Small Frontier Islands in the Clean Energy Transition Era_ Emerging Patterns and Planning Approaches

Yiota Theodora(✉) and Sotiris Piperis

Department of Urban and Regional Planning, School of Architecture, National Technical University of Athens, Athens, Greece
ptheodora@arch.ntua.gr, sotirispiperis@yahoo.gr

Abstract. In the climate crisis era, energy security or even more autonomy is critical in developmental policies of countries worldwide. This crisis, coupled with the recent geopolitical crisis in Europe and its socio-economic repercussions, calls for dedicated national strategies in support of the transition towards a carbon-free economy, largely based on domestic energy networks that utilize renewable sources (RES/MRE). Islands, in this respect, are of particular concern, as fragile natural-cultural and anthropogenic ecosystems, already under multiple pressures due to urban sprawl, over-concentration of land/maritime activities and mass tourism, all largely intensifying peak energy demand pattern. Having Aegean small frontier islands as a study reference, the article explores their energy dynamics and sketches restrictions in clean energy transition set by the scale and specificities of insular vulnerable locales. Towards this end, current conditions and trends are evaluated; and a spatial energy database is produced for serving typological classification of islands. The latter is based on a multifactorial approach for assessing small islands' energy autonomy and degree of RES/MRE utilization; identifying main factors of their energy diversification; and unveiling critical issues to be addressed in renewable energy planning. The proposed methodology aspires to step forward the discussion on sustainable energy transition of insular territories in the Mediterranean Region and beyond.

Keywords: Sustainable energy development and planning · Renewable energy sources · Green and blue infrastructures · Low-carbon energy transition policies · Insular regions and communities · Small islands

1 Setting the Stage

At a time of climate crisis and energy poverty, states across the world seek to ensure their energy autonomy and reinforce their position in strong energy networks. To this end, the policy objective is to develop sustainable national strategies for the transition to a zero carbon economy through the development of domestic energy production networks for the use of renewable energy sources [1, 2]. Nevertheless, achieving energy neutrality in practice remains an intractable issue for two main reasons. On the one hand, the

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dominant countries generating and exporting polluting energy do not intend to lose the lead even if they use clean energy at national level. On the other hand, energy-dependent countries (regardless of population size and prosperity level) lack to secure their energy independence mainly due to their increased needs (e.g. intense urbanisation, transport hubs, entrepreneurship), or failure (technological, legislative, etc.) to utilise their existing domestic sources and/or discover new forms of energy. The former case includes mainly developed countries with strong administration and infrastructure centres, while the latter concerns countries with a low technological development index that are in the process of productive reconstruction and/or modernization of their national administration, development, planning and legislation systems. In Europe, specifically, which is the broader field of the pilot focus area, the former case includes mostly the developed northern countries, while the latter includes the EUMed9 countries of eastern basin. Greece, Cyprus and Malta demonstrate special research interest due to their cross-border character; abundant natural and cultural wealth; vulnerable national economies; and the new development challenges they face in the context of global competition in the shipping and tourism sectors, which intensify their energy requirements [3–6].

Against the backdrop of intense political, social and economic upheavals at global level and they geopolitical uncertainty they induce to countries at national level, increased concerted efforts to prevent the looming ecological catastrophe -most recently at the UN Climate Change Conference (COP26, Glasgow 31.10. 2021)- have brought back to the forefront of political and scientific discussions at international level the need to change the current energy model [7]. This finding is becoming more critical following the dramatic developments in Eastern Europe and the broader SE Mediterranean region, which confirm: a) the failure to use gas as a sustainable and socially just 'transition bridge' from conventional to renewable energy sources; and b) the dependence of countries' energy transition on strong global investment interests. Through the aggravation of inequalities this causes across spatial levels, there are constant disruptions to the global energy map with a variety of consequences on the development dynamics as well as territorial/socio-economic cohesion of the countries and their regions, regardless of whether they are energy-dominant or dependent. In these extremely adverse conditions, the search for new forms of clean energy and innovative methods/technologies to use them, as well as the formulation of flexible alternative transition scenarios, pose challenges for states [8–10]. In this respect, hydrogen is already promoted as the new energy key of the 21st century, due to its fuel and energy storage capacity, while the use of marine renewable energy (MRE) is seen as the solution for the energy neutrality of coastal and island countries [11–13].

In a climate of intense concern, the energy transition of island areas (i.e. states, regions, islands) poses special research interest, mainly due to their differences in scale, structure, dynamics and needs (i.e. surface, spatial fragmentation/dispersion, climatic specificities, fragility of natural- cultural- anthropogenic ecosystems and landscapes, urbanization characteristics, density and seasonality of habitation, type of activities and degree of over-concentration on land and at sea, quality of technical/ social infrastructure, tourism development, dependence on mainland areas, etc.) [14]. These diversifications, due to a number of spatio-functional and socio-economic factors, affect the energy requirements of island regions and their variations during the year (*seasonality*) [15, 16]. At the same time, the above diversifications raise the issue of energy autonomy, especially in remote island regions with adverse climatic conditions (e.g. the Azores and Iceland in the North Atlantic ocean, Mauritius and Reunion in the Indian ocean), but also in countries with many islands and a strong concentration of small remote and border islands that are inhabited (e.g. Sweden and Greece). The diversity of island regions introduces different conditions, priorities and constraints in their energy transition process. This makes it necessary to address specifically the energy planning of insular regions and islands in the framework of national development and energy policies. The specificity of island regions has been recognised at EU level [17–23]. Hence, the relevant debate on their energy transition is constantly enriched with new initiatives in the broader EU policy framework for climate and energy neutrality[1]. These initiatives refer not only to island states, but also to countries with an island part [i.e. insular regions (NUTS2), islands NUTS3)]. Small islands are highly interesting mainly due to the strong emigration trend of their inhabitants, and the various pressures they face from their urbanization/conversion into 'pockets' of tourism development and/or energy utilization [24–26]. Greece, although intensely insular with a significant number of small islands, still lacks an integrated clearly formulated policy on energy modernization.

Given the ongoing climate and energy crises, the main question is: *how should the energy transition of islands be conducted so as to ensure their energy autonomy without threatening the local identity and carrying capacity of their natural-cultural-anthropogenic ecosystems and landscapes*? The answer is sought in the selection of a sustainable energy model. Thus, the dilemma is whether the energy transition of islands should be aimed at meeting their local needs/demands, or satisfying wider scale requirements (inter-regional, national, supranational). Undoubtedly, the choice will affect the sustainability, resilience, and competitiveness of these fragile locales. Thus, the energy planning challenge is *how to prevent any environmental and socio-economic impact on the islands to be exploited for energy* (RES/MRE).

Focusing our study on the small frontier Greek Aegean islands, this article attempts to contribute to the discussion at a critical time for the country and the world. That is, in the context of the intended withdrawal from polluting forms of energy, where pressures for immediate use of RES/MRE can degrade the island environment unless there is an integrated energy policy encompassing protection, sustainability and social justice [17, 21]. In this context, the objective is to assess the energy dynamics of small border islands and to identify the favourable/constraining factors for their energy transition-autonomy [23, 25]. To this end, fifteen islands were selected with a view to recording, mapping and evaluating existing energy conditions/trends per island. The above process results in a pool of spatial and energy data that is then used for their typological classification. It is supported that research shall be implemented on the basis of a multifactorial approach in order to: a) assess the energy autonomy of the islands and the degree of

[1] EU Legislation on Energy Transition (Laws/Directives] 1997–2021: COM(1997)599; COM(2006)105; COM(2007)575; L.2008/56/EC; COM(2008) 768; Renewable Energy L.2009/28/EC; Blue Growth COM(2012)494; Blue Energy COM(2014)8; COM(2014)254; EUCO/169/14; Climate Change Policy COM (2015)80; COM(2018)773; European Climate Law (2018/1999/EU); 2018/2001/EU; European Green Deal (COM(2019)640); COM (2020)741; COM(2021)82; COM(2021)240.

RES/MRE utilization; b) identify the factors that have played a role in the evolution of their energy dynamics; c) highlight the critical issues that must be addressed in the national energy planning so as not to burden the small islands with the development of renewable sources. The proposed methodology enables various correlations among the selected criteria and can be applied applicability across spatial units; hence it can contribute to the recent debate on the sustainable energy transition of countries with an island part in the Mediterranean and beyond.

For the approach of the research object the article is organized in six sections. The first presents the research object; the second refers to the spatial field of study and the research methodology, the third describes the development and energy dynamics of Greek insular regions focusing on the small frontier islands of the Aegean; the fourth concerns the findings of the investigation, the fifth describes the proposed typological classification for islands, while the sixth expresses thoughts on a sustainable energy transition-autonomy for insular territories.

2 Methodological Steps and Sources

This research on the energy transition of the small frontier islands[2] of the Aegean is part of a wider ongoing study on the energy neutrality of the Greek island territory in a context of multifaceted crisis and evolving climate change. The Aegean small boarder islands were not selected by chance. The occasion was previous researches on the Greek island territory [14, 27], through which emerged: α) the complexity and vulnerability of insular regions and islands, as well as their specific dynamics, as a result of their particular geographical and spatial characteristics; and b) the existence ambiguities in the practices of RES/MRE utilisation and in the relevant national legislation. However, a key role was played by a study on small border islands of the Aegean and their typological classification on regional criteria, which can identify the specificities of these vulnerable areas, as well as their ability to function as both autonomous entities and hubs of broader island networks with supra-local reach [28]. This is because, this research highlighted the critical role of the characteristics and development prospects of small islands (especially those demonstrating geographical/socio-economic isolation and *seasonality*) in their integration into the international economic system, on the one hand, and in their energy transition and neutrality, on the other. The main causes are issues pertaining to scale, adequacy of resources and infrastructures, quality of natural-cultural-built environment/landscape, accessibility and networking, development orientation, inhabitation pattern, *seasonality*. Therefore, this research is used at this stage (after the necessary data updates and enrichment of the spatial sample/assessment criteria) as a 'basis' for the establishment of the wider framework conditions/trends within which the energy transition-autonomy of the small Aegean border islands will be assessed at local level. Specifically, regarding the research area, the criteria for assessing the development and energy dynamics of islands, and the process of their typological classification, the following are noted:

[2] In the absence of an official definition of small frontier island at national and European level the selection criteria were: a) an area of $< 96\ km^2$ and a permanent population of $< 8{,}000$ inhabitants, b) islands constitute municipalities, and c) frontier islands are considered to be those bordering another country on at least one side [28].

Place of Reference: fifteen small Aegean border islands of different development - energy dynamics were selected. Islands per region (from north to south) are: North Aegean: Ag. Efstratios, Psara, Oinousses and Fournoi, South Aegean: Leros, Kasos, Symi, Tilos, Nisyros, Patmos, Halki, Lipsi, Agathonisi, Megisti, and Crete: Gavdos.

Assessment Criteria: their selection allows simultaneous understanding of the broader developmental and spatial context (qualities, vulnerability, and prospects) of islands, and more specifically their energy dynamics- autonomy. On this basis, a pool of assessment criteria established, falling into ten themes, namely: (i) geographical location [cross-border character (distance from neighbouring country], (ii) locus [i.e. surface area, density (inhabitants/km^2), geomorphology, climate], (iii) nature-culture [i.e. historic and memorial sites, natural-cultural heritage sites, protected areas], (iv) population [inhabitants and % population change (1991, 2001 and 2011)], (v) local economy - production sectors [primary, secondary, tertiary (% change by sector 2001–2011)], (vi) accessibility/networking (Multimodal Hub (MH: port and airport)], (vii) services/infrastructures of supralocal reach (administrative, technical, social), (viii) construction activity [number of buildings per island, rate of change (2001–2011)], (ix) tourism [indicators: ship/ferry passengers, overnight stay, full occupancy (2011–2020), and cruise passengers arrivals (2015–2020)], (x) energy [i.e. energy demand, energy consumption rate, production rate from conventional/renewable sources (2016–2020)]. The criteria are deliberately selected and can assess both the competitiveness and the rate of energy transition-autonomy of small border islands at the national and global level. The geographical location coupled with locus features and high quality services and infrastructures of supralocal reach bring out important specificities for islands' supralocal role. The population size indicates islands' dynamics, especially in combination with locus, local economy-production sectors, accessibility/networking and high quality services-infrastructures of supralocal reach. In addition, geographical location in combination with locus and nature-culture features can either favour or restrict islands' energy transition, as they can simultaneously meet energy demands, but also burden local identity and resilience due to the overexploitation of natural resources. Moreover, population especially coupled with local economy-production sectors, accessibility/networking, supralocal infrastructures, construction activity, and tourism may lead to increased energy demands (especially during peak seasons) with multiple effects to landscapes and biodiversity, as well as the environment. Finally, energy highly interacts with all other criteria, as it is affected by them and vice versa.

Research Process-Sources: for approaching the research object, the correlation of the criteria was done in two spatial levels (region, island) aiming at understanding: a) the broader geographical-administrative environment where the small islands interact with larger islands and continental areas, b) local peculiarities and the restrictions they set on islands' energy transition-autonomy. This was attempted by implementing two investigation procedures. The first investigation procedure pertained to the generation of six tables through the correlation of the proposed criteria [i.e. Table 1 [(i), (ii), (iii), (vii)]; Table 2 [(v), (vi)]; Table 3 [(v), (viii), (ix)]; Table 4 [(xi)]; Table 5 [(i), (vi)]; and Table 6 [(i), (ii), (iv), (x)]. The six tables provide data on administrative structure, while islands are presented by region and regional unit (from north to south), and by size, starting with the smallest in area. In the second procedure, the data of the above tables was correlated for the typological classification of the small islands according to their energy demands and the barriers they face in energy transition-autonomy. The main sources were EU texts and the current Greek institutional framework for insular/energy planning, as well as official databases of international, European and national bodies [29, 30]. The data has been processed using spatial analysis methods in a GIS environment.

Under conditions of an intense multifaceted crisis, the article aims at contributing to the relevant discussion by proposing a methodology to identify the factors that may affect energy transition and autonomy, in such a way that it can be used as a planning tool of energy policy at various territorial levels, while paving the way for subsequent re-evaluation of existing criteria for the selection/delimitation of RES/MRE areas.

3 Greek Insular Regions and Small Frontier Aegean Islands in Times of Energy Transition _ A Multifactorial Overview

In this section, the development and energy dynamics of the Greek insular regions are briefly presented focusing on the small boarder islands of the Aegean Sea based on a multifactorial approach of simultaneous monitory of the proposed criteria [(i)–(x)].

3.1 Identifying Local Characteristics and Developmental Dynamics

3.1a Greek Insular Regions

Greece is among the countries with the largest number of islands in the world. The multi-insular structure in concert with the fragmentation of its insular regions makes the Greek insular phenomenon quite unique [28]. The purely insular regions (15% of Greek territory/4 out of 13 administrative regions) constitute extremely complex spatio-functional entities of intense fragility and diverse dynamics due to the number of islands and their peculiarities. In particular, the Greek insular regions/islands of the Aegean (EU's external

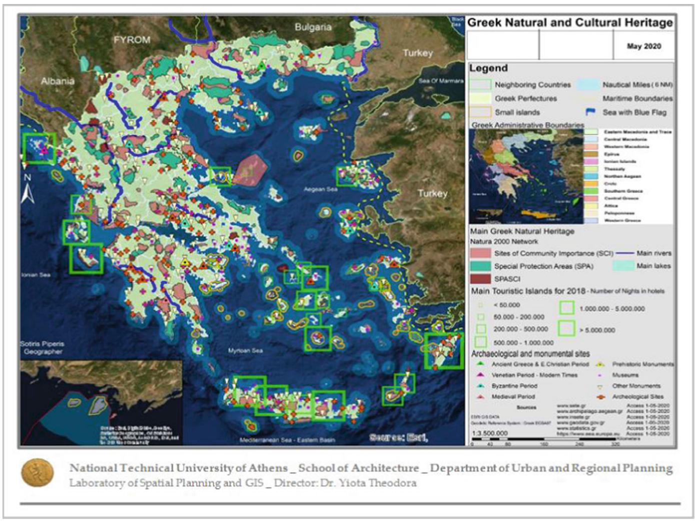

Fig. 1. Protected areas and natural - cultural heritage Sites in Greece [own elaboration]

borders) where issues of geopolitical importance, spatial discontinuity/heterogeneity - mainly in terms of expanse, identity, dynamics- coexist with incompatible activities and transnational networks (e.g. shipping, commerce, tourism, energy etc.), a concentration of natural-cultural wealth and unique landscapes/seascapes, as well as a pressure because of the strong migrant/refugee flows and the ever-increasing energy interest [14, 27] (Fig. 1).

Based on the assessment criteria, the following are briefly stated: a) South Aegean has the largest territorial fragmentation and the most significant concentration of small frontier islands; b) all insular regions are characterized by seismicity and have similar climatic conditions; especially those of the Aegean Sea which provide strong wind dynamic; c) South Aegean (5^{th} and 1^{rst} place respectively in the national ranking), Crete (6^{th} and 5^{th}), North Aegean (11^{th} and 7^{th}) and the Ionian Islands (8^{th} and 11^{th}) have the most intense concentration of nature and culture protection areas (i.e. Natura, archaeological and historical sites, underwater culture heritage); d) North Aegean in total and parts of South Aegean (small frontier islands) face significant networking issues; e) low population increase (2001–2011) is noted in Crete (+4.83%) and South Aegean (+3.54%), whilst the North Aegean (−2.93%) loses its population; f) increase of tertiary sector (>24%) with simultaneous contraction of primary (−33% up to −49.79%) and secondary sector (−12% up to −15%) was detected. The primary/secondary sectors decreased mainly in North Aegean and the Ionian Islands, whilst the tertiary sector increases mainly in South Aegean (+37.91%) and the Ionian Islands (+32.55%); g) the rate of change in building stock (2001–2011) increases mainly in North Aegean and the Ionian Islands (+16.86% and +9.26% respectively); and h) indicators of overnight stays (>−52%), occupancy (>−29,5), and cruise (>−99,45%) (2011–2020) dramatically decline due to dramatic effects of the pandemic [28, 30].

3.1b Aegean Small Frontier Islands

When it comes to the small frontier islands of the Aegean, the following are noted [14, 28, 30]: a) Ag. Efstratios, Psara, Agathonisi and Lipsi are in a more unfavorable networking situation. Leros, Symi and Megisti provide ferry connections to Turkey, Oinousses and Patmos only during the summer; b) the majority of islands has an area <50 km^2, thus creating special conditions for their economy; c) the most intense wind dynamics is to be found in North Aegean, whilst the greatest depths are to be found in Patmos, Halki and Gavdos; d) all insular regions provide a rich natural and cultural heritage on land as well at sea and belong to the Natura network of protected areas. The biggest concentrations of such areas are to be found in Gavdos, Leros, Nisyros, Psara, Halki, Patmos, and Fournoi [30(f)] (Fig. 1); e) Leros is by far the island with the greatest population followed by the smaller (in area) islands of Patmos and Symi. The majority of islands (78.57%) have a population of <1500 inhabitants. The largest population increase (2001–2011) (>50%) was recorded in Gavdos (+88%), Halki (62%) and Tilos (50%), while islands that lost population were: Ag. Efstratios, Psara, Leros and Oinousses; f) the highest unemployment rates (>50%) (2001–2011) were noted in Halki, Psara, Leros, Ag. Efstratios, Kasos and Agathonisi, with the exception of Oinousses (60% reduction in unemployment). In primary sector an increase of > 50% was recorded in Megisti (250.0%) and Nisyros (53.3%), while a decrease (>50%) was recorded in Halki (−65.6%) and Fournoi (−50.0%). In the secondary sector an increase

>50% was recorded in: Gavdos (83.3%), Halki (58.3%), Oinousses (52.0%), while a decrease >30% was recorded in: Psara (−53.6%) and Ag. Efstratios (−35.0%). In the tertiary sector the increase exceeds >100% in Gavdos (311.1%), Halki (273.7%), Agathonisi (258.35%), Lipsi and Psara, while a decrease 30% was recorded in Fournoi and Patmos. Decreases in primary/secondary sectors are mainly associated with the contraction of residents and the strengthening of tourism; g) construction activity (mainly associated with tourism development) was increased in Fournoi (344.5%), Tilos (52.1%) and Agathonisi (51.1%), and a decrease >20% was recorded in Halki and Psara [30(a)].

In particular, when it comes to tourism development, regardless of the year 2020 when indicators were dramatically decreased due to the COVID-19 pandemic, islands with positive rates (>100%) of tourism growth (after 2011) were Gavdos, Megisti and Nisyros. Based on a) the rate of change of ferry passengers disembarking, the highest positive change was recorded by Gavdos, Megisti, Nisyros and Tilos, while the highest negative one by Symi (−57.30%), Halki (−26.74%), and Fournoi (−25.80%); b) the rate of change in hotels, a positive change >300% was recorded by Agathonisi and Gavdos, while a negative one by Kasos (−20.19%), Leros (−5.14%) and Patmos (−1.14%); c) the occupancy rate change, positive changes >30% were recorded by Nisyros, Megisti, Leros and Lipsi, while negative ones (>13%) by Psara, Tilos and Fournoi; and d) rate of change in cruise passenger arrivals (2015–2020): strong differentiation was found between Patmos (+574%) and Symi (−92%). The study of the indicators is of great importance as it highlights the types of tourism and consequently the pressure that islands encounter, their role in the local economy as well as the energy demands they cause [30(e)].

3.2 Monitoring Existing Energy Patterns _ Peculiarities and Perspectives

3.2a Greek Insular Regions

As regard spatial dependence of insular regions from the mainland of the country, the most interconnected regions (underwater networks) are the Ionian Islands (along with the regions of Epirus and Western Greece) and the northern Cyclades (Andros, Tinos, Mykonos, Kea, Gyaros, Syros, Paros) of South Aegean (along with the regions of Attica and Central Greece). On the other hand the regions of the Northern Aegean and Crete (in total) and northern Cyclades and Dodecanese Islands of the South Aegean belong to the non-interconnected islands due to their geographical location and spatial structure (i.e. polynesia, intense spatial dispersal, etc.). To meet the energy needs, the islands have local production stations that face several problems in their operation, especially those on the smaller and more remote islands. For this reason, there is a project aiming at the gradually interconnection of all islands by 2030 [30(d)].

Based on the official data of the Hellenic Statistical Authority (ELSTAT 2020), the dependence of insular regions on the utilization of polluting forms for energy production remains high. Greater dependence show, in descending order, the regions of Crete, S. Aegean, Ionian Islands, N. Aegean. As regard the RES utilization insular regions are at the bottom of the national ranking [Crete 10th, Ionian Islands 11th, S. Aegean 12th, N. Aegean 13th], while they do not harness MRE. An exception is Crete, where wave energy is harnessed in an experimental phase [30(a)].

As regard energy consumption and future demands, the highest annual energy consumption (2020) show, in descending order, the regions of Crete, South Aegean, Ionian Islands and North Aegean. The region ranking based on the % change in energy consumption (2016–2020) was: Crete (+5.2%), South Aegean (+4.7%), Ionian Islands (+2%) and North Aegean (+1.5%)]. Growth trends in energy consumption in regions of South Aegean, Ionian Islands and North Aegean is mainly attributed to tourism development and less to permanent resident population growth. This is also ascertained by the % changes of population [(2001–2011): South Aegean (+2.08%), North Aegean (+2.06%), Crete (+0.03%)]; construction activity [(2001–2011): South Aegean (+16.86%), Ionian Islands (+9.26%) and Crete (+0.03%)] and tourism [(2016–2020): South Aegean (+89.3%), Crete (+24.3%), North Aegean (+21.4%)] [30(a–e)].

3.2b Aegean Small Frontier Islands

The small border islands of the Aegean belong to non-interconnected islands to the national electricity network of the mainland. They have power plants, which however face significant adequacy issues and are energy dependent on neighboring larger islands, as follows: Ag. Efstratios energy dependent from Lemnos, Oinousses from Chios, Fournoi from Ikaria, Leros from Kalymnos, Kasos from Karpathos, Symi-Tilos-Halki from Rhodes, Nisyros from Kos, Patmos-Lipsi-Agathonisi from Kalymnos, Gavdos from Crete. Furthermore, during periods of increased demands (summer months) small islands are supplied by oil tankers [30 (b–d)].

In 2016–2020 period, islands with the higher electricity consumption increase were Gavdos (17%), Agathonisi (10.0%), Megisti (3.0%) and Symi (2.0%). The majority of the islands (Ag. Efstratios, Psara, Oinousses, Fournoi, Leros, Kasos, Tilos, Nisyros, Halki, and Lipsi) maintained a stable consumption, while a significant decrease is observed in Patmos (−22.0%) which is worth studying. In 2020 the rate of electricity generation from conventional forms was at 100% for 10 of the 15 islands (i.e. Ag. Efstratios, Oinousses, Fournoi, Kasos, Tilos, Nisyros, Halki, Lipsi, Agathonisi and Megisti). In the rest of islands it exceeded 80% [i.e. Gavdos (99.9%), Symi (98.3%), Psara (96.9%), Leros (96.2%), Patmos (83.7%)]. In these islands the participation rate of RES in electricity production was limited. Finally, there is no small frontier island harnessing MRE [30(b–d)] (Fig. 2).

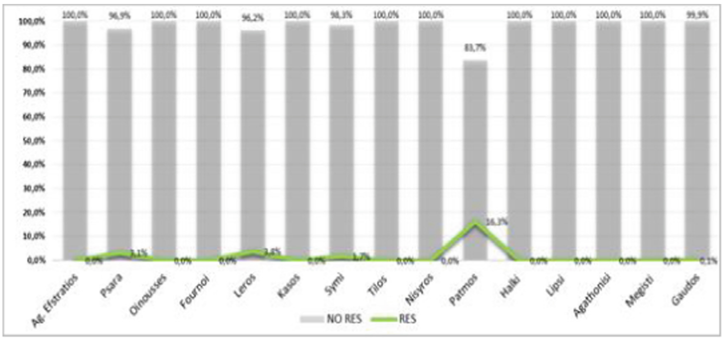

Fig. 2. Small Frontier Aegean Islands: Percentage of participation of conventional and renewable energy sources in electricity generation (2020) [30(b-d)]

Furthermore, for the assessment of the energy dynamic of small frontier islands the monitoring of energy dynamic indicators during the year is of particular interest. Through such a perspective, the multiplicity of effects of *insularity*, *seasonality* and *remoteness* on energy dynamics of islands and changing trends is ascertained. Thus, from the study of changes in the rate of energy consumption per quarter for the year 2020 it was ascertained that the highest prices were noted during 3rd and 4th quarter due to tourism. The monitoring of fluctuations among islands emerged from their rate of *seasonality*, as well as the supralocal character of tourism development.

As regard the future of energy transition, several of the under investigation small islands are found in proposals formulated at scientific/political levels. Among them, an indication reference is made to recent initiatives[3] promoted by the EU [e.g. NESOI (Nisyros, Tilos), RESponsible Islands (Tilos), Clean Energy for EU Islands (Halki, Kasos, Symi), IANOS (Nisyros)] and Greek government [GR-eco Islands (Halki)], as well as projects by private bodies in cooperation with Greek administration (central/decentralized) and research entities for the development of innovative technologies [e.g. MUSICA (Oinousses)] for the harnessing of RES/MRE in the context of smart sustainable development and the European Green Deal [2, 5, 6, 22, 23]. It is noted that Tilos is the first Greek small border island to develop an innovative model of energy autonomy through the utilization of solar-wind energy and battery energy storage awarded by the pan-European RESponsible Islands competition.

4 Conclusions Based on a Synthetic Approach of the Proposed Criteria

From the multi-criteria approach of the development and energy dynamics of insular regions and the small frontier islands of the Aegean emerged findings that highlight critical issues that must be addressed at a time of global climate-energy crisis and established absence of national insular and energy policy in Greece [14, 27, 28, 30]. In conclusion, the following are noted by thematic:

a. **Spatial dependence from the mainland and insular regions**: the rate of energy autonomy of islands is limited due to two reasons. Either because of their energy dependence from the mainland, or because they lack to develop autonomous energy structures at the intra-regional level decentralizing energy networks that harness RES/MRE. This dominant trend perpetuates dependence issues between islands and the mainland, as well issues among islands (smaller and bigger ones).
b. **Dependence on forms of energy**: The main role in electricity generation plays fossil fuels. Unfortunately, in a country provided with geophysical and climatic

[3] i.e. NESOI (https://www.nesoi.eu/content/projects-briefs), RESponsible Islands (https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/prizes/prize-renewable-energy-islands-responsible-island_en), Clean Energy for EU Islands (https://clean-energy-islands.ec.europa.eu/ and https://europeansmallislands.com/2020/10/28/29-european-islands-publish-new-energy-transition-agendas/), IANOS (https://ianos.eu/islands/), GR-eco Islands (https://ypen.gov.gr/i-chalki-ginetai-to-proto-gr-eco-island/), MUSICA (https://musica-project.eu/).

comparative advantages the harnessing of RES is still limited, whilst that of MRE is absent.

c. **Energy consumption and new demands**: Differentiations are found both between regions and at the intra-regional level (between islands). The highest consumption and growth trends are found in regions that include islands with a significant population size, which simultaneously function as gateways, supra-local tourist destinations and enclaves of development activities in primary/secondary sector (Crete, South Aegean). Moreover, lower consumption with significant fluctuations due to *seasonality* are presented by insular regions of islands of small population size, with weaknesses in their productive structure and low tourism development (mainly in North Aegean and less in the Ionian Islands). At intra-regional level, the highest energy consumption/demands are found in developed islands, but also in less developed ones that experience tourism development (regardless of their surface area and the size of their population). To this category belong several small frontier islands of the Aegean. Examples are Gavdos, Agathonisi and Megisti, due to the significant population growth (>22%) in 2001–2011 combined with the positive percentage changes in tourism in the last 10 years (>14%) in construction activity and other sectors of production (2001–2011) [i.e. primary: Megisti (250%); secondary: >50% in Gavdos; tertiary: >100% in Gavdos and Agathonisi] [30].

Based on the above, findings of general and more specific interest which could be utilized in the development of sustainable energy policy are emerged for: a) the establishment of necessary context of planning principles and guidelines and the approached methodology (phases and assumptions), b) the selection of assessment criteria and how they are correlated, c) the prioritization of energy transition options (typological classification/hierarchy of islands based on existing energy needs as well as their changing trends). In particular, it is ascertained that:

- Energy demands of islands vary depending on the degree of *insularity* [territorial fragmentation (type/intensity), spatial/socio-economic isolation and networking, local economy], *seasonality* (permanent population, multifunctionality, etc.), and *remoteness* (geographic position, connection with the mainland/insular regions). Crucial parameters in the differences in consumption between insular regions and islands in particular are: population size (inhabitants/visitors), type and number of activities and infrastructures and level of tourism development.
- The increase in quantitative indicators associated with population, local economic activity and infrastructures of supralocal reach [i.e. (iv), (v), (vi), (vii), (viii), (ix)] variously affect the energy requirements [(x)] of insular regions and islands.
- The type and intensity of the correlation of criteria related to the local economy and supra-local infrastructures [i.e. (v), (vi), (vii), (ix)] may have simultaneously positive (i.e. enhancing competitiveness by limiting *seasonality*) and negative (i.e. increasing pressures on natural-built environment and carrying capacity) effects on islands' sustainability and resilience. This raises the issue of choosing energy patterns depending on the specifics of islands.

- Criteria related to specific characteristics, local identity and carrying capacity of the natural-cultural-anthropogenic ecosystems of the islands [(ii), (iii)], especially in combination with criteria that affect their accessibility and networking [(i), (vi)] can be favorable (e.g.geomorphology, climate) or restrictive (e.g. protection areas, landscape) in their energy transition - autonomy, mainly in smaller (surface area, population size, range of local economy) and frontier islands (spatial and socio-economic isolation).

5 The Typological Classification of Islands as a Means of a More Sustainable Energy Transition

In this section, the small boarder islands are included in energy priority categories, based on the findings for their development (i.e. local identity, economy) and energy dynamics (energy transition-autonomy, new demands), as well as their evolutionary trends (risks/prospects). Thus, the proposed criteria [(i)–(x)] are related in the context of two main assumptions. The first assumption supports the importance of taking into account the parameters that affect the energy demands of the islands, while the second focuses on those that function favorably or restrictively in their energy transition and autonomy. In the first case, emphasis is given to the quantitative dimension of the parameters, while in the second case their qualitative dimension is of high importance too. The aim of the proposed typological classification is actually to highlight groups of islands with common problems and crucial issues that need to be addressed in a sustainable energy policy at local and regional level. In this sense, the classification could be used as a 'basis' for a -in a later phase- pilot implementation of energy transition-autonomy actions at island level and/or in groups of islands (Fig. 3).

Along this line, the criteria are divided into two groups. The first group includes those that affect the energy demands of islands (first assumption) [(iv) population, (v) local economy - production sectors, (vi) accessibility/networking, (vii) services/infrastructures of supralocal reach, (viii) construction activity, (ix) tourism], while the second group focuses on criteria that highlight the uniqueness of the islands (second assumption) [(i) geographical location, (ii) locus, (iii) nature-culture]. The criteria are evaluated in two phases. The first combines criteria of the first group [(iv), (v), (viii), (ix)] with energy, aiming at including islands in energy priority categories, according to their resettlement and tourism development trends and perspectives (regardless of island area or population size) [(A) <u>1st priority islands</u>; and (B) <u>2nd priority islands</u>]. In the second phase, the criteria of the second group [(i), (ii), (iii)] are also taken into account in order to highlight the barriers set by the particular characteristics of the islands and which affect their energy transition and autonomy (geographical location, climate, nature-culture, landscape etc.). It is argued that the consideration of the later criteria is a precondition for the sustainable energy transition of these vulnerable sites.

More specifically, the main methodological steps followed in the first phase were:

<u>A table with the percentage changes of the criteria of the first group [(iv)–(x)] was organized</u> in order to monitor and evaluate their changes (2001–2020).

<u>The islands were divided into groups/subgroups based on the percentage changes in inhabitants (2001–2011) and visitors (2011–2020)</u>. The choice was not random. It reflects the tendencies of the abandonment by the inhabitants and the strengthening of

tourism in islands; parameters that can affect in various ways islands' energy demand and its variation in the year. Thus, based on population change, three groups emerge: (I) islands that are losing population (abandonment trends) [North Aegean (in total), South Aegean (Leros)]; (II) islands that are gaining population (resettlement trends) [Kasos, Tilos, Nisyros, Halki, Lipsi, Agathonisi, Megisti, Gavdos], and (III) islands that maintain a stable population [Symi, Patmos]. The biggest negative change was found in Ag. Efstratios (-12%) and the highest positive in Gavdos (+88%) and Halki (+62%). To better understand the effects of *seasonality* on the small islands' energy needs, the above groups were divided into subgroups depending on the correlations of increase and decrease of residents-visitors. Hence, groups (I), (II) were divided into: (I − −), (I − +) and (II ++), (II + −), while group (III) remains, due to a stable population and reduction of visitors in Symi (−57.3%) and Patmos (−24.14%). In particular, the distribution of islands by subgroup is as follows: a) (I− −): decrease in inhabitants and visitors [Psara, Oinousses, Fournoi, Leros], (I − +): (decrease in inhabitants/increase in visitors) [Ag. Efstratios]; and b) (II ++): increase of inhabitants and visitors [Tilos, Nisyros, Lipsi, Agathonisi, Megisti, Gavdos], (II + −): increase of inhabitants/decrease of visitors [Kasos, Halki]. Of particular interest are: Fournoi (I − −) with the smallest negative change in residents (−2%) and the largest negative in visitors (−25.8%); Ag. Efstratios (I− +) with the largest negative change in inhabitants (−12%) and the largest positive in visitors (+25.1%); Gavdos (II ++) with the largest increase in residents (+88%) and visitors (+837%); and Halki (II + −) with the largest positive change in residents (+62%) and the largest negative in visitors (−26.74%) [30].

Consideration of economic activity and energy demands by island (% changes 2001–2011). The islands with the largest positive change in the primary sector were Megisti (+250%), Nisyros (+53%) and Psara (+14%). This increase in Megisti and Nisyros was accompanied by positive changes in residents (+22% + 9% respectively) and tourism (+438.27% and 198.74% in visitors respectively, and in Nisyros + 112.4% in hotel occupancy), while in Psara from negative changes in residents and visitors (−4%, −3.68% respectively). The most dynamic islands in the secondary sector were Gavdos (+83%), Halki (+58%), Oinousses (+52%) and Megisti (+36%) mainly due to construction activity. In Gavdos, Halki and Megisti the increase in the secondary sector was accompanied by an increase of inhabitants (+88%, + 68% and + 22% respectively) while especially for Gavdos and Megisti islands an explosive increase in visitors was observed in the same period (+837%, +438.27% respectively). In Halki and Oinousses the visitors decreased (−26.74% and −23.38% respectively) adjusting the energy requirements. In the tertiary sector the biggest positive changes were found in Gavdos (+311%), Halki (+274%), Agathonisi (+258%) and Lipsi (+115%) and were accompanied by an increase in population [mainly in Gavdos and Halki (+88%, +62% respectively)] and visitors [mainly in Gavdos (+837%) and less in Agathonisi (+23%) and Lipsi (+13.98%)]. Of particular interest is the increase of the hotel potential index in Gavdos (+837%) and Lipsi (+54%), and the changes in the construction activity that are mainly connected with the tourism development. At the same time, in Halki, despite the increase in population (+62%), there is a decrease in construction activity (−30%), visitors (−26.74%) and hotel staff (−53.5%). Symi and Patmos (group III) -the only islands of the sample cruise destinations-showed a decrease in the primary sector (−28%

and −45%) and in visitors (−57.3% and −24.4%). Based on the % changes of tourism indicators, Nisyros, Agathonisi, Gavdos, Oinousses are emerging as potential 'poles' of tourism and holiday residence. Regarding the energy sector, increasing consumption trends highlighted mainly in Gavdos (+17%) and Agathonisi (+10%), while the most active islands in RES assessment were Patmos (+16.3%) and Leros, Psara and Symi with percentages <4%. The negative changes in the tourism indicators are attributed to the health crisis (COVID-19) that broke out in 2020 and are worth re-examining in relation to the 2021 updated data of ELSTAT when available [30].

Taking into account the % changes of the indicators, which are expected to affect future local need and demands, the small islands fall into the following two categories of energy intervention priority (Fig. 3):

(A) 1st priority islands due to threats/risks [(I− −): Psara, (I− +): Ag. Efstratios, (III): Symi, Patmos] and opportunities/perspectives [(II ++): Tilos, Nisyros, Agathonisi, Megisti, Gavdos, and (II + −): Halki]

(B) 2nd priority islands due to threats/risks [(I− −): Oinousses, Fournoi, Leros] and opportunities/perspectives (II ++): Lipsi, and (II + −): Kasos]

Having the above classification as a basis, in the second phase are highlighted those small frontier islands that, due to their geographical location, scale (area/population size), and intense concentration of natural-cultural resources, require special attention in their energy transition-autonomy. Based on the research, the following are noted: a) 9 out of 15 islands (60%) have an area of <45 km^2, and of those four are <20 km^2 [Oinousses, Lipsi, Agathonisi, Megisti]; b) the most remote islands (distance from Turkey <15 km) are Oinousses, Symi and Megisti (<10 km) followed by Agathonisi, Nisyros, Tilos; c) there are favorable prospects for the development of RES/MRE in all islands; d) the most intense concentrations (> six sites) of nature-history-culture-protection areas (Natura, archeological sites, historical sites, underwater heritage, etc.) are found in Gavdos, Leros, Nisyros, Halki and Psara while high concentration of supralocal infrastructures (>3 types) and good accessibility (Multimodal Hub) have Leros, Kasos, Megisti followed by Symi, Patmos and Halki. Finally, Psara, Oinousses and Kasos are islands with strong historic naval tradition [28, 30(f)].

Based on the above insights, it is estimated that special attention should be given to the energy transition-autonomy of islands that: a) simultaneously experience trends of abandonment and tourism development (Ag. Efstratios, Fournoi), especially if they are among the smallest and most remote (Psara, Oinousses) [local identity alteration]; b) experience conditions of resettlement and simultaneous rural-tourist development (Nisyros, Megisti) [balanced local development prospects]; and c) have oriented their development exclusively to tourism (i.e. Halki, Symi, Kasos, Tilos, Patmos, Leros), especially if they are among the smallest and less populated (i.e. area <30 km^2, <1,000 inhabitants) since pressures tend to be more intense on their territories (i.e. Gavdos, Agathonisi, Lipsi) [carrying capacity alteration].

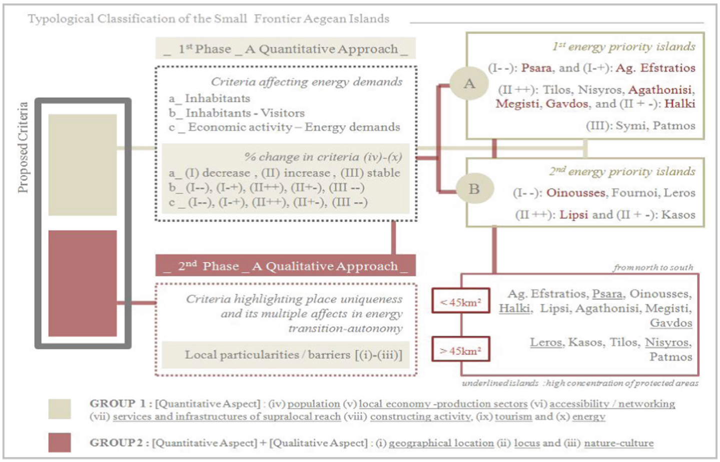

Fig. 3. Small frontier Islands: proposed energy priority categories [own elaboration]

Recognizing the importance of mitigating inequalities and preserving the climate neutrality of insular regions it is argued that priority should be given to islands (<45 km^2) with strong resettlement trends (Gavdos, Halki) and to the frontier ones that are losing inhabitants (Ag. Efstratios, Psara, Oinousses) or are being faced with the management of strong deviations in regards to the ratio of residents/visitors during the year [Lipsi, Agathonisi, Megisti (MH)]. However, of equally importance is the case of islands (>45 km^2) with increased energy demands due to population size (>3,000 and <8,000 inhabitants) and high concentration of supralocal infrastructures (i.e. transport, administration, production, social) [Leros (MH), Patmos] and those less populated (<1,000 inhabitants) with a high concentration of supralocal infrastructures and tourism [i.e. Kasos (MH), Tilos, Nisyros].

6 Paving the Way for Clean Energy Insular Regions/Islands

The need to ensure sustainable energy transition and autonomy for insular regions is not disputed. However, implementing such a goal is a real planning challenge, as it requires a balance between meeting energy demands, satisfying different investment interests, and protecting fragile natural-cultural-manmade ecosystems. Challenges and dilemmas are increasing in the case of small remote islands. There are two reasons for this phenomenon. On one hand, these islands impose their energy autonomy thanks to their strong spatial and socio-economic isolation. On the other hand, they raise special terms and restrictions in regards to their energy planning (i.e. choice of energy model, location, extent of development, etc.) due of their limited scale and high concentration of quality elements of nature-culture-landscape.

Recognizing that sustainable energy transition - autonomy in these vulnerable areas is a prerequisite for their resilience and competitiveness, it is argued that in order to achieve such an objective the answer must be sought in the typological classification of islands by simultaneous assessing the local energy demands and the barriers that each island sets (scale, natural- manmade environment, landscape/seascape). This is a different perspective from the one which has been applied for decades to the official planning level in Greece [central organization of national energy network and gradual connection of all islands by 2030, starting with those located in the most developed insular regions, i.e. Crete (2023), South Aegean (2028) and North Aegean (2029)] [30(d)]. It is an approach which chooses to support the most vulnerable islands as a precondition for a more fair (spatial and socio-economic) and climate-neutral energy planning. In other words, it aims at a more decentralized organization of energy networks oriented to the exploitation of RES/MRE with a higher index of autonomy for all islands, mainly for the smallest and most remote ones.

However, for the best utilization of such an approach at the implementation level, an overall national policy is needed. A flexible policy with a clearly defined vision and a methodological framework structured in respect to three planning assumptions, namely: a) *insularity*, *seasonality* and *remoteness* should be the main pillars of this policy framework, due to their effects on the energy demands of insular regions and islands, and the barriers/priorities they set up on a case-by-case and time basis; b) energy transition-autonomy of insular regions/islands should be sought on the basis of equal consideration of local peculiarities integrated into the national and broader international energy environment. Small frontier islands should gain an additional interest due to their vulnerable natural and manmade environment and geopolitical significance; and c) energy planning should be carried out in the context of a multifactorial approach with simultaneous evaluation of geographical, environmental, spatial and socio-economic criteria. In a difficult juncture of a multifaceted crisis, no matter how difficult could be to move toward this direction, we should reconsider the current trends and assume responsibility as active citizens, especially those of us who serve the planning process as policymakers, planners and academic teachers [31].

References

1. International Renewable Energy Agency (IRENA): Global Energy Transformation. Energy Roadmap 2050, ISBN 978-92-9260-059-4. (2018). https://www.irena.org/-/media/Files/IRENA/Agency/ Publication/2018/Apr/IRENA_Report_GET_2018.pdf
2. Gjorgievski, V., Markovska, N., Pukšec, T., Duić, N., Foley, A.: Supporting the 2030 agenda for sustainable development: Special issue dedicated to conference on sustainable development of energy, water and environment systems 2019. Renewable and Sustainable Energy Rev. **143** (2021). Accessed 6 Jan 2022
3. European Commission: European Council- Council of the European Union 2020, Climate Action-2050 Long term Strategy (2020). https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2050-long-term-strategy_en. Accessed 8 Apr 2022
4. European Commission: A European Green Deal. Striving to be the first climate neutral continent (2019). https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. Accessed 21 Apr 2021
5. European Commission: Clean Energy. The European Green Deal, Decarbonising the EU's energy system is critical to reach our climate objectives (December 2019). https://ec.europa.eu/commission/presscorner/detail/en/fs_19_6723. Accessed 10 Apr 2021
6. European Commission: Energy and the Green Deal: A Clean Energy Transition (2021). https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/energy-and-green-deal_en. Accessed 10 Apr 2022

7. UN Climate Change Conference UK 2021: COP26 The Glasgow Climate Pact (2021). https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf. Accessed 8 Apr 2022
8. Nouicer, A., Kehoe, A., Nysten, J., Fouquet, D., Meeus, L,. Hancher, L.: The EU Clean Energy Package. European University Institute (2020). https://cadmus.eui.eu/bitstream/handle/1814/68899/QM-01-20-700-EN-N.pdf?sequence=1
9. Pelleri-Carlin, P., Vinois, J., Rubio, J., Fernandes, S.: Making the energy transition a European success. Tackling the democratic, innovation, financing and social challenges of the energy union. Notre Europe Jacques Delors Institute. Studies & Reports (2017). https://institutdelors.eu/wpcontent/uploads/2018/01/makingtheenergytransitionaeuropeansuccess-study-pellerincarlinfernandesrubio-june2017-bd.pdf. Accessed 10 Apr 2022
10. Gui, E., MacGill, I.: Typology of future clean energy communities: an exploratory structure, opportunities and challenges. Energy Res. Soc. Sci. **35**, 94–107 (2018). ISSN 2214-6296. https://doi.org/10.1016/j.erss.2017.10.019
11. COM. 494Blue Growth. Opportunities for marine and maritime sustainable growth (2012). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52012DC0494
12. Ocean Energy Europe (OEE): Ocean Energy Strategic Roadmap 2016. Building ocean energy for Europe (2016). https://www.oceanenergy-europe.eu/files/ocean-energy-roadmap/
13. Khare, V. R, Dubey, R.: Blue Energy: Power from the Sea. National Conference of Green Technology (2016). https://www.researchgate.net/publication/288839358_Blue_Energy-_Power_from_the_Sea. Accessed 23 Sept 2021
14. Theodora, Y.: Aegean sea - challenges and dilemmas in management and planning for local development in Fragmented Insular Regions. Heritage **2**(3), 1762–1784 (2019). https://doi.org/10.3390/heritage2030108
15. Kuang, Y., et al.: A review of renewable energy utilization in islands. Renew. Sustain. Energy Rev. **59**, 504–513 (2016). ISSN 1364–0321. https://doi.org/10.1016/j.rser.2016.01.014. Accessed 10 Apr 2022
16. Wimmler, C., Hejazi, G., de Oliveira Fernandes, E., Moreira, C., Connors, S.: Multi-criteria decision support methods for renewable energy systems on islands. J. Clean Energy Technol. **3**(3) (2015). https://repositorio.inesctec.pt/server/api/core/bitstreams/b48ac2be-a80f-490a-9f03-8932b5bfc908/content. Accessed 10 Apr 2022
17. European Commission, Clean Energy for EU islands. Providing a long-term framework to help EU islands generate their own sustainable, low-cost energy (2022). https://energy.ec.europa.eu/topics/markets-and-consumers/clean-energy-eu-islands_en
18. European Commission: Clean Energy Vision to Clean Energy Action. Clean Energy for EU Islands Community (2022). https://clean-energy-islands.ec.europa.eu/
19. New Energy Solutions Optimised for Islands (NESOI). European Islands Facility. (2022). https://www.nesoi.eu/. Accessed 6 Jan 2022
20. Islands Commission of the CPMR: The Final Declaration adopted by its members. In: 36th Annual General Meeting, 19–20 May, Rhodes, South Aegean, Greece (2016). https://europeansmallislands.files.wordpress.com/2016/05/agenda-cpmr-rhodos.pdf
21. European Parliament: Research for REGI Committee: Islands of the European Union: State of play and future challenges. Policy Department for Structural and Cohesion Policies. Directorate-General for Internal Policies. PE 652.239 - March (2021). https://www.europarl.europa.eu/RegData/etudes/STUD/2021/652239/IPOL_STU(2021)652239_EN.pdf. Accessed 10 Apr 2022
22. Smart Islands Initiative: Smart Islands Declaration. New Pathways for European Islands (2022). https://www.smartislandsinitiative.eu/en/index.php. Accessed 8 Apr 2022

23. Groppi, D., Pfeifer, A., Garcia, D., Krajačić, G., Duić, N.: A review on energy storage and demand side management solutions in smart energy islands. Renew. Sustain. Energy Rev. **135** (2021). https://doi.org/10.1016/j.rser.2020.110183
24. Blechinger, P., Seguin, R., Cader, C., Bertheau, P., Breye, Ch.: Assessment of the global potential for renewable energy storage systems on small islands. Energy Procedia **46**, 325–331 (2014). https://doi.org/10.1016/j.egypro.2015.01.071. Accessed 2 Dec 2021
25. Andaloro, A., Salomone, R., Andaloro. L.: Alternative energy scenarios for small islands: a case study from Salina Island (Aeolian Islands, Southern Italy). Renew. Energy **47**, 135–146 (2012)
26. Ricardo Energy & Environment: Small Islands Energy System Overview. Local Carbon Energy Systems Framework. Report for Highlands and Islands Enterprise (2016). https://www.hie.co.uk/media/8139/hie-small-islands-low-carbon-energy-overview-final-report-for-publication-pdf-060420-a3410152.pdf. Accessed 8 Dec 2021
27. Theodora, Y.: Cultural heritage as a means for local development in Mediterranean historic cities-the need for an urban policy. Heritage **3**(2), 152–175 (2020). https://doi.org/10.3390/heritage3020010
28. Theodora, Y.: Tracing sustainable island complexes in response to insularity dilemmas _ methodological considerations. In: Gervasi, O., et al. (eds.) ICCSA 2020. LNCS, vol. 12255, pp. 278–293. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58820-5_22
29. International and European Databases: International Renewable Energy Agency (IRENA). https://www.irena.org; European Environment Agency (EEA). https://www.eea.europa.eu/
30. Greek Databases: (a) National Statistical Authority of Greece (ELSTAT). http://www.statistics.gr; (b) Hellenic Electricity Distribution Network Operator (HEDNO) https://deddie.gr/en/; (c) Public Power Corporation (DEI). https://www.dei.gr/en/; (d) Independent Power Transmission Operator (IPTO/ADMIE). https://www.admie.gr/en; (e) Institute of Greek Tourism Confederation-INSETE (INSETE). https://insete.gr/?lang=en; (f) Hellenic Ministry of Culture. https://www.culture.gov.gr/en/SitePages/default.aspx
31. Theodora, Y.: Landscape at Risk _ Why Planning Matters? National Symposium on the Implementation of the Council of Europe Landscape Convention in Greece. Round -Table: Landscape-based Public Policies. European Landscape Convention, Council of Europe, Trikala, Greece (2022). https://www.coe.int/en/web/landscape/trikala-march-2022