the data. Additionally, limitations may arise from the complexity of accurately quantifying the environmental benefits of implementing green software engineering practices. Time constraints exist that limit the quality of research output, this is because interviewees and participants are only available during a certain period on workdays. As with most studies, the design of the current study is subject to limitations by the dynamic nature of technology and software development, the findings might suffer from generalization. Furthermore, limited infrastructure exists in Africa to implement green software engineering, therefore the full impact of green software engineering may not be clearly investigated.

Chapter 2 REVIEW OF RELATED LITERATURE

2.1 Introduction

Researchers have intensively examined the concept of green software engineering, which focuses on building software systems with a low environmental effect. (Mishra 2017) This notion has grown in importance in Africa, where fast technological expansion has raised questions about the long-term viability of software development techniques. Experts have emphasized the need to create and invest in sustainable software practices that will be able to accommodate the current African and future generation's needs, without compromising the environment through depletion of resources. Green software is efficient, allowing coders to create speedier, higher-quality systems. These efficient solutions might also result in decreased expenses for businesses. "One of the main misconceptions about green software is that you have to do something extra, and it will cost extra," Kinsiveer states. "It doesn't cost extra—you just have to do things right."

“Moreover, software development processes often entail extensive use of energy-intensive resources, such as servers, storage systems, and networking equipment, leading to significant carbon emissions and resource depletion” (Uchechukwu et al., 2023). Renewable energy sources can play a key role in sustainability, with an abundance of sunlight in the African continent businesses and startups can opt for the cost savvy method of electricity generation to power their development and operations. Renewable energy not only reduces carbon emissions, but it also provides a reliable power supply for businesses to build and deploy software, even in remote regions. Noteworthy instances of sustainable software companies include the Namibian start-up

EcoFlow that creates, develops and distributes renewable energy solutions. Nigeria Lagos Reeddi Capsules manufactures solar-powered smart capsules for off-grid areas and the Silicon Cape Initiative, is a nonprofit organization in South Africa that advocates for sustainable tech startups. African governments have committed to the United Nations Sustainable Development Goals (SDG), which include bridging the digital divide and environmental conservation. Interestingly, Africa is becoming a hotspot for dynamic green technology, all due to skill pool of software engineers investing in sustainable coding practices

Bharany et al. (2022) Implied that green computing assisted organizations in reducing energy consumption levels and optimizing resource utilization but in the long run would support environmental conservation strategies. The GREEN-SOFT model is a framework that defends sustainable software, categorized into four sections and theoretically backed by software engineers as a basis of comparison and evaluation. The four categories involve a life cycle model, measurements, system models, and suggestions and devices for various partners. Practitioners of green software go beyond basic code optimization when it comes to software energy efficiency. They use tactics targeted at lowering both power usage and the consequent carbon emissions because they understand that electricity serves as a stand-in for carbon.

Corporate environmental policies and sustainability programs are critical to improving environmental sustainability in software development businesses. Aghelie (2017) defined sustainability as resolving and meeting current needs without the need to compromise the well-being of future generations. Authors Garg and Singla (2017), highlighted SMEs small and

medium-sized firms are increasing in numbers in the IT industry but many are not informed on significance of environmental sustainability. Companies that demonstrate a commitment to upholding sustainability standards help foster a culture amongst the employees by clearly defining environmental goals, which set targets for reducing energy consumption and carbon emissions. (Kunene et al., 2022).

Technology and innovation are critical to accomplishing the Sustainable Development Goals, and hence provide a road to global sustainability. Nigeria's science, technology, and innovation (STI) policy displays the government's dedication to research and innovation. Nigeria's industry witnessed the launch of the green economy Strategic framework in 2017, the strategy fell short of a green economy approach because it lacked a combined green economy approach. Across Africa in Rwanda's, the Green Growth and Climate Resilience plan was introduced whose goal was to develop a green economy that is resilient to climate change by expelling outdated technologies. Green technology and operations are a national goal connected with SDGs, requiring long-term commitment to improve resource efficiency and greener output over time.

Ibrahim et al (2020) argued that for software to be deemed “green” it must satisfy all high-level requirements of minimizing environmental impact by sustaining available resources and managing waste in development and software maintenance. There is a misconception that software in nature is environmentally due to the inadequate information on how it impacts the environment negatively. Booch (2015) Alluded to the notion that the current state of green

software is significantly different to that which has long been introduced and that the population's dependence on delicate software has seen the growth of Software sustainability as a field of interest, Venters et al, (2014). The Karlskrona Manifesto (Becker et al., 2014) highlights this new trend by serving as a focal point for the software engineering community to come together. It contends that software designers are accountable for the long-term effects of their designs, a stance shared by Cerf (2017), and presents a set of essential principles and commitments that drive sustainability design. These include the significance of acknowledging that sustainability is an explicit factor even if the major emphasis of the system under design is not sustainability, i.e. a concern independent of the system's purpose that necessitates action at various levels.

The above authors make an emphasis on highlighting that the continued study into the field of green software engineering continuously changes our perspective on it. Researchers have to increase awareness among software developers and users about the need of adopting and enforcing an environmentally friendly software development approach (K Raisian,2022). This is due to economic market fluctuations, business objectives as well as differences in today's Climate as compared to before. Green software engineering is a growing area of interest mainly because the ICT sector employs software to power data centers, base stations, and edge servers, among other infrastructures. All these software-based operating systems (OS) and apps are constructed using programming languages. Every line of software code is executed with a microscopic amount of processing power, which has a substantial impact on the energy consumption of the digital economy. This, however, soon accumulates in quantifiable energy consumption and accompanying carbon emissions, emphasizing the need for code efficiency.

According to IEA the Africa's region, demand for energy is growing, but modern energy use per capita remains among the lowest in the world, despite ample energy resources across the continent. Africa accounts for just 6% of global energy use and less than 3% of global energy-related carbon dioxide (CO2) emissions. This is telling of how data centers deplete the energy resources of African nations such as Zimbabwe or it's bordering neighbor South Africa, who have resorted to regular load-shedding to compensate for inadequate supply of electricity.

By giving priority to the creation of software that is readily upgraded and reduces the environmental effect of outdated technology, industry can help reduce the amount of electronic waste generated. Green software engineering heavily relies on the idea of sustainable design. From the get-go it is important to ensure that sustainability of software is implemented from the initial stages up until release. One data-driven example of how technological improvements are helping Africa make the shift to a more sustainable future is the Internet of Things (IoT) technology. South African industries such as the manufacturing industry and mining companies like Anglo-American are adopting the concept of IoT to track energy usage during operations. In the telecom industry giants such as MTN are currently able to identify inefficient regions and implement Policies, standards to minimize their carbon footprint all thanks to real-time IoT.

Energy-efficient data centers, multi-tenancy, virtualization, and other techniques allow cloud computing to lower energy consumption and carbon emissions, motivating companies to embrace the computing architecture (Gupta et al., 2022). A data center is a facility for storing and managing data on behalf of organizations. Large commercial data centers in South Africa

typically consume 12-20 MW of power. Just like their international counterparts, local facilities are sophisticated in their approach to power usage efficiency (PUE) and using the right mix of energy sources. “New South African cloud data centers are built to the same standards as hyperscale facilities elsewhere in the world. They focus on reducing PUE, and there’s a growing emphasis on renewable sources of energy,” said Tullett. Using cloud computing eliminates the need for energy-intensive data centers. Edge computing also makes it possible to redistribute processing near to users at a lower cost. According to authors such as Jin et al (2017), parallel computing offers a significant reduction in energy consumption by allowing multiple small-scale functions to concurrently run in one instance on multiple processors connected amongst each other by a network of shared memory.

Encompassing the entire product life cycle, including development, distribution, usage and deactivation, the GREENSOFT Model aims to balance software's positive and negative impacts, accounting for energy use and resource consumption .Furthermore, GREENSOFT model serves as a conceptual reference model for "Green and Sustainable Software," a movement aimed at assisting programmers, managers, and users in developing, preserving, and utilizing software in a more environmentally friendly manner. The software product life cycle model includes sustainability metrics and criteria, procedure models for various stakeholders, action recommendations, and tools that assist stakeholders in creating, acquiring, providing, and utilizing software in an environmentally friendly and sustainable way.

However, there is an imminent threat to the successful adoption of green software engineering that is a resistance to new modern computing techniques. This comes because of poor advocacy of the benefits new techniques bring along, take for instance in Zimbabwe where most engineers are made of a younger population, and management consists of the more mature. Management of these tech companies would be reluctant to adopt and unwilling to disrupt existing and functional workflows, especially if it means having to be trained to utilize the systems, as a result they settle for the traditional ways of computing, as alluded by (Almatrodi et al., 2023). Without the possibility of financial benefit and economic incentives businesses and organizations would find more of a reason to not engage in sustainable software development. Implementing green computing techniques frequently necessitates technical competence and resources, which may be missing in certain organizations. The complexity of integrating renewable energy sources, improving software for energy efficiency, and upgrading infrastructure creates implementation issues. Becker et al. (2015) state that one important problem in green software engineering is a lack of knowledge and skills among software engineers. Developers are unfamiliar with the environmental effect of software and the strategies used to create energy-efficient and sustainable software systems.

To summarize, the software development process themselves has an indirect impact on the environment such as energy usage, as large volumes of energy are required to power certain infrastructures such as data centers. Carbon emissions, and electronic trash creation. Addressing these environmental concerns demands a deliberate effort to embrace sustainable methods, maximize resource use, and reduce waste across the software development lifecycle (Babatunde et al., 2021). Software developers as well play a pivotal role in advancing environmental

sustainability and promoting a greener future for technology by adopting code optimization techniques, utilizing energy-efficient computing architectures, implementing sustainable software design principles, implementing green software development methodologies, and integrating renewable energy sources into software development infrastructure (Lukong et al., 2022; Pazienza et al., 2024).

2.2 Theoretical Framework

The theoretical framework is an overview of the definitions, theories and concepts involved in this study. The design of the theoretical framework is based on software process activities and sustainability elements. Embracing green development entails adopting knowledge and practices that promote environmentally friendly decisions and lifestyles, safeguarding the environment, and preserving natural resources for present and future generations (Agarwal et al., 2013). Green software engineering is an emerging discipline consisting of best practices to build applications that reduce carbon emissions. "Green Software Engineering (GSE) is the art of developing green and sustainable software with a green and sustainable software engineering process " (S. Naumann ,2010). In 1987, the United Nations Brundtland Commission defined sustainability as “meeting the needs of the present without compromising the ability of future generations to meet their own needs.” Sustainability with regards to Software Development/Engineering also known as sustainable software development is a software design, implementation, and deployment approach that emphasizes energy efficiency and environmental sustainability.

Technology Adoption is defined as a sociological model that describes the adoption or acceptance of a new product or innovation, according to the demographic and psychological characteristics of defined adopter groups. In the context of green software engineering, the process by which software development companies, IT professionals, and developers in Africa study, implement, and integrate sustainable software engineering technologies, methods, and practices into their workflows and operations.

The GREENSOFT model is a conceptual framework for developing green and sustainable software. The model consists of five main components: 1 software product design, 2 software development and engineering, 3 software operations and maintenance, 4 software disposal and recycling, and 5 software quality assurance. It promotes sustainability among software creators, administrators, and users. This model focuses on the life cycle of a software product. The life cycle suggested by Naumann et al. (2011) differed from the traditional life cycle in that it aimed for sustainability by evaluating environmental, social, and human compatibility, as well as total product economics.

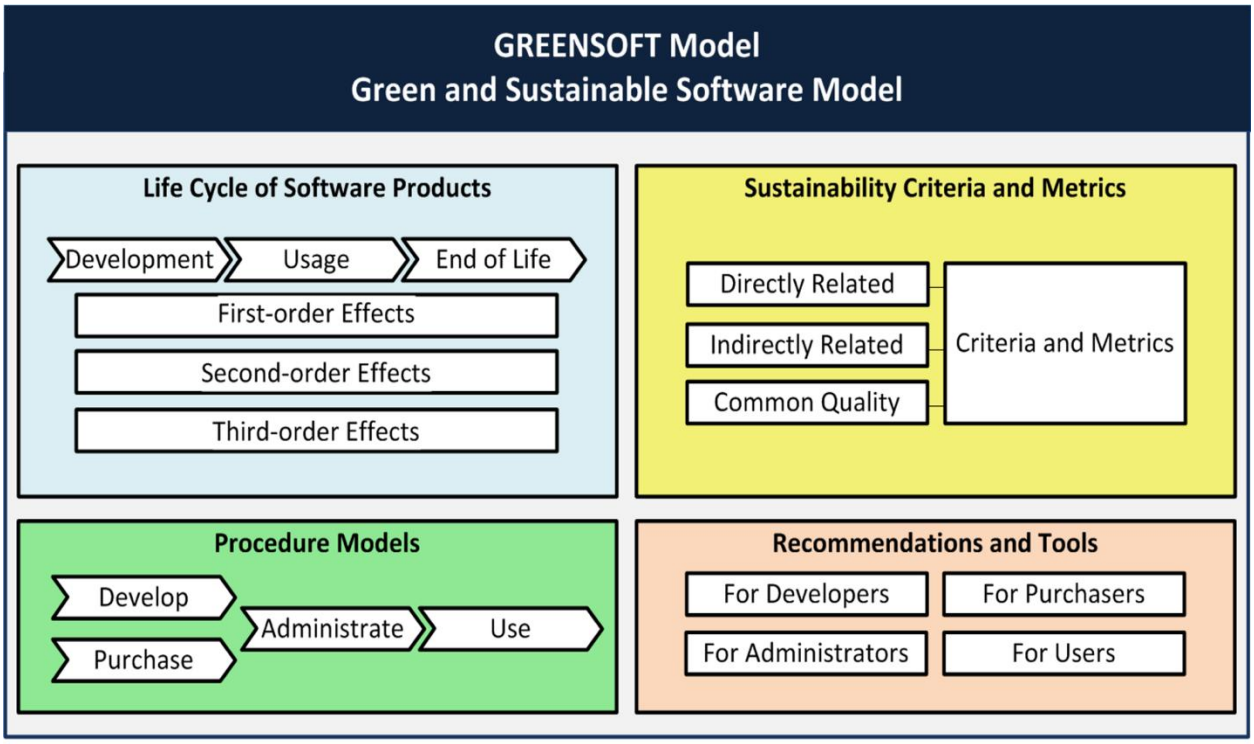


Figure 1: GREEN-SOFT Model

The GreenSoft model is an effective model that can be utilized to investigate the state of green software engineering across the continent. It serves as a lens to examine the current situation in the afro-industry, due to its systematic framework it can be used to compare, assess and improve the overall sustainability of systems. The comprehensive approach can determine the extent of environmental harm the systems could potentially inflict, throughout their existence from theory conception to production. When companies adopt policies to reduce their ICT environmental impact, they do not just lower their carbon footprint and become more resilient, they also reduce office costs and ensure their corporate social responsibility. The latter two are often mentioned as the main drivers to adopting sustainable policies by tech start-ups and SMEs in Africa, this came out of an ICT Sustainability survey launched by ITC's #FastTrackTech Africa. In this regard, the

ICT sustainability survey's core aim was to identify, analyze and evaluate the nature of ICT sustainability within the African technology industry. In addition, between the period of November 2020 up until March 2021, approximately 80 tech start-ups and SMEs from west and east Sub-Saharan Africa had actively participated and completed the survey.

The survey further highlighted the various needs and development practices of tech start-ups stakeholders. Statistics read as follows, 15% of respondents were not complying to international ICT voluntary sustainability standards such as ISO 14001 or ISO 50001.A staggering 71% were not aware of their company's bandwidth consumption, and most confessed that they had no policies set-up to mitigate environmental impact with 5% rating their environmental impact negatively. Up to 32% of respondents in East Africa and 50% of the respondents in West Africa indicated they manage their company’s electronic waste mostly by donating or selling the electronics. The #FastTrackTech Africa initiative of the International Trade Centre has responded to this need by developing a training curriculum, Greening ICT for tech SMEs, in partnership with Sustainable Business Consulting Kenya.

To evaluate the "Greenness" of a software application or system, the Greensoft model will assess it against a sustainability criterion which will investigate energy efficiency, carbon emissions, resource consumption and social responsibility. In addition, it provides a standard methodology for improving the sustainability of existing software systems, through effective goal formulation and impact evaluation procedures. One method is introducing ML Machine learning and AI artificial intelligence into the software development process. Artificial intelligence and Machine

learning can learn from past and existing data and improve performance by identifying patterns and trends without explicit programming. Therefore, processes can be optimized to run more energy efficiently, and flexibly as these technologies operate 24hrs. As a result, they hold the key to harnessing value across different sectors throughout the African continent. Financial sectors are already benefiting from these technologies as the machine learning algorithms are detecting fraud, anticipating market trends and processing bulk volumes of transactional data.

Exploring how this process-oriented approach may be modified and implemented in the African setting may provide insights into viable tactics for promoting green software engineering techniques in the area. The Greensoft Model emphasizes involving stakeholders, such as developers, users, and policymakers, to promote sustainable software development. Analyzing stakeholder engagement and cooperation in the African green software engineering ecosystem may reveal ways to deepen these links and promote a more collaborative approach to sustainability. Collaboration across sectors, including technology, energy, and environmental research, is critical for promoting green software development techniques. Industry leaders can advocate for the adoption of sustainable technology and experience real change towards acquiring worldwide sustainability goals through partnership and dissemination of best practices.

Governments are imposing strict environmental regulations and policies, with the aim to fight greenhouse gas emissions, promote energy efficiency and minimize environmental impacts. As a result, software development companies are motivated to implement sustainable practices into

their current operations to ensure standard compliance. In the long run, the organizations avoid the risk of penalties and improve their reputations as socially responsible corporations.

To curb increasing environmental concerns, green software has developed a crucial strategy to reduce digital technology impact. This paradigm change requires using sustainability concepts across the software development lifecycle, from original design to deployment and continuous maintenance. The advantage of the maturity model was that it allowed benchmarking across different organizations and provided a framework for a roadmap for process improvement, applying this maturity model to African software enterprises and organizations would aid in better understanding the current phase of green software engineering adoption and identifying areas requiring improvement. However, it is important to note and consider that developed economies such as those in the European continent have utilized this model, therefore the model's applicability to the African context may need to be further examined due to Africa's complex socioeconomic and technological terrain.

The model's emphasis on energy-efficient software design and operations may need to change to account for these energy problems. Africa remains far behind much of the rest of the world in terms of fiber network and broadband connectivity, spectrum and data center processing capabilities. Regardless, technology infrastructure is rapidly developing, specifically the Sub-Saharan region of Africa, and this is mainly due to favorable investment incentives. The limitations of this model are that it does not take into consideration local government policies

surrounding sustainability, which may be underdeveloped or inconsistently implemented without taking local software developers and organizations in mind.

2.3 Relevance of the Theoretical Framework to the Study

Theoretical framework is a systematic review of already existing theories used to develop arguments and explain phenomena. The research receives conceptual foundations, and we can determine guidelines to understand what influences the adoption of sustainable software development practices in the African continent. Greenness as a concept was evaluated and models such as the green soft framework were discussed in how they help organizations and people integrate sustainability into the already existing software development process. The theoretical framework highlighted the key progress being made by small tech startups in Africa who have adopted this concept in a bid to play their role in achieving the SDG goals as set by the UN.

CHAPTER 3 METHODOLOGY

3.Introduction

In this Chapter a detailed description of how the Study will be undertaken to investigate the state of green software engineering in Africa. According to Schwardt (2007) research methodology is a theory of how an inquiry should proceed. In the research methodology research design, data collection methods will be discussed, including data analysis techniques and ethical considerations. The chapter therefore explains how the data for the study will be collected, interpreted and presented.

3.2 The Research Design

A research design is an approach or framework for conducting a research project, which entails describing an approach and procedure for collecting and analyzing data with the purpose of answering research questions. According to Leedy (1997), research design is a study framework that outlines data collection methods. A well-structured study should include a clearly stated research topic, a detailed data collection plan, and a process for evaluating and interpreting the findings. Durrheim (2004) defines research design as a strategic framework that connects research topics to strategy execution. The researchers MacMillan and Schumacher (2001), define it as a research strategy that involves selecting individuals, study environments, and data collection methodologies to address specific research questions. A well-planned research design considers all of these factors.

According to Sing (1998), Correlation research design involves collecting two or more sets of data from which relationships can be identified by the researcher. So, an investigation between variables is undertaken free from researcher manipulation and controlling. The direction of a correlation can be either positive or negative, further allowing researchers to investigate patterns, trends. Johnson et al (2014) suggested a correlation coefficient, that is a numerical index that would provide valuable insight about direction and relational strength between variables. The coefficient number ranges from –1 to 1 where no correlation would be equivalent to 0, if the number is greater than zero, there is a positive correlation whereas if the number is less than zero, there is a negative correlation.

Correlational research is more suitable when research data has to be collected quickly, as a result this helps in generalizing any findings. The correlational study is non-experimental. For instance if we were to investigate non-causal relationships, we can learn more about how the world really works allowing us to make predictions. The data collection methods that would be of more use include surveys which can use questionnaires to measure your variables of interest, as they are a faster and flexible method to collect standardized data from participants. Another method in Naturalistic Observation, that involves watching and recording variables without reference in a natural setting.

Descriptive research design is quantitative research that is appropriate if the research objective is to identify trends, characteristics and frequencies. It utilizes quantitative data and qualitative research to collect information for formulating predictions about a particular problem. Aiming to

systematically and accurately describe the target population, presents views, trends, and attitudes are described. Descriptive research involves gathering data that describe events and then organizes, tabulates, depicts, and describes the data collection (Glass & Hopkins, 1984). The overall nature of Descriptive research design is immensely dependent on instrumentation for observation and measurement. Descriptive research delivers summary data including mean, median and mode used to develop statistics on the data. Mean implies an average between a set of data, median refers to the middle value when data is arranged in a numerical order and lastly, mode would be a value that frequently appears among the datasets.

According to Williams (2007), descriptive research is research design used to examine the situation involving identification of attributes of a particular phenomenon based on an observational basis. Descriptive research data collection types include the likes of Surveys in the form of semi-structured interviews to gather quantitative information on a certain problem. Descriptive Research design however has its shortcomings since as much as it may provide an understanding on the what, who and where's of a phenomenon it will however limit understanding on cause-effect of the situation. If information on a variable is not accurately sourced, take for example a study where the participants maybe engaging in socially immoral activities (substance abuse), the results may not be entirely reliable.

Ethnography is a Qualitative Research design method which primarily deals with the discovery, collection of data and description of certain group cultures. Maxwell (2013) encourages

qualitative research on the beliefs, values, aspirations and attitudes that correlate to relational bonds, phenomena that cannot be reduced as mere variables. Culture in this instance would refer to the systematic behaviors, norms and standards a society would form over many generations. It may include beliefs, morals, laws as well as a pattern of human activity, language and the interconnectedness with each other. Important to note that ethnography research is a key qualitative method in which a researcher may either observe or interact with the target population in which they play the role of obtaining critical and valuable cultural information. Participant observation is the primary data collection technique accompanied by interviews with members of the group therefore it is a fully immersive approach that is open and flexible. Instead of proving the accuracy of a general theory or testing a hypothesis, ethnography provides a rich and detailed account of the culture allowing for the exploration of different components of the tested group.

Hughes & Sharrock (2002) imply that in the context of data collection without anything significant and nothing hidden to look for, data is often laid out in plain sight. Ethnography is advantageous as it gives a researcher direct access to the behavior of a cultural group useful for a first-hand learning approach, spontaneously taking notes of dynamics, they could have been overlooked had they not been asked. However, it can prove to be time consuming especially if research conclusions are to be drawn up quickly and large amounts of observations would have to be compiled and analyzed to give an overall picture. Furthermore, in ethnographic research it is very much prone to observer bias, if a researcher would only focus on one aspect and neglect other components of the test grip. Iacono, Brown, and Holtham (2009), they identified disadvantages to this research approach that is it lacks range, as attention and focus is particularly drawn to one phenomenon resulting in criticism of lack of generalizability.

Another form of qualitative research design is a case study which is described as a detailed study of a specific topic either a group events place or phenomenon. It is the most suitable research design approach if you are seeking to describe, compare and understand different features of the research problem being addressed. Case studies have the tendency to lean more on qualitative data using methods such as interviews and observations (e.g. newspaper articles). The main types of case studies include descriptive case studies, explanatory case studies, exploratory case studies. Exploratory case studies explore the phenomenon, to gain primary insight and knowledge in which hypothesis will be drawn from. Descriptive case studies offer a detailed account of a certain case focusing on describing its processes and characteristics, to help further understanding of the case. Explanatory case study is often utilized for casual investigations to explain factors that contribute to a particular phenomenon.

3.3 Population and Sampling

Population also known as the target population may be defined as a group that possesses specific characteristics from which you seek to draw conclusions from. Malhotra NK et al (2007) implied that a small fraction of the population could make inference concerning a larger population. Creswell and Creswell (2018) clearly defining the target population is a crucial step in the research design process, as it establishes the boundaries of the population from which the study sample will be drawn. For this study, the target population consists of individuals actively working in the IT industry such as software consultants as well as normal civilians of all races, age groups, educational status, socio-economic status. Therefore, the involvement of both formal

and informal participants in the target population is supported by Hussain et al (2021), who brought focus to the significance of the contributions and presence to the informal technologies sector in developing countries. To add-on, stratified random sampling will be the sampling method of choice, as it will select a participant from each stratum.

3.4 Data Collection Instruments

1. Document Analysis is a systematic approach to review and evaluate documents both electronic and printed material. Naturally the process allows for a quality investigation as data is from established sources, review will be carried out from industry reports, publications and organizational policies related to sustainable software development in Africa.
2. Observation refers to the gathering of study data through the process of noting behavior, examining and watching events without intervention or variable manipulation. “It is an attempt to observe events as they naturally occur” Flick (2006). It may include on-site visits to the participants location, in a bid to collect firsthand insights on the implementation of green practices.

3. Questionnaires can be identified as a list of questions used to collect information from respondents. A relevant questionnaire would be one that is “valid, reliable and unambiguous” according to Richards et al (2002). Question definition and wording are important to maintain a sense of clarity and impartiality.

3.5 Data Collection Procedure

After careful consideration of the research design our study will follow, it is of paramount importance to continue our systematic approach and commence data collection. A letter requesting approval to conduct a study at Tano Digital Solutions was delivered, to ensure we had legal access to company information. After acquiring all formal permission, the collection of data will then begin from respondents.

3.6 Analysis and Organization of data

According to LeCompte and Schensul, research data analysis involves breaking data into a narrative and analyzing it to derive insights. Therefore, there's a reduction from large volumes of complex data into smaller parts that bring along clarity. The data analysis method reduces a big amount of data into smaller fragments, resulting in clarity. Particularly questionnaires will be presented in the form of Google forms, such that at the completion of the survey the responses will be gathered and displayed in the form of graphs and charts. The visual representation of data will go through narrative analysis, a method that examines data obtained from multiple sources like field observations, questionnaires and document analysis.

3.7 Ethical Consideration

Ethical considerations in research are a set of principles that guide your research designs and practices. They can be considered as the guidelines for doing and disseminating scientific and other research at higher learning institutions, including universities. Furthermore, Bartneck et al.

(2021) argue that although ethics refers to moral theory, morality refers to a complex system of rules, principles, and standards that impact or attempt to influence people's conduct. Ethics focuses on norms, assessments, and principles, rather than individual values. According to Bhandari (2022), ethical issues of study design should always be considered, including voluntary involvement that means that people can opt in or out of the research at any given time.

The ethical issues were crucial in the design and implementation of this qualitative investigation. Voluntary participation and informed consent were essential guiding concepts. All potential participants received a detailed information sheet outlining the study's purpose, data collection procedures (individual interviews and focus groups), expected time commitment, potential risks or discomforts, and confidentiality safeguards. At the same time, sample members were asked to sign a Debriefing and Withdrawal Letter. The aim of both letters was to reassure participants that their participation in the research is voluntary and that they were free to withdraw from it at any point and for any reason. Next, participants were clearly informed about the aims of the study, although they were informed that their answers were considered Confidential and used strictly for academic reasons of this research. In addition, special care will be taken to ensure that the data collection process avoids coercion, and participants are not inappropriately influenced.

Confidentiality and anonymity were strictly preserved throughout the qualitative data gathering and interpretation processes. All questionnaire responses will be securely maintained and only accessible to the researcher. The results were anonymous, meaning all names and potentially personally identifiable data would be erased, such that none of the participants would be

identifiable. The study carefully assessed the potential risks to participants, which were established to be minor because the study did not involve any physically invasive procedures

3.8 Summary

This chapter has presented the research methodology. Key aspects of the methodology discussed in this chapter include, research design, and target population, and sampling procedures. The study employs a qualitative research design to investigate the state of green software engineering in Africa. A survey of the communications industry. Non-probability sampling methods such as purposive, convenience and quota sampling are to be used. Data collection methods to be used include observation and document analysis.

Chapter 4 DATA PRESENTATION, ANALYSIS & INTERPRETATION

4.1 Introduction

This chapter focuses on data presentation, data analysis and its interpretation for the investigation of the state of green software engineering in Africa. The findings were collected in relation to the research objectives in the first chapter, which sought to explore the awareness, understanding and practices of GSE within the Zimbabwean context. The survey questions were designed to uncover the level of awareness and knowledge of GSE among the respondents, assess their understanding of its principles, and evaluate the practices currently being implemented in Zimbabwean tech companies and academic institutions. The data gathered provides a critical viewpoint of the current state of Green Software Engineering by focusing on the experiences of university students as well as industry professionals working in Tech companies. Data and findings collected in the research capture the perspectives of these two distinct groups, each response represents individual opinions of the participants, offering a pathway to contribute to an even more sustainable and GREEN future. Hence, the chapter is structured to ensure clarity and consistency, firstly through a demographic presentation to provide context for the participants and paint a clear picture of their backgrounds. The findings are then sorted thematically using Visual aids, including charts and graphs to enhance the understanding and highlight trends.

4.2 Data Presentation and Analysis

The data analysis for this study was conducted using a mix of approaches, combining both quantitative and qualitative data from the two surveys. The data presented in this section was taken from the completed survey. The survey targeted employees at TANO Digital Solutions, a company providing SAP services, to assess their awareness and implementation of green software engineering practices. The second survey targeted university students in Zimbabwe specifically at Africa University, primarily from computer science, business, and other disciplines, to assess their awareness and understanding of green software engineering. Quantitative data was analyzed using descriptive statistics to summarize participants' awareness levels and their perceived importance of sustainable practices in software development. Visual representations, such as bar charts or pie charts, were employed to facilitate a clearer interpretation of the data. Qualitative data from open-ended questions within the survey were analyzed thematically to identify recurring patterns and insights, such as knowledge gaps, challenges to implementation and suggestions for improvement. The use of both approaches allowed for a comprehensive understanding of the current state of green software engineering awareness and practices, both within an organizational context and among future software engineers.

Data Analysis of Tano Digital Solutions Survey

Respondent Demographic

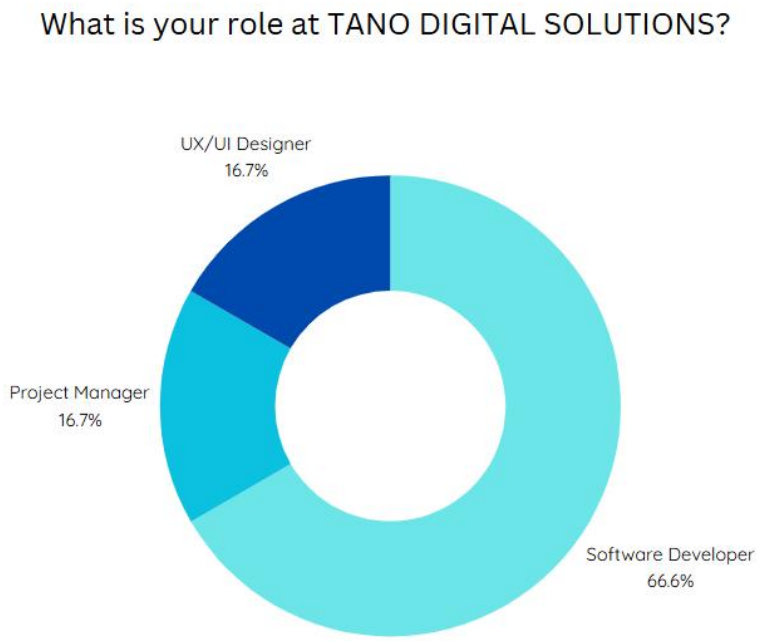


Figure 2: Role at TANO

Most respondents were software developers with them making up 66.7% of the respondents, who play a significant role in the software development process at Tano Digital Solutions. Project managers who usually oversee the product development comprised 16.7%, and the other smaller percentage made up of UX/UI Designers.

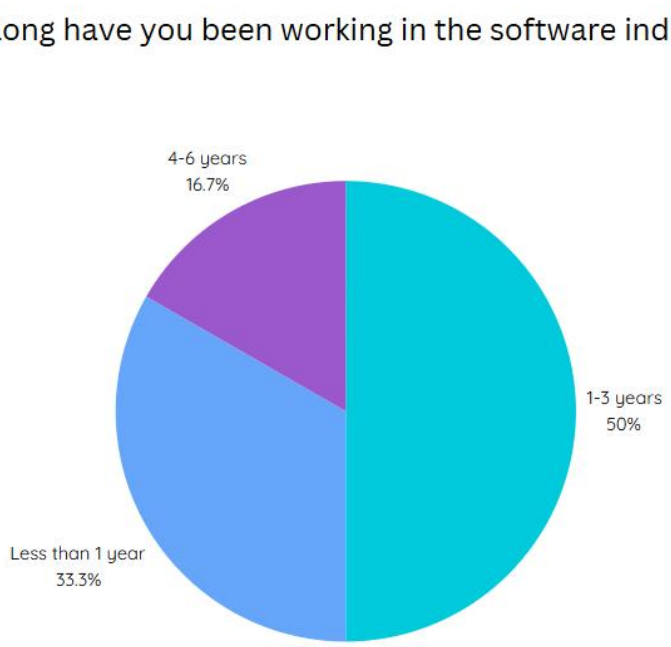


Figure 3:Time in the Software Industry

In terms of experience, it is worth noting that 66.7% employees have been working in the software industry for more than 1 year ranging between to 1-6 years, with only 33.3% registering that they are new entrants with less than a year experience in the industry. This distribution suggests that most respondents are relatively early in their careers, which may influence their familiarity with green software engineering practices and their ability to implement them effectively.

Respondent Awareness

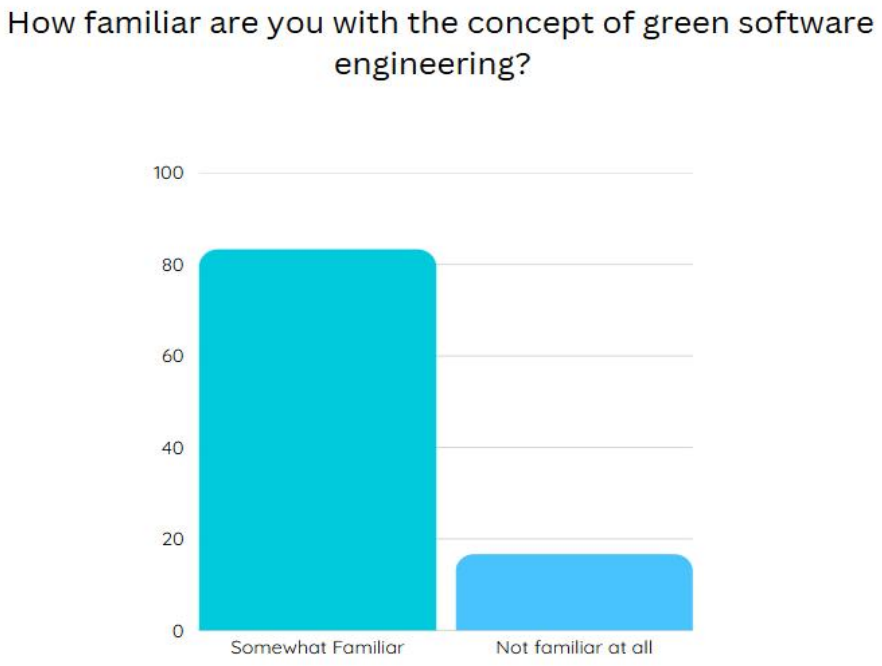


Figure 4: Familiarity with GSE concept

In terms of Familiarity with the concept of Green Software Engineering 83.3 % are somewhat familiar with the concept, whilst 16.7% seemed to not be informed at all, further indicating a need for more training and dissemination of knowledge on the topic.

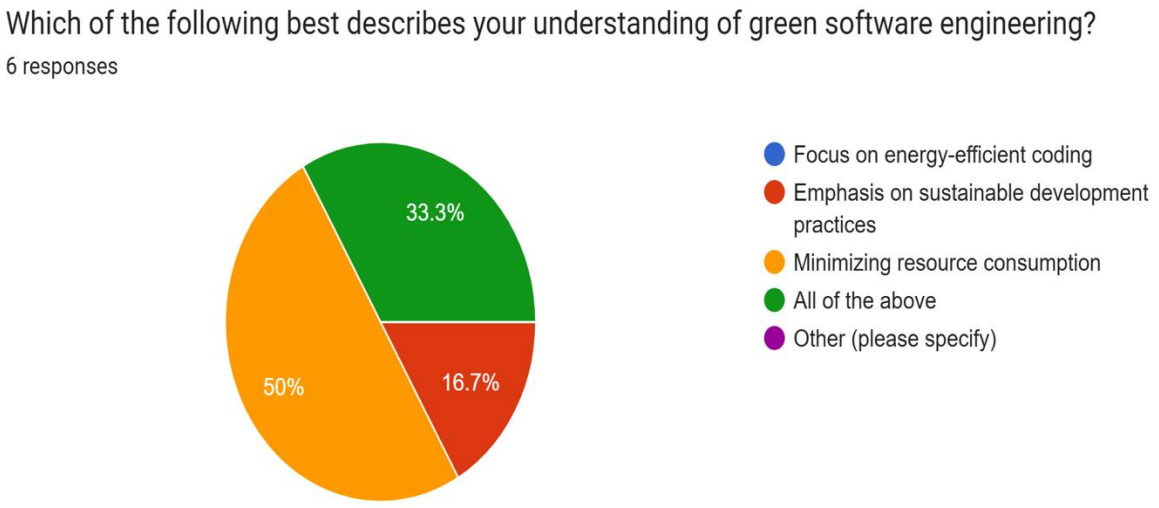


Figure 5: Understanding of GSE

The above graph paints a clear picture of the understanding of the concept of green software engineering within TANO Digital Solutions. 33.3% of the respondents defined it as “All of the above “which includes energy efficiency, sustainable development practices and reducing resource consumption. Half the respondents focused on minimizing resource consumption, whilst 16.7% put emphasis on sustainable development practices.

Current Practices

The survey highlighted that TANO Digital Solutions has adopted a few green software engineering practices, however the extent of implementation may vary. Respondents that referenced Cloud computing solutions as one of the practices averaged at 40%, with the justification that leveraging cloud computing ultimately reduces energy consumption and

resource usage, minimizing the environmental impact of software. Mentioned by 20% of respondents recycling and responsible disposal of outdated hardware is an ongoing practice, this helps reduce electronic waste (e-waste) and promotes sustainability.

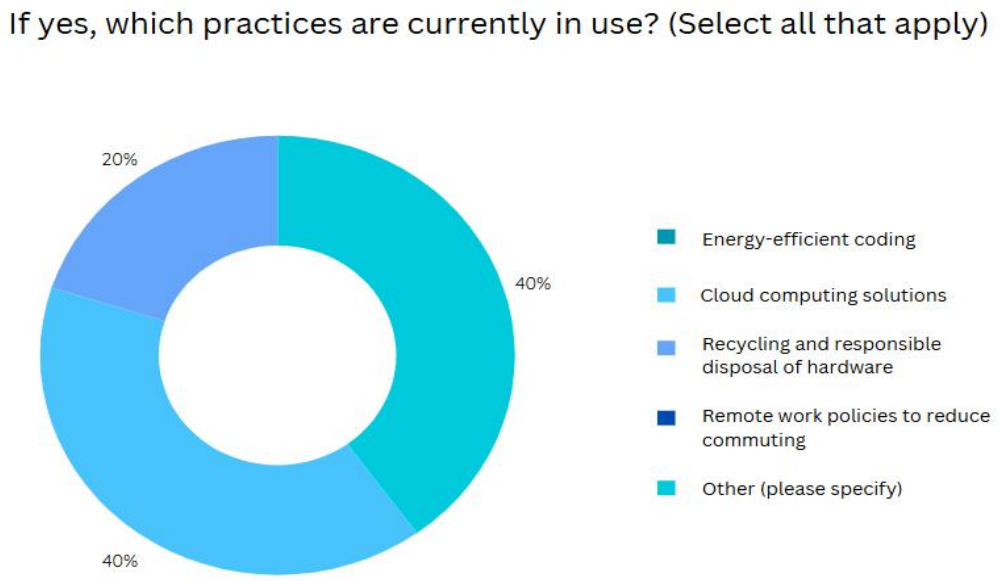


Figure 6: Practices Currently in use.

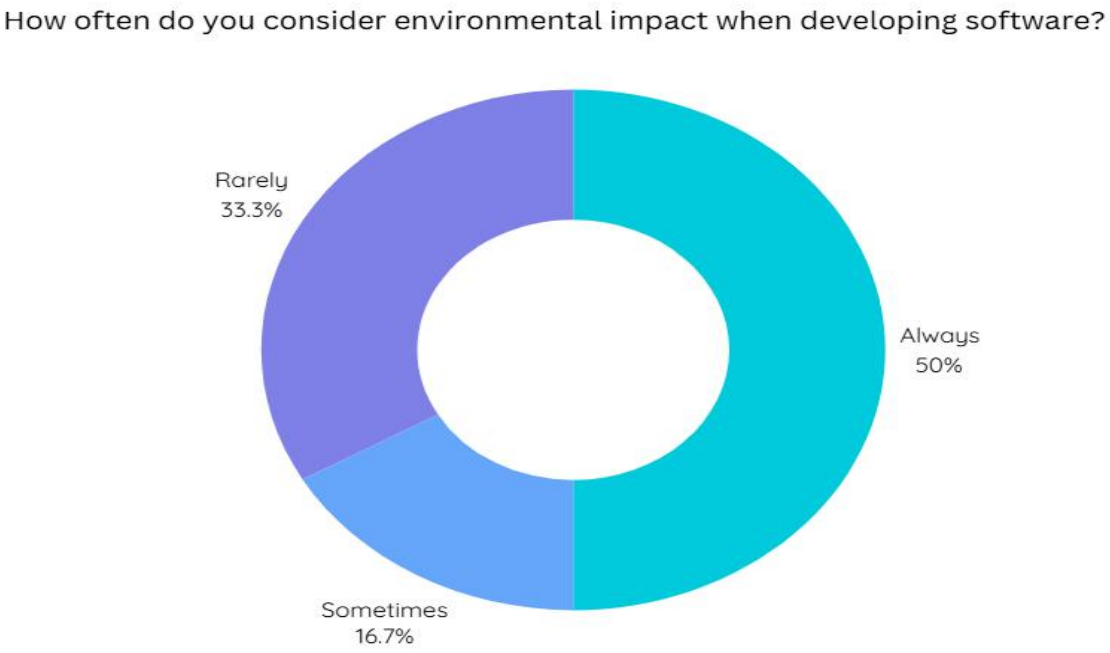


Figure 7: How often environmental impact is considered

During the survey, participants were asked how often they consider environmental impact when developing software. 50% indicated that they always consider it within the development process, while on the other hand 33.3% rarely ever considered it to be of importance. However, it is key to note that the remaining 16.7% still consider the impact Sometimes.

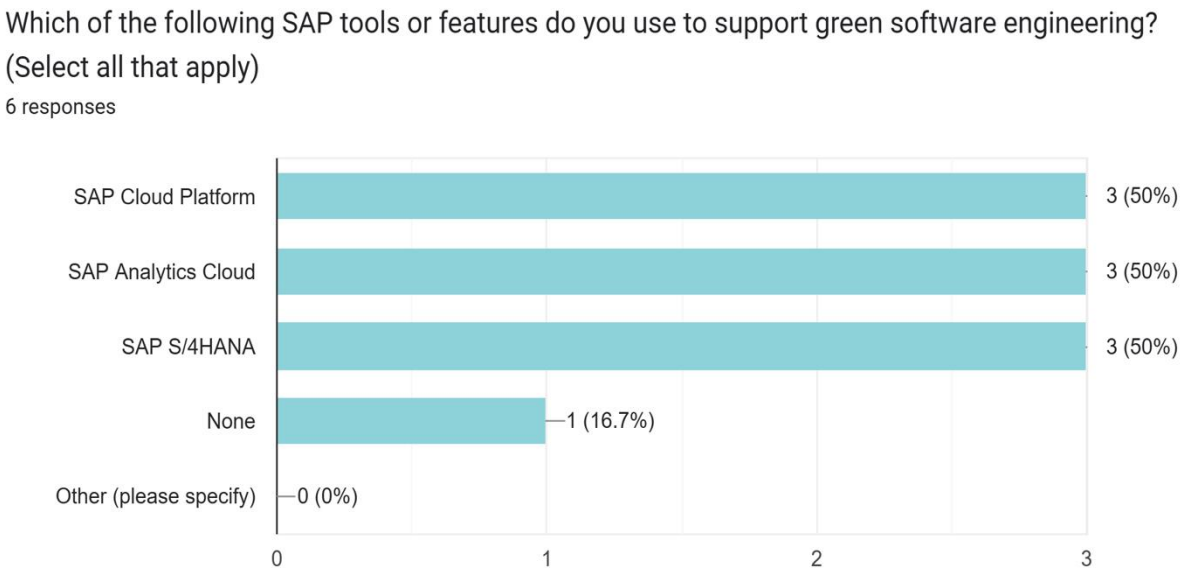


Figure 8: Tools and features used to support GSE.

From the above table it was established that 25% of the respondents utilize SAP Cloud platform which enables cloud-based development, reducing the need for on-premises infrastructure and promoting energy efficiency. Furthermore, the other 50% were split between two practices which are SAP S/4 HANA which supports resource optimization and SAP Analytics Cloud that monitors resource usage respectively.

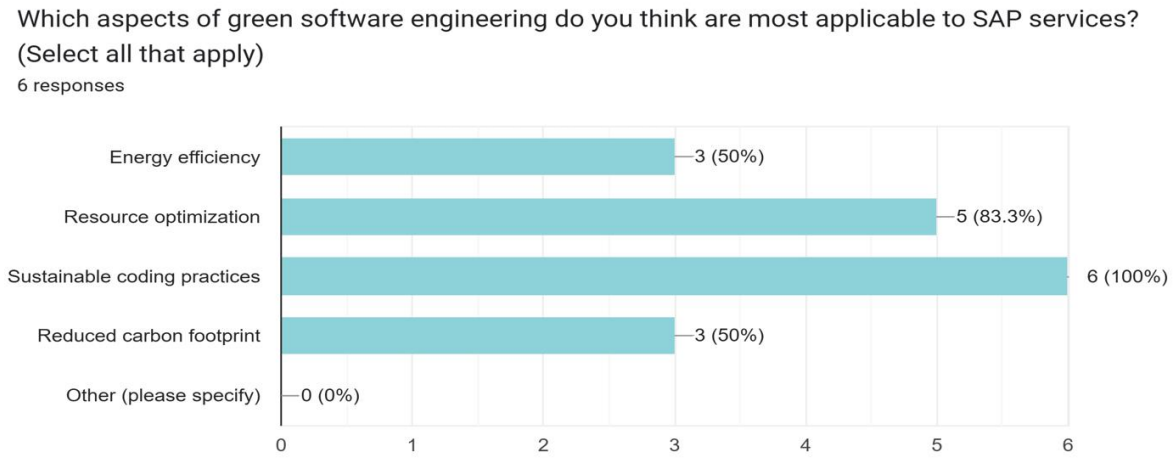
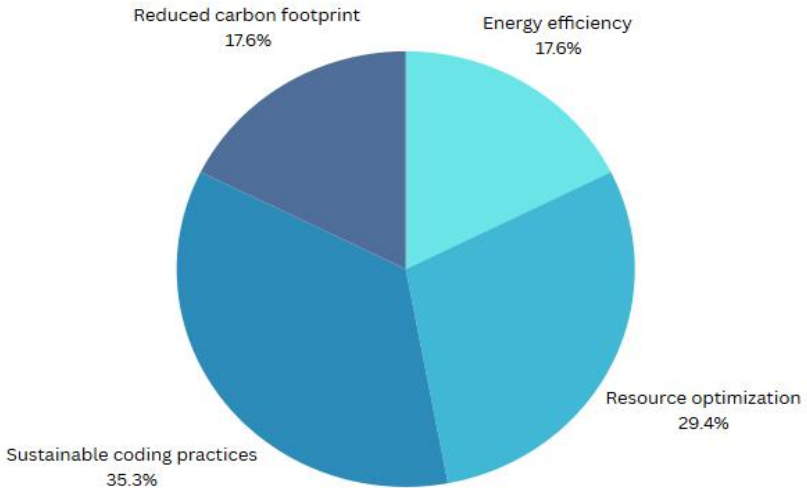


Figure 9: Aspects of GSE.

Both the graph above and below reflect the aspects of green software engineering that are most applicable to SAP services, respondents were asked to select all that apply to the question. Mentioned earlier in the introduction TANO is an SAP partner that offers software solutions for its clients. 50% of the respondents agreed that Reducing carbon footprint and Energy efficiency are applicable to SAP, whilst each respondent recognized sustainable coding practices as the most applicable to SAP services. Respondents that selected Resource optimization made up



83.3%.

Figure 10: Aspects of GSE that are most applicable.

Tools and technologies

The focus is to examine the tools and technologies that TANO Digital Solutions employees use to support green software engineering.50% of the respondents either use Virtualization software or Code optimization tools, that reduce hardware that often contributes to e-waste. 16.7 % found Energy monitoring tools to be useful within green software engineering, far less compared to those that utilize other tools.

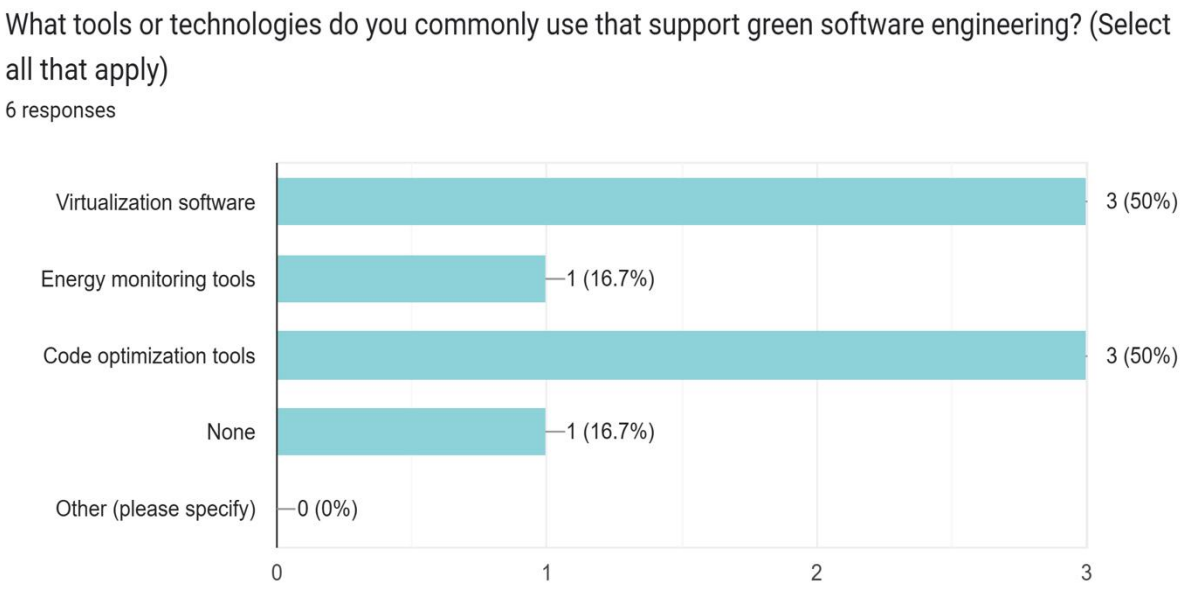


Figure 11: Tools and Technologies that support GSE.

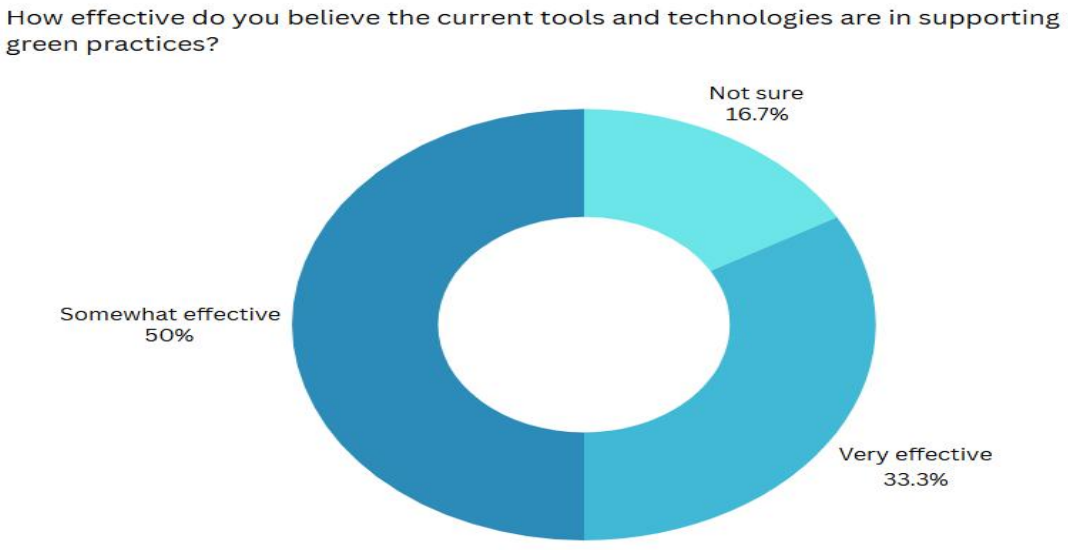


Figure 12: Effectiveness of tools & technologies in supporting GSE.

Somewhat Effective was selected by 50% respondents, giving a sense that more could be done to ensure the effective integration of green features, such as providing training on the tools. 16.7% indicated that they were Not sure, although it a small percentage of the employees it highlights the limited exposure and the uncertainty of the true effectiveness of existing tools. Lastly, 33.3% of TANO employees believe that the current tools are effective in reducing environmental impact.

Challenges and Barriers

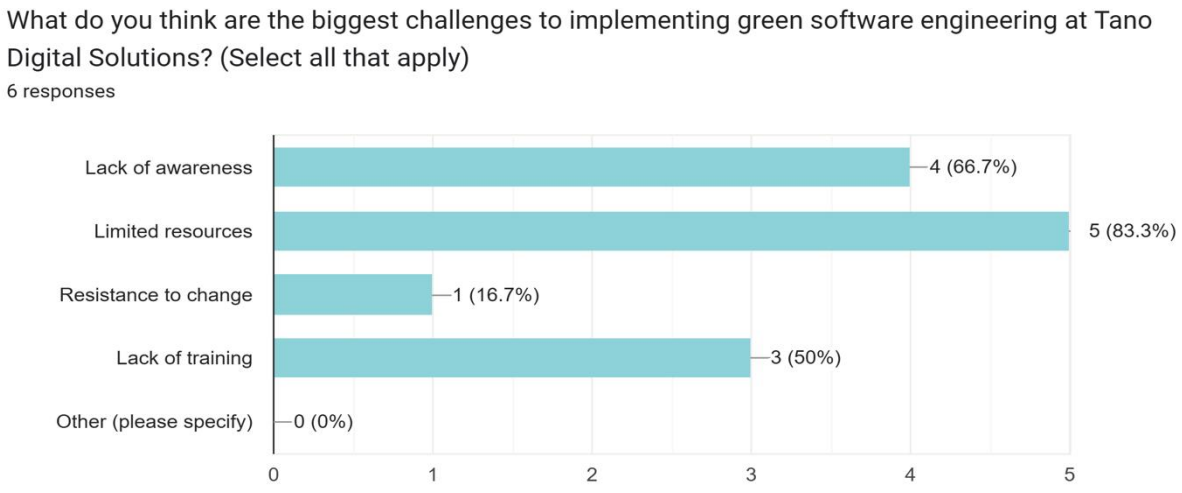


Figure 13: Challenges to implementing GSE at TANO

The above diagram depicts what TANO employees described as the biggest challenges to implementing green software engineering. 83.3% agreed that Limited resources were to blame for TANO's inability to implement green software engineering successfully. Whereas 50% argued that a lack of training was a bigger challenge, given that without adequate training

employees wouldn't know how to utilize tools with the green features. About 66.7% set Lack of awareness as one of the biggest challenges, whilst 16.7% implied that a resistance to change was an obstacle, because TANO may not be in the position to embrace GREEN yet.

Respondents were asked if they could describe a specific challenge they encountered related to green software engineering. TANO employees replied as follows “currently none that i am aware of” immediately implying some may be unaware they are encountering challenges, which is a claim further supported by another respondent who highlighted limited awareness and resources. Many organizations, especially SMEs, lack the necessary awareness, expertise, and financial resources to prioritize sustainability in software development. However, one employee seemed to understand the message of sustainability and green engineering, as they clearly described the challenge of running heavy software frameworks such SAP which would require more processing power.

Impact and Importance

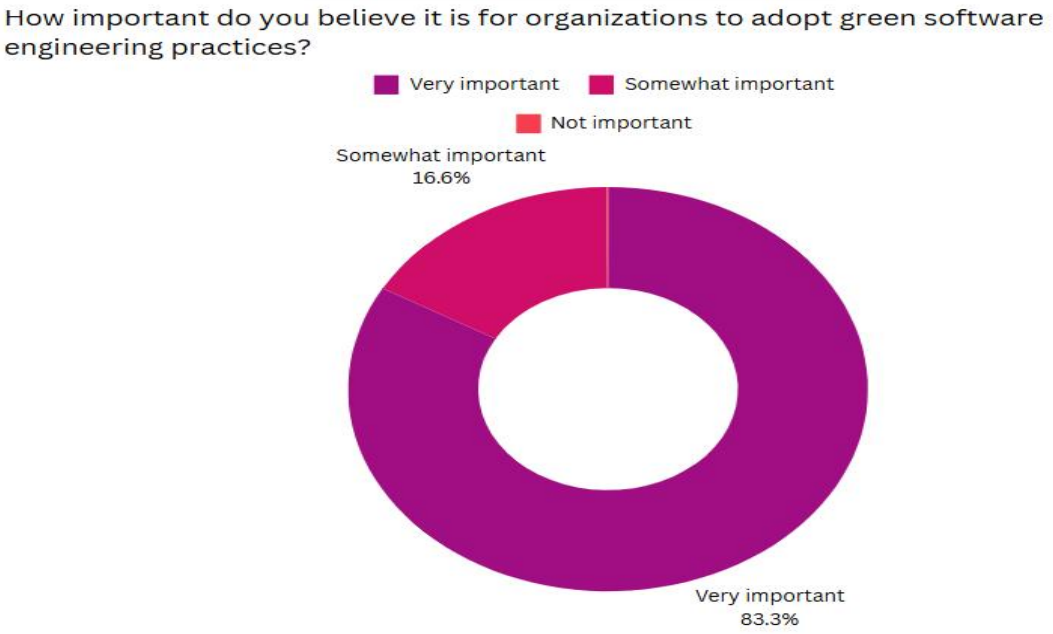


Figure 14: Importance of adopting GSE practices to organizations.

From the diagram above we can establish that 83.3% earnestly believe that it is important for organizations to adopt green software engineering, as they deemed it ‘Very Important’. Whilst 16.7% argued it is not entirely important nor irrelevant, instead it is ‘Somewhat Important'. However, it represents that the employees and respondents acknowledge the significance of green software development techniques and tools.

When asked how green software engineering practices could benefit TANO Digital solutions, respondents mentioned ‘cost efficiency ‘and ‘less electricity bills’ implying that optimizing resource usage and increasing energy efficiency, which result in lower operational costs. In addition, employees noted that with green software there would be a ‘reduced wastage of

resources' overall leading to better resource management, more efficient code and faster applications as indicated by another. The responses further justify that adopting green practices could enhance the overall user experience, whilst providing economic advantages.

Respondents were asked what changes they would suggest for improving green software engineering initiatives at TANO Digital solutions, a proposed multi-faceted approach that would see to organizational, technical, operational changes. To add on, initiatives included establishing a green team and setting sustainable goals, which would define a track key performance indicator whilst the team would oversee the implementation of green practices. In addition, respondents highlighted the importance of Adopting Energy –efficient Technologies such as cloud computing, optimizing resource utilization as well as the use of sustainable software development methods to reduce waste and improve efficiency. Operational initiatives included reducing e-waste through recycling and responsibly disposing electronic waste, while simultaneously promoting remote work and digital collaboration to reduce commuting related carbon emissions.

Regarding training and resources that employees thought would help their organization to adopt green software engineering more effectively, they mentioned training, certifications and access to resources as fundamental enablers of the adopting of green practices. Acknowledging that is key to offer training on sustainable software development methods, such as Agile and DevOps, and their application in green software engineering. As well providing access to frameworks and tools that support green software engineering, such as energy-efficient software development kits

(SDKs) and sustainability metrics tools to further guide implementation. Therefore, a recurring concept is that of educating, collaboration to somewhat empower and equip employees with the necessary knowledge and skills to utilize opportunities where green computing could be effectively implemented.

Lastly, to conclude the survey respondents were presented with a question, in relation to additional thoughts or comments regarding green software engineering or sustainability at TANO digital solutions. There was a shared theme all across the response that it would be best to embrace sustainability, whether through adopting a culture of sustainability or incorporating green software engineering into the company's long-term strategy. Though others expressed optimism in the fact that through collaboration and sharing of knowledge as well as guidance and Leadership commitment to sustainability it would be easier. On the other hand, some feel that due to the nature of the company's focus, which is mainly business process applications, it would be difficult for Tano to truly embrace the GREEN digital future.

Data Analysis of University student Survey

Respondent Demographic

$$\text{Response Rate} = \frac{\text{Number of completed Survey responses}}{\text{Total number of Survey respondents}} * 100$$

Total Surveys sent	**Number of Respondents**	**Completed Survey**	**Response Rate**	**Response Rate %**
30	30	27	0.9	90

Table 1 : Response Rate

The Demographic of the respondents was sectioned to highlight the Age, Gender as well as if they were currently in the IT industry, to draw conclusions from an unbiased point of view.

Most respondents (63.4%) were between 18-24 years old, with a smaller percentage of 6.8% those being aged between 28-33+, whilst those between the ages of 25-27 were 29.8%. Through the results, it was established that only 33.3% of the participants were currently or have worked in the IT industry whilst the other 66.7% registered having no experience in that field. Despite the varying experience levels, male respondents 51.9% outnumbered their female counterparts of 48.1%.

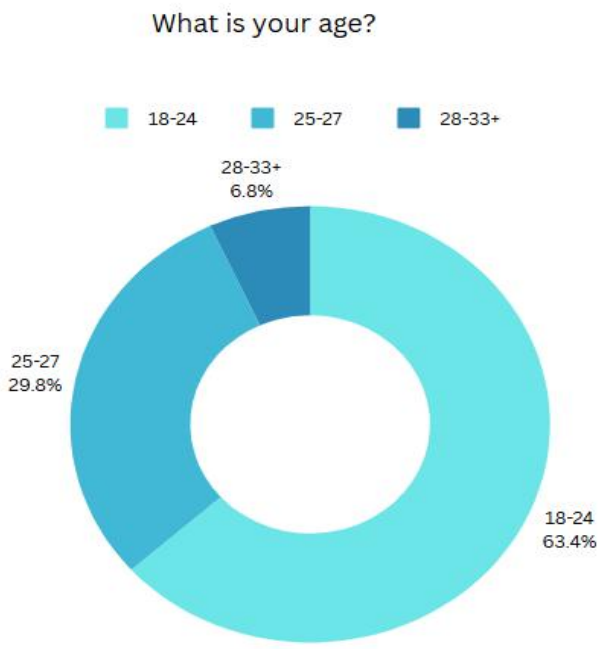


Figure 15: Age

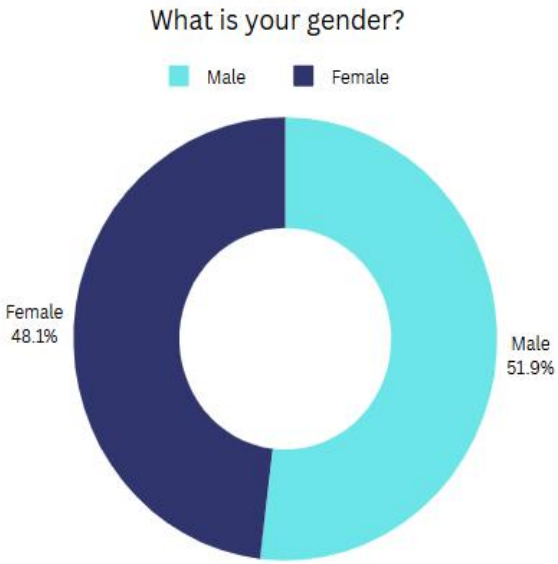


Figure 16: Gender

Currently in the Industry

This section was targeted towards those that are currently in the industry so as to get further insight on their knowledge of green software engineering and its practices. When asked what their roles were in the industry 50% work as Software Developer, some 16.7% as UX/UI Designers and the remaining as project managers. Very few responses were recorded when participants were asked how long they had been working in the software industry, those that did ranged from 16.7% having worked for more than 6 years, whilst 33.4% ranged between 1 and 6 years.

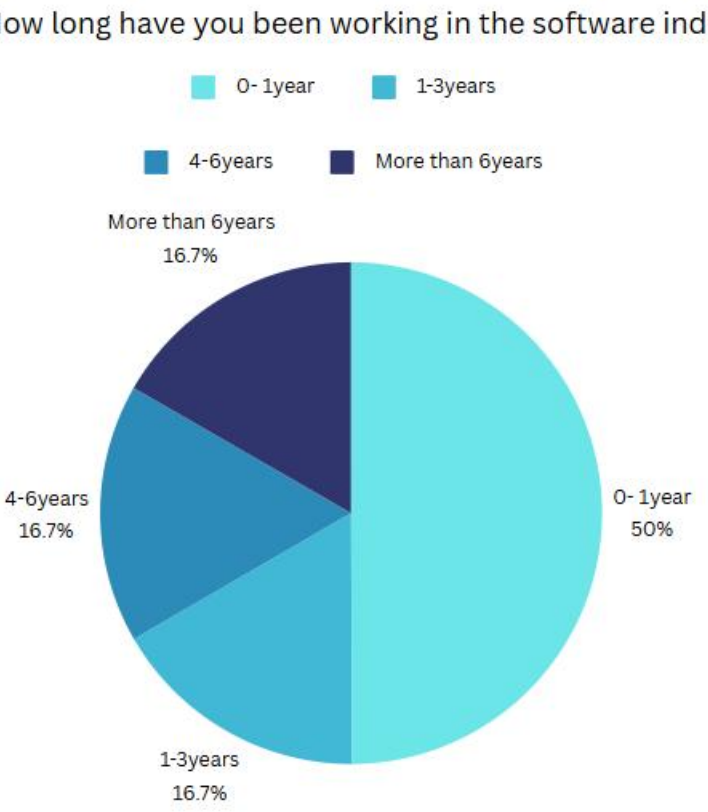


Figure 17: Years working in the Software industry

After an inquiry whether their organization has currently implemented any green software engineering practices, 66.7% responded 'No' whereas 33.3% of the participants were not entirely sure. This immediately implies that green software engineering is poorly implemented or not practiced within the organizations students where employed. As a result, we further embarked to understand if students understood green software engineering. Interestingly 50% described the concept as that of minimizing resource consumption, whereas 16.7% others argued the focus on energy –efficient coding and emphasis on sustainable development practices.

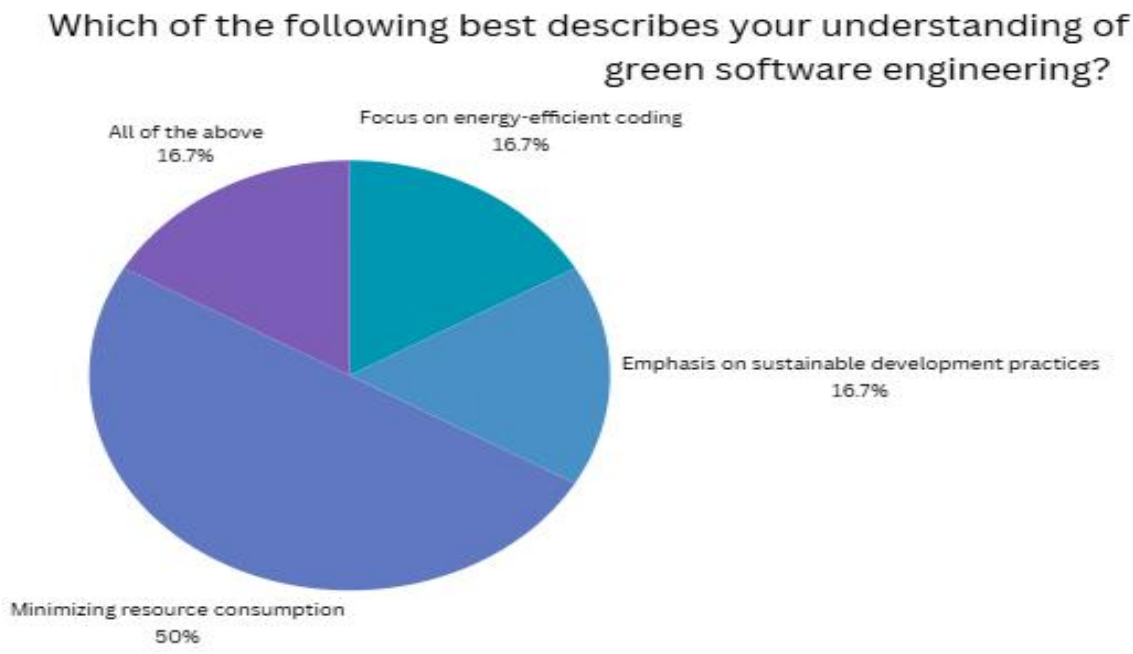


Figure 18 :Best description of understanding of GSE

After establishing the understanding that respondents had on the concept of Green software engineering, an inquiry was made on the tools and technologies they commonly use that support green software engineering. Although 33.3% confessed to not using any, 50% utilize Virtualization Software, so after reviewing the most commonly cited tools were energy monitoring tools, code optimization tools as well as the virtualization software.

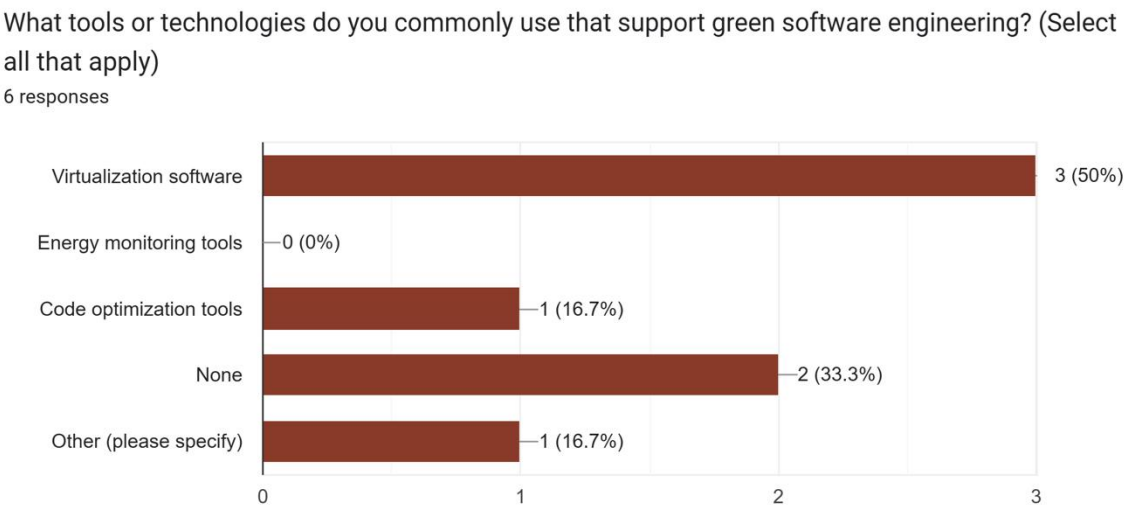


Figure 19: Tools and Technologies commonly used to support GSE.

As the survey continued respondents were asked to describe a specific challenge they have encountered related to green software engineering. ‘Convincing organizations to adapt to green software engineering’ this highlighted a resistance that could emanate from leadership and stakeholders, because of other short-term goals such as profit maximization over sustainability. ‘Optimizing algorithms for energy efficiency while maintaining performance’ optimizing of such algorithms would require experts due to their complex nature there would be an increase in development time and costs. Respondents highlighted that green technologies, practices and tools are still in their infancy stage, therefore information on how to utilize such tools and the benefits of sustainability are still limited.

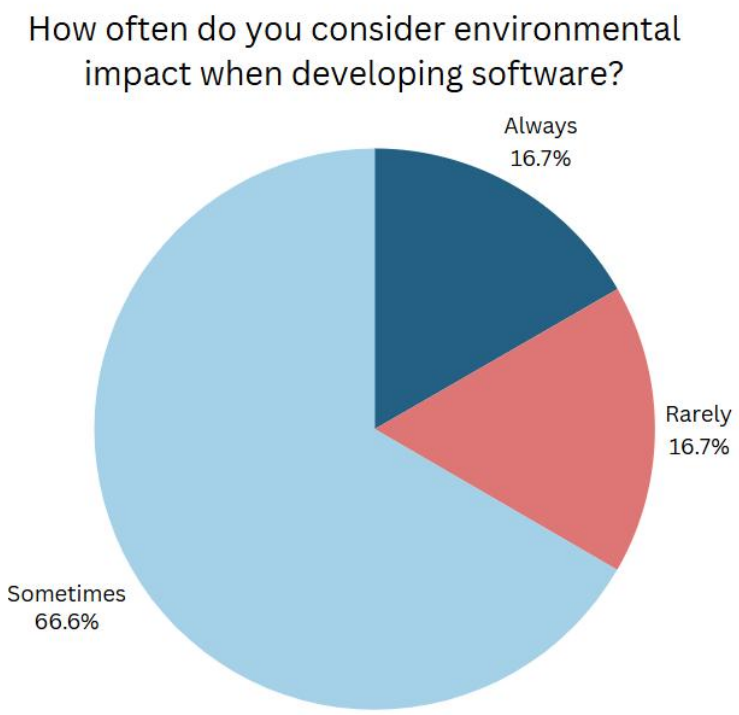


Figure 20: How often Environmental impact is considered

The above diagram displays the responses of participants, when they were asked how often they consider environmental impact when developing software. The larger part of 66.6% recorded Sometimes, including 16.7% that Always consider, however there were 16.7% that thought otherwise and confessed to rarely ever considering. This suggests that sustainability is rather an after-thought and not necessarily a priority.

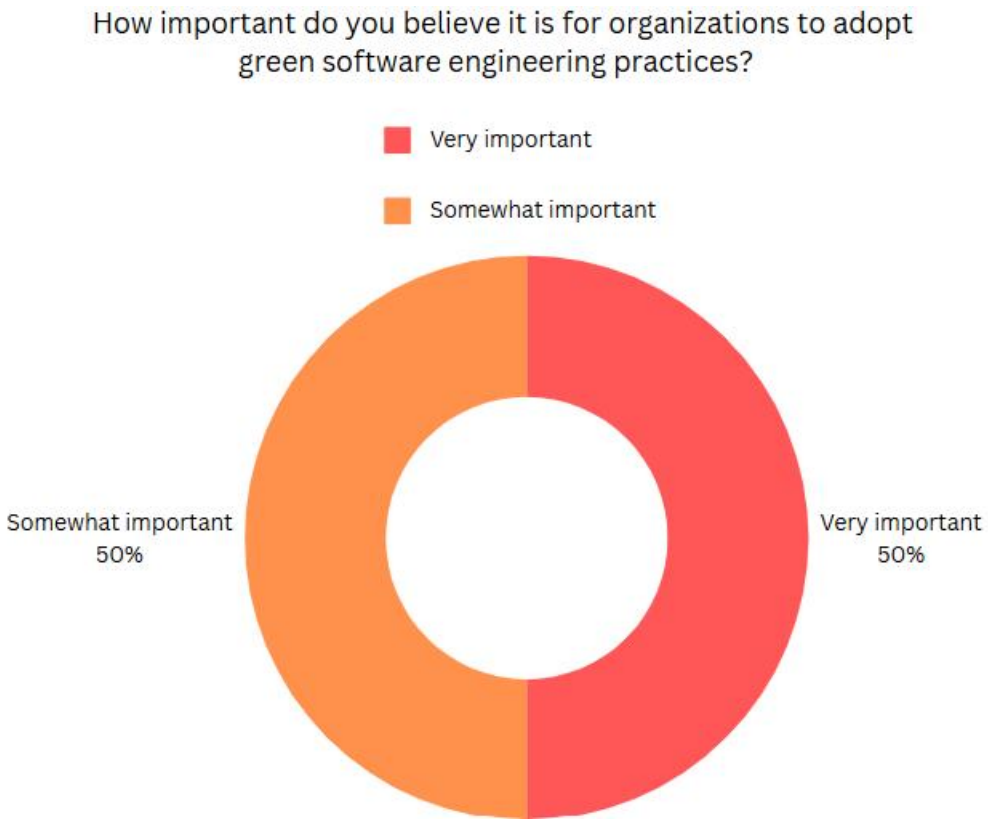


Figure 21: Importance of organizations to adopt GSE practices

Shown above by the diagram is the equal distribution of response, when asked How often do you consider environmental impact when developing software. 50% considered the impact to be 'Very important' while the other 50% only considered it to be somewhat Important.

Further into the survey participants were asked what additional training or resource they thought would help their organization in adopting green software engineering more effectively. Majority of responses 75% suggested inhouse training in the form of workshops to build a better appreciation of the green tools and frameworks. The other 25% advocated for Companies to

implement more policies, making sustainability a priority and encouraging employees to contribute to a green digital future.

Awareness and knowledge

The aim of this particular section was to collect opinions and views from respondents who were not in the IT industry

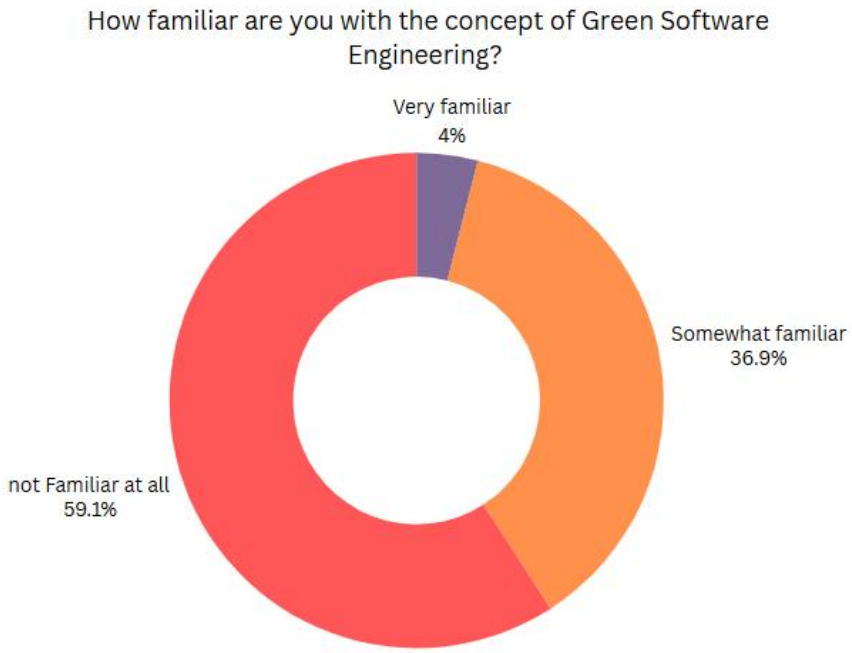


Figure 22: Familiarity with the concept of GSE

Only 36.9% were Somewhat familiar with the concept of green software engineering, while 59.1% were Not familiar with the concept at all, with a small percentage of 4% being

familiarized with the concept. This clearly depicts a picture of the poor popularity of the concept further backing the need to raise more awareness.

How would you define Green Software engineering? Nearly 70% of the responses carried the theme of software and technologies that minimize environmental impact, ‘Using technology in an ecofriendly way’, as well as a software development approach that focuses on reducing energy use and environmental impact. However, the remaining 30 % had ‘no idea’ what it was or mistook the concept of green software engineering to be a program.

Further into the survey, participants were asked ‘Where did you learn about it’, 50% discovered it through Online resources be it websites or adverts, 15% responded University courses were responsible for their knowledge of green software engineering. 10% learnt about it in either workshops or seminars. The remaining percentage heard it through conversation and collaboration with peers.

Understanding of Green software

This section sought to uncover the education background of the survey participants.

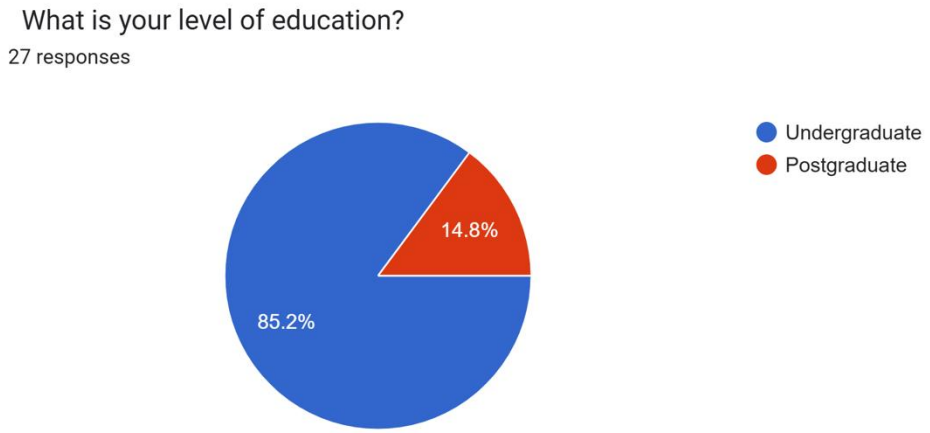


Figure 23: Level of education

The level of education of the respondents differed with 85.2% being Undergraduate whereas 14.8% were Postgraduate. This shows that most of the participants are either pursuing tertiary education or have already acquired it.

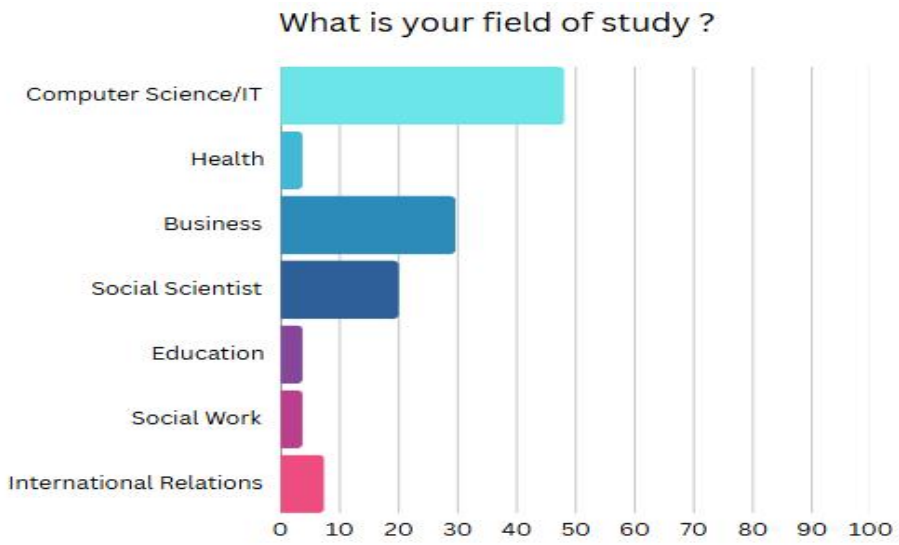


Figure 24: Field of study

The above diagram depicts the different colleges/departments the respondents belong to. Majority 38.9% belonged to the College of Engineering and Applied science, whereas the College of business and Management contributed to 33.3%. Furthermore, College of Social sciences, Theology, Humanities, and Education comprised 22.2%. The College of Healths, agriculture and Natural sciences made up the smaller percentage.

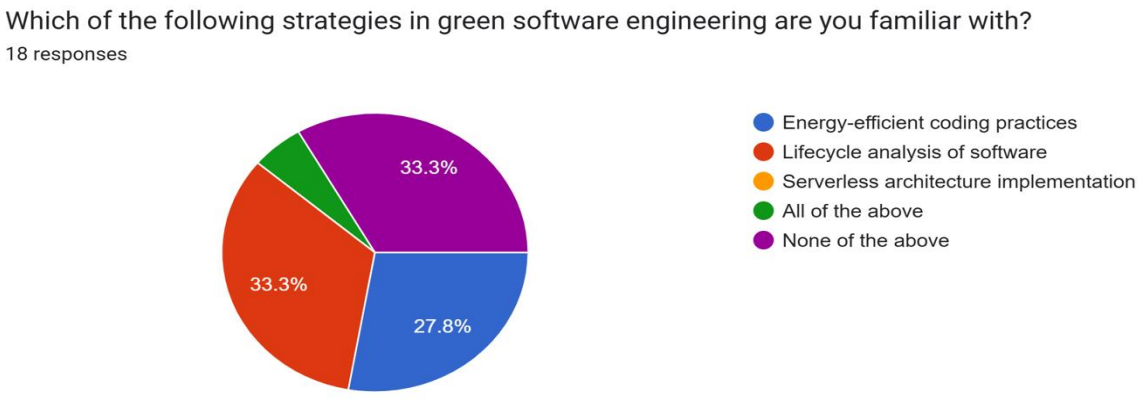


Figure 25:Familiarity with GSE strategies

Although 33.3% confessed to not being familiar with any of the above strategies, 27.8% recognized energy-efficient coding practices with 33.3% were familiar with Lifecycle analysis of software.

How effective do you believe the current tools and technologies are in supporting green practices?

Very effective	Somewhat Effective	Not effective	Not sure
0%	55.6%	22.2%	22.2%

Table 2: Effectiveness of current tools and technologies

When asked how effective current tools and technologies were in supporting green practices, 55.6% of the participants voted 'Somewhat effective' however 44.4% others either said they were 'not Effective' or 'Not sure'.

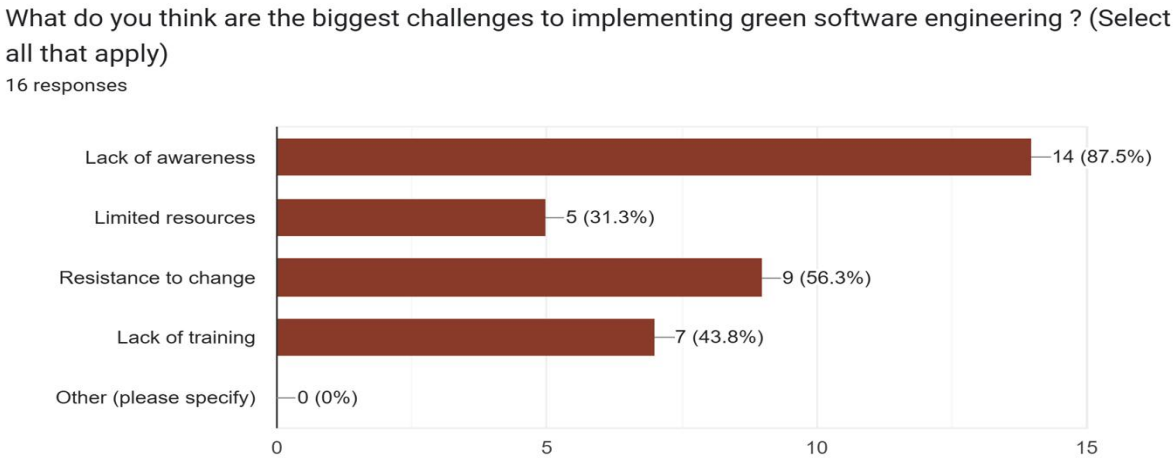


Figure 26: Biggest Challenges of implementing GSE.

The most cited challenge was the 'Lack of awareness' at 87.5%. Resistance to change at 56.3% was another challenge to implement and 'Lack of training' 43.8%. Another challenge that was highlighted is that of 'Limited resources'.

Practices and Implementation

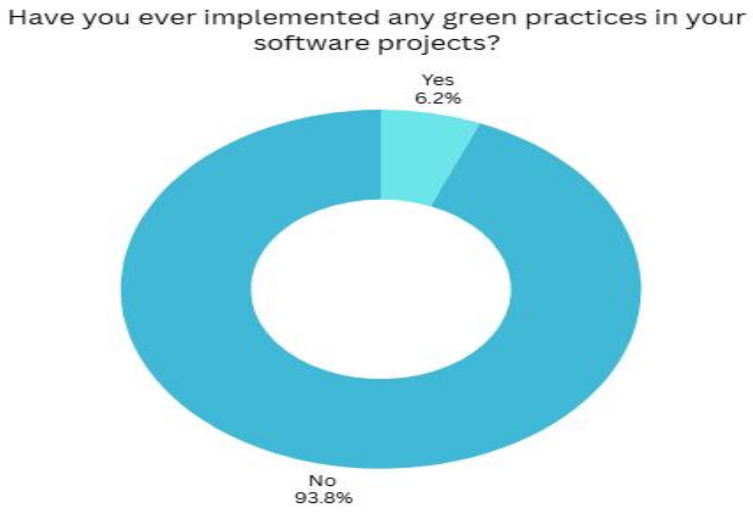


Figure 27: Implementation of Green practices in own software projects.

Respondents were asked if they have implemented any green practices in their software projects 93,8% responded ‘No’ whereas 6.2% suggested ‘Yes'. This implies that green software engineering is not widely practiced among students.

Further into the survey a description of their experience and principles they applied was enquire and among the few respondents who implemented green practices, examples included optimizing code for energy efficiency and reusing code to minimize redundancy. However, most respondents did not answer this question.

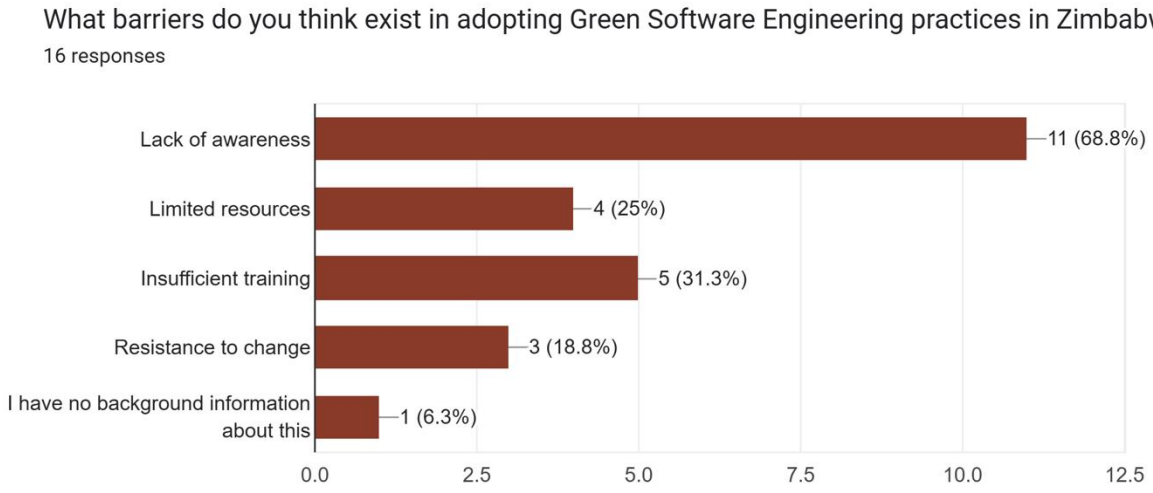


Figure 28: Existing barriers that hinder adoption of GSE practices in Zimbabwe

In the scenario of Zimbabwe ‘Lack of awareness ‘68.8% seemed to be the biggest barrier in adopting green software engineering. ‘Insufficient training’ came in second at 31.3%. A quarter of the respondents identified ‘Limited resources’ as one of the major barriers and 18.8% stated it was ‘Resistance to change’.

Are there any local initiatives, organizations, or companies that you are aware of that promote Green Software Engineering or sustainability in software development?

Yes	No	Not Sure
13.3%	46.7%	40%

Table 3: Awareness of local initiatives

Regarding if they were aware of any initiatives being taken to promote green software engineering in software development, majority of the participants 86.7% were either 'Not sure' or did not know of any. The remaining percentage 13.3% responded 'Yes' however, this highlights the lack of visibility and advocacy.

Respondents were asked for their opinion on what steps could be taken to promote green software Engineering in universities and Zimbabwe. The most common suggestions included raising awareness through programs (40%), incorporating green software engineering into university courses (30%), and offering free certified courses (20%).

Attitudes Towards Green Software Engineering

How important do you think it is to incorporate sustainable practices in software development?

Very Important	Important	Neutral	Not Important
44.4%	37%	14.8%	3.7%

Table 4: Importance of Sustainable practices

Most students 44.4% justified that it is 'Very Important' to incorporate sustainable practices in software development. 37% others voted that it was 'Important', however 3.7% believed it was 'Not important'.

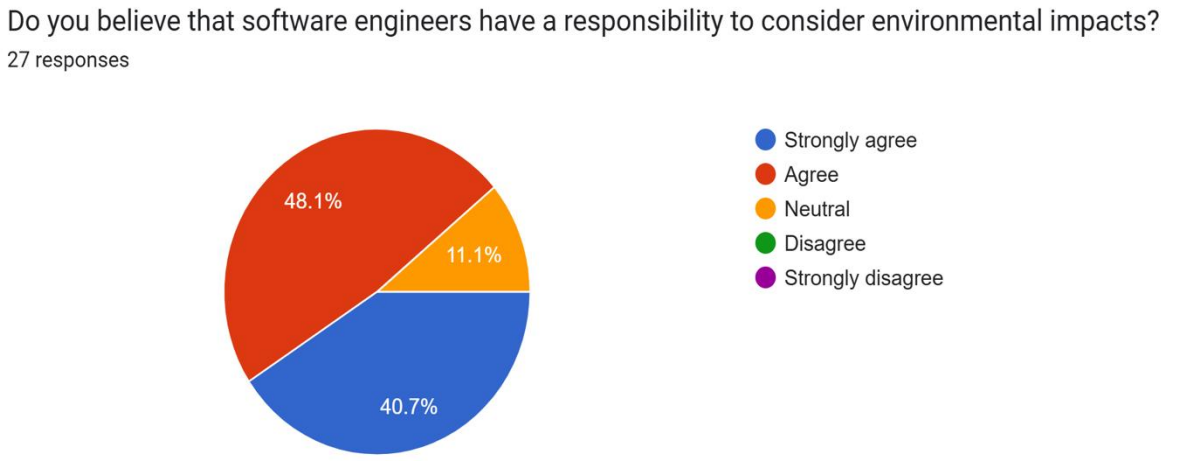


Figure 29: Responsibility Software engineers have in considering environmental impact

Majority of the respondents 88.8% agreed with some emphasizing that they believed software engineers have a responsibility to consider environmental impacts. However, 11.1% were somewhat neutral.

When asked what the benefits of green software engineering are, respondents believed 65.4% ‘environmental protection’ and 15.4% ‘Improved efficiency ‘to be the major benefits. Other benefits included ‘cost reduction’ at 11.5%.

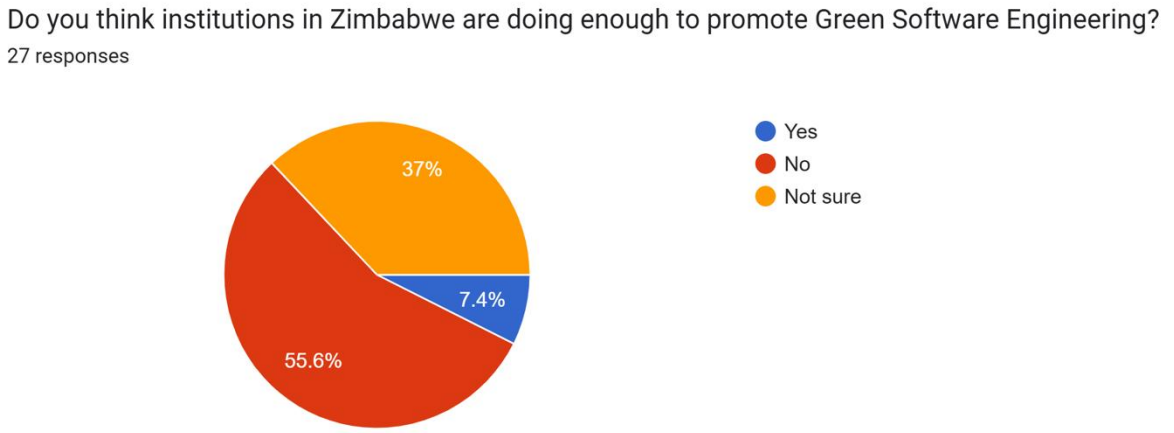


Figure 30: Extent institutions are promoting GSE

Lastly, 55.6% respondents replied ’No’ when asked whether Zimbabwean institutions were doing enough to promote green software engineering. 37% were not entirely sure whereas 7.4% believed they were doing enough.

4.3 Discussion and Interpretation

The results from both surveys highlighted a major gap among the university students and TANO Digital Solutions in the awareness of green software engineering, despite its significance. Although industry professionals are knowledgeable of the concept of Green Software Engineering, they aren't informed on the practices and approaches to implement sustainability.

Nearly 84% of TANO employees were somewhat familiar with the concept, however without implementation it renders the knowledge of the concept useless.

The survey highlighted that 40% of TANO Digital Solutions has adopted a few green software engineering practices, however the extent of implementation may vary with respondents referencing Cloud computing solutions as one of the practices. The implementation of cloud computing solutions revealed the role the cloud plays in ensuring sustainability, because cloud platforms offer scalability and flexibility, allowing developers to optimize resource usage based on demand, minimizing energy consumption during periods of low activity. Cloud platforms offer a range of tools and services that can help developers implement green software engineering practices, such as carbon footprint reporting and resource optimization tools.

Regarding, 59.1% of the university students that were unfamiliar with the concept, gave an insight into the current disconnect between industry exposure and academic integration. Education is key as it helps future developers understand the environmental impact of software development and the importance of sustainability. Some 68.8% of the respondents alluded to the lack of awareness as a barrier to the adoption of green software practices in Zimbabwe, but that could be easily curbed by Facilitating Collaboration and Knowledge Sharing.

Respondents identified different challenges to the successful implementation of green software engineering such as lack of awareness, limited resources and economic constraints. TANO specific hindrance is due to the nature of the organization, as management would rather prioritize

profits over sustainability, backed by 16.7% of the employees that underlined the resistance to change. Reflecting on the limitations of Zimbabwe's tech industry, for instance TANO that uses SAP which is a Legacy system might lack energy-efficient alternatives therefore making transitions to green nearly impossible or complicated.

There is a consensus and attitude between TANO and the university students that green software engineering is of great importance, 83.3% TANO Employees deemed GSE as "very important," citing cost savings, whilst 81.4% University Students combined "very important" and "important" supported sustainable practices but lacked implementation avenues. Regardless of the seemingly low knowledge and practices in use, both groups share the same optimism alluding to the benefits of going green caries such as, cost saving and reduced e-waste. Giving the impression that there is a perceived implementation gap of GSE due to training deficits and weak policy support.

Chapter 5 : SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter blends the findings from the investigation on the state of green software engineering in Zimbabwe. The objectives of the study were to examine the Software development methodologies utilized by African tech-companies, whilst assessing the potential role communication plays in facilitating GSE awareness. In addition, the effectiveness of African Government intervention and policies was studied, as well as the impact implementing green software engineering practices has on the environment and economically. Lastly, an exploration to identify potential barriers that would hinder the adoption of green software engineering in the African technology sector.

5.2 Discussion

- The current state of Software development methodologies utilized by African tech-companies. The demand for software solutions has surged across various sectors due to rapid digitization spurred by events like the COVID-19 pandemic. In Zimbabwe tech companies adopt Agile and lean methods of software development, as these are making it easier to negotiate through economic instability and a fast-evolving market met by unreliable infrastructure. 66.7% of TANO developers used traditional Agile/DevOps, with only 40% integrating cloud-based sustainability practices. So Agile seems to be a more dominant methodology, due to its flexibility making it suitable for African countries that are often meant with unstable currencies causing unstable economies. Whereas lean methodology is currently relevant to African countries because it allows for

scalability during development, in countries such as Zimbabwe it is valuable as it makes resource optimization possible given the lack or limited funds.

- Role communication plays in facilitating knowledge dissemination on the concept of "Green Software Engineering" is evident in the results because 50% discovered it through Online resources be it websites or adverts and the remaining percentage heard it through conversation and collaboration with peers. When people effectively communicate with each other, they can share knowledge, exchange ideas, and disseminate accurate information to a wider audience. Many people are not yet aware of the serious impacts of the climate crisis and are not taking action to address it, so through informing people promotion of 'green' initiatives is aided. Therefore, government-sponsored training workshops under the ministry of IT and use of tech communities such as LinkedIn would bridge the awareness gaps.

- The effectiveness of African Government intervention and policy making in promoting software implementation. The Global Innovation Index (GII) annual report (2021) indicated that boosting the level of innovation in underdeveloped nations is mostly dependent on present governmental support. For instance, subsidy policy can stimulate the research and development of green software practices innovation, financial support can cultivate and expand the implementation of such practices while disseminating information through training and workshops.55.6% of respondents felt that institutions in Zimbabwe are not doing nearly enough to promote GSE. Regulations governing the disposal and management of electronic waste (e-waste) may impact software engineering

practices, by encouraging tech firms to adopt energy efficient and low-carbon software solutions. Among the African countries intervening, in 2016 Ghana passed the Hazardous and electronic waste control and management act (Act 917) that outlined the management and disposal of hazardous electronic waste as well as establishment of an e-waste fund.

- The impact of implementing green software engineering practices on the environment and the potential Economic benefits. According to the International Energy Agency (IEA), data centers utilize around 1% of global power and are anticipated to increase in the future years. The use of renewable energy to power data centers reduces carbon emissions but also improves a company's resilience in the face of fluctuating energy costs. Economically, there will be an increased growth to the tech industry and job creation, as engineers and developers would be needed to implement and maintain these green systems. Green systems use fewer resources, which translates into long-term cost savings. Green software development also uses technologies such as virtualization to enhance resource efficiency. Virtual machines (VMs) enable different operating systems to operate on a single physical server, decreasing the number of actual servers required. Furthermore, it encourages the efficient use of cloud computing by lowering idle server time and adopting serverless computing. For instance, writing more efficient code during the development phase of the SDLC reduces the energy required to run that code while simultaneously reducing the cost of maintenance. Green coding can help reduce the carbon footprint of software applications by reducing energy consumption and greenhouse gas emissions.

- potential barriers (such as technical skills) that would hinder the adoption of green software engineering in the African technology sector. The African tech ecosystem is rapidly expanding, with software development emerging as a vital component of this growth. According to recent reports, the demand for software developers in Africa has reached unprecedented levels, fueled by the need for digital transformation across various sectors. As the industry matures, developers must adapt to new technologies, methodologies, and market demands. Among the potential barriers, 43.8% respondents highlighted lack of training as a key barrier, but this is due to the high costs of the learning certifications which cannot be afforded by the average Harare based developer. Further the need for sponsorship and government assistance is emphasized to ensure accessibility to crucial skills.

5.3 Conclusions

In addressing the first research question, the study highlighted the dominance of current methodologies and green alternatives utilized in the Zimbabwean scene. Agile methodology implemented by 66.7% at TANO promotes enhanced collaboration and increased flexibility but puts more focus on speed and functionality rather than sustainability. Through the research, it was established that tech firms in Africa are still heavily dependent on outsourced tools and

technologies either European or western, the downfall of this approach is that most do not cater for the African domain which is subject to frequent power cuts. Africa currently houses over 179 data centers scattered all over the continent, by integrating renewable energy sources into data center power supplies is a critical step in achieving sustainability goals and reducing these facilities' environmental effect. By transitioning from conventional power sources, such as fossil fuels that release greenhouse gases when burned.

Moreover, an assessment on the energy consumption patterns of software development in African countries and how they contribute to environmental challenges, and what sustainable practices can be implemented to address these issues. Studies carried out by the European Union and the UN have clearly indicated that African countries, particularly West African countries, have become e-waste dumping sites for developed countries. The poor e-waste management has a negative impact on the environment due to non-biodegradable nature, and the waste itself often contains toxic chemicals that are harmful to human health such as mercury. E-wastes usually appear in the form of outdated computers and servers used in the software development process. It was established that most African countries contribute to environmental degradation through data centers, with over 179 data centers in the continent they require large quantities of energy. Since the facilities are made constant, a consistent supply of power is required to keep physical infrastructure such as servers as well as backups available, but this means data centers in most parts of Africa are dependent on fossil fuels (coal). As a result, the use of fossil fuels, that are non-renewable sources of energy, further contribute to the carbon emissions CO2, sometimes altering and destroying ecosystems.

To curb these implications on the environment, data centers can adopt more renewable and environmentally safe methods of powering the facilities, the likes of using solar panels to generate power for servers. In addition, governments can play their part by incentivizing, through offering tax incentives to green startups and companies' governments would encourage more institutions to adopt sustainability into their long-term goals due to the economic benefits. If the government went further as to impose regulations for instance regarding the safe and sustainable management of electronic waste, while establishing strict compliance policies to make sustainability more mandatory rather than optional. These government initiatives would tremendously assist in mitigating the negative impact software development has on the environment.

The study sought to understand what exactly was hindering the effective adoption of green software engineering practices within the African continent. While, identifying the various methodologies and software models that may assist in overcoming adoption barriers, among the barriers Limited awareness, business goals, policy gaps and cost of implementation to be highlighted more. Awareness refers to the knowledge or perceptions of students and staff about green computing practices and its capabilities in promoting environmental sustainability, it helps future developers understand the environmental impact of software development and the importance of sustainability. According to Mohd Rizaimy et al. (2018), adopting green practices is complicated since it entails a variety of processes that must be understood and altered. Without the awareness of GSE, Africa would particularly continue to see an increase in E-waste that is non-biodegradable, followed by a larger carbon footprint caused by fossil-fuel powered data centers.

Therefore, the government should intensify its effort to inform the people about the value of adopting green practices by spreading information through a range of avenues, including the media, the radio, the television, and even exhibitions. Due to frequent change in technology, businesses and tech companies would be less likely to adopt sustainability into their long-term strategies due to increased risks, infrastructure and training costs, as it requires allocation of resources and reengineering of some processes and systems. The lack of experienced green experts would further push businesses to resist the idea of sustainability, because they would be forced to outsource expertise proving to be less cost efficient in the long run. Economically, the high initial investment costs for green software development may become a barrier to the adoption, especially if it conflicts with business priorities such as survival or scaling up. As a result, the costs of adopting green practices in Africa may need to be weighed, but there exists a gap where local governments can encourage implementation through subsidies or incentives, either one of these findings would assist in the upskilling of African developers and help leverage peer networks.

The integration of renewable energy sources and energy-efficient technologies in software development can contribute to environmental sustainability in Zimbabwe. It is possible to dramatically minimize environmental effects by using cloud services powered by renewable energy and improved infrastructure. The use of renewable energy will lessen the burden of the strain on Zimbabwe's natural resources, without exploiting the environment. While energy efficient software designs such as the cloud allow Zimbabwe to harness the scalable and flexible infrastructure that significantly enhances operational efficiency. Since the cloud can be hosted online it reduces costs of maintaining and setting up data centers that require large quantities of

energy and water, this assists in environment sustainability as these data centers often release high levels of heat into vulnerable ecosystems.

Society and stakeholders play a critical role in ensuring that software technologies they use assist in promoting sustainability in their nation. Through collective actions from both parties' sustainability can be effectively achieved and foster innovation to tackle sustainability on a global scale. Governments have a key role in leading this revolution by enforcing policies and setting regulations to favor the adoption of these policies, through tax breaks offered for companies using solar or hydro energy over fossil-fuels. Consumers should therefore opt for service providers and suppliers that conform to green policies set by the government, for instance purchasing products produced through green software engineering (e.g., Apple's 100% clean energy pledge). Another stakeholder is local IT businesses who have the corporate responsibility of disclosing their software development process through transparency reports, this will make them more accountable and force them to implement green software engineering principles into software development. Schools and Universities should raise more awareness on the concept of GSE and sustainability to ensure people are aware of their responsibility in contributing to the nation's sustainability. The concept of green computing should be integrated into courses and training workshops offered to future developer, to promote research on low-carbon architecture that will lay foundation for collaboration leading to the creation of new efficient technologies

Zimbabwe's ability to implement green software engineering practices is dependent on cultural and socio-economic factors such as digital culture of the nation, low awareness, limited access to

renewable energy. The nature of Zimbabwe's digital culture is that the population is heavily dependent on application software for communication, money transfer services (e.g. Ecocash) and streaming apps, but these apps can be data heavy. Streaming apps require large data centers to be hosted, that are usually powered by fossil fuels, the concern is that in terrains such as Zimbabwe where power outages are a norm these data centers would be powered by generators that use diesel contributing to the nations carbon footprint. But to combat the negative impact of digital culture, public campaigns can help build awareness on consumers' digital habits through social media. Socio-economic factors include the high costs involved in setting up green efficient infrastructure that runs on renewable energy, Zimbabwe is mostly sunny throughout the year. Such that data centers can take advantage of the abundance of solar energy to power their energy intensive systems. To combat the costs, IT companies can receive incentives from the private sector or the government in the form of tax breaks awarded to companies utilizing renewable energy in their development process. Allowing the same companies to redirect funding towards setting up efficient infrastructure, upskilling their developers and investing into the innovation of new technologies.

5.4 Implications

This section seeks to highlight the significance of the research findings on the state of green software engineering in Zimbabwe. Furthermore, the study will expand on the discussion of GSE, setting the tone as to how this research contributes to the practice and future research on Green Software Engineering in Zimbabwe.

1. **Developer**

   First implication, regarding Developers and Industry experts the research exposed a major gap between the industry knowledge on sustainability and the current skills of the developers. Most are familiar with the concept but have not incorporated the principle or rarely consider it when developing software. Acknowledging their resistance to adopt green tools and practice fueled by management's goals and resource constraints. Tools such as optimized algorithms more suited for Zimbabwe, are what developers should be investing time into and tailoring to meet the needs of Zimbabwe. Improvement of tools could be easily achieved by use of collaborative platforms such as GitHub repositories, where developers can share knowledge on green technologies.

2. **Government**

   The study highlighted the role and importance of government intervention in establishing frameworks and policies that support the adoption of green software engineering. Government investment in the software industry is critical for accelerating green technology. By utilizing the potential of AI to unlock underutilized data and improve industrial efficiency, the Zimbabwean government can drive considerable decarbonization initiatives and encourage long-term economic growth. Currently, the government needs to collaborate with academic institutions and environmental groups and mandate carbon emission standards.

3. **Zimbabwean universities**

Universities implications are very straightforward, with the survey revealing that 59.1% students were not familiar with the green engineering concept, implying that Zimbabwe is far from successfully implementing GSE. However, there is a shared sentiment that the integration of GSE is a critical need within academic curricula, so that students are equipped with practical skills and foster a sense of environmental responsibility. Education plays an important role in empowering individuals, without Zimbabwe's future developers would be unable to effectively manage issues to do with environmental sustainability. Academic institutions should partner with IT firms and tech communities to curate courses that are relevant and in line with sustainable coding and energy efficient system designs.

4. **Environmental groups**

Respondents referenced a ‘Lack of awareness’ as one of the major barriers hindering the adoption of GSE this is due to the poor dissemination of knowledge on the topic. Sustainability is often discussed as meeting the needs of the present without compromising the ability of future generations to meet their own needs. However, this study underlined the non-existent efforts of Environmental groups in Zimbabwe, that could be pushing for corporate accountability and transparency in the IT sector. Therefore, more could be done by environmental groups

5. **Tech companies**

Tech companies should ensure sustainability as a priority throughout their software development process, ensuring they use renewable energy sources to power their infrastructure and considering the adoption of cloud into their overall strategy. Local firms such as TANO Digital solutions use cloud computing solutions, whilst ensuring the safe and responsible disposal of obsolete hardware. Apart from that there is a need for training in response to lack of technical skills in green software principles

5.5 Recommendations

The Zimbabwean government can drive decarbonization initiatives and encourage long-term economic growth. As it stands the government needs to collaborate with academic institutions and environmental groups and mandate carbon emission standards. Taking the lead in strengthening policy frameworks, such that companies will feel more compelled to conform into the new ´Green´ this can be done by incentivizing, awarding tax breaks to those tech firms that are utilizing green software practices.

I would recommend training and a more enhanced education that takes sustainability into consideration, while educating software developers and students about green software and its prospects. To advance and promote green software, further research and development is required in multiple areas including environmental impact assessment, standards and regulation, and harnessing software for environmental sustainability. Such that universities partner with IT firms

and companies to develop courses for students that are relevant, informative and prepare them with the necessary skills to tackle future problems

In addition, I recommend the use of various mediums of communication to spread the concept of GSE across Zimbabwe, such that individuals are aware of their responsibility in ensuring the sustainability of their nation. To appeal to the younger generation, pushing the agenda of green Tech would be most appropriate over social media apps where they can share ads with fellow peers. Radios would be most suitable for the more mature age group, slowly but surely the new of GSE would be spread. Campaigns by environment groups funded by the Government and private sector, bring more awareness to the multiple green approaches, such as leveraging AI, Cloud adoption and code optimizing.

As the tech industry continues to expand, amidst the growth of these new technologies, and it would be in the best interests for Zimbabwe to embrace these tools. The likes of AI by leveraging technologies such as AI that are becoming more mindful and efficient about their carbon footprint. A carbon-aware application modifies its behavior dependent on the carbon intensity of the grid from which it draws power. A carbon-efficient application is intended to use less energy while providing the same or nearly the same functionality. With the existence of various technologies and tools it would reduce the data center reliance due to the green tools dynamic resource allocation abilities.

5.6 Suggestions for Further Research

Further study could address gaps in literature related to the state of green software engineering in Zimbabwe. Future researchers may investigate the topic under different data, for instance investigating the operational challenges and benefits of using renewable energy sources to power data centers in Zimbabwe. Apart from that, Zimbabwe is a farming country therefore agriculture is one industry that is subject to evaluations as too whether it is sustainable, due to farming practices that utilize harmful chemicals. Hence, research could be carried out to assess the environmental impact of Agricultural tech-software and the potential opportunities green tech offers rural communities. Computer science and software engineering students at African university could collaborate and utilize green optimizing code algorithms and other sustainable development approaches and evaluate which one of the approaches is most likely to integrate seamlessly into the University's overall IT strategy.

Project Budget

Description	Cost	Budget
Miscellaneous	$30	
Printing	$20	
Data & Internet	$50	
TOTAL		$100.00

Table 5: Project Budget

Project Timeline

Dates	Activities	Completed
1 April-May 2024	Drafting of proposals – Chapter 1 & 3	x
28 June 2024	Submission of proposals to AUREC	
1 August-Dec 2024	Data Collection	
1 January – Feb 2025	Submission of Chapter 4 & 5 write up	
28 March 2025	Deadline Submission – Final Research copy to respective College	

Table 6: Project Timeline

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APPENDICES

List of Appendices

APPENDIX 1: Questionnaire Survey Instrument targeted at TANO

1. **What is your role at Tano Digital Solutions?**

   (Open-ended)

2. **How long have you been working in the software industry?**
   a. a) Less than 1 year
   b. b) 1–3 years
   c. c) 4–6 years
   d. d) More than 6 years

3. **How familiar are you with the concept of green software engineering?**
   a. a) Very familiar
   b. b) Somewhat familiar
   c. c) Not familiar

4. **Which best describes your understanding of green software engineering?**
   a. a) Energy efficiency
   b. b) Minimizing resource consumption
   c. c) Sustainable development practices
   d. d) Reduced carbon footprint
   e. e) All of the above

5. **Does Tano Digital Solutions implement any green software engineering practices?**
   a. a) Yes
   b. b) No

c. c) Not sure

6. **If yes, which practices are in use?** *(Select all that apply)*
    a. a) Cloud computing solutions
    b. b) Recycling/responsible hardware disposal
    c. c) Energy-efficient coding
    d. d) Virtualization
    e. e) Other: ____

7. **How often do you consider environmental impact when developing software?**
    a. a) Always
    b. b) Sometimes
    c. c) Rarely
    d. d) Never

8. **Which SAP tools/features support green software engineering?** *(Select all that apply)*
    a. a) SAP Cloud Platform
    b. b) SAP Analytics Cloud
    c. c) SAP S/4HANA
    d. d) Other: ____

9. **Which aspects of GSE are most applicable to SAP services?** *(Select all that apply)*

a. a) Energy efficiency
b. b) Resource optimization
c. c) Sustainable coding practices
d. d) Reduced carbon footprint
e. e) Other: ____

10. **What tools/technologies do you use to support GSE?** *(Select all that apply)*
    a. a) Virtualization software
    b. b) Energy monitoring tools
    c. c) Code optimization tools
    d. d) Other: ____

11. **How effective are current tools in supporting green practices?**
    a. a) Very effective
    b. b) Somewhat effective
    c. c) Not effective
    d. d) Not sure

12. **Biggest challenges to implementing GSE at Tano?** *(Select all that apply)*
    a. a) Lack of awareness
    b. b) Limited resources
    c. c) Resistance to change
    d. d) Lack of training
    e. e) Other: ____

13. **Describe a specific GSE-related challenge you've encountered.**

(Open-ended)

14. **How important is organizational adoption of GSE practices?**

a. a) Very important
b. b) Somewhat important
c. c) Neutral
d. d) Not important

15. **How can GSE benefit Tano Digital Solutions?**

(Open-ended)

16. **Suggested changes to improve GSE initiatives at Tano.**

(Open-ended)

17. **Additional training/resources needed for GSE adoption.**

(Open-ended)

18. **Any other comments on GSE or sustainability at Tano.**

(Open-ended)

Appendix A

APPENDIX 2: Questionnaire Survey Instrument targeted students at AU

Demographic Information

1. What is your age?
    a. a) 18-20
    b. b) 21-23
    c. c) 24-26
    d. d) 27+
2. What is your gender?
    a. a) Male
    b. b) Female
    c. c) Other

3. Are you currently working in the IT industry?
    a. a) Yes
    b. b) No

4. If yes, what is your role in the industry?
    (Open-ended)

5. How long have you been working in the software industry?
    a. a) Less than 1 year
    b. b) 1-3 years
    c. c) 4-6 years
    d. d) More than 6 years

6. **Does your organization implement any Green Software Engineering practices?**
    a. a) Yes
    b. b) No
    c. c) Not sure

7. **If yes, which practices are currently in use?** *(Select all that apply)*
    a. a) Cloud computing solutions
    b. b) Recycling/responsible hardware disposal
    c. c) Energy-efficient coding
    d. d) Virtualization
    e. e) Other: ____
8. **What tools or technologies do you use that support Green Software Engineering?** *(Select all that apply)*
    a. a) Virtualization software
    b. b) Energy monitoring tools
    c. c) Code optimization tools
    d. d) Other: ____

9. **Describe a specific challenge you have encountered related to Green Software Engineering.**
    (Open-ended)

10. **How often do you consider environmental impact when developing software?**

a. a) Always
b. b) Sometimes
c. c) Rarely
d. d) Never

General Awareness & Attitudes

11. **How familiar are you with the concept of Green Software Engineering?**
    a. a) Very familiar
    b. b) Somewhat familiar
    c. c) Not familiar at all

12. **How would you define Green Software Engineering?** *(Open-ended)*

13. **Where did you learn about Green Software Engineering?** *(Select all that apply)*
    a. a) University courses
    b. b) Workshops/seminars
    c. c) Online resources
    d. d) Peer conversations
    e. e) Other: ____

14. **Which aspects of Green Software Engineering do you understand?** *(Select all that apply)*
    a. a) Energy-efficient coding practices
    b. b) Sustainable software development lifecycle

c. c) Minimizing resource consumption
d. d) Eco-friendly hardware usage
e. e) Other: ____
f.

15. **What is your level of education?**
    a. a) Undergraduate
    b. b) Postgraduate

16. **College affiliation:**
    a) "College of Engineering and Applied Sciences"
    b) "College of Business and Management"
    c) "College of Health Sciences"
    d) "College of Social Sciences"

17. **Field of study:**
    a. "Computer Science/IT"
    b. "Business Administration"
    c. "Software Engineering"
    d. "Social Work"
    e. "International Relations"
    f. "Education"
    g. "Health Sciences"

18. **Which Green Software Engineering strategies are you familiar with?** *(Select all that apply)*
    a. a) Energy-efficient coding practices
    b. b) Life Cycle analysis of software

c. c) Sustainable DevOps practices

d. d) None of the above

Barriers & Opportunities

19. **What do you think are the biggest challenges to implementing Green Software Engineering in Zimbabwe?** *(Select all that apply)*

a. a) Lack of awareness

b. b) Limited resources

c. c) Institutional resistance

d. d) Economic constraints

e. e) Insufficient training

20. **Have you ever implemented any Green Software Engineering practices in your software projects?**

a. a) Yes

b. b) No

21. **If yes, please describe your experience and the principles you applied.**

(Open-ended)

22. **Are there any local initiatives, organizations, or companies that you are aware of that promote Green Software Engineering or sustainability in software development?**

a. a) Yes

b. b) No

c. c) Not sure

23. **How important do you think it is to incorporate sustainable practices in software development?**

a. a) Very important

b. b) Important

c. c) Neutral

d. d) Not important

24. **Do you believe that software engineers have a responsibility to consider environmental impacts?**

a. a) Strongly agree

b. b) Agree

c. c) Neutral

d. d) Disagree

25. **What do you believe are the benefits of Green Software Engineering?** *(Select all that apply)*

a. a) Environmental protection

b. b) Cost reduction

c. c) Improved efficiency

d. d) Other: _____

e.

26. **In your opinion, what steps can be taken to promote Green Software Engineering in universities and Zimbabwe?**
(Open-ended)

27. **Do you think institutions in Zimbabwe are doing enough to promote Green Software Engineering?**
    a. a) Yes
    b. b) No
    c. c) Not sure

Appendix B

Dear MAHACHI EVA MRS

Thank you for paying using the CBZ Touch Bill Payment service in respect of:

Institution Name	210456
Student's Name	MAZVITA EVITA MAHACHI
Student Number	210456
Amount	USD 15
Date	26-Jun-2024
Narration	TUTION AND OTHER FEES 210456 AFRICA UNIVERSITY CBZ BANK REF 015FBPM241780003

Emailed
For & on behalf of CBZ Bank

.

Appendix C

Africa University,
AU, 1 Fairview Rd,
Old Mutare, Zimbabwe
+263 8688002151

Human Resource Executive
Tano Digital Solutions,
First Mutual Park, 100 Liberation Legacy Way,
Borrowdale,Harare

29/07 /2024

Dear Madam,

Re: Permission to conduct research at TANO Digital Solutions.

I hope this letter finds you well. My name is Mazvita .E.Mahachi am studying towards a Bachelor's degree in Software Engineering at Africa University I am writing to respectfully request your permission to carry out research at Tano Digital Solutions.

The objective of my study is to explore the current state of green software engineering, identify key challenges and barriers to its adoption, examine the environmental impact of software systems , and propose a framework for integrating sustainability considerations into software engineering practices in the African region. Given Tano Digital Solutions well-established software development operations in five African countries. I believe the organization would be an ideal institute for this research.

The research will entail collecting data from the staff of Tano Digital Solutions, specifically the development teams, project managers through structured interviews and questionnaires with.Preferably allowing me the opportunity to conduct a mixed-methods study involving both qualitative and quantitative data collection. The research efforts would be suited to cause little disturbance to your day-to-day operations while maintaining the confidentiality of any sensitive material. Participants will be asked to give their written or verbal consent before the research begins. Their responses will be treated confidentially, and identities will be anonymous unless otherwise expressly indicated. Individual privacy will be maintained in all published and written data resulting from the study.

Thank you in advance for considering my request. I feel that this study has the potential to make a significant contribution to the field of green software engineering, and I would be pleased to collaborate with Tano Digital Solutions on this important project.

Approved By:

MARCELLINE CHIEZA — Printed name & Title

Signature

31-7-2024 — Date

Yours sincerely,
Mazvita Mahachi
Africa University.
mahachim@africau.edu

Appendix D

AFRICA UNIVERSITY
A United Methodist-Related Institution

COLLEGE OF ENGINEERING AND APPLIED SCIENCES

31/07/2024

Africa University Research Ethics Committee

Ref: Approval for AUREC Proposal Submission

Mazvita Mahachi has worked on the proposal Titled:" **INVESTIGATING THE STATE OF GREEN SOFTWARE ENGINEERING IN ZIMBABWE : A CASE STUDY OF TANO DIGITAL SOLUTIONS**" with the assistance of the supervisor and I confirm that it is ready for reviewed by your esteemed committee.

Respectfully submitted,

Timothy Makambwa	
Supervisor's Name	Supervisor's Signature
Timothy Makambwa H.O.D	H.O. D's Signature

Appendix E