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Assessment of Energy, Mobility, Waste, and Water Management on Italian Small Islands

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Abstract: Small islands are recognized for their vulnerability to climate change. In this context, mitigation and adaptation policies are needed, but the ecological transition must be based on data. This study aims to assess the level of sustainability reached by 26 of the inhabited Italian small islands; it collects and analyzes the data and initiatives on the energy, mobility, waste, and water sectors and discusses the islands' steps toward sustainability. The findings show that 18 of the 26 islands are not interconnected with the national grid and that the renewable sources cover less than 5% of the energy demand on 25 of the 26 islands. The number per capita of private vehicles reaches 90 cars per 100 inhabitants on three islands. The average of the separate collection of waste on the islands is 52%, which is far from the minimum recommended threshold of 65%. Pipelines or tankers on 17 of the 26 islands guarantee the water supply, and desalination plants are still not the rule, while the presence of wastewater treatment has been detected on 12 islands, and it often provides only partial treatment. An ambitious multi-stakeholder sustainability plan for each island should be developed to overcome the typical barriers of the island and to increase the building capacity in order to use economic incentives for that goal.

Keywords: small islands; decarbonization; energy transition; water–energy–waste nexus

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1. Introduction

All small islands around the world share common features: a small population; limited economic diversity; relative remoteness, leading to isolation and challenges for trading and access to fundamental services; and pressure on resources, depending on tourism peaks; however, small islands also have unique biodiversity and cultural richness, which constitute strong tourism attractors. Thus, in addition to the effects of climate change that hit the entire Mediterranean, the dependence on resources from the mainland [1] makes the Mediterranean islands one of the most vulnerable areas of Europe.

Islands encompass a small fraction of Earth's surface; yet. they harbor an array of extraordinary flora and fauna. With approximately 50,000 plant species and 15% of all mammals and birds, these remarkable ecosystems exhibit exceptional biodiversity. Some islands serve as thriving biodiversity hotspots, while others showcase a more limited but still significant range of species. As microcosms of ecological and evolutionary processes, islands hold great scientific significance. Furthermore, islands, along with their surrounding coastal marine areas, foster unique ecosystems that host numerous endemic species found nowhere else on the planet. These ecosystems bear the imprint of an unparalleled evolutionary history and represent irreplaceable treasures [2]. However, island species also face heightened vulnerability, as demonstrated by the fact that approximately half of the recorded animal extinctions in the past 400 years have been island-dependent. Over the last century, islands have encountered mounting pressures, such as invasive alien species, habitat alteration, overexploitation, and, increasingly, the impacts of climate change and pollution. Safeguarding the biodiversity of islands has become an urgent priority in the preservation of these invaluable and threatened ecosystems [3].

Among the different threats afflicting islands, climate change has the most widespread effects, and while its effects are global, Europe in particular is warming up faster than many other regions. According to the IPCC (Intergovernmental Panel on Climate Change), Europe and the Mediterranean region, where the small Italian islands are located, will face negative climate change impacts that are mainly related to an increase in average and maximum temperatures, to an increase in the frequency of extreme weather events, such as heatwaves and droughts, and to changes in rainfall leading to a worsening of the already existing conditions of strong pressure on water resources, such as reduced water quality and availability [4].

As with many Mediterranean small islands, Italian small islands are heavily dependent on fossil fuels and must deal with specific problems such as the small-scale generation of electricity, high distribution costs, underutilization of renewable energy source (RES), potential, high seasonality of human presence, water scarcity, unprocessed wastes, an antiquated model of mobility [5,6]. In preserving these islands, policies have certain roles. For example, Lam-González et al. analyzed the most relevant impacts of climate change in island tourist destinations and the associated adaptation policies [7]. These places are predominantly focused on tourism, which constitutes their main economic income. Thus, land protection and adaptation to climate change through the adoption of policies in these tourist destinations are very important, however, such policies are more difficult to apply than in other areas of the world as small islands are not able to access expertise, data, and financial resources as easily as larger cities, as is also indicated by Major et al. [8].

In light of the unique circumstances surrounding the fragility of small islands, the 2015 Paris Agreement recognizes that small islands are particularly vulnerable to climate change. At the same time, owing to their potential as pioneers for new technologies, islands are recognized as enhancers of resilience and mitigation strategies against global climate change through decarbonization of the energy sector and of other sectors, such as agriculture and transportation.

There are some EU (European Union) initiatives (e.g., the New Energy Solutions Optimised for Islands (NESOI) Island Facility [9], and the Clean Energy for EU islands Secretariat [10]) focused on energy transition. More specifically, the CE4EU initiative intends to support EU islands in their clean energy transition. The core objective of the initiative is to assist islands with the exploitation of their own renewable energy sources and the adoption of innovative technological solutions in order to reduce their dependence on fossil fuels and to enable them to benefit from lower energy costs, better air quality, and lower greenhouse gas emissions.

Over the last twenty years, a few initiatives related to the introduction of energy self-sufficiency in isolated locations have been observed. For example, in the case of Bornholm, Samsø (Denmark), a non-self-sufficient island, the problem was addressed by ensuring a balance between energy supply and demand, by conserving excess, and by smart energy management [11]. Another project on the small El Hierro island (Canary Islands, Spain) implemented the first megawatt-level energy project by linking wind power generation with energy storage systems, using the water storage to exploit the pumping system between two artificial lakes [12].

However, the decarbonization path also includes waste management and the circular economy, water management, sustainable tourism, and mobility. To reach sustainable development objectives, the first important steps should be to collect data and to monitor the evolution of changes affecting islands. Most of the research on ecological transition on small islands focuses on the technical issues related to energy grids, or it considers non-Mediterranean islands or small island developing states (SIDS).

There is still a distinct lack of extensive studies on small Mediterranean islands, despite their high level of vulnerability to the impacts of climate change. Recently, Angel Mena-Nieto et al. published a comparative study from 2000 to 2035 focused on waste in the Balearics and the Canary Islands [13]. Domenico Curto et al. made an evaluation of the optimal renewable electricity mix for Lampedusa Island through the adoption of a technical and economical methodology [14]. As Doorga comments, one of the problems in collecting data and extrapolating relevant variations at the small island scale, e.g., with regard to climate scenarios, is the coarseness of the spatial resolution of satellite data [15].

This study collected and assessed the data on the energy, mobility, waste policies, water supply, and wastewater of maritime small islands, which are not yet available at the Italian and European level, focusing on 26 of the inhabited Italian small islands. The focus of the study was to supply data, which were still lacking, that could help policymakers in defining a framework for the Italian small islands. The strength of this contribution is the attempt to outline a multi-sectorial assessment of the sustainability of the Italian small islands, putting together in the analysis the data and the practices regarding energy, mobility, waste, and water. This allows a baseline which will be useful in monitoring and assessing the efficacy of the policies that will be adopted with regard to sustainability. These 26 inhabited Italian small islands in 2021 reached 188,368 [16] inhabitants, covering a total surface area of 842.54 km^2 [17]. Moreover, this study assesses the small islands' steps on the road to sustainability through the collection and analysis of the data and initiatives on energy, mobility, and waste and water management, as well as the policies adopted. A comparison of the paths to sustainability applied by other islands in the world is also made. Specific attention was focused on the successes and limits of the existing policies, and they were evaluated in terms of environmental sustainability and the identification of technological and non-technological barriers.

2. Materials and Methods

2.1. Data Collection

Detailed data from several official and governmental sources were collected; the data were focused on 26 inhabited Italian maritime small islands (Figure 1). The data were collected between 2017 and 2021, depending on the data availability. The Gorgona Island, Municipality of Livorno, and the Palmaria islands, Municipality of Portovenere, were excluded from the analysis because of their very small populations of less than 300 inhabitants.

The purpose of the data collection was to analyze the baseline scenario and to monitor the evolution towards sustainability by analyzing the most recent data available on the energy, mobility, waste, and water sectors. The strategies implemented by different islands were compared with those of the international studies focused on small island policies.

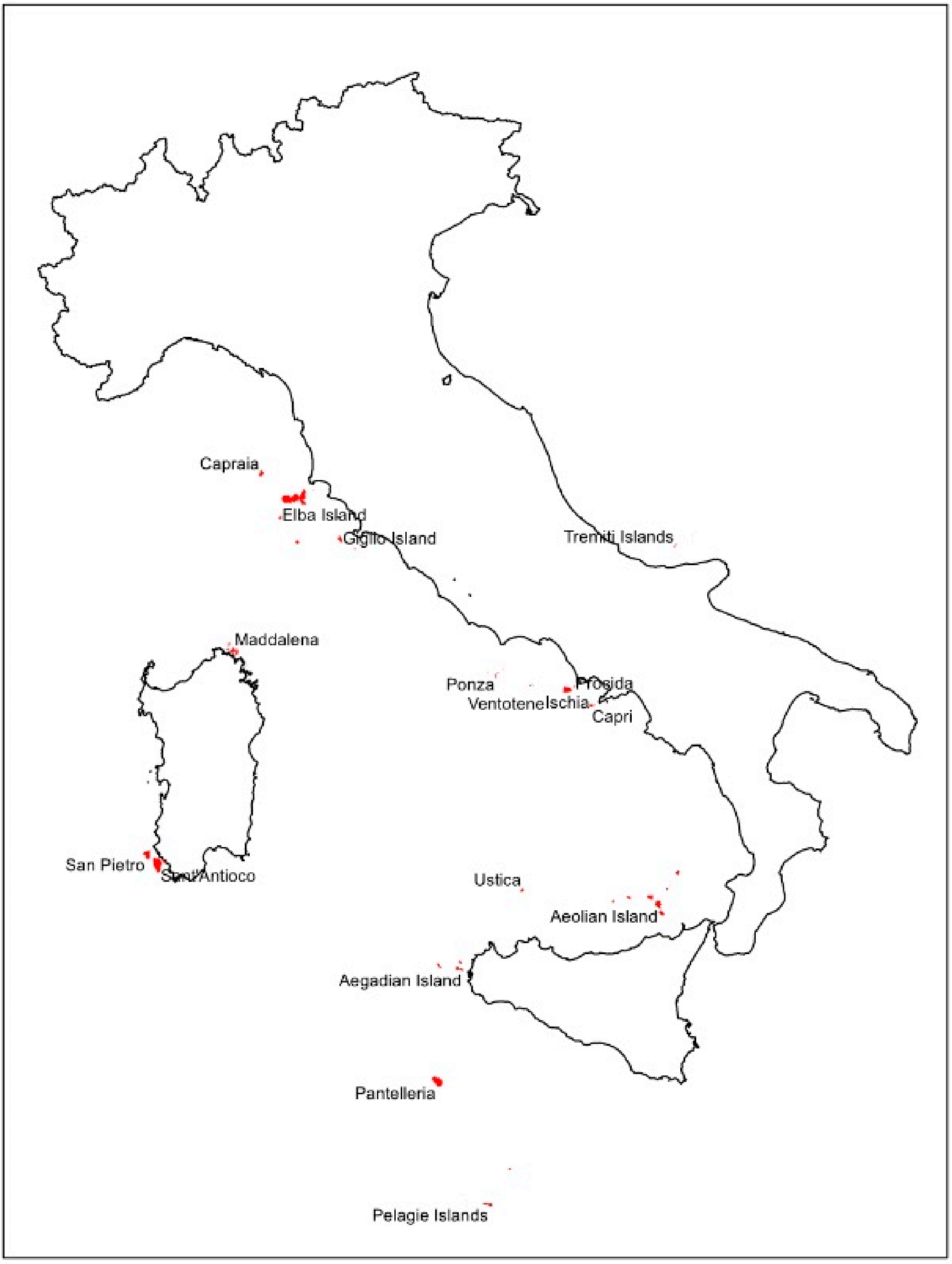

Figure 1. Map of Italian maritime small islands.

Data from several databases were collected from several institutions and companies: Automobile Club d'Italia (ACI) [18], Istituto Nazionale di Statistica (ISTAT), the European Commission Urban Waste Water website [19], Gestore dei Servizi Energetici (GSE S.p.A.) [20], Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) [21], local electricity management companies (Table 1), and the Italian Ministry of Economic Development (MiSE) [22]. Data were provided by the municipality and the water management companies' websites (Table 1). For each island, data on the main power sources, annual electricity production from fossil fuels, energy management companies, and installed power from renewable sources (photovoltaic, wind, and solar surface of solar thermal) were collected. Regarding the depuration and drinking water supplies, the water supply arrangements, the status of wastewater treatment, and the purification treatments applied were taken into account. The data on waste management included the waste collection method and the separate collection percentage, which included the data per capita and the urban waste production per capita for each municipality. Regarding the mobility sector, the vehicle fleet and the distribution of vehicles per European Emissions Standard Class (EESC) were collected, and the car ownership rate was calculated.

Table 1. Years and source of data.

Source	Data	Years
ACI	Vehicle fleet and European Emissions Standard Class of car fleet	2019, 2020, 2021
ISTAT	Number of inhabitants; Islands/Municipal surfaces	2019, 2020, 2021; 2011
European Commission Urban Waste Water Website	Presence of wastewater treatment, treatment status	2020
ISPRA	Waste sorting	2019, 2020, 2021
Municipality websites	Waste collection method	2021
Local energy management company— Società Elettrica Liparese S.MED.E Pantelleria spa S.EL.I.S. Lampedusa spa Società Elettrica di Favignana spa Società Elettrica Ponzese Enel Produzione Società Impianti Elettrici srl Impresa Elettrica D'Anna Bonaccorsi S.EL.I.S. Marettimo spa Germano Industrie Elettriche S.EL.I.S. Linosa spa I.C.EL. srl	Energy sources	2021
MiSE Ministerial Decree 14 February 2017	Annual electricity production from fossil fuels	2017
GSE	Photovoltaic power installed, wind power installed, and solar area installed	2019, 2020, 2021
Municipality and water management company websites	Water supply arrangements	2021

2.2. Data Analysis

The data were collected from individual municipalities, as data were not available for a single island belonging to a municipality consisting of several islands. The data were aggregated for multiple-municipality islands. Groups of islands governed by a single municipality were similarly treated in aggregated form. The data on the main source of energy, the annual electricity production from fossil fuels, the energy and water management companies, and the water purification systems were collected on an island-by-island basis.

The annual electricity production from renewable energy [MWhe/year] was calculated by multiplying the nominal power installed per the number of equivalent hours of use [20].

Energy demand covered by renewable sources was calculated by the ratio of the annual electricity production from renewable energy [MWhe/year] to the total annual electricity production (from fossil fuel+RES) [MWhe/year].

The water treatment status was categorized as partial or total. Partial means that the ratio between the load treated yearly and the optimal treatment load (both in terms of equivalent inhabitants) is less than 1; total means that the ratio is 1.

The waste collection methods were classified into these categories: ecological platform, road bins, door-to-door collection, domestic composting, road bells, and on-call service. Separate waste collection per capita was calculated by dividing the total separate waste collection by the number of inhabitants for each year. Urban waste per capita was calculated by dividing the total urban waste by the number of inhabitants for each year.

The vehicle fleet data were categorized as follows: buses, freight vehicles, special vehicles and tractors, cars, and motorcycles. For each year, the vehicle fleet data were collected according to class and aggregated as indicated above. The percentage of vehicles for each year and class was calculated by dividing the total of a vehicle class by the total fleet per island. The vehicle fleet per EESC for each year was calculated by dividing the total number of vehicles in each EESC, including undefined vehicles, by the total number of vehicles. Then, for each year, the vehicles corresponding to classes 0, 1, 2, and 3 and classes 4, 5, and 6 and the undefined vehicles were added up. The cars per capita rate was obtained by calculating the ratio of the total number of cars to the population.

The state of the art of the existing policies, legislations, and regulations was considered through official websites, public tenders, and project rankings.

3. Results

The results shown in the graphs can also be found in table format in the Supplementary Materials.

3.1. Energy

Among the 26 inhabited islands considered, 18 are still not interconnected to the national energy grid (Pelagie Islands, Egadi Islands, Tremiti Islands, Aeolian Islands, Ponza, Ventotene, Ustica, Capraia, and Giglio Island). Thus, the energy systems of these islands rely mainly on fossil fuels that are imported from the mainland and have higher costs [23]. The liberalization of the Italian energy sector in 2009 contributed to the lowering of costs for the small islands inhabitants. In fact, the UC4 (component of expenditure for determining the cost of energy to cover the increased costs of 12 small electricity companies operating on minor islands) economic incentive, which is now contained in the ARIM (component of system charges allocated to various facilities and incentives) incentive, was introduced in the electricity bills to cover the higher costs for electricity production on the small islands, thus guaranteeing the same price for energy on islands as on the mainland.

However, with the new European targets on the reduction in CO_2 emissions [24], the small islands need a change in pace because today their electric energy production is provided by old and polluting diesel systems. In fact, with the REPower EU plan, the European Commission proposes to increase the EU's 2030 target for renewables from the current 40% to 45% [24]. This plan aims to raise the total generation capacity of the EU's renewable energy plants to 1236 GW by 2030, which is a more ambitious target than the 1067 GW envisaged under EU package "Fit for 55" [25]. The situation concerning energy provision and renewable energy sources diffusion is described in Table 2 and Figure 2 (Table S1), Figure 3 (Table S1), and Figure 4 (Table S1).

On the Italian small islands, fossil fuels are the main source of energy, which is mainly produced by diesel engines. Renewable energy is produced by photovoltaic (PV) and wind power plants, and solar thermal plants are also installed. Only the islands of Pantelleria, Ventotene, and Sant'Antioco have wind power plants, solar thermal plants are present on every island except for Capraia, and photovoltaic plants have been built on all of the inhabited islands.

As far as solar thermal energy is concerned, Ponza is the island with the most dedicated square meters per inhabitant, followed by Capri, Salina, and Procida. San Pietro island has the best kW per inhabitant ratio for wind power.

Table 2. Power source, annual electricity production from fossil fuels [GWhe/year], and energy management companies on small inhabited Italian islands. Power source is fossil diesel generator, except for Capraia, where biodiesel is used. Islands with no value for electricity production are connected to the national grid [22].

Islands	Power Source	Annual Electricity Production from Fossil Fuels [GWhe/Year]	Energy Management Companies
Alicudi	Diesel generator	400	Enel Produzione
Capraia	Biodiesel	2.76	Enel Produzione
Capri	Interconnected with national grid		Enel Produzione
Elba Islands	Interconnected with national grid		-
Favignana	Diesel generator	15.47	Società Elettrica di Favignana S.p.A.
Filicudi	Diesel generator	1.4	Enel Produzione
Giglio Island	Diesel generator	10.3	Società Impianti Elettrici S.r.l
Ischia	Interconnected with national grid		-
La Maddalena	Interconnected with national grid		-
Lampedusa	Diesel generator	3.766	S.EL.I.S. Lampedusa S.p.A.
Levanzo	Diesel generator	600	I.C.EL. S.r.l
Linosa	Diesel generator	2.8	S.EL.I.S. Linosa S.p.A.
Lipari	Diesel generator	34.8	Società Elettrica Liparese
Marettimo	Diesel generator	2.04	S.EL.I.S. Marettimo S.p.A.
Panarea	Diesel generator	3.14	Enel Produzione
Pantelleria	Diesel generator	44.17	S.MED.E Pantelleria S.p.A.
Ponza	Diesel generator	11.5	Società Elettrica Ponzese
Procida	Interconnected with national grid		-
Salina	Diesel generator	9.16	Enel Produzione
San Pietro	Interconnected with national grid		-
Sant'antioco	Interconnected with national grid		-
Stromboli	Diesel generator	3.92	Enel Produzione
Tremiti Islands	Diesel generator	3.87	Germano Industrie Elettriche
Ustica	Diesel generator	4.87	Impresa Elettrica D'Anna Bonaccorsi
Ventotene	Diesel generator	2.7	Enel Produzione
Vulcano	Diesel generator	7.28	Enel Produzione

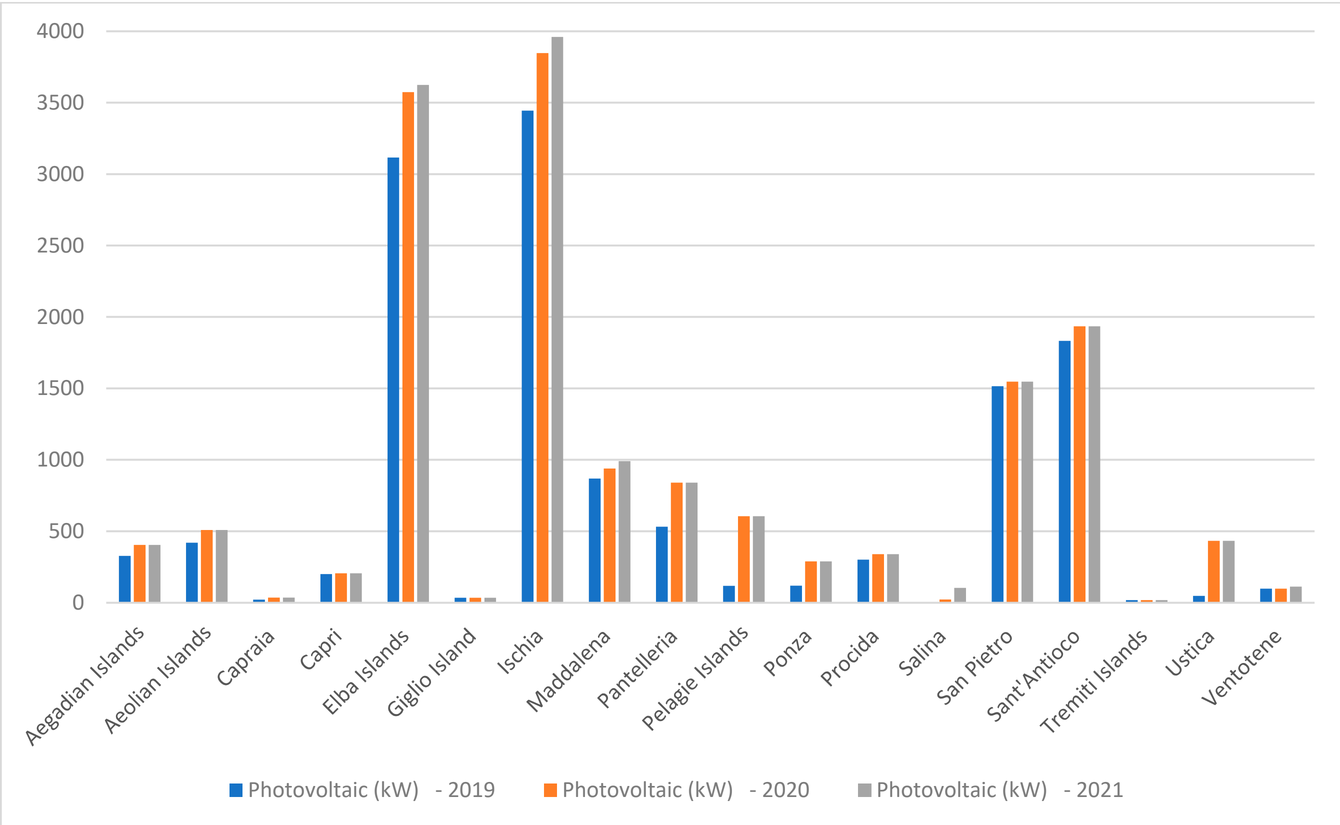

Figure 2. Photovoltaic power installed on Italy's smaller islands in 2019, 2020, and 2021 [26].

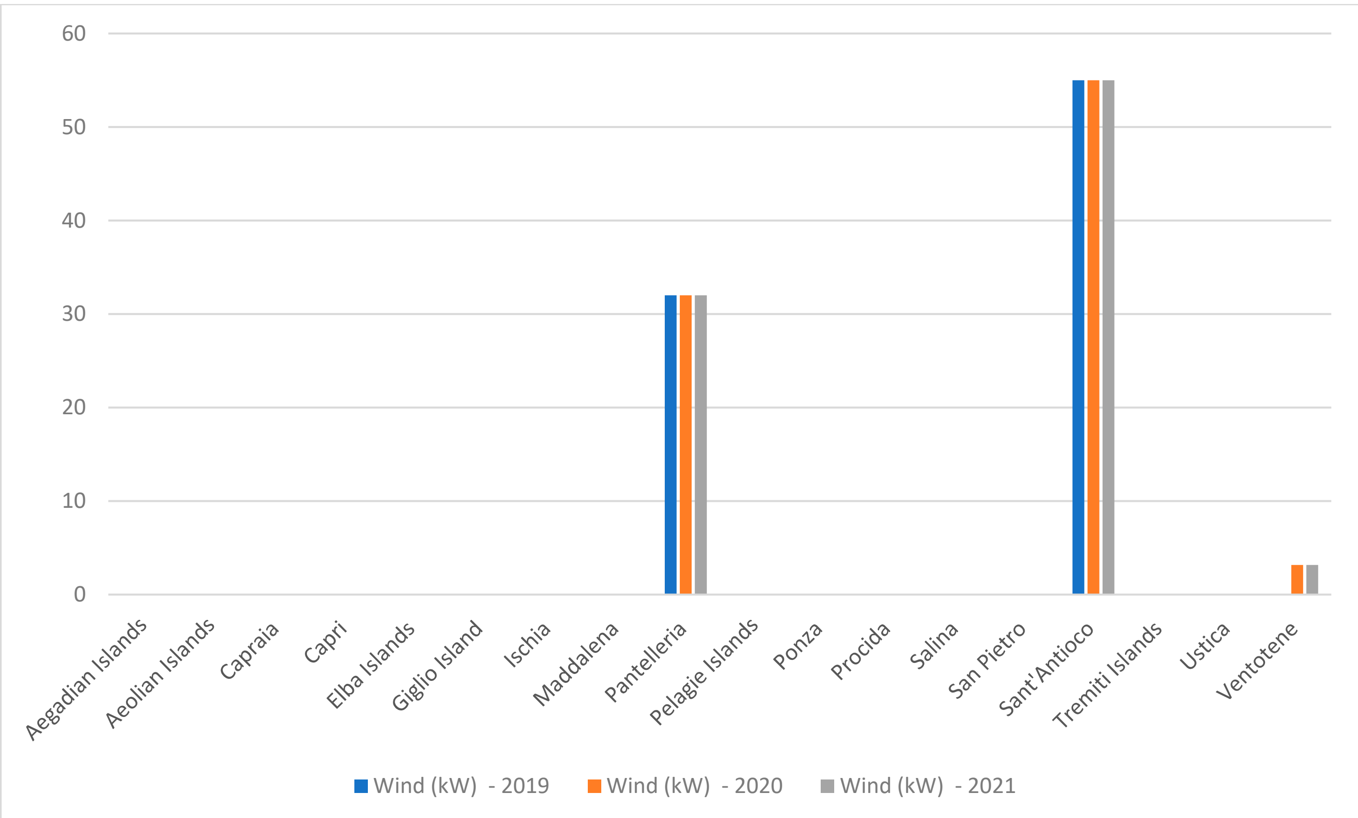

Figure 3. Wind power installed on Italy's smaller islands in 2019, 2020, and 2021 [26].

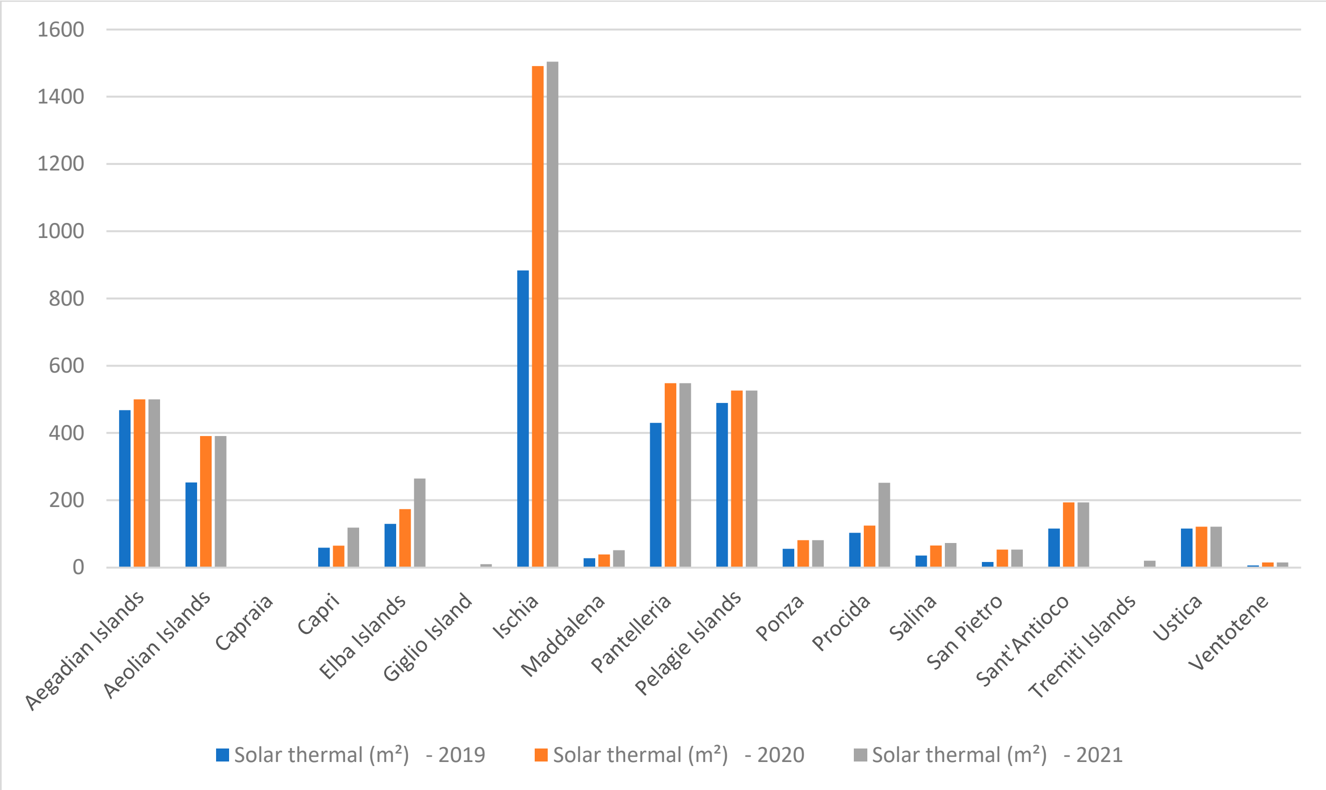

Figure 4. Solar thermal installed on Italy's smaller islands in 2019, 2020, and 2021 [26].

By December 2021, power generation plants from renewable energy sources, including photovoltaics and wind power, had been installed on the small islands, with a total capacity of 27,958.59 kW_e. The islands with the highest photovoltaic plant development are all non-interconnected with the mainland. The islands that most increased their installed power between 2019 and 2021 were the Pelagie, Ponza, Ventotene, and Salina islands. The growth of RES penetration is partly due to the incentives provided by the Ministry of Economic Development. Although this is a positive sign, the RES plants installed are still insufficient to meet the targets to be reached by 31 December 2020, according to the decree issued by the same Ministry in 2017, which fixed the objective in terms of energy production from renewable sources [22]. The best results were achieved by Ustica, which exceeded the target by reaching 432 kW of RES installed compared to the target 280 kW, and in Capraia, where the use of fossil fuels for energy production was completely eliminated.

Table 3 shows that the energy production from renewable sources covers less than 10% on all the small islands. All the islands are a long way from reaching the target of 100 percent support from renewable sources.

Despite the European policy that requires climate neutrality by 2050, with an economy with net-zero greenhouse gas emissions [27], very few islands are 100% powered by renewable energy in the European context. As an example, [28] mentions the islands of Samsø in Denmark and Pellworm in Germany. By virtue of a combined system exploiting wind and water power, El Hierro became fully energy self-sufficient. The energy is produced by five wind turbines and by pump storage hydroelectricity, and it satisfies the demands of the 10,000 inhabitants [29].

Table 3. Comparison between annual electricity produced from renewable energy and fossil fuel—covering of energy production from renewable sources. Data on electricity produced from RES were collected from GSE [20,26].

Islands	Annual Electricity Production from Renewable Energy [MWhe/Year]	Annual Electricity Production from Fossil Fuel [MWhe/Year]	Energy Demand Covered by Renewable Sources
Aegadian Islands (Favignana, Levanzo, Marettimo)	475.23	17,510	2.64%
Aeolian Islands (Lipari, Vulcano, Stromboli, Panarea, Filicudi, Alicudi)	598.45	50,540	1.17%
Capraia	41.77	2760	1.49%
Capri	242.56	Interconnected with national grid	-
Elba island	4261.6	Interconnected with national grid	-
Giglio Island	40.81	10,300	0.39%
Ischia	4657.42	Interconnected with national grid	-
Maddalena	1164.83	Interconnected with national grid	-
Pantelleria	1043,5	44,170	2.31%
Pelagie Islands (Lampedusa e Linosa)	711.62	40,460	1.73%
Ponza	340.21	11,500	2.87%
Procida	399.58	Interconnected with national grid	-
Salina	121.72	9160	1.31%
San Pietro	1819.54	Interconnected with national grid	-
Sant'Antioco	2370.14	Interconnected with national grid	-
Tremiti Islands	21.64	3870	0.56%
Ustica	508.78	4870	9.46%
Ventotene	137.41	2700	4.84%

In general, the other islands have not achieved a satisfactory RES coverage compared to demand. In 2019, in Gran Canary island, only 16.7% of the total installed capacity was based on renewable sources, amounting to only 7% of the annual electricity production [30]. Other examples are reported by Kuang et al., 2016 [23], where no case study reaches 100% electricity production from renewable energy, but most cases show higher ratios than those of the Italian islands.

The concept of renewable energy communities (REC) entails a novel approach to development, centered around the sustainable production and utilization of energy. Specifically, the implementation of building retrofits and energy communities holds significant potential for marginalized regions like small islands, serving as a catalyst for value creation and facilitating economic and social recovery in the aftermath of the pandemic. The utilization of cutting edge technologies within renewable energy communities enables the formulation of inventive energy management models. By fostering innovative forms of collaboration and governance within the energy sector, REC aims to empower local communities, benefiting both individuals and the community as a whole, while simultaneously offering valuable services within the region [31]. The European Commission introduced a set of proposals known as the Clean Energy for all Europeans Package in November 2016. The primary objective of this package was to assist the European Union in meeting its commitments under the Paris Agreement. Consequently, eight legislative acts were adopted between 2018 and the first half of 2019, signifying a comprehensive reform of the EU's energy policy framework. These legislative measures were enacted to align the European Union with its clean energy goals and to facilitate the transition towards a more sustainable energy future [32]. Of particular importance are the Directives 2018/2001, or RED-II [33] (which introduces the "Renewable Energy Communities"), and 944/2019 [34] (which defines the "Citizens' Energy Communities"), which are being implemented by the member states.

The problems related to such a slow development of renewable energy sources on small islands are various and concern both photovoltaics and wind power. The obstacles to the diffusion of RES do not generally depend on technological barriers, but rather on non-technological barriers. Excessively rigid landscape constraints, complex connection to grid requests, slow authorization procedures, are just some of the non-technological barriers that prevent the implementation of an adequate energy transition in these territories. In Spain, for example, the same problems can be observed: bureaucratic procedures were considered one of the biggest obstacles to the spread of wind energy [35].

3.2. Mobility

The issue of mobility on the islands is twofold: it involves local mobility, which includes managing summer tourism peaks, and the connection with the mainland. The transport sector is closely related to the energy sector: Raveendran et al. claim that the transport sector constitutes the main area of energy consumption on small tourist islands, as fuel for local power stations has to be transported from the mainland [36].

The vehicle fleets on all inhabited Italian islands are predominantly made up of cars, but in the Egadi Islands, Procida, and Capri, for example, a good percentage, up to 40%, is made up of motorbikes (Figure 5, Table S2). Goods transport vehicles are more numerous on Pantelleria and in the Tremiti Islands. Buses or private shuttles (i.e., any vehicle for the transport of persons equipped with more than nine seats, including the driver's), are particularly numerous in absolute terms on Ischia and the island of Elba, followed by Pantelleria, the Aeolian Islands, Sant'Antioco, and La Maddalena. There are far fewer buses for local public transport services and very few powered by alternative technologies to fossil fuels. Some islands such as Favignana and Pantelleria have participated in public tenders to finance low-emission buses, but this is still not enough to guarantee a zero-impact fleet on all the islands.

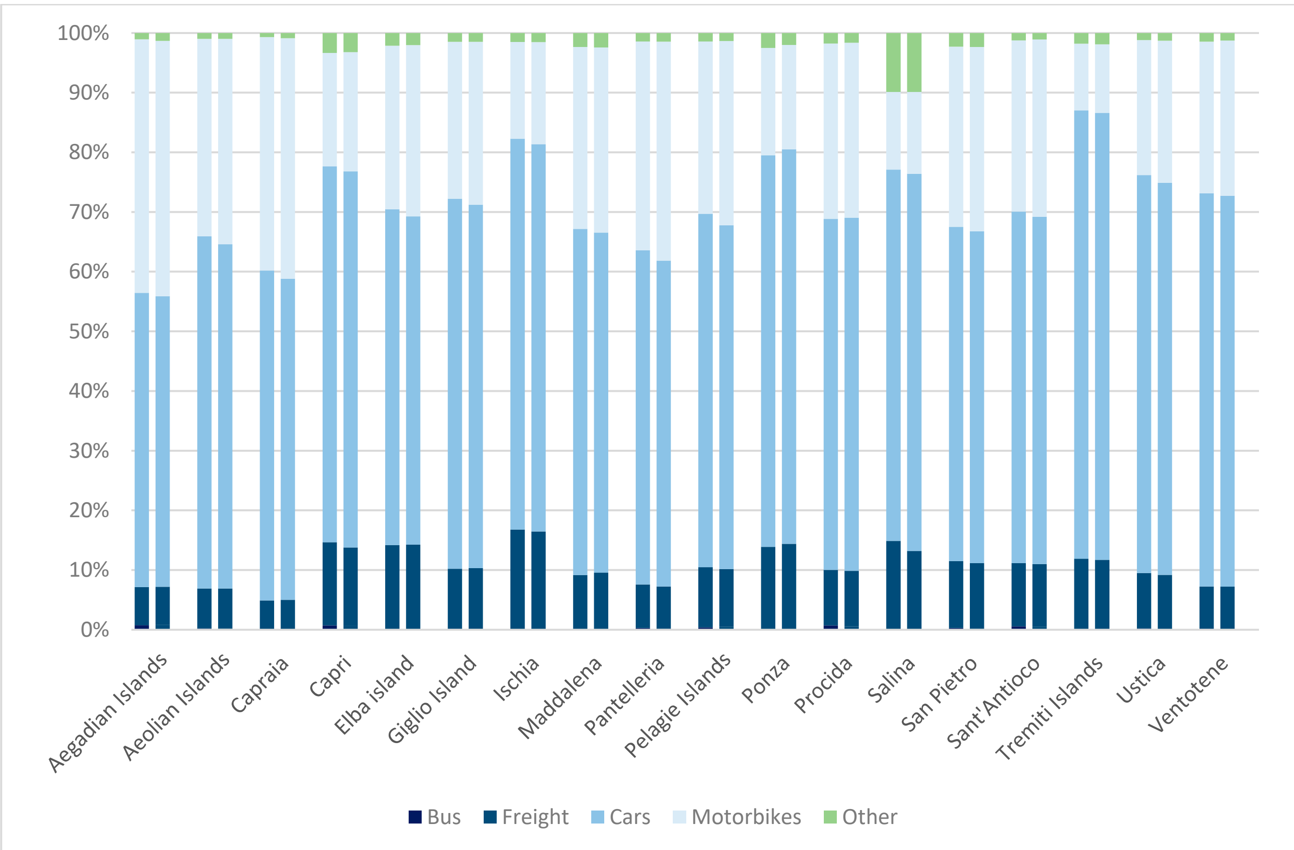

Figure 5. Breakdown of the vehicle fleets 2019–2021 in the small island municipalities.

During the last three years some different trends have been registered: on most islands, the number of motorbikes has increased, and the number of vehicles has decreased; the percentage of buses has also decreased on many islands, possibly due to the reduction in tourism following the pandemic crisis.

Among the Italian small islands, Lampedusa, Linosa, and Pantelleria had the highest number of vehicles per inhabitant in 2021, with the equivalent of 0.9 cars/inhabitant, while Capri had the lowest, with the equivalent of 0.3 cars/inhabitant. During the last three years, only the municipality of Procida reduced the number of vehicles per inhabitant, while the municipalities of Capraia, Pantelleria, Favignana, Ustica, and Carloforte increased it between 2019 and 2021. No changes were recorded on the other islands (Figure 6, Table S3).

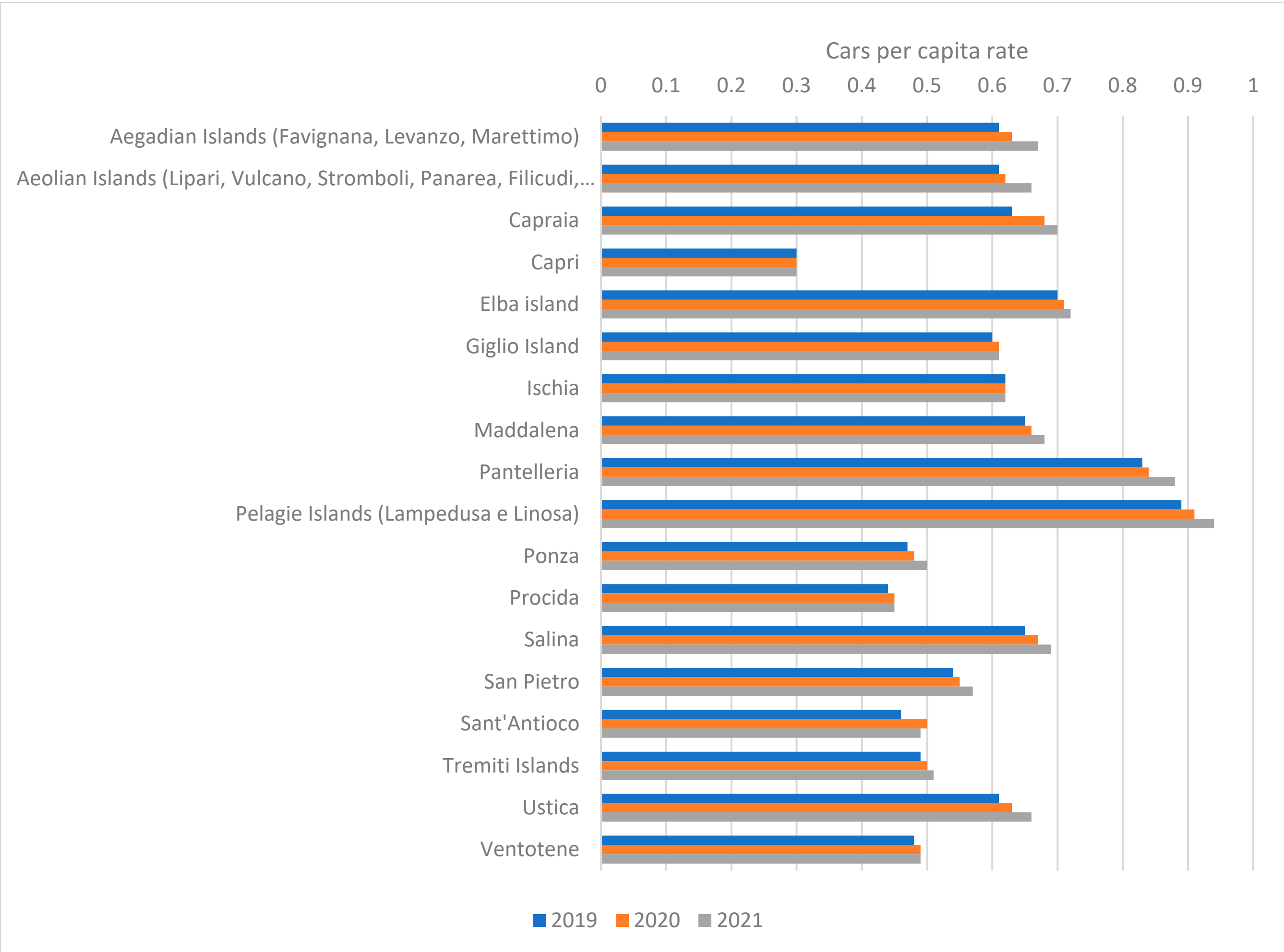

Figure 6. Cars per capita rate on the small islands.

The islands with the newest car fleets in 2021 were San Pietro with 77% and Procida and Elba islands with 72% Euro 4, 5, and 6 emission vehicles; the most obsolete cars were in the Pelagie Islands and on Salina island with 50% Euro 0, 1, 2, and 3 emission vehicles. The islands that made the most progress in the 3 years were Isola del Giglio, Isola d'Elba, Ventotene, and San Pietro (Figure 7, Table S4).

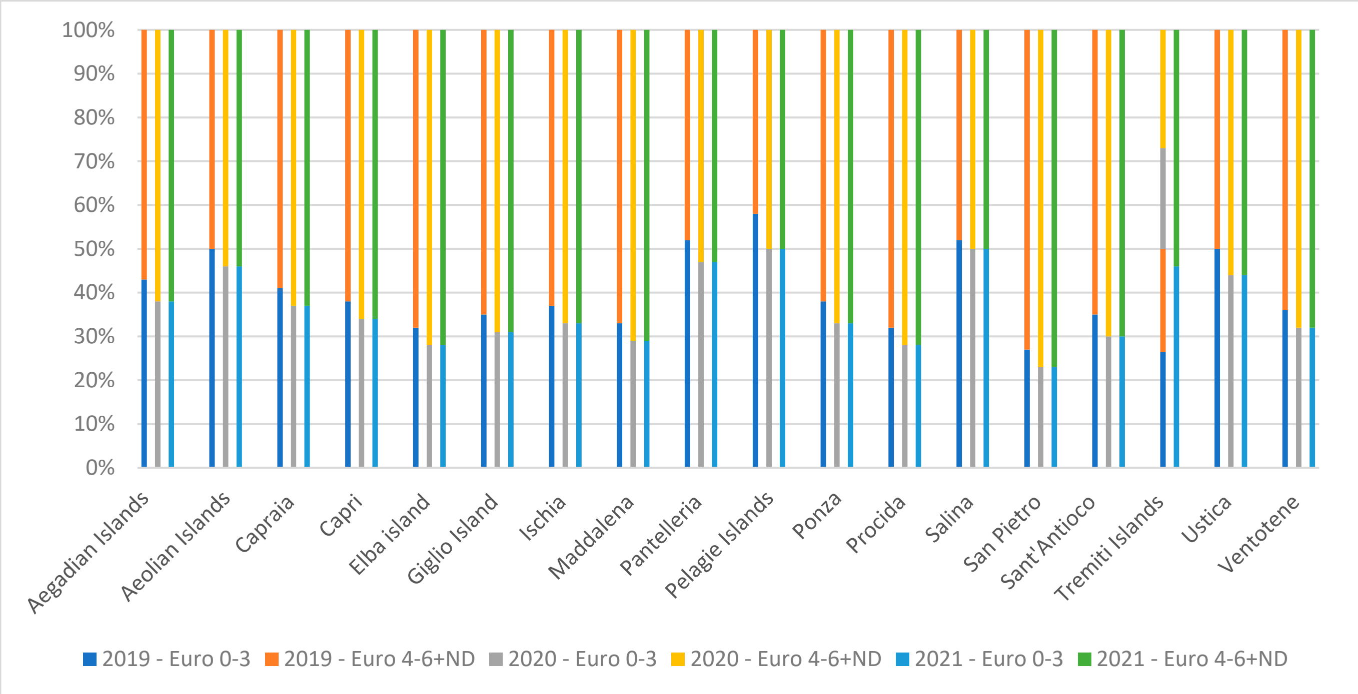

Figure 7. Breakdown of the vehicle fleets by European Emissions Standard Class 2019–2021 in the small island municipalities.

Private cars are the most common means of transport on most of the small islands. This is due in many cases to the structure of the road network which makes connections in the most remote areas of the island difficult. However, in view of the decarbonization goals, a strong push towards the use of renewable energy sources to power vehicles is needed, together with the incentivizing of the use of shared services and local public transport and the use of bicycles.

A good practice adopted on the island of Giglio through the LIFE SILVER COAST project involved the creation of an electric bicycle sharing service, three charging stations, and an electric boat. However, few data and little experience exist on the subject of cycling on Italian islands. There are interesting European case studies that demonstrate how non-technical barriers can be broken down. For example, the study by Maas and Attard [37] focusing on the islands of Limassol (Cyprus) and Las Palmas de Gran Canaria (Canary Islands), shows how planning dedicated infrastructure and traffic-calmed roads can facilitate the overcoming of the perception of reduced road safety, the main obstacle to cycling. Another study conducted by Ramos-Real et al. surveyed the citizens of Tenerife on their intention to purchase an electric vehicle to replace a conventional vehicle; it was found that almost half were willing to change their vehicle, especially if national incentives were available [38]. These two case studies suggest that the implementation of policies aimed at decarbonization could incentivize the use of more sustainable vehicles on the smaller Italian islands.

3.3. Waste Management

Overall, the capacity to sort waste increased between 2019 and 2021 on all the islands. The average separate collection achieved on the islands was 52% (Table 4).

Table 4. Waste sorting on small inhabited Italian islands from 2019 to 2021. Data are measured in kilograms per inhabitant per year (kg/in*year).

Islands	2019			2020			2021			2021
	Separate Collection (%)	Separate Collection per Capita (kg/in*Year)	Urban Waste per Capita (kg/in*Year)	Separate Collection (%)	Separate Collection per Capita (kg/in*Year)	Urban Waste per Capita (kg/in*Year)	Separate Collection (%)	Separate Collection per Capita (kg/in*Year)	Urban Waste per Capita (kg/in*Year)	Waste Collection Methods
Aegadian Islands (Favignana, Levanzo, Marettimo)	72%	490.19	683.29	75%	501.85	665.04	80%	581.27	729.1	Ecological platform, road bins, door to door
Aeolian Islands (Lipari, Vulcano, Stromboli, Panarea, Filicudi, Alicudi)	23%	176.00	749.93	22%	151.76	678.42	39%	266.73	685.47	Ecological platform, domestic composting, road bins, on-call service
Capraia	42%	391.65	936.41	40%	307.08	763.92	41%	366.46	897.78	Ecological platform, domestic composting, road bins, road bells
Capri	61%	522.93	860.75	61%	421.72	694.96	61%	484.92	791.37	Ecological platform, domestic composting, road bins, door to door
Elba Island	65%	586.54	906.34	63%	514.53	822.77	66%	593.16	902.19	Ecological platform, domestic composting, road bins, door to door
Giglio Island	30%	320.27	1054.39	31%	310.21	994.69	30%	316.68	1043.08	ecological platform
Ischia	44%	284.19	650.66	41%	239.08	589.99	45%	279.06	625.06	door to door, ecological platform
Maddalena	71%	506.33	713.12	68%	462.49	680.99	69%	510.15	736.61	door to door, ecological platform
Pantelleria	71%	363.72	512.49	73%	396.74	544.33	78%	451.48	577.98	Ecological platform, domestic composting, road bins, door to door, on-call service
Pelagie Islands (Lampedusa e Linosa)	5%	46.90	926.06	11%	96.70	898.99	20%	231.04	1158.09	Ecological platform, road bins, door to door, on-call service
Ponza	9%	72.22	810.50	11%	84.84	779.77	9%	73.74	834.61	road bins
Procida	70%	432.94	619.70	69%	426.83	618.62	71%	473.83	665.57	Ecological platform, domestic composting, door to door
Salina	51%	303.72	592.07	40%	202.17	509.77	34%	33.64	98.73	Road bins, door to door, ecological platform
San Pietro	56.4%	323.80	574.12	72.6%	391.77	539.34	84%	478.57	571.82	door to door, ecological platform, on-call service
Sant'Antioco	80%	381.01	477.38	82%	447.00	544.73	82%	465.83	571.40	door to door
Tremiti Islands	38%	275.00	717.90	55%	473.81	863.30	63%	886.13	1404.62	road bins
Ustica	20%	82.53	409.30	13%	44.40	350.52	13%	53.06	417.57	Ecological platform, domestic composting, door to door, on-call service
Ventotene	18%	120.94	681.79	24%	166.51	685.34	34%	300.99	876.39	door to door, road bells, on-call service, domestic composting

The island of San Pietro is the island with the highest rate of separate waste collection, reaching 84%, followed by Sat'Antioco island (82%), the Aegadian Islands (80%), Pantelleria (78%), and Procida (71%). Compared to the previous years, in 2021 the general percentage of waste sorting was fairly stable, with a few exceptions. The Aeolian Islands saw a sharp increase (from just 22% to 39%). A similar trend was seen on San Pietro island (from 72.6% to 84%) and finally on Ventotene (from 24% to 34%).

The percentage of sorted waste compared to the total produced waste has even become worse on some islands, especially on Ponza island, where it has fallen from 11% to 9%.

The islands producing more waste per capita are the Tremiti Islands with 1404,62 kg per person/year, followed by the Pelagie Islands with 1158.9 kg. Ustica, Salina, Sant'Antioco, San Pietro, and Pantelleria produced less than 600 kg of waste per person per year.

All the waste produced and collected on the islands is transported by ship to the mainland because there are no waste treatment and recovery plants on the smaller Italian islands. The treatment methods and percentages therefore refer to the national ones, which are shown in Figure 8 (Table S5) [21,39].

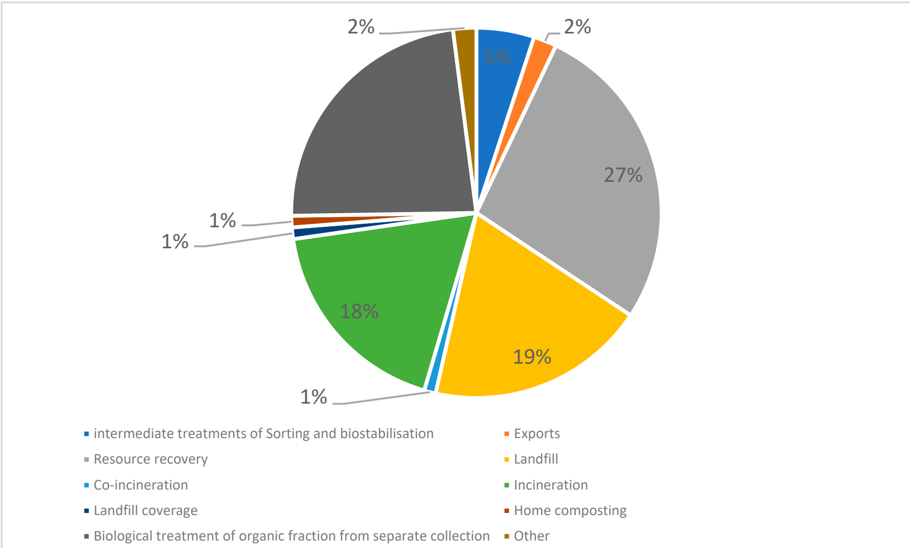

Figure 8. Percentage breakdown of municipal waste management, year 2021 ([21,39]).

Therefore, one of the most pressing issues in the administration's budget is the transport of unsorted waste to the mainland plants, which takes place by ship and which is added to the costs of disposal. When the maritime connections are interrupted due to bad weather conditions, waste is retained for up to 10 days, and this creates several management problems.

On many islands, the door-to-door collection service has not yet been activated. The most common waste collection methods are road bins and the ecological isles. Door-to-door collection could greatly contribute to the increase in separate waste collection, to the creation of local employment, and to the promotion of home or community composting wherever possible. However, it is not always easy to implement this service, especially in areas difficult to reach or during the high season, when the numbers of tourists dramatically increase.

Having an integrated waste cycle management within their natural boundaries is a significant but necessary challenge for the islands, especially in the summer season, when they see a fivefold average increase in the number of visitors.

In the study conducted by J. Royle et al., the Maldives were used as a case study to show the utility of managing waste directly on the island. Plastic Drawdown presented a range of strategies aimed at significantly reducing the influx of plastic waste into the marine environment, with the potential to achieve an 85% reduction by 2030. This initiative specifically focused on advocating for the elimination of single-use plastic waste throughout the Maldives. The findings and recommendations put forth by Plastic Drawdown played a pivotal role in shaping the Maldives government's determination to establish ambitious targets, which were publicly announced at the United Nations General Assembly in 2019. By aligning with these targets, the Maldives aimed to demonstrate their commitment to combatting plastic pollution and safeguarding the marine ecosystem [40].

El Hierro, a part of the Canary Islands, has embraced a sustainable development strategy centered around the overarching theme of "El Hierro—zero waste." One of the fundamental components of this strategy involves implementing a series of initiatives aimed at the production of biogas through the valorization of stockbreeding effluents and sewage via methanogenic fermentation. This approach is rooted in the principles of resource reuse and the efficient utilization of limited water resources. As part of the strategy, various ongoing experiments are being conducted to explore the synergistic potential of integrated biogas production and water bio-recycling systems. These endeavors not only contribute to the island's sustainable development goals but also serve as valuable models for similar regions seeking to optimize resource utilization and minimize waste [41]. There is still a lack of experience in biogas production on the smaller Italian islands. However, there are good practices for raising awareness among the population in the Tremiti Islands to reduce plastic waste, including, in particular, the use of biofoam crates to replace expanded polystyrene crates for transporting fish products and the use of an innovative compost bin capable of composting the organic fraction and also biodegrading bioplastics.

3.4. Water

On the Italian small islands, the water management-related problems mainly concern drinking water supply and are closely linked to the scarcity of water resources. Climate change effects and the growth of water demand are amplified in isolated settings [42]. In fact, drinking water is a limited commodity, and the means to access it are energy-intensive when accounting for transport by tankers, the construction and power supply of desalination plants, the construction of underwater pipelines, and the critical issue of network maintenance. Water and energy demands increase during summer, when water consumption intensifies due to both climatic conditions and tourist flows. In fact, water consumption per capita is higher for tourists than for island residents [43]. Table 5 describes the means of water supply and wastewater treatment on the islands considered in the study.

Some islands are still fully supplied by tankers all year, while others use this service during peak tourist season, when other sources of supply cannot cover the overall needs.

The presence of desalination plants on small islands is increasing every year, but the time needed to design and build them is still very long; this is also due to negative opinions and lack of interest among citizens. The delays in the construction of these facilities are causing considerable inconvenience to the population and tourists, and it is often difficult to cover an island's water needs. Only 10 of the 26 islands surveyed have desalination plants, which are sometimes still insufficient for the island's needs, despite the high energy consumed in the process [42]. As with the mobility sector, maximizing the production of energy via renewable sources would lessen this burden and help the water supply sector.

As things stand now, the best approach for the islands which are close enough to the mainland is to be entirely supplied by submarine pipelines. However, this is true for only nine minor Italian islands, which are supplied either from the mainland or from neighboring islands.

In addition, small islands are experiencing difficulties with wastewater purification. According to the available data [19], there are still too many islands without wastewater treatment systems, where discharges are poured directly into the sea (Capraia, Giglio Island, Ponza, Ischia, Linosa, Favignana, Marettimo, Levanzo, Ustica, Stromboli, Filicudi, Alicudi, Panarea, Salina—almost 50% of those analyzed). Moreover, the existing purification systems are often incomplete and inefficient, as is the information about their operations. On the islands where there are plants, water treatment on just over half of the islands is "more stringent" (tertiary treatment), but the rest have only primary or secondary treatment. In the latter case, the plants are unable to treat the entire load, and therefore, a percentage of wastewater is not treated. Some plants have been confiscated and are therefore not in operation (e.g., in Lampedusa) or are under infringement proceedings for the violation of Council Directive 91/271/EC [39] concerning urban wastewater treatment (e.g., in Procida), which requires member states to ensure that human settlements are provided with a sewerage network and a wastewater treatment system, whether primary, secondary, or as appropriate depending on the sensitivity of the area, by 2000 or 2005 according to the population level. A few innovative actions have been undertaken on the Italian islands to solve the water supply, water saving, and purification issues. These actions include the Horizon 2020 Hydrousa project [44], in which feasibility studies of solutions tested in other project pilot sites on the island of Elba are planned.

Table 5. Water supply arrangements, Presence of wastewater treatment, type of wastewater treatment, and treatment status. ND: not defined.

Island	Water Supply Arrangements	Presence of Wastewater Treatment	Type of Wastewater Treatment	Treatment Status
Alicudi	Tankers	no	-	-
Capraia	Desalinator	no	-	-
Capri	Submarine pipelines	yes	more stringent	partial
Elba Islands	Submarine pipelines, wells/fresh water sources	yes	more stringent	partial
Favignana	Submarine pipelines, desalinator, wells, storage tanks and tankers	no	-	-
Filicudi	Tankers	no	-	-
Giglio Island	Desalinator	no	-	-
Ischia	Submarine pipelines	no	-	-
La Maddalena	Submarine pipelines	yes	more stringent	total
Lampedusa	Desalinator	yes	Secondary	partial
Levanzo	Submarine pipelines and tanks	no	-	-
Linosa	Desalinator	no	-	-
Lipari	Reverse osmosis desalinator	yes	Secondary	partial
Marettimo	Karst water sources being restored, Submarine pipelines and tankers	no	-	-
Panarea	Tankers	no	-	-
Pantelleria	Desalinator	yes	Primary	partial
Ponza	Tankers	no	-	-
Procida	Submarine pipelines	yes	ND	partial
Salina	Tankers	no	-	-
San Pietro	Submarine pipelines	yes	more stringent	total
Sant'antioco	Submarine pipelines, wells/fresh water sources	yes	more stringent	total
Stromboli	Tankers	no	-	-
Tremiti Islands	Tankers	yes	more stringent	total
Ustica	Desalinator	no	-	
Ventotene	Desalinator	yes	more stringent	total
Vulcano	Desalinator and tankers	yes	ND	partial

4. Discussion

In recent years, the European Union has prioritized the EU Green Deal as a fundamental framework for shaping its future [27]. Concurrently, the concept of the blue economy has gained significant attention. Within this context, the islands face a unique dual challenge: they must strive for both recovery and sustainability while operating with fewer resources compared to mainland regions. Consequently, the situation of islands necessitates a distinct coordination of efforts and the allocation of resources to successfully recover from the pandemic and effectively transition towards a green, digital, and resilient future. For the EU islands, the ongoing dilemma between economic development and sustainability has persistently shaped their trajectory over the past decade. Finding a balance between these two objectives remains a continuous endeavor for these regions.

4.1. Energy

Renewable energy installations are growing but still too slowly compared to the targets Italy committed to in the Paris Climate Agreement [45] and the European 2050 target for a full decarbonization. Although on some islands there is high potential for solar and wind energy, the actual number of renewable energy plants is among the lowest nationwide. Renewable energy technology implementation depends mainly on local conditions in terms of geography, resources, funding, research capacity, and political willingness. Many islands continue to rely on costly and harmful fossil fuels, especially diesel and heavy oil generators.

Many island communities suffer issues like social desertification and a scarcity of islander expertise, a heavy reliance on good political will, a lack of energy market options, and some institutional isolation from the mainland. Furthermore, the cost of power generation on non-interconnected islands can be up to ten times higher than on the mainland, and islanders lack sufficient personal funds as well as knowledge of how to obtain funding from third parties. To achieve progress, island energy communities require additional knowledge in the financial aspects of project development.

At the same time, renewable energy technologies are encountering opposition due to worries about the aesthetic of their landscape or the environmental implications, as well as a reaction to a lack of local community involvement in project development and an overall unequal cost–benefit distribution. Renewable energy communities have been shown to be of assistance in resolving these concerns and in improving people's participation in renewable energy and energy efficiency project development. While difficult, coordination among all stakeholders in the development of such projects and campaigns is critical for a seamless and rapid decarbonization of EU islands that leaves no one behind.

Not all islands have a carbon reduction strategy in place. From defining specific roles and responsibilities for the development of renewable energy projects, to navigating complex legal and regulatory frameworks, to identifying and pursuing appropriate financial opportunities, island administrations require assistance in building their own capacities and connecting to experts in order to mobilize specific expertise to fill capacity gaps, such as those around tendering issues.

As possible sites for solar and wind farms, island communities frequently lack the skills to negotiate national tendering processes, putting them at greater risk of embarking on an arduous technical, legal, and economic trip before seeing a return on their investment.

Moreover, high energy costs serve as a persistent obstacle for island economies, significantly impeding their capacity to invest in infrastructure aimed at mitigating reliance on imported fuels. Despite the potential affordability of locally generated renewable energy for island communities, considering the inflated costs associated with imported fossil fuels, the upfront capital investment required for establishing renewable energy systems often remains beyond the financial reach of many islands. This financial barrier hinders their ability to capitalize on the long-term economic and environmental benefits offered by renewable energy sources, perpetuating their dependence on costly imported fuels [46].

Furthermore, the adoption of renewable energy and energy efficiency measures holds the potential to bolster the resilience of islands against natural hazards and economic shocks. By reducing the necessity for costly and occasionally unreliable fuel imports, these sustainable energy solutions contribute to enhanced island resilience. Additionally, the implementation of distributed electricity generation systems diminishes the vulnerability of the energy supply to severe weather conditions. This decentralized approach ensures a more robust and reliable power supply, even in the face of adverse weather events. By prioritizing renewable energy and energy efficiency, islands can fortify their resilience, reduce dependence on imported fuels, and create a more secure and sustainable energy infrastructure [47].

The growth of renewable energy production is also a key action in the reduction in emissions from domestic heating and cooking systems. Currently, domestic heating on the islands in winter is provided by fireplaces and small wood-fired systems and gas cylinders, which are also widely used for cooking. Reducing gas use is now possible by replacing these systems with modern integrated renewable energy plants, energy storage, and heat pump systems that can meet domestic needs.

This strategy can be achieved with building renovations, such as by facilitating access to the incentives and by increasing the production and self-production from renewable sources in buildings, including through the creation of energy communities.

The exploration of the power interconnection between the islands and the mainland regions has been studied as a potential strategy to enhance the integration of renewable energy sources (RES) in island energy systems. In the case of Greece, Georgiou et al. conducted an analysis on the impact of interconnecting Greek islands with the mainland and the implications for RES integration. Their study concluded that such interconnections bring about significant economic and environmental advantages for the Greek power sector. By establishing these interconnections, the Greek power sector can leverage the benefits of increased RES penetration, fostering a more sustainable and cost-effective energy landscape. The findings of this study shed light on the potential of power interconnections as a strategic approach for facilitating the integration of renewable energy sources in island regions [48].

Furthermore, Alves et al. studied the interconnection between isolated power systems, which can decrease the RES variability and, thereby, minimize the problems associated with their intermittency. A scenario considering the interconnection between the power systems of the two islands of Pico and Faial in the Azores is proposed with the objective of increasing the share of RES power in the total power production [49].

Based on an analysis of the configuration of hybrid renewable mini-grids (HRMGs), the demonstrated potential of wind, photovoltaic (PV) systems, electromechanical storage, and reliable control systems signified a promising future for non-interconnected islands. With the current pricing of renewable energy (RE) technologies, HRMGs emerged as the most cost-effective and feasible solution.

The role of public policies is critical in defining business models that facilitate the hybridization of diesel generation plants. Moreover, the implementation of suitable business models plays a crucial role in supporting the successful attainment of RE goals on small islands. These models aim to achieve multiple benefits, including lower electricity prices, reliable electricity services, socioeconomic advancements, and environmental improvements. By aligning public policies and business models, non-interconnected islands can realize the potential of renewable energy technologies, leading to a more sustainable, affordable, and resilient energy future [50].

In light of the surge in energy demand during the summer season, there are three potential solutions to consider. Firstly, one approach is to enhance the installed power capacity while implementing energy storage systems to capture surplus energy generated during the winter months. This stored energy can then be effectively utilized to meet the heightened demand during the summer period.

Secondly, another option is to increase the installed power capacity from renewable energy sources (RES), even if this necessitates a temporary reduction during the winter when energy demand is lower. This approach optimizes the utilization of RES, prioritizing their contribution during peak demand periods.

Lastly, where feasible, the interconnection of islands with the mainland grid can offer a viable solution. This integration enables the sharing of energy resources between islands and the mainland, thereby allowing for the management of energy production and consumption through a larger and more reliable grid. Consequently, this interconnection minimizes balancing issues and promotes a robust and sustainable energy supply.

By considering and implementing these three solutions, island energy systems can effectively address the increased energy demand experienced during the summer months, ensuring a stable and efficient energy supply throughout the year [51].

The favorable meteo-climatic conditions of the Italian islands allow the adoption of a unitary approach in optimizing the production of energy by RES, taking into account the necessary technological diversifications. By working simultaneously on these decarbonization targets, existing fossil fuel power plants can be progressively reduced and definitively closed.

4.2. Mobility

As for mobility policies, the aim should be to reduce the demand for private mobility by pushing for the integration of collective mobility, sharing the use of bicycles and electric scooters connected to a smart electric recharging network powered by renewable sources, and banning access to non-resident cars in summer periods on all islands. Policies, provisions, projects, and initiatives in this direction are increasingly present on the Italian minor islands, but it is clear that a strong acceleration of interventions is needed.

4.3. Waste

Concerning waste management, one of the highest costs in the budgets of local administrations is the shipping of waste to mainland plants, adding to the pre-existing disposal costs.

It is therefore of fundamental importance for local authorities to launch prevention policies to reduce waste production at the source, by implementing information and containment measures and speeding up separate collecting, through door-to-door collection; this would also contribute to the creation of jobs and the promotion of home and community composting. However, virtuous actions in the waste sector are not lacking on the Italian minor islands.

4.4. Water Management

The demand for freshwater on the islands is constant. However, freshwater resources have been restricted due to increased demand and climate change impacts, especially in island areas. Freshwater delivery today is a high-impact sector that could be improved thanks to desalination units. However, desalination plants consume electrical or electrical/thermal energy, which increases the energy demand [52]. Moreover, the electrification of consumption and electric mobility will also cause the energy request to increase. From that perspective, the water–waste–energy nexus should be further investigated and should considering waste management as part of the solution.

The objective of interventions concerning water resources should be the realization of a virtuous model of water management, which reduces consumption and recovers wastewater and losses to improve the distribution network. For supplies, a programmatic strategy should be formulated to replace ship transport with more efficient desalination systems with a low environmental impact and powered by renewable sources.

Precise planning is therefore needed to find a remedy for the shortcomings that affect not only the health of water and its users, but also the attractiveness of the islands for tourists. New approaches are needed in order to encourage the completion of existing sewage treatment systems, including the adoption of innovative types of treatment for the reuse of wastewater (such as refining and phyto-purification plants), as well as those for isolated users.

4.5. General Consideration

The problems causing the transition's slowdown are the lack of information about the opportunities and benefits of these interventions for citizens and companies, including those from a financial point of view; the difficult access to credit linked to the pandemic; and the complexity of the procedures caused by the constraints set by the superintendency.

It is necessary to work through these issues in the upcoming years. In fact, if we want to accelerate the ecological transition, it is necessary to define a shared national strategy to finally design a future without fossil sources for highly specific contexts, like those of the small islands.

On the small islands, the need to work on the waste–water–energy nexus is necessary because of the isolated nature and scarcity of resources, which could be an issue for the inhabitants, but it could also be an opportunity for innovation.

Polido et al. identify three key arguments to enhance sustainability on small islands: the change in the decision-making paradigm for greater transparency and accountability; the effectiveness of good governance and community empowerment; and increasing resilience in order to face vulnerability [53].

5. Suggested Strategies for Enhancing Sustainability Extents

Like small islands in other parts of world, Italian maritime small islands are facing some technical and non-technical barriers typical of isolated areas: the small scale, which makes the return of investments lower or slower than on the mainland; high distribution costs; high seasonality of human presence; lack of skill and abandonment by the younger, more educated portion of the population; and legal restrictions for new energy power plants claiming to protect the islands' landscape and biodiversity.

Nevertheless, some good performances in some islands regarding specific sectors (e.g., cars per capita in Capri or the separate waste collection on small Sardinian islands) show that the insularity condition is not a constraint per se. The first thing the islands need is to have the ambition to become effectively sustainable. Then, the different level of governance can help them to reach the goal.

Some elements seem to be more crucial than others in a strategy that aims to enhance the Italian islands' sustainability: the first step could be to establish a permanent coordination among all the small islands' administrators and relevant ministries, to share ambitious pathways, goals, and policies through concrete and measurable step-by-step actions. A second phase should consider putting in place a data-based monitoring system in order to verify the efficacy of the policies implemented in the short-, medium- and long-term.

Concerning the energy production and considering the huge potential in terms of the renewable resources of Italian small islands (sun, wind, and geothermic), the ambition should be to reach 100% energy demand cover by renewable sources by 2050 thanks to a system of incentives and an enabling framework which also includes interconnected islands.

Reducing the waste production on islands, including by commercial and touristic activities and promoting separated waste collection through a door-to-door system which also takes into account the heavy seasonal touristic presence, are the only way to improve waste management performance on the islands.

The water distribution should be improved, with a national plan to fix and make more efficient the water transport network to avoid any water wastage. The islands municipalities should approve building regulations to save and recover storm water, which can be reused, and implement policies for the redevelopment of public spaces to mitigate the impact of extreme weather events.

The islands policymakers need to limit the arrival of private cars on the island through economic disincentives and bans and by promoting alternative mobility such as the electric local public transport, including on-demand services, integrated with a shared mobility system and a clean energy sea connection.

Finally, for an ecological transition that will also be sustainable for the islanders, the tourism should be regulated, and the touristic model must pursue the distribution of the touristic presence all through the year, preferring activities that can promote the valorization of the landscape, biodiversity, and natural resources in which the islands are rich.

6. Conclusions

The study analyzed the data related to the energy, mobility, waste, and water sectors of 26 Italian small islands, the policies adopted, and the barriers on the path of sustainability and climate change adaptation and mitigation.

The study showed that the actions undertaken to date on Italian islands are insufficient: all the islands still depend on energy from fossil fuels; many others are not self-sufficient regarding water supply; on the islands, all waste fractions, including organic waste, are transported to the mainland for disposal, except in exceptional cases where private individuals have equipped themselves with compost bins. The issue of mobility sees few shared mobility solutions and a high number of vehicles per inhabitant, and public services with more efficient vehicles powered by renewable energy are still lacking.

Only timid steps have been taken thanks to the European projects and initiatives financed by ministries.

To give strength to interventions in the environmental field and against climate change on the smaller Italian islands, it is necessary to build a plan of action to be implemented on all islands, supported by regional, national, and European policies.

The path to decarbonization is even more challenging for small islands, but at the same time, they can represent small laboratories and pilot areas to try out the ecological transition. Supporting small islands as they transition to clean, environmentally responsible, and locally generated energy will help to protect local ecosystems and the health of communities. In this regard, the water–energy–waste nexus is crucial for the sustainability of small islands.

A strategy involving actors at a local and national level is essential to support the projects side by side and to overcome the difficulties that may hinder change.

One of the central issues concerns the installation of new renewable sources and waste treatment plants in relation to the Superintendence of Cultural Heritage, which is called upon to give its binding opinion on any type of intervention, regardless of its size. It is necessary to involve the Ministry of Culture and the superintendencies in this pathway to decarbonization to overcome these problems by defining regulations for the simplification of interventions with specific guidelines. From this perspective, it is possible to achieve effective coordination among the Italian islands and to avoid missing the opportunities defined at a European level with programs and resources (including the PNRR—The National Recovery and Resilience Plan from the Next generation EU funds) [54].

A climate and environmental sustainability plan for each island should be developed in line with goals of European and national strategy (such as the Green New Deal, the PNRR, and the National Energy and Climate Plan [55]), with clear objectives for 2030, outlining the solutions for an energy model focused on renewable sources and addressing the challenges for the proper management of the water and waste cycle and the reduction in waste.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su151511490/s1, Table S1. Renewable Energy Sources power installed in Italy's smaller islands in 2019, 2020 and 2021; Table S2. Breakdown of the vehicle fleet 2019–2021 in the small islands Municipalities; Table S3. Cars per capita rate in the small islands (2019–2021); Table S4. Breakdown of the vehicle fleet by European Emissions Standard Class 2019–2021 in the small islands Municipalities; Table S5. Percentage breakdown of municipal waste management in small islands (2021).

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References

1. Cassin, L.; Melindi-Ghidi, P.; Prieur, F. Confronting Climate Change: Adaptation vs. Migration in Small Island Developing States. *Resour. Energy Econ.* **2022**, *69*, 101301. [CrossRef]
2. Cartwright, J. Ecological Islands: Conserving Biodiversity Hotspots in a Changing Climate. *Front. Ecol. Environ.* **2019**, *17*, 331–340. [CrossRef]
3. Russell, J.C.; Kueffer, C. Island Biodiversity in the Anthropocene. *Annu. Rev. Environ. Resour.* **2019**, *44*, 31–60. [CrossRef]
4. Ali, E.; Cramer, W.; Carnicer, J.; Georgopoulou, E.; Hilmi, N.; Le Cozannet, G.; Lionello, P. Cross-Chapter Paper 4: Mediterranean Region. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022; pp. 2233–2272.
5. Diane, C.; Erika, M.; Evangelos, R.; Christoforos, P.; Antun, P.; Daniele, G.; Goran, K.; Davide, A.G. A Methodology for Energy Planning in Small Mediterranean Islands, the Case of the Gozo Region. In Proceedings of the 2019 1st International Conference on Energy Transition in the Mediterranean Area (SyNERGY MED), Cagliari, Italy, 28–30 May 2019; IEEE: Piscataway, NJ, USA, 2019; pp. 1–6.
6. Kougias, I.; Szabó, S.; Nikitas, A.; Theodossiou, N. Sustainable Energy Modelling of Non-Interconnected Mediterranean Islands. *Renew. Energy* **2019**, *133*, 930–940. [CrossRef]
7. Lam-González, Y.E.; García, C.; González Hernández, M.M.; León, C.J. Benefit Transfer of Climate Change Adaptation Policies in Island Tourist Destinations. *Tour. Manag.* **2022**, *90*, 104471. [CrossRef]
8. Major, D.C.; Blaschke, P.; Gornitz, V.; Hosek, E.; Lehmann, M.; Lewis, J.; Loehr, H.; Major-Ex, G.A.; Pedersen Zari, M.; Vásquez Vargas, M.J.; et al. Adaptation to Climate Change in Small Island Settlements. *Ocean Coast. Manag.* **2021**, *212*, 105789. [CrossRef]
9. NESOI | New Energy Solutions Optimized for Islands. Available online: https://www.nesoi.eu/ (accessed on 7 July 2023).
10. European Commission. Clean Energy 4 EU Islands. Available online: https://energy.ec.europa.eu/topics/markets-and-consumers/clean-energy-eu-islands_en (accessed on 3 March 2021).
11. Frydrychowicz-Jastrzębska, G. El Hierro Renewable Energy Hybrid System: A Tough Compromise. *Energies* **2018**, *11*, 2812. [CrossRef]
12. Godina, R.; Rodrigues, E.M.G.; Matias, J.C.O.; Catalão, J.P.S. Sustainable Energy System of El Hierro Island. *Renew. Energy Power Qual. J.* **2015**, *1*, 46–50. [CrossRef]
13. Mena-Nieto, A.; Estay-Ossandon, C.; dos Santos, S.P. Will the Balearics and the Canary Islands Meet the European Union Targets for Municipal Waste? A Comparative Study from 2000 to 2035. *Sci. Total Environ.* **2021**, *783*, 147081. [CrossRef]
14. Curto, D.; Favuzza, S.; Franzitta, V.; Musca, R.; Navarro Navia, M.A.; Zizzo, G. Evaluation of the Optimal Renewable Electricity Mix for Lampedusa Island: The Adoption of a Technical and Economical Methodology. *J. Clean. Prod.* **2020**, *263*, 121404. [CrossRef]
15. Doorga, J.R.S. Climate Change and the Fate of Small Islands: The Case of Mauritius. *Environ. Sci. Policy* **2022**, *136*, 282–290. [CrossRef]
16. Istituto Nazionale di Statistica (ISTAT). Demografia in Cifre. Available online: https://demo.istat.it/ (accessed on 11 April 2022).
17. Istituto Nazionale di Statistica (ISTAT). Principali Statistiche Geografiche Sui Comuni. Available online: https://www.istat.it/it/archivio/156224 (accessed on 11 April 2022).
18. Automobil Club d'Italia Automobil Club d'Italia Database. Available online: www.aci.it (accessed on 20 April 2022).
19. Office International de l'Eau European Commission Urban Waste Water Website—Italy 2013. Available online: https://uwwtd.eu/Italia/content/home-page (accessed on 29 April 2022).
20. Agrillo, A.; Dal Verme, M.; Liberatore, P.; Lipari, D.; Lucido g Maio, V.; Serace, V. (Eds.) Rapporto Statistico 2020 Energia Da Fonti Rinnovabili in Italia (Gestore dei Servizi Energetici S.p.A.—Direzione Studi, Monitoraggio e Relazioni Internazionali—Funzione Statistiche e Monitoraggio Target). March 2022.
21. ISPRA Data Elaboration from the Catasto Nazionale Rifiuti 2019. Available online: https://www.catasto-rifiuti.isprambiente.it (accessed on 3 May 2022).

22. Decree of Ministry of Economic Development of the 14 February 2017. Coverage of the Needs of the Smaller Islands Not Interconnected through Energy from Renewable Sources. Available online: https://www.mise.gov.it/images/stories/normativa/decreto_ministeriale_14_febbraio_2017_energia_isole_minori.pdf (accessed on 13 March 2002).
23. Kuang, Y.; Zhang, Y.; Zhou, B.; Li, C.; Cao, Y.; Li, L.; Zeng, L. A Review of Renewable Energy Utilization in Islands. *Renew. Sustain. Energy Rev.* **2016**, *59*, 504–513. [CrossRef]
24. European Union. *REPowerEU Plan, COM(2022) 230 Final*; European Commission: Brussels, Belgium, 2022.
25. Fit for 55. Available online: https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/ (accessed on 7 July 2023).
26. The Data on Power from Renewable Energy Sources. Installed in Italy's Small Islands Have Been Collected by the Authors through a Specific Request to the GSE (Italian Energy Services Manager) in 2022.
27. A European Green Deal. Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 7 July 2023).
28. Groppi, D.; Astiaso Garcia, D.; Lo Basso, G.; De Santoli, L. Synergy between Smart Energy Systems Simulation Tools for Greening Small Mediterranean Islands. *Renew. Energy* **2019**, *135*, 515–524. [CrossRef]
29. El Hierro Was Inserted in Best Practices by European Union—DG Environment. World's First Energy Sufficient Island 2014. Available online: https://ec.europa.eu/environment/europeangreencapital/first-energy-sufficient-island/ (accessed on 1 September 2022).
30. Berna-Escriche, C.; Vargas-Salgado, C.; Alfonso-Solar, D.; Escrivá-Castells, A. Can a Fully Renewable System with Storage Cost-Effectively Cover the Total Demand of a Big Scale Standalone Grid? Analysis of Three Scenarios Applied to the Grand Canary Island, Spain by 2040. *J. Energy Storage* **2022**, *52*, 104774. [CrossRef]
31. Mutani, G.; Santantonio, S.; Brunetta, G.; Caldarice, O.; Demichela, M. An Energy Community for Territorial Resilience: Measurement of the Risk of an Energy Supply Blackout. *Energy Build.* **2021**, *240*, 110906. [CrossRef]
32. European Commission. Clean Energy for All Europeans Package. 2018. Available online: https://energy.ec.europa.eu/topics/energy-strategy/clean-energy-all-europeans-package_en (accessed on 29 December 2022).
33. European Parliament. *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources (RED II)*; European Parliament: Strasbourg, France, 2018.
34. European Parliament. *Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on Common Rules for the Internal Market for Electricity and Amending Directive 2012/27/EU*; European Parliament: Strasbourg, France, 2019.
35. Iglesias, G.; del Río, P.; Dopico, J.Á. Policy Analysis of Authorisation Procedures for Wind Energy Deployment in Spain. *Energy Policy* **2011**, *39*, 4067–4076. [CrossRef]
36. Raveendran, V.; Alvarez-Bel, C.; Nair, M.G. Assessing the Ancillary Service Potential of Electric Vehicles to Support Renewable Energy Integration in Touristic Islands: A Case Study from Balearic Island of Menorca. *Renew. Energy* **2020**, *161*, 495–509. [CrossRef]
37. Maas, S.; Attard, M. Policies to Promote Cycling in Southern European Island Cities: Challenges and Solutions from Three 'Starter' Cycling Cities. *Transp. Res. Procedia* **2022**, *60*, 52–59. [CrossRef]
38. Ramos-Real, F.J.; Ramírez-Díaz, A.; Marrero, G.A.; Perez, Y. Willingness to Pay for Electric Vehicles in Island Regions: The Case of Tenerife (Canary Islands). *Renew. Sustain. Energy Rev.* **2018**, *98*, 140–149. [CrossRef]
39. Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). *Rapporto Rifiuti Urbani, Edizione 2022*; Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA): Rome, Italy, 2022.
40. Royle, J.; Jack, B.; Parris, H.; Elliott, T.; Castillo, A.C.; Kalawana, S.; Nashfa, H.; Woodall, L.C. Plastic Drawdown: A Rapid Assessment Tool for Developing National Responses to Plastic Pollution When Data Availability Is Limited, as Demonstrated in the Maldives. *Glob. Environ. Chang.* **2022**, *72*, 102442. [CrossRef]
41. Morales, Javier Narea Sun, Wind and Water. The New El Hierro Island's Allies, ITC—Instituto Tecnológico de Canarias Las Palmas de Gran Canaria, Canary Islands, Spain. 2001. Available online: http://www.globalislands.net/greenislands/docs/spain_El-Hierro-1.pdf (accessed on 13 September 2022).
42. Giudici, F.; Castelletti, A.; Garofalo, E.; Giuliani, M.; Maier, H.R. Dynamic, Multi-Objective Optimal Design and Operation of Water-Energy Systems for Small, off-Grid Islands. *Appl. Energy* **2019**, *250*, 605–616. [CrossRef]
43. Pérez, D.M.G.; Martín, J.M.M.; Martínez, J.M.G.; Sáez-Fernández, F.J. An Analysis of the Cost of Water Supply Linked to the Tourism Industry. An Application to the Case of the Island of Ibiza in Spain. *Water* **2020**, *12*, 2006. [CrossRef]
44. HYDROUSA—Demonstration of Water Loops with Innovative Regenerative Business Models for the Mediterranean Region. Available online: https://www.hydrousa.org/ (accessed on 18 July 2023).
45. United Nation. *Paris Agreement*; United Nation: New York, NY, USA, 2015.
46. Serpell, O. *Innovation in Isolation: Islands and the Energy Transition*; Kleinman Center for Energy Policy: Philadelphia, PA, USA, 2020.
47. Weir, T.; Kumar, M. Renewable Energy Can Enhance Resilience of Small Islands. *Nat. Hazards* **2020**, *104*, 2719–2725. [CrossRef] [PubMed]
48. Georgiou, P.N.; Mavrotas, G.; Diakoulaki, D. The Effect of Islands' Interconnection to the Mainland System on the Development of Renewable Energy Sources in the Greek Power Sector. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2607–2620. [CrossRef]

49. Alves, M.; Segurado, R.; Costa, M. Increasing the Penetration of Renewable Energy Sources in Isolated Islands through the Interconnection of Their Power Systems. The Case of Pico and Faial Islands, Azores. *Energy* **2019**, *182*, 502–510. [CrossRef]
50. Eras-Almeida, A.A.; Egido-Aguilera, M.A. Hybrid Renewable Mini-Grids on Non-Interconnected Small Islands: Review of Case Studies. *Renew. Sustain. Energy Rev.* **2019**, *116*, 109417. [CrossRef]
51. Milone, D.; Curto, D.; Franzitta, V.; Guercio, A.; Cirrincione, M.; Mohammadi, A. An Economic Approach to Size of a Renewable Energy Mix in Small Islands. *Energies* **2022**, *15*, 2005. [CrossRef]
52. Mehrjerdi, H. Modeling and Optimization of an Island Water-Energy Nexus Powered by a Hybrid Solar-Wind Renewable System. *Energy* **2020**, *197*, 117217. [CrossRef]
53. Polido, A.; João, E.; Ramos, T.B. Sustainability Approaches and Strategic Environmental Assessment in Small Islands: An Integrative Review. *Ocean Coast. Manag.* **2014**, *96*, 138–148. [CrossRef]
54. Italian Government. National Resilience and Recovery Plan (Piano Nazionale Di Ripresa e Resilienza) (PNRR). Available online: https://www.governo.it/sites/governo.it/files/PNRR.pdf (accessed on 23 May 2023).
55. Ministero dello Sviluppo Economico; Ministero dell'Ambiente e della Tutela del Territorio e del Mare. *Piano Nazionale Integrato per l'Energia e Il Clima*; Ministero delle Infrastrutture e dei Trasporti: Rome, Italy, 2019.