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Review

Contribution of Renewable Energy Sources to the Sustainable Development of Islands: An Overview of the Literature and a Research Agenda

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Abstract: Renewable energy sources (RES) have significant potential to contribute to the economic, social and environmental energy sustainability of small islands. They improve access to energy for most of the population, they also reduce emissions of local and global pollutants and they may create local socioeconomic development opportunities. The aim of this paper is to provide a review of the theoretical and empirical literature on the contribution of RES to the energy sustainability of islands, focusing on the main results and the methodologies used. Papers are classified according to their coverage of the three dimensions of the triangular approach to sustainability (economic, environmental and social). The review also takes into account whether and how the procedural sustainability has been tackled in those papers. It is acknowledged that although several topics have been covered by the existing literature, there are promising avenues for future research on several fronts, both thematic and methodological.

Keywords: sustainable development; renewable energy; islands

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1. Introduction

In current societies, access to energy is a major factor for sustainability in both developed and developing countries. Small islands are particularly vulnerable in this regard: their geographic position strongly limits the possibility of grid connection to a larger electricity network. Since most small islands lack fossil-fuel sources, fuels have to be imported, which exposes them to increases in fossil fuel prices.

For a short time, islands have been somewhat forgotten in the renewable energy and sustainable development discussion, with sustainable development understood as encompassing a triple economic, social and environmental dimension (see section 3). However, recently, islands were included in the agenda for cooperation initiatives in forums like the European Union and the United Nations. Countries in Europe are developing renewable energy projects in their islands, from the use of wind energy to illuminate the hotels in the Canary Islands to solar energy for households in Crete [1].
Besides the individual national projects, there is a variety of partnerships, initiatives and networks created to transfer, develop, investigate and employ technologies, as well as to set up an effective energy policy, with due consideration to the particular needs of islands (Box 1).

Box 1. Islands in the international discussion on sustainable development. International initiatives to contribute to the sustainable development of islands. Source: Own elaboration.

The international interest in the potential contribution of sustainable development to islands was integrated in the agendas of organizations like the European Union and the United Nations (UN). The initiative Environmental and Development in Coastal Regions in Small Island was launched by the latter and responds to calls for integrated approaches to major coastal problems. It assists its island members toward environmentally sound, socially equitable and culturally appropriate development of their coastal regions [2].

Small Islands Developing State (SIDS) is a net established in 1997 with the primary goal of supporting the sustainable development of SIDS through enhanced information and communication technology (ICT). The concerns on the special conditions of SIDS such as remoteness, isolation and geographic dispersion, poor connectivity, limited human and technological capacity, and the need for greater international recognition and assistance in reducing SIDS' economic and environmental vulnerability gave rise to the creation of this network [3].

In 2000, the Global Sustainable Energy Island Initiative (GSEII) was created. It comprises NGOs and multilateral institutions, which hold a common idea and goals for SIDS. GSEII programs works in nine islands in the Caribbean, Pacific and Indian Ocean Regions at the national level to develop strategic frameworks for sustainable energy development in the islands. The general aims of this network are to reduce dependence on fossil fuels, negative impacts on local environments and greenhouse gas (GHG) emissions. Private investment and trade is encouraged and some strategies are used to enhance socioeconomic development and to secure energy independence [4].

Other international efforts are targeted to a specific region, such as the Pacific Islands Energy for Sustainable Development partnership (PIESD) that was launched in 2002 as a result of the cooperation of the energy stakeholders in the Pacific Island Countries and Territories (PICTs), intergovernmental organizations, major donor partners and the private sector with the main objective to achieve a sustainable energy sector [5].

Box 1. *Cont.*

In 2003, another partnership was created between developing and developed countries: 100% Renewable Energy Islands. It focuses on the sustainable development of SIDS and energy for sustainable development. It assists island states to meet 100% of their energy requirements from renewable energy sources (RES) by helping them with the preparation and planning, organization and all the technical, financial and managerial inputs required to implement the 100% RES plan. [6]

The European Union co-funded European REislands (European Renewable Energy Islands), a partnership in which Sweden, Spain, Italy, and Greece cooperate, and which aims at increasing awareness of RES, and encouraging citizen motivation and commitment to move towards a 100% RES environment. [7]

Another international partnership is the Energy Development Island Nations. It was created in 2008, with the main objective to advance the deployment of renewable energy and energy efficiency technologies in islands across the globe. This objective is intended to be accomplished by offering islands the necessary resources to help them develop sound policies and finance clean energy technologies [8].

Renewable energy sources (RES) have significant potential to contribute to the economic, social and environmental energy sustainability of islands. RES improves access to energy by most of the population, but also reduces emissions of local and global pollutants and may create local socioeconomic development opportunities. The aim of this paper is to provide a review of the theoretical and empirical literature on the contribution of RES to the energy sustainability of islands (focusing on the main results and methodologies used) and to identify promising lines for future research on this topic. It should be stressed that the review of the international initiatives on RES and islands is focused on the description of the political claims of each initiatives, rather than on specifying the size of intervention or the selected RES technologies.

This paper is structured as follows. The next section explains our interpretation of sustainable development, the main characteristics of islands from an energy sustainability perspective and how renewable energy can theoretically contribute to their sustainability. The main findings of the review on the literature on the contribution of RES to the sustainable development in islands are provided in Section 3, whereas a discussion of this literature is provided in section 4, which also points out some directions for further research.

2. Sustainable Development and Renewable Energy in Islands

The aim of this section is to explain how sustainable development is interpreted in this paper (2.1), to describe the main characteristics of islands from an energy sustainability perspective (2.2) and to discuss the potential contribution of RES to the sustainability of islands (2.3).

2.1. Our Interpretation of Sustainable Development

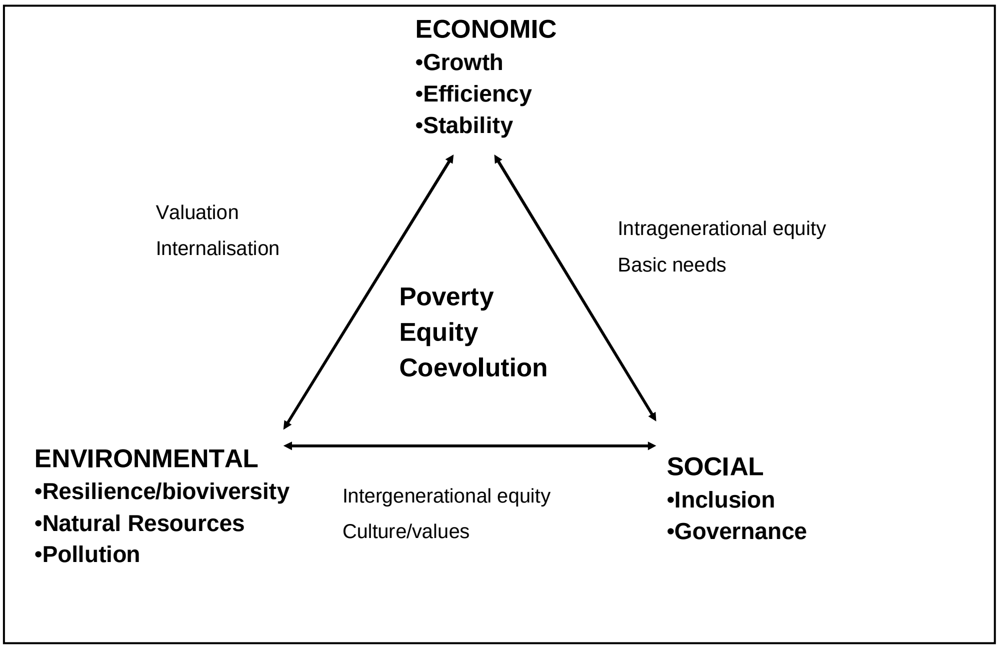
Sustainable development (SD) has traditionally been defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs [9]. However, this is far from being an operative definition which could allow us to say whether a given country, region or, for the purposes of this paper, island, is in a transition process towards sustainability or the extent to which a given development proposal is "sustainable".

Particularly, the territorial dimension of SD calls for the use of a more operative approach to sustainability, which is adapted to the regional or local territorial contexts. In this regard, two major conceptual frameworks to assess the sustainability of specific development projects in specific territorial areas can be distinguished: substantive and procedural sustainability.

The first one considers how a specific project contributes to the improvement of the economic, social and environmental conditions of a specific territory, thus to the welfare of its population. The literature on SD has tried to make this substantive approach operative through three major approaches: (1) Sustainability as the maintenance of the stock of capital (natural, man-made, human and socio-cultural); (2) the triangular approach, which considers the three interrelated dimensions of sustainability (economic, social and environmental) and; (3) the materials balance approach [10,11]. Regarding substantive sustainability, and for the purpose of this paper, the second approach is used in order to identify how a specific renewable energy project influences the economic, social and environmental dimensions of the sustainability of a given island.

The triangular approach takes into account the three dimensions of SD (economic, social and environmental) and tries to assess the sustainability of a given development proposal according to them (Figure 1) [12]. This approach continues to be highly influential. It forms the basis of the structure of the indicators of SD collected by key organizations all over the world, including the UN, the OECD and the European Commission [13,14].

Figure 1. The dimensions of sustainability and their interrelationships. Source: [15].



Therefore, following this approach, a sustainable local policy must tackle the three dimensions of sustainability with the aim to increase the standard of living of its citizens, *i.e.*, it has to be sustainable from a substantive perspective:

Environmental. Reduction of local and global pollution (among them, emissions of greenhouse gases), lower exploitation of the natural resources in the territory and maintenance of the resilience (ability to adapt to change), integrity and stability of the ecosystem.

Economic. Increase of regional per capita income, improvement in the standard of living of the local population, reduction of energy dependence and increase in the diversification of energy supply.

Social. Some authors stress that SD cannot be achieved without the sustainability of social and cultural systems, which includes the achievement of peace and social cohesion, stability, social participation, respect for cultural identity and institutional development [15]. Reducing unemployment and improving the quality of jobs (more permanent jobs), increasing regional cohesion and reducing poverty levels are key actions at local level to achieve social sustainability. For example, activities such as renewable energy deployment, which are an alternative to traditional agriculture, should be encouraged. This has a particularly positive psychological impact on the prospects of the young local population.

Due account should be taken of the impact of a renewable energy project on the three sustainability dimensions (economic, social and environmental). The deployment of renewable energy projects may contribute to these three dimensions of local sustainability in islands.

However, a given project should not only be sustainable according to the aforementioned three dimensions. It should also comply with the "procedural sustainability" approach. This is a participatory approach which takes into account the opinions and interests of all stakeholders [16]. This calls for a wide social participation process in the implementation of SD instruments and activities at the local level whereby all interested parties are involved. The acceptance or rejection of the project by the local population can make the implementation of a renewable energy project and its contribution to local sustainability either a success or a failure.

The "procedural sustainability" stream of the literature argues that the analysis of the sustainability of a given development proposal (project) should not only focus on the impact of this proposal but, also, on how this impact is perceived by the local population, how the benefits are distributed among the different actors and how this perception and distribution affect the acceptance of the project and, thus, its feasibility.

Of course, both approaches to SD (substantive and procedural) are interrelated. The local sustainability impacts of a renewable energy project depend on the features of the local actor network and on the conditions and characteristics of the stakeholders themselves. In turn, the greater the benefits for the local communities, the greater the attractiveness of local areas and the greater the possibilities for the social acceptance and success of the project. At the end, support for renewable will depend to a large extent on the perception of its benefits at the territorial/local level. The deployment of renewable energy projects would benefit from the previous engagement of local actors because the rejection of the project by these actors could make its implementation a difficult endeavour.

The approaches adopted in this paper are the triangular and procedural approaches. A local SD strategy should combine a top-down (triangular sustainability) and a bottom-up (procedural sustainability) approach. Both approaches are crucial to analyze the contribution of renewable energy sources to local and regional sustainability. First, renewable energy deployment can contribute to the three sustainability dimensions at the regional level. Second, the existence of local participatory processes is crucial for the implementation of renewable energy projects because the acceptance of this project by the socioeconomic actors in a given territory facilitates its deployment.

2.2. The Main Characteristics of Islands from an Energy Sustainability Perspective and How Renewable Energy Can Contribute to Their Sustainability

Even though islands around the world have different landscapes and a diversity of natural resources, they share some common features that are relevant regarding the aforementioned triple dimension of SD. On one hand, they usually have good renewable energy resources, notably wind, solar and ocean. In addition, their lack of fossil fuels makes them highly dependent from foreign energy sources, and thus, economically vulnerable. Scarcity of drinkable water is also often an important problem, which makes them dependant on external supplies from the mainland or, alternatively, on setting-up desalinization plants, which consume a significant amount of energy [17-20]. Many papers have stressed that desalination with RES may represent a valid and economically interesting option to the energy-intensive process of desalination (see 21 for an overview), especially when fossil fuels for water transportation are too expensive or when there is no electricity grid to feed the desalination plant in remote and arid areas, where the use of conventional energy is costly or unavailable. This is precisely the type of situation of many islands. If desalination is an energy-intensive activity and energy supply in the island is based on fossil-fuel sources, then a security of supply crisis could lead to a parallel water availability problem. Large tourist inflows aggravate this problem, thus leading to significant increases in water and energy demand during the tourist seasons. Using RES for desalination could kill these two birds with one stone. However, it is not only an issue of how RES can contribute to desalination, but also what desalination can add to RES. As argued by [22], the stochastic nature of RES and expensive energy storage limits the penetration of RES to the power generation system of a region, but desalination systems allow to use the available RES potential in an economically efficient manner. The energy produced is consumed for potable water production which can be stored economically for a large period of time before consumption.

There are plenty of desalination methods using RES. Following [22], the RES-desalination coupling schemes could be divided in two categories: 1. RES-desalination coupling schemes that require the RES unit and the desalination unit to be located in the same area (such as Wind-shaft-Mechanical Vapor Compression (MVC) coupling, Solar thermal-heat-Thermal Vapor conversion (TVC), Solar thermal-heat-Multi-Stage Flash Distillation (MSF), Solar thermal-heat-Multi-Effect Distillation (MED), Solar thermal-heat-Distillation, Geothermal-heat-Thermal Vapor conversion (TVC) and Geothermal-heat-Multi-Stage Flash Distillation (MSF)) 2. RES-desalination coupling schemes that do not require the RES unit and the desalination unit to be located in the same area (such as Wind-electricity-Mechanical Vapor Compression (MVC) coupling, Wind-electricity-Reverse Osmosis (RO), Solar PV-electricity-Reverse Osmosis (RO), Solar PV-electricity-Mechanical Vapor Compression (MVC) coupling, Geothermal-electricity-Mechanical Vapor Compression (MVC) coupling and Geothermal-electricity-Reverse Osmosis (RO)). Their selection should be made taking into consideration simplicity, easy handling, availability, maturity of the technology, guarantee of fresh water production, suitability of the system to the characteristics of the location, possibility of future increase of the system capacity, efficiency, availability of local support and simplicity of operation and maintenance of the system, among others [21].

Two main interrelated aspects of the contribution of RES to the SD in islands are deemed very relevant, but not limited to them: poverty alleviation and security of supply.

On one hand, access to energy has been highlighted as a major factor to reduce poverty levels of the local population, although both in islands and mainland [23,24]. According to the report from the UN on energy and environment, "The Energy Challenge for Achieving the Millennium Development Goals", there is a clear relationship between access to energy and achieving the Millennium Development Goals [23].

On the other hand, lack of adequate energy services is a constraint to development, which is probably more relevant in an island context than on the mainland [8,16,24]. Lack of energy limits the potentials of meeting basic needs of those who require energy to undertake essential domestic, agricultural and educational tasks, to support health and transport services, and to initiate or develop manufacturing or trading enterprises [24]. Therefore, access to energy may reduce some of the barriers to SD in islands (as well as on the mainland), such as poverty, poor state of health and education and environmental degradation. Renewable electricity may meet the increasing demand for commercial energy for those with access (mainly in cities), and provide access to modern, efficient and clean forms of energy for the majority of the population in isolated and rural areas, alleviating poverty. As stressed by Pérez and Ramos [25], small-sized electricity systems, which are not connected to other systems, present a series of characteristics that complicate and raise the costs of electricity supply: (1) generation units cannot be too big as the loss of one generator would have a large effect on the overall system. This makes it difficult to exploit economies of scale to the same level as in large electricity systems and complicates the technical management of the network with regard to frequency and voltage. (2) More reserve capacity needs to be maintained to ensure adequate supply, meaning that islands cannot take advantage of the possibilities inherent in interconnected electricity systems, which generate greater stability in a system. Weisser [26] also argues that electricity supply in these territories is more expensive because there are high fuel transmission costs. These constraints require a different approach from that of mainland territories. Roper [27] notes that electricity prices in SIDS are generally between 20 and 35 cents (US) per kilowatt hour, which is much higher than prices in the USA or Europe. Secure supplies of affordable and reliable energy are an essential element of economic and social development. Electricity is vital to the delivery of social services such as health, education, water and sanitation, and it enables job creation and frees time for productive pursuits. At present, 70% of Pacific residents do not have access to electricity and depend on a mix of fuel wood, kerosene and batteries for energy supply.

Therefore, since energy is critical in reducing poverty and enhancing development opportunities, security of energy supply in islands is a crucial topic from the perspective of SD. Securities of supply issues are deemed relevant everywhere, but they can be particularly relevant in islands, given their isolated geographical situation.

Security of supply has two main sides. On one hand, it refers to foreign energy dependency. On the other hand, it reflects the reliability of different energy sources to provide energy where and when it is needed. Regarding the first aspect, RES are unambiguously highly beneficial in the regard that the fuel (the renewable resource) is indigenous to the territories.. As argued by Maria and Tsoutsos [28], the energy balance could be improved with the reinforcement of energy independence and safety and decentralization of energy production systems, simultaneously reducing losses of transferred energy and national energy dependence.

However, on the second aspect the assessment is not so clear. Some RES are intermittent, thus it is not easy to guarantee a specific energy supply at a given moment in time. The lack of interconnections with the mainland reinforces this problem compared to places in the mainland. Of course, back-up capacity may mitigate this problem, although at a cost. The need for back-up capacity may be stronger for the same level of penetration of RES than in the mainland. A combination of different types of RES (*i.e.*, so-called hybridization) may also contribute in this regard.

Of course, from a triple sustainability perspective there are other benefits of RES in islands, including reduction of emissions of pollutants (both local and GHG). From an economic and social point of view, RES have the potential to contribute to local development opportunities and jobs. The local community could be beneficiated with their inclusion in the process of development the RES and also it could revitalize the economy of underdeveloped community areas. Economically, RES could deliver investments in remote areas, increase in local employment, and reduction of currency loss when importing conventional fuels. The money saved by the reduction of fossil fuels use, would allow more financial resources to be allocated in other critical social and economic sectors and towards implementation of SD policy in general.

3. The Review

Given their potential advantages from a SD point of view, as explained in the previous sections, some studies have been carried out on the contribution of RES to the SD of islands. This section identifies the most relevant studies in this context. The overview of the literature performed in this paper is not necessarily exhaustive, but it is certainly representative of the topic of RES and SD in islands. The next section discusses some of the results of these studies. Further details on each study can be found in the Appendix.

Regarding the scope of the review, we are only interested in studies that analyze the effect of RES on any of the three dimensions of SD (economic, environmental and social) in islands, although studies related to the analysis of barriers to the uptake of RES in islands are not within the realm of this review. In contrast, given their relevance for the SD of islands, papers dealing with public policy issues (what specific RES promotion policies are appropriate in islands as compared to the mainland and how RES can and should be promoted in order to improve the SD of specific islands) are also the object of this review.

Concerning the method used to carry out the review, the papers included in this study were selected using the database Science Direct according to their compatibility with the aim of this article (RES contributing to the sustainability of islands). There was no date limit for the publications except that set by the database. This was complemented with an internet search and with informal interviews with renewable energy experts in Spain in which the interviewees were asked about studies on SD in islands.

Of course, the islands included in this review differ in some respects, for example, distance from the mainland: those islands in the Mediterranean, particularly, the Greek islands, are relatively close compared to those in the Pacific and Atlantic Oceans . In addition, population density widely differs (see Appendix).

Notwithstanding, these islands have several common features, which are highly relevant in an energy sustainability perspective. They are small islands in places with temperate climates, most of them belong to democratic states and have medium to high development levels.

Furthermore, they are usually tourist sites, receiving a significant, and often increasing, number of tourists, which aggravates the problems of energy and water supply with the existing capacity, especially during peak tourist periods [29]. This is particularly the case in some islands in the Caribbean and Mediterranean area. For example, the Canary islands received 12 million tourists in 2008, compared to a local population of two million. Crete received two million tourists, compared to 624,000 inhabitants. The Spanish island of Ibiza in the Mediterranean received 540,000 in August 2009 *versus* a local population of 114,000 inhabitants [30,31].

The difficulty for grid connections to a larger network in the mainland, together with the difficulty to implement certain energy sources (hydro and nuclear), especially in the smaller islands, usually makes them highly dependent on fossil-fuel energy sources. This dependency is reinforced by the fact that lack of interconnections makes reliability an even greater issue than in the mainland. Renewables may reduce this dependency, although fossil fuels will continue to represent a large share in the electricity generation mix because back-up capacity is likely to be necessary with high penetration of RES.

The information of the review has been structured in the following manner. We have identified which dimension (economic, environmental and social) of sustainability is affected. Papers dealing with procedural sustainability are included under the social dimension. In addition, the specific theme tackled is mentioned. Usually, the study concerns more than one dimension.

In order to include studies under the headings of the economic or the social dimensions in the following table, many studies dealing with energy supply issues are considered predominantly economic when this affects private businesses and fall under the social dimension when the provision of a public good like education is affected. It is considered both economic and social when it affects the supply of energy for the whole population (citizens).

Table 1. Structuring the information of the review according to the triple dimension of sustainability. Source: Own elaboration.

Study	Sustainability dimension			Theme
	Economic	Social	Environmental	
Manologlou *et al.* [19]		X (procedural)	X	Water supply Public acceptance
Kassels [32]		X		Impact on education
Kaldellis *et al.* [20]	X			Technological and economic feasibility of RES (grid).
Plescia [29]	X			Energy supply in the tourist industry
Bağcı [33]	X	X		Energy supply for the population
Michalena & Tripanagnostopoulos [34]	X	X (procedural)		Solar as a tourist attraction and energy supplier

Table 1. *Cont.*

Study	Sustainability dimension			Theme
	Economic	Social	Environmental	
Weisser [26]	X	X		Public-policy related issues
Weisser [35]	X	X		Public-policy related issues
Duic *et al.* [36]	X			Energy supply. Focus on costs and grid integration.
Miranda and Hale [37]	X		X	Social costs: valuation of production (private) and environmental (externality) costs.
Benjemaa *et al.* [17]		X	X	Water supply
Duic *et al.* [38]	X			Technology transfer under the CDM
Vujčić & Krneta [39]		X	X	Water supply
Krajačić *et al.* [40]	X	X		Energy supply
Maxoulis & Kalogirou [41]		X (procedural)		Public awareness
Corsini *et al.* [42]	X	X	X	Energy supply and water supply
Maria & Tsoutsos [43]	X	X	X	Energy supply. Planning of RES should consider environmental impacts.
Oikonomou *et al.* [44]	X	X (procedural)		Economic viability. Public acceptance.
Matera *et al.* [23]	X	X	X	RES use in transport
Stuyfzand & Kappelhof [18]		X	X	Water supply (desalinization)
Singal and Varun [16]	X	X		Energy supply. Costs of different options.
Zsigraiová *et al.* [44]	X	X		Energy supply
Zafirakis & Kaldellis [45]	X			Technical analysis of energy storage including RES
Dimitropoulos & Kontoleon [46]		X (procedural)		Local resistance to wind power
Chiaramonti *et al.* [47]	X		X	Energy and water supply
Davies [48]	X	X		Energy supply, cost savings and employment benefits
Lavi and Lavi [49]	X	X	X	Commercialization of ocean technology
Yu and Taplin [50]	X	X (procedural)		Efforts regarding to international bilateral and multilateral aid for RES
Bueno and Carta [51]	X			Economic/technological feasibility

The dimension predominantly covered is the economic one, whereas the social, and especially, the environmental aspects have received less attention (see next section). Regarding the geographical coverage, as illustrated in Figure 2, most of the studies focus on the Mediterranean region, especially Greece and Spain. The reason could be the local interest to fulfill the goal of the European Union of Renewable Energy development and the relatively high economical level of these European islands in comparison with others, which favors RES deployment.

Figure 2. Geographical coverage of the reviewed studies. Source: Own elaboration.

Another criterion for classification of the studies is those dealing with renewable energy planning and those with renewable energy use. The literature on renewable energy planning includes ex-ante assessments of the viability of different renewable energy options, considering the local RES [36,40,43], and ex-post studies on economical performance evaluation of existing RES [50]. Concerns about the environmental impact of RES plants and issues related to energy storage systems were other aspects studied in the renewable energy planning literature.

Concerning renewable energy use, the use of renewable energy in islands was proposed to resolve some inherent problems of islands like desalting of brackish or seawater to supply drinking water, tourism, education, seasonal energy buffering and to support private investment.

On the other hand, the technical feasibility of various options for integrated energy and resource planning of RES in islands are topics that can usually be found in this literature. This is done with different methodologies [52].

4. Discussion and Some Directions for Future Research

The previous section provided an overview of the literature on the contribution of RES to the SD of islands. The main features of this literature are discussed here and their major drawbacks and gaps in knowledge indicated, suggesting some directions for future research. The review suggests that although several topics have been covered by the existing literature, there are promising avenues for future research on several fronts, both thematic and methodological.

(1) Security of supply is certainly a main factor in favor of the uptake of renewable energy sources in islands, if not the most important driver. Lack of interconnections with the mainland (whether electrical or through oil pipelines) makes them more vulnerable in this regard. Electricity generation is normally based on fossil fuels (often oil). Fossil fuel energy sources need to be shipped from the mainland. In addition, the small size of many islands makes them inaccurate for the implementation of

some energy technologies (particularly, nuclear and large hydro). In addition, the relatively small size of power plants is a barrier to the achievement of economies of scale in electricity production. Given the geographical situation of the islands covered in this review (see Figure 2) they are likely to profit from high sun radiation levels. This, together with generally high-quality winds, suggests that their wind and solar potentials are likely to be high. However, the benefits of renewables in terms of security of supply are assumed in the literature rather than measured. In particular, there are no comparisons of the costs and benefits of a greater uptake of RES in terms of security of supply. In other words, a greater penetration of RES entails benefits in terms of security of supply for the local population in islands, but also costs because the uptake of these technologies needs to be subsidized. In addition, RES have an ambiguous relationship with energy security. While it is true that they reduce the need for non-indigenous energy sources, their intermittency (in the case of solar and wind) can be problematic in this regard, specially in a small territory, because of the difficulty to offset a lower availability of the energy resource in one location with a greater availability in another location, as it is the case in large islands (see Sinden [53] for the case of the U.K.). The need for back-up capacity is unavoidable, represents an added cost and makes fossil-fuel sources necessary in the end. These aspects need to be tackled in further research.

(2) At a more general, broader level, there is also a lack of assessment of the costs and benefits of different renewable energy alternatives with respect to other key aspects apart from lower energy dependency, including local environmental impacts. For example, although there are some papers dealing with the local socioeconomic benefits of RES, the analysis of these benefits, which in studies in the mainland have been mostly related to greater development opportunities and job creation [11], is scarce. The environmental impacts of new RES plants (*i.e.*, visual impact and land use) on tourism need to be taken explicitly into account. Tourism usually represents a large share of islands' total income, *i.e.*, a conflict between tourism and RES may exist, although [29,34] suggest that this does not necessarily has to be the case.

(3) In addition, the social dimension of the contribution of RES to the SD of islands has hardly been tackled. In particular, public acceptance issues of RES in islands seem to have been neglected to some extent, with some exceptions (see Table 1). This points out a weakness of the reviewed literature in terms of procedural sustainability. Often, successful adoption and diffusion of innovations is assumed to be merely an issue of securing the techno-economic dimension. In practice, many technological projects are facing severe resistance from various stakeholders. Successfully diffusing innovations relies on creating the societal acceptance of the technology. How this social acceptance can be created in islands is an interesting topic worth exploring.

(4) On the other hand, the environmental dimension is not sufficiently tackled. There is a surprising paucity of analysis both on the environmental impacts of RES in islands (with the exception of María and Tsoutsos [28]) and, more importantly, on the environmental problems that can be alleviated through the use of RES. The fact that most of papers deal with energy aspects of RES in islands, and much less with environmental aspects, might be a reflection of these aspects being significantly less relevant with respect to the mainland considerations, as argued by one of the reviewers of this paper. Renewables might not significantly improve the environmental dimension, since they use valuable land more inefficiently than imported fossil fuels. Since islands are usually rinsed by maritime winds and currents, emissions of local pollutants might not be a significant issue as on the mainland.

However, environmental impacts are not only related to soil occupancy or emissions of pollutants. There are other impacts that should be acknowledged. These include water use and water pollution, but also soil occupancy related to the storage of fossil fuel reserves and GHG emissions. When islands are in countries with GHG commitments (*i.e.*, Kyoto Protocol), then the shift from fossil-fuel energy sources to RES is relevant to comply with those commitments. Finally, environmental impacts affect the social acceptability of RES projects. They are thus very relevant not only from a triangular sustainability perspective but also from a social (procedural) sustainability point of view.

(5) In short, there is a surprising lack of multicriteria studies on this topic, *i.e.*, detailed studies on how RES can contribute to the different aspects of the three dimensions of SD, as defined in this paper (*i.e.*, economic, social and environmental). We defend a more holistic approach than has been applied so far in the literature to analyze the contribution of RES to the SD of islands. With the exception of [49], the literature has focused on a particular aspect without due regard to other aspects which are crucial from a sustainability perspective. The existing literature provides a partial analysis in this context. To our knowledge, no study encompasses all the dimensions of sustainability, although some may deal superficially with specific aspects of the three dimensions (see Table 1).

(6) Related to issues of public acceptability, but also to the application of new methodologies, there is a growing body of studies which try to infer the willingness to pay (WTP) for RES with either contingent valuation or choice experiments methodologies (see, for example, [54] and [55]). However, only a few have been carried out in islands, mostly the U.K**.** and in Greece (e.g., Koundouri *et al.* [56], who analyze public attitudes towards renewable energy generation and their WTP for a wind farm in the Island of Rhodes (Greece), identifying significant positive values deriving from the proposed project). By allowing a comparison of the costs and benefits of the implementation of RES projects, these methodologies may be useful in supporting political decisions. It would be useful to identify whether such WTP would be greater in islands compared to the mainland. Although it is, of course, very difficult to compare studies in different places and control for the different variables which affect the valuation of RES, this would provide a hint of how is RES valued in islands compared to the mainland, *i.e.*, the specific features of islands which make RES particularly beneficial for these.

(7) Regarding the geographical coverage, this has proven to be highly uneven, with an overrepresentation of Mediterranean islands and an under representation of islands in other parts of the world. We believe there is a great potential to carry out in-depth analysis in islands particularly in Asia and Africa, because of the general link between RES and poverty alleviation. Mediterranean islands have already a comparatively high standard of living and access to energy, although, as other islands in the world, they illustrate on the potential and significant pressure of large tourist inflows energy resources. Yet, as stated elsewhere (see 2.3), in the poorer islands in the world, the improvement in the access to energy is mostly related to poverty alleviation.

(8) In addition, the contribution of RES to the transport systems in islands is hardly tackled, with the exception of [23] and [36]. This is a serious gap in knowledge, in so far as virtually all papers focus on electricity and heat, none focuses on cooling and only two concentrate on the analysis of RES uses in transport. Given the relative scarcity of fuel sources in transport compared to electricity generation and the fact that this sector is highly dependent on oil (which makes islands highly exposed to energy supply risks), this is a serious omission. RES can contribute to the needs of the transport sector in two manners: through the production of biofuels and through production of electricity to fuel electric cars.

Both have their disadvantages. Biofuel production is likely to interfere with other land uses, in places (islands) where land may not be abundant, especially in the small ones. Electric cars are still rather expensive and will remain so for some time [57]. Both certainly limit the extent to which RES can be introduced in the transport sector in islands, but this topic deserves further research.

(9) The public policy dimension has been mostly absent, with the exception of [26] and [35]. There is an abundant literature on RES support schemes (see [58]), which does not differentiate between islands and mainland. Therefore, it would be interesting to investigate what specific RES promotion policies are appropriate in islands (compared to the mainland) and how RES can and should be promoted in order to improve the SD of specific islands. A recent pioneering work in this direction is [25] for the case of the Canary Islands. It should also be analysed what are the differential barriers to RES with respect to the mainland. Roper [27] provides a preliminary analysis. Soil occupancy might be a more relevant barrier than on the mainland.

(10) As shown in the review (Table 1), many studies on RES in islands deal with energy supply while the focus of others is on how RES can improve water supply (mainly through their contribution to desalinization). Access to water is obviously a key aspect of SD in islands, but the contribution of RES to water supply may conflict with its contribution to energy supply. An integration of perspectives has been lacking, *i.e.*, co-optimization of the contribution of RES to water and energy supply.

(11) Hybridization between different types of RES, understood as the use of a mix of different RES, may be particularly relevant in islands compared to the mainland, given the potential contribution of a combination of RES (with respect to one single RES) to the reliability of energy supply and the potential availability of a mix of renewable energy resources (wind and solar). Biomass is the least intermittent RES, while the major differences in hydro production occur from year to year or season to season. In contrast, wind and solar are highly intermittent and more unpredictable (*i.e.*, less "manageable"). Of course, combining less intermittent with more intermittent RES would enhance the reliability of the system or the social benefits compared to the single use of RES. But even the combination of those intermittent RES (wind and solar) could be beneficial in this regard. This is so because, while the availability of the wind resource improves in winter and at night, the solar resource is available with daylight and more in summer time. To our knowledge, there has not been any analysis on the contribution of hybridization of RES to the security of supply in islands.

(12) In addition, the main contribution of RES to either peak load or base load in islands (compared to the mainland) should be analyzed. In this regard, the lack of interconnections with the mainland may reduce the potential contribution of RES to base load compared to the mainland. In contrast, the existence of a tourist peak in the summer may enhance the relevance of solar technologies to provide peak demand. This is a very relevant topic in islands given that many of them are recipients of large tourist inflows, especially during the summer season (for example, the population of the Spanish island of Ibiza, 114,000 inhabitants, may increase six-fold in August), which increases the need for peak-load capacity compared to other seasons in the year.

(13) Finally, the methodologies used in the papers reviewed vary depending on the type of study. Often times the authors used a combination of literature review and study cases. Techno-economic studies are also abundant. There is a need for, both, quantitative and in-depth case studies. The impact of RES on the SD of islands can be analyzed with either quantitative or qualitative approaches. Both

methodologies provide useful information and have their advantages and disadvantages. Therefore, they should not be regarded as substitutes. As discussed in [11], quantitative studies on the socioeconomic impacts of RES in the mainland have generally focused on employment effects with two types of models: (a) *input-output* (IO) approaches; and (b) more simple spreadsheets-based analytical models. The later calculate only the jobs created in the production, construction, installation, management and O&M of the different components of the technology or the electricity generation plant. Ratios of jobs created in all those stages per MW of installed capacity are provided, although these ratios differ across studies. In contrast, IO approaches calculate the direct and indirect employment as a result of induced effects from the project [59].

Both quantitative approaches have advantages and drawbacks (see [11]). In the context of this paper, there are some disadvantages of quantitative studies. They are not able to capture the relevance of the local context of islands and cannot analyze the interests of local stakeholders and the relationships between them. In the case of RES deployment, these issues can be analyzed with the help of qualitative studies in the form of case studies. These allow the identification of economic and social relationships which are hidden in quantitative studies.

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52. For example, RenewIslands consists in four steps: (1) mapping the needs, (2) mapping the resources (3) devising scenarios with technologies, and (4) modelling the scenarios. Another methodology used was EMERGENCE 2010, an stages-based methodology that selects the more feasible projects based in background information like energy consumption, financial parameters, then a cost analysis model. At the third part, the existing barriers are studied and are concluded with a socio-economic analysis in a community participatory manner [41].
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Appendix

Table A. Selected studies on the contribution of renewable energy sources to the sustainable development of islands. Source: Own elaboration from the reviewed studies.

Author/year	Region/island name	Population/surface/density	RES technology	Methodology	Summary
Manologlou *et al.* [19]	**Mediterranean sea/Milos (Greece).**	5000 in. 151 km^2 33 in/km^2	Geothermal	Interviews with local residents. Stakeholder analysis	The main objective in this article is to examine the local residents' views and opinions on the effects of the construction of a desalination plant on the island of Milos, with a problem of water supply. Interviews are carried out in order to identify the credibility of the project, environmental concerns and current situation regarding water supply in the island. The main finding was that the lack of water is highly problematic and that the construction and operation of a water supply plant is welcome by the overwhelming majority of the local population.
Kassels [32]	**Caribbean/Galapagos (Ecuador).**	18,000 in 7,527 km^2 2.4 in/km^2	Generic (all RES)	Case study	Like other islands, Galapagos use fossil fuels to generate electricity. A renewable energy project to supply electricity to an environmental educational centre serves to raise awareness of RES.
Plescia [29]	**Mediterranean sea/Ibiza (Spain).**	114,000 in. 541 km^2 210 in/km^2	Hybrid system (photovoltaic/diesel)	Case study	In this article the authors propose the design of a hybrid system of diesel and photovoltaic technology tailored to the needs of hotel and restaurants in Ibiza. Taking into account that the connection to the electric grid represents a substantial investment, the local companies need to use RES technologies not only due to environmental concerns but also for practical reasons.
Bağcı [33]	**Pacific/Hong-Kong (China)**	1.3 million in. 1,104 km^2 1,177 in/km^2	Solar, wind, tidal, wave, energy crops and municipal solid waste.		This study explores the Peng Chau island's potential to employ alternative energy resources to generate electricity. Six technologies are considered: solar, wind, tidal, wave, energy crops and municipal solid waste. The renewable resources of the island had been analyzed to determine the feasibility of those technologies. The study concludes that the best combinations of technologies for this specific case are solar-wind, solar-wave or wind-wave.

Table A. *Cont.*

Author/year	Region/island name	Population/surface/ density	RES technology	Methodology	Summary
Michalena & Tripanagnostopoulos [34]	**Mediterranean sea/unspecified**	N.A	Solar	Literature review	This paper focuses on the potential of the natural environment of the Mediterranean islands, specifically, solar energy, and the energy and aesthetic needs of its main economic activity: tourism. The conclusion is that turning solar energy systems into a driver for specific types of tourism is possible, if the specific social needs and aspirations of the local population are taken into consideration.
Weisser [26]	**SIDS**	N.A	Generic (all RES)	Literature review	RES in the SIDS are analyzed from the public policy perspective, providing reviews of the drivers and arguments for power sector reform and presenting the available reform options and their implications on the up-take of renewable energy technologies (RETs). The author provides recommendations that discourage full privatization of the power sector, and also defend less stringent lending conditions by international assistance bodies.
Weisser [35]	SIDS	N.A	Generic (all RES)	Literature review	The use of RES technologies is analyzed from the perspective of energy policy, taking into account the structure of electricity planning. It also analysed the economic and financial difficulties of the SIDS and their inherent characteristics and argues that a more holistic as well as detailed analysis is necessary to identify the potential economic benefits of RETs.

Table A. *Cont.*

Author/year	Region/island name	Population/surface/ density	RES technology	Methodology	Summary
Duic *et al.* [36]	Atlantic/Corvo, Porto Santo and Mljet	Corvo: 470 in 17 km^2 27 in/km^2 Porto Santo: 4,475 in. 42 km^2 106 in/km^2 Mljet: 1,110 in. 100 km^2 11.1 in/km^2	Hydrogen, wind, solar, biomass and geothermal	Scenario analysis using "RenewsIsland" (assessment of energy and resource flows): 1. mapping the needs, 2. mapping the resources 3. devising scenarios with technologies, 4. modeling the scenarios.	The authors perform an assessment of alternative scenarios for energy and resource planning, applied to several islands (Corvo, Porto Santo and Mljet islands) using the methodology "RenewIslands". This methodology helps to integrate energy and resource flows, based on the island needs, its resources, and the applicable technologies. The result of the study was that it might be beneficial to look for possible integration of resource flows, like for example integration water supply system with reversible hydro in Corvo, or electricity and transport systems through hydrogen storage in the Porto Santo or Mljet islands.
Miranda and Hale [37]	Caribbean sea/Puerto Rico	4 millions in. 8,875 km^2 450 in/km^2	Waste-to-energy	Techno-economic and environmental analysis of a technology (cost-benefit analysis)	Researchers analyzed the competitiveness of waste-to-energy (WTE) at Puerto Rico, analyzing the production and environmental costs of this technology and comparing it with the traditional landfill and oil-driven energy production. The production costs used in this study were compiled from historical data. The environmental cost where calculated using a marginal damage cost function and actual emissions of specific pollutants. The study shows that WTE represented a good management option when landfill production and externality costs were high, fossil fuel production and externality costs were high, WTE production and externality costs were low, and when WTE production processes were able to maximize energy efficiency.

Table A. *Cont.*

Author/year	**Region/island name**	**Population/surface/ density**	**RES technology**	**Methodology**	**Summary**
BenJemaa *et al.* [17]	Mediterranean sea/Gran Canaria (Spain) and Milos (Greece).	Gran Canaria: 830,000 in. 1,532 km^2 541 in/km^2 Milos: 5,000 in. 151 km^2 33 in/km^2	Generic (all RES)	Literature review	Even though this article does not discuss the use of RETs for water desalination at islands specifically, it explains how the local renewable resources can be matched with desalination technology to satisfy one of the most essential needs at the islands. The study concluded that using three different renewable energies resources, seven desalination technologies could be employed at Tunisia.
Duic *et al.* [38]	SIDS	N.A	Wind	Comparative techno-economic analysis of two competing technologies (benefits and costs)	This paper concentrates on the case SIDS (particularly, Santiago Island) and on how the Clean Development Mechanism (CDM) is expected to influence the transfer of clean energy technologies under the aegis of the Kyoto Protocol. Researchers concentrate on two technologies: wind power and combined cycle electricity production. They found that, if the potential value of the CDM is taken into account, the wind plant could be economically feasible if diesel capacities were replaced by combined cycle plants.
Vujčić & Krneta [39]	**Mediterranean sea/several islands in the county of Split and Dalmatia (Croatia).**	N.A.	Wind	Literature review and case study	After studying the water needs and the renewable resources of the island, the authors proposed a hybrid plant consisting basically of the reverse-osmosis desalination system (RO), while the proposed source of electric power would be the wind plant. The speed of construction, modularity and considerably lower costs of investment make the process of desalination a priority

Table A. *Cont.*

Author/year	Region/island name	Population/surface/ density	RES technology	Methodology	Summary
Krajačić *et al.* [40]	**Mljet (Croatia), Porto Santo (Madeira, Portugal), Terceira (Azores, Portugal), Malta**	Mljet: 1,110 in. 100 km^2 11.1 in/km^2 Porto Santo Porto Santo: 4,475 in. 42 km^2 106 in/km^2 Terceira 58,000 in. 382 km^2 151 in/km^2 Malta: 413,000 in. 316 km^2 1,308 in/km^2	Hydrogen from RES	RenewIslands (see above) and H2RES: a modeling tool for balancing hourly time series of water, electricity, heat and hydrogen demand and appropriate storages	This article summarizes the results of several islands on hydrogen as an energy vector using the RenewIslands methodology. The primary goal for using hydrogen as an energy vector on islands was to increase the penetration of renewable energy, to ensure security of energy supply and to satisfy the energy demand with local resources. The results show that hydrogen as an energy vector is a technically feasible solution beyond fossil fuels and that it can achieve those goals.
Maxoulis & Kalogirou [41]	**Mediterranean sea/Cyprus.**	836,000in. 9,251 km^2 90 in/km^2	Solar thermal, PV, biomass and wind energy.	Stakeholder analysis, literature review, case study.	An island with a high dependency of oil started using renewable energy with its accession to the European Union. The technologies used were: solar thermal, PV, biomass and wind energy. This island now generates more than four percent of renewable energy from 0% four years ago. The authors concluded that the successful completion of the strategic plan for RES requires the increase of public awareness and the reinforcement of the environmental consciousness of all stakeholders.

Table A. *Cont.*

Author/year	Region/island name	Population/surface/ density	RES technology	Methodology	Summary
Corsini *et al.* [42]	**Mediterranean sea/Ventotene (Italy)**	710 in. 300 km^2 2.3 in/km^2	Hydrogen from solar	Simulation model TRNSYS for solar-hydrogen systems, using the component model library HYDROGEMS.	The study compares two renewable energy buffering strategies for seasonal buffering in an island context; a hydrogen-based system and a desalinated water-production system with a simulation model for solar-hydrogen systems, using the component model library HYDROGEMS and an in-house made OWC library. The suitability of both models for the winter renewable energy buffer is proven. Both are able to satisfy peak energy and water demands.
Maria & Tsoutsos [28]	**Mediterranean sea/unspecified**	N.A.	Wind	European and Greek normative review	The authors were mainly interested in the co-existence of environmental protection and energy supply policies and the contribution of wind energy to both. They find out that the application of the principle of proportionality, as a suitable legislative tool for resolving future conflicts, contributes decisively to discovering the limits beyond which the use of RES in energy production clashes with the preservation of the natural landscape.
Oikonomou *et al.* [43]	**Mediterranean sea/Dodecanese islands (17 islands)**	990,000in. 69,464 km^2 14 in/km^2	Wind	EMERGENCE 2010, an stages-based methodology that selects the more feasible projects based in background information (energy consumption, financial parameters).	The researchers identify which wind projects satisfy the energy target for 2010, which ones are economically feasible and the limitations in terms of grid access, proximity to tourists sites and negative public opinion. A socio-economic study was performed with the aim to know the public opinion on energy issues and technologies, their energy behavior and attitude. This study presents a flexible methodology to improve the contribution of RES towards regional sustainability, through the implementation of an integrated RES project selection and planning procedure which, from the early stages, can involve the local community and regional authorities and calls for the support of public opinion (participatory planning).

Table A. *Cont.*

Author/year	Region/island name	Population/surface/density	RES technology	Methodology	Summary
Oikonomou *et al.* [43]	**Mediterranean sea/Dodecanese islands (17 islands)**	990,000in. 69,464 km^2 14 in/km^2	Wind	Second, a cost analysis model is developed. At the third part, the existing barriers are studied and are concluded with a socio-economic analysis in a community participatory manner.	The researchers identify which wind projects satisfy the energy target for 2010, which ones are economically feasible and the limitations in terms of grid access, proximity to tourists sites and negative public opinion. A socio-economic study was performed with the aim to know the public opinion on energy issues and technologies, their energy behavior and attitude. This study presents a flexible methodology to improve the contribution of RES towards regional sustainability, through the implementation of an integrated RES project selection and planning procedure which, from the early stages, can involve the local community and regional authorities and calls for the support of public opinion (participatory planning).
Matera *et al.* [23]	**Mediterranean sea/Sicily (Italy).**	5,036,670 in. 25,460 km^2 197 in/km^2	Hydrogen from RES in transport	Techno-economic analysis of a project that consists in vehicle design, hydrogen production from RES and methane, and implementation strategies to develop a hydrogen and renewable energy economy	The aim of this study is to develop a transportation system based on hydrogen from renewable energy sources. The microcars using this technology can solve the problems related to individual mobility in protected areas with efficient, noiseless and non-polluting vehicles and introduce an easy-to use technology oriented to tourism and car rental.

Table A. *Cont.*

Author/year	Region/island name	Population/surface/ density	RES technology	Methodology	Summary
Stuyfzand & Kappelhof [18]	**Unspecified**	N.A.	Combination of RES (solar, wind, biomass).	Case study; Literature review	This article explain how water desalination (wd) could be accomplished using a floating, high-capacity desalting island based on a combination of RES. Some issues are considered like intermittency of some RES, energy storage, extreme weather conditions, corrosion of materials and construction costs. The authors claim that this technology may obtain enough water of high quality using 50% less energy (about 2 kWh/m3), and that it requires less frequent and less laborious maintenance, leading to higher plant productivity.
Singal and Vaun [16]	Neil Island, India	2,600 in. 12 km^2 216 in/km^2	Biogas, biomass, solar PV	Literature review and case study. Local data were collected with survey door to door covering all the households in all the five villages at Neil Island	In this paper, a study is carried out on the SD of renewable energy sources aimed at fulfilling the energy demands of a remote island. The authors took into account the costs of biogas, biomass, Solar PV and diesel power generation. They found that the conventional diesel power plant can be replaced by RES in a self-sustainable manner to achieve energy independence in a remote island. Two of these resources are even cheaper than the conventional diesel generation system. Only solar system is costlier.
Zsigraiová *et al.* [44]	**Atlantic ocean/Cape Verde**	506,000 in. 4,033 km^2 125,665 in/km^2	Energy recovery from waste incineration	Environmental, economic and 3D-GIS modeling.	This paper provides a model that integrates optimization of waste incineration with energy recovery and production of combined heat and power (CHP), the heat being used for drinking water production. It models Cape Verde's problems of poor primary energy and drinking water sources with a 3D-GIS. The results show that application of municipal solid waste incineration as a treatment alternative for the solid waste in Cape Verde is feasible. In addition to elimination of waste, it is also a potential energy source.

Table A. *Cont.*

Author/year	Region/island name	Population/surface/ density	RES technology	Methodology	Summary
Zafirakis & Kaldellis [45]	Mediterranean sea/Crete (Greece).	624,000 in. 8,335 km^2 74 in/km^2	Wind	Techno-economic analysis of competing technological alternatives (no environmental analysis)	The main target of this study is to evaluate the economic performance of a dual mode compressed air energy storage (CAES) system combined with wind farms already operating. The island of Crete is used as a case study. Life-cycle electricity production costs, including the energy storage installation, were calculated. The researchers concluded that the dual mode CAES configuration is cost-effective to replace the outmoded gas turbines currently used to cover peak loads at extremely high electricity production costs.
Dimitropoulos & Kontoleon [46]	Aegean sea/Greece.	11.2 millions	Wind	Extensive literature review, focus group sessions and pilot testing	This paper identifies, analyzes and evaluates the factors which give rise to the resistance of local communities to the sitting of wind farms in their vicinity. The results of the analysis show that the conservation status of the area where the wind farms are to be installed, along with the governance characteristics of the planning procedure are the most important determinants of local community attitude with respect to wind farms.
Chiaramonti *et al.* [47]	Atlantic ocean/Canary Islands (Spain)	2,075,968 in. 7,273 km^2 285 in/km^2	Biomass (energy crops)	Techno-economic analysis. Case study	The study defines a techno-economic compromise between energy crops, a biomass generator, a desalination unit and a irrigation system, using an arid area of Tenerife as the reference case study (experiment). The study found that the proposed system is energetically balanced and, in addition, it leads to some product surplus (in terms of energy, biomass, water or rescued land). Regarding the economics of the entire system, this is today less favorable, mainly due to the current high prices of the few commercial technologies existing in the bioenergy market, which are not developed at an industrial level.

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Author/year	Region/island name	Population/surface/ density	RES technology	Methodology	Summary
Davies [48]	**King Island, Tasmania**	1,720 in. 1,101 km^2 1.5 in/km^2	Bioenergy (energy crops and wood-to-energy)	Case study	This paper describes the problems faced by Kelp Industries in selecting an alternative fuel source, issues related to wood supply, and the cost savings and employment benefits to the wider community. The fuels taken into consideration were: air dry fuel wood, industrial diesel fuel, L.P. gas and electricity. The potential cost savings of the wood and other aspects were studied. The result was good for the private business (lower costs) and also for the island due to the multiplier effect of the investment in the local economy.
Lavi and Lavi [49]	U.S. islands	N.A.	Ocean thermal energy conversion (OTEC):	Literature review and case study	This paper addresses economic, social and environmental issues involved in the commercialization of ocean technologies (OTEC) in U.S. islands. The authors show that OTEC can provide the U.S. a renewable resource at a competitive price compared to other technologies. However, even if OTEC was both technically and economically sound, many factors delayed OTEC penetration into the U.S. mainland market on a sufficiently large scale. The author also anticipated that private ownership of OTEC-dedicated production facilities and of commercial OTEC power plants is not likely to materialize independently of some government involvement, at least in the early commercial stages. Therefore, government financial incentives will be necessary.

Table A. *Cont.*

Author/year	**Region/island name**	**Population/surface/ density**	**RES technology**	**Methodology**	**Summary**
Yu and Taplin [50]	Pacific islands		Generic (all RES)	Document research.	This paper assesses the international bilateral and multilateral aid for RES in the Pacific islands from the late 70s to 1996. The authors conducted a survey (among the donors) between November 1995 and May 1996. The results reveal that, in the future, international aid for RES in the region could be enhanced and improved with further financial and human resources, better institutional development, local community involvement, creation of joint ventures and more efficiency in the management of the aid.
Bueno and Carta [51]	Atlantic Ocean/Canary Islands (Spain).	2,075,968 in. 7,273 km^2 285 in/km^2	Wind powered pumped hydro storage system	Application of an optimum-sized economic model	This study focuses on the grid-related barriers discouraging the penetration of RES in the electricity system of the Gran Canaria island. It proposes the installation of a wind powered pumped hydro storage system. Basically, this system uses excess electricity production, in periods of low demand, to pump water to a deposit situated at a certain height. This water is then recovered through a turbine to cover peak load demand. The results indicate that the penetration of RES can be increased by almost 2% at a competitive cost.