Considerations for Solar Development: Comprehensive Assessment of Solar Production Benefits and Consequences in Portugal

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Considerations for Solar Development: Comprehensive Assessment of Solar Production
Benefits and Consequences in Portugal

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School for International Training, UAL Spring 2023
ISPR-3000: Independent Study Project
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May 8, 2023
Abstract

In this paper, the potential for solar energy development in Portugal is explored, with a focus on the Alentejo region of Portugal. The Fernando Pessoa Photovoltaic plant that is approved for construction in the Santiago do Cacém municipality is analyzed. The size of the plant and the location are considered when studying the environmental, social, and economic impacts of the project. The possibility of a centralized solar array in Sines is also explored as an alternative, taking into account the environmental and social impacts on local communities. Additionally, the feasibility and benefits of implementing a decentralized energy grid, utilizing scattered small-scale solar arrays, energy storage systems, and smart grids are discussed. However, significant cost barriers and logistical challenges must be overcome to achieve a transition to a decentralized energy grid. The implementation of government incentives, public-private partnerships, and community engagement strategies can help ensure a sustainable and equitable transition to a decentralized and renewable energy (RE) grid in Portugal.

Keywords


Acknowledgements

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## GLOSSARY

### 2.1 Terms and Concepts: Energy Justice and Equity

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<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Energy Colonialism</td>
<td>Energy colonialism is the reinstatement of past colonial relationships between a centralized area of power and an area distanced from it that is responsible for developing energy infrastructure to support the colonist community. Energy colonialism materializes these socio-historical, economic, and political power relations as related to the use of RE and the deployment of related infrastructures and practices. RE colonialism is a form of neo-colonialism that involves the separation of energy consumption and generation (<a href="#">Batel, 2021</a>).</td>
</tr>
<tr>
<td>Energy Democracy</td>
<td>An energy democracy refers to a system in which control over decisions regarding the energy system is made through citizen participatory governance. The goal is to create a sustainable, equitable and participatory energy system that is socially inclusive and environmentally sustainable (<a href="#">Szulecki, 2017</a>). The system framework prevents the major centralization of the energy system and places decision-making in the local population that is most affected by energy infrastructure and energy poverty.</td>
</tr>
<tr>
<td>Energy Poverty</td>
<td>Energy poverty refers to the lack of electricity and other energy services, such as clean cooking fuels, or the inability to afford energy prices at home. It is commonly associated with poor regions and developing countries and has negative impacts on the health, education and economy of the region. Areas experiencing energy poverty provide a barrier to sustainable development because cheap and immediate electricity is desired to force development, and this energy is often most easily sourced from fossil fuels.</td>
</tr>
<tr>
<td>Environmental Justice</td>
<td>Environmental justice is rooted in the fundamental right of all individuals to be protected from environmental degradation. The framework of environmental justice seeks to mitigate disproportionate environmental risks across all communities and distribute equal benefits of a healthy environment to all individuals. The framework adopts a public health model of prevention as the preferred strategy, as to provide environmental health before certain populations suffer destructive impacts (<a href="#">Bullard, 1994</a>).</td>
</tr>
<tr>
<td>Renewable Energy Transition</td>
<td>RE Transition refers to a shift in reliance on fossil fuel and other nonrenewable energy sources to sustainable sources of electricity</td>
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generation. This transition movement is motivated by factors such as climate change, energy security, and sustainability. It involves the incorporation of a variety of political policies, technology, and social changes to support cleaner infrastructure (Mejía-Montero et al, 2020).

2.2 Terms and Concepts: Solar Energy System Components and Performance Metrics

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed-Tilt Solar Panels</td>
<td>Fixed-tilt solar panels do not track the angle of the sun throughout the day, and are therefore less efficient individually, but are necessary in some construction projects. They are set to an angle that will be most optimal for the entire day and do not shift. Construction of these panels can be done in areas with harsher topography than is allowed by tracker systems, and more panels can be fit into the same area as less inter-row spacing is necessary.</td>
</tr>
<tr>
<td>Solar Aspect Angle</td>
<td>The solar aspect angle is the measure of the angle between the solar panel and the direction of sunlight (Diehl, 2020). The angle to which a solar panel should be set to maximise energy output depends on the latitude of the array.</td>
</tr>
<tr>
<td>Solar Irradiance</td>
<td>Solar irradiance is the amount of solar radiation that reaches the Earth’s surface per unit area (Garner, 2015). This is an important measure to determine the amount of energy that solar panels can use in varying locations. A geographic evaluation of solar irradiance is a useful tool to determine which locations have a high PV potential output.</td>
</tr>
<tr>
<td>Specific Yield</td>
<td>In the context of this research study, a specific yield is the amount of energy that a solar module can generate per unit of installed capacity for a set duration of time. The units are kWh/kWp/year, meaning the total amount of energy produced over the power output times a one-year energy generation period. In other words, this is a measure of the performance of a solar PV system and represents the amount of energy that the system can expect to produce under normal operating conditions. This number is simulated in the PVsyst software and is one of the most important outputs for comparison between systems (PVsyst, 2023).</td>
</tr>
<tr>
<td>Tracker Solar Panels</td>
<td>Solar panels are often constructed with a system of trackers that slowly bend the angle of the solar panels throughout each day to maintain a solar aspect angle that is most efficient by tracking the angle of the sun.</td>
</tr>
<tr>
<td>Back of the Meter Solar Array</td>
<td>Solar systems that are installed as back-of-the-meter projects do not connect to the centralized energy grid in any way. They are 'back of the meter' as their energy production is not measured or used in the grid. Instead, energy consumption from back of the meter projects is on-site and involves small</td>
</tr>
</tbody>
</table>
energy transportation losses. These arrays often support decentralized energy system infrastructure.

1. Introduction

As global energy demand continues to rise and climate change concerns intensify, the need for a global-scale transition to renewable energy (RE) is imperative. The urgent task requires a plethora of solutions involving governments, businesses, and individuals alike. The United Nations (UN) and the European Union (EU) collaborated on the 2030 Agenda for Sustainable Development, which provides a shared blueprint for peace and prosperity among people and the planet (United Nations SDGs, 2023). At its core are 17 sustainability goals that link the priorities of all agreeing countries in bringing about the flourishing future they desire, while also mitigating climate change. A crucial sustainable development goal (SDG) that is most relevant to the work of this paper is SDG number 7: Affordable and Clean Energy. SDG 7 entails providing electricity to everyone and developing electric networks with clean energy sources. The 2030 Agenda came into force in 2015, with the target date of achievement in 2030, making this year, 2023, the midpoint of the roadmap. Therefore, this year is an important time to evaluate current progress and rapidly mobilize initiatives to achieve the SDGs.

In 2020, the total capacity of RE globally was around three terawatts, which makes up roughly 29% of all power generation (United Nations SDGs, 2023). Unfortunately, SDG 7 is not on track for achievement in 2030, and about 60% of global power generation capacity is still composed of fossil fuels. During the decade of 2010 to 2019, the total consumption of RE increased by a quarter; however, the total share of RE in consumption was only 17.7%. Solar and wind technologies compose a major portion of the growth in the RE sector, especially as widespread droughts have reduced the production of hydroelectric power worldwide. Photovoltaic (PV) systems are the fastest-growing energy technology by capacity, and combined with wind power the two sources compose 90% of the total growth of 522 TWh in 2021 (Internal Energy Agency, 2021). Developing solar energy infrastructure requires vast amounts of land and improvements to the energy grid to host the additional energy capacities.

"Portugal remains reliant on imported fossil fuels, which accounted for 76% of primary energy supply in 2019 (43% oil, 24% natural gas, and 6% coal)” and requires a mix of solutions to achieve their sustainability goals (Internal Energy Agency, 2021). Portugal developed their roadmap for achieving a mix of their personal sustainability goals, and the seventeen UN SDGs. The government initiative is called the “Plano Nacional Energia e Clima 2030” or PNEC, meaning the 2030 National Energy and Climate Plan (Bernando, 2019). The objective is to reach 80% renewable energy production by 2030, with a significant increase in solar and wind power, and a shutdown of all coal plants in Portugal by 2029. This plan requires the ambitious growth of solar energy from 1.9 GWh produced per year to 9.9 GWh (European Connection, 2019). Additionally, there is greater production of green energy in the north of Portugal due to consistent and strong winds, making it a desirable location for wind energy generation (Nunes, 2019). The north of
Portugal contains a larger complex of transmission lines than the south, but also much harsher topography and lower solar irradiances (APREN, 2018). The south of Portugal contains more intense sunlight and flatter land regions, including areas with little vegetation due to the drier climate. Reaching Portugal’s goals for solar development will likely require expansion in the southern regions. This will also serve to balance the load of RE production between the north and south while leveraging the favorable climates and geography unique to each region (Global Solar Atlas, 2023). This paper focuses on solar farms in the southern regions of Portugal.

To achieve zero reliance on nonrenewable sources of energy, Portugal needs to expand a multitude of clean energy infrastructures. Greater energy demand occurs during the day and the development of solar arrays can supply the grid during the high-demand periods when the sun is exposed. In 2018, Portugal ran the entire country off RE for 63 hours, with the main contributions coming from wind and hydropower (APREN, 2018). Available energy from wind was relatively consistent with some variation due to the weather, and hydropower was controlled to meet the necessary demand. A major challenge of solar energy is that, unlike hydropower or energy generated from fossil fuels, the production of electricity cannot be easily regulated to fit the exact needs of the grid. For this reason, it is necessary to ensure the transmission or distribution line a solar array is connected to will make use of the entirety of the electricity produced by the system during the day. If energy is produced in excess, a method of storage can complement the system by reserving electricity in batteries or hydroelectric dams.

The implementation of a solar farm is a complex initiative that requires engineering, economic, social, and environmental considerations. One must consider the feasibility of installing solar in the chosen location and its efficiency as well as the total expected production. Then, a cost-benefit analysis is used to determine whether installation is worth it over time, and legislative incentives can work to make such projects economically viable. This cost-benefit analysis also include external costs, such as environmental degradation factors that will cause expenses in the future. Social impacts surrounding a solar generation project must also be considered, which can be complex, making them difficult to understand and control. The shift in land use dynamics can influence public identity, and often resistance from the local population occurs when the array strikes these impacts.

The following criteria are thus developed for the site location of major PV electric generation plants. The location must have abundant solar resources, with few cloudy days and small soiling losses. Soiling losses occur in regions where the panels become obstructed by snow, dust, or other matter that blankets the area of the solar cells. The site must also have abundant land availability that is clear of wetlands, floodplains, harsh topography, and shading blockages. If necessary, trees may be removed to clear land for the array which develops environmental issues for the production of environmentally friendly energy. Zoning and other legal and environmental barriers to land use must also be considered by the interested party before proceeding with a

---

1 Transmission lines are reserved for moving wholesale quantities of electricity and extend greater distances. Distribution lines are responsible for delivering electricity from the substation to a customer and contain smaller quantities of energy over a shorter distance (Hertzog, 2012).
selected site. The array must be in close proximity to transmission lines if the production power is high and can be positioned near distribution lines if it is of a smaller production capacity. Finally, community support and economic viability must be reviewed early in the planning process to address concerns and ensure the benefit of interested parties. With RE development incentives and reinvestments in the local communities, these conditions can become more favorable for stakeholders and residents impacted by the presence of the array.

1.1 Research Objectives

This study aims to assess the social and environmental impacts of large-scale solar arrays, evaluate the risks associated with developing solar energy plants, and identify social and environmental injustice mitigation techniques. These include methods that serve to safeguard local populations and everyone's right to a healthy and sustainable environment. Using the Fernando Pessoa PV Plant by Iberdrola as a case study, the potential risks to the local community are analyzed to answer the overarching question:

Is there a better way to support the RE transition in Portugal with solar energy in such a way that mitigates social and environmental justice issues?

This question will be explored by: 1) evaluating the production potential of the solar plant with a system of similar size in an alternative location; 2) the physical and social differences between the two systems will be compared; and 3) a report on the potential effects of the solar array is developed along with an action plan for development that benefits both the local community and Portugal’s sustainability goals.

2. Background and Literature Review

2.1 Current State of RE in Portugal

A major aspect of Portugal’s energy strategy is the use of renewable energy sources within Portugal and the advancement of energy independence (IRENA, 2013). In 2001, Portugal launched the E4 Programme (Energy Efficiency and Endogenous Energies) which set a goal of 39% of the total electricity consumption in Portugal to come from RE sources. The incorporation of a feed-in-tariff policy mechanism is also used to promote the development of RE sources. The tariffs provide a guarantee of payment for electricity that is fed into the grid from RE generation sites (IRENA, 2013). This legislation scheme was first enacted in 1988, and over time the feed-in tariff law experienced updates that made it applicable to wind and solar technologies and changed payment schemes to be more favorable for RE development.

In 2019, 30.6% of the gross final energy consumption in Portugal came from RE sources, with 54% of all electricity needs and only 9% of transportation energy needs met by RE (Internal Energy Agency, 2021). Portugal enacted a new system of allocating grid connection capacity that involved the use of solar PV auctions in 2019. Since the system was rolled out in 2019, over 1.95
GW of RE generation projects have been granted network capacity reserve titles, with the majority of these being solar PV projects (Internal Energy Agency, 2021).

Due to major pressure from the market and policies, the two largest coal plants in Portugal permanently shut down in 2021. These include the 1.3 GW Sines and 0.6 GW Pego coal-fired power plants, and this is a major reason for the demand for a centralized and clean energy generation project to power Sines (Internal Energy Agency, 2021). The infrastructure already exists to bear the load of 1.2 GW sent for consumption in Sines, which is evidently why the system size of the Fernando Pessoa plant is proposed to be 1.2 GW as well.

2.2 PVs in Portugal

![Graph generated by the author based on data from Direção-Geral de Energia e Geologia. Source: DGEG, n.d.](image)

The proportion of total energy consumption from renewables in Portugal is the eighth highest among all countries that are members of the International Energy Agency (Internal Energy Agency, 2021). Another major reason for the uptick in solar development is the “electricity generation costs from solar PV decreased from around €0.5/kWh in 2000 to a worldwide average below €0.05/kWh in 2019” (Silva & Sareen, 2021). This tenfold decrease has driven major developments and is a key reason why solar is prominent in Portugal’s plans for a sustainable future.

One of the largest PV power plants in Portugal is located in Amareleja. The plant covers 280 hectares and is composed of 2,520 solar trackers (262,080 modules) generating about 93 GWh
per year (Acciona, n.d.). The energy supplied is needed to reach Portugal’s goals, but when a sum of land of this size is repurposed to produce electricity, environmental and social injustices can occur. It is important to note the diction used by the project developers when describing the land they intend to occupy. Amareleja was often described as being mostly a “wasteland” and a “deactivated airfield” (Silva & Sareen, 2021). This diction is problematic as it tries to represent an area as completely empty when it is in fact inhabited. This creates a presentation to the public that the area is remote and away from where they live, and therefore justifies principles of energy colonization and the concept of “not in my backyard.” By creating this view of Amareleja to the general public, it creates an allowance for these companies to come in and establish their solar farms without comprehensive consideration for the community. However, the pushback of the local population is a powerful force and can influence these energy companies to establish mitigation efforts for environmental and social impacts. For example, the developer of the Amareleja project enacted a plan to protect plant and bird species and monitor the effects of the solar farm on biodiversity in response to locals’ concerns (Silva et al., n.d.).

The four main topics that cause opposition to solar projects are their environmental impact, the landscape impact from a visual intrusion perspective, their archaeological and cultural heritage impact, and their economic impact (Silva et al., n.d.). Additionally, the repurposing of so much land can have major effects on a community as the identity of the locals is influenced by the use of their land. Amareleja is a fitting example of this as they experienced plentiful rural tourism before the installation and believed tourism numbers would plummet after solar construction. The solar farm became a major part of the village’s identity and they adopted the nickname “Land of the Sun” (Silva et al., n.d.). This demonstrates the strong impacts that solar power can have on the identity of a whole community, thus altering its reputation and inevitably changing the lives of its inhabitants.

2.3 Integration of Energy in the Portuguese Grid

The process of allocating available energy capacities on the grid is regulated by the government of Portugal. All electricity generation projects must attain a network capacity reserve title from the network operator before a production license can be issued to the project developer (Internal Energy Agency, 2021). If the transmission or distribution line that the generation project will be hooked up to has available capacity for more energy, the network operator can issue this title through standard procedure. If additional infrastructure to the grid is necessary to house and transport the produced electricity, the developer of the project is expected to pay all associated costs.

The other method of receiving permission to interconnect an energy generation project is through auctions. A certain amount of energy capacity is auctioned to the developer, and then they gain the rights to establish their projects and sell their electricity into the grid at the permitted location. When these rights were first auctioned, a connectivity floor of 10 megawatts was established (Silva & Sareen, 2021). With a minimum amount of energy that must be injected into
the grid, this system favored large companies over small solar developers. Additionally, it gave this right to the developer without the consideration of land use and adverse effects that may be felt by local communities. The next stages of the development process involve assessments of the landscape, but a claim was already made to the company by auction, making location choices for development simple and not comprehensive. This organization of energy-injecting placement is a source of environmental injustices regarding solar PV projects in Portugal, and the repercussions and potential solutions will be discussed further in this paper.

2.4 Environmental Justice Issues of Energy Colonialism

The development of RE must adopt an approach that considers the proportion of its effects on multiple scales and from varying perspectives. The goal should be to further energy democracies and allow for citizen participation to safeguard locals from harmful energy infrastructure development. It is possible to develop RE projects with major considerations for the local populations, but such plans must be designed using a bottom-up approach. Under this approach, during the planning stages, residents are informed and given a space to share input and concerns. This direct connection between the plans and those that are most affected by the project can uphold the integrity of plans set to mitigate environmental justice issues.

Issues arise when the influence of locals is displaced by large and powerful outside sources that seek to develop energy infrastructure in rural areas separated from the predominant locations of consumption. When a large multinational company receives approval to build a large PV plant in a rural area, its main considerations are costs, construction methods, and energy output. A prime example of a system that enforces this unjust development is the concept of carbon credits. The concept of carbon credits is to set a carbon emission maximum per company or nation, and if you emit less than the threshold, you can sell your remaining credits for a profit (Batel, 2021). If one emits more than their threshold, they must purchase carbon credits from others. This system adds economic considerations to an environmental issue that is currently not valued in the global economy. The trading of these credits may serve to balance carbon emissions on a global scale in a way that can be easily adopted by international capitalist economies; however, this system primarily places the burden of clean energy production on the global South and rural communities. Urban and wealthy areas will continue to make very modest carbon reductions while inflicting the weight of the global RE transition on the energy-colonized communities (Batel, 2021). The enforcement of RE colonialism stems from the application of power over a dependent area for the purpose of producing RE.

This is evident in a plan to harness the solar energy availability from the Sahara desert (Batel & Devine-Wright, 2017). The project is supported by the United Kingdom, and the rhetoric used by media and other actors to describe this plan and similar projects is dangerous, as it creates a divide between an area of power and one of dependence. These projects justify their development by stating they will be “making use of the abundant unused solar energy in the deserts and wind on their seashores to promote global energy” (Batel, 2021). However, this essentially means that
European countries would like to import RE from North Africa and the Middle East. The danger with these statements is the classification of these countries as “deserted,” “poor,” and “wastelands,” as it enforces a lack of consideration for how RE development will affect locals. Additionally, it serves as a justification for large companies to take charge in these regions and disregard methods that involve citizen participation to ensure community concerns are addressed. The use of citizen participation to form these solutions can serve to safeguard local communities while also developing actionable strategies to combat climate change.

2.4 Decentralized Energy Systems

Common electricity generation plants that utilize non-renewable sources provide large amounts of energy in a single location where it can then be packaged and shipped along transmission and distribution lines. “Decentralized energy generation involves more mixed-scale production facilities with multiple nodes of production in the network” (Boucher, 2016). This energy generation development scheme can empower individuals and communities, giving them the ability to produce and allocate energy according to their decisions. This can lower energy poverty, and significantly reduce energy transportation losses. Communities can develop greater degrees of self-sufficiency, and enact an energy democracy that involves greater participation and a bottom-up approach to decision-making that regards the region’s electric needs.

To properly transition to a decentralized energy grid, a mixture of technologies and improvements are required. An abundance of renewable and scattered energy production sources, energy storage systems, and smart grids are needed to control the added complexities of the system. The significant cost of grid restructuring is a major barrier to the transition, and the decisions made are often upheld for many generations as society falls into this solidified position. For this reason, it is crucial to make resolutions that are sustainable and can be used by future generations to come.

An argument against decentralized electric grids is that on smaller scales, energy consumption can be variable, and if proper energy storage infrastructure does not exist, then some electricity could be underutilized. A system in which decentralization of the energy grid was achieved by placing solar on all of the rooftops of a community, but then connecting the energy to the grid at each site would solve this issue. The resident can use the energy generated by their solar panels, and if they overproduce feed it back into the grid and sell the energy to the utility. Homes that require more energy than they produce from their panels can then utilize this energy. This would require meters that work in both directions in residential electric interconnections to measure data on energy consumed and produced.

The benefit of solar energy is that it can be scaled on many levels. This multi-scalar availability provides a possibility for the environmentally just development of clean energy infrastructure in a decentralized manner that will also mitigate energy transportation losses.
3. Methods

This study seeks to explore alternatives to the Fernando Pessoa PV energy generation plant that reduces environmental and social injustices while still allowing Portugal to meet its sustainability goals.

3.1 Research steps

1st The issues and complaints with the Fernando Pessoa PV plant are reviewed and discussed. The collection of complaints ultimately produces a list of demands to be fulfilled in order to reduce said injustices.

2nd An interview with a volunteer from GEOTA – Spatial Planning and Environmental Study Group – named Mr. Miguel Sequeira is conducted.

3rd Proposal of an alternative location for a centralized solar generation plant for the sake of comparison to the Fernando Pessoa plant.

4th An action plan for achieving energy equality and sustainable renewable electricity generation in Portugal is discussed.

3.2 Data sources

The primary data sources of this research come from an interview with a volunteer from GEOTA that was conducted over the phone on April 24th, 2023 in an open-question format with a duration of approximately 30 minutes. Additional primary sources include outputs from the Helioscope and PVSyst softwares used to simulate the two solar PV systems.

Secondary sources of data include maps, energy tables, and trends provided by organizations such as the International Energy Agency. Additionally, the accounts of locals in Santiago do Cacém are compiled by the Agência Portuguesa do Ambiente and used to understand the perspective of locals on the Fernando Pessoa project.

3.3 Interview

GEOTA is a national Environmental NGO with a public utility status that has existed since 1981 (GEOTA, n.d.). Their mission is to defend the environment and promote sustainable development, and they have engaged with solar projects in the Alentejo region of Portugal,
including the Fernando Pessoa project. The objective of the interview is to better understand renewable development in Portugal. The greatest challenges with RE and key issues with the Fernando Pessoa plant are discussed during the interview.

The questions asked in the interview:

- How has GEOTA engaged with local communities to promote RE projects without hindering territorial planning or the local environment?
- What challenges has GEOTA faced with respect to RE projects?
- What are GEOTA's perspectives on the balance between rapid sustainable development and environmental justice in Portugal's energy sector? What is the best way to mobilize the country to achieve its SDG goals without creating environmental or social justice issues in the production of new energy plants?
- What are your and GEOTA's thoughts on the Fernando Pessoa PV plant? How can it be altered to reduce issues, and is there an alternate location(s) that should be considered?
- Why do you think Iberdrola selected this location?
- What are your thoughts on Iberdrola’s website discussing their plans to create 2500 jobs (mostly local) and have shepherds utilize the space as pastures for sheep and beehives? They also say this will boost crop yields in surrounding farmland and that they will replace the eucalyptus trees they cut down with indigenous trees.

3.4 The model

The environmental and social justice issues derived from the Fernando Pessoa plant being a centralized model of energy development, are identified and alternatives are proposed. Helioscope – a user-friendly solar design software with helpful mapping graphics – is utilized to envision this solar array and calculate a reasonable system size given the available area. Next, the efficiency and total production of an array of that size is simulated using PVSyst software. This software is a tool designed just for the solar industry, which creates, simulates, and analyzes solar energy systems. It is well known for its accuracy and flexibility because it allows for specific inputs on solar modules and inverters as well as varying weather conditions in the model simulation. Climate data from MeteoNorm 8.0 as a TMY file – typical meteorological year – for the exact coordinates of the system of interest.

Various parameter inputs in PVSyst are kept constant between the two systems that are considered. This way the comparison is accurate even if the outputs contain a margin of error:
● A 530Wp solar module designed by SunPro Power would be used by both systems, as original designs for the Fernando Pessoa power plant involved 530Wp modules and the SunPro Power modules are of generic design.
● A generic inverter of 2000kW size is assumed as inverters with high power outputs will be needed for a plant on the sizing scale of the Fernando Pessoa array.
● The minimum spacing between solar rows is desirable to reach the maximum system size within a given area, and it is achieved by calculating the minimum distance between modules to prevent any inter-row shading between the hours of 9 AM and 3 PM during the shortest day of the year, which is a common standard to uphold.

The two centralized systems are compared through an engineering, environmental, and social lens, weighing the benefits and drawbacks of system size, location, and other parameters. After a comprehensive review of both sites, an approach to solar development with a strategy of decentralization is researched and compared from an economic, social, environmental, and logistical feasibility perspective. The final stage of this research paper will be to holistically compare the Fernando Pessoa plant, my chosen location, and a decentralized approach and develop an action plan for solar development in Portugal. Local communities and the greater Portugal region are considered from a multi-scalar viewpoint to highlight the benefits, but also shortcomings of the plan.

3.5 Limitations

Various limitations of this study prevent an absolute answer to the best method for developing solar infrastructure. Although many factors are considered, a plethora of reasons can affect the influence of solar infrastructure, and the achievement of solar development goals without any negative impacts is unlikely. Instead, this paper seeks to identify adverse impacts and explore mitigation methods.

Additionally, there are various limitations within the modelling software that reduce the accuracy of the production and loss outputs. For example, the exact specifications of the panels and inverters that would be used in reality are unknown to me, so a generic model is used instead. Topography within the chosen regions is also not considered in the simulation. Topography was considered to choose the site location but for the purpose of the simulation within PVSyst, a flat rectangular plane is utilized. This further establishes its outputs as just an approximation; however, all assumptions and limitations are constant across the two sites of comparison: The Fernando Pessoa plant and the chosen location. This allows a fair comparison of how system size and the exact location influence efficiency and system performance.

3.6 Ethics

This study does not seek to define a single answer to the RE development strategy, as any method will lead to disproportionate effects for some populations. The suggestions in this paper
will include plans that still affect certain populations more than others, and the goal is not to identify one overarching situation that is ethically justifiable.

The primary data collected in this study are via solar modelling software and an interview with a volunteer from GEOTA. Miguel Sequeira was sent and signed a consent form to ensure that the inclusion of his input was approved and to inform him of his right to refuse to answer any questions. The rest of the data collected was from secondary sources to organize and develop the investigation. This paper assumes full responsibility for treating existing works fairly and accurately and providing correct citations to assign credit properly.

4. Results and Discussion

4.1 Fernando Pessoa PV Plant Concerns

The Fernando Pessoa PV Plant, formerly known as “The Happy Sun is Shining” (THSiS) will be the largest solar farm in Europe, occupying 1244.95 hectares and producing approximately 2148 GWh of electricity per year (Agência Portuguesa do Ambiente et al, 2021). The site is located in Vale de Água and São Domingos in the Alentejo region of Portugal and will occupy 6% of the entire area of these towns. Furthermore, the site is located in a region composed of 915 hectares of forest, with most of the vegetation being Eucalyptus trees. Additional tree species include cork, oak, and montado, which would also be destroyed during construction. The site-clearing phase would involve the deforestation of approximately 1.5 million trees.

The Association for the Sustainability of the Earth System (ZERO) – a Portuguese NGO with the goal of societal intervention in Portugal to defend sustainable values through proactive participation – stated they deem initiatives counterproductive that aim to replace covered forestry for the construction of mega solar parks in the fulfillment of renewable production targets, degrading areas with a relevant function of provision of ecosystem services: including the capture of carbon, a refuge for biodiversity, and spaces of enjoyment of nature (Agência Portuguesa do Ambiente et al, 2021). “[Solar is a technology that can be installed in urban and industrial environments that are already occupied and degraded by anthropic activities, allowing the production of electricity near the places of consumption, which allows a significant reduction of environmental impacts and transport losses of energy, and this should be the primary form of photovoltaic use]” (Agência Portuguesa do Ambiente et al, 2021). To achieve this, the Portuguese government must create more advantageous energy tariffs and subsidized self-consumption panels that can be placed on public buildings and homes.

A landowner named Nuno Coelho Virgílio in the area where the Fernando Pessoa plant will be built says he “[doesn’t understand how it is possible for this to be approved when it destroys millions of protected trees when under twenty kilometers away there are abandoned places with no use where the center could be built]” (Agência Portuguesa do Ambiente et al, 2021). The land owned by Mr. Virgílio is designated as part of the national ecological reserve (REN) and the national agricultural reserve (RAN), and 80% of the total land to be occupied falls under at least
one of these designations. The locations 20 kilometers away he is referring to, though, are not large enough to host a system of the same grandeur as the Fernando Pessoa plant. However, this type of project must exist on much smaller and scattered scales across multiple locations.

Iberdrola points out in their plans for construction that eucalyptus is an invasive species in Portugal and is also very prone to forest fires which is a major issue in the country. They state their plans to plant the equivalent number of cut trees with replacement and indigenous species elsewhere (Matos, Fonseca & Associados, 2019). However, one must consider the duration of time it takes for these trees to mature and the additional risk that the trees never reach adulthood. These indigenous trees can take decades to reach maturity and before they attain this stage in their development they release more carbon than they sequester. It is also important to realize that while on a global scale, the carbon and oxygen levels can be balanced by planting trees in an alternative location, the local impacts will be felt. This ties into the concept that plans must be reviewed from a multi-scalar point of view, as a global holistic perspective may not be appropriate when local environmental injustices are created. Furthermore, the heat effect from PV panels is better understood in more arid rural regions. A PV plant as large as Fernando Pessoa will provide a heating effect to the region and the influence on a more temperate climate is less predictable.

A quantitative approach can be used to compare the carbon benefits of solar panels versus the developed eucalyptus forest. Each tree can capture between 140 and 260 kilograms of carbon each year, and the associated carbon offset of each solar panel is between 150 and 250 kilograms per year (Agência Portuguesa do Ambiente et al, 2021). 1.5 million trees will be removed and replaced with approximately 2 million solar modules. They serve to balance out from this perspective, but solar panels do not release any of the oxygen utilized by all of the life in this region. Another important consideration is the effects of this carbon sequestration by the forest at a local level, as a nearby refinery releases an abundance of carbon dioxide in close proximity to the municipality of Santiago do Cacém. The current forest sequesters approximately 65,000 tons of carbon dioxide each year, and in 2020, the Galp de Sines Refinery issued 1,177 tons of carbon dioxide. The localized climate impacts of such a major shift in land use, combined with existing emissions that would no longer be locally sequestered are unknown. With scattered projects of smaller size, impacts on the environment bear more minor effects on each region, thus distributing the load of the RE transition.

Vale de Água and São Domingos also experience rural tourism which is projected to have significant reductions after the installation of the Fernando Pessoa PV plant. The page on Iberdrola’s website introducing the Fernando Pessoa plant states that the project will create 2,500 jobs, most of which will be held by local workers (Iberdrola, 2023). The public consultation report prepared by Agência Portuguesa do Ambiente conflicts with this statement and states that Iberdrola will not provide the magnitude of local jobs they claim (Agência Portuguesa do Ambiente et al, 2021). In either case, these jobs would be replacing the consistent work of rural tourism jobs with the temporary work of installing the Fernando Pessoa plant. After it is operational, the plant will only require a few dozen employees to provide maintenance and upkeep. Rural tourism exists in
numbers of approximately 2,000 tourists visiting per year, which is 70% of the occupancy rate in 2019 and 65% of the occupancy rate in 2020 (Agência Portuguesa do Ambiente et al., 2021).

With this in mind, Santiago do Cacém residents demand new studies to find alternative locations and development strategies. Protege Alentejo is a civic group formed in March of 2021 with the objective of contesting and preventing the realization of projects that adversely impact peoples who were born or have always lived in the Alentejo region (Agência Portuguesa do Ambiente et al., 2021). However, if the project must proceed, Protege Alentejo has set a list of demands to help mitigate impacts on the local population. One demand is that a tree curtain, surrounding the perimeter of the solar field, of at least 200 meters is installed and maintained to provide a physical barrier between residential areas and the array. All destroyed trees must also be replanted, and some of those trees can be contained in this curtain. They also demand that the total PV area be reduced by 200 hectares, which is roughly a 15% reduction in the total size of the project. Among other demands include: fencing the perimeter of the array at the inner boundary of the tree curtain, installing power line connections underground, removing noise pollution from transformers existing outside of the PV area zones, ensuring public roads and properties are not affected, and guaranteeing that soil, subsoil and groundwater are not compromised. These demands seek to hide the presence of the system by creating separations between the local community and the energy production zone. This further demonstrates the concept of “not in my backyard,” as few people wish to exist near large centralized PV plants, however, their frustration is justified as they are not the primary consumers of the energy.

To protect the livelihood of the residents, other demands were included by Protege Alentejo to compensate those whose business is degraded by the plant. Those who own property along the site are to be paid a rental fee and tourism entrepreneurs are to be paid an equivalent of 50% occupancy at the potential of the units for 30 years (Agência Portuguesa do Ambiente et al., 2021). Farmers and livestock breeders are to be compensated per hectare or per head of cattle, to also be paid for the thirty-year duration. Additionally, they demand the entire population of Santiago do Cacém be paid the annual minimum wage for the duration of the array’s operation. To uphold their tourism industry, demands include: financing promotional actions in the region to draw tourists, creating signaled trails and picnic tables to promote outdoor space, and creating an interpretation center on the azimuth of the sun and link the architecture and culture of Alentejo to justify the new landscape of solar panels from a touristic perspective. This last demand is particularly interesting as it seeks to mitigate cultural shifts that may result from such a large repurposing of space.

Finally, Protege Alentejo advocates for the creation of a company called Sunshine, SA with the sole purpose of dismantling the entire operation in thirty years. This company would entail a 100,000 euro share of the capital of the project and would contain the power to disassemble a billion-euro project when the time comes.

These actionable strategies to protect local residents of Santiago do Cacém and the Alentejo region are comprehensive and unlikely to be met. Iberdrola has already received approval to move forward with its plans, and the public consultation report came after an initial investment in the region. Many of the benefits guaranteed by Iberdrola to the community are inherent in the
installation of a solar farm. These include job creation, synergy with educational institutions, and recovery of areas adjacent to the solar parcel (Agência Portuguesa do Ambiente et al, 2021). It is necessary to push further than just the requirements for approval. If the project were developed including the input of residents from the initial phase, these demands of Protege Alentejo could be better incentivized and incorporated into the blueprint for the operation.

4.2 Interview with GEOTA volunteer

An interview with a volunteer from GEOTA named Mr. Miguel Sequeira was conducted to better understand renewable development in Portugal. Mr. Sequeira has a master’s degree in environmental engineering from the NOVA School of Science and Technology in Lisbon and has a Ph.D. researching ways to support the sustainable energy transition at a city scale. He volunteers with GEOTA on topics such as carbon pricing, centralized solar plants, and lithium mining in Portugal. Mr. Sequeira is one of the EU's Climate Pact Ambassadors in Portugal, and he wishes to incorporate citizen participation in climate change mitigation and adaptation.

Mr. Sequeira stated that GEOTA engages with local communities to better understand their concerns, and then they try to influence and participate in the public consultation process to improve the project. They find that in many large solar projects, there is a lack of planning and promoters do not take proper concern for local communities. A major challenge is the lack of information and communication applied to locals by environmental NGOs. As a result, locals may only receive information from what they hear on television or from plans that are already being implemented without their consultation or knowledge. Mr. Miguel explained that a lack of consultation from the beginning leads to a major increase in the likelihood of opposition, and often there can be missed opportunities to improve the project.

Another major challenge of solar development is that the locations of these energy plants are chosen by the developer which can be a third-party company that has no stake in the area. Oftentimes, the chosen location is where the project can be implemented the fastest and cheapest, making it very difficult to prioritize the mitigation of environmental injustices. Mr. Sequeira believes that the government should pose a greater intervention in these projects to promote development on reasonable scales and stated “the strategy of the government is lacking compared to what it could be.”

During a conference in Spain, Mr. Sequeira discussed the actionable strategies to achieve the sustainable development goals. The main priority should be to improve energy efficiency and reduce total consumption. He stated that around 70% of buildings in Portugal are inefficient in their energy usage, and they can be retrofitted to include more efficient technologies. He believes that it is possible to reduce consumption in residential areas and small businesses by around 40% if the issue of building efficiency is tackled. Energy poverty is also a major issue and improving the efficiency and performance of buildings is justifiable as a priority not just for environmental but also social reasons.
According to Mr. Sequeira, the next priority for Portugal involves the promotion of
decentralized energy infrastructure. He is in favor of small-scale and decentralized rooftop solar
arrays and stated that roughly half of electricity consumption, according to data from 2016, could
be supplied by rooftop solar if installed everywhere. Solar is also unique in how it can be applied
on so many scales and can also be involved in parking lots as a canopy. Mr. Sequeira stressed,
though, that solar should be implemented within areas of consumption and that urban solar
infrastructure must take priority over rural and agricultural areas.

Regarding the Fernando Pessoa PV plant, Mr. Sequeira stated that the biggest issue is not
deforestation or a lack of regard for locals, but rather the sheer size of the plant. Location is not
the reason for all the issues it brings, and any alternative to this plant should be considered on a
much smaller scale. Other issues that do involve location selection are the great distance between
Santiago do Cacém and Sines, an urban area that most of the solar energy will go towards
supplying. Transportation losses are in proximity to twenty or even thirty percent. A coal plant
near Sines was recently shut down, and the goal of this plant is to replace the existing centralized
energy system infrastructure with one powered by the sun. The system setup requires revision, and
this magnitude of energy cannot come from one pinpointed source.

When asked about other locations for large solar arrays, though still of much smaller
magnitudes than Fernando Pessoa, Mr. Sequeira recommended a Portuguese study done by the
Laboratório Nacional de Energia e Geologia (LNEG) of low-impact locations for RE development.
The study\(^2\) determined that 12% of continental Portugal includes areas that are of low impact and
desirable locations for RE projects. This study has received lots of controversy as it included some
areas that people do not believe are suitable for such development. These limitations are
acknowledged, but it is still a good starting point for identifying possible alternative locations.

### 4.3 Analysis of Location and Decision Rationale

Potential locations for an alternative to the Fernando Pessoa project that would minimize
environmental injustices were considered by evaluating multiple maps. Firstly, an important factor
included proximity to urban areas of high energy consumption to reduce transportation losses and
injustices that stem from the large separation of production and consumption locations. Secondly,
maps of transmission lines, solar irradiance, satellite imaging, and the low impact from renewables
map as discussed earlier were layered to pinpoint a desirable location.

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\(^2\) Laboratório Nacional de Energia e Geologia study of geographic regions in Portugal that have less environmental
and heritage sensitivity with a view to the deployment of renewable energy power plants (LNEG, 2023).
The above map shows areas of strong solar irradiances in darker red, making many locations in the Alentejo and Algarve regions desirable. The convergence of three major transmission lines in Sines – located in the southwestern region of Portugal – provides an existing robust energy infrastructure for the connection of additional produced energy. Since these requirements were satisfied in close proximity to Sines urban area, the location was evaluated in greater detail using the LNEG map of areas that are less sensitive to RE infrastructure development. By less sensitive, LNEG claims these locations are suitable for the development of renewable electricity projects while safeguarding the local environment and cultural heritage (LNEG, 2023).
A closer evaluation of the green locations above via a satellite map revealed the outlined location as containing no residential buildings in close proximity and containing some trees in relatively low density. The area borders a highway, so visual considerations due to solar glare may need to be factored into project planning. A potential solution could be a barrier of trees between the southern edge of the area that borders route A26. Occupying the borders of the area are company locations for Repsol, Medway, and Euroresinas.

Repsol is a multinational Spanish energy company that operates in the oil and gas industry as well as in the RE industry. In Sines, Repsol is a large petrochemical complex that includes a refinery, a chemical plant, and a cogeneration plant. The chemical plant produces ethylene, propylene, and polypropylene, which are used in a range of products, including plastics and packaging materials (Repsol, n.d.). The company provides many jobs and represents a significant amount of economic activity in Sines, but due to its emissions and negative environmental impact, they are striving towards carbon neutrality by 2050. For this reason, it is possible they may want to develop solar in the surrounding area and would be an important company to consult during the planning stages of this solar project.

Medway is a Portuguese company that operates in the transportation sector, particularly with railways (Medway, n.d.). It is one of the largest private operators of rails in Portugal. Their website includes several pages detailing their commitment to sustainability and a page where
customers can evaluate how shipping materials through them reduces their carbon footprint. The site in Sines contains an area for storage and shipping containers stacked high. Since it is located near the port of Sines many of these shipping containers make their way into large shipping rigs in the ocean to transport materials around the world. The specific services they offer on this site include parking, storage of all types of cargo, and the sale of maritime containers. The implementation of solar energy in the surroundings of their property is unlikely as roads will be unaffected and their business is not dependent on the appearance of their surroundings.

Euroresinas is a chemical company headquartered in Sines, and this location is the site where they produce textiles and resins (Euroresinas, n.d.). They are located near the northwest corner of the proposed site and on the other side of the road. The proposed location for the solar plant lacks residential areas, and the businesses that occupy the surrounding area are likely to experience few effects from the plant. Additionally, some of the businesses’ processes are energy intensive, thus applying high demands on the electric grid infrastructure at this location. The addition of solar nearby these business operations could serve to utilize a large sum of energy without long transport lines and thus align with Mr. Sequeira’s strong sentiment of prioritizing efficiency. The following section will evaluate the efficiency of this solar site compared to the location and size of the Fernando Pessoa PV plant.

### 4.4 Helioscope and PVsyst Analysis and Comparisons

Helioscope software was used to estimate the system size of a solar array placed in the chosen location from above. The map in Figure 2 was overlaid on the Helioscope mapping platform to set the limits of the solar farm. Next, a satellite map was inspected to provide keep-out zones on every road and obstruction in the area that would remain in existence after the construction of the array. Then a solar module size and brand were chosen that would be most similar to the specifications used by Iberdrola at the site of the Fernando Pessoa. An inspection of the specifications for the Fernando Pessoa PV modules revealed plans to use 530 Watt modules set up in an arrangement of two panels high per row at a solar elevation angle of 15 degrees (Agência Portuguesa do Ambiente et al., 2021). Helioscope contains data on the Sunrise SR-72M530HLPro (530W) solar modules, which fit similar specifications to the panels used by Iberdrola. The discrepancy between the actual modules and the ones used in the simulation provides negligible impact when we solely use the data to draw a comparison between the site location and system size of the Fernando Pessoa and the chosen Sines PV farms.

The specifications for the modules manufactured by Sunrise Energy were acquired online, and the dimensions were used to calculate the minimum inter-row spacing possible. This calculation allows the system to contain the maximum solar module surface area without each row casting a shadow on the row behind it between the hours of 9 am and 3 pm during the shortest day of the year. This is a common benchmark used to determine the minimum distance between rows. The dimensions of the solar modules given by Sunrise are 1133mm by 2278mm.
In order to calculate the inter-row distance, the height between the back edge of the panel and the front edge of the panel is determined. As seen in the above diagram on the right, the distance between each row is dependent on the tilt of the panels, the solar elevation angle, and the azimuth angle. Because the panels are arranged in landscape orientation with 2 panels high, the length used will be double the width, or 2266mm.

\[
Height = \text{width} \cdot \sin(\text{solar elevation angle})
\]

\[
Height = (2 \cdot 1133\text{mm}) \cdot \sin(15^\circ) = 586.48\text{mm}
\]

Then, the sun elevation angle based on the coordinates of the site location is calculated. The coordinates 37.99 Lat, -8.8 Long were taken from Google Earth, and the following chart was produced detailing the sun elevation angle relative to the horizon (Google Earth, n.d.).
Using the given data and applying the criteria that the worst-case scenario for sunlight be December 11th between 9 am and 3 pm, the dashed green line was extended to estimate a 16° angle of solar elevation. Now to determine the distance of the casted shadow at this time the following formula is used.

\[
\text{Shadow Length} = \frac{\text{height}}{\tan(\text{sun elevation angle})}
\]

\[
\text{Shadow Length} = \frac{586.48\text{mm}}{\tan(16^\circ)} = 2045.30\text{mm}
\]

The final step in determining the minimum row distance is to account for the azimuth angle, which accounts for the sunlight not being applied from due South all day. The azimuth correction angle is determined by the variation from 180° as shown in Figure 4, which is 43°. The following formula is therefore used to find the final minimum inter-row spacing required.

\[
\text{Minimum Row Spacing} = \text{Shadow Length} \cdot \cos(\text{Azimuth Correction Angle})
\]

\[
\text{Minimum Row Spacing} = 2045.30\text{mm} \cdot \cos(43^\circ) = 1495.84\text{mm} = 4.91\text{ft}
\]

The final inter-row spacing used in the helioscope and PVSyst simulations is therefore 4.91ft. The array built in Helioscope using this specification is estimated at 330.2 MWp with a total of 623,016 modules.
The above is an image of the proposed system generated using Helioscope and Google Earth softwares. The next stage of the comparison involves PVSyst simulations to compare the energy output of the proposed site and the Fernando Pessoa PV plant. The following inputs were used for the proposed site: 623,016 modules, system size of 330.2 MW, inter-row spacing of 4.91 ft, SunPro Power M10-HIEFF-530Wp-35V modules, Generic 2000kW inverter, panel height above ground of 9.19 ft in accordance with site plans for the Fernando Pessoa plant, landscape orientation with two modules high per row, coordinates for MeteoNorm file of (37.981697, -8.798881), and default thermal, soiling and ohmic losses.

The inputs to model the Fernando Pessoa PV plant were identical except for the following parameters: 2,343,400 modules, system size of 1242 MW, and coordinates for the MeteoNorm file of (37.885535, -8.561529). The following outputs were generated:
The important takeaway from this simulation comparison is the specific production is 1637 kWh/kWp/year for the site in Sines and 1650 kWh/kWp/year for the Fernando Pessoa site. This means the Fernando Pessoa plant would be more efficient and produce more energy per unit area in its location; however, it is important to note that the difference in the specific yields is only about 0.7% less efficient. This difference is more than accounted for when you consider the distance between Sines city center and the locations.
The proposed location is about 7.5 kilometers away from the city center, and the Fernando Pessoa plant is about 30 kilometers away (Google Earth, n.d.). The total energy produced per year by the proposed location is estimated at 540.6 GWh and the Fernando Pessoa plant is estimated at 2,049.5 GWh by this simulation and estimated at 2,148.2 GWh according to the Agência Português de Ambiente (Agência Portuguesa do Ambiente et al., 2021). This leaves a discrepancy of about 0.46% between the simulation run above and the estimates sourced from Iberdrola concerning total energy generation per year. The proposed plant in Sines is estimated to produce 26.4% of the amount of energy that the Fernando Pessoa project would generate.

At about one-fourth the size and occupying approximately 270 hectares, the proposed location is still a large centralized energy generation plant. In order to meet the energy demands that would be satisfied by the Fernando Pessoa location, multiple plants in locations closer to consumption are necessary. The LNEG map of zones that are less sensitive to renewable development can be used to identify similar sites, but the limitations of this map must also be considered for logistical and justice reasons.
4.5 Implementing a Decentralized System in Santiago do Cacém

A decentralized solar energy system could be implemented in Santiago do Cacém in order to increase their energy autonomy and uphold environmental justice. There are a total of 1,031 buildings in the region where the Fernando Pessoa array will be built, and we can consider this roof space in a plan for energy decentralization in the area (Agência Portuguesa do Ambiente et al., 2021). A company like Iberdrola could offer 500Wp self-generation solar kits to each home for a cost of approximately 1,000 euros including the cost of the kit and installation (SOLARIMPACT, n.d.). These residents could then have their energy contracted with Iberdrola and receive energy benefits such as a discount, while still paying Iberdrola for electricity. Residents receive discounted energy and greater electric autonomy without cultivating village land space for solar, and Iberdrola profits from existing as the contracted energy provider for the area. If 1,000 homes adopted solar on their rooftops and each placed a 500Wp module for 1,000 euros, the total cost of the project would be one million euros and have a total energy capacity of 500kW. This system size is approximately 0.04% of the system size of the Fernando Pessoa plant and about 0.1% of the cost. As evident, a major barrier to decentralized development in this case is due to a much smaller scaled project, and a cost of roughly double per unit of energy. Hence, the need for government incentives is imperative.

4.6 Discussion of Solar Development Action Plan in Portugal

Many issues of environmental injustice can be mitigated if power is held at the source of affected areas. As discussed earlier, if RE generation plants are to be installed in many locations, considerations must be made for local populations, and the locals themselves are most capable of dictating these necessary considerations. A bottom-up approach and strategy of RE development that empowers and improves communities, rather than degrading one area for the benefit of another, must be implemented.

Government incentives and subsidies for rooftop solar can motivate the needed decentralized green energy transition. If these prices become competitive with centralized energy systems, the market can shift in favor of individuals and more localized communities. Portugal’s government can offer tax credits or other financial incentives to residents, businesses, and communities that install solar arrays on small scales at the location of consumption. The implementation of public-private partnerships that prioritize community engagement and feedback can ensure these projects are installed sustainably and equitably.

After the mass implementation of small-scale and scattered solar arrays, more rural areas can be considered as in this paper. Low-impact zones should be utilized and the centralized plants should be located in close proximity to urban areas where all of the energy can travel a short distance to the point of consumption. The location proposed for a centralized solar array in Sines identifies one possibility, and if an array were to be established there, the first step in the process would be to consult those that occupy the area and its surroundings. This includes the businesses
identified earlier and the residents of the municipal area. Finally, additional benefits to the local community must be allocated based on the results of the consultation with the locals. This scheme is easier said than done, but necessary to implement a sustainable future for electricity in Portugal.

5. Conclusion and Future Research

Portugal has experienced a major uptick in transitioning to RE sources since the beginning of the century, particularly in the solar energy sector. The country currently contains the ambitious goal of carbon neutrality by 2050, and solar energy is a key component of achieving this target. This paper has highlighted the potential for both centralized and decentralized solar energy development in Portugal, and the various factors that should be considered in the planning and implementation of such projects. It is clear that a bottom-up approach, that prioritizes community engagement and feedback, is necessary for the successful implementation of solar energy projects. Furthermore, the government can play a crucial role in incentivizing and promoting the adoption of small-scale and scattered solar arrays. Through such efforts, Portugal can achieve a more secure, sustainable, and equitable energy future that benefits both the environment and its citizens.

Further research should be conducted to determine additional locations for solar arrays, and specific fiscal implementation strategies that the Portuguese government could enact. A study of citizens’ and businesses’ behavior could provide useful in understanding the necessary incentives to produce an uptick in rooftop solar installations. This information can be compiled to carry out the major expansion of decentralized solar energy systems and increase the energy autonomy of Portugal.
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Appendix
Miguel Sequeira – GEOTA Volunteer – Consent Form

PARTICIPANT INFORMED CONSENT TEMPLATE

Title of the Study: Assessment of Solar Production Benefits and Consequences in Portugal
Researcher Name: Jonathan Marcuse

My name is Jonathan Marcuse, I am a student with the SIT Portugal: Environmental Justice and Sustainability program.

I would like to invite you to participate in a study I am conducting (for partial fulfillment of my BS in Environmental Engineering). Your participation is voluntary. Please read the information below, and ask questions about anything you do not understand, before deciding whether to participate. If you decide to participate, you will be asked to sign this form and you will be given a copy of this form.

PURPOSE OF THE STUDY

The purpose of this study is to assess the social and environmental impacts of large-scale solar arrays. Looking specifically at Portugal’s renewable energy transition, it seeks to evaluate the risks associated with the development of solar energy plants and identify environmental injustice mitigation techniques. The research will focus on the recent undertaking of the Fernando Pessoa PV Plant by Iberdrola, and its potential risks to the local community to answer the overarching question: Is there a better way to support the renewable energy transition in Portugal with solar energy in such a way that mitigates environmental justice issues?

STUDY PROCEDURES

Your participation will consist of a series of questions regarding GEOTA’s initiatives, solar development in Portugal, and a conversation regarding the Fernando Pessoa Photovoltaic plant. The interview will require approximately 30 minutes of your time. You will not be recorded or videotaped.

POTENTIAL RISKS AND DISCOMFORTS

There are no foreseeable risks to participating in this study and no penalties should you choose not to participate; participation is voluntary. During the interview you have the right not to answer any questions or to discontinue participation at any time.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

No anticipated benefits.
CONFIDENTIALITY

Any identifiable information obtained in connection with this study will remain confidential if you do not elect to have your name and position included in either the presentation or articles associated with this work. See the section below to state your preference. If you do not wish to have your identity shared, when the results of the research are published or discussed in conferences, no identifiable information will be used.

PARTICIPATION AND WITHDRAWAL

Your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study.

“I have read the above and I understand its contents and I agree to participate in the study. I acknowledge that I am 18 years of age or older.”

Participant’s signature ___________________________ Date 27/04/2023

Researcher’s signature ___________________________ Date 27/04/2023

---

Consent to Identify Interviewee

Initial one of the following to indicate your choice:

X (initial) I agree to have my name and position included in the research paper.

_____ (initial) I do not agree to having my name and position included in the research paper and would like my responses to be anonymous.

---

Consent to Quote from Interview

I may wish to quote from the interview with you either in the presentations or articles resulting from this work.

Initial one of the following to indicate your choice:

X (initial) I agree to have my statements from the interview included as quotations.

_____ (initial) I do not agree to having my statements from the interview included as quotations.
RESEARCHER’S CONTACT INFORMATION
If you have any questions or want to get more information about this study, please contact me at Jonathan.mar[redacted] or my advisor at catia.duarte[redacted].

RIGHTS OF RESEARCH PARTICIPANT – IRB CONTACT INFORMATION
In an endeavor to uphold the ethical standards of all SIT proposals, this study has been reviewed and approved by an SIT Study Abroad Local Review Board or SIT Institutional Review Board. If you have questions, concerns, or complaints about your rights as a research participant or the research in general and are unable to contact the researcher please contact the Institutional Review Board at:

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