School of Electronic Engineering and Computer Science

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Final Report

Programme of study:
MSc Computer Science

Project Title:
Art, Unplugged: In the search of a sustainable off-grid power solution for immersive art installations

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Abstract

Immersive art installations have been growing in popularity across the years. Their increasing reliance on access to electrical power raises many concerns about their sustainability and impact on the environment. This dissertation explores and discusses the development of an universal, off-grid sustainable power solution for art installations, with a focus on photovoltaic solar power. This project makes use of qualitative research, thematic analysis and system design to propose a theoretical framework that can be used across numerous contexts.

The study is grounded in analysis of existing real-world installations, specifically the *Dendrophone* and *Streamers* installations in the Alice Holt Forest by Dr Peter Batchelor and Dr Luigi Marino respectively, as well as interviews with six artists who make use of solar power in their work. Key themes were identified through the thematic analysis of said interviews, such as energy storage, aesthetic considerations, affordability and community engagement.

In response, the proposed solution presents a data-driven solar energy forecasting and battery simulation platform, which allows users to predict photovoltaic energy availability based on several parameters. By integrating environmental data, machine learning models and user-specific power load requirements, the tool assists in planning and optimizing off-grid energy systems for immersive installations.

By addressing different aspects from the fields of computer science, renewable energy and art, this project proposes a sustainable solution and advocates for ecological accountability within the art industry. The resulting framework can serve as a scalable model for designing self-sustainable power solutions for art installations.

Contents

1.Introduction

This chapter introduces the background, aim, and objectives of the project, focusing on the exploration of sustainable power solutions for immersive art installations, concluding with the research objectives to be accomplished throughout the course of this project.

1.1.Background

In the very rapidly technologically advancing world, we can observe how well technology starts to intertwine with and enhance many industries and areas of knowledge, one of them being the arts. A great deal of modern artistic projects, exhibitions and artworks started incorporating electronic and digital elements in order to express what was previously beyond the capabilities of any artist. Christiane Paul (2003), in her *Digital Art* textbook states that “digital technologies and interactive media have challenged traditional notions of the artwork, audience and artist” (Paul, 2008:21). Digital technology has become an inseparable part of many artistic projects and interventions that have begun to gain more and more popularity over the years. For instance, the teamLab *Planets* installation, which is one of the teamLab collective’s exhibitions known for their focus on the use of digital art and technology in their works "has set the Guinness World Record for the world’s most visited museum dedicated to a single group or artist”, welcoming over 2,500,000 visitors between 2023 and 2024, as they report on their website (‘teamLab Planets in Tokyo sets Guinness World Record for visitor numbers’, 2024). Meow Wolf, an arts company which owns several large scale immersive digital art installations across the United States “have welcomed over 2 million visitors through the doors of three locations in the last year”, as Blooloop reports (‘Meow Wolf’, nd.). This comes to show the extremely high interest of the public in the promptly advancing field of digital art. The rise in the number of immersive technological art exhibitions was so significant that the trend was noticed and investigated in articles such as the Anna Wiener’s article for the New Yorker, *The Rise of “Immersive” Art* (Wiener, 2022).

It comes as no surprise that with the rising interest in digital art technologies, concern about electric energy usage arises. The immersive art exhibitions that make use of different types of apertures including projectors, LED lights and various sensors rely exclusively on constant access to electricity. By looking at the energy usage of museums and collectives that feature different immersive art experiences, we can see how substantial energy consumption becomes over time. Tate Modern, one of London's most representative art galleries, in their Extract from Annual Accounts 2019-20 has reported that their total electricity usage in the year 2019-20 has reached 27.9 GWh (Board of Trustees of the Tate Gallery Annual Accounts 2019-20, 2020). This amount could power over 2,500 average U.S. households for a year long, according to the statistics from the 2020 Residential Energy Consumption Survey (eia.gov, 2025). This trend is quite alarming, as excessive electric energy usage in turn creates demand for more energy production, which constitutes a great percentage of greenhouse gases emission responsible for climate change, as United Nations reports in their Causes and effects of climate change release (un.org, 2020).

This dilemma leaves us thinking of an appropriate solution to this problem. Artistic installations and interventions have been found to be gaining popularity and representation throughout the years. Artists by coming forward with an approachable solution would certainly become a great inspiration for the general public in being climate-conscious. Additionally, there is clearly yet a lot to be done in terms of ecological accountability in this field. The solution should focus on using as much renewable energy as possible in order to minimize the costs of maintaining such installations and reduce the very negative impact they have on the climate. One of such energy sources is solar power. While carrying out research on any possible existing approaches to this problem, I was able to find a few examples of artists that made use of solar panels to power their installations, such as the art collectives Studio Lemercier, KompleX KapharnaüM and Squidsoup. I believe that this might be a great starting point for further investigation of this topic.

For this project, I have decided to investigate this topic as a whole and try to look at possible solutions to this problem. The research question that I will try to answer in this project is: **How can we devise a power solution to achieve**

self-sustainability of art installations, and how can we apply this knowledge in the art industry?

1.2.Aim

The aim of my project is to conduct a thorough analysis of different power solutions in an attempt to eventually design a theoretical framework for a fully self-sustainable solution, as well as an interactive prototype. As a starting point of my analysis on how to get there, I have decided to work with two sound installations created by Dr Peter Batchelor and Dr Luigi Marino, which are a part of the Your Sonic Forest exhibition (https://sensingtheforest.github.io/exhibition/) in the Alice Holt Forest, UK, created and maintained by the Sensing the Forest project team. I believe that this is a really good starting point for this research-based project as it is an already existing sound installation that is also local to me, which will allow me to carry out hands-on practical work with the installation. Because these are already fully constructed and operational installations, I can analyse how they work and gain full understanding of the construction, setup and operation of them. This in turn will allow me to dive straight into my main aim of this project, which is designing a framework for a fully self-sustainable power solution for such an installation.

The ideal outcome of this project will involve a designed and replicable theoretical framework of a power solution for sound installations that will allow them to be fully self-sustainable in terms of energy use. If I manage to successfully deliver this, it will mean that sound installations will be operational 24/7/365 without any additional power sources. This will not only address the social and ethical considerations of excessive electrical energy use that affect climate change that I have described earlier as a proof of concept, but it will also make such installations cost-effective and will greatly reduce the time and frequency of any maintenance operations needed.

1.3.Objectives

This subchapter outlines the objectives pivotal in the process of creating my project, focusing on analyzing existing projects, consulting with experts, and constructing a theoretical framework as my solution.

1. Carry out a thorough literature review of existing digital art installations and sustainable power solutions to gain understanding of what we're working with.

2. Conduct an analysis of Peter Batchelor's and Luigi Marino's installations, their architecture, energy usage and technological aspects to base my project on:

    2.1. Review log files and calculations on the energy usage of the installations provided by other people working on the Sensing the Forest project to identify areas for me to focus on

    2.2. Visit the Alice Holt Forest to see and work with the sound installation in person to see how it is constructed, how it operates and measure what is its energy usage over time

3. Reach out to artists and collectives behind immersive and digital art installations to gather more information on how the problem of energy use and consumption is dealt with currently and what technologies are used to date:

    3.1. Interview Dr Peter Batchelor and Dr Luigi Marino to gather information about how their installations operate, how they source energy at this point in time and how we could approach working on this moving forward

    3.2. Establish a conversation with art collectives and artists that have implemented renewable energy sources into their immersive and digital art to see how they have approached the problem of energy consumption and how I could learn from their projects in implementing my own solution

3.2.1. Studio Lemercier - Brussels-based art collective co-directed by artist Joanie Lemercier and curator Juliette Bibasse. They specialize in immersive installations that involve light projections on unconventional surfaces like water mist and custom-built structures.

3.2.2. KompleX KapharnaüM - multidisciplinary artistic team that creates innovative installations in urban environments. Their projects often involve collaboration with local communities and are designed to spur a debate about the urban landscape.

3.2.3. Squidsoup - UK-based collective known for immersive, interactive installations that blend art, technology, and science. They focus on exploring human perception using light, sound, and motion to create engaging experiences. Their work has been featured in numerous festivals and exhibitions, highlighting their innovative approach to interactive art.

4. Construct a theoretical framework of an energy solution for the installations that will be both as self-sustainable and cost-efficient as possible and report my progress in real time to the project team

5. Construct an interactive prototype of the solution as a proof of concept

2. Literature Review

2.1 Introduction

This chapter provides a comprehensive literature review on the use of renewable energy solutions, particularly solar power, in art installations, while exploring the technological advancements in photovoltaic (PV) panels and the challenges of implementing sustainable, off-grid power systems in sound art, concluding with the identified research gap.

2.2 Renewable energy solutions for art installations

While analysing existing research on different renewable energy solutions used in powering art installations, I was able to identify two different types of renewable energy used, being solar power and wind energy.

2.2.1 Solar power

Solar power is the most commonly seen source of green energy when it comes to art installations. According to Nathanson, “artists and designers have been exploring the aesthetic possibilities of the modern photovoltaic (PV) cell since its invention in 1954” (Nathanson, 2021:1). This resulted in a great deal of artists integrating PV panels with their art installations in various ways. Those installations cover a range of different aesthetic outputs and desired functionalities, ranging from LED-based installations to musical performances.

One of such installations is the *Pond Station* created by Zach Poff (2015). It consists of PV panels generating energy, microphones that record underwater activity and an Arduino microcontroller that controls the transmission of the recordings and power distribution. A great benefit of using solar power for this installation are the real-time updates about sunlight levels, battery charge and system status available online. This not only solves the issue of energy sourcing in a sustainable way, but also provides additional insights into the operation of this installation. A disadvantage of that solution however is the uptime of the

Figure 1: A photo of Zach Poff and his installation. (Poff, 2024)

streaming. The installation can operate only from dawn until dusk due to the energy levels not being sufficient otherwise.

2.2.2 Wind energy

Wind energy has also made its way into the world of art, however it has not been as widely popularised as solar energy powered installations. An example of an art installation that uses wind energy is *Perpetual Motion* by Dr Chris Meigh-Andrews (Meigh-Andrews, 1998:28). It consists of a wind turbine that powers a monitor that displays an image. In theory, this artwork in a great way showcases how we could use natural resources to produce electric energy. However, the wind turbine used in this installation is placed inside an arts centre and is powered by an electric fan that is plugged into a wall socket, which defeats the purpose of the wind turbine producing electrical energy as a whole. However, the artist himself states that the rapidly developing technology will "hopefully enable us to reunite in a harmonious balance with our environment" (Meigh-Andrews, 1998:31).

Figure 2: An image of *Perpetual Motion* by Chris Meigh-Andrews (Meigh-Andrews, 1998)

2.3 Technological background of PV panels

PV panels have become a major part of how we approach renewable energy today. According to IEA, solar power is one of the largest renewable electricity technology alongside with hydropower and wind energy (IEA, 2024). PV panels have been popularised as an efficient, affordable and feasible renewable energy solution in the fields of construction and residential/domestic settings.

Vijayan et al. in their *Advancements in Solar Panel Technology in Civil Engineering for Revolutionizing Renewable Energy Solutions* review discuss the great performance and efficiency of different types of PV panels, which "achieve exceptional energy conversion efficiency", showcasing the progress in this area (Vijayan et al., 2023:4). For this reason, more and more engineers and designers decide to use solar power in their construction, as it continuously grows in popularity thanks to the many advantages that such a solution brings. This movement perfectly represents the approach towards sustainability and supports commitment to reducing greenhouse gases emission and energy independence.

PV panels have found many more applications, one of them being much smaller-scale projects. Kris De Decker has published a comprehensive guide on how to build a solar power system that can satisfy virtually any of the user's personal needs, ranging from battery-based solutions to direct installations powering a range of appliances (Decker, 2023). This release shows how accessible solar power actually is for the general public. With a bit of research and guidance, everyone is able to construct their own off-grid solar power system that will efficiently provide power for any appliance given.

Living Energy Farm (LEF) is an inspirational example of how PV energy can be incorporated into sustainable living. This community shows how energy autonomy is possible by using completely off-grid power solutions. LEF demonstrates how with the use of PV panels it is possible to operate numerous systems and household appliances without relying on grid power (Livingenergyfarm.org, 2024).

The technological advancements greatly influenced the efficiency and performance of PV panels. With the development of **monocrystalline silicon (Mono-Si)** solar cells, solar technology became redefined thanks to the high energy conversion efficiency of those cells. By using single-crystal structures, those cells achieve unequalled performance which in turn increases the total energy output (Vijayan et al., 2023). Furthermore, introduction of Passivated Emitter and Rear Cell (PERC) technology has even greatly increased the efficiency of such solutions by utilising a reflective surface that enhances light capture.

While not as efficient as monocrystalline silicon cells, **polycrystalline silicon (Poly-Si)** panels are also a very popular choice thanks to its cost-effectiveness, which aids projects that need to take a budget into consideration. Introduction of those panels has expanded the scope of PV technology by providing a whole range of solutions, both large-scale and smaller setups. In addition, the design of half-cut solar cells has become an important milestone in the PV technology field by reducing shading losses and increasing the energy output overall (Vijayan et al., 2023).

Technology	Efficiency	Advantages	Challenges
Monocrystalline Silicon (Mono-Si)	Very high energy conversion efficiency, up to 23% (Sun et al., 2021)	High efficiency, very good performance and energy output	More expensive in production than Poly-Si cells
Polycrystalline Silicon (Poly-Si)	Moderate efficiency ranging anywhere between 5%-15% (Becker et al., 2013)	Cost effective solution effective for budget-conscious projects	Lower efficiency than in Mono-Si cells and increased potential for energy loss
Monocrystalline PERC (Mono-PERC)	Up to 22% (Tripathi et al., 2020)	Increased yield of energy thanks to the reflective surface	Complexity of the system and manufacturing costs
Half-Cut Solar Cells	Up to 22% (Huyeng et al., 2024)	Reduces the energy loss from shade	High complexity of installation

Figure 3: A comparison of different PV technologies based on Vijayan et al., 2023.

We can see how greatly solar power has influenced people's approach to energy independence and sustainability. Looking at De Decker's guide, it is clear that with resources like these constructing your own self-sustainable power solutions is indeed very realistic. This extends to design focused on satisfying one's personal needs and driving them to be mindful of energy saving practices. Solar energy has become a crucial component in both personal and community-organised energy projects.

2.4 Sound art

This part will cover examples of sound art exhibitions specifically.

Figure 4: A photo of the *Transition Soundings* installation (Birchfield et al., 2006)

Birchfield et al. in their study of the *Transition Soundings* installation discuss the distinctive organisational and artistic factors of sound art in public spaces. *Transition Soundings* is a solar-powered interactive sound wall installed at a bus stop in Tempe, Arizona that operates in response to the audience's movements. The artwork invites the public to investigate sound by moving in proximity to the installation, which creates a "ripple" sound effect, enhancing the audience's awareness of urban and natural soundscapes. By generating sound in response to physical presence, such installations engage audiences in unique ways, providing both a playful and reflective experience (Birchfield et al., 2006). Furthermore, sound installations like those have to take into consideration the acoustics of their surroundings to avoid contribution to noise pollution. Birchfield et al. stated that installations are ought to establish a balance between the installation's own sounds and the already existing sounds of a public setting, ensuring that the work adds value to the soundscape without disturbing it. This is a crucial consideration for any sound art installation that aims to tone in with its environment, whether it involves urban or natural landscapes.

PV technology is a promising solution for powering sound installations sustainably, especially in outdoor areas. Scott Smallwood’s research on solar sound art discusses the way how PV technology can be used to integrate environmental consciousness into sound installations. Smallwood’s installations use PV panels that allow the intensity of sunlight to influence how sound is generated, directly reflecting the installation's operation based on natural energy cycles. This aligns with principles of acoustic ecology by making the installation’s sounds responsive to conditions such as weather and time of day. For example, Smallwood’s solar-powered ***Solar Noise Discs*** are small instruments that emit sounds based on the amount of sunlight exposure. The sound output of each device depends on available sunlight, creating a shifting audio experience that represents the relationship between art and nature. (Smallwood, 2011).

Numerous pieces of solar sound art examine the potential of PV powered installations. These installations not only showcase sustainability in practice but also illustrate how sound art can enhance our engagement with natural energy sources.

Alvin Lucier’s *Solar Sounder I* uses solar panels to produce sounds that change depending on the angle and intensity of sunlight, subtly mirroring the Earth’s rotation. This installation instead of being controlled by people is shaped by natural cycles, highlighting Lucier’s interest in creating an "environmentally interactive" sound experience (Smallwood, 2011).

Craig Colorusso’s Sun Boxes consist of twenty PV-powered speakers. Each speaker produces a separate guitar piece that changes alongside with the availability of sunlight. These independent sound sources together create a multifaceted, dynamic soundscape that changes in real-time. The installation encourages visitors to experience something that feels alive. This piece shows how solar-powered installations create an art experience that connects visitors directly to the site’s environmental conditions (Smallwood, 2011).

Nigel Helyer’s Meta-Diva installation, which is powered entirely by solar energy, consists of multiple speakers emitting naturalistic sounds, like birds or insects. Meta-Diva uses PV panels to power each speaker separately, producing an ambient soundscape that harmonizes with local wildlife. Each part of the installation reacts to sunlight intensity, creating an experience that mirrors and enhances the natural sounds of the environment. Helyer's work showcases a form of sound art that not only coexists with but enhances its natural setting, bridging ecological awareness with artistic expression (Smallwood, 2011).

We can see numerous examples of sound art installations that meticulously create a soundscape that blends in with the environment of the installation to provide a immersive experience to the audience. Robin Minard in his *Sound Installation Art* release suggests that "the fusion of art and life is an essential aspect of the installations" (Minard, 1996:2). This shows how in many ways the implementation of sound art in installations can provide us with an intriguing, inspiring and insightful experience that connects and alters our perspective of space and sound.

The perfect example of integrating solar power in sound art installations has been developed and presented by Dr Luigi Marino, who I have had the honour of working with during this project, in the *Developing DIY Solar-Powered, Off-Grid Audio Streamers for Forest Soundscapes: Progress and Challenges* paper for the CHIME Annual One-day Music and HCI Conference 2024, Milton Keynes, UK. Luigi has created an installation consisting of two solar-powered, off-grid audio streamers placed in different locations for capturing forest soundscapes. The DIY approach demonstrates a growing interest in environmentally responsive sound systems that not only document natural environments but also drive public engagement through open access and real-time streaming. This project aligns with broader trends in sound art that prioritise ecological accountability, and it reinforces the need for accessible, replicable tools that bridge artistic practice with sustainable design.

2.5 Challenges in implementation of off-grid power solutions

Creating PV-powered sound art installations in public or outdoor spaces requires considering some technical challenges, which can be grouped into several categories:

2.5.1 Durability in different environmental factors

Sound installations powered by photovoltaic (PV) technology must be designed to withstand different weather and environmental conditions. For example, in the Arlanda Express sound installation in Stockholm, designers had to focus on ensuring that the installation will be durable against elements such as rain, wind, and temperature changes, while at the same time also adapting to the busy atmosphere of the transportation hub (Torehammar and Backe, nd.). The design had to ensure that the PV panels, as well as their sensitive components like speakers and sensors, remained protected from all kinds of environmental factors to maintain longevity. This is pivotal as the performance of both the solar panels and sound systems is directly impacted by exposure to outdoor conditions.

2.5.2 Aesthetic appeal and acoustic incorporation

In sound art installations, aesthetic appeal is just as important as its technical functionality. Designers must ensure that the installation tunes in with the ambient sounds of the environment, without contributing to noise pollution. For example, in urban environments, where high levels of background noise are common, careful acoustic planning is necessary to prevent the installation from being a disruptive or overwhelming addition to the soundscape. The Arlanda Express project shows how designers were able to balance the integration of the sound installation with the acoustics of the transportation hub.

2.5.3 Availability of solar power

One of the major challenges is the variability of solar energy. The amount of sunlight available directly impacts the performance of PV-powered sound installations. Since solar energy levels vary depending on the time of day, weather conditions, and seasonal changes, this variability can affect the reliability of the installation. Ensuring that the installation can operate consistently despite these changes requires strategic positioning of the solar panels to capture the maximum amount of sunlight. Furthermore, systems must be designed to store energy effectively or be supplemented with other sources of power during periods of insufficient sunlight.

2.5.4 Self-sustainability

As PV technology advances, the possibilities for creating fully off-grid, self-sustainable sound installations continue to expand. Advancements in solar efficiency, as discussed above, combined with increasingly affordable PV materials, allow artists to experiment with larger installations and more complex sound systems. However, this presents a challenge in system integration, as careful planning is needed to ensure that each component operates without compromising the installation's sustainability or performance. Moreover, the growing complexity of such installations requires innovative energy management systems to balance power demands effectively.

2.5.5 Ecological impact and awareness

Finally, sound artists showcase the wide ecological implications of solar-powered installations. These installations go beyond just its functionality by promoting environmental awareness and encouraging sustainability. As PV technology allows for the creation of self-sufficient systems, the installations teach us about ecological principles, encouraging the audience to reflect on their relationship with energy consumption and environmental awareness. By incorporating solar energy into the art itself, these installations not only minimize environmental impact but also serve as a reminder of the importance of renewable energy sources.

2.6 Conclusion and identified research gaps

Current PV-power sound art installations have demonstrated the potential of integration with natural energy sources, combining art, technology, and environmental consciousness to enhance sustainability in public spaces. However, while these installations successfully invite audiences to experience them, they often focus on temporary or site-specific responses to environmental factors without offering a universally adaptable model for a sustained, off-grid power solution. This gap indicates a need for a systematic approach that can extend the principles of PV-powered sound art into a scalable, sustainable model capable of supporting continuous, energy-autonomous sound installations in varied settings.

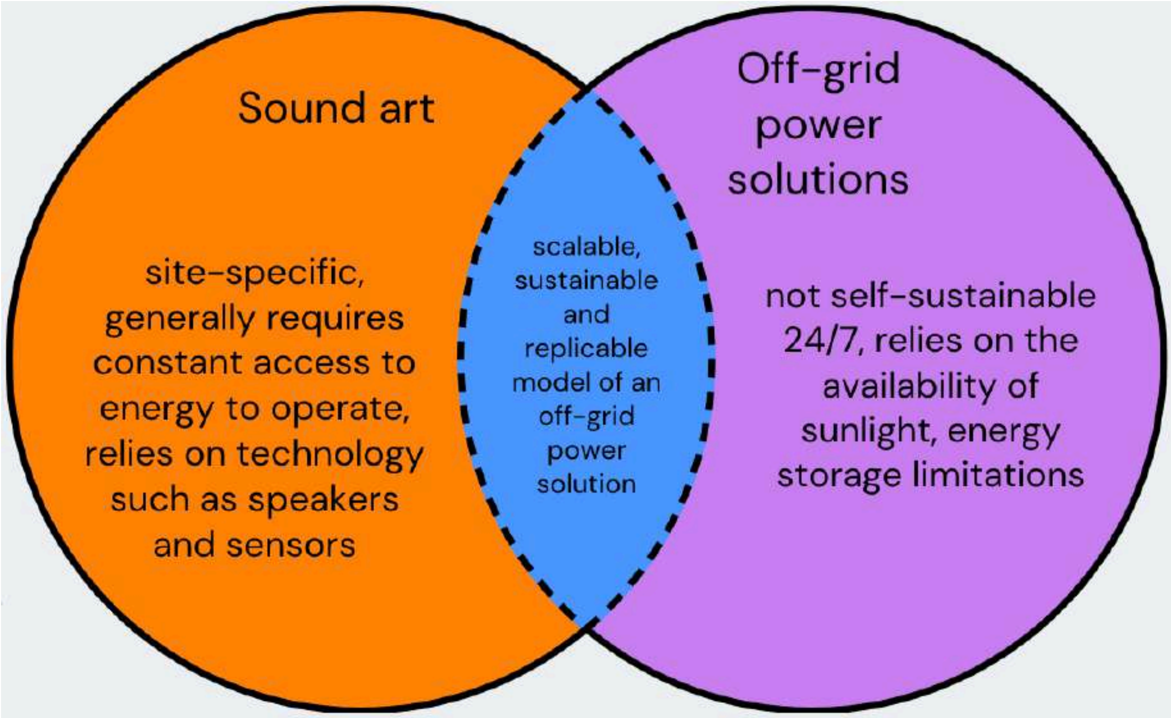

Figure 5: A Venn diagram presenting the identified research gap.

My project aims to address this gap by developing a universal theoretical framework of a power solution that not only supports immersive sound art but also demonstrates an adaptable framework for off-grid installations. This research will focus on optimizing PV panel efficiency, energy storage, and environmental resilience, thereby creating a replicable model that enhances both the durability and ecological impact of sound installations, aligning with sustainable practices across multiple types of public spaces and weather conditions. Circling back to the research question outlined earlier on in this report: **How can we devise a power solution to achieve self-sustainability of art installations, and how can we apply this knowledge in the art industry?**, the solution addressing the research gap will aim to provide self-sustainability to art installations, while its scalability and replicability will make the findings more applicable to the art industry in general.

3. Methodology

3.1 Introduction

This chapter goes over the methodology of the data gathering, analysis and system design methods chosen for this project and the rationale for them.

3.2 Primary research

In order to decide which research approach and methods will be the most suitable for my specific project and study, I have decided to refer to literature on research methodology (Tengli, 2020).

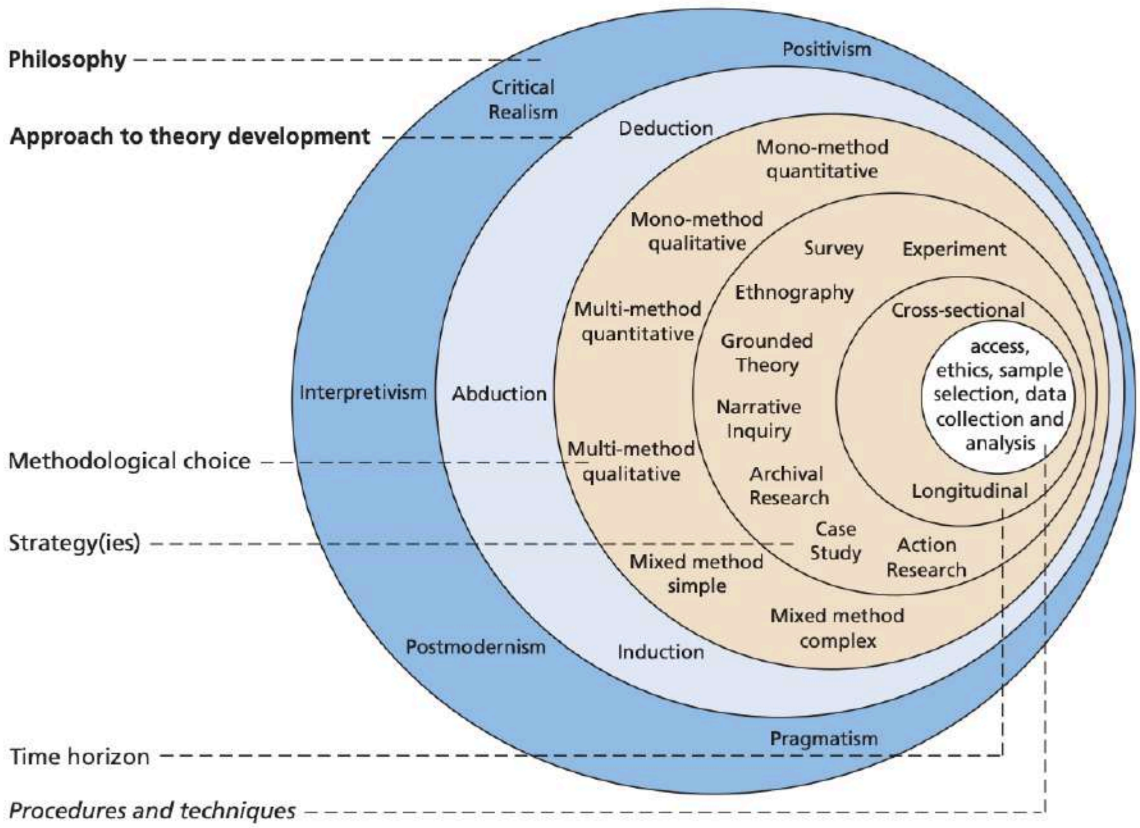

Figure 6: The ‘research onion’, term coined by Saunders (Saunders, Lewis and Thornhill, 2023)

The research onion model allows us to analyse all aspects of the research design to be considered in order to construct a sensible research design (Saunders, Lewis and Thornhill, 2023).

3.2.1 Research philosophy

Starting off with the first layer, we have to determine the best research philosophy approach for this project. This project undertakes the **pragmatism** approach, as it 'seeks to improve practice by the application of concepts' (Tengli, 2020). It focuses on finding practical solutions to real-world problems, which perfectly fits the research question I have outlined earlier in the project, which is to devise a self-sustainable power solution for art installations. The problem and the proposed solution are clearly defined.

3.2.2 Approach to theory method

The second layer touches on the approach to theory method. In the case of my study, an **abductive** approach is the option undertaken, as it combines elements of both inductive and deductive approaches. On one hand, it allows for the in-depth analysis of existing solutions and theories in order to examine the technological framework of the topic, but on the other hand it allows for the implementation of innovative elements that address the issues that existing solutions might not have answered yet. This is possible thanks to an iterative design approach that will allow me to continuously implement already existing theories and solutions while still adding on new elements that will aim to bring the design closer and closer to the final solution.

3.2.3 Methodology approach

For this project, I have chosen a **qualitative research** approach to gain a deeper understanding of the technicalities involved in sound art installations, specifically regarding supplementing energy. Qualitative research is particularly efficient for exploring complex topics such as the intersection of art and technology, where the aim is not to generalize findings to a larger population, but rather to understand the experiences, insights, and perspectives of individuals involved in this field. The decision to make use of qualitative methods comes from the research question itself which requires detailed exploration of the experiences and professional practices of artists who are directly involved in the creation and maintenance of sound art installations. Quantitative approach on the other hand might not be that suitable, as it focuses strictly on categorisable and specific data that might not bring any significant analysis results. This approach often misses out on the complexity and depth of the topic due to its nature of analysing categorical and numerical data. It is efficient for measuring specific factors one at a time, but it would fail to show the complexity of the topic or relationships between different factors taken into consideration or the challenges faced in implementation (Flick, 2022). Qualitative approach is known to be best investigated by methods such as interviews and interpretive methods as they are meant to explore different phenomena in-depth. This especially applies to expertise and experiences, which are not able to be expressed numerically (Creswell, 2007).

3.2.4 Research strategy

The research strategy chosen for this study is **ethnography**. This is thanks to its ability to provide a holistic understanding of how sound art installations and off-grid power solutions intertwine. It allows for in-depth analysis of the expertise, experience and creative processes of artists, which gives us insight into how energy autonomy influences such practices and technical challenges. Ethnography ensures that the proposed solution is founded in the real-world needs and practice, addressing the gap between technological innovation and creative expression. This is also a more appropriate approach than for example surveys or experiments as it allows to fully investigate the topic in a way that exhausts all possible aspects and questions that may arise, which is not the case for other research strategies mentioned. This strategy aligns with the project's goal of developing a sustainable off-grid power solution for art installations, where context-specific insights are pivotal (Hammersley and Atkinson, 2007).

3.3 Data gathering

The study design and protocol for this project has been approved by the School of Electronic Engineering and Computer Science Devolved School Research Ethics Committee under the reference number QMERC20.565.DSEECS24.112.

Engaging with artists through **semi-structured interviews** allows for flexibility in the conversation, enabling the interviewees to share their expertise and insights in their own words while still providing a framework to address key research topics. They are a better choice than e. g. surveys, as the topic of my study requires an in-depth analysis of a certain field, and surveys would result in a very narrowed down set of answers to specific questions that will not have the data granularity needed for this level of data analysis. I am aiming to conduct two in-person interviews and three online interviews. I believe that this ratio will allow me to gather a varied range of ideas and opinions from a range of artists and art collectives which then in turn will help me come up with a novel approach to my solution, while at the same time will not become a redundant number of interviews, as it is expected that some part of the data gathered across different art installations will share the same technological framework and therefore will not bring anything new into my project. As an interviewer, I can engage in a two-way conversation that will maximise what I can bring out of the interview and will broaden my understanding of the topic. The interviews will be audio recorded which will then allow me to efficiently analyse the data gathered throughout the course of the study.

The questions designed for the interview can be found in Appendix 1 to this report.

3.4 Data analysis

Data analysis will involve working with the data gathered in the study, which will be stored in the form of audio recorded interviews. For the purpose of transcribing the interviews, I will make use of NVivo, qualitative data analysis software that allows for transcription of media, as well as a range of other operations useful in data analysis (the licence is provided for me as a student by Queen Mary University of London). The approach of data analysis I want to utilise is **thematic analysis**, which focuses on identifying ideas crucial for understanding the data in relation to the research question (Braun and Clarke, 2012). It involves analysing data, categorising it into ideas or themes and then describing each of them with the supporting data. This approach is great for systemic analysis of data and allows for in-depth analysis, which is crucial for my specific research topic. Thematic analysis will allow me to analyse all aspects needed for the design of my solution, e. g. challenges in integrating power solutions in art installations, the concept of sustainability with art installations, design implications and more.

3.5 Risk register

The table below was constructed using the template given in the *School of Electronic Engineering And Computer Science Undergraduate Final Year Project Student Handbook 2024/25*.

Description of risk	Impact of risk	Likelihood rating	Impact rating	Preventative actions
Interview audio recording device failure	Need to re-record interviews	Low	Medium	Recording the interviews using two different devices as a backup
Delays in completing deliverables and project milestones	Less amount of time for reviewing results/report	Medium	High	Regularly review progress and timeline across the academic year, adjust/ rearrange tasks if needed
Overestimation of the scope of the project	Failure to meet all objectives of the project	Medium	High	Focus on the core goals of the project, prioritise tasks
Obtaining few responses from potential interview candidates	Lack of data	Medium	High	Reach out to as many collectives and artists as possible

3.6 Conclusion

This chapter has outlined and explained the choice for the chosen rationale for the methodology behind the project. I have justified the choices made to make sure that the study will bring me as many insights as possible. This is to provide a basis for the study carried out and described in the following chapter.

4. Study - Interviews with solar power artists

4.1 Introduction

This chapter introduces and describes the study involving interviews with solar power artists. It goes over the methodology behind and presents the results of thematic analysis.

4.2 Tool selection

The final product of this project will be a **theoretical framework.** A theoretical framework is a foundation for understanding the key concepts and relationships within a study. It provides clarity and focus by looking at how the study is connected to different theories, as well as how we can generate new ones from the data gathered. It is essential for grounding research in an academic context by directing the research methodology and result analysis (Creswell and Creswell, 2014). For this project specifically, the theoretical framework will be based on qualitative data gathered from semi-structured interviews, as described earlier in the data gathering subchapter. This framework will identify key themes, ideas and relationships necessary for integrating self-sustainable energy solutions in sound art. An example of such a theoretical framework is the systems thinking theory. It examines the relationships between complex systems and how they operate and defines a system as a set of interconnected components (Meadows, 2009).

To develop the theoretical framework, this study will use **thematic analysis**. Thematic analysis is a qualitative method used to identify and analyse themes within data. This approach will make sure that the framework is based on the participants' expertise, experiences and insights. (Braun and Clarke, 2012).

The thematic analysis will follow the six step approach as defined by Braun and Clarke (2012):

- Phase 1: Familiarising yourself with the data

    - Involves transcribing the interviews and familiarising oneself with the transcripts to fully understand the data

- Phase 2: Generating initial codes
    - Identifying key phrases/ideas and assigning codes (labels) to them
- Phase 3: Searching for themes
    - Grouping codes together to examine the underlying patterns in data
- Phase 4: Reviewing potential themes
    - Reviewing themes to make sure all are coherent, distinct and relevant
- Phase 5: Defining and naming themes
    - Assigning meaningful names to emerged themes
- Phase 6: Producing the report
    - Supporting the produced themes with quotes/data gathered

The theoretical framework will provide a vast understanding of how sound art installations can operate sustainably using off-grid power solutions. By applying thematic analysis to qualitative data, this framework will connect artistic, technical, and environmental considerations in a cohesive model.

4.3 Interviews carried out

Throughout the course of data collection, I have managed to carry out seven interviews with several artists:

- Dr Peter Batchelor- the artist behind the *Dendrophone* sound installation in the Alice Holt Forest (Appendix 2)
- Dr Chris Meigh-Andrews- author of several solar-powered installations, including *Interwoven Motion* (Appendix 3)

- Sarah Hall- creator of numerous PV architectural glass installations, including *Lux Nova* (Appendix 4)
- Elizabeth Monoian & Robert Ferry- founding directors of the Land Art Generator Initiative, which focuses on design implementing renewable energy, including solar power (Appendix 5)
- Alex Nathanson- author of the book *A History of Solar Power Art and Design* and numerous art installations making use of solar power (Appendix 6)
- Shala Akintunde- multidisciplinary artist implementing solar power in his installations (Appendix 7)

4.4 Familiarisation with the data

In order to familiarise myself with the data, I have manually reviewed all transcriptions of interviews (generated by iOS Voice Memos transcript feature, Microsoft Teams and email interviews) in order to edit out any mistakes and format the interviews accordingly. Then, I have reread all the transcripts and identified and assigned codes to interview fragments using NVivo in order to identify any patterns that emerge. The codes were then categorised into themes (Braun and Clarke, 2012).

4.5 Themes identified

The figure below presents the most commonly occurring codes across all interviews alongside with the number of times they have occurred.

Code	Number of occurrences	Number of interviews
collaboration	23	2
community	22	2
immersion	21	1
sound	20	2
innovation	19	1
accessibility	18	3

environment	17	1
aesthetics	16	3
grid	15	2
storage	14	3
downtime	11	6

Figure 7: Table of code occurrences across all interviews

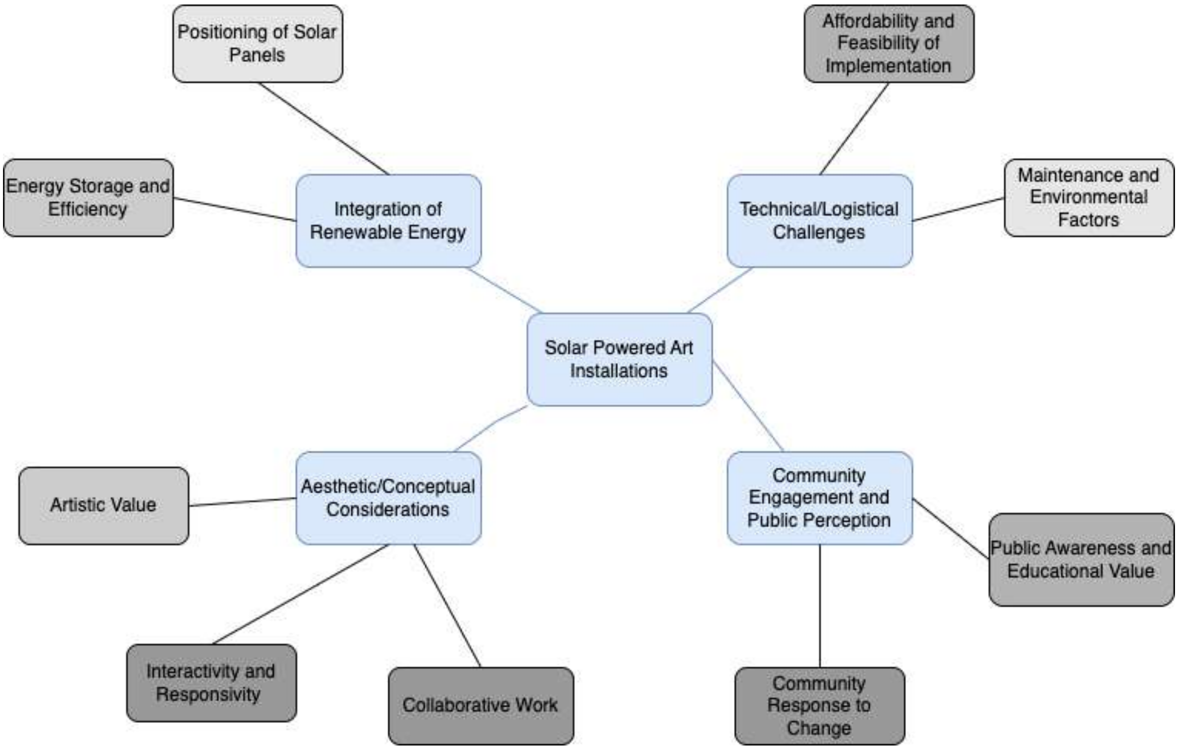

Figure 8: Map of themes identified

The figure above presents a map of themes and sub themes identified in the process of thematic analysis. The intensity of the colour is informed by the number of code occurrences within the interviews found in the figure above.

Integration of Renewable Energy

A very important theme emerging from the interviews was the integration of renewable energy into art installations. Most interviewees put focus on designing installations in a way that they are energy efficient and adaptable to different conditions.

Positioning of Solar Panels

The positioning of solar panels is a critical consideration when designing installations. As one interviewee noted:

The main considerations with citing are orientation, angle, and obstructions. If it's an all-year-round installation, the panels need to be tilted to the latitude angle for maximum efficiency. (Nathanson)

Another interviewee highlighted the challenge of integrating solar panels into a shaded environment:

One other factor affecting solar installation is the client's tendency to plant trees near solar installations. I ask them not to - they do not understand trees grow and shade the panels. (Hall)

Energy Storage and Efficiency

Interviewees mentioned the importance of how energy is stored, specifically battery technology, in ensuring efficient operation of installations. An interviewee shared:

Wherever I went, we had to have batteries, and I used deep cycle batteries that were designed to be used for renewable energy. But they had to be portable, the batteries were always part of the display (Meigh-Andrews).

Others highlighted the need for optimizing energy consumption:

Rather than oversizing the system, we allow the installation to respond dynamically to available solar energy. The intensity of the soundscape changes based on sunlight exposure (Nathanson) .

Aesthetic/Conceptual Considerations

Many interviewees highlight the importance of the relationship between technology and artistic vision, where renewable energy is not just a functional component but also an integral part of the artwork's aesthetic and conceptual design.

Artistic Value

Some interviewees discussed the challenge of merging solar technology with artistic expression:

It was a challenge to bring solar panels together with art glass and have this accepted as an art installation (Hall) .

Another artist emphasized the transformative potential of integrating energy generation into the artistic experience:

Art and culture have always been at the forefront of driving the acceptance of new ideas by humanizing them. I wanted to do that for sustainability (Shala) .

Interactivity and Responsitivity

The role of audience interaction and environmental responsiveness was also discussed. One interviewee explained:

I got interested in what happens when a viewer comes into a space and experiences the space in a particular way. So creating wind in the space, then changing that wind into electricity and then changing that electricity into a display, really interested me a lot, and it was about transduction, that experience of changing energy from one form to another. And that was the central message/metaphor idea in the work. And so all the works that use renewable energy, whether they're solar, wind or a combination of the two, for me, were about that central metaphor of the relationship between one form of energy into another, and making that visible or experiencible for the visitor in the space or outside (Meigh-Andrews).

Technical/Logistical Challenges

While the idea behind energy-autonomous installations was supported, interviewees highlighted several technical and logistical barriers to implementation.

Affordability and Feasibility of Implementation

Financial constraints were a recurring issue, particularly in obtaining and maintaining high-efficiency solar components:

Using ever more speakers, meant it became increasingly prohibitive, just because of the expense (…) So eventually I got to the point where I need to do this affordably. So I moved on to Raspberry Pi's, and was able to do a another kind of flat panel arrangement, which I've called Cascade, and that has 256 channels (Batchelor).

Funding can also be limited because the industry I'm helping to create hasn't been fully established yet (Shala).

Maintenance and Environmental Factors

Several artists raised concerns about maintenance and environmental impacts:

On the flip side, weather conditions and nature's influence (erosion, plant growth, even small creatures) can affect performance, particularly battery life, over time. Many innovations are solving these issues as we find new ways to integrate solar generation into our communities, including current and future infrastructure (Shala).

Another interviewee discussed how natural factors can interfere with system operation:

There's things like leaf fall, which of course is covering up the solar panels. So that's a very practical issue. Where you have your installation might have impact on that kind of thing (Batchelor).

Community Engagement and Public Reception

Some artists noted the importance of community involvement and the perception of solar-powered art in public spaces.

Public Awareness and Educational Value

Several interviewees viewed their work as a means to promote awareness of renewable energy:

It's still a relatively novel concept, so education is a huge part of the process for both partners and stakeholders. Even solar electricians sometimes don't see the potential for imagination in the field (Shala).

Community Response to Change

However, integrating solar technology into art faced some resistance:

We were already seeing some push back- "not in my backyard" reaction to communities who were reticent to change or felt like these were blighting on landscapes in some way. We wanted to pull the imagination of the world towards this challenge by offering examples of energy landscapes that were designed to be beautiful places to merge with natural landscapes (Land Art Generator Initiative).

This thematic analysis provides insights into the complex interplay of technology, aesthetics, sustainability, and practical challenges in the development of energy-autonomous sound art installations. The findings highlight both the potential and the constraints faced by artists working at the intersection of renewable energy and immersive digital experiences.

4.6 Conclusion

The interviews conducted with artists provided crucial real-world insights into the practical, aesthetic, and philosophical challenges of sustainable installation design. Through thematic analysis of the conversations, recurring patterns emerged around energy storage reliability, system affordability, visual integration of technology into art, and the role of community engagement in sustainable art. These findings directly informed the design and priorities of the proposed solution, particularly the emphasis on flexibility, modularity, and clear visualisation of energy flow.

5. Proposed solution - Solar energy forecasting and battery simulation system

5.1 Introduction

This chapter goes over the technical aspects of the proposed solution, as well as presents the functional interactive prototype of the system. It is then evaluated against different reliability considerations and future work is discussed.

5.2 Overview of proposed system

The proposed system aims to facilitate an adaptable framework for powering art installations using photovoltaic (PV) solar power by addressing the self-sustainability of said installations and autonomy. The design of the system is based on insights from the interviews carried out in my study described in Chapter 4, as well as the analysis of existing installations. The system is designed to analyse and forecast energy production and usage in real time.

5.3 System requirements

The system requirements were outlined with the use of insights gathered from the interviews with artists working with solar-powered and off-grid installations. Their concerns around accessibility, energy planning and reliability helped define the technical parameters of the system. This system is designed to serve as a planning and simulation tool to support the design of solar-powered systems for off-grid art installations. Its main function is to help users assess whether a given solar setup will be viable and sustainable over time.

The following input variables have been identified as essential to the system's operation, based on recurring themes from the interviews and real-world installation analysis:

- **Location:** to retrieve location specific solar irradiance data

- **PV panel tilt and azimuth:** to reflect the real-world orientation of the installation and simulate how efficiency of energy production is influenced
- **Month**: to analyse how solar availability changes seasonally
- **Battery capacity and system voltage**: to simulate battery storage and state over time
- **Panel power rating**: to determine how much power can be produced under optimal conditions
- **Load power:** states how much energy the system consumes which is essential in determining the self sustainability of the installation

In addition, I have identified some non-functional requirements to aid the system design:

- **Free and open access:** the tool should be usable without any proprietary software or licensing
- **Intuitive:** it should support use by artists and designers with various levels of technical experience
- **Modular:** it should be applicable to a wide range of setups, from small installations to more complex energy systems

System requirement	Interview theme	Explanation
Location	Positioning of Solar Panels	Location and sun exposure are the main factor in efficiency of solar power production
PV panel tilt and azimuth	Positioning of Solar Panels	Tilt and orientation were identified as vital for optimising energy production
Month	Environmental Factors	Need for design based on solar availability
Battery capacity and system voltage	Energy Storage and Efficiency	Essential for uninterrupted operation

Panel power rating	Affordability and Feasibility of Implementation	Choosing an appropriate panel is based on the available budget
Load power	Technical/Logistical Challenges	Helps to plan for system demands basing on capacity, especially for remote locations
Free and open access	Public Awareness and Educational Value	Supporting accessibility facilitates broader interest and participation
Intuitive	Artistic Value	Artists emphasized the need for tools that support creativity, rather than obstruct it
Modular	Affordability and Feasibility of Implementation	Allows the system to scale up or down based on available resources

Figure 9: Table of system requirements

Figure 9 presents a table of identified system requirements linked to the interview theme that motivated it as well as an explanation. This is to ensure that the proposed solution directly supports the goals of its intended user base.

5.3 System components

The proposed system will consist out of several components:

1. **Data acquisition** - solar irradiance data acquired from an external solar irradiance database for the purpose of its visualisation over time and to feed the forecast model

2. **Forecast model** - a model which by using fetched solar irradiance data will be able to forecast and visualise said values for different months and locations

3. **Battery simulation** - by using the forecasted values basing on user input parameters will simulate and visualise battery charge levels over time

4. **Interactive dashboard** - combines all components together and allows for user interaction and operation of the system

5.4 Rationale for the proposed solution

This subchapter goes over the rationale chosen for designing and implementing the solution. The resources and libraries chosen for the implementation have been based on the system requirements outlined in Chapter 5.2. Figure 10 presents a diagram showing the architecture of the proposed system and the data flow as well as how the resources used are integrated.

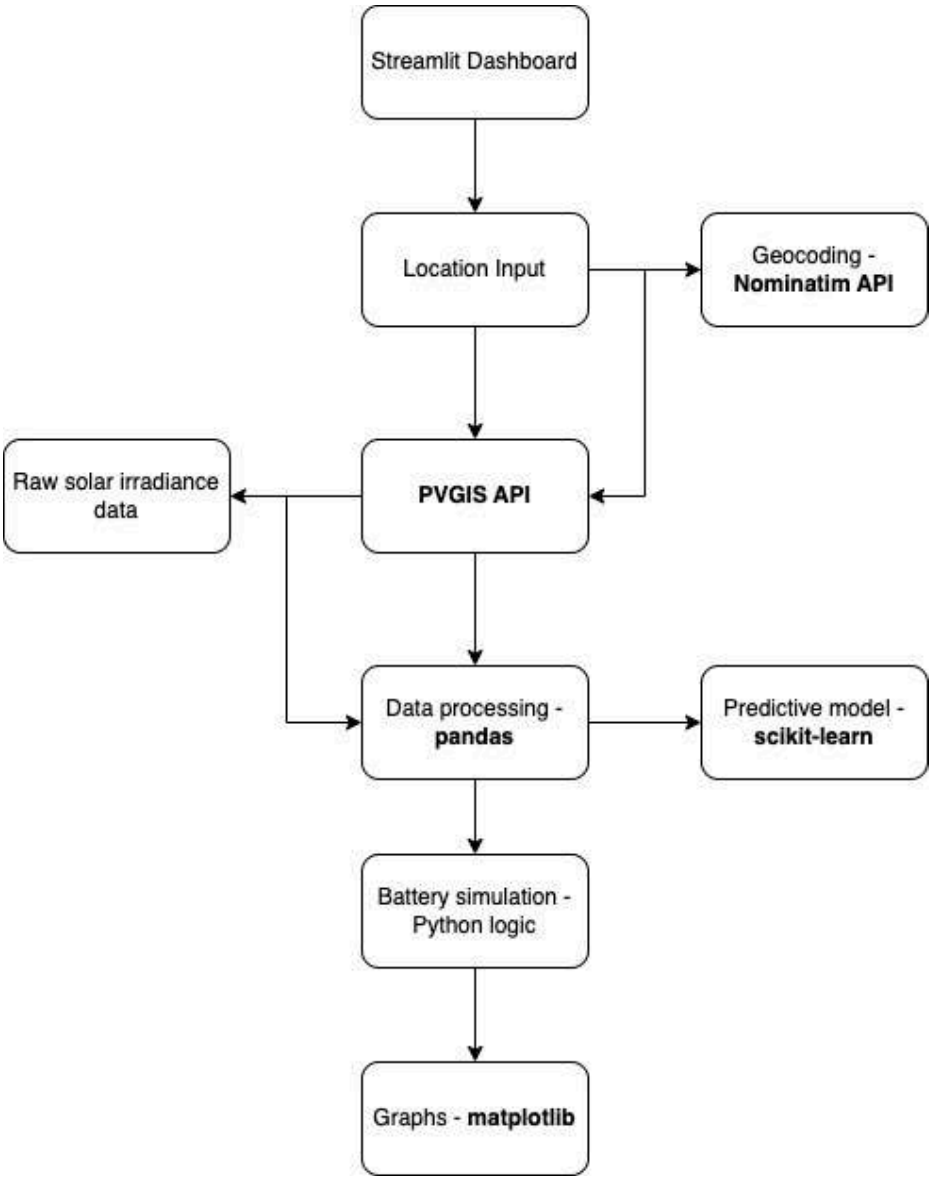

Figure 10: Libraries and resources in a pipeline visualisation

Streamlit

Streamlit is a Python-based, open-source framework which allows for efficient and accessible prototyping and deployment of Python apps. I have chosen this framework as it is an adequate choice basing on the scope of my project and its requirements, e. g. use of Python libraries (Streamlit.io, 2024).

scikit-learn

scikit-learn is a Python library that contains various tools essential for data analysis and machine learning algorithms. I have chosen to use this library for the purpose of creating a solar irradiance predictive model.

matplotlib

Python library for constructing graphs - I have chosen to use this library for the purpose of creating graphs that visualise data output from algorithms used.

pandas

I have chosen to use this library as it provides data structures essential for storing and processing data pulled from external APIs.

PVGIS API

As the data source for the purpose of data analysis and forecasting, I have decided to use the Photovoltaic Geographical Information System (PVGIS) database and their API. PVGIS provides solar radiation data for nearly any location in the world, which makes this a perfect tool for my system which is meant to help the user plan and design PV-based power solutions for their installations (The Joint Research Centre: EU Science Hub, 2024).

Open-meteo

Open-meteo is an open-source weather API that provides historical weather data for any specified location. I chose to use this API for the purpose of obtaining said data pivotal for my solar irradiance and battery charge forecasting model (Open-meteo.com, 2022).

Nominatim

This API is an open-source tool which I chose to use for the purpose of geocoding location coordinates by name. This is essential for user interactivity with the system (Nominatim.org, 2025).

5.5 Prototype of the solution

In order to showcase the findings of my study presented in the previous chapter and ground my research in a practical application, I have constructed a functional, interactive prototype of a PV solar power visualisation and forecasting system. This is for the purpose of demonstrating my findings and vision for a solution, providing a basis for any future work and manifesting the software engineering and design skills outlined by my study programme.

All of the coding was done in Visual Studio Code and the entire project and its dependencies are available in the GitHub repository here.

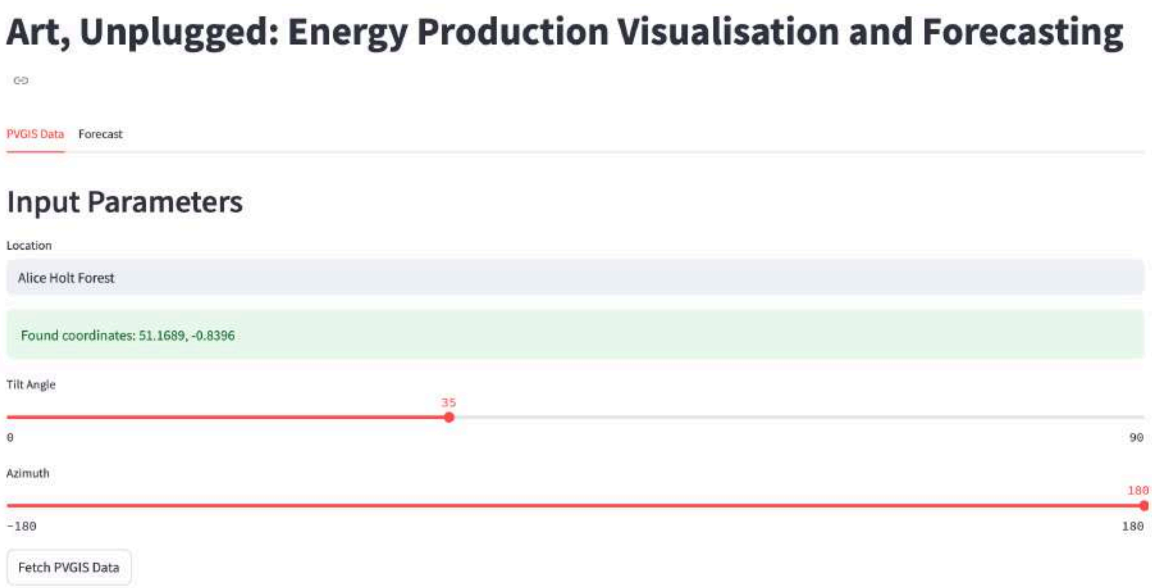

Figure 11: Landing page

Figure 11 presents the landing page. The first tab pulls solar irradiance data from the PVGIS database - which contains solar irradiance data essential in simulating and forecasting solar power production - basing on the location, tilt angle and azimuth parameters put in by the user. The location bar geocodes the location basing on the input from the user by using a Nominatim API call. This is because the PVGIS data use latitude and longitude coordinates for storing location. The user input text is plugged into an HTML call to the Nominatim API which then returns the `lat` and `lon` coordinates of the said location. The placeholder values are set for Alice Holt Forest as this is where the installations by Dr Peter Batchelor and Dr Luigi Marino, which I got to see and analyse in person, are located. Upon pressing the Fetch PVGIS Data button, the system makes a PVGIS API call using the parameters from the user input and Nominatim API call.

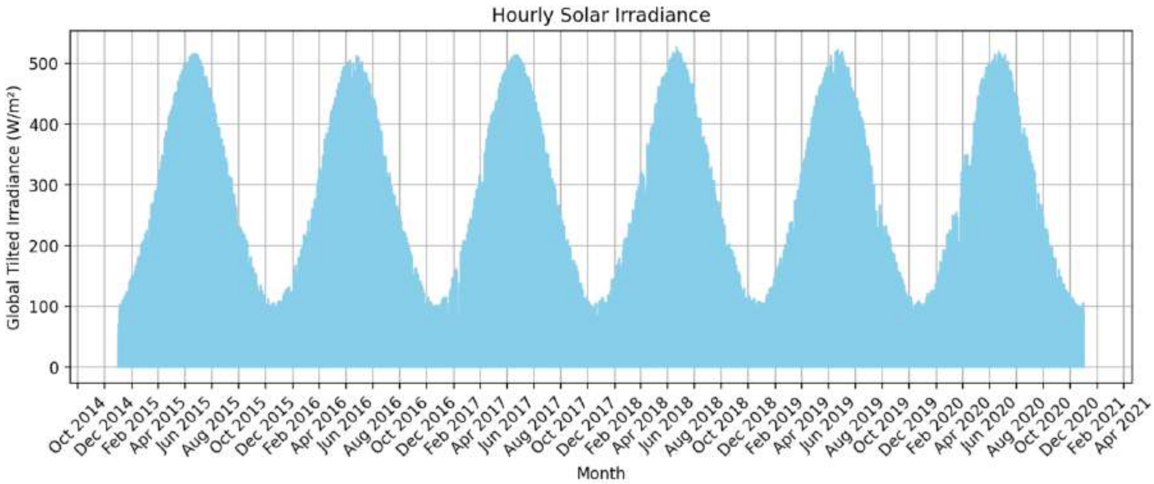

Figure 12: Hourly solar irradiance data for Alice Holt Forest presented on a graph

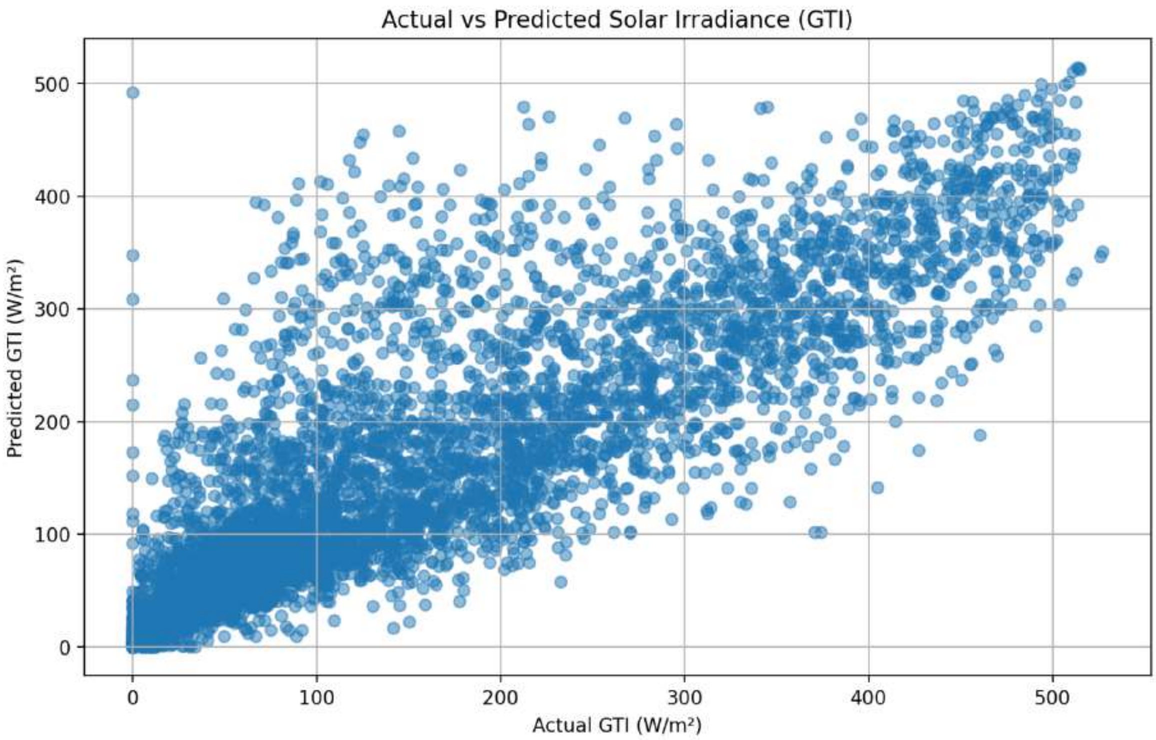

Figure 13: Actual vs predicted solar irradiance data for Alice Holt Forest

Figures 12 and 13 present the two graphs generated by the program, for demonstration purposes I chose Alice Holt Forest as the location. The first graph demonstrates actual PVGIS solar irradiance data measured in Global Tilted Irradiance (GTI) in W/m^2, a measure that is the total amount of solar radiation projected onto a tilted surface (solar panel), which is pivotal in calculating energy yield of all PV systems (as explained in Chapter 2.3). The data is spanned over five years (2015-2020) in order to provide enough data for the predictive model to be as accurate and reliable as possible. The end year chosen is 2020 as this is currently the furthest scope of data available from PVGIS. The graph lets the user see how solar irradiance changes over the months and years for the given location. Looking at the example of Alice Holt Forest shown in Figure 12, it can be noticed that solar irradiance across multiple years is at its peak April throughout June. This information is vital for efficient and sustainable planning of the design of the installations.

Having fetched the PVGIS data, the predictive model is trained with said data. For this purpose, I have decided to use the `RandomForestRegressor` as it is a machine learning model that combines numerous decision trees in order to predict continuous values, in this case GTI.

```
model = RandomForestRegressor(n_estimators=100,
random_state=42)
model.fit(X_train, y_train)
y_pred = model.predict(X_test)
```

I have decided to use 100 trees in order to optimise the credibility of results and a fixed random seed of 42 to ensure that the model behaves identically across different runs to allow for consistent evaluation and analysis. Figure 13 presents the graph comparing the GTI values predicted by the model to the actual GTI value taken from the PVGIS data. The system also displays the R2 score of the model where value 1 shows perfect prediction and value 0 shows no correlation. For this particular case of Alice Holt Forest, the R2 score is 0.829, which shows that the model provides a reliable prediction of solar irradiance. This is important as this score shows how well the model predicts actual levels of energy produced, hence, how much can it be trusted with designing an installation in a given time and space.

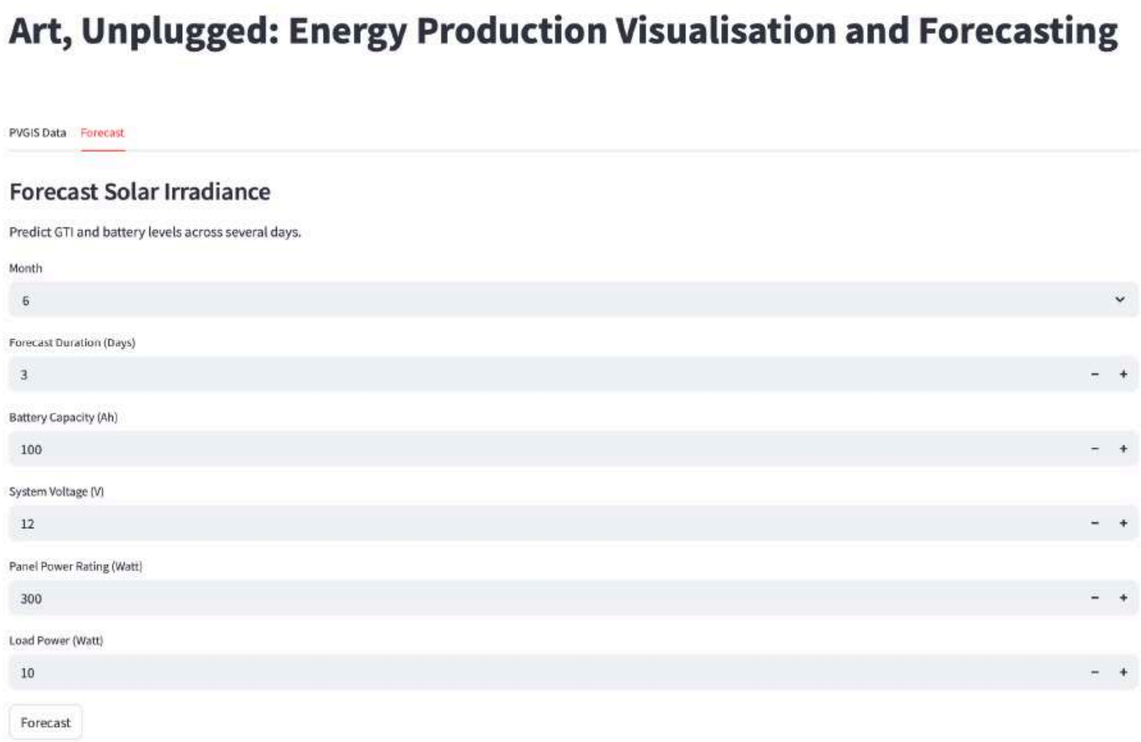

Figure 14: Second tab of the dashboard

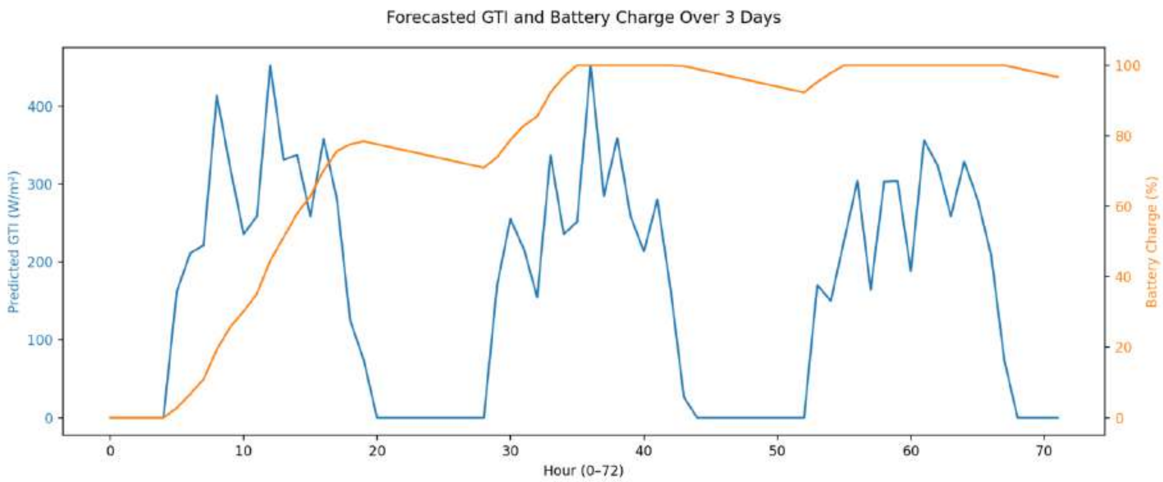

Figure 15: An example graph showing simulated battery charge levels and predicted GTI

Having fetched the PVGIS data and trained the predictive algorithm, the second tab labeled Forecast allows the user to simulate and visualise battery charge levels across time. This is for the purpose of determining how much power can be obtained across multiple days, and thus, whether an installation designed can be made self-sustainable in chosen conditions. The user inputs the month of the year, number of days to forecast for, capacity of the battery storing the energy produced by the panel, the system voltage, the power rating of the PV panels used and the total load power of the whole installation. The terminology used is explained further in Appendix 8. Basing on those parameters, the system uses the model previously trained to predict and forecast different GTI values for all hours throughout the number of days defined by the user and visualises the change throughout the days. Then, it simulates the battery charge cycle using the parameters specified by the user and the forecasted GTI values from the model using a calculation with an assumed overall PV power generation efficiency of 90% (to account for any losses in the process to make the simulation more realistic):

```
charge_wh = (gti/1000) * panel_power * 0.9  # 90% efficiency
```

The graph allows the user to see how solar irradiance changes throughout multiple days for a given month. This is useful for seeing how efficient the PV power production will be at different times of the year. The graph also simulates and models the battery charge cycles across multiple days taking into account the capacity of the battery, the power rating of the PV panel and the total load power (power used) of the installation, which gives the user a quite realistic simulation of how the battery levels will change over time, thus, how long the installation will be able to operate continuously basing on the power produced by the PV panels.

5.6 Initial reflections

The demonstrated prototype of the solution grounds my research in a practical approach and showcases the functionality and applicability of my findings. The system enables the user to realistically visualise, model and simulate solar irradiance, PV power production and battery charge cycles. This allows anyone who wants to power their installation using solar power to determine whether the installation can be made fully self-sustainable basing on numerous factors, such as the power requirements of their system, the power rating of the PV panels and capacity of the battery. This helps with optimising factors such as the power load of the installation. The system operates on multi-year data for specified locations which increases the validity of the findings and the reliability of the predictive model. Allowing the user to choose the location and time makes this system useful in virtually any scenario and conditions.

The system takes numerous real-world factors into consideration which makes it quite usable and realistic, however there are also some factors that might potentially compromise the validity of the system. There are several factors that might influence the production of solar power by PV panels negatively, such as drops in efficiency due to high/low temperatures, dust, leaf fall, shading or tilt angle. Additionally, the system assumes static load power of the installation but that might not always be the case, e. g. installations that use hardware with different levels of activity throughout the day. While the proposed solution demonstrates strong proof of concept performance, several limitations still remain.

5.7 Future work

The constructed prototype is a great basis for a complex and modular system. Some of the other functionalities and components that could be implemented in the future include:

Hardware integration

As a further extension of the proposed solution, future work could involve the integration of physical hardware components to capture real-time environmental and energy data directly on-site. By connecting low-cost microcontrollers such as a Raspberry Pi or Arduino, equipped with the appropriate sensors, it would be possible to move beyond modeled and forecasted data toward real-world measurements. This can be achieved with the use of appropriate sensors and software.

Usage optimisation

While the current system allows users to simulate battery charging and discharging under fixed load conditions, real-world installations often have dynamic energy demands that vary throughout the day. Hence, implementing variable load profiles or automated demand response features for the system in the future might help users optimise their energy usage in off-grid environments.

5.8 Conclusion

The proposed solution successfully demonstrates an initial stage of a functional prototype for designing off-grid, solar-powered art installations. By integrating data-driven solar irradiance forecasting with battery simulation, the system allows users to visualize energy availability and storage capacity over time based on real-world environmental parameters. Through the use of location-specific PVGIS data and a machine learning model, the solution offers an accessible, practical tool for sustainable project design. The flexibility of input parameters (location, tilt, battery capacity, load consumption) supports applicability to a wide range of installation scenarios. Although some simplifications exist, such as static load assumptions, the prototype provides a robust foundation for future enhancements.

6. Discussion

6.1 Introduction

This chapter discusses the outcomes of the project by critically analysing how the research findings and the developed prototype address the research gap identified in the literature review. It reflects on the way interview insights were integrated into the design of the prototype and how it consolidates all aspects of the project into a cohesive, practical proposed solution.

6.2 Addressing the motivation for the project

The literature review for this project, carried out and described in Chapter 2, identified the need for a replicable, scalable framework for sustainable off-grid energy use in art installations. Across the years, solar power has been continuously explored and integrated into art installations, which is discussed in works like Alexander Nathanson's *A History of Solar Power Art and Design* (Nathanson, 2021). Most existing works in this field, such as the *Pond Station* by Zach Poff (2015) use power solutions that were designed specifically for the requirements of said installation and relevant environmental variables, but there is no generalisable tool or planning system that others can adopt. My project directly addresses this gap by developing an initial prototype of a system that allows artists to assess the viability for any installation based on environmental and energy requirements.

The forecasting and battery simulation tool transforms these theoretical concerns into a practical resource. By incorporating solar irradiance data, load consumption, and battery characteristics, the prototype allows for reliable planning of off-grid power solutions. This goes beyond the artistic documentation of solar integration discussed by Smallwood (2011) and Nathanson (2021) by offering an accessible, interactive tool. It also directly engages with the technological and logistical challenges outlined in the literature, such as variability of solar availability (Chapter 2.5.3) and the need for long-term planning and resilience in design (Chapter 2.5.4).

6.3 Integrating research insights in the solution design

Rather than presenting a fixed setup, this project aims to empower the public to simulate and plan for energy autonomy across diverse contexts. The interviews conducted with artists in solar-powered and off-grid art, as described in Chapter 4, highlighted a consistent consideration- there is no unified blueprint when it comes to powering art installations. Environmental conditions and technical limitations all vary drastically from one project to another. Through recognising this diversity, the core mission of the proposed solution lies in its adaptability and responsiveness to unique project requirements.

Interviewees consistently highlighted the need for systems that could respond to solar availability and accommodate different power loads. The system prototype developed in this project directly responds to those concerns by allowing users to enter custom environmental and technical parameters, such as location, tilt, azimuth, battery capacity and power load requirements.

By integrating interview informed values, such as modularity, visualisation, and usability into a dynamic, data-driven platform, the prototype advances a practical response to the challenges identified in both the literature review and my research. It bridges the technical and creative domains by offering a scalable, replicable tool that supports both environmental responsibility and artistic autonomy.

6.4 Prototype evaluation and further implications

While the initial prototype developed in this project addresses the core research objective, which is enabling simulation and planning of off-grid solar power solutions for art installations, it is essential to evaluate its limitations and consider its broader implications. The assessment of the scope of the solution and performance is fundamental in assessing its viability as a long-term solution and a foundation for future development.

The prototype currently assumes static load profiles and fixed seasonal weather conditions within the forecasting model. In reality, energy demand may fluctuate depending on the time of day, audience interaction or multimedia intensity, especially in complex immersive environments. Furthermore, real-world solar energy performance can be influenced by numerous factors such as dust accumulation (Said et al., 2024), unexpected shading, equipment degradation, or climate variability elements which are not yet accounted for in the simulation. These simplifications, while appropriate for a proof-of-concept, may limit the accuracy of long-term predictions without further refinement.

A more comprehensive evaluation of the system's effectiveness would require iterative testing with its intended user base, that is artists designing art installations that require a reliable power solution. Sharing the prototype with them for real-world testing, feedback, and critique would provide deeper insights into usability, artistic integration, and conceptual alignment. Such engagement would not only validate the system's practical value but also offer a feedback loop for further refinement, ensuring the tool remains responsive to the evolving needs of its users.

Despite these limitations, the implications of the prototype are promising. It lays the groundwork for future work, that is improvements and additional functionalities. Its potential to be adapted for other contexts, such as outdoor events or educational platforms in art and sustainability further supports its relevance. As an open, modular tool, it can also serve as a teaching resource or be extended through hardware integration and live environmental feedback.

6.5 Conclusion

This chapter has demonstrated how the initial prototype answers the research question of this project '**How can we devise a power solution to achieve self-sustainability of art installations, and how can we apply this knowledge in the art industry?'** by addressing the research gap identified in the literature; the absence of a universal, scalable tool for designing off-grid, solar power solutions for art installations. By critically analysing how the system incorporates the insights from interviews with artists, it has become evident that the initial prototype lays the ground for a full interactive solution that bridges the creative and environmental needs of contemporary art practices.

The discussion has shown how the system's adaptability and usability align with both academic literature and the real-world experiences of artists. While current limitations such as static power load assumptions and simplified environmental modelling restrict the prototype's predictive precision, the implications point towards a promising foundation for future work, including user testing, hardware integration and broader application across creative and educational contexts.

This chapter consolidates the project's conceptual, technical, and artistic contributions, restating the relevance and necessity for sustainable, replicable tools in supporting environmentally conscious art practices.

7. Conclusion

This project set out to investigate how sustainable, off-grid power solutions can be integrated into art installations through the development of a replicable and adaptable planning and simulation framework. Motivated by the increasing ecological footprint of digital and sound-based artworks and a documented lack of generalisable energy planning tools in existing literature, the study adopted a mixed-method approach that combined a critical review of prior work, qualitative interviews with artists and the design of an initial prototype.

Through thematic analysis of interview data, the research identified key concerns, such as environmental variability, storage and load constraints, aesthetic integration and system accessibility, which directly informed the system requirements and functionality of the proposed solution. The resulting prototype enables users to simulate solar irradiance and battery charge cycles across user-defined scenarios, thereby offering a flexible and intuitive platform for evaluating the viability of off-grid solar systems tailored to specific artistic and environmental contexts.

In doing so, this work bridges a gap between technological planning and creative practice, providing a foundation for both practical implementation and further interdisciplinary exploration. While limitations remain, particularly in regard to real-world variability and the need for user testing, the project demonstrates the feasibility of a tool that supports both ecological accountability and artistic autonomy.

Future work should focus on extending the prototype through user testing, hardware integration and deployment in live settings. As a conceptual and technical foundation, this project offers a scalable basis for sustainable innovation within the art industry.

Ultimately, this project delivers more than a technical solution- it introduces a replicable, scalable framework that advocates for ecological accountability within the art industry. In doing so, it aligns perfectly with the broader vision of this dissertation: enabling self-sustainability in art by equipping artists with the tools to consider energy responsibility without compromising artistic intent. This work represents an initial, but significant contribution towards a more sustainable future for digital and immersive art.

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Appendices

Appendix 1: Questions used in the interviews

1. Can you tell me about your background in artistic installations?
2. What is the technology behind the operation of your installation(s) (board/OS/peripherals)?
3. What benefits and challenges have you faced while sourcing electric energy to your installation(s)?
4. What factors did you take into consideration while thinking about the positioning of solar panels?
5. How do you measure energy usage of your installation(s)? How does that relate to the amount of energy produced by the solar panels?
6. How does the electric energy circulate within your installation(s), what kind of storage and connection hardware did you implement?
7. What is the uptime and downtime for your installation(s)? How does the energy consumption change over time, is it different depending on any other factors?
8. What are the main factors affecting the performance of your installation(s)'s energy sourcing, both positively and negatively? Do you feel there is anything that could be done or investigated in order to neutralise the negative ones?
9. Do you have any vision/ideas/thoughts on the future of artistic installations and solar powered solutions as a whole?
10. Do you have any other comments, ideas or suggestions that you feel would be vital for this project and for my investigation?

Appendix 2: Transcript of the interview with Peter Batchelor

An adapted version of this interview is available on the Sensing the Forest project website.

Aleksander Skutnik 0:02
Okay. So, hello Pete, thank you so much again for the consideration. And wanting to take part in my interview that I will be carrying out for the purpose of data collection for my final year project. So yeah, I'm meeting you because you are an artist involved with sound art, which is one of the main areas that I'm aiming to explore in my project. So first, maybe, could you just tell me about your background in artistic installations, maybe some works to date, and what are your main like scopes of interest?

Peter Batchelor 0:42
So I didn't really start out doing sound art at all. I was doing composition for fixed medium, which was in particular acousmatic music, which is, this will be something familiar to you, I'm sure, but basically, it's music which uses the recorded sound primarily and is interested in kind of exploration of rich, kind of immersive soundscapes, and the presentation of those tends to be over well, used to be produced in stereo, and then my experience of it was to be diffused in a concert hall, so where you take a stereo file and you wiggle faders and you transmit it to multiple channels. And when I started my PhD, I started working in multiple channels, and I started wondering where I would I sort of felt I'd said as much as I wanted to say in that kind of fixed medium domain. So I was looking for alternative ways of doing that. And I sort of explored, kind of like electronics performance, but also integrating these kind of rich sound worlds. And I started doing installations at that point, and I continue to have a significant interest in kind of the multi channel, just because I like that ability to immerse my listener. I still conceive of things very much as a kind of a holistic soundscape. So rather than conceiving all of the speakers as independent units, I think of them as a field, and I transmit things and and, but it's, the way that that that field kind of is amorphous, or kind of able to move around that space. So those are the kinds of soundscapes that I produce or produced. But I was interested in ever more kind of elaborate, multi channel systems without much money. And so although I was able to do sort of eight channel, and those were the standards, and I did a piece, my last piece of my PhD was 12 channel, kind of, you know, in a circle. But I wanted more than that. So the last piece I produced of my PhD, which was a long time ago. In fact, 20 years ago was was studies on canvas, which was a 30 channel, kind of 30 speakers behind black canvas. The idea was to generate these kind of realistic soundscapes behind by that. My apologies, by the way, if I'm saying too much, but this is just where I'm coming from. So I tried that, and then I developed this grids project, which was these kind of just lots of lots of channels. The reason why perhaps this is significant is because of the fact that trying to do ever more, ever more speakers, or try to use ever more speakers, meant it became increasingly prohibitive, just because of the expense, and also because, you know, a machine like this, you can send it to interfaces, but the interfaces will only output to X number of channels, so it's usually eight

channels, or 16 channels with ADAT interface or or you can aggregate them and you can get more, but you're still quite limited. So I managed to get up to, I think, yeah, I managed to get up to sort of a 40 channel installation, which was a development of this, the canvas project, which was a kind of surround dome, and that was, well, it would have been 40 channels in a geodesic dome, because with a 2v geodesic sphere, sorry, you can get 40 speakers, as long as you don't need room for a dome. But as I say, just increasing numbers. So eventually I kind of got to the point where I need to do this, you know, affordably. So I moved on to Raspberry Pi's, and was able to do a another kind of flat panel arrangement, which I've called cascade, and that has 256 Channels. And the way I've done that is to not particularly in a not particularly sophisticated way, to aggregate the Raspberry Pi's say, 32 Raspberry Pi's each with an eight channel interface and and they're just communicating with each other via OSC. So in terms of, in terms of the facilitation of these things, it's sort of, it sort of evolved in that way. And these systems become, I found the term media multiplicities, which is basically where you know you've got, you've got these self contained systems, but you can aggregate them, and they just build up, and then you find a means of them communicating with each other, and you end up with these big systems. And so for the cascade project, a lot of it was granulation, which so, so I'm not too reliant on synchronization between the systems. So granulation, you can, you know, you basically, broadly speaking, till you roughly when to put a grain and another grain, another grain. So you can build up these kind of textures which are quite realistic. So again, going back to the achismatic, it's building these textures which are rich and immersive. And because so many real world sounds use or involve these kind of aggregated clusters of sound, like raindrops or, you know, ivory sound, pretty much leaves rustling, but, oh, but they operate spatially. So you get this kind of spatial kind of, experience by by doing that. So that's basically the systems that I've built. And as I say, because they are modular, it means that they are scalable, and you can make more and more, you know, according to how many of these, in this case, Raspberry Pi's interface for HL interfaces you want, and then you can obviously use the apps to do that. So I think that sort of preempts some of the questions I think you might be coming to. But I thought if I said that, yeah, that helps.

Aleksander Skutnik 7:15
Absolutely, yeah, thank you. That's very impressive. Yes, like you mentioned, that kind of introduces My second question, which is, what is the technology behind the operation of your installation? So you mentioned the Raspberry Pi, and the design of your installation has been like modular, in a sense. So, so, yeah, so Raspberry Pi is like as a controller of that all, in terms of OS, did you maybe program anything additional to, like, when thinking about integration of that, all like, Are there any peripherals, perhaps, that you use to integrate that? Or what's like, the main factor, just like, combining all of that?

Peter Batchelor 7:58
Sure. So, so yes, I program, I program my own stuff. So I'm a Max MSP user. I'm not particularly sophisticated in that regard, but I get by. And a lot of it is just triggering of samples or granulation, that sort of thing. So the Raspberry Pi's obviously don't function with Mac, so I use PD, and that fulfills my needs perfectly adequately. In fact, the cascade I was using Ableton to send sort of

automation data to control the granulation on the Raspberry Pi's. And so, yeah. So in terms of, in terms of the software that that's all kind of taken care of, the other technology is, say, Raspberry Pi's, to these sort of some point one channel interfaces, which are very cheap. They're a bit like this kind of Creative Sound Blaster cards as were, which are some point one interfaces they declare themselves to be. But they they operate from Mac and also from from Linux. You know, they operate quite, quite seamlessly and easily, luckily for me, and then out to kit amps, basically. So I use they were A-class amps, which I realized when I started this project weren't particularly efficient. So I'm now using D-class amps, which seem to do the job they need to do much, much more efficiently. And in terms of communicating between the Pi's, I, in this case, I'm using Wi Fi through an independent kind of modem, you know, Wi Fi modem, which you see. So it's all consumer stuff, which perhaps is worth pointing out. I don't. Build my own additional kind of stuff, mainly because I don't have the wherewithal to do that, but also, but it does have its advantages in terms of being relatively robust and cheap and reliable, because I wouldn't know, I mean, judge it by the way that I program my PD stuff. You know, I probably don't troubleshoot as reliably as I should. So, so it's more like some work.

Aleksander Skutnik 10:30
Yeah, but definitely with that one you mentioned that could improve the replicability of such solutions and also accessibility, for sure, because it's like.

Peter Batchelor 10:39
Exactly, yeah. I mean, that's why, you know, when I get round to it and I actually write something about this, then you know that at least is something that is relatively off the shelf and easy for people to replicate.

Aleksander Skutnik 10:52
Yeah, that's perfect. Thank you very much. So while implementing like over the course of your like experience and expertise of your installations, would you have any like main benefits or challenges that you have you could identify while sourcing electric energy to your installations? Because, as you mentioned, your installations use various types of technologies that, of course, need power. So what's how have you approached this? And perhaps, are there any good sides to it, or challenges perhaps, that you have faced while designing and integrating the Power Solutions themselves?

Peter Batchelor 11:32
Sure, yes. Main one is that it's ugly, inevitably. So every bit of cable that you have to add is a, you know, is something that you have to somehow disguise or make moderately attractive. But yes, in most cases, I run off the mains or have done, and that's why this particular project is, has been, you know, informative for me. So up to this point, it has been just, you know, powering a computer and, and the, the, sorry, the amps for this project, we didn't have that option. So you, I think you've already interviewed Luigi, and we have the same thing, we're quite a long way off grid. There was talk of us somehow running some cabling from from the Forestry buildings, probably this one, but that wasn't practicable, so, so it was a question of finding an off grid solution, which we have done. I can't remember whether that one of the next questions come comes to that, or I

can carry on and talk about that now. So what I've done in this case is to use, we were looking at various battery solutions that could be changed by Forestry staff originally, and we thought about, you know, the sort of mobile phone charger batteries, which was naive, because they weren't very, very much, but it's such was my ignorance when I started the project, which is not impressive. But anyway, so we were looking at that. We were looking at various other battery solutions. And ended up with with leisure batteries of some kind. We looked at the sort of lithium ion batteries that are sort of portable, you know, self contained units, not particularly reliable. So I'm afraid, in the end, we've resorted to the lead acid leisure batteries, which are 96 Ampere-hours. I think it's 92 or 96 anyway, you know, enough to power it for a certain amount of time. I wasn't initially thinking about solar panels, and then Luigi kind of discovered we've kind of bounced off each other a little bit. And so now it's running off, I think, the 120 watt panels. So I've got four of them, so it's for 480 optimally, for various reasons. Again, I don't know whether we come to this bit yet, but that's the challenge of where we are, which is under canopy.

Aleksander Skutnik 14:13
Exactly, so like the positioning of the installation itself, and like the variability of sunlight, I guess in this case, which affects the energy output, essentially from the.

Peter Batchelor 14:24
Significantly. And again, in my ignorance, you know, I thought, well, there is, there is ambient light, but of course, it's not sunlight. So it varies. I don't know how useful this is, but it varies from about 0.2 Amp to actually, sometimes even 2, if you get and this is, this is in the forest area. I imagine if it was outside the forest, it would be much more, obviously, much more reliable, and probably even more than that.

Aleksander Skutnik 14:53
Yeah, that's perfect. Thank you. So for. The numbers you just gave me about the energy production. Which tools do you use to measure energy usage? Is this, I think we actually saw the solar power control when we were visiting your installation before. So how does that work, and how does that relate to the amount of energy produced, like consumed, yes, exactly. So, yeah. So how do you measure that, and how maybe like, either in percentages or like, how does that relates to what your installation actually uses?

Peter Batchelor 15:34
Yeah. So it as you saw there is a controller for the solar panels, which comes as part of the package, and that tells us input and output. So, so, so I measure it that way. But while I was testing, I was just using a USB, I can't remember what you call it, but basically it's one that measures your power usage, so that that gave us an indication of what, what it would be. And I was using some adapters to convert to 12 volt barrel kind of plug in order to capture, you know, to measure everything. So the what I'm using across the system. So I don't know whether you want me to break it down, but I can do; the amps, which are eight stereo amps, they take about 0.5, I think. The Raspberry Pi zeros take about point between 0.1-0.2 depending on how much they're doing. The Wi Fi modem takes about 0.1, and then the timer switch takes a fraction as well. So all in all,

it's declaring that it's taking about 1 amp. Okay, so obviously that's more than I'm necessarily getting from the from the solar panels. So we've dealt with that basically by saying, well, the installation will only run for a certain number of hours per day, and it will charge for as long as you know. It charges depending on the weather conditions and obviously the time of year and everything. I'll be honest, I haven't directly measured what those are because there are so many variables. I don't know how, how accurate it would be, so it's a bit suck it and see. And, but it seems, it seems to run, I mean, over the over September time when, of course, you know, we were sort of around the equinox, it was still, it still run for a month without the battery needed to be changed, and then it conked out, and that was it. And I, to be honest, I don't what it's done more recently, because I've, I've been preoccupied with with other things, so I haven't been able to check it properly. So over the next couple of months, I'll be able to tell you more if, if you want me to send you more. Yeah, but again, sorry, very long winded answer.

Aleksander Skutnik 18:07
No, the more extensive the answer the better for me. So from what you said, um, it looks like about half of the energy usage is the stereo speakers themselves.

Peter Batchelor 18:19
the amplifiers. Yes, yeah, yes, okay, cool. Well, I mean, but that, I mean, that's part of the challenge, really, with an audio installation, is that it's very power hungry, and so that was, that was quite something to try and make it as efficient as possible while maintaining some degree of quality. One thing, which is, is is different about perhaps anything I might do in the in the concert hall, of course, you're working with as high quality speakers as you possibly can. You're working with Genelecs and, you know, and such, like in an installation environment. You You don't, you know, you don't do that. So the emphasis shifts towards the what this what the speakers afford you in terms of specialization and and, as we talked about earlier, kind of integration with the natural environment. But if you're interested and haven't already come across it, there's an article by Robin Minard called 'Sound installation art', where he talks about that kind of thing, specialization in relation to installations. So I don't know how much depth you want to go into.

Aleksander Skutnik 19:24
That that definitely will be useful. Yeah, so you also kind of mentioned that before, but usages of your uptime and downtime of your installations, they're not like. Perhaps, what are the factors influencing that? So you know, of course, some periods of time where the generation of energy would be like highest and bring most efficiency from solar panels. So do you perhaps, like, so do you schedule like, when the system operates and when it's like, down, and how does it work?

Peter Batchelor 20:08
Yes, you know, in a, you know, less than sophisticated way. So I have, I have a time switch, basically, which will start at around about 11 o'clock, it's just before 11, and then shuts down at just after five. So so that obviously just clicks on and clicks off, and then the Raspberry Pi's deal with the shutting down fractionally

before that the shutdown happens. So again, it's a consumer solution, but it works, and has worked, so that that's all right, if, optimally, I would prefer to change the startup or shutdown time so that they they're different in the winter, I could probably do that. I could program that in. I couldn't, obviously change the timer switch. I think the system takes about point one amp in complete kind of standby mode, so to speak. So it's still consuming, but it wouldn't be consumed so much. So maybe I should, maybe I should think about that actually.

Aleksander Skutnik 21:11
Definitely, yeah, yeah. So that's also definitely one of the considerations to take into account, like the uptime of the installations, like, because necessarily, it doesn't have to be 24/7 for some installations. And, yeah, it's good. Like, how we use all that. It doesn't really require that much kind of maintenance to it, because, like I said, it's a timer switch, so you don't really have to manually interfere with that. So that's good.

Peter Batchelor 21:39
And that obviously depends on, you know, factors of daylight, but also the fact that we are in a forest that has sort of visitor visitor times, actually. I mean, ideally I would probably start sort of eight or nine o'clock in the morning, because that's when a lot of people are walking their dogs. But in terms of more general installation, you know, practice, you could think about those things, you know, because exactly when, when it's actually going to be listened to.

Aleksander Skutnik 22:08
Thank you. Yeah, so definitely, that's one factor to take into consideration. Um, so we talked about how, of course, the location, positioning of the solar panels affects the levels of energy production when it comes to solar panels in general, with the usage of photovoltaic panels, are there perhaps any other factors that influence the energy sourcing for installation, either positively or negatively? So, apart from sunlight variability, is there anything else that you feel you also mentioned, like the components themselves, so like with different components, you get different quality and also different energy, like consumption, kind of Is there anything else that perhaps you've maybe identified that affects the efficiency of your power solution, either positively or negatively and do you feel like there could be anything done in the future to investigate or like change anything to neutralize The negative effects?

Peter Batchelor 23:19
Sure. There's, in terms of just where we are in the forest, there's things like leaf fall, you know, which, of course, you know the solar panels covering up. So that's a very practical issue. So where you have your installation might have impact on, on, on that kind of thing. And of course, it's in a public space, which means that, you know, it's eminently kickable by anybody who wants to. Fortunately, nobody has. So there's that aspect there. There are greater efficiencies I could implement on the Pi's themselves, in terms of the software, again, I'm managing through AI telling me what to do to, you know, to implement some efficiencies which, which has helped, trying to think, well, it's mainly the kind of startup shutdown stuff, but it's also turning off the desktop and that sort of thing, which otherwise I probably wouldn't have really known how to do, Just because it's not my Well, I'm just learning those kinds of things. I could possibly

program the D, D amps, D class amps, because they have means of intervening on those to to schedule volume changes and that sort of thing and shut down for those, all of which, again, they they require a level of knowledge which I can learn, of course, but in terms of the ease of accessibility, if you were just trying to say to people, this is how you can do this very easily. Obviously. That makes it more complicated. So there are things I could do to optimize. Definitely, I'm trying to think that there's anything else write, any notes in relation to this question. What number question is it?

Aleksander Skutnik 25:12
that was 8.

Peter Batchelor 25:15
so negative. So tree canopy fixed, fixed solar panel angle. Of course, I could change that. And I think I said earlier, but I don't know what I said on this. When I came this morning, they were at about a sort of 30 degree angle, which is ideal for over the summer, I guess. But in the winter, they recommend, as Luigi has done, making them steeper. I have done a bit, although I don't think it'll make a huge amount of difference in terms of where they are at the moment. Yeah, could improve with real time monitoring hybrid systems. I can't remember what I meant by that.

Aleksander Skutnik 25:50
Yeah, okay, cool, yeah. Definitely like the angle as well. I was also talking to Anna before, how, like, everyone suggests that during different like seasons of the year, this angle differs, like the ideal angle differs, because, apparently it can make a quite a difference in energy production. But that is, of course, something I could also investigate further down my project and see how that could be put down into actual numbers and how that relates to the efficiency of that. Yeah, do you perhaps have any vision or like ideas or thoughts on the future of such artistic installations, either in general or sound art specifically, and solar powered solutions as a whole? Because we can see that it definitely it is possible to integrate them, and we can see more and more people doing that, just like you. So yeah, do you have perhaps any maybe vision on how this could look like in the future?

Peter Batchelor 26:57
I think that the main, the main variable, as it were, is probably just the increasing efficiency of things like the Raspberry Pi, I think the D class amps, or amps, and that kind of technology, probably you're not going to get huge amount of difference in terms of what they can do with the available power. But Raspberry Pi's, you know, it's not that, I think, not long ago that they released the Raspberry Pi 2 before the Raspberry Pi 1 just wouldn't have been sufficient for this. The Raspberry Pi 2 is probably equivalent to the raspberry sorry, 0.2 is equivalent to the Raspberry Pi 3-ish in terms of what it's capable of, and that's made this feasible. So if that trend continues, and of course, it will, I mean, the Raspberry Pi 5 is a game changer. I would have used that, have I had a good and then I could have used real time granulation, that sort of thing, which would have enabled a great deal more control, because I haven't actually told you what, what it's actually doing at the moment, which I can do, but it's not very sophisticated at the moment. You know, it's using, it's using fairly simple means

to generate sound. It's just choosing between different sound files, but a fairly substantial library of sound files that allows us to to actually have different sounds depending on the different weather conditions or environmental conditions. So with increasing CPU and efficiency of machines that will become, yeah, that'd be that much more capability to do more things.

Aleksander Skutnik 28:39
Yeah, definitely, controllers like that, Raspberry Pi, like you mentioned, definitely with the increasing like, as well advancements in that field, definitely more functions and like, even tools, in a sense, to operate and manage such installations could become available and the performance itself, which could definitely help. So that's also one thing to consider. Yeah, I think I pretty much asked you about all aspects that I was wanting to talk to you about. Do you have any final like comments, ideas, or perhaps additions that you feel would be pivotal for this project and for my investigation?

Peter Batchelor 29:19
Sure, so I was just having a look at what I came up with earlier. I think most of them we've covered. As I say, my my interest in terms of exploring that kind of rich soundscape thing ever more feasible again, with changing and increasing power of or efficiency of CPU systems? No, I didn't really have anything. I might come back to you if I think of something, yeah, of course, but I don't think there's anything. Of hand occurs to me, yeah.

Aleksander Skutnik 30:02
Yeah, that was a very exhaustive list of responses, thank you very much, it was very informative and will definitely help me a lot while looking at things needed for my solution, so thank you so much for the time and for the interview.

Appendix 3: Transcript of the interview with Chris Meigh-Andrews

An adapted version of this interviews is available at the Sensing the Forest project website.

Alex: Thank you again so much for your interest and the time taken to take part in my study.

Chris: You're welcome.

Alex: Thank you. So, yeah, first question to just introduce you and your work. Can you tell me about your background and artistic installations-work up to date? What are your areas of interest?

Chris: Well, I started working with video in the 70s, single screen stuff. And around 1980 I made the first installation piece, which was a stack of three monitors and three channel landscape piece. And I didn't really do a lot more with it with that kind of approach, until about the beginning of the 90s. Around the beginning of the 90s, I decided to abandon single screen work because I got interested in what happens when you put a screen in a space. So that instead of it being just about the screen content- what's actually on the surface of the screen or behind the screen, what's being displayed, it was what was being displayed relative to the space it was in, and then I started thinking about, well, where does this screen go, how much space does the screen occupy, what kind of space is it in? What's the relationship between one screen and another if you use more than one? And so you're then into the territory of installation. You're into the territory where there's an inter relationship between one screen and another, between the spaces and the screens. And that then led to thinking about structure, you know, sculptural questions. If I stack these screens, then it is a different experience. If I put them facing the wall, you know, then somebody's gotta go around them. You know, so it poses those sorts of artistic problems. Those were the things that interested me. I started thinking about myself as a kind of sculptor. And that continued across the 90s, and into the naughties and all the rest of it. I also started to be interested in what might happen if you were to try to take those things outdoors. What would happen if you made an installation, , and instead of it being in a gallery space, it was outside. And of course, at that time that was really a problematic, you know, because these things were not designed to be outside. They weren't weather-proof, they weren't reliable, they were vulnerable, expensive. And I started thinking about, you know, how I might get around that problem and started thinking about the fact that, well, there were these things called solar panels, could we power something with renewable energy? And that's where it started. As you know, the first piece I made was P*erpetual Motion*, which was deliberately inside the gallery and it was with not solar panels, but with a wind turbine. As I said to you next door, I got interested in what happens when a viewer comes into a space and experiences the space in a particular way. So creating wind in the space, then changing that wind into electricity and then changing that electricity into a display, really interested me a lot, and it was about transduction, that experience of changing energy from one form to another. And that was the central message/metaphor idea in the work. And so all the works that use renewable energy, whether they're solar, wind or a combination of the two, for me, were about that central metaphor of the relationship between one form of energy into another, and making that visible or experiencible for the visitor in the space or outside.

Alex: Exactly. A very important concept of like the actual experience for the viewer, for the audience. That's very interesting. Thank you. So looking at your solar installations, I know, of course those will vary, but is there perhaps like a specific technology behind the operation of them, is there like a common factor or perhaps does it look differently for every single one of them?

Chris: It does work differently from one to another. As you know, the principal difference for me was whether it was outside and using sunlight or whether it was interior and being lit with artificial light. Those were the two variables. Now, there's always the question of how much power can you get and how reliable is that power? And as you know, obviously, if you are outdoors using natural light, it varies a great deal from day to day and depending on the time of the day. So that has to be factored in- in one way or another. Conceptually, in other words, if you want to make that part of the work, make that part of the experience of the work. In a piece like *Sunbeam*, it was very important that it was getting sunlight in the daytime that was then stored and made available to present the work at night. So it was that thing about daylight held, then represented as images of the sun in a the case of of that piece. So I'm not sure if that answers your question directly, but it varied from piece to piece, and it would be part of the conceptual and artistic intention to look at that, because a visitor, a viewer, whatever you want to call him/her, the person visiting the work, wherever it is, is asked to engage with the work. We might use the term in common here, interactivity. But I would say to you that it's not necessarily about, you know, pushing a button or, you know, I don't know what, pulling a lever or moving from one space to another. But interactivity is intellectual engagement with the work, whatever it is, whether it's a drawing, whether it's a painting, whether it's a musical composition, there is always going to be something that you- as the visitor bring to the work, your own knowledge, experience and interests, and how that engages with the work, the intention of the artist or the maker of the piece. So that's what I mean by interactive.

Alex: Exactly. And conveying, being able actually to convey what you want to express through your work, I guess.

Chris: Be careful here, because I think it's interesting that a lot of people who are not necessarily artists always think that artists are about expressing themselves. That's not true. Okay. It's about communicating something. An artwork is dead if it's only about the maker. It has to be something that the viewer can engage with because he or she brings something to bear on it. That's what I mean by interactivity. If you come into a room and the drawing you see means nothing to you and you can't bring any of your own experiences to bear on it, it's a dead work, right? If it's only a work by someone who's saying, look at me, aren't I creative? It's not interesting, right? So, at that level, it's not about, you know, somebody telling you something. It's about a conversation.

Alex: So it kind of works both ways.

Chris: It has to be. That’s really important, and I think any artist worth his or her “salt” will say that. And if they don't, they're not really artists. They're just exhibitionists.

Alex: True. Like you mentioned, in your artwork and like other pieces in general, like you talked about just before how the viewer perceives it is quite important, how well they're able to like you said, interact with the piece.

Chris: Interact with it or engage with it. Yeah, that's right. I mean, think about a novel that you might read. The novel is interesting because you enter the world of the novel, but you also, you know, you're using your own experience of people and situations and personalities and situations in order to really engage with the book. Yeah. It's like that...

Alex: So that's about the background of the installations. While implementing solar power, in general sourcing energy to your installations can you define any benefits or challenges that you have faced, any major considerations that you had to consider or think about?

Chris: There were lots. Benefits are working with other people who are coming at the creative problem that you've posed in another way or in their way. And then the engagement that you have with them, that's the benefit, you know, like bringing together a team of people to work on something is a wonderful, a marvelous experience. You know, you can work in your garret; A starving artist in garret doesn't engage with the world in any way. But if you’ve got a project where you need technological input, structural engagement, you know: How do I make this thing strong enough to hold weight? Getting the input of other creative individuals, is a real benefit. So that's the first part of your question. And in terms of challenges, did you ask about-?

Alex: Yeah, challenges, like maybe challenges or problems/obstacles?

Chris: Well, there are lots of obstacles. First of all, the things never do what they say they're gonna do, do they? You know, if you go to solar panel and it tells you on the package that it'll deliver this much energy from this much light and so on, it never does, and it's in ideal situations. I mean, I'll give you a perfect example of that, with *Mothlight*- the third iteration or the second iteration of that was in a gallery in Salford. And it was beautiful, the gallery was called ‘the glass box’ and it had windows all round, and I set the thing up and it looked great. It was like looking into an aquarium. There it was, all working. But because it was enclosed in a glass room, the lighting, the artificial lighting heated up the room to the point where the efficiency of the solar panels dropped. They got hot, and as you know, they're rated within particular set of ambient temperatures. If it's too cold, the voltage drops, if it's too hot, the voltage drops. And this dropped radically, it got hot really quickly. So I had to hire an air conditioning unit, install it into the gallery space, drill a hole in the wall to put the exhaust through, and I nearly did my arm in with the drill, I had to find this huge drill and drill through this thick chunk wood on the floor. Anyway, so constraints include, you know, the demands of the space. You know, obviously with the outdoor piece (Interwoven Motion), I had to have a specialist people from the forestry commission to scale the tree and they went up the tree with all their harnesses and then put special pulleys systems into place so we could pull up the wind turbine right up to the top of the tree, but also just we had to have specialist people. So there are always constraints that have to do with the environment that you decide to use. If it's a gallery space, it could be the footfall, it could be the temperature, it could be the lighting situation. It could be power constraints, you know, if you're going to get a lot of energy, if you're using artificial light, you've gotta get the power in there to light the things. So there are nearly always physical and then there's the resistance of people to what you're doing. “Oh, you can't put that there.” The first version of *Mothlight* was in Calci in the Natural History Museum in a little town just outside of Pisa in Italy, in a very ancient building. And I had to drill through the ceiling to suspend the structure and it was an ancient ceiling. It was, you know, I don't know, a 16th century building. So yes, there are lots of things that have to do with the situation. You find yourself in the environment that you're working with, the resistance of those people who started out being the people you thought were enabling you to do something, all of those kinds of things. That is natural. It's normal. It wouldn't matter whether you were doing a solar energy project or I don't know, you know, painting the walls black, you know, because there's really always those sorts of things. So there's a resistance of the people around you. And, you know, then comes your skills as a negotiator, right? You'll find this again with your project, so, you know, people, well, kind of stop at a certain point and you've got to convince them. So there's that sort of thing. But I think the technological ones have to do with the limitations of the kit, okay? It nearly always doesn't do exactly what it says on the tin. And so you've got to be adaptable. You've either got to go with those restrictions or go round them by adding, you know, or changing the plan in some way, so that and, you know, sometimes one can feel really kind of restricted and, you know, oh, this is my idea and I'm not changing it. But I think it's better not to do that. Be like something that bends in the wind a bit.

Alex: You mentioned actual efficiency of the hardware. I guess you could say logistical aspects, perhaps any specific restrictions to the site itself.

Chris: Accessibility, I mean, sometimes it's taking you ten hours to do something you thought you could do in an hour and they're standing there telling you that ‘look, we're closing now’, and you say, but I need another hour and a half or whatever it is, you know. And then there's things like health and safety. I've had that a few times. In the Victoria and Albert Museum, I had no health and safety, whereas- I mean it's was not a solar piece, but I did a piece at the South Bank in the Royal Festival Hall, and it had to be inspected by someone from the Southwark council , some kind of health and safety. He turned up, and he tested the circuits, and he said 'no, this isn't safe, you can't run this’. So there are, you know, you will find if you've got to install something somewhere, there are sometimes health and safety questions. Or you can't have that hanging from there, or that's too low, or that's too dangerous, or there’s too many wires or the wires are in places they shouldn’t be. What you call logistical, but there are health and safety things. So when we did *Sunbeam* outside, we had to do a report for the police because of the traffic The huge solar panel that rotated followed the sun, and we were covering it in the evening and then projecting onto it. the projector was in a building on the other side and it was projected across the road. So we had to do risk assessment. We had to do risk assessments with the police in order to do the piece and so on. Yeah. So there are things like that, okay? Which is directly relevant to using technology, because usually you're using the technology in a way that it's not intended. right? Or it wasn't designed for. I mean, I would say to you and this is probably true for the other artists you've talked to, artists who worked with technology are often trying to use the technology in ways that it wasn't originally intended to be used for. You know, like taking a kit outdoors that isn't designed to be outside, or hanging things from the ceiling that, you know, shouldn't be up there. Or wiring things together in a way that's inappropriate, or using them beyond their capacity, all of that. But that's what artists who worked with technology end up having to do, or want to do. And that's part of their function, you know, certainly reappropriating technology.

Alex: Definitely. Perfect. Moving on, as we discussed some of your pieces are meant to be indoors some of them were outdoors, so I know probably the answer to my question is going to vary depending on the type, but were there any factors that you took into consideration while thinking about like the actual positioning of the solar panels or how many of them, and how they're going to be positioned and think of the energy production output, perhaps maybe there are some uptimes and downtimes for the installations?

Chris: Well, in some cases, we use a timer and we'd say, okay, you know, this thing is gonna run only a certain amount of time each day in order to restrict the amount of power we needed. So *Interwoven Motion* was done that way. *Sunbeam* was only for an hour at night. I mean, we had almost limitless power with that because it was a huge solar array. It wasn't a solar panel, it was a massive solar away. You've seen pictures of that.. I guess the thing is there were always considerations such as how many panels were practical, could they be afforded. I did get some sponsorship for some things. And so, you know, but there was always restrictions about how much they were going to let you have. So there was always this compromise between what you ideally wanted and what you could get away with and what was possible. So what I would generally do was think about, okay, how much power do I need to run this bit of kit? And if I can't do that, start restricting which things I power up and in what way? So let me see if we can give you an example. Okay, with something like, I generally used to power the crucial element of the display, because that was the thing that I had to make the relationship between transitution of light into electricity and then back to light. Okay? So generally what I would do is say, okay, what's the minimum that I need to make this conceptually work? And generally it would come down to the display, all right? That would either be the projectors or the screens. I often used LCD screens or well, I had CRT screens originally, but then LCD screens because they used less voltage. But for example, *Mothlight 2* used projectors onto glass. And so what I did there was I cheated. I used these two projectors, they had infrared, they had a way of receiving a signal via infra for red. So I made the solar panels power, the infrared, generator rather than the projector. So projectors were being powered by the mains of electricity and the infrared signal was sent that was powered by the solar panels. So if you like, the constraints were always: okay, what's the minimum I can get away with here in order to conceptually make the point I want to make with the idea of renewable energy. So it was always like that, which is why I guess something like *Interwoven Motion* ends up with wind and solar, because I hoped that the combination of the two would be sufficient to power this one little screen down the bottom, in fact, even with, you know, quite a lot of daylight, the wind wasn't sufficient. The considerations were always, what's the minimum I can do to make this conceptually pure, conceptually function?

Alex: That kind of also refers to what we've talked about already, but how do you measure energy usage of your installations and how does that relate to the amount of energy produced by the solar panels? So is there perhaps a some sort of microcontroller that you use for measuring...

Chris: That’s a question you’re gonna have to ask John Calderbank, because basically I always gave him the problem. I said, okay, look, I want to power this here, can we do it? And what are limitations? I only always worked with an assumption that if I couldn't do what I wanted, that I would cut back on what it was I was trying to power up. So it was always on that way around. So I didn't measure. We were measuring voltage and so on to see what we were getting, but it would vary so much, especially outdoor things. You could control the indoor things precisely. For example, there was a piece I did which was with a set of solar panels around the room, and there was lighting and the lighting switched off and turned to the next one. It was all on timers. And so, you know, I knew that I could measure that and set it up so that whilst it was on, it would provide power and as soon as it's reached off, it would kill the thing. So I worked very, very simply. I didn't use any computer technology. No, I think the thing is that, you know, we're talking about things that were done now some years ago. I think the panels are more efficient now. I think that the control of whatever technology you want to display or whatever kind of experience you want to give the viewer, was the most important aspect. I ended up doing sound pieces because that was going to be possible with less power, right? So in both the sound pieces, there was an electric fan involved. So you've got a wind chime and a microphone the solar power was powering the fan to blow the wind chimes which are inside the glass box, and it was powering the amplification and the distortion and sending it out to the speaker outside. so it was you trying to find ways to minimize the demands of the power you supply.

Alex: Definitely. So you could definitely say that looking at indoor installations you have some sort of like a controlled environment?

Chris: A completely controlled environment except from the factor of temperature, and I suppose the efficiency of the panels that you're using, their threshold all of that, the usable energy that you get, which interestingly enough, did drop off, it wasn't always constant. It did seem to vary and it was mainly, I think the temperature, but there may have been other factors that I wasn't aware of. Temperature affects the batteries as well as you know, I mean, I have an electric car and it's telling me that my ranges dropped. You know, yesterday we went to Chertsey and back, and it was enough power to do that, but it was cold and I did see it wasn't giving me the sort of range that I was expecting. Placement (of solar panels) makes a difference. I mean, in the case of the sort of panels in the tree, you know, I tried to get them right out beyond the branches but you know, as the sun goes round, you've got shadows. It's not conventional, you know, like a solar installation on the roof of a house, you know, that's all calculated because they know, there's nothing overhanging or if there is. I was told I can't have them on my house because of my chimney. You know, it casts too much shadow on the area of roof where I could put solar panels. So there is something with an installation where you've got an aesthetic consideration of where those panels go, because, they needed to be visible to the viewer. You don't hide them away. I mean, and well, with *For William Henry Fox Talbot*, they were invisible, because they were on the roof of Lacock Abbey, but because it was a conceptual thing and, the signal was relayed to the Victoria & Albert Museum. So the people were mainly seeing the piece remotely, so they didn't see the solar panels. They took my word for it, and there was a diagram, and in fact, in a display case with the solar panel on the camera. But in the actual installation, the solar panels were not visible to anybody visiting. But generally, if you're making an art installation, where you want to make the point that there's a relationship between the way the energy is provided and how it's being used, then they need to be visible. And so that will affect the conditions that they're in, you know, relative to the position of the sun or any other lighting source that you're using. So there is a direct relationship there between the aesthetics of the piece and the message, idea, concept.

Alex: Definitely. Generally speaking what kind of, how will energy circle with your installations and like what kind of storage would that implement? So you mentioned for one, of your artworks it would like collect like a great deal of energy. Wouldn't that be then stored somewhere?

Chris: You can't directly power anything with solar panels, you know? There's always gonna have to be a storage. So it was always batteries. Wherever I went, we had to have batteries and I used, deep cycle batteries that were designed to be used for renewable energy. But they had to be portable, but the batteries were always part of the display. They were always sitting there, you know, and they were usually in series and all of that. So, yeah, just deep cycle batteries, 12 volt nearly always, in the case of all the outdoor pieces, there were 12 volt, deep cycle batteries. And a regulator, obviously, you know, to make sure that the voltage is constant. I mean, that you probably use a computer control system now. I had a regulator built. I worked with a company called Wind and Sun, who used to be in Oxford, and now they're in Herefordshire. I think. And they built me a regulator, which was stolen out of the installation. I used it several times in several different pieces, because the concepts that is really important to me is that I reuse materials. So when an installation is finished, it comes to pieces and the components are stored and then used again, if possible, on the next work. And so with the sound piece, the one in Nottingham, they were all in a glass house and on the last day of the installation, somebody stole everything, including the nice little regulator I had, if you look at the documentation for *Mothlight* in the glass box thing, there's a closeup of the regulator sitting there on the next to the battery. And it is just, you know, making sure that the voltage is constant and all of that.

Alex: In a few artworks , for example, when I was interviewing Peter Batchelor for his installation, he used a Raspberry Pi based controller. So that definitely an interesting way of approaching this.

Chris: And cheap too. They're not expensive and they're pretty reliable. Yeah, I've messed around with them but I've not used not used any kind of computerized technology with my renewable pieces so far.

Alex: I see. I know it will vary across multiple installations, but in general is there an uptime and a downtime for the operation of your installations and would you say that the energy consumption changes over time again in the uptime and downtime, is there any points where like the energy consumption is like very low due to like the installations being in downtime, is there any other factors depending on that?

Chris: I suppose the thing is obviously if you're installing in a gallery or an interior space, you've got business hours, you know, and so you can tailor it. You don't have to have the thing switched on when you don't need it, and it could be that it's charging up while you're not using it. So there's that obvious thing. Outdoor pieces are more interesting, because what I was interested in was that I wanted people to come across this by accident. In the case of the forest piece, (Interwoven Motion) it was something that I wanted to be running as much as possible, but I knew that it couldn't run all the time. So I designed it to switch off at night. Literally, at sunset, it went off and it didn't come on again till the morning, and that's very simple, you know, a timer in between this system, but that didn't mean that meanwhile, it couldn't be receiving charging, you know, it couldn't be charging up if there was light. So those are the sort of concerns. It's really about who's seeing it and when and how. It's as simple as that. So, but, you know, you could build into anything, you could say, well, you know, for example, there's a show on at the Tate at the moment, which is called Electric Dreams, it's not directly relevant to what we're talking about, but there are some pieces in there that are only on each hour for ten minutes. Some kinetic pieces. So what they've done is they've got a little notice and it just says, this is gonna be running on the hour and then not again until the next hour. So you could, with a solar powered installation, where you've got control over it, make people aware that it's possible to restrict- that would be one way making sure you go enough power.

Alex: I guess if you are facing site specific installations that just simply cannot produce that much energy, you could perhaps just like adjust this.

Chris: Or, you allow that to be the case, as we did with *Interwoven Motion*, we said, well, if it isn't running, it's still all there. And you know, you come across something that isn't working. And that can be part of the experience.

Alex: Do you feel like there is anything that could be possibly done or investigated further in order to neutralise or counter the negative effects?

Chris: Well, I guess the first thing is to find the most efficient panels and that would require research, because there's probably a direct relationship between cost and efficiency, I suspect. But you've also got size to deal with, haven't you? Because, you know, panels come in various sizes, and they're made of different materials and all of that. So I would think one of the things that might be relevant as a resource for artists, maybe, is some kind of survey of what's available or what sort of prices and what their outputs are, what are their reliabilities like and all of that. I think that would be quite important. I mean, obviously the technology is moving on very fast. Prices are coming down. They're becoming more efficient. They're becoming more reliable, and I suspect the threshold under which they would work would be improving. In other words, less light still gives you sufficient power. But I think that's the sort of thing, and that's gonna change across time, but a survey of the current availability costs versus efficiency, that kind of thing, would be interesting to do. I mean, it would be probably a little difficult for you with your budget to do it. But there might be a lot of information online that you might be able to dig into, because there's certainly obviously a relationship there between availability, cost and efficiency that is important, I think, for anybody who's considering, can we do this? Is it feasible with the budget we've got? What are the kind of conditions we want to work under? And what it is we want to power up, and for how long and in what kind of situation, is all of that going to be irrelevant. Also, I suppose weight, you know, might be a factor, you know, how portable they are, how easy is it to get hold of them? You know, you could find, there’s the perfect panel but they're on back order. and we won't be able to get them in time for the deadlines for the piece we're working on. you know, because nearly always if it's a project, they're gonna say to you, oh, well, you can have the gallery between, October the 1st and November the 21st and then there's another show coming in. So it's got to be then, and you find, yeah, there's these perfect panels, but they're back ordered and we can't get them in time, or whatever. So there's a logistical, practical really nitty gritty kind of stuff that one doesn't think about when is in the hypothetical mode of, oh, yeah, we can do that. We can put that there, we can do it. Then you actually get down to the practical thing of can you get hold of them, how much are they? Are they reliable? you know, do they work under the kind of conditions that we need them to work under? It could be that, you know, a certain panel is rated is very highly, but it's not very good in low temperatures. It's not very good high temperature. It's only good between, you know, certain sorts of conditions and temperatures. That kind of thing. All of that is relevant, depending on the application, depending on the demands of the project. That's why I ended up trying to get an engineer to work with me on it because there was were so many things for me to worry about, and so I needed somebody else to worry about some of that.

Alex: Definitely. So I guess this could be considered with some sort of like a risk register where, like, you could just be like, hey, what if this happens or we don't get this in time like you just mentioned or all the other things that could go wrong, what is the probability that? It will go wrong and how badly it will affect the project.

Chris: When you're working with technology, it nearly always doesn't do what you expect it to do first time you do it. You plug everything in and it doesn't work. And then you have to go back. Oh, is it here? Is it here? You know, and that’s an interesting part of the process. But yeah, you do need to have a look at what is available, how much it costs relative to what it can do. how practical is it?

Alex: Do you have any final thoughts, visions, ideas on the future of art installations and solar power solutions as a whole?

Chris: The novelty’s worn off, that's one thing that, when I started working with them, some people didn't know what they were. They would come into the room and say, what are those square things? Now everybody knows what a solar panel is, so there's a level at which they have become ubiquitous. And so any kind of conceptual relationship between what the thing is doing and how it's doing it has changed. And will continue to change. Because any object has a kind of cultural resonance, especially technological things. They have a a sell by date and the meanings and associations related to those technological objects change across time. So you need to think about that in relation to your window of opportunity, I think, why are you're doing it. So I think they say that the novelty value, in other words, the curiosity that people will have as to what something is and what it's doing will have changed. And so the reasons for using solar panels for me is no longer the same. It's not about, you know, oh, that's really unusual and interesting and that's not what you would expect them to be used for. So if you are using them, you have to think about what you are using them for and how that's going to be interpreted by the people who look at it. That's I think central to this question of, the use of technology any technology. you know, the people's knowledge of what things are and what they do. Whether it's a novel use of it and so on will change. And so that's a factor.

Appendix 4: Interview with Sarah Hall

This interview is also available on the Sensing the Forest project website.

Alex: Can you tell me about your background in artistic installations?

Sarah: I studied Architectural Glass at Swansea College of Art, UK, apprenticed with Lawrence Lee (Glass Master at the Royal College of Art), received my City & Guilds in Architectural Glass, studied Islamic techniques in glass (Jerusalem) for one year, returned to Canada and established my own studio in 1980 creating contemporary work exclusively of my own design. I have created hundreds of architectural glass commissions for secular and sacred space. Throughout my career, I have explored many techniques. In 2019, I was awarded the Order of Canada for my contributions to architectural and environmental glass.

Alex: What is the technology behind the operation of your installation (board/ OS/peripherals)?

Sarah: In this interview I will focus on one installation: Lux Nova, Regent College, UBC (fig 1). This project fits your requirements as sustainable off-grid power solution for immersive art installations. (Some of my other solar projects are grid-tied). Twelve solar panels are integrated into a wind tower which sits above an underground Theology library. The solar glass and art glass are created as thermopanes and collect energy, which is passed first through a controller, then inverter and into battery storage. In the evening, a column of LED's is illuminated using the stored solar power. This illuminates the artwork, the tower and park at night. The LED column is programed to be a two hour cycle of changing colour. The battery storage system is clearly visible from the library floor by looking up into the tower.

Alex: What benefits and challenges have you faced while sourcing electric energy to your installation?

Sarah: It was a challenge to bring solar panels together with art glass and have this accepted as an art installation. It was the first installation of its kind in North America and there were different safety certifications for the different types of glass. There were none that matched my technology. Eventually the German safety certification CEN was accepted. A huge benefit was seeing the tower alight at night with energy generated by sunlight alone – what a delight!

Alex: What factors did you take into consideration while thinking about the positioning of solar panels?

Sarah: It was important that the panels were facing east and were not shaded - to collect as much energy as possible. None of the cells are obstructed or shaded by the artwork.

Alex: How do you measure energy usage of your installation(s)? How does that relate to the amount of energy produced by the solar panels?

Sarah: There is a monitor in the Library which shows how much energy is being collected at any given time. The purpose of the solar energy collection is to power the LED column at night – and to showcase solar technology in a beautiful, new way. If less energy has been collected (overcast, rainy days) the LED column is illuminated for less time that night.

Alex: How does the electric energy circulate within your installation(s), what kind of storage and connection hardware did you implement?

Sarah: The energy stored in the battery bank feeds the LED column at night. There are four batteries in the bank.

Alex: What is the uptime and downtime for your installation? How does the energy consumption change over time, is it different depending on any other factors?

Sarah: I would say there is not a downtime for the installation. It looks good collecting energy during the day and was specifically designed for both its daytime and nighttime appearance. The solar energy is collected during the day and used at night (from battery storage). It is seasonally changeable and depends on how many overcast days there are. If there are several in a row the light will only be one for a few hours. The good news is that there has always been some energy to power the LED column. I like the fact it is responding to sunlight in a real way – not “switched on” from the grid.

Alex: What are the main factors affecting the performance of your installation’s energy sourcing, both positively and negatively? Do you feel there is anything that could be done or investigated in order to neutralise the negative ones?

Sarah: There is maintenance for the batteries needed so they are easily accessible. The exterior of the glass needs to be cleaned bi-annually. This is easy to do. The only consideration I would change is the proximity of my installation to the School of Engineering at UBC. Engineers love to see if they can damage art on campus. Perhaps engineers can have their own world...somewhere..

One other factor affecting solar installation is the client’s tendency to plant trees near solar installations. I ask them not to - they do not understand trees grow and shade the panels.

Alex: Do you have any vision/ideas/thoughts on the future of artistic installations and solar powered solutions as a whole?

Sarah: I am very excited by the new organic solar products being developed. These dye- sensitive solar surfaces (Oxford Photovoltaics) will be able to be printed in many patterns and offer bird-friendly solar collection glass. What an environmental bonus!

Alex: Do you have any other comments, ideas or suggestions that you feel would be vital for this project and for my investigation?

Sarah: I think it might be interesting to contact Oxford Photovoltaics and see what the state of their research is.

Appendix 5: Transcript of the interview with Elizabeth Monoian and Robert Ferry

Alex: Could you tell me about your background in artistic installations? What have you been working with and what was the inspiration behind it, as well as the scope of your work?

Elizabeth: Well, I have a master's in Fine Arts from Carnegie Mellon University, and shortly after finishing that MFA I founded the non profit organization that is now the Land Art Generator Initiative with the mission of working collaboratively and in an interdisciplinary fashion with global participants. It was shortly after founding that nonprofit that I met Robert- we moved to the Emirates and had this greater vision of, rather than us sitting down and designing regenerative infrastructure, what if we put out a call to interdisciplinary teams around the world?

Robert: The motivation was to engage creatives around the world. Artists, architects, engineers, scientists, to work collaboratively and in interdisciplinary teams to take a more intentional approach to the design of energy landscapes, which in 2008 when we were brainstorming the Land Art Generator Initiative, we were already seeing some push back- "not in my backyard" reaction to communities who were reticent to change or felt like these were blighting on landscapes in some way. We wanted to pull the imagination of the world towards this challenge by offering examples of energy landscapes that were designed to be beautiful places to merge with natural landscapes. That was also coinciding with a time where the technology was exploding in terms of the versatility of building integrated photovoltaics and other renewable technologies to find interesting ways of manifesting themselves in the built environment, and so we put together a field guide to renewable energy technologies to bring all of these information to creative community so that they could utilize this. Every creative project should have some sense of permanence in the world, whether that be a building, a public art work or any installation, should be conceived of and implemented in a way that over its entire life cycle is net beneficial for the planet and climate, which means that we need to start using these materials that that generate energy from the sun in ways that make that possible.

Alex: Starting with this, could you tell me more about what is the technology behind the operation of your installations? Is there a common denominator or does it vary for different projects?

Elizabeth: It is project by project and competition by competition. When we founded the Land Art Generator Initiative, we were very much focused on renewable energy technologies as the baseline for the design brief itself that there had to be an integration of renewable energy technology. Since that time, we've held design competitions for a wide range of site typologies and thus that design brief has expanded at times. So for example, we've asked teams to imagine water harvesting technologies for various competitions, including this year for Fiji, but that started in LAGI 2016 for Santa Monica. Our site was off from the Santa Monica Pier near the breakwater, and Southern California was under a drought conditions, so we thought, it would be a critical component to increase the design brief to include water harvesting technologies. Also, LAGI 2020 Fly Ranch was a really interesting example in which we asked teams to utilize energy technologies and water technologies. Fly Ranch is an off grid site, so they also need agriculture, shelter and waste management. It's a very comprehensive design brief to include multiple systems for survival out on that site. And in terms of constructed projects, we continue to expand that and our goal is to build Land Art Generators in every city around the world of course. The first few have focused a lot on solar photovoltaic, but we did install in the UK 2 1/2 years ago *Windnest*, which was using wind technology as the creative media.

Alex: Could you identify any benefits or on the other hand, challenges while sourcing electric energy to installations, either logistical, site specific conditions or any other challenges you could think of?

Robert: Every project has its own set of conditions in terms of on-site renewable energy for art installations. One challenge might be that there is a value to temporary art that engages people- with an event that is not intended to be a permanent installation- and in those situations, it may be more challenging to incorporate renewable energy because these technologies have their own carbon footprint. A solar module today costs some carbon to make it because we live in a petroculture. In order to pay off that carbon debt, that solar panel needs to create clean electricity from the sun for around six months, and then its carbon debt is paid off. If your installation is not going to be up for six months and you're buying a solar panel to power it and you don't have a reuse in mind already for that solar panel, you may be doing more harm than good if that solar panel isn't able to fulfill its highest purpose, which is to put clean energy into a grid for 30 years. Every solar panel should do that and if the installation doesn’t allow for that to happen, then that could be a challenge.

Alex: While thinking of positioning the solar panels, did you have any considerations in mind? Perhaps any site specific like conditions that affected the production of photovoltaic energy, either in a positive or negative way?

Robert: It's important to note that we are working first within the realm of art and public space, creative place making and secondly, in the realm of energy generation, meaning to say that most efficient kWh is not our primary goal. We know how to do that would be to find what latitude you're at and install the solar module facing South at that proper inclination angle. Anything that's off from that, you're going to see some sort of conversion efficiency loss. However, there's a lot of flexibility even in the utility solar space to modify that. There's a lot of work in vertical orientation of modules, and the corrugated approach where you have East and West facing so that it generates a double curve throughout the day. There's a lot of consideration in terms of matching what the peak demand is, and often that's in the late afternoon as the sun is setting. So a vertical West facing installation can be valuable to the grid beyond just kWh that it's generating, but certainly that solar module facing West vertically is not going to produce the most kWhs per year. Certainly with working within the realm of creative practice, that gives us a bit of a license to put solar modules and orientations that aren't optimum, but even within the engineering calculus, there are more than one ways to install a solar module.

Elizabeth: I think there's two questions working together and there's an answer that hasn't been positioned yet and that's that talking about the value of public art and what it does for cities and economic impact. So there's an example that we cite often in our lectures, it’s a project called New York City Waterfalls by Oliver Eliison. This is not one of our projects, it's not a Land Art Generator, but it's a really good example of the impact of public art. It was up for four months in New York City, in Brooklyn, and it cost $15.5 million to install at the time. That's on the higher end of public art. But during those four months, it brought in $53,000,000 in incremental spending, it’s been very well studied and that's what public art does. It drives people to a place. It brings people from around the world. People gather, they spend money in a place. And so I wouldn't lose sight of that value of a Land Art Generator. We are energy technology- yes, and putting kilowatt hours into the grid- yes, but at the same time, these projects as they're built will be real economic drivers for a city.

Alex: How does electric energy circulate within your installations?

Robert: I think in most cases with some exceptions like Fly Ranch, where Elizabeth mentioned it's way off grid, we’re mostly installing these artworks and connecting them to an electricity grid that exists, one that has some mix of renewables already on it, but is today, in 2025, still quite dirty with gas and maybe even coal within the mix. In a small way, we're decarbonizing the grid by providing net metered electricity into that grid, but that's a very small component. More than that, we are demonstrating the value of regenerative design in art making and that by by making these examples of energy installations that are inspiring the public about the future. We can help to shift the climate conversation away from doom and gloom and apocalypse towards ‘here's a future that we all want to that we all desire to have and and hopefully inspire more collective action to build that better world’. But if we don't tell the story of what that world can be, that's the first step, that we must engage the public imagination in understanding that transition away from fossil fuels is not about sacrifice or asceticism or going backwards. It is going forwards and it will improve materially the quality of life of everyone.

Alex: Is there an uptime and downtime of your installations and what is it that affects it and the energy consumption of the installations during those times?

Robert: Yeah, every project has its own concept that is built around the generation and the utilization of energy from the artwork itself. Some projects have some storage component that is used as a way to shift the generation of the energy in terms of how it goes into the grid so that it is in coinciding with the peak demand of the city. So like I said earlier, that's often around 6:00 PM when people come home from the work day. That's usually when energy demand spikes. It's also when the sun is setting in. Solar power generation is low, so projects like *Energy Duck* and *Night and Day*, *Energy Duck* is 2014, *Night and Day* is LAGI 2018. They both have this concept built into their whole artwork that celebrates this evening release of energy, and *Night and Day,* it’s this water storage that has been slowly pumping water up into it, then releases it at the end of the day and it flows through a turbine and it throws energy under the grid just when the grid needs it, and *Energy Duck*, it's this gravity battery- the entire artwork's weight is allowed to sink slowly into the water and microturbines in its belly generate energy. So everyone can go and they can see the duck sinking at sunset and adding more energy into the grid, and then if they're up in the morning at sunrise, they can watch it slowly rise up again. This is a way of reinforcing the time value of energy in society through an artwork that's communicating that message. Each project takes its own approach based on what it is the artist team is seeking to communicate and the experience that they want the artwork to have with the people who visit.

Alex: What would you say are the main factors that affect energy production both positively and negatively?

Robert: The type of photovoltaic technology matters greatly. The most conventional type is monocrystalline silicon photovoltaic, which operates at the most efficient conversion efficiency when it is getting sun perpendicular to the panel, when the sun shines away from that angle, it has a rapid fall off in its energy production. Organic photovoltaics have the same energy production over 180 or 130/140° angle of incidence. An organic photovoltaic module is not as sensitive to its orientation to the sun, it's generating the same amount of energy, but that organic photovoltaic module is more sensitive to UV light and it degrades more quickly over time, so it would have to be replaced more frequently. Each has its pluses and negatives. It's very difficult to compare them apples to apples because they're very unique. They have their own material properties. So an artist seeking to create with photovoltaic technology as a medium should first research each one of those options and see which is the most appropriate for the use that they're intending it to be to get forward their expression, what is they mean to convey, and then the amount of energy that's generated over a year on average can then be calculated based on the technology and the orientation. Even if you have a solar module that is oriented in an unoptimal angle to the sun, maybe it doesn't pay back its carbon debt in in six months, maybe it pays it back in a year, or maybe it pays it back in two years, but if you're designing a permanent installation, it is going to be there for 30 years, maybe 40 years, so, our goal is not to provide the cheapest kWh to the grid.
Our goal is to create a regenerative artwork, that regenerative moment in time when it's paid back instead and it becomes net positive for the planet that this artwork was installed. The work that we're now developing in Houston, the Arch of Time by Ricardo Mariano, we estimate that it won't hit its net positive condition, it won't become truly regenerative until around year five or six because there's so much concrete and steel that's required to hold the structure. It's a very dynamic asymmetrical load and it requires significant structural foundation, so the carbon debt of that steel and concrete is larger. It will take six years for the artwork to become that positive, but it will become that positive. The only thing that is of primary importance to us is that the work satisfies that regenerative definition, that at some point in the future, and it could be six months, it could be 10 years, It will then become better for the planet that the artwork was installed then were not to have been installed.

Alex: Do you have any final ideas, thoughts, comments or perhaps a vision on the future of artistic installations and solar powered solutions for them? Any suggestions perhaps, or areas that I might be vital for this project?

Elizabeth: Yeah, I would just add that with the trillions of dollars going into the energy transition, there is really dynamic and terrific opportunity for communities to be a part of the conversation for creatives to be at the helm of some of the design, but that it is important that that does happen, that we don't neglect community in the design of this infrastructure.

Robert: Yeah, and that by co-creating, that the energy transition can therefore be something that we all do together rather than having it be something that's done to us and then that way we can help accelerate deployment and avoid the friction that is occurring in communities that feel like they don't have agency in this process. I just want to make sure that you're looking back through the history of solar art. It's pretty rich throughout the 20th century. Going back to the Do Nothing Machine by Ray and Charles Eames might be one of the first contemporary examples of a solar powered artwork. So it might be fun for you to take a dive through that history if you haven’t already.

Appendix 6: Transcript of the interview with Alex Nathanson

Aleksander: Can you tell me more about your background in art installations?

Alex: I started working with solar in 2014. I was co-curating an exhibition of electronic artwork for a show called Night Light, and the show was in a community garden in Queens, NY and when we planned the show, we were told we could get an extension cord from a neighbor for power, and then the garden community members had a falling out with the neighbor and so that wasn't available, but it was a show of like electronic artwork, so we had to figure out a new way to to power everything and we turned to solar power. Before that, I was doing a lot of media art work, a lot of video art and a lot of multimedia performance stuff in collaboration with like sound artists, like building instruments and interactive video pieces that would be performed. When I started working with solar in 2014, that kind of slowly took over and became the focus of my practice.

Aleksander: Could you tell me more about the technology behind the operation of your installations?

Alex: The hardware hasn't really changed much over the last decade. It's become a little bit easier to find it, it used to be much harder to find stuff online, but now it's pretty easy. It’s basically a standard off-grid system. So you have your solar panel, you have your charge controller, you have a battery, you have an inverter if you need AC power, you have cabling over current protection, mounting components and closure and that's basically it. A timer ends up being really important for a lot of our installations. It'll be to automate when the piece is on and that is really important because often the size of the system is pretty constrained. You spec the system for a certain amount of runtime and the timer allows not deplete the battery excessively. I'll use like an over current protection device. So if the battery is getting depleted, it'll just shut down and then return on when there's enough power. That system basically hasn't changed in a decade. There are now a lot of more accessible consumer devices. These like power stations that are an all in one kind of off grid units. But I find those are not good for a lot of our installations because when those turn off, they often don’t turn back on, so you need to manually press a button which makes it hard to actually have an installation, even if it's not in like a remote area, if it's just like in a sculpture garden, you still need to have a tech go walk over and press a button. Only if you don't have a timer and you know if you build the the system I described with all the different components that you don't need a human involved. There are easier systems to install, but those require human intervention often to maintain.

Aleksander: Could you talk me through any benefits and also challenges you have faced while sourcing electric energy to your installation?

Alex: There's a lot of really interesting companies that are always kind of innovating with some new technology in this space, whether it's a new type of solar panel, a new, different chemistry or a different form factor. The same is

true with batteries. A lot of these companies go out of business really quickly. I think that can be a challenge because if I spec something for a client, it might be that that component might not actually be available in a year or two. So I think that's the biggest challenge, there's a lot of cool stuff that people have invented that maybe was only commercially available for like a year and the company went out of business or whatever. There was a battery company that made a battery I really liked and they they just went out of business really quickly.
So it was kind of a bummer because I had switched over to designing systems with this battery.

Aleksander: What factors did you take into consideration while positioning solar panels?

Alex: The main considerations with citing are, there's orientation, so you always kind of need it facing the equator. If it's off grid, you want it facing if you're in the Northern Hemisphere S, if you're in the southern Hemisphere N. The angle which you need to optimize for the time of year. So if it's gonna be an all year around installation, you typically tilt it to your latitude angle.
Then there are of course obstructions and obstructions are kind of the hardest piece of it. You either need to do a physical, onsite site inspection/site assessment or it's kind of slightly more complicated if you need to use software that uses satellite 3D models from satellites and things if you really wanna be precise so you know, I think a lot of artists don't necessarily need a lot of precision. It's more about making sure their expectations are aligned with the reality of how it works.

Aleksander: How do you measure energy usage for your installations and how does that relate to the amount of energy that is produced?

Alex: For designing a system, you need to understand the solar exposure, there's models that you can use, right. Based on orientation and azimuth, you can get the sun hours. Then you need to do a site assessment like I mentioned to think about obstructions. I think there's a small amount of charge controllers that have kind of open source or open source communities have created, you know, GitHub repositories with scripts to interact with them. There's not that I know of a charge controller that has an API that they make easily available at the scale most artists are working, which is really kind of absurd but because a lot of products have like a Bluetooth app, but they don't actually make the API public. If you're a good kind of sleuth, you can use Wireshark and identify registers and then kind of reverse engineer stuff a little bit. There's not just like a charge controller or a power station that's designed with, you know, IoT kind of interactivity in mind. Every couple years, I check and see if there's anything new on the market, but I haven't, as far as I know, there's not a single charge controller that has intentionally designed API that users can use.

Aleksander: Could you tell me more about how this electric energy circulate within your installations?
Like what kind of storage?
Perhaps they use 'cause? I assume you can't like really directly power anything from.

Alex: I actually do a lot of like direct drive solar stuff in my work, but those tend to be fairly small scale. It's a lot of small sound installations, because electronic synthesis doesn't really need a lot of power to make an audible signal. With sound installations you can really get away with. There's a thing called the solar sounder, which I write about in my book, which doesn't use batteries. For little mechanical kind of kinetic sculpture things, I've definitely done those without any power storage. You can use big capacitors or super capacitors for small amounts of storage for those things and then for bigger installations. These days I'm mostly just using the lithium ferrule phosphate batteries. Those are just sealed AGM batteries.

Aleksander: Is there an uptime and downtime to your installations?

Alex: A lot of the work I do is meant to respond to the available energy. It's going to use whatever is available. So rather than oversizing a system to make sure it works all the time, I do that for clients because I think a lot of artists who want me to consult on their projects, they don't actually wanna make something that's responsive to the amount of light or the size of the solar panel or battery. They just wanna make something that will work without great connection. So that's a little different, but in a lot of my work, it’s working with the intensity of the light. So it'll sound different if there's more light than if there's less light or it will behave a little differently.

Aleksander: Could you identify any positive and negative factors that influence the energy sourcing for insulation?

Alex: I’m a big advocate of artists understanding the characteristics of the energy source they're using. And then designing around those characteristics and not thinking of them as limitations, but as aesthetic choices and opportunities, so in the same way that a sculptor might choose wood or ceramics and there's pros and cons for both, there’s things you can do in one that you can't do in the other. The same is true, I think, for energy sources. I don't tend to frame stuff in that way as being positive or negative. As far as making it kind of more affordable or more accessible, it's all gotten pretty cheap, you know. I think that the more solar is installed globally, the cheaper the stuff becomes, the more accessible the hardware is. But you know, I think like I mentioned, there are these power station products that are these all in one boxes and those make it really easy because you basically do no wiring. It's all kind of prepackaged. The downside is, you don't get as much fine tooth detail and how you can control it, because you're kind of dealing with this thing manufacturer already set up. I would love to see one of those that like is fully programmable. That would really make stuff much more accessible for artists.

Aleksander: Do you have any visions, ideas or thoughts on the future of artistic installations and solar powered solutions as a whole?
And any comments or ideas perhaps that you feel would be vital for this project and for my study?

Alex: The way any technology is interpreted in our installation is gonna be very dependent on its kind of cultural context. In the 11 years that I've been working with solar art, it's gone from being a thing where solar was just becoming mainstream and kind of accessible to being something that was very common place, and then today with the Trump administration, it's been kind of under attack again. That changes the way artists can use it because it means people will respond to it differently because they have a different emotional and sort of cultural context for it. I think it just kind of underscores the value of artists, the cultural place of these technologies and the kind of need for artists to explore it because it's not just a quantitative thing. It's not just about efficiency, it's about just kind of the much more complex, socio cultural aspects of technology transitions. In the US, is it gonna be seen as something that is inherently kind of liberal? Today, the people who make the most money out of from solar are are in right wing Republican States in the US, which maybe people outside of the US aren't aware of, and so I think that is kind of complicates it because that wasn't the case 10 years ago. Those states weren't necessarily embracing solar power and wind power, but because it made economic sense. It's the way we understand it and relate to it.

Appendix 7: Interview with Shala Akintunde

Alex: Can you tell me about your background in artistic installations?

Shala: I've been an artist for as long as I can remember. I think i still have drawings on the walls of my mother's womb. Growing up, I made my own toys, and that evolved into the public installations I create today. I honed my craft in architecture, product development, and design at the University of Illinois, then developed my solar art practice after some years in creative direction and music marketing.

Alex: What is the technology behind the operation of your installation(s) (board/ OS/ peripherals)?

Shala: I'm a solar artist. I make solar murals and sculptures that generate electricity. I use custom building-integrated photovoltaics (BIPVs) along with various photovoltaic and optoelectronic technologies.

Alex: What benefits and challenges have you faced while sourcing electric energy to your installation(s)?

Shala: The main benefit is tapping into a natural resource that doesn't require cords or conduits. My work stands out, and the novelty lets me explore new ways to engage with communities. The challenges, though, are significant. It's still a relatively novel concept, so education is a huge part of the process for both partners and stakeholders. Even solar electricians sometimes don't see the potential for imagination in the field. Funding can also be limited because the industry I'm helping to create hasn't been fully established yet.

Alex: What factors did you take into consideration while thinking about the positioning of solar panels?

Shala: If you're asking what influenced my decision to use solar panels as an art medium, I would say I was driven by the social impact, weighing both the challenges and rewards. I also considered the cultural significance of advancing innovation in the technology. Art and culture have always been at the forefront of driving the acceptance of new ideas by humanizing them. I wanted to do that for sustainability.

In using this medium, the factors I often have to consider are their usablity and flexibility. For each project, I think about the logistics—positioning, durability, power generation, and tracking. Aesthetics are my priority, and the utility serves that. My work is unique in that the beauty, inturn, enhances the growth of the utility.

Alex: How do you measure energy usage of your installation(s)? How does that relate to the amount of energy produced by the solar panels?

Shala: I use apps like MySolarEdge or Enphase Enlighten to monitor energy production and usage.

Alex: How does the electric energy circulate within your installation(s), what kind of storage and connection hardware did you implement?

Shala: It's a standard setup—wiring, charge controller, battery, inverter, and monitoring systems like any typical solar rig. Depending on the scale, the system can include grid connections and electrical panels. I focus on creating simple, artistically designed solar systems that engage the community.

Alex: What is the uptime and downtime for your installation(s)? How does the energy consumption change over time, is it different depending on any other factors?

Shala: My work generates energy during the day, or peak sun hours, and powers the installation's feature attraction or display in the evening. Excess energy is either stored in batteries or fed back into the grid. Energy consumption stays fairly consistent, but weather and natural events like erosion or plant growth can reduce power generation over time.

Alex: What are the main factors affecting the performance of your installation(s)'s energy sourcing, both positively and negatively? Do you feel there is anything that could be done or investigated in order to neutralise the negative ones?

Shala: Climate change is bringing more sun exposure to some areas so that is an interesting positive. The growing adoption of solar technology is making development easier and more integrated into various solutions.

On the flip side, weather conditions and nature's influence (erosion, plant growth, even small creatures) can affect performance, particularly battery life, over time. Many innovations are solving these issues as we find new ways to integrate solar generation into our communities, including current and future infrastructure.

Alex: Do you have any vision/ideas/thoughts on the future of artistic installations and solar powered solutions as a whole?

Shala: My medium will continue to grow and become more integrated. The goal is for solar art to increase adoption and foster biophilic integration into our communities and nature. I am proud to be a catalyst for this movement, helping to make it ubiquitous.

Alex: Do you have any other comments, ideas or suggestions that you feel would be vital for this project and for my investigation?

Shala: No, just thank you for your interest in my work and for promoting this emerging and important creative medium.

Appendix 8: Terminology used

1. **Photovoltaic (PV) panel**: A solar panel that converts sunlight into electricity using semiconductor materials, such as mono and polycrystalline silicon

2. **System voltage (V)**: The electrical voltage of the system defined by the battery/inverter setup. This value affects how much energy (in Wh) the battery can store and deliver

3. **Power rating (W)**: The maximum amount of electrical power a panel can produce under Standard Test Conditions (STC) - those are defined by solar irradiance of 1000 W/m^2 and a cell temperature of 25°C

4. **Load power (W)**: The total amount of power consumed by the installation and all of its peripherals

5. **Battery capacity (Ah):** This indicated how much electrical power a battery can store, measured in ampere-hours. By multiplying by system voltage we get the total energy storage in Watt-hours, e. g. a 200Ah battery at 12V can store 2400Wh.

6. **Global Tilted Irradiance (GTI):** The total amount of solar radiation on a tilted surface both from direct and indirect sunlight exposure

7. **Watt-hour (Wh):** Measure of electrical energy used to quantify battery storage or energy consumption, one Watt sustained for one hour; Wh = Voltage x Ah