NATIONAL SCIENCE, TECHNOLOGY AND INNOVATION COUNCIL (NSTIC)

Promotion of Food Security and Modern Agriculture

Project Title:

Development of a Solar-Powered Water Chilling Mechanism to Boost High-Value Crop Cultivation in Low Land Areas of Sierra Leone

-A Demonstration Project-

Submitted by:

University of Sierra Leone

Njala University

University of Johannesburg (Consulting)

Industry Partners

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1. Executive Summary

Tropical climate regions of the world are usually characterized by higher average temperatures ranging from 18 ^{o}C to 40 ^{o}C, which are known to decline by an average of 0.5 ^{o}C per 100 m increase in altitude. Coastal areas are often plane while the interior can be mountainous, thus both temperatures and rainfall are higher in the coastal areas and become less in the interior of tropical countries. The favorable temperatures of high land regions (around 500 m altitudes) of the tropics allow for high value crops to be grown on hills and mountain sides, notable farming areas of the interior of most tropical climate countries. For most low land regions with altitudes of below 200 m the high temperatures limit bacterial activates in soils such as actinomycetes that enhance growth of high value crops. This is one major reason for the lack of large scale agricultural activities in low land areas of tropical climate countries.

Sierra Leone, as a tropical country, has high average temperatures all year round, with monsoon rainy seasons that can range from May to November in the north and April to November in the South. This period can experience high rainfall averaging 2000 – 3000 mm with the highest in the coastal areas. The landscape ranges from low land areas in the west and south-west to mountains in the east and north-east, thus the temperature is high in the lower ranges of the coastal areas and low in the interior as one reaches altitudes of over 1000 m. It is therefore no surprise that the bulk of large scale commercial farming is in the higher hilly regions of the country. Lowland farming is seldom practiced except for vegetables in some planes that experience annual flooding

Sierra Leone, with its abundant agricultural potential, faces challenges in maximizing crop yields in part due to the impact of high temperatures in low-lying areas. This project focuses on the development and implementation of a solar-powered water chilling mechanism tailored to the unique low planes agricultural landscape of Sierra Leone. The system is designed on the Rankine refrigeration cycle that maintains the agricultural bed at a conducive temperature favorable to the grown of the right microbial activities to boost high value crop cultivation in low land areas of Sierra Leone. By mitigating the adverse effects of tropical heating of soils, the project aims to boost the cultivation of high-value crops, contributing to food security, agricultural innovation, climate impact mitigation, research, job creation and economic development of the country.

The primary objective of this project is to address the specific agricultural challenges faced by Sierra Leone which are low annual yields limiting income of farmers and the concomitant poverty particularly of people living in rural areas of the country.. The system aims to increase lowland farming practices by enhancing the productivity of high-value crops in these areas, ensuring a sustainable and resilient agricultural sector, using refrigeration technology. A suitable low land area in the vicinity of Njala University main campus is chosen as the demonstration site and crops to be grown include cassava, rice and some vegetables. The

team will study aspects of the climate for the chosen demonstration site, the soil biology, toxicology of the soil from contaminant chemical production in the area as the maim data to be collected. This data will be used to design a cooling mechanism that maintains water at chosen temperatures for circulation through the agricultural bed. The circulating water cools down the agricultural bed to the desired temperature for bacterial activities to enhance crop growth. Water for the system will be obtained from nearby aquifers and the use of an atmospheric water generator (AWG), stored in a large tank, and purified to ISO irrigation standards for use for both the refrigeration system and irrigation. This setciup will be used to demonstrate that high value crops like cassava and rice can produce more than one yields a year through well planned farming systems that are irrigated throughout the year.

Thus this solar-powered water chilling system is tailored to address the unique climatic and topographic conditions of Sierra Leone, taking into account factors such as temperature variability, humidity levels, soil microbiology and specific crop growth requirements. The project will ensure collaborating partnerships between institutions (University of Sierra Leone, Njala University and University of Johannesburg), local farmers, agricultural experts, climate impact mitigation experts, industry partners both local and international and communities to incorporate indigenous knowledge and ensure the system meets the practical needs of Sierra Leonean farmers and society at large. The project will build capacity and provide training programs to local farmers on the operation and maintenance of the solar-powered water chilling mechanism, empowering them to utilize the technology effectively. Moreover, the system will be powered by solar energy, the most abundantly available form of renewable energy source that is readily available in Sierra Leone year round.

By maintaining optimal growing conditions, the solar-powered water chilling mechanism aims to significantly increase the yield of high-value crops while using solar power not only reduces operational costs but also promotes sustainability by minimizing the project's carbon footprint, while mitigating the impact of extreme temperatures on crop production. The system will be designed to be easily adaptable to different crop varieties, providing flexibility for farmers in diverse agricultural settings. The project will contribute to climate resilience in agriculture by mitigating the impact of rising temperatures on crop production. The economic viability of the system will be assessed by considering factors such as return on investment, operational costs, and potential income generation for farmers. The project will contribute to a more stable and diverse food supply for Sierra Leone by enhancing the yields of high-value crops. The high-value crops will have the potential to improve the economic conditions of farmers, creating new opportunities for income generation. Harnessing solar power promotes sustainable agriculture, reducing dependence on non-renewable energy sources and minimizing the environmental impact of crop cultivation. Collaboration between institutions and industry partners ensures this project brings together some of the

leading experts in the field to address a most pressing problem of the country and developing lasting solutions while creating jobs and improving opportunities for research, knowledge creation, sharing, innovation and dissemination of knowledge.

The implementing team will conduct a comprehensive assessment of agricultural needs in low-lying areas of Sierra Leone to inform the design and implementation of the solar-powered water chilling system. The team will collaborate with government agencies, industry partners, local NGOs, and community leaders to garner support and ensure a holistic approach to the project implementation. A robust monitoring and evaluation framework will be established to assess the impact of the biogas plant and gas cooking stove on society, environmental impact, climate change mitigation, economic outcomes, and overall community well-being. Going forward the team will propose strategies for a wider implementation of the project nationwide and patenting of the knowledge and technology generated from the project.

In June 2022 the University of Sierra Leone (USL) signed a research and teaching collaboration agreement with the University of Johannesburg (UJ) in South Africa. As part of this agreement the USL can access the state of the arts research facilities of the UJ with potential for exchange of knowledge, teaching staff travels and student exchanges. This project will be undertaken under this collaboration with UJ as an international partner to provide consulting expertise to the Sierra Leone based team.

Keywords: Sierra Leone; Agriculture; Technology; Innovation; Water Chilling Mechanism; Microbiology; Environmental Impact; Climate Change Mitigation Strategies.

2. Background and Rationale

Advanced agriculture in the current world economic climate can help lift people out of poverty, promote economic growth, and enhance food security. Among all spheres of human activity, agriculture is the first sector of the economy to be so greatly influenced by climate change. Plant growth and yields are affected by temperature variability as the rate at which crops progress through several developmental stages and the subsequent duration of the entire growth period is greatly influenced by changes in temperature, the plant type and the region of cultivation [1].

Countries that are found within tropical climate regions are generally characterized by high annual average temperatures; hence high-value temperature crops are often cultivated [2]. Howe er, low soil temperatures favor the growing of high-value crops that are known to have a higher return per hectare of land than other widely cultivated crops, thereby presenting enough opportunities for farmers to increase their income. The agricultural industry is in high demand for these high value crops, making it profitable while creating pressure on land use. As a result, over-farming occurs, exposing the nearby inhabitants to severe soil erosion

with potential of landslides [3]. Growing these crops in tropical lowland areas, however, is difficult due to the high soil cooling load required, except through greenhouse farming which involves cooling the entire air volume of planting zones or on few cool higher altitudes that have climates comparable to highland regions [3].

Studies has shown that cooling the soil rather than conditioning the air volume of the entire planting zone within the greenhouse is essential for encouraging the growth of the appropriate micro-organisms for high-value crops to grow successfully. Population growth has led to a greater need for food and a reduction in planting space, some of which are unable to sustain high value crops due to high temperatures. The already stressed agricultural ecosystem is impacted by climate change, industrial and environmental waste generation, particularly high value crops which are highly dependent on low soil temperatures for optimal performance. This poses a significant challenge of the sustainability and profitability of these cultivation operations. To address this problem, the design of a solar thermal chilled machine is required which can efficiently cool the agricultural soil to create favorable soil conditions for optimal performance of planted high value crops.

Sierra Leone has identified agriculture as a key driver of economic development and attaining food security requires focused strategies to boost agricultural productivity. This project aligns with the country's development priorities by addressing the urgent need for sustainable solutions to enhance agricultural productivity, especially in the face of climate change. The project holds scientific significance by bridging the gaps between global research in advanced technologies and the specific needs of Sierra Leone's agricultural landscape. It contributes valuable insights into the complex relationship between environmental conditions and crop productivity. The urgency stems from the immediate impact of climate change on crop yields and the livelihoods of Sierra Leonean farmers. The magnitude of the problem is substantial, as high-value crops are critical for both economic stability and nutritional diversity in the country.

The project is of special importance for the private sector, particularly for companies involved in agriculture and renewable energy. The development and implementation of solar-powered water chilling mechanisms can open new market opportunities, drive innovation, and contribute to sustainable business practices. The proposed research project addresses the need to build research capacity in Sierra Leone by fostering collaboration between local research institutions, government agencies, and international partners. It provides a platform for skill development and knowledge transfer, contributing to the country's research and development infrastructure.

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3. Project Goal and Specific Objectives

The goal of this project is to enhance agricultural resilience and improve food security in Sierra Leone by developing, implementing, and augmenting a solar-powered water chilling mechanism tailored for low-lying areas, thereby fostering sustainable cultivation of high-value crops in tropical climate regions. The system aims to provide a controlled and conducive environment for the cultivation of high-value crops, ensuring optimal growth conditions and high yields per hectare of cultivated land

3.1 Specific Objectives:

- Conduct community sensitization drives to generate critical support for the project among local communities particularly Chiefs and farmers (Team).
- Allocate suitable land area in the vicinity of Njala University main campus of 10 acres or more for this demonstration project (DVC-AB).
- Determine types of high value crops to be grown on the demonstration plot, layout and planning of the agricultural beds (PS).
- Determine the precise climatic parameters for each identified high-value crop to maximize yield and quality (PS).
- Conduct environmental impact assessment for the chosen demonstration location (VK).
- Study the microbiological conditions of the soils at the chosen demonstration site conducive for the right bacterial activity for each selected high value crop type (FJ-E).
- Investigate toxicology conditions of the soils for potential contaminants that may affect the growth and food quality of the chosen crops (MD).
- Investigate requirements for installation of a solar power system for the demonstration project including sizing of panels (DVC KGM).
- Determine design variables for the development of the water chilling mechanism (SAI).
- Develop a solar-powered water chilling mechanism specifically adapted to the climatic and geographical conditions of low-lying areas in Sierra Leone (MAC & DVVK).
- Implement efficient solar energy harvesting technologies to power the chilling mechanism, ensuring sustainability and minimizing environmental impact (DVC KGM, VK, MAC & DVVK).

- Investigate and adapt the technology to the unique requirements of high-value crops commonly cultivated in Sierra Leone, considering temperature thresholds, humidity levels, and growth patterns (Team).
- Conduct a comprehensive economic feasibility study to evaluate the viability of implementing the solar-powered water chilling system in Sierra Leone's agricultural sector (EOC).
- Assess the economic benefits for farmers, including potential income generation, cost savings, and long-term sustainability (EOC).
- Develop prototypes of the solar-powered water chilling mechanism based on the findings from feasibility studies (MAC & DVVK).
- Construct and manufacture of the system, including large tanks and an atmospheric water generator of 1000 L/day capacity (Local and International Industry partners and the Team).
- Install and demonstrate the solution to the Government, farmers and other stakeholders (Team0.
- Plan an irrigation system using the water recycled from the atmospheric water generator (PS & FJ-E).
- Integrate the Fourth Industrial Revolution (4IR) tools into the system such as IoT for remote monitoring of the system (DVC KGM, MAC & DVVK).
- Foster collaboration with local communities, farmers, and relevant stakeholders to ensure the technology aligns with their needs and practices (Team).
- Potentially disclose an invention for patenting (Team).
- Develop strategies for large scale implementation of the project outcomes around Sierra Leone (Team).
- Develop and implement training programs to empower local farmers with the knowledge and skills needed for the effective operation and maintenance of the new system.
- Training of postgraduate students at both USL and NU at Masters and PhD levels. Subject specific areas will include Agriculture, Economics, Engineering and Environmental Science.
- Develop strategies for dissemination of knowledge generated from the project in the form of conference papers, journals papers, book chapters and books.

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4. Project Methodology and Approach

This comprehensive methodology combines rigorous research and development, community engagement, user participation, and robust data analysis to address the specific challenges faced by low-lying farming regions in Sierra Leone. The activities outlined aim to not only develop an effective solar-powered water

chilling mechanism but also ensure its successful implementation and long-term sustainability in collaboration with local communities and industry partners.

4.1. Research and Development

4.1.1. Objective: Develop a Solar-Powered Water Chilling Mechanism.
Activities:

Literature Review:

- Conduct an extensive review of existing solar-powered chilling technologies, agricultural cooling systems, and sustainable practices in tropical regions.
- Identify key challenges and opportunities related to solar-powered water chilling in low-lying tropical areas.
- Identify key variables required for the development of a solar-powered water chilling mechanism in Sierra Leone.
- Investigate soil and crop science that enhances the growth of high value crops on low lying areas of Sierra Leone.

Collaboration with Experts:

- Engage with experts in renewable energy, engineering, and agricultural sciences to form a multidisciplinary team.
- Establish partnerships with research institutions and industry experts to leverage existing knowledge and expertise to inform the design process.

Feasibility Studies:

- Conduct familiarization visits to low lying areas of Sierra Leone to study the geological conditions that may impact agricultural activities.
- Develop critical support for the project among Chiefs, farmers, local communities and stakeholders.
- Conduct on-site assessments in low land areas of Sierra Leone to determine the specific climatic and topographic conditions.
- Collect and analyse soil samples for microbiology, toxicology and other environmental impact conditions.
- Assess the energy requirements, water sources, and crop-specific chilling needs.

Prototyping:

- Develop prototypes of the solar-powered water chilling mechanism based on the findings from feasibility studies.
- Test prototypes in controlled environments to assess their efficiency and reliability.

4.2. Implementation

4.2.1. Objective: Implement the System in Low-Lying Areas

Activities:

Site Selection:

- Utilize geographical information systems (GIS) and climate modelling to identify suitable low-lying areas in Sierra Leone for system installation. Preferably around the vicinity of Njala University main campus.
- Consider factors such as sunlight exposure, proximity to water sources, and accessibility.

Construction and installation:

- Collaborate with local engineering firms for the construction of the solar-powered water chilling infrastructure.
- Collaborate with international partners in South Africa where local partners cannot complete the construction of the system.
- Ensure that the design adheres to safety standards and is adaptable to the local context.
- Implement the chilling system in selected sites, integrating it with existing irrigation infrastructure.

Integration with Irrigation Infrastructure:

- Work with local agricultural agencies to integrate the chilling system with existing irrigation infrastructure.
- Implement smart irrigation practices based on real-time data from the chilling mechanism.
- Install an atmospheric water generator developed in South Africa with a 1000 L/day capacity to boost both the system water circulation and irrigation.

Monitoring and Optimization:

- Install monitoring devices to collect data on temperature regulation, energy consumption, water usage, and crop performance.
- Integrate 4IR tools for remote monitoring of the system.
- Continuously optimize the system based on real-time data and user feedback.

4.3. Training and Capacity Building

4.3.1. Objective: Provide Training to Local Farmers and students

Activities:

Workshops and Training Sessions:

- Conduct workshops to train local farmers on the operation and maintenance of the solar-powered water chilling system.
- Include sessions on sustainable agricultural practices and maximizing crop yields.
- Training of postgraduate students.

Community Engagement:

- Foster community engagement through participatory workshops and knowledge-sharing sessions.
- Establish farmer cooperatives to encourage collective responsibility and shared learning.

User Manuals and Guides:

- Develop user-friendly manuals and guides in local languages for the ongoing reference of farmers.
- Provide accessible resources for troubleshooting and system maintenance.

4.4. User Participation

4.4.1. Objective: Foster Community Engagement

Activities:

Community Meetings:

- Organize regular community meetings to update stakeholders on project progress and gather feedback.
- Establish a feedback loop for continuous improvement based on user experiences.

Demonstration Farm:

- Set up demonstration a farm in collaboration with local farmers to showcase the benefits of the solar-powered chilling mechanism.
- Encourage hands-on learning and experimentation.

Inclusive Decision-Making:

- Involve local farmers in decision-making processes related to the project, considering their knowledge and preferences.
- Adapt project strategies based on community input.

4.5. Objective: Involve the Private Sector in the Project

Activities:

Stakeholder Workshops:

- Organize workshops involving representatives from the private sector, including agribusinesses and distributors.
- Gather input on system design, functionality, and potential collaboration opportunities.

Collaborative Decision-Making:

- Establish a joint decision-making committee with private sector representatives to inform project strategies.
- Involve private sector partners in key decisions related to implementation and scalability.

Technology Transfer:

- Facilitate technology transfer activities, allowing private sector partners to understand and adapt the chilling mechanism for commercial applications.
- Explore potential business models for sustained collaboration beyond the project duration.

4.6. Data Collection and Analysis

4.6.1. Objective: Monitor and Analyze System Performance

Activities:

Data Collection Devices:

- Install sensors and data collection devices to gather information on energy consumption, chilling efficiency, and crop growth.
- Ensure the integration of data collection with user-friendly interfaces.

Data Analysis:

- Analyse collected data using statistical methods and modelling techniques.
- Employ software such as R or Python for statistical analysis and modelling.
- Evaluate the correlation between chilling system performance and crop yield.

Feedback Mechanism:

- Establish a real-time feedback mechanism for farmers to report issues and observations.
- Use qualitative and quantitative data to assess the overall impact of the chilling mechanism.

Access and Sharing:

- Facilitate controlled access to project data for authorized personnel.
- Share aggregated and anonymized data with stakeholders, ensuring privacy and compliance with regulations.

Archiving:

- Develop a data archiving plan for long-term storage and accessibility of project-related data.
- Ensure compliance with data retention policies and ethical standards.

4.6. Conceptual and Theoretical Framework

4.6.1. Sustainable Development Goals (SDGs):

- Align the project with relevant UN 2030 SDGs, particularly those related to zero hunger, clean energy, human capital development and sustainable agriculture.

4.7. Technological Framework:

- Ground the project in established principles of solar energy harvesting, water chilling technologies, and precision agriculture.

4.8. Social Framework:

- Emphasize community-based approaches, traditional leadership participation, social inclusion, and capacity building to ensure long-term sustainability.

4.9 Ethical Considerations

Confidentiality:

- Implement strict confidentiality measures for any personal or proprietary information collected during the project.
- Obtain informed consent from participants, clearly outlining the use and protection of their data.

Biological Samples:

- The project team will clearly stipulate the collection and handling procedures for any biological samples.
- The project team will ensure compliance with ethical guidelines and obtain necessary approvals.

Laboratory Procedures:

- All laboratory procedures and protocols related to data collection will be specified, ensuring transparency and reproducibility.

- The team will ensure relevant ethical standards are complied with and seek approval from relevant ethical review boards.

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5. Anticipated Outputs and Outcomes

The project aims not only to generate valuable outputs such as reports and guidelines but also to bring about tangible changes in agricultural practices, economic conditions, and policy frameworks in Sierra Leone. By engaging with stakeholders at multiple levels, the project seeks to ensure the sustainable adoption of the solar-powered water chilling mechanism and contribute to the broader development goals of the region. The project anticipated outputs and outcomes are listed herein:

5.1 Outputs:

- Concise understanding of the challenges of farming on low land areas of Sierra Leone.
- Scientific details of the soils of some low land regions of the country, including environmental impact, microbiological conditions and toxicology assessments.
- Detailed technical reports on the development, testing, and optimization of the solar-powered water chilling mechanism.
- Economic analysis reports on the viability of the system in the context of Sierra \Leone's needs and capacity.
- Protocols for the installation, operation, and maintenance of the solar-powered water chilling system.
- Comprehensive guidelines for replication and adaptation of the technology in low land areas around the country.
- User-friendly training modules and manuals for local farmers, detailing the operation and management of the solar-powered chilling mechanism.
- Educational materials on sustainable agricultural practices and maximizing crop yields.
- Educational brochures, pamphlets, and infographics targeting local communities, highlighting the benefits of the solar-powered water chilling system.
- Public awareness campaigns through local media to disseminate information on sustainable agriculture and the project's impact.
- Clear plans for technology transfer, outlining how the private sector and agribusinesses can adopt and adapt the chilling mechanism for commercial purposes.
- Strategies for engaging with local businesses and fostering collaborations for widespread adoption.
- Scientific publications in peer-reviewed conferences, journals, books, sharing insights and innovations with the broader research community.

- Training of postgraduate students from USL and NU.

Outcomes:

- Contribution to enhanced food security, agricultural innovation and food safety in Sierra Leone.
- Local farmers experience higher crop yields due to the year-round cultivation enabled by the solar-powered water chilling mechanism and its irrigation system.
- Improved incomes for farmers as a result of increased crop production and the cultivation of high-value crops throughout the year.
- Potential for development of agribusiness by youths and young graduates who will adopt the system for implementation in other low land areas of Sierra Leone (job creation and entrepreneurship).
- Adoption of sustainable agricultural practices, reducing the reliance on seasonal cultivation and promoting long-term environmental sustainability.
- Private sector entities in Sierra Leone actively adopt and integrate the solar-powered chilling mechanism into their agricultural operations.
- Recognition and integration of project findings into regional and national agricultural policies, promoting the adoption of sustainable technologies.
- Regular communication with relevant Government Departments, including the Ministry of Agriculture, Ministry of Water Resources, Ministry of Rural Development, Ministry of Works and Ministry of Energy.
- Workshops and policy briefings for policymakers and government officials, showcasing the project's impact and potential contributions to national agricultural and energy strategies.
- Collaboration with regional agricultural and climate organizations to share project outcomes.
- Participation in regional forums and conferences to discuss the broader applicability of the solar-powered water chilling mechanism.
- Engage with local government authorities and agricultural extension services to ensure the incorporation of project findings into local agricultural policies.
- Collaborate with community leaders to facilitate knowledge-sharing sessions and encourage community-led initiatives.
- Establish partnerships with local agribusinesses and distributors through workshops and collaborative decision-making.
- Facilitate technology transfer and support private sector entities in adopting and adapting the chilling mechanism for commercial use.
- Regular community meetings and feedback sessions to ensure that local perspectives are considered in project activities.

- Empower local communities to advocate for sustainable agricultural practices at the local and regional levels, with a greater focus on women participation.
- Potentially register a patent of the invention arising from this project.

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6. Knowledge Utilization and Dissemination

The target audience includes the academic community, researchers, local farmers and agricultural workers, government officials, policymakers, think tanks, private sector entities, the general public, local communities, agribusinesses, distributors, online community and media outlets. The dissemination plan for the project employs a multifaceted approach to share and apply project insights. Scientific publications will target academic communities, contributing to the research domain, while technical reports and guidelines will be crafted for agricultural services and engineers. User-friendly training materials will empower local farmers, with public awareness campaigns ensuring broader community understanding. Private sector collaboration will be emphasized through workshops, aiming to facilitate technology transfer. Policy influence is pursued through workshops and briefs targeted at policymakers and community-led advocacy. Media engagement strategies will include press releases and social media campaigns for wider public outreach. Open Access compliance aligns with principles of inclusivity, and making research findings readily accessible. This approach ensures a comprehensive and targeted dissemination strategy to maximize the impact of the solar-powered chilling system in Sierra Leone.

Awareness/Dissemination plan for Year 1:

Dates	Activity	Description of the activity
January-February 2024	Building a stakeholder forum	The Team will meet with NSTIC and other Government stakeholders to present this intervention and its benefits to Sierra Leone. The forum will meet every 3 months thereafter for continuous reporting of implementation progress.
March-April 2024	Meeting the local leadership of the implementation regions	The Team will meet with Paramount chiefs, locals in villages and District Councillors of the demonstration region. These meetings and presentations will be held to build support from the local leadership
April 2024	Community sensitization events	Event to be attended by community members, local leadership. the Team,

		NSTIC, affected Ministries and other governmental and non governmental agencies.
May –June 2024	Preparation and presentation of mid-year report on the agricultural model intervention	By the Team.
July-December 2024	Social events in both	Visit to schools, hospitals, religious houses of warship, traditional leaders, youth and women's organizations and other NGOs operating in the regions on sensitization activities. By the team.
July-December 2024	Science awareness	Drafting and publishing journal papers, conference papers, book chapters and books by the Team..
December 2024	Preparation and presentation of yearend report on the agricultural model intervention	By the Team.

Awareness/Dissemination plan for Year 2:

Dates	Activity	Description of the activity
January-February 2025	Stakeholder forum meeting on the agricultural model intervention	Consolidation of year 1 implementation activities and review of project work plans for year 2.
March 2025	Demonstration event at the chosen project implementation site – cooling mechanism	Event to be attended by community members, local leadership and Sierra Leone Government.
April 2025	Demonstration event at the chosen project implementation site – irrigation mechanism	Event to be attended by community members, local leadership and Sierra Leone Government.
May –June 2025	Preparation and presentation of mid-year report on the agricultural model intervention	By the Team.
July-September 2025	Social events	Visit to schools, hospitals, religious houses of warship, traditional leaders, youth and women's organizations and other NGOs operating in the regions on

		sensitization activities.
July- September 2025	Science awareness on the agricultural model intervention	Drafting and publishing of journal papers, conference papers, book chapters and books by the Team.
September 2025	Preparation and presentation of project closing report	By the Team.

7. Project Governance

The management of the University of Sierra Leone and the Njala University will play a supportive role, ensuring resource allocation and facilitating collaboration between academia, industry, and community stakeholders. The project team is outlined in Table 1 which demonstrates that the project will be led by two ladies from USL and NU. The team comprises of experts in their respective fields ranging from engineering to economics to agriculture and environmental science with a combined total of more than 150 years of experience in Academic and research work. The selected industry partners are seasoned in their respective industrial applications with GEM Water Management Solutions having branches in South Africa, Ghana, and the USA. The governance structure is pivotal to the project's success, ensuring a holistic approach that combines academic rigor with practical applicability and stakeholder engagement. The project governance structure is designed for effective oversight and collaboration. The project will establish a governance committee comprising key stakeholders, including academic researchers, agricultural experts, traditional leadership and representatives from the private sector. This committee will provide strategic direction, ensure alignment with project objectives, and oversee decision-making. Advisory roles will be filled by experts in renewable energy, agriculture, and climate science, contributing valuable insights and overall project guidance. The research team is composed of highly qualified individuals with expertise in engineering, agronomy, earth science, and environmental science, each assigned specific roles in system development, testing, and community engagement. The project aims to foster collaboration with between universities, research institutes and industry pattners to leverage diverse perspectives and resources. The involvement of the private sector will be integral, with agribusinesses and distributors actively participating in workshops and decision-making sessions.

8. Suitability of the Host Institutions

Collaboration between the University of Sierra Leone (USL) and Njala University (NU) and the consultancy of the University of Johannesburg (UJ) presents an exceptionally suitable host for the proposed project. The participating Departments of these universities offer a unique blend of expertise in engineering, agronomy, soil science and environmental science, aligning perfectly with the interdisciplinary nature of the project. UJ boast a robust technical infrastructure while both USLand NU have a pool of highly qualified researchers with a proven track record in renewable energy and agricultural research. Leveraging these resources, the universities have previously spearheaded impactful initiatives in many area of academic endevour, showcasing a commitment to community outreach and development. These universities have, in the past, maintained strong connections with the private sector, ensuring active collaboration in project workshops and decision-making processes. This project harmonizes seamlessly with the overarching research strategy of both universities, which prioritizes innovative solutions to address local challenges, thereby reinforcing their status as ideal joint host institutions with the capacity to drive meaningful impact in Sierra Leone's agricultural landscape.

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9. Capacity Building

The proposed project places a strong emphasis on capacity building at both individual and organizational levels. Final-year Undergraduate and Post-graduate students, including MSc. and PhD candidates, will be actively involved, offering them opportunities for hands-on research experience, data analysis, and technology development. Specialized training activities are envisaged for students to enhance their skills in renewable energy, agricultural engineering, and sustainable practices. Additionally, training workshops and knowledge-sharing sessions will be conducted for local farmers, promoting the adoption of the solar-powered chilling mechanism and sustainable agricultural practices. The project also plans to enhance the capacity of project partners, particularly in the private sector, through collaborative workshops and technology transfer sessions. This holistic approach to capacity building ensures that knowledge and skills are disseminated across various stakeholders, fostering sustainable impact beyond the project's duration in the form of small and medium enterprises (SMEs) in energy and agriculture.

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10. Monitoring and Evaluation Strategy

The monitoring and evaluation strategy for the proposed project adopts a comprehensive approach to ensure effective progress tracking and impact assessment. Regular monitoring will involve the installation of data collection devices to capture real-time information on energy consumption, chilling efficiency, and crop performance. The research team will conduct frequent site visits to assess the physical implementation of

the chilling mechanism and its integration with irrigation infrastructure. Continuous optimization will be informed by the collected data, ensuring the system's efficiency and addressing any emerging challenges. Evaluation activities will include a robust data analysis process, utilizing statistical methods and modeling techniques to measure the correlation between chilling system performance and crop yield. Feedback mechanisms will be established to engage farmers in reporting issues and observations, providing valuable insights for ongoing improvements. This strategy ensures that the project's objectives are met and that its impact on crop cultivation us understood and continuously optimized.

Indicator	Description of the indicator	How the indicator will be tracked over the duration of the project to show impact
Scheduling	Timelines for implementation, dissemination and reporting	• Targets for each phase of the implementation and demonstration met and reported on timeously.
Awareness	Understanding of the value and benefit of the agricultural model intervention by the locals in the implementation region	• Number of sensitization events held. • Number of varied locations for events. • Number of community members participating in each event.
Low land region soil quality	Improvement in soil quality from study of soil microbiology, toxicology and reduction in agricultural waste generation	• Reduction in harmful chemicals and heavy metals in the soils of the demonstration site. • Biochemical analysis showing improved soil quality from generation of the right microorganisms that favour growth of high value crops.

Water generation from AWG	Collection and storage of water from atmospheric water generator (AWG)	• Quantity of water collected and stored in the large tank, as reported by the installed water flow meters. • Regularity of maintenance and servicing of the water supply system. • Review of tank capacity informed by quantity of water generated by AWG.
Irrigation	AWG and waste water purified to ISO irrigation standards and used to irrigate the demonstration plots	• Number of yields produced per year through introduction of mechanical irrigation. • Rate of irrigation of nearby farms in the implementation region.
Drinking water use	Quantity of drinking water accessed in the vicinity of the implementation region as compared to AWG generation capacity	• Regular report from water flow meters taken. • Size of tank connected to AWG reviewed. • Review of AWG generation capacity.

11. Gender, Ethics and Sustainability

In addressing gender considerations, the project recognizes the importance of inclusivity and equal participation. A gender-sensitive approach will be implemented throughout the project, ensuring that both men and women in the farming communities have equal access to training, resources, and opportunities. The project, which is led by two dynamic and highly specialized women, will actively involve women in decision-making processes and capacity-building initiatives. Data collection will be disaggregated by gender to assess the differential impact of the solar-powered water chilling mechanism on male and female farmers. This approach aligns with the broader goal of promoting gender equality in agricultural practices and ensuring that the benefits of the project reach all members of the community.

Ethical considerations are paramount, and the project will obtain ethical approval from relevant institutional review boards, incuding from the University of Johannesburg research ethics committee for guidance. For projects involving human subjects, informed consent will be sought from participants, clearly explaining the nature of the project, potential risks, and benefits. Privacy, dignity, and integrity will be rigorously protected throughout the research process. Confidentiality measures will be implemented for any personal or proprietary information collected, and participants will be assured that their data will be used solely for research purposes. The project will strictly adhere to ethical guidelines and seek approvals from relevant ethical review boards, University of Johannesburg research ethics committee, ensuring the highest standards of research conduct.

The project is designed with sustainability at its core. Beyond the research phase, the solar-powered water chilling mechanism will be integrated into local agricultural practices to ensure ongoing benefits. Training activities will empower local farmers with the knowledge and skills needed for long-term sustainability. Collaborations with the private sector will explore commercial applications, fostering economic sustainability. Donor partnerships will be sought to support the scaling of the technology. The project aligns with the two institution's ongoing commitment to sustainable development, ensuring that its outcomes have a lasting positive impact on both agricultural practices and the local economy. In terms of funding sustainability, the project will explore partnerships with donors and engage in ongoing discussions with potential funders to ensure continued support beyond the initial phase.

Key risks inherent to the project include technological challenges, community acceptance, and potential environmental impacts. To mitigate technological risks, a thorough prototyping and testing phase will be implemented, and continuous optimization will address emerging challenges. Community acceptance will be addressed through extensive engagement and awareness campaigns. Environmental impacts will be carefully monitored, and the project will adhere to sustainable agricultural practices. Assumptions include community receptiveness and the adaptability of the chilling mechanism. Mitigation plans involve regular community feedback sessions, adaptation of the technology based on real-time data, and adherence to environmental best practices. These risk-mitigation strategies will be continuously assessed and refined throughout the project's lifespan. This proactive approach to risk management aligns with the project's commitment to achieving its objectives while minimizing potential challenges.

Risks	Description	Mitigation
Lack of electricity during installation	Blackouts, power outages can affect the installation work	Power banks and/or generators will be used by the industry

work		implementation partners. This will also reduce power bills on home dwellers at the installations sites
Theft and vandalism	There is a risk of some community members stealing installed components	Local industry partners.will install burglar bars, cages with good protection mechanisms. Community sensitization activities will be held to develop a sense of community ownership of the installations.
Dust and smoke pollution	Due to dusty roads traversed by vehicular traffic and the burning of grass and domestic waste in the villages	The atmospheric water generator and water chiller will be inbuilt with dust proofs, while all filters and flow meters have protective covers. Half yearly maintenance will be undertaken at the installation site.
Religious and traditional practices	Arising from belief systems and cultural practices, some communities may not be open to some developmental activities	The Team has been carefully selected to have members from all regions around the country where installations will take place. They will advise on the belief systems of their communities. The team will then hold meetings with community leaders, local and traditional leadership and religious leadership to discuss the benefits of this agricultural model intervention to their localities

12. Proposed Budget and Timelines

Project Activities	**Year 1**	**Year 2**

	Q1 (Jan 2024-Mar 2024)	**Q2 (Apr 2024-Jun 2024)**	**Q3 (Jul 2024-Sep 2024)**	**Q4 (Oct 2024-Dec 2024)**	**QI (Jan 2025-Mar 2025)**	**Q2 (Apr 2025-Jun 2025)**	**Q3 (Jul 2025-Aug 2025)**	**Total**
Materials and data collection equipment procurement	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	**$7,000**
Safety equipment for the Team Members and local staff	$3,000				$3,000			**$6,000**
Community sensitization Workshops and Training	$500	$500	$500	$500	$500	$500	$500	**$3,500**
Prototype Development and Testing			$4,000			$4,000		**$8,000**
Land use for planting		$5,000						**$5,000**
Purchase, import and installation of 5000L/day AWG			$30,000					**$30,000**
AWG and water chiller housing building construction			$5,000	$5,000				**$10,000**

Data Collection and Analysis	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	**$10,500**
Public Awareness Campaigns	$1,000	$500	$500	$500	$1,000	$500	$500	**$4,500**
Local travel	$500	$500	$500	$500	$500	$500	$500	**$3,500**
International travels	$5,000				$5,000			**$10,000**
Dissemination via Journals			$3,000			$3,000		**$6,000**
Dissemination via international conferences		$5,000			$5,000			**$10,000**
Total	**$12,500**	**$14,000**	**$46,000**	**$9,000**	**$17,500**	**$11,500**	**$4,000**	**$114,500**

Funding support already received			
Funding source	Funding amount [$] (excl. VAT)	Year in which funding received	Description of what the funding was / or will be, used for
University of Sierra Leone	$20,500	2023	Office equipment, Use of University official vehicles, Staff time, lecture theatres for workshops
|Njala University	$20,500	2023	Office equipment, Use of University official vehicles, Staff time, lecture theatres for workshops
Industry Partners	$29,500	2023	Technician salaries times 2 technicians, mobile power bank/generator for location with limited power availability, Draughtsman
Total	**$69,500**		
Total Budget Requested	**$45,000**		

Budget Motivation

Project Budget Summary

The project is expected to run for around two (2) years and the budget is given in the budget table. The budget summary indicates the total cost of running the project, to include cost of travel, accommodation and cost of equipment use. These various cost items are motivated herein.

Disbursement phases

The budget is designed into 7 phases of 3 months each. The NSTIC and any other governmental and nongovernmental agencies supporting this project can disbursement funds in each phase as per the totals per phase given in the budget table.

Staff time

The team comprises 10 participants who are all Academics with duties associated to their respective roles at their Universities. These Academics will devote time and effort to the project at a cost to their respective Universities.

Cost of equipment and materials

Some equipment used to examine and collect data at the installation site will need to be bought. For instance the team wil need a thermal imaging camera that captures precision changes in temperature at the demonstration site, a testo pocket vane anemometer for measuring air flow velocity and others. In addition, soe farming tools, boots, gloves and other materials will be required.

Community sensitization event

As part of the Government's policies, communities and stakeholders will need to be updated and motivated to support the project.

Proctoring and testing

Close collaboration with local industry partners will facilitate the development and manufacturing of the water chilling model. Where facilities and technical capacity is not available in Sierra \Leone the international industry partner will build the water chiller model in South Africa for installation at the demonstration site.

Purchase and installation of an AWG

Te international industry partner, GEM Water, is a manufacturer of a model atmospheric water generator in South Africa. This system condenses water from the air at the location it is installed and can generate up to 1000L of drinking grade water per day. This will be used in the water chiller and for irrigation allowing the team to demonstrate to Sierra Leone the potential of growing more than one yield per year.

Data collection and analysis

From its launching date members of the team will make regular trips to the demonstration site to collect date for their respective roles on the project. For instance Prof Felixtina Jonsyn-Ellis and Mr Mohamed Dumbuya will collect soil samples from different parts of the demonstration plots for microbiological analysis and contaminants determination, respectively.

Public awareness campaigns

The team will make use of facilities such as national media, TV and social media platforms to inform the government and the general public on the progress, gains, lessons, challenges faced and benefit of the project to the country and its people.

Local travels

This project covers an important area of national interest, which is food security. Thus the team will travel extensively locally to various parts the country for feasibility studies, data collection, awareness campaigns and building critical stakeholder support.

International travels

Team members will make some international travels as pat of this project. For instance, some test works may have to be done in South Africa such as at the state of the arts lab facilities of the |University of Johannesburg. Furthermore, Prof Kallon in South Africa will also need to travel to Sierra Leone from time to time to render consultancy services on the project.

Dissemination via journals, conferences and books

This will form an integral part of the project, as findings at all stages of the project will be reported to the scientific and scholarly world via peer reviewed journals, accredited conference proceedings, book chapters and books as the case may be.

Alternative funding sources

The participating institutions will make contributions to the success of the project in kind. For instance staff time will be covered, the institutions will make available their buildings and lecture theatres as host venues for some events, official vehicles will be made available to team members for local travels with petrol cost covered, etc. The Team will also organize fund raisers to generate more income to cover other cost of the project not covered by the NSTIC.

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1. Rasul, G., et al., Effect of Temperature Rise on Crop Growth. Pakistan Journal of Meteorology, 2005. 8(15): p. 53-62
2. Morille, B., C. Migeon, and P.E. Bournet, Scientia Horticulturae Is the Penman – Monteith model adapted to predict crop transpiration under greenhouse conditions ? Application to a New Guinea Impatiens crop. Scientia Horticulturae, 2013. 152: p. 80-91
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APPENDICES

Appendix A: Project Team

The Team is made up of Academics from USL and NU with a combined total of over 150 years of teaching and research experience. The participating industry implementation partners have a combined experience of 20 years in the industrial sectors of water, energy, agriculture and general engineering services.

Dr Salmatta Abiodun Ibrahim – Project Team leader

Dr. Salmatta A Ibrahim is a distinguished geologist, hydrogeologist, engineering scientist, environmental geologist, gender and human rights activist, humanitarian worker, and a passionate advocate for scientific solutions to environmental challenges. Dr. Ibrahim's journey in the realm of education and research began in 1993, when her profound interest in the intersections of environmental science, sustainable energy engineering, engineering geology, and climate change emerged. As a postgraduate teaching assistant in the United Kingdom, Dr. Ibrahim passionately imparted knowledge to PhD, Masters, and Undergraduate candidates, specializing in Sustainable Engineering and Sustainable Energy. Her commitment to education is underscored by her dedication to shaping the next generation of leaders in the field of agricultural sustainability. Throughout her career, she has consistently strived to find innovative and practical solutions to scientific complications within her environment.

As a gender and human rights activist, Dr. Ibrahim has consistently advocated for equality and inclusivity within the scientific community. She firmly believes in the power of diversity and recognizes the urgent need for more women to pursue careers in STEAM (Science, Technology, Engineering, Agriculture, and Mathematics). Dr. Ibrahim tirelessly works to inspire and empower young girls and women to break barriers and embrace scientific professions, fostering a more balanced and inclusive scientific landscape.

In addition to her remarkable professional achievements, Dr. Ibrahim has also made a significant impact as a humanitarian worker. She has actively participated in numerous humanitarian missions, providing critical aid and relief to communities affected by natural disasters and other crises.

Dr. Salmatta Abiodun Ibrahim's comprehensive education, diverse experience, and commitment to innovation makes her a valuable asset to any academic institution seeking to advance the frontiers of Agricultural and Sustainable Engineering. Her passion for education, coupled with her leadership in the agricultural and energy projects, sets her apart as a dynamic and influential figure in the field. Dr. Ibrahim envisions a future where agriculture harmonizes with environmental sustainability, and communities thrive through resilient and efficient farming practices. Her dedication to addressing climate change challenges aligns with her overarching goal of fostering a sustainable and equitable future for agriculture.

Dr Salmatta Abiodun Ibrahim, as one of two female participants on this project Team, is the Project Team Leader.

Prof Felixtina Jonsyn-Ellis – Project Co Team Leader

Degree: BSc. General Biology Nazareth College, Kalamazoo, Michigan, USA .

Degree: MSc. (Hons) Microbiology University of Muenster, Muenster, West Germany,,

Degree: Ph.D. Environmental Microbiology University of Liverpool, Liverpool School of Tropical Medicine,

Scientific positions:

Principal contact or the Partnership of Aflatoxin Control in Africa (PACA) for Aflatoxin elimination in the food chain.

Programme Leader –Microbiology- Sierra Leone Agricultural Research Institute (SLARI)

Part of a team to collect representative sewage samples from capital cities across the globe and other sentinel sites and analyze them for occurrence of antimicrobial resistance genes and other hazards using amongst others, metagenomics analysis. :

Partnership with Friedrich-Loeffler Institut, German Federal Institute for Animal Health-Collaboration in Infectious Disease Research and Training

National Project Coordinator for FAO/University of The Gambia project to strengthen the Agriculture Programme

National Project Coordinator for EU project on Environmental and Socio-Economic contribution of Palm Geotextiles to Sustainable development and soil conservation.

Member of the Steering Committee of the Reduction of Emissions from Deforestation and Forest Degradation (REDD+)

Empowerment of rural women (Community Based Organisations) to practice sustainable agriculture, agro-forestry, soil conservation and biodiversity-Global Environment Fund (GEF) Small Grants Mushroom cultivation techniques (after Training Workshop on Mushroom cultivation-Mutare, Zimbabwe

Designing & Using Geotextile mats to prevent soil Erosion- EU-BORASSUS. Research focus on Sustainable Development ,Soil Conservation and Preservation-issues

Lecturing and supervisory Experience (1st to final year) in various topics of Biology, Microbiology, Immunology and Parasitology. Supervised several Undergraduate, Masters and PhD students (locally and internationally).

Published several articles in the field of mycotoxicology and the following in the field of soil conservation, biodiversity and ecosystem conservation

The potential contribution of palm mat geotextiles to soil conservation and sustainable development, p. 303-306 In: J.A. Martinez-Casanovas, I. PlaSentis, M.C.R. Martin and J.C.B. Solanes (Eds) Soil and Water Conservation under Changing Land Use, Universitat de Lleida, Spain 2006
Contributions of biogeotextiles to sustainable development and soil conservation in developing countries: the Borassus Project p 123 – 141 In: E. Tiezzi, J.C. Marques, C.C. Brebbia and S.E. Jorgensen (Eds) Ecosystems and Sustainable Development VI. WIT Transaction on Ecology and the Environment, Vol. 106, 2007

The BORASSUS Project: aims, objectives and preliminary insights into the environmental and socio-economic contribution of biogeotextiles to sustainable development and soil conservation, p 601-610 In: A. Kungolas, C.A. Brebbia and E. Beriatos (Eds) Sustainable Development and Planning III, Vol. 2, Wessex Institute of Technology (WIT Press), Southampton, UK -2007 The potential contribution of palm mat geotextiles to soil conservation and sustainable development, p. 303-306 In: J.A. Martinez-Casanovas, I. PlaSentis, M.C.R. Martin and J.C.B. Solanes (Eds) Soil and Water Conservation under Changing Land Use, Universitat de Lleida, Spain 2006

Contributions of biogeotextiles to sustainable development and soil conservation in developing countries: the Borassus Project p 123 – 141 In: E. Tiezzi, J.C. Marques, C.C. Brebbia and S.E. Jorgensen (Eds) Ecosystems and Sustainable Development VI. WIT Transaction on Ecology and the Environment, Vol. 106, 2007

The BORASSUS Project: aims, objectives and preliminary insights into the environmental and socio-economic contribution of biogeotextiles to sustainable development and soil conservation, p 601-610 In: A. Kungolas, C.A. Brebbia and E. Beriatos (Eds) Sustainable Development and Planning III, Vol. 2, Wessex Institute of Technology (WIT Press), Southampton, UK

Prof Felixtina Jonsyn-Ellis, as one of two female participants on this project Team, is the project Co-Team Leader and will play the critical role of microbioanalysis of the oils at the agricultural model demonstration site.

Prof Kelleh Gbawuru Mansaray – DVC of FBC/USL

Prof Kelleh Gbawuru Mansaray is an Engineer and one of the leading pioneers in the design and development of renewable energy programmes in Sierra Leone. He holds a Bachelor of Science degree in Physics from the University of Sierra Leone, Master of Science degree in Renewable Energy Technologies from Carl von Ossietzky University in Germany, a Doctor of Philosophy degree in Biological Engineering (with specialization in Bioenergy Systems) from Dalhousie University in Canada and a one-year experience as a postdoctoral researcher in Chemical Engineering at the University of British Columbia in Canada among other qualifications. He is currently the Deputy Vice Chancellor of Fourah Bay College, University of Sierra Leone.

Prior to his appointment as Deputy Vice Chancellor, Prof. Mansaray served in a number of administrative leadership positions including Officer-In-Charge of the United Nations Industrial Development Organization in Sierra Leone (2013 – 2016) and Dean of the Faculty of Engineering and Architecture at Fourah Bay College, University of Sierra Leone (2017 - 2022). Prof. Mansaray has impeccable record in the University of Sierra Leone and has brought to the University his breadth and depth of experience both as an Academic and an application-focused researcher with several publications. He has supervised many undergraduate and postgraduate student projects which have resulted in prototypes and public installations especially in the areas of applied technology and renewable energy.

Prof. Mansaray has received several recognitions and awards at national and international levels including a recognition in the coveted global 2023 AD Scientific Index for his passionate contribution to the furtherance of Academia, recipient of a University of Sierra Leone award in recognition of his contribution to research, a United Nations award in recognition of his special contribution to the South-South and Triangular Cooperation and a meritorious candidate of the Natural Sciences and Engineering Research Council of Canada. He is a member of the International Association for Solar Energy Education, a member of the Professional Engineers Registration Council of Sierra Leone and a Fellow of the Sierra Leone Institution of Engineers.
The wealth of experience of Prof Kelleh Gbawuru Mansaray in the field of renewable energy will be of valuable contribution to this project as a key Team member.

Prof Alieu Mohamed Bah – DVC of NU

Prof Alieu Mohamed Bah was born in Moyamba town, Kaiyamba Chiefdom, Moyamba District. He attended the Seven Days Adventist (SDA) Primary School Moyamba and proceeded to the Moyamba Boys

Secondary School, where he obtain his GCE ‘O’ level. In 1989 he gained admission in Njala University College where he pursued his BSc in Agricultural Education and graduated in 1993. He also obtained his Master's degree in 2007 in Agricultural Education. He did his PhD at Zhejiang University PRC from 2008 to 2011 where he obtained his doctorate degree in Crop Science.

In 1999 he was appointed as Principal for Kulafai Rashideen Islamic Secondary School in Moyamba town till February 2012. In 2012 he joined the Njala University as lecturer 1 in the Crop Science Department. In 2015 he was promoted to the rank of Senior Lecturer and in 2019 promoted to Associate Professor. In 2015 he was appointed as Head of the Crop Science Department till August 2022. In 2020 he was elected as the Dean for the School of Agriculture and Food Sciences till August 2022. In September 2022 he was appointed as the Deputy Vice Chancellor for Njala Campus and a position he still carries

He has been a member of the Senate and University Court since 2014. He was appointed into various University committees and conducted various investigation. He was also the Acting Radio station manager FM 92.5 for almost two years. He has supervise students at Under raduate, Master's, MPhil and PhD. He has a lot of publications and has in 2022 released three rice varieties using mutation induction technology. He is a member of various organizations both within and outside the University. He has attended so many international trainings and conferences. He is married with children.

Prof Alieu Mohamed Bah is a key Team Member and he will advise the team on aspects of agriculture and how to improve farming practices in Sierra Leone.

Prof Daramy Vandi Von Kallon – Associate Professor at University of Johannesburg:

Prof Daramy Vandi Von Kallon is a Sierra Leonean holder of a PhD in Computational mechanics obtained from the University of Cape Town (UCT) in 2013. He holds a year-long experience as a Postdoctoral researcher at UCT during 2013. At the start of 2014 Prof Kallon was formally employed by the Centre for Minerals Research (CMR) at UCT as a Scientific Officer. In May 2014 Prof Kallon transferred to the University of Johannesburg (UJ) as a full-time Lecturer, Senior Lecturer and later Associate Professor in the Department of Mechanical and Industrial Engineering Technology (DMIET). He currently teaches simulation-based modules at this Department to final year of Bachelors and Honours students and serves as Head of the Quality Assurance Committee of the Department. Prof Kallon has more than twelve (12) years’ experience in research and ten (10) years of teaching at University level, with industry-based collaborations. He is widely published, has supervised from Masters to Postdoctoral and has graduated two (2) PhDs and twenty (20) Masters Candidates. Prof Kallon’s primary research areas are Acoustics Technologies, Design and Development, Water and Energy Technologies and Vibration Analysis. Prof

Daramy Vandi Von Kallon will provide expert consultancy support for this intervention project as a representative of the University of Johannesburg.

Prof Evelyn Pwen Carew

Prof. Carew attended the Prince of Wales School, the Sierra Leone Grammar School, and Fourah Bay College (FBC), all in Freetown, Sierra Leone. He graduated from FBC with B.Sc. (Hons) in Mathematics. His postgraduate research was in *Numerical Solution of Differential Equations* (M.Sc. Reading, UK) and *Computational Fluid Dynamics* (CFD) using the *Finite Element Method* (FEM) to model *viscoelastic flow* (Ph.D. Wales, UK). The latter involved advanced programming and computational techniques. His research interests are in numerical solution of differential equations, computational fluid and solid mechanics, viscoelasticity, soft-tissue biomechanics, mathematical modelling of biological materials and systems, evaluating key parameters of disease epidemics, and mathematics pedagogy. He has over forty peer-reviewed publications, conference proceedings and abstracts; one book Chapter and one book Review. He currently serves as the Dean of the Economics Faculty at FBC.

Prof Evelyn Owen Carew is a Team Member and will be responsible for the economic analysis of the agricultural model to be developed and installed.

Prof Patrick Andrew Sawyer

Professor Patrick Andrew Sawyerr was born on 24th March 1959 to Edward and Matilda Sawyerr, a middle-class family, on Njala University campus. He attended the Njala Experimental Primary School, the Njala University Secondary School, and Njala University College (University of Sierra Leone) where he studied Agriculture General at the BSc Level. This qualified him for a scholarship to Iowa State University in the USA where he studied Soil Morphology and Genesis at the MSc level in 1986. He returned to Njala University to teach and study for a PhD degree in Soil Science, where his research focused on soil and water conservation. He has taught for 30 years, supervised the thesis of several students (undergraduate and postgraduates) in Soil Science and Engineering, published over 10 papers in peer review journals and produced several soil survey technical reports in consultancies dating back to 1986.

Professor Sawyerr is currently the Dean of the School Agriculture and Food Sciences, Njala University and Coordinator of the EU funded National Comprehensive Soil Survey project which will wind up this year. Professor Sawyerr is married to Francess Bailey with three children, all boys, now men, Arnold, Kevin, and Edward. He has been happily married for 40 years.

Prof Patrick Andrew Sawyer is a Team \Member and will lead the aspect of agriculture related to this project.

Dr Michael A Conteh

Dr Michael A. Conteh is a Senior Lecturer and currently the Dean, Faculty of Engineering and Architecture (FEA), Fourah Bay College, University of Sierra Leone. He received his PhD in Mechanical Engineering at the Southern Illinois University, Carbondale, USA, in 2016. He obtained his MSc from the University of Cape Town, South Africa, in 2003. He joined the FEA in 1999 as a Research Teaching Assistant after his BEng (Hons) degree and has served the Department of Mechanical Engineering in various positions from 2004 to date. He possesses over 18 years of research and teaching experience at University level. His primary research interests are in the fields of mechanical engineering design, energy recovery and storage, energy efficiency, renewable energies, and operations research and statistics. He is a member of the Professional Engineering Regulatory Council (PERC) of Sierra Leone.

Dr Michael A. Conteh is a Team Member of this project and together with Prof Kallon from South Africa will design the water chilling mechanism.

Dr Victor Kabba

Victor Tamba Simbay Kabba was born in Koidu City, in the diamond rich district of Kono. He began his primary education in the Roman Catholic Boys School in Koidu City and later completed in R. C. BOYS primary School in Lunsar, Port Loko district. He entered the then Miatta Stevens (now Murialdo) Secondary School where he obtained a Division One at the G.C.E O'levels at first attempt. He later proceeded to the Sierra Leone Grammar School in Freetown to do his Sixth form. Dr. Kabba entered Njala University College University of Sierra Leone in 1996 and graduated with a Division One in Geography/Biology in 2001. He was then recruited by the Department of Geography and Rural Development that same year as Research and Teaching Assistant. Dr. Kabba Obtained his MSC Education in Geography the following year. In 2007 he was awarded a scholarship to pursue a PhD in Land Resource Management at China University of Geosciences(Wuhan). He returned home in 2011 and two years later was appointed as Director, Institute of Geography and Development Studies, School of Environmental Sciences, the position He held until 2021. Dr. Kabba is a Senior Lecturer. In 2020 he was.appointed Dean, School of Environmental Sciences, the position he still holds. Dr. Kabba served as Senate Representative to Njala University Court. He has served on several investigation committees in the University. He has a number of publications to his credit. He has served as Consultant for both national and international institutions, including the European Union.

Dr Victor Kabba is a Team Member and will assist the team in the area of environmental and climate impact assessment and developing mitigation strategies.

Mr Mohamed Dumbuya – Secretary to the Project Team

Mr Mohamed Dumbuya is a Lecturer at Njala University Sierra Leone for past fifteen years serving in Environmental Chemistry Department, School of Environmental Sciences now change to Basic Sciences. He is currently a doctoral candidate with the Federal University of Technology Minna Nigeria working on: ***Heavy metals and Mycotoxin in soils and rice cultivated in Sierra Leone Inland Valley Swamp in all districts in Sierra Leone***. He lectures courses on Environmental Sciences, Environmental Toxicology, Soil Chemistry and Introduction to water chemistry for the past ten years. He holds a seven years membership with the International Association for Food Protection (IAFP) and currently belongs to AFoSaN Food Safety Group, Sierra Leone-European Union program on Chemical, Biological, Radiological and Nuclear (CBRN) Regional Training on High Risk Chemical facilities-Center of Excellence: With Certificates of completion as Level-1 Industrial Risk Mitigation Trainee, representing Njala University Sierra Leone as certified by EU-CBRN and UNDPSL team of experts. Mr Dumbuya serves as core member for reputable scientific committees on standards development and networks in Sierra Leone and also the Founder of Njala Environmental Technician Sierra Leone (NETSL) consortium, a registered independent consultancy firm, that is conducting research on Environmental Impact Assessment and industrial safety management for work places in Sierra Leone since 2011 to date with the EPA SL. He has experience in supervising and assessing of industrial risk of pollution, contaminants and work place exposure management for both wet and dry working environments including national environmental auditing for project sustainability.

Mr Mohamed Dumbuya will serve as Secretary to the project Team for this project.

International Partner

Mr Martin Charles Paulsen – CEO of Gem Water:

Martin Paulsen is a multifaceted individual with a diverse career spanning law, trade unions, and business ventures. Born with a passion for legal studies, he earned his Law Degree from the University of Western Cape in 1988, setting the foundation for his future endeavors. After completing his education, Martin delved into the world of law, specialising in contract law and dispute resolution. His expertise in these areas laid the groundwork for a successful career in advocacy and negotiation.

In 1991, Martin made a significant shift in his career by joining the National Union of Metal Workers, where he aimed to advocate for workers' rights and fair labor practices. His dedication and leadership abilities did not go unnoticed, and he later moved on to the South African Clothing and Textile Workers Union. As he progressed in the trade union movements, Martin's skills as a chief negotiator came to the

fore, allowing him to play a crucial role in various sectors of the trade unions. Martin's journey continued to evolve, and he later assumed the esteemed position of Secretary General of the National Union of Leather Workers. In this capacity, he made significant contributions to the welfare of leatherworkers, striving to improve their working conditions and ensure their rights were protected.

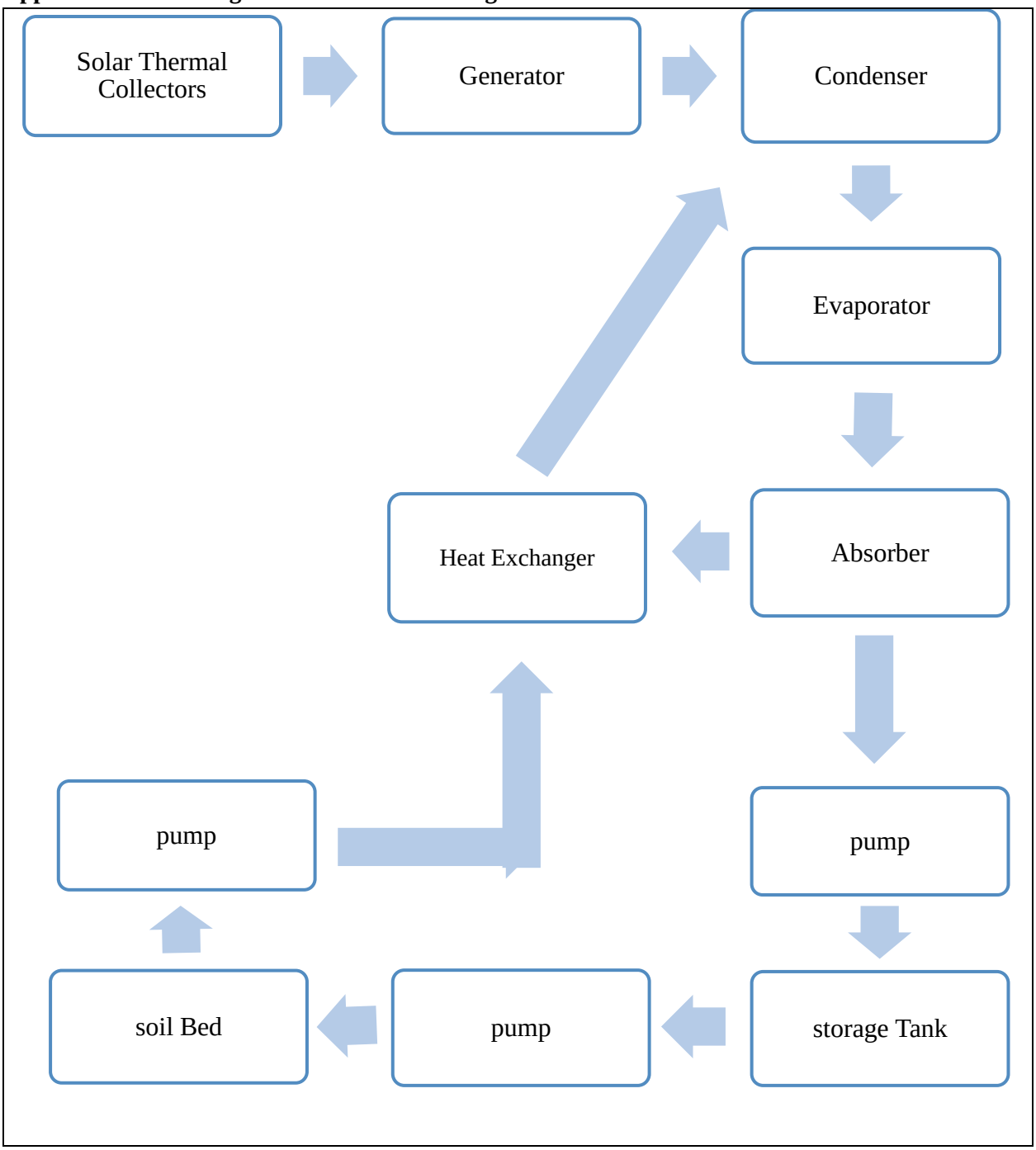
Expanding his reach beyond national boundaries, Martin was appointed as the International Labour Organisation (ILO) coordinator for Sub-Saharan Africa. This role gave him the opportunity to work on a broader scale, addressing labor issues and promoting better working standards throughout the region.

After an impressive 15 years in the Trade Union Movements, Martin decided to explore the world of business. Drawing upon his experiences, knowledge, and entrepreneurial spirit, he ventured into various enterprises. As a Director of several companies like DAUBO INVESTMENT HOLDING COMPANY, LEAPRO PROPERTIES, and LEAFUND PROPERTIES, Martin demonstrated his acumen in managing businesses and navigating complex corporate landscapes.

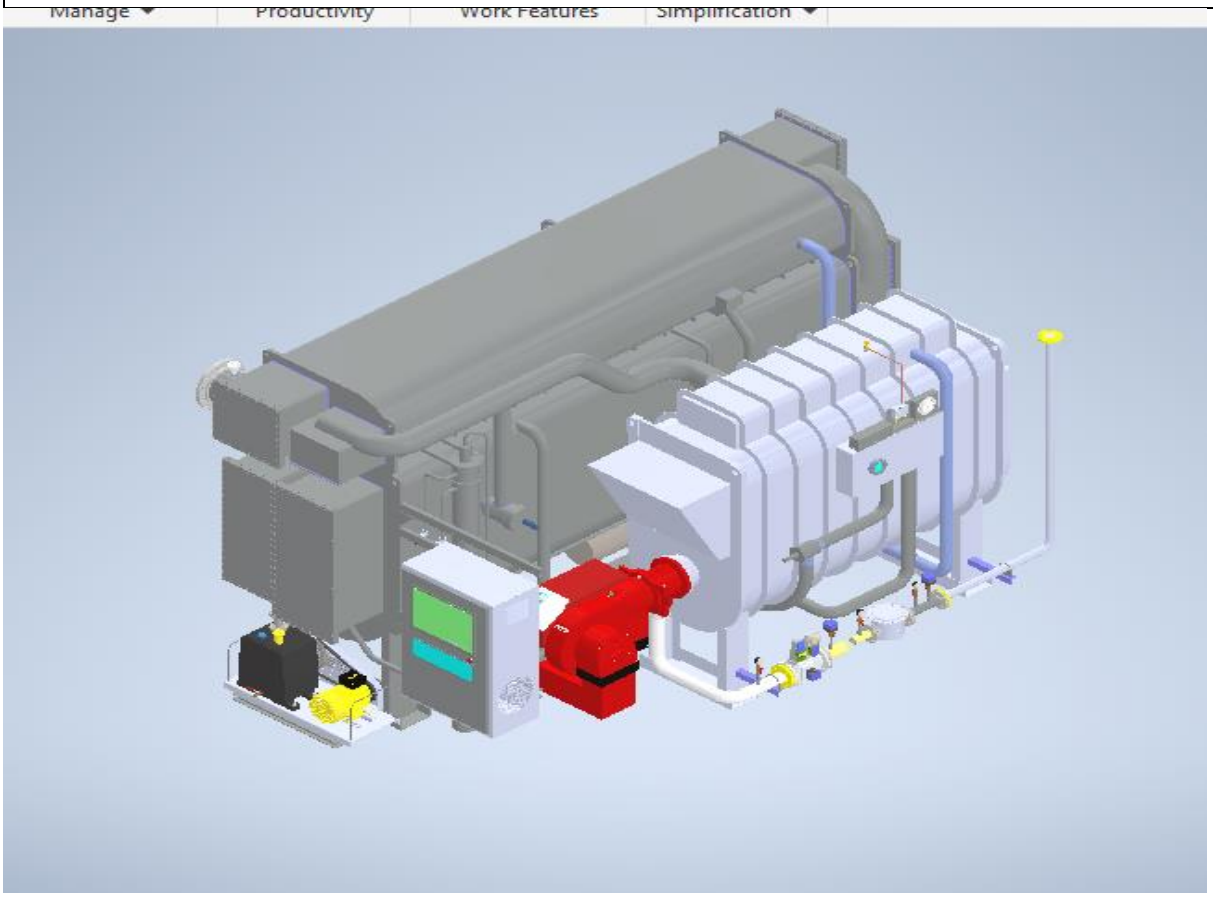
Beyond his directorial roles, Martin's ingenuity and innovation led him to found several companies of his own. Quad Lock Building Systems and International Concrete Forms were construction companies specialising in alternative building technologies, GEM WATER MANAGEMENT SOLUTIONS, company that specializes in the manufacturing in the technology of Atmospheric Water Generators (AWG), and GEM HYDROPOWER are some of the ventures he pioneered. Each of these companies catered to different sectors, reflecting his commitment to environmental sustainability and infrastructure development.

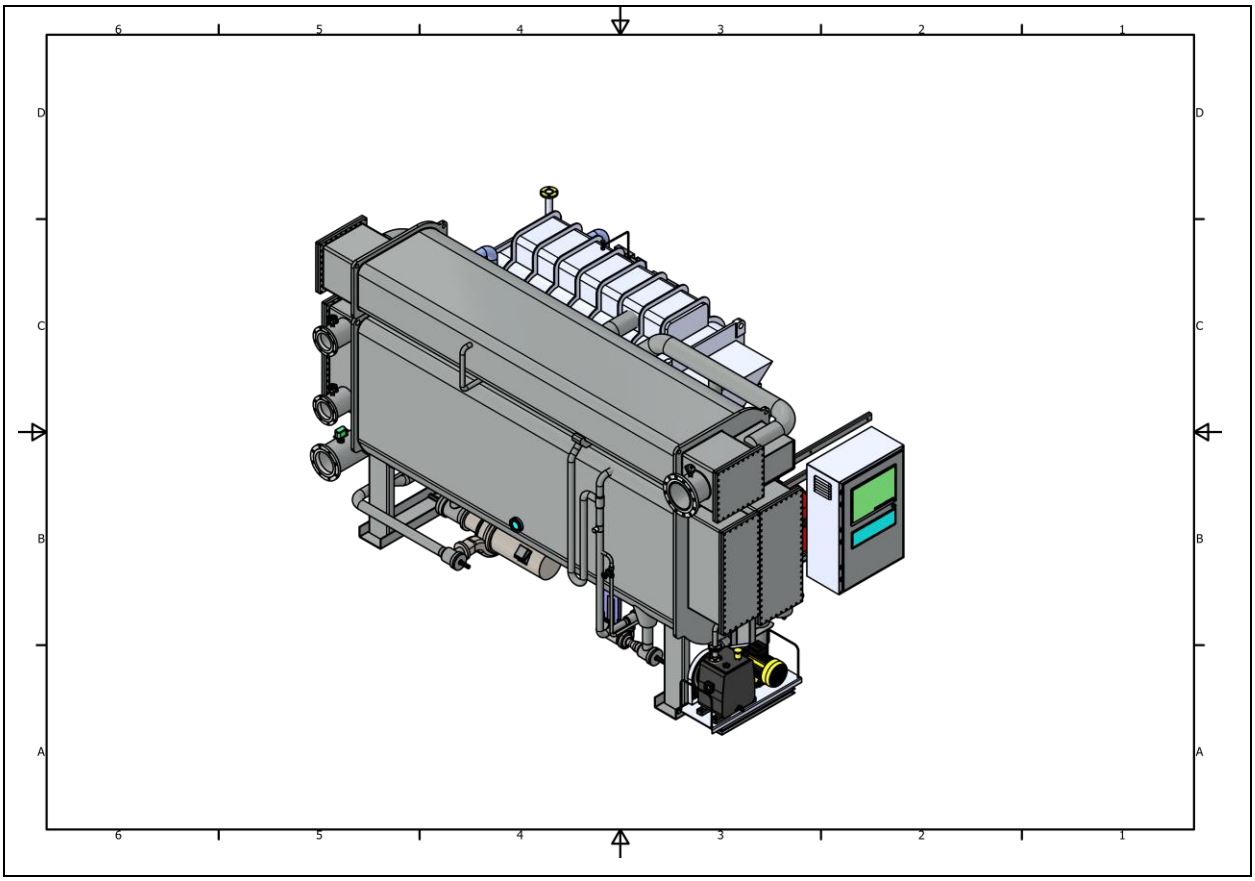
Throughout his remarkable journey, Martin Paulsen has been a driven and dynamic force, making an indelible impact on the Labour Law, and business landscapes. His dedication to justice, fair labor practices, and innovative entrepreneurship has left a lasting legacy, inspiring many to follow in his footsteps.

Appendix B: Flow diagram of the water chilling mechanism

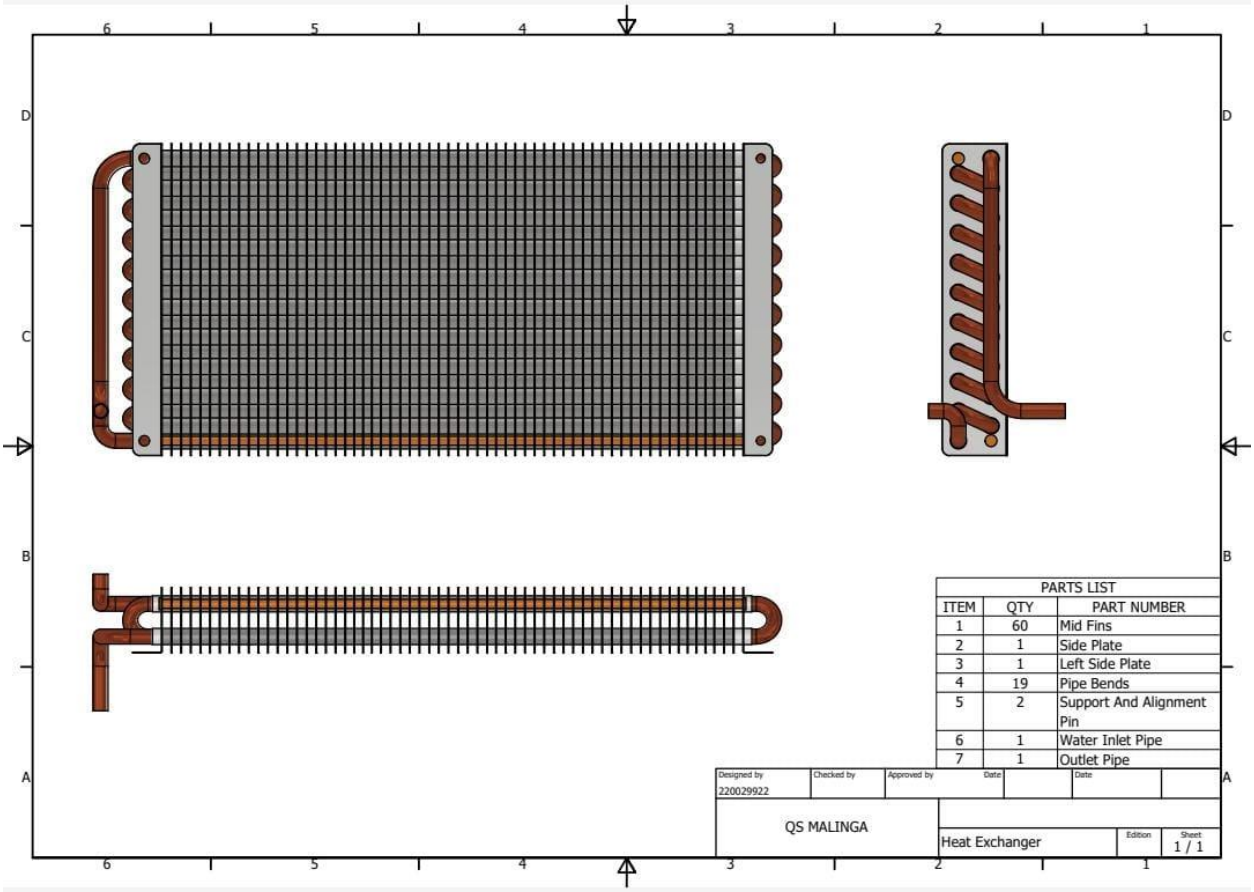


Appendix C: Preliminary Model of the Water Chiller




6
5
4
3
2
1
D
C
B
A

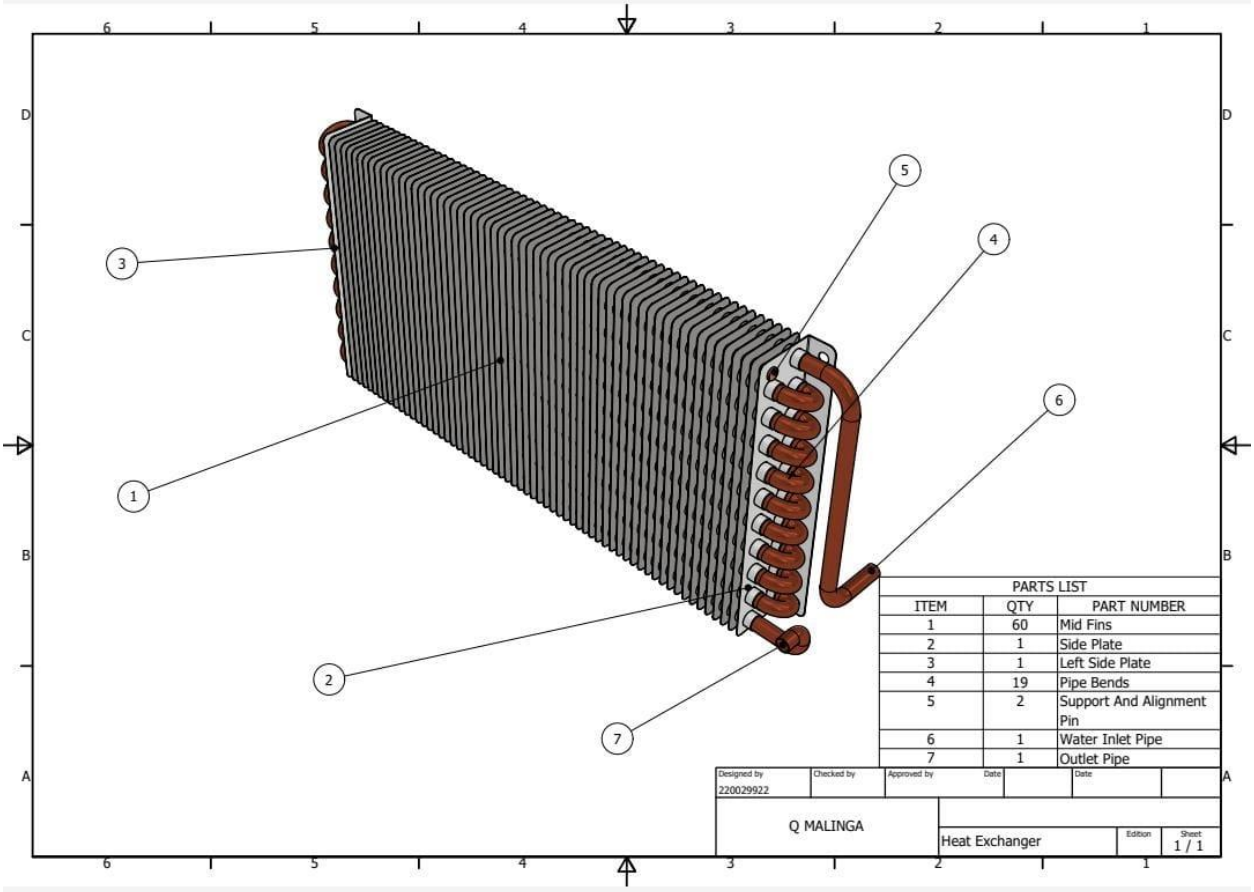
Appendix D: Initial Heat Exchanger Design



PARTS LIST		
ITEM	QTY	PART NUMBER
1	60	Mid Fins
2	1	Side Plate
3	1	Left Side Plate
4	19	Pipe Bends
5	2	Support And Alignment Pin
6	1	Water Inlet Pipe
7	1	Outlet Pipe

Designed by	Checked by	Approved by	Date		Date	
220029922						

QS MALINGA	Heat Exchanger	Edition	Sheet 1 / 1

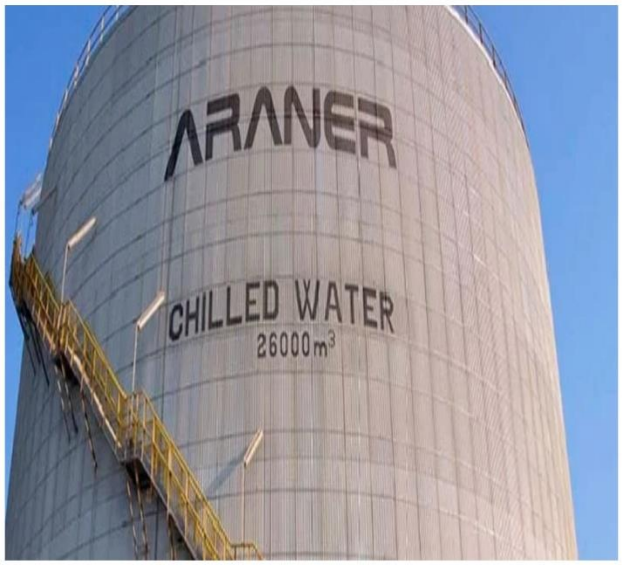


PARTS LIST		
ITEM	QTY	PART NUMBER
1	60	Mid Fins
2	1	Side Plate
3	1	Left Side Plate
4	19	Pipe Bends
5	2	Support And Alignment Pin
6	1	Water Inlet Pipe
7	1	Outlet Pipe

Designed by	Checked by	Approved by	Date	Date	
220029922					

Q MALINGA	Heat Exchanger	Edition	Sheet 1 / 1

Appendix E: Potential tank model



Appendix F: Endorsement Letter