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Evaluation of a Great Agrovoltaic Implementation in an Isle Using SWOT and TOWS Matrices: Case Study of Gran Canaria Island (Spain)

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Abstract: Nowadays, we are heading towards global decarbonisation, with each sector involved contributing partial solutions to the problem, without realising that an overall vision is necessary. Photovoltaics emerged as a technology that requires a lot of surface area, which is why it has been integrated into buildings and other human infrastructures (BPVI). The effects of the implementation of AVS on an island have been analysed, observing the territory's energy use, population, and social and topographical realities, collecting all the peculiarities that could be affected by a massive implementation of this technology. The method to be followed is a SWOT and TOWS analysis, widely employed in all types of scientific studies. The increase in the island's resilience has been assessed, as has its decreasing its dependence on the outside. In this case, it has been observed that conventional PV is currently being installed on agricultural land to decarbonise electricity production, which mostly relies on oil and does not consider that the island is a territory with a high food dependence on the outside; a high unemployment rate; a high factor of soil desertification, meaning fires are frequent; a high rate of abandonment of agricultural land; and a shortage of flat land. Therefore, we affirm that the island's carbon footprint will increase by not taking all these factors into account. In addition to punishing the local economy by destroying fertile soil, local food and jobs, the current method of energy production increases the need for subsidies to import food products from abroad. In addition, we claim that the use of AVS reduces the water needs of the crop, which is relevant on an island with great water scarcity. It is concluded that 11 of the 17 UN Sustainable Development Goals would be improved with the use of agrovoltaic technology.

Keywords: agrovoltaics; TOWS matrix; electric system; descarbonisation

Citation: Pulido-Alonso, A.; Quintana-Suárez, J.C.; Rosales-Asensio, E.; Feo-García, J.J.; Florido-Suárez, N.R. Evaluation of a Great Agrovoltaic Implementation in an Isle Using SWOT and TOWS Matrices: Case Study of Gran Canaria Island (Spain). *Land* **2024**, *13*, 2043. https://doi.org/10.3390/land13122043

Academic Editors: Marta Gallardo, Julio Fernandez Portela, David Cocero and Lara Vilar

Received: 4 October 2024
Revised: 14 November 2024
Accepted: 16 November 2024
Published: 28 November 2024

1. Introduction

The European Council, in 2023, set an ambitious target: "to reduce Greenhouse Gas (GHG) emissions by at least 55% by 2030 and achieve climate neutrality by 2050" [1]. This would cover all areas of energy production, but in certain places, work is being done to decarbonise the energy sector, penalising and preventing real decarbonisation. In this context, Gran Canaria faces specific challenges due to the conversion of agricultural land into photovoltaic orchards, which can have negative repercussions on food sustainability and carbon emissions related to the transport of food from abroad.

This article shows the beneficial effect that could be had by widely implementing AVS technology on an island with an isolated system of electricity production. The potential of agrovoltaic technology is analysed as a viable solution to address these challenges [2], enabling the simultaneous production of energy and food, avoiding the destruction of soil fertility, and establishing a strategy that could help advance the European Council's decarbonisation goals without compromising food sustainability or biodiversity. The implementation of agrovoltaic systems can improve biodiversity by providing shade and microhabitats for various animal species in general, mostly, insects. In addition, it contributes to the reduction in soil temperature under solar panels, which can help retain moisture and improve soil quality [3].

The combination of solar energy and local agricultural production reduces the need for food imports, with the consequent benefit of generating clean energy that directly contributes to reducing GHG Emissions [4]. Studies carried out in Gran Canaria have demonstrated the economic and technical viability of agrovoltaics using greenhouse roofing [5], suggesting that its application on the island could be a practical and beneficial solution even in the open air.

The articles that carry out SWOT and TWOS studies determine which of the 17 Sustainable Development Goals (SDG) would be affected by a wide implementation of this technology, but all these analyses have been developed in other countries with different circumstances to those of the Canary Islands, whether due to technological development, climatic conditions, customs, or territorial location, such as Malaysia [6], Ethiopia [7], India [8] and Vietnam [9]. The conclusions of each study differ depending on the place where the research is carried out; just as an environmental impact study of an action is related to the type of project, it is also related to the place where it is implemented.

In the background of the study, we have an Ultraperipheral Region, in the form of a heavily populated archipelago, with a protection of the territory that reaches approximately 40% of its surface [10,11] (see Figure 1), where there are 19 sites of scientific interest, 27 protected landscapes, 54 natural monuments, 16 special natural reserves, 11 integral natural reserves, four national parks, 11 natural parks, seven rural parks and seven biosphere reserves declared by UNESCO, as shown in Table 1. It is evidently a hotspot of biodiversity in the world, belonging to the Mediterranean Basin [12], where it mostly only uses oil as a primary energy source, its main economic activity being tourism; it is deficient in drinking water and has a strong food dependence on the outside, but it has ample natural energy resources, with the trade winds that are present in the archipelago 80% of the year, and in regard to solar energy, it has 4800 daylight hours a year [13].

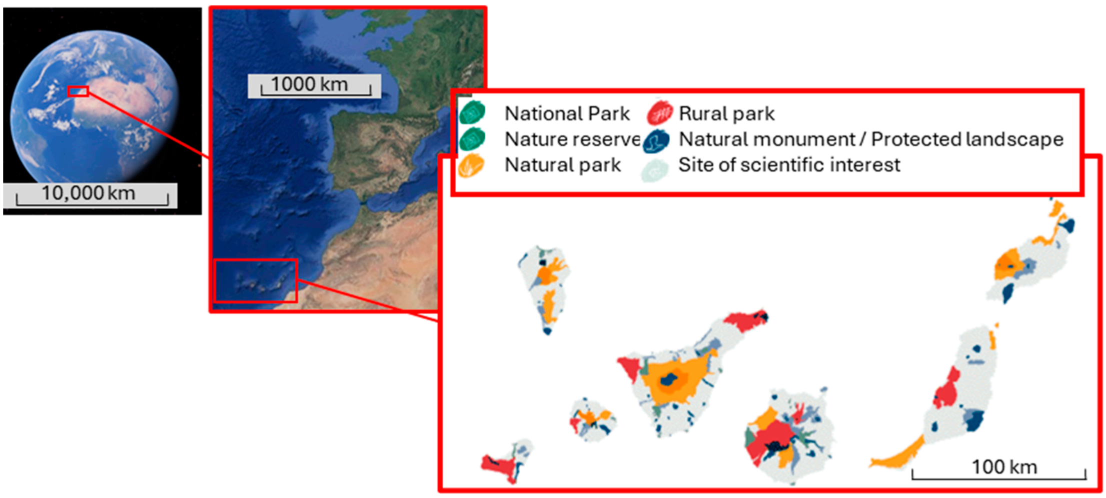

Figure 1. Protected natural areas of the Canary Islands. Source: Canary Island Network of Protected Natural Spaces [10].

Table 1. Areas of natural protected spaces of the Canary Islands [ha]. Source: Canary Island Network of Protected Natural Spaces [10].

Island	National Park	Natural Park	Rural Park	Nature Reserve	Natural Monument	Site of Science Int.	Total	% Protection
El Hierro			12,488	1069	2511		16,068	58
Fuerteventura		17,455	16,544		13,612	116	47,727	29
Gran Canaria		13,333	29,893	11,109	17,946	276	72,557	43
La Gomera	3984	1757	1993	783	2040	313	10,870	33
Lanzarote	5107	19,270		165	10,888	200	35,630	39
La Palma	4690	12,593		2059	5560	111	25,012	35
Tenerife	13,571	46,612	22,482	7053	14,638	387	104,742	49
Total Canarias	27,352	111,020	83,401	22,237	67,195	1402	312,607	40

The aim is to analyse the advantages of implementing AVS on a massive scale where land is very scarce and poorly used, in line with the current reality of technology and the island.

The European Union aims to achieve a high rate of decarbonisation [14], as all human communities on the planet are currently doing, but after the pandemic we have gone through, the fragility of the population on the island has been revealed, as it is totally dependent on the outside from the point of view of the economy, energy and food and water production for human consumption (derived from the energy dependence of desalinating sea water). AVS appears as one of the many actions to be carried out to achieve a greater resilience of the local population, in the face of global upheavals.

This is the reason why it has been decided to apply this recognised methodology, to obtain some conclusions in the face of the actions that have been taking place these days on the island, including declaring conventional photovoltaic installations on the ground to be of "Public Interest", to bypass existing territorial planning, and allowing them to be installed on agricultural land in the name of false decarbonisation [15].

The objective of this study is to analyse the strengths, opportunities, weaknesses, and threats of this technology on an island with an isolated energy system. The TOWS matrix is applied after considering the previous aspects and trying to find ways to reinforce the opportunities and reduce the weaknesses through possible actions. From this analysis, a certain list of actions to be carried out to achieve the objectives will appear, to make the implementation of AVS in Gran Canaria more appealing.

2. Materials and Methods

AVS consists of taking advantage of the same land surface to implant photovoltaic panels, which will generate electric energy, compatible with agricultural or livestock use [16]. This technique was originally conceived by Adolf Goetzberger and Armin Zastrow in the 1980s [17,18], but the concept did not become popular until the last decade.

In this context, the combination of land use and energy production emerges as an innovative and sustainable solution, already studied for some decades [19]. This system allows the coexistence of agricultural production and solar energy generation on the same land, offering, with this combination, an opportunity to revitalise abandoned arable land and increase energy and food self-sufficiency [20]. Combining elevated solar panels with agricultural crops not only maximises land use (see Figure 2), but also provides shade and protection for crops [21], reducing water evaporation and improving the microclimatic conditions of the arable environment [3]. This approach creates a perfect symbiosis between agriculture and energy, sharing the same space for a common purpose, allowing not only the joint production of food and energy, but also indirectly contributing to decarbonisation without the need to abandon productive farmland.

Figure 2. Agrovoltaic system (AVS). Own elaboration.

This approach is a more expensive technology than ground-level photovoltaics, and presents a series of drawbacks, where the project actions must be analysed together with the fragility of the environment to assess the impact produced, but it also provides a multitude of benefits at other levels [22,23].

Knowing and listing the aspects that influence a business model is, in this case, particularised for the AVS, analysing all the internal and external aspects, positive and negative. But the planning of this activity will be developed in a specific environment, with unique characteristics; common effects may appear in any other place, but there will be specific aspects in the specific environment of study, in this case, on the island of Gran Canaria. It is necessary to have the presence of people who know the method and the environment. Despite having had access to similar analyses, their differentiation is relevant, because they are in another enclave [6].

The characteristics of the activity and the aspects of the environment that could be influential are going to be divided in four sections:

- Strengths: those positive internal aspects, which will be encouraged to make something stronger or more effective.
- Weaknesses: all those internal aspects, but in this case, negative ones, which will be reduced as far as possible.
- Opportunities: positive external possibilities from which advantage can be taken.
- Threats: These are the external problems, obstacles or limitations that can prevent or limit the development of the analysis activity in the defined environment, so a way should be found to avoid or mitigate them.

The SWOT is useful, but by itself, it does not generate concrete actions to improve. That is where the TOWS matrix comes into play. Described for the first time by Heinz Weihrich in 1999 [24], this procedure helps to take measures with the characteristics found, defining the actions to be carried out in the future, in order to reduce threats, use opportunities, build strengths and overcome weaknesses. It combines internal and external forces to generate decisive actions on how to use the information collected to achieve better results. To do this, a matrix will be created, where internal and external aspects will be compared.

- Strengths and Opportunities: Use strengths to maximise opportunities.
- Strengths and Threats: Use strengths to reduce threats.
- Weaknesses and Opportunities: Reduce weaknesses to develop opportunities.
- Weaknesses and Threats: Avoid threats by reducing weaknesses.
- A SWOT analysis is most helpful before you implement a large change, when you launch a new national initiative at any scale, if you would like to identify opportunities for growth and improvement. It is a scientific method widely used in all types of current studies, and of course, in engineering problems, energy systems and agrovoltaics, as can be seen in the following quotes [7,9].

3. Results SWOT Analysis

3.1. Result of the Implementation of AVS in Gran Canaria

A series of problems will arise on the island of Gran Canaria, which the implementation of AVS on a large scale could partially alleviate; many of which are common with a large part of Spain and Europe [25].

- The food dependency of the Canary Islands on basic consumer products is 80% [26]. This reality has been going on for many years, and it has not been solved, despite the fact that it has been on the political table for more than 20 years [27,28].
- Abandonment of agricultural land. A total of 66% of agricultural land in the Canary Islands is out of use, and in the case of Gran Canaria, the percentage is more than 60% [29]; it is a recurring problem throughout Europe [30].
- Desertification of the soil is a global national problem [31], and affects Gran Canaria by more than 70%; resuming agricultural work could partially alleviate this problem, avoiding erosion and bringing soil fertility back.
- External energy dependence, exclusively on oil with null diversity. It is observed in [32] that of the primary energy consumed in the Canary Islands in 2020, 96% was oil. In Gran Canaria, 81.35% of electricity production came from oil. In addition, there is the bunkering service that is carried out from Gran Canaria, which is like a service petrol station in the middle of the Atlantic Ocean [31]. The amount for this concept is EUR 2.16 million. Energy dependence from abroad is a European problem [33].

Agrovoltaics arises to partially alleviate the enormous dependence on foreign energy, which is doubly polluting, since it contaminates its local use and its transport to the island.

- Shortages of freshwater. In Gran Canaria, 62% of the water used by humans comes from desalination [34]. The desalination plants are supplied directly from the grid, exchanging oil for water, since oil is mostly used on the islands to produce electricity [23,25].

3.2. Reality of Renewable Energy Production Facilities in Gran Canaria

Of the primary energy used in the Canary Islands, renewable energy accounts for 1.18%; if we included, in addition to internal consumption, the energy supplied to ships, we would be talking about 0.74% [35]. In Figure 3, we can see the evolution of the implementation of photovoltaic power installed in the last 20 years in Gran Canaria, with direct connection to the electrical grid. To know the total renewable energy of solar energy on the island, we have counted 114 MW of peak installed power, using data from 2019, of which 9.63 MW is located on arable land, occupying an area of 196,208 m^2. A total of 189.5 MW is currently pending administrative approval by the authorities, occupying a cultivated area of 11,100,074 m^2, which represents an increase of 1937% in 5 years, and a loss of arable land of 10,903,866 m^2 [36,37].

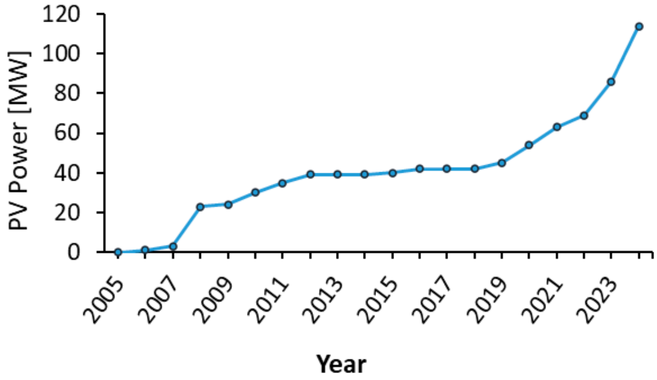

Figure 3. Photovoltaic power connected to electrical grid in Gran Canaria. Own elaboration. Source: Consejo Insular de Energía (Cabildo de Gran Canaria) [33,34].

Many of these installations are being built on agricultural land, as it is cheaper and easier to obtain. Figure 4 shows an installation that occupies an area of 5763 km^2, where the construction of a 10 MW plant at ground level has been authorized, and other installations already built in the same circumstances can also be seen [38].

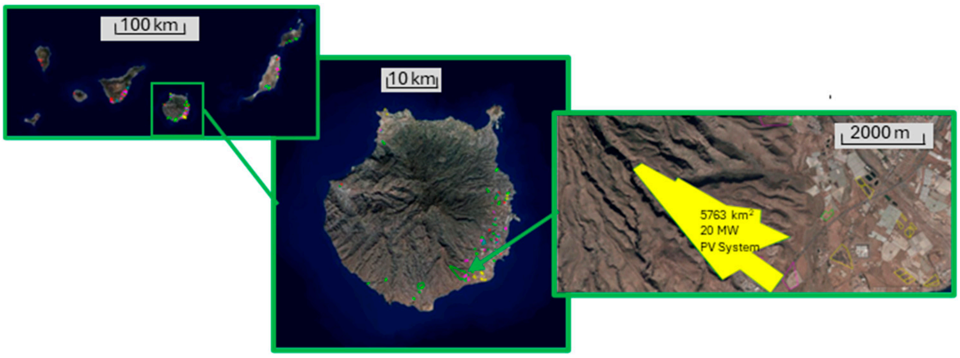

Figure 4. One photovoltaic farm of 10 MW/5763 km^2. Fixed tilt ground mounted PV System in Gran Canaria. Source: Gobierno de Canarias [38].

Currently, a pumped hydroelectric power plant is being built in Gran Canaria, which will allow increasing the integration of renewable energy into the grid, reducing the current curtailment ratio [39,40].

Another circumstance to be considered in the electrical isolation of the Canary Islands is the great sea depths existing between the islands, in some cases, exceeding 4000 m deep, which prevent a simple interconnection and, thus, create a global system on an archipelago scale.

3.3. Socio-Economic Reality of Gran Canaria

In the last two decades, Gran Canaria has had a population increase of 15% and has been without a major tourism project for almost 20 years. No public housing has been built in the last 20 years, creating a great shortage.

Speaking of the Canary Islands, it had an unemployment rate of 16.19% in December 2023 [27]. The rate of risk of poverty and social exclusion is 38%, which means that many people are in poverty, even when they are working. With a strong and marked social inequality, 0.3% of Canarians accumulate a figure equivalent to half of the GDP [41]. In these last two decades, the arrival of foreign tourists to the Canary Islands has increased by 50%, but despite this situation of prosperity, EUR 1700 of per capita income has still been lost. As a result of this circumstance, the deterioration of essential public services such as health, education and the social-health system is observed.

In certain islands in the archipelago, water insecurity has been declared, and it was proposed in March 2024 to declare a water emergency at the level of the entire archipelago, after widespread supply problems [42,43], the contamination of some coastal areas by sewage and concern about the deterioration of natural spaces and beaches due to an uncontrolled expansionist desire. However, if the entire planet consumed resources in the same way as the Canary Islands, 3.84 planets would be needed to cover that demand [44].

This is a very strong economic, social and environmental reality, which will require many corrective actions, but we will be able to see that one of them must be the AVS.

3.4. Strengths

These are the internal initiatives that work well; that is, they contribute in a positive way.

3.4.1. Creating, Conserving and Stabilising Jobs

Resuming the agricultural use of the land would mean recovering jobs for the primary industry; indirectly, cleaning and packaging facilities for agricultural products would be created, and even the circumstances of creating factories for the elaboration and manufacture of processed products, and their associated distribution chain, could create jobs. Today, these tasks are not covered because they do not exist, and there are not people who are responsible for operating and maintaining the photovoltaic installation and electrical grid, although these will be fewer, and more temporary, since the advantage of photovoltaics is that, as it has no moving parts, its maintenance is reduced. The Canary Islands have a high unemployment rate of 16.19%, according to data from December 2023 [45].

3.4.2. Preventing Soil Desertification and Keeping It Alive

On the island, over the years, large areas of agricultural land have been cleared; the land without roots loses the ability to fix the fertile layer to the soil, and it has been eroded by rain and wind, becoming degraded without the possibility of performing its productive function. Uncontrolled construction in rustic areas, the intense extraction of groundwater and the abrupt orography of the land with large slopes has led to a desert landscape.

The island of Gran Canaria is one of the most desertified areas in Spain [46]. Nowadays on the island, the fertile soil resource is not given value, so one way out of this situation is to implement agrovoltaics on all abandoned agricultural land.

In this GIS tool, you can view all the photovoltaic installations on the ground in the Canary Islands, both built or authorised without construction yet [38].

3.4.3. Promoting Commercial Development of Zero-Kilometre Products

The agricultural products that are most consumed on the island should be analysed to try to produce the largest possible quantity in situ. In addition, the production of certain crops could be spread out over time to facilitate a continuous supply of food, considering the beneficial climate in the Canary Islands. The possibility of introducing new crops compatible with the climate and type of soil could be studied, to try to promote their consumption among the population.

The benefits of consuming local products are multiple: Food is fresher and tastes better, seasonal, helps to preserve farmland and green space, promotes food safety, stimulates variety, supports the community's economy and creates a sense of community, highlighting the reduction in the carbon footprint in a forceful way and the contribution of food to the local population [47].

3.4.4. Additional Income for Farmers

One of the many reasons why agriculture has been abandoned is that it is very exposed to situations of low profitability. The reasons may be various, such as the appearance of pests that ruin the harvest, or the arrival of ships with the same merchandise that lowers prices. Having continuous extra income, obtained by another, alternative means, provides farmers with greater peace of mind and security in their economy [48].

3.4.5. Reduction in the Carbon Footprint and Production of Oxygen

AVS reduces the carbon footprint for four reasons.

1. It returns abandoned agricultural land to use; because it is cheap and unproductive, the land is currently being used for many other purposes, such as housing ground-based photovoltaic installations [38]. Crops absorb CO_2 from the air and emit O_2.
2. Renewable electricity is produced without producing any GHG emissions, thereby partially limiting the emissions from the island's two thermal power plants.
3. Part of the transportation to the island of certain foods consumed by the population, which has 857,171 inhabitants and is visited by 3.6 million tourists a year, is avoided; currently, more than 80% of the food products on the island comes from abroad, coming in ships from distant places, consuming fuel. Given the circumstances of the islands, many of the costs of these imports are subsidised by the Central Government. In the local market you can find apples from different origins including Chile and Italy, pears from Holland and Belgium, and kiwis from New Zealand, as well as many

raw or processed foods from abroad. Each transport involves the emission of large quantities of GHG, such as N_2O and CO_2, in addition to other pollutants associated with fossil fuels.

4. AVS allows a reduction in the imported fuel that is subsequently used in the two thermal power plants on the island, where 83.4% of the island's electricity is produced, where the fuel used is derived from petroleum. In 2020, all the petroleum consumed in the Canary Islands came from Nigeria, 5200 km from the islands [32].

3.4.6. AVS Is Cheaper than Rooftop Installations

The cost of photovoltaic installation per kW installed on the roof of buildings is higher than for AVS [23], which are larger installations and require less labour in their assembly and less equipment and auxiliary means in their operation.

3.4.7. Better Use of the Land

If two hectares were available, with one used for photovoltaic on the ground and the other for agricultural purposes, the production of both would be 100% electricity and 100% agricultural products. If half the land is used, only one hectare with AVS would produce 83% electricity and 103% agricultural products [49,50]. In Gran Canaria, there is a high population ratio, large areas of protected land and a shortage of flat land, making use of the land a necessity and a measure to be adopted.

3.4.8. Reduction in Water Demand

By producing partial shade on the crops, the thermal stress of the plants and animals that benefit from it is reduced, requiring a smaller amount of irrigation water. By having electricity generated on the plot itself, and if the agricultural land is located near the coast, as in many cases of the island's farmland, sea water could be captured, and after a desalination process, provide irrigation water to the crops, as already occurs in some farms on the island [51,52].

3.4.9. Greater Efficiency of Combining Panels and Agriculture

The presence of vegetation, by capturing solar radiation, and by the evo-transpiration of the plants, reduces the ambient temperature by a few degrees; this effect causes an increase in the voltage and the output power of the panels, equivalent to increasing the kWh/kW of the installation [53], and these coefficients can be observed in any catalogue of photovoltaic panels.

3.4.10. It Favours Island Biodiversity

The island has a population of endemic birds and is also a passageway for migratory birds between Europe and Africa. The land is also home to endemic lizards, shrews and bats. But it is worth noting that the existence of crops and flowers favours a land with a great island biodiversity of invertebrates, many of them pollinators. In the Canary Islands, there are 125 species of bees, of which 98% are solitary species, with four out of 10 endemic species. There are species associated with some type of plant, so that one species depends on the other, and as contemplated by the current CAP, at least 4% of the crop surface must be left out of exploitation as fallow or for the protection of biodiversity. This is in addition to the mitigation of climate change (CC) and the need to improve the sustainability of farms and their contribution to biodiversity [54,55].

3.4.11. Protection of Crops from Inclement Weather

These structures partially protect against severe weather, although it is true that the island is at a latitude where few episodes of extreme weather occur. The last time the island was affected by an episode of this type was in 2005, with Tropical Storm Delta, although the effect on crops was not significant [56].

3.4.12. Rainwater Collection

The panels can be equipped with rainwater collection systems, by placing channels and recovering the rainwater by gravity, which can be used to irrigate the crop, preventing the water that runs off the panels from falling to the ground, creating runoff that erodes and damages the soil. There are many AVS installations that, today, have these systems [57].

3.4.13. Improving the Image of Energy Producing Companies

Without a doubt, there are many energy and non-energy companies that fly the flag of zero emissions, supporting and using green energy in their advertising. An example of this in Spain is the case of Iberdrola [58], and this also occurs internationally, where there are hundreds of such companies [59].

The AVS is one of these energies where many companies, simply by adopting it, could use this current flag as a form of promotion and brand image that uses renewable energy.

3.4.14. Consolidation of Distributed Generation

Until a few years ago, electricity networks were vertical, with power plants at the head end producing the energy, and the consumer facilities downstream. The ideal was to produce the energy where it is going to be consumed, limiting its transport and distribution.

Today, this concept has changed due to the incorporation and integration of renewables, and, by common sense, the ideal is to create a distributed generation system, which will allow electricity to be provided to consumption centres far from conventional power plants, without distance limitation.

3.4.15. Contribution to the Circular Economy

Considering that agricultural production is going to increase, not only are agricultural products produced for local consumption, but, in parallel, a series of organic waste is generated, which can be given another use, such as fertilisers for agricultural or garden areas. Another option is to produce biogas or insects [60], which, in turn, could serve as food for fish farming [61].

3.5. Opportunities

These are the positive aspects of external factors, which do not depend on the activity itself and affect the rest of the activities.

3.5.1. Collective Self-Consumption

In Spain, self-consumption is much more profitable than injecting power into the grid. In these times, collective self-consumption must be analysed or an energy community established. In Europe, the transition towards a low-carbon model is being promoted, with the aim of creating a sustainable energy sector that stimulates growth, innovation and employment, while improving the quality of life, expanding the available options, reinforcing consumer rights and, ultimately, promoting savings on household bills. This can be seen in the energy directive [62].

3.5.2. Stopping Agricultural Abandonment

The abandonment of agricultural land is a current problem in Europe [30,63], Spain [64] and the Canary Islands [65] and Gran Canaria [29]. In Gran Canaria, with an arable area of 30,000 ha, more than 60% is unproductive; in Spain, this figure is 20%. In the period 2015–2030, about 11% (more than 20 million ha) of agricultural land in the EU is under high potential risk of abandonment; any case it is to possible read that "Just now 15.1% of total EU land is abandoned or underutilised" [66]. The working and economic conditions that farmers receive must be improved, since they not only produce zero-kilometre food, but also take care of soil fertility, contribute to biodiversity, contribute, in many cases, to the conservation of the landscape, and positively influence local climate. It is important to highlight that due to CC, there are more episodes of extreme heat, increasing the risk of fires; having cultivated soil reduces this risk compared to having land full of stubble. In Spain, rural abandonment is pointed out as the main cause of fires [67].

3.5.3. Increased Food Autonomy

A total of 80% of the Canary Islands' food basket is imported from abroad. Food sovereignty is a right of the people to regulate and guarantee access to food that they consider to be a cultural, ecological and economic issue, allowing access to safe, nutritious and appropriate food, and as an objective to reduce dependence on the outside. In this way, an improvement in resilience and economic development can be achieved, obtaining better environmental sustainability and contributing to preserving local biodiversity. There are many programs carried out to increase local production, almost all without much result [68].

The agricultural surface on the island of Gran Canaria is 29,042 ha, of which only 38.84% is cultivated. With this land used, approximately 20% of the food needs of the island are covered, both for residents and for tourists. The ratio of the occupation of photovoltaics directly on the ground is 1.5 ha/MW, considering the implementation of only agrovoltaics in only 10% of the abandoned agricultural land. Considering the coefficient of photovoltaic use of 83% of the land, the agricultural production of the same would not be affected [47]. A total 982 MW would be obtained. On the other hand, thanks to this measure, food self-sufficiency would increase from 20% to 23.15%.

3.5.4. Greater Resilience to External Changes

After the last international COVID-19 pandemic, the entire hotel industry was closed. Such is the importance of tourism for the regional economy that this sector has come to generate approximately 40% of employment and 35% of the Canary Islands' GDP. The service sector creates close to 78% of the GDP in the Canary Islands. Thanks to the AVS, there is the power to create both food and energy wealth and to strengthen the community, reducing dependence on the outside.

3.5.5. Reduction in Energy Poverty

In 2021, the XII Arope report [69] states that in the Canary Islands, almost 38% of the population was at risk of poverty and/or social exclusion, making it the region with the greatest rate of severe poverty in the country. Cáritas, in 2022, warned of the increase in poverty and social exclusion, with women being the group most affected. With this type of project, wealth and jobs are created in both the agricultural and electrical sectors, so AVS will undoubtedly contribute to reducing this problem.

3.5.6. Decrease in the Rural Population

A worldwide phenomenon from a historical point of view is the abandonment of rural areas and increasing concentration in large cities. In the case of Spain and the Canary Islands, the coastal areas have been the most attractive, due to the development of tourism.

According to a study carried out by Caixa, 28% of the rural territory of Spain is depopulated. If we focus on the specific case of the island of Gran Canaria, five inland towns and a total of 750 inhabitants have been depopulated [70]. This is a social phenomenon that continues to increase, due to the lack of economic options to mitigate such circumstances of rural abandonment. With the implementation of the AVS, this situation could be stopped.

3.5.7. Versatile and Economical Installation

According to the IRENA document [71], the most economical form of electricity generation in 2022 was photovoltaic, at USD 0.049/kWh, behind only onshore wind, at USD 0.033/kWh. Photovoltaic is also considered highly versatile, being able to grow in a modular way, increasing sections by incorporating panels with their respective inverters, and growing progressively at the pace needed, informed by evacuation, economic and any other limitations.

3.5.8. Crops Favourable to Partial Shading

We have consulted DIN SPEC 91434 [72], which indicates that when AVS is available for a crop, in no case should more than 15% of the available soil be lost for this reason. The effect of partial shading on crops is as follows: Vegetables that produce single-flowered fruit such as peppers, tomatoes, cucumbers and pumpkins are less tolerant of shaded areas and should, therefore, be planted in full sun. Root vegetables such as beets, carrots and potatoes will grow in partially shaded areas while leafy vegetables such as chard and spinach are more tolerant of shade and can be grown in more shaded areas. In any case, this ultraperipheral region of Europe is located at a latitude with one of the highest radiations in Europe due to its proximity to the equator.

3.5.9. Creation of a New and Specialised Labour Fabric

The agricultural sector, which is largely abandoned today, could be partially recovered, and workers will also be qualified to attend to, install and maintain this technology. The Canary Islands have a high unemployment rate [45].

With the same 10% of the abandoned agricultural land, the number of jobs on agricultural land put back into production would increase by 2434 agricultural workers, for which the data on the active employment population by sector in the province of Las Palmas for the year 2023 have been used. This would reduce the unemployment rate on the island, counting only the agricultural work phase, by 1.76%. This would have to be extended to the cleaning of agricultural products, packaging, transport, distribution and, finally, the maintenance of the operation of photovoltaic installations.

3.5.10. Creation of a Novel Economic Niche

A new line of possible investment is opened, with a significant local component. This allows an increase in stable economic activity, since it is not only about creating these installations, but also about operating and maintaining them, providing the opportunity to introduce and strengthen technological companies. All companies related to agricultural activity would be strengthened: irrigation, seeds, fertilisers, etc.

3.5.11. Co-Existence of Solar Panel Structures with the Crop

There are many hanging or trailing crops, in which hanging structures are usually used, based on sticks or ropes to promote their growth, and to keep the fruits off the ground. The same structure of the panels could be used for this purpose, sharing utility.

3.5.12. Possibility of Compatible Use with Livestock (Range-Voltaic)

There is currently a large livestock population on the island; the AVS can make the use of the land compatible, and the use of the land can be agricultural or pasture, so it should be considered in both aspects. The livestock population on the island is quite large, and in 2023, comprised 12,649 cattle, 19,263 sheep, 47,388 goats, 5989 pigs, 1362 horses, 360 donkeys and 2477 rabbits [73].

3.5.13. Reduction of Direct Subsidies

By implementing AVS installations, the production of green electricity will increase, the demand for water from crops would be reduced and the supply of local agricultural products would increase. Therefore, the administration would save on subsidies for various concepts of energy production. The Central State Administration covers the costs of the extra cost of electricity generation in non-peninsular territories, which are outside the Iberian Peninsula (such as the Canary Islands) [74,75]. There are also irrigation subsidies for agricultural farms in the Canary Islands from the Central Government [76] or the regional government [77]. There is a decrease in aid for the transport of goods from the national and regional governments, and it should be noted that this affects specific items for the agricultural sector [78,79].

3.5.14. Contribution to EU Decarbonisation Objectives

In recent years, the fight against CC and the objective of sustainable growth is gaining prominence on the international agenda. Complying with the reduction in polluting emissions depends on a sufficiently large number of countries adopting efficient mitigating measures aligned with international agreements. International cooperation is essential to implement the commitments made under these agreements, to carry out the energy transition and to curb CC [80]. Both the G-20, which includes the largest GHG emitters among its members, and the International Monetary Fund are increasingly incorporating climate considerations into the exercise of their respective functions. The European Union (EU) is an active part of this global commitment, in which capacity it exercises a certain leadership, and is pursuing increasingly ambitious objectives. In compliance with the European Green Deal, the EU has given legal status to its climate neutrality objective in the European Climate Law and has launched several pioneering policies for its implementation, such as the Objective 55 package of measures [81], which requires the achievement of the climate objective of reducing EU emissions by at least 55% by 2030. EU countries are working on new legislation to achieve this objective and make the EU climate neutral by 2050.

Since 16 January 2024, shipping companies covered by ETS 1 for maritime transport must monitor their emissions based on an approved monitoring plan [82], imposing much more restrictive conditions than the International Maritime Organization (IMO) regarding the schedule for reducing emissions from ships, introducing them into emissions trading, given how well it has worked in other sectors.

The European Union is also aware of the emissions associated with agriculture [83], so this type of installation could contribute to reducing emissions from any agricultural activity, ahead of a directive that will soon be in force that will restrict its GHG.

Regarding the fact that agrovoltaics would reduce the carbon footprint compared to photovoltaics currently being carried out on land, it should be noted that agriculture in Europe has a CO_2 capture capacity of 1.96 t CO_2/ha/year [84]. Of the hectares that are currently abandoned, 10% will be converted into agricultural farms, thanks to AVS. This would allow the absorption of 3481 t CO_2/y.

The CO_2 emissions caused by container transport, and we will consider this modality for food, are reported, by the EU, as being 32.1 g CO_2/t/Mile; however, for the transport of liquid fuel ships, they are 21.2 g [82]. The implementation of 982 MW photovoltaic assumes an average value of 1100 h/year. According to the data of the Gran Canaria electricity grid and its consumption in tons of fuel and the energy produced through this technology [84], it is obtained that the transport of 229,668 t fuel/year would be avoided. As indicated, all the fuel used in the Canary Islands comes from Nigeria, 4000 miles away. Therefore, in this concept, only the emission of 19,476 t CO_2/y would be avoided.

Knowing that Gran Canaria imports 727,472 t food/y annually, the vast majority comes from mainland Spain, 900 miles from Gran Canaria; with agrovoltaics, food autonomy would be increased by 3.15%. Considering only the emissions avoided from the port-to-port transport of that quantity of food, 827 t CO_2/y would be avoided. The truth is that apples from Italy and Chile, pears from Holland and Belgium and kiwis from New Zealand arrive on the island, so the assumed data is very conservative.

The energy produced by agrovoltaics will not have to be generated by the island's thermal power plants. Based on the data provided in document [85], the emissions associated with this generation of 0.75 tCO_2/MWh have been considered. This will have an impact of 810,150 t CO_2/y.

Adding up all these saved emissions, this corresponds to a reduction in emissions of 833,935 t CO_2/y due to the implementation of AVS on 10% of the abandoned agricultural land on the island.

3.5.15. Contribution of 11 of the 17 UN SDGs for 2030

On 25 September 2015, world leaders adopted a set of global goals to eradicate poverty, protect the planet and ensure prosperity for all as part of a new sustainable development agenda (see Figure 5). Each goal has specific targets to be achieved by 2030 [86]. We will review the different objectives set; to achieve sustainable development, it is important to consider in any strategic policy the fulfilment or non-fulfilment of the same. This issue has been analysed in other papers, obtaining similar results [7].

Figure 5. Global goals affected by agrivoltaics. Source: Department of Economic and Social Affairs (United Nations [86]).

Objective 1. End poverty: By producing wealth, local food and energy, and by creating jobs, we contribute to reducing the existing poverty on the island. This opportunity is related to of the global goals for sustainable development (GGSD).

Objective 2. Zero hunger: By producing food and creating jobs, some of them skilled, we can reduce the food needs from abroad, lowering the prices of certain products. This opportunity is related to Sections 2.1.1, 2.1.3, 2.2.3 and 2.2.6 of the GGSD.

Objective 3. Good health and well-being: Local and fresh products offer several advantages, including being tastier and more nutritious, cheaper and more ecological. Then, by promoting the production and consumption of local products, we will be improving the health of the local population and that of the tourists who come to visit us. This opportunity is related to Sections 2.1.3 and 2.2.3 of the GGSD.

Objective 4. Quality in education: While, in the EU, the school dropout rate is 9.6%, in Spain, it is 13.6%, and in the Canary Islands it is 15.1% of students. Promoting teaching in this area at all levels, as explained in Section 3.1.1 of the GGSD, will create new employment opportunities, with the possibility of practical, manual and theoretical work, as well as research.

Objective 6. Clean water and sanitation: Water is a very scarce commodity on the island, which is highly populated. A total of 62% of the water used comes from desalination [87], but there are many fields of crops and population at high altitudes. The town of Artenara is located at 1270 m above sea level, and given the difficulty of desalinating water on the coast and raising it to such an altitude, the current island hydrological plan does not contemplate the need to raise desalinated water to an altitude higher than 300 m [88], with rainwater and aquifer water currently being sufficient to supply from that altitude upwards. The truth is that the outlook is that precipitation with CC will decrease, reducing 20% by 2100 [89]. It is a complex challenge to materialise and energise, although most of the population lives on the coast. In Gran Canaria, fog collectors capable of collecting up to 250 L of water per m^2 per month have been presented. This opportunity is related to Sections 2.1.8 and 2.1.12 of the GGSD.

Objective 7. Affordable and non-polluting energy: A total of 20.6% of the electricity generation in Gran Canaria is from renewable sources, according to data from 2021. Speaking at the archipelago level, electricity consumption is only 37.00% of internal consumption, and this comprises 65.27% of the total energy consumed on the islands, since the fuel service to ships comprises 34.73%. Therefore, only 2.69% of the global energy is covered from the Canary Islands by renewables [65]. This implies that we are very far from decarbonisation by 2050, and without a doubt, AVS must appear in the list of various solutions, as all of them will be needed to get closer to this objective. This opportunity is related to Sections 2.1.14, 2.2.1 and 2.2.7 of the GGSD.

Objective 8. Decent Work and Economic Growth: In any case, local wealth is generated by energy and food production, which improves the economy and increases employment. This opportunity is related to Sections 2.1.1, 2.1.4, 2.1.15, 2.2.4, 2.2.9 and 2.2.10 of the GGSD.

Objective 9. Industry, innovation and infrastructure: A technology not already implemented on the island would be introduced, and it will be necessary to provide power evacuation infrastructures, to capture this energy and direct it to consumption centres. In this sense, the Spanish electricity grid (REE) is advancing in investment for lines and substations, in areas with high energy resources, in order to provide an outlet for the generated power [90]. This would promote companies that supply devices to serve and maintain this type of installation, both photovoltaic and for crops, and everything that entails: electrical networks, seed houses, packers and distributors of agricultural products, mechanical structure companies, etc. This opportunity is related to Section 2.1.9 of the GGSD.

Objective 12. Guarantee consumption and production patterns: To date, the Central Government subsidises the production of electricity using oil in the Canary Islands, recognising the cost of an additional 50.8 MW for the island of Gran Canaria to guarantee the supply of electricity [74]. In addition, the increase in the costs of the production of electrical energy in the isolated electrical systems of non-peninsular territories, such as Gran Canaria, will be compensated out of the General State Budget, according to Law 24/2013, of December 26, of the electricity sector. The amounts and forms of payment for the year 2019 can be seen in the following official document: "*Resolución de 18 de julio de 2023, de la Dirección General de Política Energética y Minas, por la que se aprueba la cuantía definitiva de los costes de generación de liquidación y del extracoste de la actividad de producción en los territorios no peninsulares para los grupos titularidad del grupo Endesa correspondiente al ejercicio 2019*" [75]. These costs assumed by the Central Government of Spain would be reduced, as more energy would be generated through renewable energy in the event of a strong implementation of AVS, since the costs are associated with installed power, which would not change, as well as the energy produced, the latter being the concept that would fall significantly.

Furthermore, as has been indicated, more than 80% of agricultural products comes from abroad. This causes these products to have a larger carbon footprint, due to transport, and a shorter shelf life, due to the time stored and the transport of goods. For this reason, among others, the Canary Islands remains the second community in Spain in terms of food waste in the country [91]. The use of waste from agricultural activity, to give it value, would reduce the demand for external fertilisers. This opportunity is related to Sections 2.1.8, 2.1.12, 2.1.15, 2.2.3 y 2.2.13 of the GGSD.

Objective 13. Action for the climate: Increasing renewable energy and local food production will significantly reduce emissions, as already mentioned, for four reasons. It will reduce the consumption of oil to generate electricity, reduce the transport of oil and food from abroad to the islands and increase crops. This opportunity is related to Sections 2.1.2, 2.1.5, 2.1.7 and 2.2.2 of the GGSD.

Objective 15. Life of Terrestrial Ecosystems: Cultivating in AVS fields takes care of the soil and biodiversity, keeping the soil alive and avoiding the need to occupy more land to generate or cultivate. It has already been said that the Canary Islands are part of a biodiversity hotspot, because they are isolated from the continent, with a high rate of endemism, and it has also been said that implementing AVS fulfills the objectives of the current CAP, which proposes maintaining a minimum of 4% of land fallow or in reserve for biodiversity [51,52]. This opportunity is related to Section 2.1.10 of the GGSD.

3.6. Weaknesses

AVS prevent an organisation from performing at its optimal level. They have the potential to reduce progress or provide an advantage to other competing activities. It is necessary to minimise weaknesses and analyse how these systems can be improved 3.5.1. C of the GGSD

3.6.1. Conflict of Interest When Mixing Two Unrelated Activities

A symbiosis between the two activities is necessary, with each one having to adjust and adapt to the other. It must be considered that both occupy the same physical space and solar radiation, so a balance must be achieved between the crops to be planted and the type of installation to be used, since, as indicated by the CAP, it is a commitment to perform crop rotation. Areas more exposed to the sun and more covered areas could be left, being able to plant a different crop in each area based on the radiation required by it. In the case of using agricultural machinery, its mobility must be considered, as well as the free space to be left around it or the height of the panel structure. In the case of accompanying livestock, a similar analysis must be performed. On the other hand, electricity and water do not get along very well, with water being something common and necessary in a plantation. Once a photovoltaic installation is carried out, the plot will be conditioned in its use, due to the difficulty of changing its physical configuration. Although we have read about fixing the structure using helical anchors, to affect the ground as little as possible [92], in any case, it is not designed to be moved. Therefore, we must think carefully about what we want to develop in the following years.

3.6.2. Visual Impact on the Landscape

There are agricultural lands on the islands with a high landscape value; it is understood that there must be social acceptance of these developments in those areas. However, agricultural land can also be found in places with a completely degraded landscape. We think that the administrative body that plans the territory will establish the possibilities of occupying the land. It should establish locations where the landscape is preserved, prohibiting this type of installation.

3.6.3. Need for Nearby Electrical Consumption

Ideally, the transportation of electricity should be avoided, and the energy should be generated close to the consumption points. Typically, agricultural areas do not have a high electrical demand. In this case, we are dealing with a relatively small island. When the crops are relatively close to urban centres, in any case, within the initial study, it is essential to consider the use of the energy to be generated, or the evacuation routes. It is important that there is a platform for the owners to communicate with similar ones, in order to be able to propose collective evacuation routes, as well as to get in touch with the electricity distribution company, to analyse the existing planning and opportunities.

3.6.4. Weakness of Power Lines in Agricultural Areas

In general, until today, agricultural areas did not have relevant facilities, neither for generation nor for consumption, so the lines that run through these areas are weak. If several projects of this type were to be concentrated, it could cause problems with the evacuation of the power produced, which could lead to limiting the installations to be carried out, or forcing the installation of installations isolated from the network. Investments will have to be made in the extension of evacuation lines and/or the use of algorithms that allow the use of the energy produced [93].

3.6.5. Immature Technology

In 1981, the journey of this technology began, and nothing is standardised today; the methodology of these projects is changing. It is necessary to make it known and to standardise it. To expand this technology, it is necessary to obtain support from the administrations, investment funds from those that decide to support it and the will of the owners of farms.

3.6.6. Risk of Accident or Reciprocal Breakdown

Agricultural work often involves moving earth and digging, but there will be underground electrical cables, as well as the presence of vegetation that could lead to a fire outside the farm, which would not happen if the panels were there alone; this electricity could cause hot spots. Distances, spaces and measures must be considered in the design to ensure that an action on one of them causes the least possible harm to another. Water and electricity will have to coexist on the same land, with the appropriate precautions.

3.6.7. Loss of Flexibility in Agricultural Exploitation

Once a structure for a PV installation is installed on agricultural land, the use of said land will be conditioned throughout the useful life of the installation, about 25 or 30 years.

3.6.8. Soil Reclamation

The desertification of the island of Gran Canaria is a major problem. To implement agricultural use in a large part of the land designated for this, a soil regeneration plan must be developed. This entails an increase in investment, but reclaiming the soil is a social necessity.

3.6.9. Installation and Maintenance Costs Are Higher than for PV Installations on the Ground

It is true that, as the panels must be separated and raised, they are more expensive installations than conventional ones on the ground, due to the structures and the need to work at height, which makes their execution and maintenance more expensive. The existence of both activities sharing the space will imply a limitation in the work to be carried out in each of them.

3.6.10. Crops Intolerant to Shade

Vegetables that produce fruit with only one flower, such as peppers, tomatoes, cucumbers and pumpkins, are less tolerant of shade areas, so they will be planted in full sun, resulting a priori in them having limited compatibility with AVS. Therefore, before making any decisions on implementation, it is important to think carefully about what is being given up in this area.

3.6.11. Weak Political Instruments

The lack of legislation and appropriate support and the prohibitive amounts of initial financial commitment required are the fundamental causes of the slow start. In Gran Canaria, there are no installations of this type. All current photovoltaic installations are being installed directly on the ground, bypassing the planning that exists on the ground, by declaring these installations of public interest [15].

3.7. Threats

These are external situations or circumstances (political, economic, social, technological factors, etc.) that could occur in the future and that may constitute a risk or negatively affect the activity.

3.7.1. The Price of Electricity and Curtailments

The price of electricity falls at midday, and the prices of solar Power Purchase Agreements (PPAs) have decreased in Spain in recent years.

The number of photovoltaic installations, many of them relying on self-consumption, means that demand falls at midday, and thus, the price of electricity on the grid has been reduced in recent years during the hours of the greatest solar production. This phenomenon is called the duck curve, due to the new shape that the electricity demand curve takes [94,95].

In Spain, the price of electricity is the same for the entire country; solar photovoltaic continues to be the technology that is experiencing the greatest growth, with an installed capacity in Spain of 25,549 MW at the end of 2023 [96]. This has had an impact on the sale price of electricity, in the central hours of the day. When PV production is maximum, the price paid for the generation of electricity to the grid falls greatly, reaching zero on some days, as can be seen in Figure 6, with the market price of electricity between 11:00 p.m. and 16:00 p.m. being EUR 0.0/MWh [97].

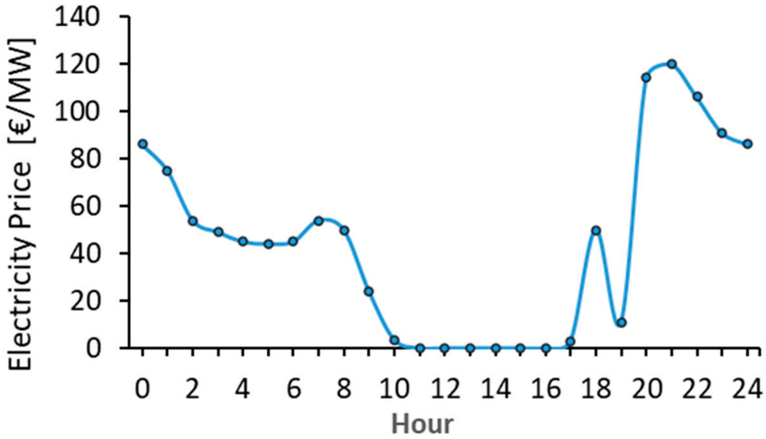

Figure 6. Spain electricity price, 28/09/2024 [97].

Power Purchase Agreement (PPA) prices are falling across Europe, except in Romania. The drop in component prices from China is having a strong influence on this. Spain has the lowest PPA price in solar power in the whole of the EU. This is undoubtedly bad news for all photovoltaic generation installations [98].

Another situation that occurs on certain occasions, when the grid operator forces part of the renewable generation to be disconnected, due to the limitations of the system to be able to absorb said production, is called "curtailment", which means losing the energy produced, and not being able to charge the generators for it, so despite the existence of solar resources, their installation is disconnected. From January to March 2023, 113 GWh of renewable energy has been limited in Spain, 36.8% more than in the whole of 2022 [95]. This phenomenon also occurs in Gran Canaria, and even more so considering that the production must be consumed entirely on the island, because it is an isolated system. This situation is a major problem for electrical transport systems when a high percentage of energy generation from renewable sources reaches the grid [40,99–101]. The following issues appear as buffers for this situation:

- Expansion of the transmission capacity of the traditional grid to reduce congestion: The possibility of interconnecting Gran Canaria with other islands such as Fuerteventura or

Tenerife has been analysed [102,103]. The electrical system would become larger and could be regulated more easily, allowing the integration of greater renewable power.

- Participation in a real-time energy market to buy and sell energy called the Western Energy Imbalance Market (WEIM): According to the EIA, in 2022, 10% of curtailments in California were avoided, thanks to trading in this market [104]. In Spain, with the current electricity pricing system at a national level, it will be difficult to have systems like this, since the peninsula is an electrical system, and almost all the Canary Islands are independent systems. The Canary Islands are not interested in charging electricity independently, since the generation systems on the islands are much more expensive than in the rest of the national territory [105], and consumers throughout Spain pay the same price.
- Greater implementation of flexible solutions to the system through energy storage in rapid response systems, such as batteries, to respond to demand.

In this sense, a pumping station is under construction on the island to improve the penetration of renewables [106], promoting flexible loads of all kinds, especially Power-to-X [107].

3.7.2. Water and Fertiliser Consumption

Agricultural facilities require two high-cost products, such as water and fertilisers. Fresh water is expensive on the island, since it is scarce; as indicated above, 50% of the water used on the island is desalinated, in fact, Gran Canaria is the place in the world with the highest number of desalination plants per km^2. Fertilisers currently come mostly from abroad, and emissions from transport must be added to those produced in their production. In fact, NH_3 production is responsible for 1.8% of global emissions. In 2023, the Canary Islands consumed 2193 tons of nitrogen fertilisers from abroad [108].

3.7.3. Loss of State or CAP Aid, Due to Not Being Recognised

As the AVS is not a conventional agricultural facility, it could lose the aid assigned to this type of infrastructure by the Spanish State or the European Union. There are countries that consider the AVS as one of the essential strategies to achieve their decarbonisation objectives [109].

3.7.4. No Specific Regulatory Legislation for the Sector

To date, the projects that have been carried out have been based on the DIN SPEC 91434:2021-05 [72], but the truth is that today, there is no regulation that even names this technology in Spain. It would be convenient if there were soon, and if this type of installation could be covered under a specific standard, or in some new section of an existing standard.

3.7.5. New Pests Due to the Shade Created

By changing the conditions of the natural environment, and causing partial shade with irrigation, the evolution of some plant species could be triggered, as could the implantation of some pathogenic agent, of the bacterial, fungal, or moss type, that affects the crop to be planted, requiring the use of new chemical pesticides. Currently, much progress has been made in ecological pesticides, including the use of insects to combat certain pests [110].

3.7.6. The Presence of Crops Around the Panels Can Increase Maintenance Work

AVS encourages a greater presence of birds that defecate on the panels, and the growth of plants that cause shade on them, due to the presence of water next to the electricity and the roots next to the buried electrical conduits. These are some of the new challenges to counteract when designing. It should not be forgotten that in addition to the birds that live in the Canary Islands, 300 different species of birds pass through the Canary Islands during their migration between Africa and Europe. This should be considered in the design and location of the plant, keeping it away from wetlands.

3.7.7. Variability in Income and Expenses

AVS implementation can be limited by the extra cost of both farms sharing space and by the fluctuating prices of both products: vegetables and electricity. Policies must appear that prioritise the general interest over other installations that damage the environment, even if only by occupying fertile and productive soil, or that are unsuitable for other human activities.

3.7.8. Competition with Imported Agricultural Products

On many occasions, the market is filled with external agricultural products, lowering sales prices and making it impossible to continue with the local cultivation of that product due to low competitiveness, for the following reasons:

- Lower production costs
- Subsidised products
- Imported products have regulations and production standards of origin, which are less demanding than local ones [111].

In all these cases, unfair competition occurs that affects the objectives of decarbonisation, food security and national vulnerability.

3.7.9. Correct Environmental Management of Solar Panels at the End of Their Useful Life

Currently, between 95 and 99% of the components of solar panels can be recycled, except for the polymers used in the glue of the components at the end of the useful life of an installation, which is between 25 and 30 years. Directive 2012/19/EU on waste electrical and electronic equipment establishes how to carry this out, and is transposed into Spanish legislation [112,113]. There are new technologies that include other materials such as lead, cadmium, selenium, gallium, indium, etc. In any case, since there is no recycling plant on the islands, it will be necessary to take charge of their transfer to mainland Spain to give a second life to all these materials.

As mentioned in Section 2.4.1 of the GGSD, since photovoltaic production follows the schedule of available solar radiation, it would be interesting to be able to combine it with storage, the most common storage system being electric batteries. These elements could introduce chemicals that are difficult to handle and manipulate in greater quantities, and require them to be transferred to recycling plants. In addition, their useful life is significantly shorter than that of the panels, so it would be convenient for the administration to control the entry and use of these products.

3.7.10. Robberies

Private property is not respected, in fact, we can frequently find news of theft in different properties on the islands. Life is very expensive, and the properties are generally poorly guarded [114], so investing in a generation system and leaving it on a property without a surveillance system in Gran Canaria is a great risk.

3.7.11. Risk Due to Adverse Natural Situations

As already mentioned, the last tropical storm that has passed through the Canary Islands was the Delta in 2005 [56], Although it is true that on the island of Tenerife, it brought down a power line, which left part of the population without power for several days, its effect on the cultivated land, and more particularly, in Gran Canaria, was nothing to highlight. Although it is true that with the advance of CC, these episodes could be repeated, with even greater force, it has a very low probability of happening [115,116].

Fires have become very prevalent on the islands. High temperatures and dryness favour their occurrence, and while the last major fire in Gran Canaria was in 2019, fires are frequent every year [117].

We must not forget that this is an island of volcanic origin; however, on the island of Gran Canaria the last eruption was about 2000 years ago. Volcanic activity on the islands exists today, but increasingly further into the Atlantic Ocean, that is, further away from the coast of Africa. The last two eruptions have been on the islands of El Hierro (2012) and La Palma (2021) [118].

In the last millennium, 11 Tsunamis have affected the Canary Islands, but since the 15th century, there have been none recorded. The probability of this happening is low. It is important to consider that most of the population is concentrated at low altitudes [119].

In the face of all these natural risks, including robberies, it is advisable to secure the facility.

All internal and external, positive and negative characteristics have been analysed, focusing on the island of Gran Canaria, Spain and Europe, accounting for the territory's reality and its environment. Although general aspects have appeared, so have many particular factors.

4. CAME Matrix Solution

Once the SWOT matrix has been applied and worked on, the CAME analysis must be applied. The CAME matrix tries to correct weaknesses, adapt to threats, maintain strengths and exploit opportunities.

Now, the matrix will consist of mixing internal and external aspects, creating the following interactions:

- Strengths and Opportunities: Use strengths to maximise opportunities.
- Strengths and Threats: Use strengths to reduce threats.
- Weaknesses and Opportunities: Reduce weaknesses to develop opportunities.
- Weaknesses and Threats: Avoid threats by reducing weaknesses.

4.1. Strengths–Opportunities

4.1.1. Create an Organ of a School of Designers of Agrovoltaic Solutions (EDSA)

Dependent on the Agricultural Training School ECA and Las Palmas de Gran Canaria University ULPGC, both already existing on the island, knowledge will be transmitted to future farmers, economist and engineers, allowing for the creation of a qualification that goes deeper into this practice. In order to be able to carry it out in the most efficient way, since it is not enough to know the fundamentals, it must be linked to the reality of the place. We see another article that deals with the same situation in Vietnam [8], finding many similarities in the aspects of improving soil efficiency, fighting CC, reducing emissions and promoting the study and research of this science; however, within the threats, adverse weather events are included, such as snow. The following are episodes that, in our latitude, it does not make sense to consider:

- Creating lines of training and research based on the needs at all levels, from vocational training modules to university degrees (bachelor's and master's). With this action, knowledge is created at all levels, both at the level of assembly, operation and maintenance and at the level of researching certain practices or solutions to specific problems that may arise.
- Analysing the current crops in Gran Canaria, including tomatoes, bananas, vegetables, potatoes, cereals, legumes, vines, citrus fruits and subtropical fruits, conducting a study of their water, climate, altitude and solar radiation needs depending on the type of crop, so that the implementation of each of them could require specific and particular solutions for each condition.
- Analysing livestock herds on the island, studying the possible optimal solution for each type of animal, terrain and location. The needs for sun and space must be considered, which may condition the installation in each case.
- Analysing of micro-climates. The island of Gran Canaria is almost circular with a diameter of 50 km, so very small, but given its altitude of 1956 m, and the dominant trade winds, the climatic conditions change a lot in a very small space. Average radiation levels are falling due to the presence of the natural phenomenon known as "donkey belly", which is common in the northeast of the islands, exceeding 65% of the days across many years [120,121].

- It is, territorially, a very complex space due to its orography, high population density, multitude of protected areas and the distribution of the electricity transmission and distribution grid throughout the territory.

Clients, individuals or companies interested in setting up an AVS installation do not have to know about this; it is not valid for them to have a study carried out outside, where the local conditions that the installation will encounter have not been considered at all. Therefore, the following services must be provided:

- Advising on the creation of self-consumption installations and energy communities, putting interested parties in contact with electricity distribution companies and the local Department of Industry.
- Advising on environmental aspects, mitigating the negative aspects and promoting the positive ones, and implementing projects to that improve profitability at an individual or community level.
- Providing information on the most economical and profitable electrical solutions, supports and anchoring of the structure, cable channelling, electrical connection to the grid, position and orientation of panels, monitoring systems, etc.
- Analysing and introducing improvements; a complete monitoring system of the facilities and the crop is essential. This includes monitoring the humidity, irrigation, irradiation, growth, product, etc.

i. Tax deductions or financial aid.

Projects that produce social or environmental benefits have subsidies or tax deductions, depending on the time and place, and they are some of the tools that administrations must defend the common good. A series of items have been established that should be considered to receive these aids or deductions:

- Creation of local employment or contracting of services that generate them.
- Care, protection and restoration of the soil. It must be considered that the soil is treated as a natural capital that must be conserved.
- Creation, care and service to promote the growth and maintenance of biodiversity. It is a social responsibility to maintain these spaces and create ecological corridors between the different protected spaces that allow living beings to interact.
- Reduction in the carbon and water footprint of the activity to be carried out. All the devices that are part of the process will be considered; it is the only way to encourage achieving real decarbonisation, dragging the supply of fertilisers and water and evaluating the implementation of systems that minimise their need.
- Creation of policies that support the production and consumption of zero-kilometre products, as well as reducing regulatory barriers and offering incentives.

ii. Establish agreements with banking entities and investment funds.

To facilitate the economic flow to this type of projects, EDSA will carry out a prototype installation and show the results that will serve as an example to financial entities. These companies will be put in contact with potential entrepreneurs, advising them on the implementation of the business plan [122].

iii. Establishing a meeting point between investors in energy storage systems.

Whether collective or individual, it would make it possible to manage the energy produced. EDSA will contact the representatives of energy companies and storage systems, to act as consuls for AVS installations to be built on the island. The union of these two activities could form a virtual power plant (VPP).

4.1.2. Analyse the Possibility of Implementing an Attached Processing Plant (Power-to-X)

An attached processing plant provides added value to agricultural production. It can serve as a flexible demand, or some type of Power-to X-system, with which this non-manageable electrical energy could be converted into heat or cold energy to be used in a process related to food elaboration or preservation. There is also the possibility of obtaining gas or combustible liquid to be used in agricultural machinery, or to be sold as a by-product. In the case of producing hydrogen, carbon could then be extracted from agricultural waste, obtaining methanol, or the compound considered at any given time. This flexible load would allow consumption to be adjusted to optimise the operation of the plant, maximise economic benefits, or allow management services to be offered to the electrical system, in any case, achieving greater energy autonomy.

4.2. Strengths–Threats

4.2.1. Create a Local Representative Body for This Type of Installation

EDSA will conduct a search for similar organisations in the rest of Spain and Europe, to defend rights, and collaborate in the preparation of specific regulations and standards for the activity. With this representative body, contact is maintained with the European, national, autonomous and island administration, to promote installations of this type and establish common objectives, proposing opportunities for subsidies or tax reductions in the exercise of the activity. In Italy, there is already an association, The Italian Sustainable Agrivoltaic Association (AIAS) [123], and in Denver (USA), there is a congress in 2024.

4.2.2. Analyse New Forms of Agrovoltaic Development

At EDSA, new lines of research will be drawn up to transfer AVS to other environments, such as parks, gardens and urban orchards. Additionally, proposals will be developed that, at a reasonable cost, can minimise the possible impacts of this technology, overcoming the problems and limitations that it would encounter.

4.2.3. Ensure the Economic Viability of the Facilities

We need to analyse the ways to obtain fertilisers, water and irrigation systems, individually or collectively. The island has a strong lack of water [89], so it is essential to have a supply of water with a projection for the future. Currently, there are desalination plants on the island, using renewable energy as a source of energy; in these cases, all the water production is used for the irrigation of the cultivated lands [52].

Due to the large amount of fertilisers (F) that must be imported for local consumption, in 2019, 4785 t of nitrogenous F, 1359 t of Phosphate F and 3024 t of Potassium F were imported to the Canary Islands [124], the possibility of creating the shortest possible journey in the import of fertilisers must be studied, taking into account that in front of the Canary Islands, there are some of the largest phosphate mines in the world, located in Morocco [125]. Another possibility is to propose circular economy techniques and recover phosphates from wastewater treatment plants at a local level. Likewise, techniques are being put into practice to reduce the need to use this type of fertiliser, whose market has not stopped growing worldwide in recent years; it seems that this market shows trends towards a more sustainable and rational use [126].

With respect to nitrogenous F, there is currently a Spanish company that is producing green nitrogen fertilisers [127] from air and green H2. Several facilities of this type could be grouped together, to use part of their energy in the production of green F, water desalination and other products [128].

4.2.4. Implement Mechanisms to Avoid the Duck-Curve Effect

It is necessary to match generation with electricity demand through individual or collective installations. The massive implementation of photovoltaics in the grid is causing many problems around the world. These problems are named in the articles [94,95], and the possible solutions to this phenomenon include the following:

- An energy storage system, where surpluses and shortages due to the oscillation of the solar resource can be managed.
- A rolling reserve, or fast-response storage systems, able to respond with their inertia to variations in frequency.

- Other clean sources: Unlike solar or wind energy, sources like nuclear, hydroelectric, biofuels and geothermal can operate continuously and fill in the demand gap.
- Demand management: It is possible to try to change the distribution of electrical demand, using prices or other instruments, to shift loads or flexible generation systems towards those hours of high generation.
- Changing the orientation of solar panels: More vertical photovoltaic systems can be installed, and E-W orientation, whose production curve is quite different from the conventional one, affecting the duck curve less, overlaps with a greater demand [129,130].

Of these tools, it will be necessary to see which ones would be more viable to implement in the island's electrical system and to what extent, analysing them and promoting the idea that these measures are carried out, from an economic point of view and one that is compatible with the national and EU electrical market. This work would be carried out by a division of the EDSA, dedicated to this matter.

4.2.5. Influence of New Pests

A change in the conditions of the natural environment could lead to the presence of new plant pests, insects, fungi, prototists or monera, which could colonise the crop, or disappear due to the shadows created by the panels. A team will be dedicated to studying the possible effects of this change.

As well as ecological ways to counteract them, and to optimise the management of plant development close to the panel structures, there is knowledge available at the ECA, a centre dedicated to teaching agricultural work, specialised in the use of pesticides and knowledgeable about EU regulations regarding their use.

Phytosanitary products are pesticides used in agriculture and forestry to protect crops and other plants from pests and diseases, but excessive use or improper use of these can have a negative impact on soil, groundwater and agricultural biodiversity, and indirectly, can also have harmful effects on human, animal and plant health, which is why the use of these products is subject to rigorous regulation through EU legislation on pesticides [131].

Whenever possible, and as a first option, biological control will be used, which involves the mass production and release of natural enemies, such as parasitoids and predators, to combat pest-causing insects in an environmentally friendly manner [132], establishing close collaboration with the ECA, in order to be able to use this way of working to control potential pests.

A priori, agrovoltaics should be implemented progressively in the different crops and areas, and the results should be monitored much more carefully in this first phase, given the nature of this type of installation. And the effects that are observed should be observed, before carrying out a massive implementation. In any case, the crops will have to be monitored for the appearance of new pathogens, and this task would also be carried out by a division of the EDSA.

4.3. Weaknesses–Opportunities

4.3.1. Tax Deductions for Those Plots That Aim to Increase the Productivity of Anthropised Soil

It is necessary to avoid having to degrade more territory, because it is true that doing so is difficult and increases the OPEX and CAPEX of both activities, by using the same land. It is true that with AVS, the productivity of the soil is increased, by making two activities compatible on the same plot, safeguarding the anthropisation of more soil for this reason, but the economic cost of both activities that must be used during installation and maintenance is greater, compared to the cost of using the soil for each single activity. Because the actions to be carried out must be respectful of each other, it is up to society to bear this extra cost, because the soil is being protected, thanks to this effort. It can be oriented in two ways, by benefiting crops that implement AVS, or by penalising those that do not, i.e., photovoltaics at height and sharing the soil with agriculture is more expensive than on the ground directly, so they should not receive the same payment. The payment for the first option can be increased, or a charge can be added to the second option. Or, as has been done in Italy, where the government has directly prohibited photovoltaic installations on agricultural land [133]. One of the autonomous communities of Spain, Aragon, has proposed charging a tax on those photovoltaic installations that occupy land, but not on those on roofs or sharing other uses [134].

4.3.2. Supporting Those Projects That Must Try to Minimise Their Impact

The administration must assume that there are places where, for various reasons, the crop to be used can be any crop, and the AVS installation can also be used, but there are special areas, mainly due to their high landscape value, for example la Geria in Lanzarote [135], where the crop must be the vine, and the landscape has a high value. These installations could be dispensed with, or a higher cost could be assumed, creating natural visual barriers, using smaller installations, or using transparent panels and structures integrated into the environment. In any of these cases, the cost of these installations would skyrocket. Therefore, the tax aids or exemptions must be in accordance with these measures that must be adopted.

4.3.3. Financial Aid or Tax Advantages for Soil Restoration Work

Those lands that try to return to agricultural and solar exploitation must be supported. There are many types of aid provided for work that promotes agriculture, because it is an activity that provides many collateral values, such as creating employment, producing zero-kilometre food, and maintaining the domestic biodiversity of the islands. There are four native goat breeds: Majorera goat, Northern Tenerife goat, Southern Tenerife goat and La Palma goat. It is essential that man not only preserves wild biodiversity, but also domestic diversity [136].

Creating habitats that improve the life of wild biodiversity, generating jobs and conserving the soil and traditional landscape are also part of the support of the culture and traditions that are sustained as long as the activities of this group are preserved [137].

As has been seen, this island is subject to strong desertification, which would be stopped with the entry of the land into exploitation, so it would be reasonable to provide bonuses for this concept. There are also carbon credits [138]. There is a lot of spending on the island to recover natural soil, and reforesting in order to stop this trend [139].

4.3.4. Technical Advice and Occupational Safety

Two types of work will be undertaken in the same space, so both activities will interact, creating new occupational risks. Farmers will probably not be used to having to navigate underground electric cables within the crop itself, nor will electricians be used to working at heights and with the presence of water due to irrigation. EDSA must have a group that analyses both activities and completes a qualification aimed at personnel who can safely carry out their work activity in this type of installation. Until yesterday, both activities were analysed and their risks defined separately [140,141].

4.3.5. Support for the Development of This Type of Installation by Reinforcing Evacuation Lines and Transformation Centres in Order to Be Able to Take Advantage of This Resource

In Spain, the transport of electrical energy is a monopoly, and the only company that does so is "Red Eléctrica de España", a public–private joint venture that, among other tasks, is managing the country's energy transition. Therefore, they are making large economic investments in electrical transport infrastructures that allow the energy generated in areas with large natural energy resources to be transported to areas with a high demand for this resource. In the Canary Islands, they have reinforced the electric grid with new lines and substations with greater capacity in those areas where a high concentration of on- and off-shore wind farms is expected. In parallel, the same provision should be made for the large-scale implementation of agrovoltaic systems, reinforcing lines and substations in production areas [90,142].

Likewise, the company that distributes electricity on the islands, EDISTRIBUCIÓN Redes Digitales, S.L.U, is betting on the digitalisation and monitoring of the facilities, which allows for the improvement of data collection, alarm and protection systems to adapt the facilities to the new challenges presented by smart grids, and thus, be able to manage the distributed generation of the new renewable energy parks, self-consumption, and the progressive implementation of electric vehicle charging points [143].

4.4. Weaknesses-Threats

4.4.1. All the Negative Aspects of This Technology Will Be Studied

AVS is a technology that has been expanding throughout the world for years, and it will be essential to analyse and study other existing facilities, to take or discard ideas or models while trying to minimise all the deficiencies or weaknesses that are observed in these facilities, increase the compatibility between both activities and lower the costs of the facilities and adapting them to the reality in which they are found.

4.4.2. Contact with Other Facilities Around the World to Share Know-How

This should be performed not only from a technological point of view, but also from an administrative point of view, analysing the support measures that are used and are applied in other similar or alternative environments, and mainly, at both a national and a European level.

5. Discussion

We compare this study with studies in other countries. In both cases, the same SWOT methodology has been used.

In the study carried out in Ethiopia [6], the effect of the implementation of AVS installations on the Sustainable Development Goals is observed, obtaining that the 11 ITEMS collected here are affected, plus objectives five and 10. The reality in Ethiopia is very different from that existing in an EU territory, fully electrified and with policies at all levels of gender equality currently implemented, as well as social protection. Therefore, the possibility of influence of this type of installations by themselves, on these two objectives, has been dismissed. Coinciding in the remaining 11 that we share, despite having similar aspects, the realities between territories are very different, which makes more than 80% of the study different. For example, in Ethiopia, the improvement in Education is based on the fact that it would increase the availability of electricity, enabling lighting for extended study hours and access to charging for computers and other technology, which is logical in a territory with scarce electrification. In a fully electrified territory, this aspect is supported by the opening of practical studies from two existing local education centres, creating specific studies between both to facilitate, expand and particularise the local implementation of these systems at different scales from vocational training to research studies.

There is another study carried out in Vietnam [8]; however, the difference in environments is so noticeable that when considering the strengths, weaknesses, opportunities and threats, the coincidences do not exceed 5%, which confirms the statement that these analyses are like a tailor-made suit; just as the procedure is the same, each reality must be analysed in order to obtain valid conclusions.

Regarding the analysis of whether it is more convenient to develop another form of renewable energy, it should be said that the most widely developed are photovoltaic and wind energy. Although, in a good location in Gran Canaria with 1 MW installed, wind energy could obtain 4 GWh/year, photovoltaic energy only 1.8 GWh/year. However, they are energies that complement each other; just as there are days with strong sun and windless, there are extremely windy nights. It is not an option to do without either of them, since both contribute to the energy supply to the system.

Comment has been made on the great social rejection that the implementation of renewable energy within the rural area in Spain is awakening, forcibly imposing a change in land use [https://elpais.com/espana/andalucia/2024-10-04/100000-olivos-en-peligro-co mo-las-megaplantas-fotofoltaicas-pueden-sustituir-al-paisaje-del-olivar-andaluz.html, accessed on 15 November 2024].

Without a doubt, financially compensating the owner of the land, to share its use, is important, looking for formulas that make it an economically attractive solution. As has been said, care must be taken not to affect places with a high landscape value, which must be respected.

It is logical that the farmer wants the land for himself alone, as is the case with the owner of the photovoltaic installation; it is cheaper and more comfortable. But it is a social duty, and the political class must understand it this way, to favour compatibility of use in order to preserve the value of the soil and obtain maximum production from already anthropised soil.

6. Conclusions

Environmentally, AVS is considered convenient after the analysis carried, and it will complement other multiple renewable generation systems. It is necessary, since anthropised soil cannot continue to grow indefinitely. It is more expensive and complex to obtain food and electricity simultaneously from the same land, but the soil must be preserved as much as possible, as it has been so severely punished in recent years. As has been seen above, with a wide implementation of AVS, progress would be made in 11 of the 17 objectives that the UN has established to achieve sustainable development. Then, it is interesting to analyse and personalise the implementation of this technology, since the realities of each territory are different. For this reason, the reality of the island of Gran Canaria has been analysed, considering the strengths, threats, opportunities and weaknesses, and subsequently, using the TOWS matrix to enhance the positive aspects and reduce the negative ones. It has been concluded that it would be of great value for the existing study and research institutions on the island to open a line of work in this direction. These institutions are an agricultural school and the local university, where it would be possible to delve into different aspects: economic, technical, energy and environmental. There are specialists in all these subjects, and fundamentally, they are well acquainted with the environment where this technology is intended to be implemented.

Basically, we are on an island with high biodiversity, which is heavily supplied with energy from foreign oil, with abandoned agriculture, the depopulation of its rural areas, a high dependence on foreign food and fertilisers, a shortage of flat land and a lack of fresh water, with a low per capita income and a high unemployment rate. It is observed that the orderly and studied implementation of AVS could greatly improve all these aspects.

Assuming the implementation of AVS on 10% of the abandoned agricultural land on the island, 2434 direct jobs in agriculture would be created. CO_2 emissions on the isle would be reduced by 833,935 tCO_2. In addition, 1776 ha of abandoned land would be regenerated.

It would be interesting to test various experimental agrovoltaic plants, ones that are monitored, accompany various crops and have various configurations, to collect data from real measurements. The person who works the agricultural land is not going to test this new and unknown technology for him; the electric generator is not going to mess with crops. This task should be performed by the administration, which, through incentives, promotes this type of action, because the main beneficiary is a scarce social resource, i.e., flat land. Incentives or possible tools that the administration should use to promote the appearance of this type of installation should be analysed.

Author Contributions: Conceptualisation, J.J.F.-G. and A.P.-A.; methodology, A.P.-A.; software, E.R.-A. and J.C.Q.-S.; validation, J.J.F.-G. and J.C.Q.-S.; formal analysis, E.R.-A.; investigation, A.P.-A. and N.R.F.-S.; resources, N.R.F.-S.; data curation, A.P.-A. and J.C.Q.-S.; writing—original draft preparation, A.P.-A.; writing—review and editing, A.P.-A. and N.R.F.-S.; visualisation, E.R.-A. and J.C.Q.-S.; supervision, N.R.F.-S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: All data published in this paper have been obtained from the following sources of information: https://www.grafcan.es/; https://www.gobiernodecanarias.org/istac/; https://www.gobiernodecanarias.org/planificacionterritorial/materias/informacion-territorial/enp/; https://www.ree.es/es; https://agriculture.ec.europa.eu/common-agricultural-policy_en#:~:text=The%20common%20agricultural%20policy%20(CAP,and%20keeps%20rural%20areas%20vibrant; https://www.omie.es/; https://sdgs.un.org/goals; https://www.aemet.es/es/serviciosclimaticos/cambio_climat/result_graficos?w=2&opc1=Espan&opc2=P&opc3=Anual&opc4=0&opc6=1; http://www.aguasgrancanaria.com/pluviometros.php; https://ecoisla2030.org/plan-estrategico-del-sector-primario-para-gran-canaria/; https://energy.ec.europa.eu/topics/markets-and-consumers/energy-communities_en; https://www.energiagrancanaria.com/wp-content/uploads/2019/03/sintesisconclusionesfb.pdf, accessed on 12 June 2024.

Conflicts of Interest: The authors declare no conflicts of interest.

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