STUDY

Renewable Energy Developments in Greek Islands

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- Renewable energy on islands provides an excellent opportunity for economic development in Greece taking into account that the islands of the Aegean sea are characterized by a significant potential mainly of wind and solar energy.
- Greece already has a history of being a first mover in Europe for the use of renewables on islands with Kythnos – for solar, wind and microgrids, and Ikaria – for hybrid with storage.
- The use of renewables on these islands would economically benefit the citizens and the local communities, as the current cost of energy production is high compared to the mainland.
- Several new jobs can be created by implementing renewable energy sources on islands both temporarily during the construction phase, as well as permanently for operation and maintenance.
- The Aegean islands provide huge opportunities for innovative technological solutions, such as hybrid systems including pumped storage as well as desalination systems, and sophisticated control systems.
- Greek islands can serve as ideal testbeds for the operation of systems with very high penetration of renewables and provide valuable experience for the transfer of innovative technologies in larger interconnected systems.

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Authors' note: This policy paper was drafted by the authors in December 2014 and most of the content was defined based on available data and public debate until then (January 2015). Since April 2015 Prof. Nikos Hatziargyriou is Chairman of the BoD & CEO of HEDNO S.A. (Hellenic Electricity Distribution Network Operator S.A.) and Ioannis Margaris is executive Vice-Chairman of the BoD of HEDNO S.A. In some places the text is updated according to recent developments.

A. Executive Summary

The global economy seems to be in the midst of a complex transformation, not only financial, which should aim at new sustainable forms of living and production models. Scarce natural recourses with fragmented intellectual, immaterial production, have produced several bottlenecks in the field of innovation models in terms of technology, institutional bodies, policy mechanisms, cost and management techniques. Islands can provide us with the necessary social and natural field of experimentation towards such a complex innovation process. On a global level, distributed production lines and other novel technology paradigms resemble the concept of insularity taking advantage of ICT technologies. Within this context products and services need to be more adaptive, personalized, replicable and transferable responding to the real, local conditions of social and economic life.

Energy, as a key means of production and reproduction in modern economy, lies in the center of this transformative process and needs to be addressed with reference to facilitative structures, shifts in the technology paradigm and institutional-policy-governmental initiatives in order to accelerate the adoption of sustainable ways of living. This challenge appears even more so vital in the case of Greece and other European countries, which have been experiencing severe financial and social crisis during the last 5 years. Based on available resources - both natural and technical -, the Greek energy sector could play a fundamental role in the transformation and transition process of the national production pattern towards a new, sustainable and socially equitable system. This short policy paper aims at identifying the potential for innovative methods and technologies in the electricity sector, focusing on ways to facilitate large penetration of renewable energy sources (RES) in the non-interconnected island power systems of Greece.

A radical restructuring of electricity markets in Continental European countries began in the late 1990s, a process still ongoing. The underlying premise was the EC's policy guideline regarding competition through market liberalization, which is believed to eventually lead to price reduction and security of supply through activation of the market forces in the energy sector. In Greece the national government adopted the EU Directives into national legislation starting in 1999 with the Law 2773/1999, regarding unbundling of the electricity sector (production-supply, transmission-distribution). Many issues which affect this process, including market power of different actors, investment schemes as well as specific geographic concerns, which affect the planning and operation of the power system, are still major concerns in the public debate around the energy sector and the respective policies. A series of reforms of the legislation have followed since 1999, including the introduction of a mandatory pool (Law 3175/2003), a balancing market and bilateral agreements (Law 4001/2011).

Planning, operation and market regulation of small-sized isolated electricity power systems - the ones referred to as Non-Interconnected Island Power Systems (NIIPS) in this report - has also been under continuous transformation during the last two decades, mainly due to the introduction of RES production plants in the energy mix. The power system, market and grid operator of NIIPSs is the Hellenic Electricity Distribution Network Operator S.A. (HEDNO S.A.), which was founded in 2012 according to Law 4001/2011. HEDNO S.A. was formed by the separation of the Distribution Department from the Public Power Corporation S.A. (PPC S.A.), in compliance with 2009/72/EC EU Directive relative to the electricity market organization with the goal to undertake the tasks of the Hellenic Electricity Distribution Network Operator. It is a 100% subsidiary of PPC S.A., however, it is independent in operation and management fulfilling all the independence requirements of the above-mentioned legislative framework.

HEDNO S.A. tasks include operation, maintenance and development of the power distribution network in Greece, as well as the assurance of a transparent and impartial access of retailers, consumers, local producers and all network users connected at the distribution network, in general. Specifically for NIIPS, HEDNO is responsible for the system operation and for their security of supply. These tasks make HEDNO S.A. the main stakeholder of the electricity systems of NIIPS, and following the European trends, the basic smart grid driver in the electricity system of Greece, in general.

1. This contribution is calculated as net receipts to Greece from sea transports. According to sector representatives, shipping as a percentage of GDP will rise to 4.9% and 5.7% of GDP in 2014 and 2015, respectively, from 4.2% of GDP in 2013 (Hellenic Shipping News 2014).

Greece comprises 124 inhabited islands, 36 of which are non-interconnected to the mainland, that form 32 groups of islands and lay mostly in the Aegean Sea. Small and medium sized NIIPS in Greece, which host 15% of the Greek population, account for almost 10% of the total national electricity consumption. These systems are supplied by autonomous power stations, based on oil generation units (diesel and heavy fuel for small and medium systems) and some steam turbines in the larger NIIPS, Crete and Rhodes.

Specific characteristics of these isolated power systems complicate the operation patterns and lack advantages related to economies of scale, resulting in increased costs. The inherent technical aspects, when it comes to planning and operating isolated power systems, require sophisticated ad hoc methodologies in order to implement any master plan of large integration of RES in modern power systems.

Any efficient - economically, technologically and environmentally - strategy should provide solid steps of ensuring compliance with the three pillars of energy policy: economic efficiency, environmental protection of local systems and security of supply through diversification.

With the possible exception of the largest islands, market structure in such systems cannot in most cases follow efficiently the mainstream approach applied in the context of the continental power system - the variable and stochastic nature of renewable energy input and the high fuel transmission costs limit the integration of RES and this in turn requires hybrid models of regulation and competition, as discussed in recent literature. In February 2014, the Regulatory Authority for Energy (RAE) of Greece introduced the Operation Code for Non-Interconnected Islands (NII Code), which aims to regulate the operation and the transactions at NIIPS, opening the framework for competitive markets, in both production and supply activities. The European Commission, acknowledging unique conditions, granted to Greece derogation from the provisions of Chapters III and VIII of EU Directive 2009/72/EC for the NIIPS: i) for the refurbishing, upgrading and/or expanding of PPC's existing power plants until 1.1.2021, ii) for the supply activity, some years after the adoption of the NII Code, until the necessary infrastructure is in place. This process is managed by the Regulatory Authority for Energy (RAE) of Greece following consultation and suggestions from HEDNO S.A. in its capacity as the NII Operator. In June 2016, official opening of the retail market in Crete is announced.

After 1999 one of the fundamental processes affecting further expansion of the RES sector have been the regional and local land use plans, defining possible locations for newly installed RES plants. This process has been controversial involving several conflicts within local communities and public administration, leading to significant delays during the permission process of new RES projects or even during the installation. Social tensions did not provide the necessary consensus for a shift in technology paradigm.

In this paper, it is argued that Renewable Energy on islands can provide a testbed for economic development taking into account local geographical, sociological and institutional dynamics. An overview of the current conditions of the electricity sector on the Greek islands is provided including main operational and economic aspects. The paper concludes with some general guidelines towards a coherent policy for the necessary background of socio-technological and policy innovation.

B. Current State of Affairs on the Greek Islands

B1. Operational and Market Characteristics of the Greek Islands

The 32 NIIPS,[1] which lay in the Aegean Sea, are characterized by significant RES potential, mainly wind and solar, while there are very significant amounts of geothermal energy and to a lesser extent of biomass and hydro. In some cases, depending on the size of the island, the population, the type of load, this potential could be sufficient to fully cover the demand in terms of yearly energy balance, even though the necessary market conditions, funding schemes, technology infrastructure and legislative framework might not be in place at the moment. During the last ten years, significant efforts have been made to further enhance RES integration in the islands, although the legislative and investment framework has been under continuous reform mainly due to factors related to the general

1. There are 32 non-interconnected island power systems: these include more than 32 islands, since some of the smaller ones are interconnected to larger ones, creating complexes of islands e.g. Kos-Kalimnos.

financial environment in Europe and Greece specifically. Still, the regulatory framework provides obstacles for a high penetration of RES making relevant project proposals economically unattractive. Electricity prices have been rising - mainly through taxes and levies - and the feed-in-tariff mechanism has gone through major revisions during the last 4 years.

Apart from the legislative and investment restrictions, there are significant technical and operational considerations, which make any target of 100 % RES supply in the island systems a real challenge. Island systems are nowadays supplied by autonomous power stations owned and operated by PPC, which use mainly light diesel-fueled units leading to high costs of generation and operation, apart from the environmental and social cost inherent to the use of fossil fuels. The unit commitment is performed by HEDNO S.A., which is also responsible to provide the 7 year expansion plan of the thermal units and for the technical approval of the RES projects.

Some basic features of NIIPS are:

- High operational costs due to employment of diesel oil fuel units.

- High RES potential, mainly solar and wind.

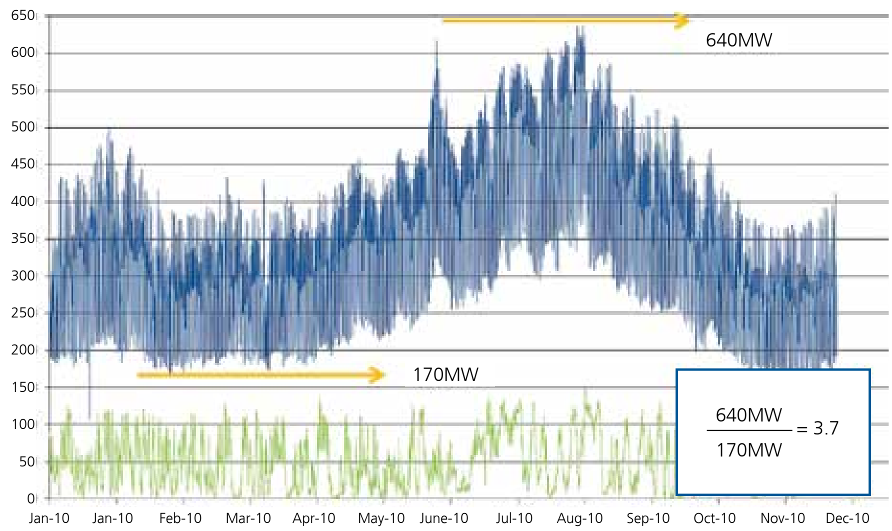
- Environmental pollution (emissions, noise etc.) from the local autonomous power stations, which are mainly installed close or within cities.

- Challenging reliability of supply, since any damage in the central thermal station or even minor faults in the distribution grid might lead to disconnections, especially during the summer season. Due to the size of the units and costs, the classical N-1 criterion of secure operation is often challenged.

- Low values of Load Factor:[2] This is due to seasonal variations of the electricity demand, which is related to the summer touristic profile of the load in most NIIPS. The low Load Factor sets several problems in the efficient planning of thermal expansion and often requires increased energy reserves, which in turn lead to high investment costs. During winter months, conventional thermal power plants are required to operate in low levels of power output, resulting to low efficiencies.

Among the most challenging features of island systems, which need to be addressed during operation, are:

Table 1: Transformation of the Load Factor throughout the year 2010



2. Load Factor: the ratio of current demand versus installed capacity of generator units in a power system.

- Technical Constraints of the Thermal Units

- Dynamic Penetration Limits

- Instant Penetration

Non-interconnected island operation is significantly complicated by the lack of interconnections that provide the necessary support in power, in case of power imbalances, in large interconnected systems. Moreover, interconnected systems comprise a large amount of rotating masses in the operating units, which maintain frequency close to nominal, in the critical first instants after a fault or other disturbance. On islands, the maintenance of frequency stability is a major concern and imposes operating conditions that need to be carefully respected in determining efficient power reserves. The integration of high amounts of RES technologies means that higher reserves need to be maintained in order to ensure available power generation during large and sudden production variations, i.e. when wind power is reduced rapidly due to wind speed fluctuations, adequate power generation should be available in the form of spinning reserve in order to take over the load having been supplied previously by wind power plants. In many cases, wind and/or solar plants are concentrated geographically in certain areas of the NIIPS, which increases the probability of sudden loss of production capacity. The inability of RES units to provide inertia, in the form of rotating masses, complicates further the system response in case of disturbances and affects the necessary spinning reserves.

RES plants installed in NIIPS are subject to operational constraints, due to technical restrictions of the conventional generator units connected to the same grid. These units, using mainly light diesel or heavy fuel oil, should not operate below a specific threshold of power output in order to avoid wear and increased maintenance. This limitation, known as 'technical minimum', is relatively high, often very conservatively kept at 40-50 % of the nominal capacity of the conventional unit.

A different limitation, often referred to as 'dynamic penetration limit', is dependent of the explicit characteristics of the NIIPS (size, type of conventional units, load type etc.) and expresses the dynamic stability of the system, i.e. the effect of faults or unplanned units disconnection on the operation of the system in terms of voltage and frequency. Technical management of the power system in terms of voltage and frequency control is clearly more demanding, since the inertia of the system (sum of the rotating inertias of the generators) as well as other relevant control functions is limited due to the lack of any interconnected power system support.

These constraints are incorporated in the everyday planning of the system operation in Greek NIIPS. The methodology applied is based on RES and load forecasting data which are utilized to optimize the next day operational plans based on availability of conventional units and other factors related to the operation of the system, known to the operator of each NIIPS, e.g. maintenance schedule, ramp up time etc.

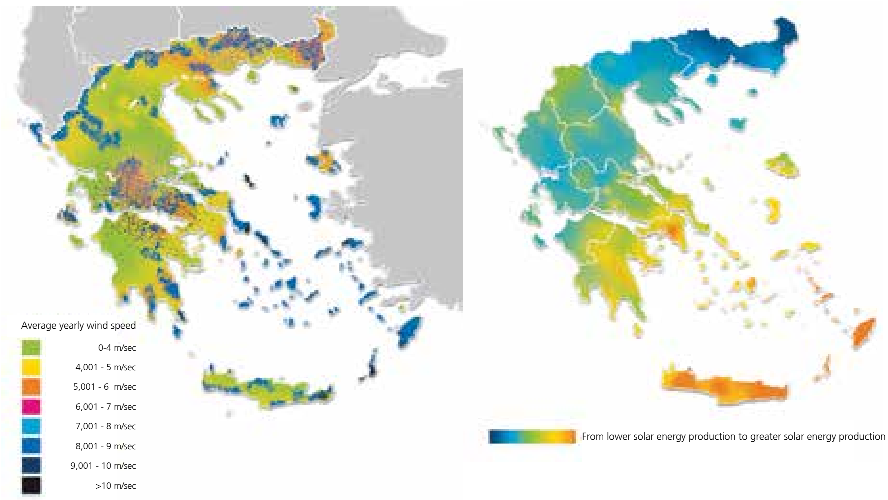
HEDNO S.A. as the power system and market operator of NIIPS has drafted a long-term business plan (2015-2020) and key strategic projects to be implemented in the islands focusing on the above mentioned technical challenges in order to make sure new aspects of power system operation and planning, e.g. demand side flexibility, storage capacities, energy management of systems with high RES participation, could be available within the following years. HEDNO's national investment strategy for the years 2015-2020 - 1.25 bn € - includes complex infrastructure projects both for the mainland distribution grid and the NIIPS, which will apply innovative tools, methodologies and operation patterns for the NIIPS. These investments will provide the necessary technology infrastructure, in order to support further integration of RES in Greek NIIPS.

The derogation from the provisions of Chapters III and VIII of EU Directive 2009/72/EC for the NIIPS regarding the opening up of the market (production and supply) defines the necessary infrastructure to be developed in NIIPS in the coming years. Regulatory Market issues are defined by the Operation Code for Non-Interconnected Islands (NII Code) issued by RAE. The retail market in Crete, the largest NIIPS in the Greek Aegean island complex, is opened in June 2016.

B2. RES potential in NIIPS and current RES Capacity

The islands and the coastal regions in Greece have the best wind and solar energy resources. Geothermal and hydro potential is also available in some NIIPS, although exploitation of these resources has not followed the rapid growth of the wind and solar sectors.

Figure 1: Overview of Aegean islands geothermal resources



Source: www.enermed.cres.gr/RES_Technologies_EL_EN

Geothermal Energy

Geothermal generation can provide base-load electricity in low cost. The Aegean Islands enjoy high and low-temperature geothermal resources with significant high-enthalpy reservoirs being present in the Aegean volcanic arc. The islands of Milos, Lesbos and Nisiros seem to offer the best potential for future geothermal energy development.

Table 2: Overview of Aegean islands geothermal resources

			Reservoir	**Total flow**		**T_{max}**	**Equilibrium Temp***		**TDS**
Island	**Geothermal Field**	**Map Symbol**	Depth (m)	*tones/ hour*	*litres/ min*	*Recorded*	*T K-Na*	*T K-Mg*	*(g/kg)*
Milos	East Milos	M1	1000-1400	340	5668	323	322	334	80
Thera	Santorini		50-350	-	-	65	174	110	54
Nisyros	Kaldera	N2	100-1900	75	1250	350	256	225	80
Lesvos	Argenos	A2	150	300	5001	90	217	127	12
	Stipsi	Th	150-220	200	3334	95	-	-	5
	Polichnitos		50-200	400	6668	92	-	-	12
	Thermie		50	200	3334	60	175	110	36
Chios	Nenita well		300-500	60	1000	82	210	152	75
	Ag. Markella		-	-	-	35	217	139	38
	Spring		-	-	-	54	244	149	7
	Agiasmata Spring		40-120	100	1667	100	-	-	40
Samothraki	Therma wells		-	-	-	55	257	171	13
	Therma spring 1		-	-	-	49	243	169	20
	Therma spring 2								

*The equilibrium temperatures were calculated using the ternary K-Na-Mg geothermometer of Giggenbach (1988)

The Geothermal Development Plan of the Center of Renewable Energy Sources of Greece (CRES)

In 2010, geothermal experts of the Center of Renewable Energy Sources of Greece (CRES) published a 20-year national geothermal development plan, heavily incorporating the geothermal potential of the Aegean Islands (Karytsas and Mendrinos, 2010). A national goal was thus set to establish 400 MWe of geothermal energy across Greece until 2020, 270 MWe of which on Aegean Islands. Local reactions however is a big hurdle for geothermal exploitation in islands.

Table 3: The CRES geothermal development plan for the Aegean islands

Island	Inferred Peak T(°C)	2013	2017	2020-25
Milos	>300	15	15	150
Santorini	170-300	-	5	10
Nisyros	>300	10	10	40
Samothraki	240-260	-	5	20
Chios	210-240	-	20	20
Lesvos	170-200	-	5	20
Kos	160-190	-	5	10
Total		**25**	**65**	**270**

Other energy sources can also be used to tackle the energy problem of the islands: the use of liquefied natural gas, hydrogen, fuel cells (with local production of hydrogen for the cells) and co-generation (tri-generation with district cooling). Seawater desalination process can also be used for energy storage.

Table 4: Electricity Generation Data in NIIPS - July 2015

NIIPS	Installed Thermal Capacity 2014 (MW)	Peak Load 2014 (MW)	Thermal Energy Production (MW)	RES Energy Production (MWh)	RES Penetration in Electricity Production
Crete	819,25	601,70	232.411,98	70.729,96	23,3%
Rhodes	232,61	198,50	87.278,07	14.837,87	14,5%
Lesvos	92,50	63,69	22.939,61	4.846,97	17,4%
Kos-Kalimnos	120,05	95,30	42.052,55	5.354,50	11,3%
Limnos	21,58	14,00	5.335,02	767,60	12,6%
Milos	20,60	12,00	4.222,15	1.097,12	20,6%
Paros	73,72	70,00	22.504,63	4.696,30	17,3%
Chios	69,93	43,30	15.532,74	2.753,62	15,1%
Siros	39,70	20,60	8.268,51	725,21	8,1%
Samos	47,75	29,95	10.247,25	3.457,02	25,2%
Karpathos	17,90	11,30	4.235,76	529,57	11,1%
Mikonos	49,84	42,00	16.682,30	518,57	3,0%
Total	**1721,06**		**506.038,68**	**111.286,65**	**18,0%**

Table 5: Installed capacity of RES on selected Greek islands

NIIPS	Installed Capacity (MW)		
	WIND	*SOLAR (PV)***	*Total RES*
Crete	194,36	78,29	272,95*
Rhodes	49,15	18,16	67,31
Kos	15,20	8,78	23,98
Lesvos	13,95	8,84	22,79
Samos	8,38	4,37	12,75
Chios	9,08	5,17	14,25
Siros	2,84	0,99	3,83
Paros	12,96	4,21	17,17
Rest NIIPS*	9,08	7,17	17,99
Total NIIPS	**307,49**	**135,84**	**453,02**

**A small hydropower plan is included 0,3MW*
***PVs on rooftops are not included*

Table 6: Special Program “PV on rooftops” in NIIPSs

Special Program “PV on rooftops” in NIIPSs (power ≤ 10kW)*		
NIIPSs	***Total Power Committing Electric Space (MW)***	***Total Power of Installations in Operation (MW)***
Crete	19,55	16,80
Chios	1,69	1,6
Rhodes	1,41	1,15
Paros-Naxos	0,88	0,85
Siros	0,71	0,70
Kos	0,52	0,50
Rest NIIPSs	1,52	1,41
Total	**26,28**	**23,01**

**Date: March 2014*

Table 7: Geographic distribution of installed RES capacity (%) in NIIPS (July 2014)

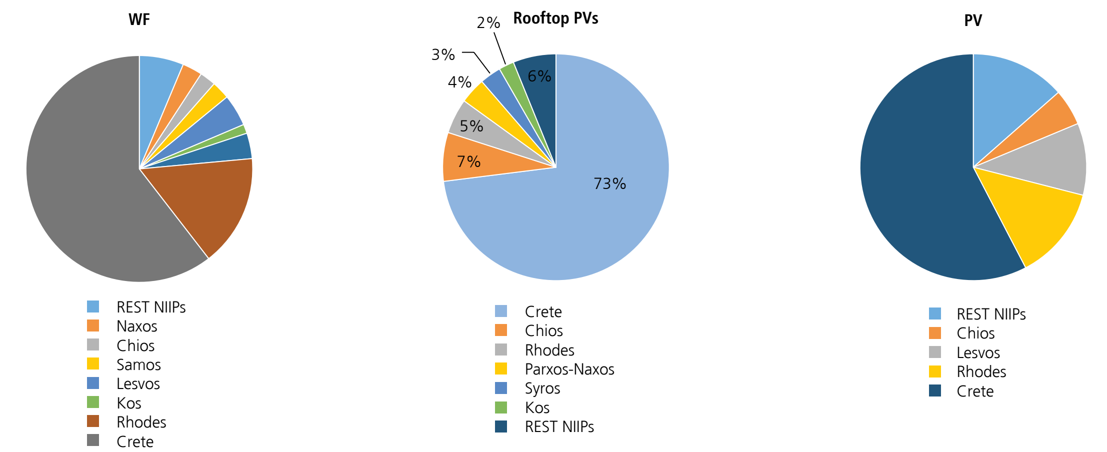
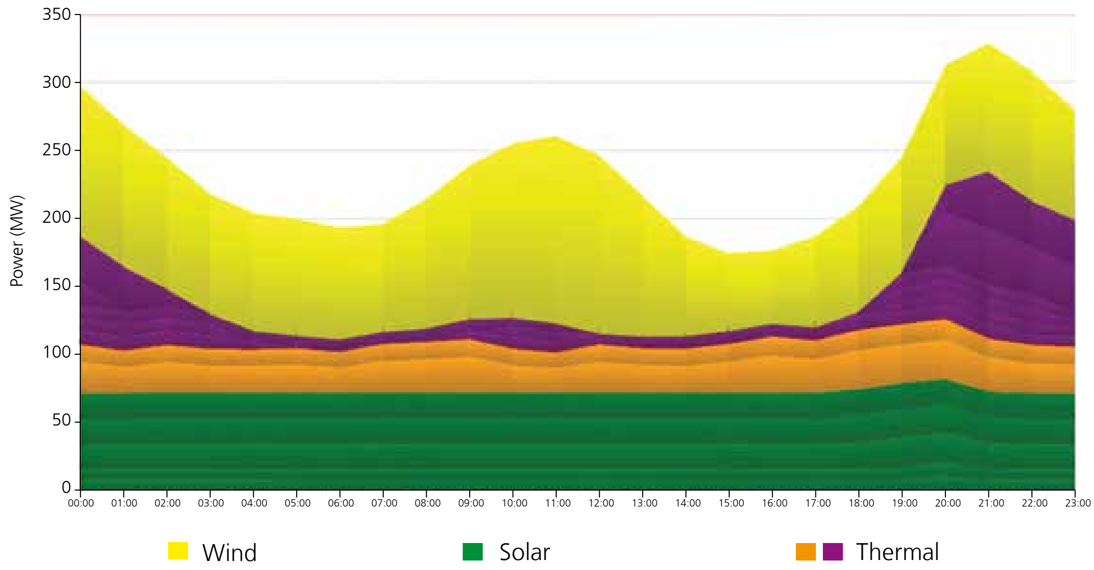


Figure 2: Characteristic energy mix Crete on 24/04/2011



Three examples of adoption of high-levels of RES on Greek islands

1) Kythnos – First mover for solar and wind on islands in Europe

The first wind farm in Europe, with an installed capacity of 100 kW was realized in Kythnos. The project was developed within the Greek-German bilateral cooperation in scientific research and technology by a Consortium of PPC and MAN/Neue Technologie in collaboration with the University of Kassel and SMA. The official starting date of its operation was 15 April 1982 and the ultimate objective was the integration of the wind farm into the operation scheme of the diesel station and not just a simple connection to the grid. Main target was to achieve high wind energy penetration close to 25% and stable power supply system, an extremely ambitious target at that time.

Soon after, the Kythnos Solar Photovoltaic Plant of 100kWp with batteries was realized within the frame of the EC/DG XII Research Program 1980-83 by a Consortium of Siemens AG, the Public Power Corporation and Varta. Within this R&D project the design, development, manufacture of the equipment and installation were carried out. The official operation of the plant started the 1st of July 1983 after the successful erection and commissioning. The PV plant with the storage was designed to operate in parallel with the Diesel power plant and the Windpark.

Kythnos also claims the first Microgrid system in Europe in the small valley of Gaidouromantra. This is a 3-phase low voltage system formed by battery inverters, electrifying 12 houses. The generation system comprises 10 kW of PV, of Photovoltaics divided in smaller PV sub-arrays, a nominal 53kWh battery bank, and a 5kW diesel genset. The aim of the system is to be supplied by 100% from the solar energy produced by the PVs or stored in the batteries, i.e. the diesel genset is intended only as a back-up unit, in case of prolonged clouds or in emergency. The "System House" built in the middle of the settlement is used to house the battery inverters, the battery banks, the diesel genset and its tank and the computer equipment for monitoring and the communication hardware. The grid and the systems were installed in 2001, in the framework of two European projects (PV-MODE, JOR3-CT98-0244 and MORE, JOR3CT98-0215) by CRES, SMA and University of Kassel. Later on, within the 6th Framework Programme (2002–2006) in the More Microgrids project sophisticated, decentralized control approaches have been developed and installed by NTUA. An agent-based Load Controller has been designed and used to monitor the status of the power installation by taking measurements of voltage, current and frequency in order to coordinate the energy management of the Microgrid, in order to increase the energy efficiency by minimization of the diesel generator usage and the shift of load consumption (irrigation pumps) during hours of PV production excess.

2) Ikaria – Hybrid with reverse hydro storage

Ikaria's hybrid station is one of the first of its kind in European islands. Ikaria is located in the eastern part of Greece and has a thermal installed capacity of 12.160 MW. The peak power consumption in 2009 was 7.98 MW. There is one Thermal Station with 10 generators.

The goal is to use the hydro and wind potentials of Ikaria. The project consists of:

- two small hydroelectric power plants with capacities of 1.05 MW and 3.1 MW respectively

- one wind farm with a total capacity of 2.7 MW

- a pumping system with a total capacity of 3 MW

Furthermore a new Control and Dispatch Centre is going to be installed in the island of Ikaria. The total yearly net electricity production capacity is estimated around 9.81 GWh and is sufficient enough to cover a large part of Ikaria island's demand. Despite the delays in the project's implementation, it is expected to provide key lessons for the operation of pumped hydro storage supporting RES in mainland Greece.

3) Smart Island HEDNO S.A. Initiative (2015 - ongoing project):

In 2015 HEDNO S.A. started planning the implementation of an innovative smart island in the Aegean region, with the aim to reach RES penetration of more than 60-70% annualy in a reliable, secure and cost effective way by applying novel methodologies for energy and grid management control. This process included several studies and simulations during the planning period and consultation with the Regulatory Authority of Energy (RAE) of Greece and the Greek Ministry of Environment and Energy in order to identify the main legislative barriers. Results of the planning studies and the consultation process are expected to be publicly announced by the end of 2016. The experience and know-how developed during the Smart Island project will provide HEDNO S.A. and the relevant regulation and policy institutions in Greece the necessary experience with the required methodologies to be applied in the planning, operation and market design for NIIPSs in the future.

B3. Operational Framework and Costs

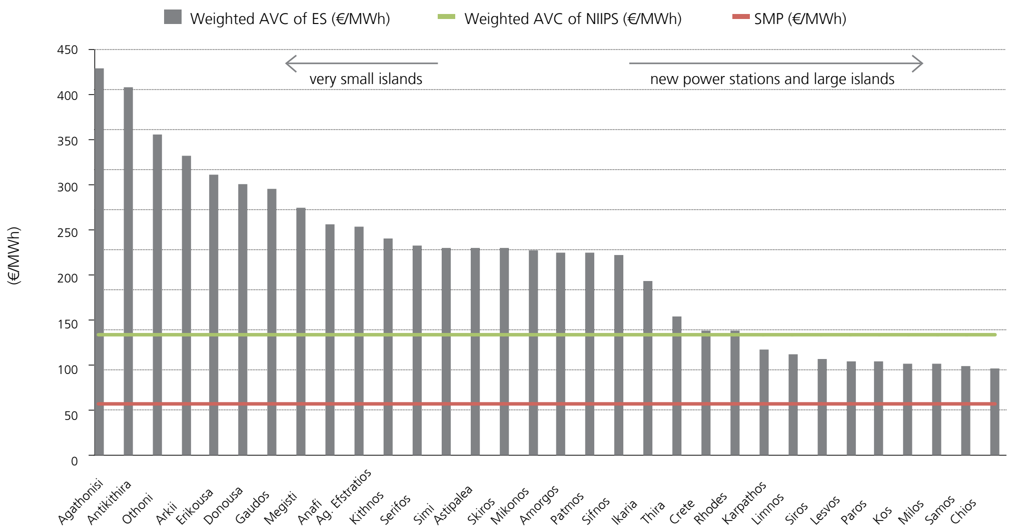
The legislative framework defining technical requirements, policy, planning, operation procedures and connection standards for RES in NIPPS is included in the Non-Interconnected Islands Code (Greek Government Gazette 304/B/11.02.2014). The Day Ahead Scheduling (DAS) defines - on a daily basis - the dispatch algorithm of dispatchable diesel generation units in order to ensure secure operation of NIIPS according to the security and operational standards specified in the Code. The methodology of this scheduling process is based on designing and solving the problem of maximizing RES penetration while minimizing the total operational cost of conventional production units throughout the day ahead. The operator of the NIIPS is obliged to prioritize electricity produced by RES plants, including hybrid stations and high-efficiency cogeneration plants (CHPs), instead of conventional units' production, given that secure operation of the system is ensured. This obligation does not include the technical minimum production of the so-called must-run conventional units, as these have been defined for each NIIPS as well as for units, which are necessary for the provision of ancillary services, when these cannot be provided by RES or high-efficiency cogeneration units (CHPs).

The following diagram illustrates the cost of electricity in NIIPS for 2013 and 2012 and the System Marginal Price, which is the price base that every market actor pays or gets paid. The System Marginal Price, defined upon the combination of price and quantity offers made by available units and the hourly demand level, is the price bid of the last unit committed to operate, in order to meet the total demand.

Table 8: Average Total Costs and Average Variable Costs of electricity production for major NIIPS, 2015 (€/MWh)

NIIPS	Average total costs	Average variable costs
Agathonisi	999,8	428,2
Antikithira	1260,9	408,0
Othoni	719,3	355,2
Arkii	821,6	332,9
Erikousa	758,0	310,9
Donousa	914,1	300,5
Gaudos	670,7	295,1
Megisti	445,2	273,6
Anafi	480,6	256,5
Ag. Efstratios	496,7	253,6
Kithnos	410,8	239,7
Serifos	375,0	231,1
Simi	332,4	229,4
Astipalea	367,5	229,3
Skiros	357,2	228,8
Mikonos	302,8	226,8
Amorgos	398,5	225,4
Patmos	310,3	224,8
Sifnos	342,7	222,6
Ikaria	339,1	192,4
Thira	215,2	153,8
Crete	180,4	137,7
Rhodes	191,0	136,9
Karpathos	244,2	115,9
Limnos	194,4	112,2
Siros	196,8	107,5
Lesvos	152,5	104,4
Paros	153,1	103,3
Kos	152,3	101,5
Milos	204,6	100,4
Samos	179,0	99,7
Chios	161,1	96,7

Table 9: NIIPS cost data for 2015 – Average Cost (AVC) and System Marginal Price (SMP)



The high operational cost of NIIPS is shared by all customers in Greece through the Public Service Obligations (PSO), so that inhabitants of islands enjoy the same electricity tariffs, i.e. the higher supply costs of the island systems are subsidized by the society as a whole. According to a recent report by the Regulatory Authority (RAE), 783.97 m € and 771.2 m € were required during 2013 and 2012, respectively to cover the operating costs of NIIPS. More than half of this budget refers to the operation of the largest island, Crete (388.6 m € and 415.6 m € for the respective years). In some of the NIIPS, e.g. Paros, Naxos, Crete, Rhodes, already installed RES power plants - mainly wind - tend to decrease the cost of operation through reduction in fuel consumption. This high operational cost has traditionally fueled public discussion on interconnections i.e. Cyclades (Siros, Paros, Mikonos) and Crete interconnection to the mainland as well as initiatives such as the HEDNO S.A. Smart Island initiative described in the previous section.

B4. Interconnection of NIIPS

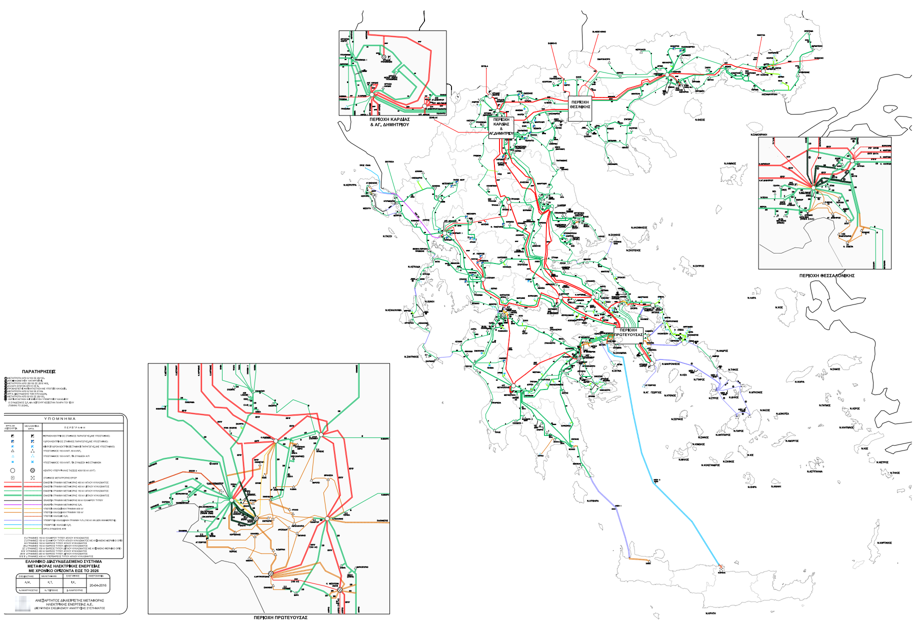
Given the high fuel costs in NIIPS, a revived public debate is currently carried out regarding interconnection plans for some of the islands in the Aegean Sea, i.e. some of the Cyclades islands, and the major project of interconnecting Crete to the mainland. Some of these plans have been discussed for more than 2 decades, although the necessary technical infrastructure, ownership and funding schemes were not in place. It should be noted, that in most of these plans, there is great interest expressed by private investors of large RES power plants in the respective islands, i.e. Crete, North Aegean Sea.

According to the Law 3851/2010, the system operator - at that time DESMIE, together with PPC - carried out feasibility studies for the interconnection of Aegean Sea islands to the mainland through AC and/or DC technology. The main benefits assumed in these studies were:

- Long-term security of supply of NIIPS
- Reduction of the operational production cost and therefore reduction of the Common Benefit Services costs distributed among customers
- Development of the RES potential in NIIPS

These studies resulted in the Preliminary Plan for Aegean Islands Interconnections illustrated in Figure 3.

Figure 3: Preliminary plan for Aegean islands interconnections



Contracts were recently signed between the relevant stakeholders (IPTO, MEECC, private contractors - Sept. 2014) including the interconnections of Tinos-Siros, Siros-Mikonos, Siros-Paros with 150 kV underground and submarine cables. According to the first phase of the project, Siros will be interconnected to Lavrio terminal (South Attica) via 150 kV submarine cable towards the end of 2016. Prysmian and Greek cables will provide the interconnections, while Alstom Grid and ABB will provide substations and the reactive compensating equipment. This interconnection should be completed by 2019 including Naxos in the interconnected infrastructure. The budget for the first phase has been announced to be close to 240 m €, provided by the European Investment Bank (EIB) and the National Strategic Reference Framework (NSRF) funds.

The major interconnection plan of Crete to the mainland via Athens has been included in the latest version of the Ten Year Network Development Plan (TYNDP) 2014-2023 of IPTO, published in March 2014. According to this, the project could be complete by 2020 with a budget of approx. 1 bn €. During 2015-2016 the interconnection of Crete to the mainland via Peloponnese has been debated among the relevant stakeholders and is expected to be completed within the following 3-4 years. A second, longer DC interconnection with Attica is planned for the near future. The complexity of such interconnections requires detailed planning and technical studies including long-term planning of energy security and capacity in Crete taking into account expected regulation and policy requirements of the following years. A dedicated consultation is currently in progress among the key energy actors (Ministry of Environment and Energy, Regulatory Authority of Energy (RAE), ADMIE S.A, HEDNO S.A., PPC S.A.)). Interconnection plans for islands in the North Aegean Sea, i.e. Limnos, Lesvos, Chios etc. have also been debated, although no specific roadmap has yet been announced. Some of the scenarios include activation of public private partnerships (PPPs) as funding schemes. In any case, it is highly unlikely that all islands of the Aegean sea, especially the ones further from the mainland and with a small number of inhabitants will be interconnected.

B5. CO_2 Emissions

Diesel generators, which are used for electricity generation on the NIIPS are the most polluting form of energy generation. With CO2 emissions from diesel generators are estimated to be between 780 to 1,100 g / kWh and are on par and for older generators most likely significantly worse than coal. Especially in the light of the Paris COP21 Agreement, it can be assumed that there will be more pressure on the heavy CO2 emitting forms of electricity generation and, hence, PPC has already announced a program for the retirement of the older diesel units.

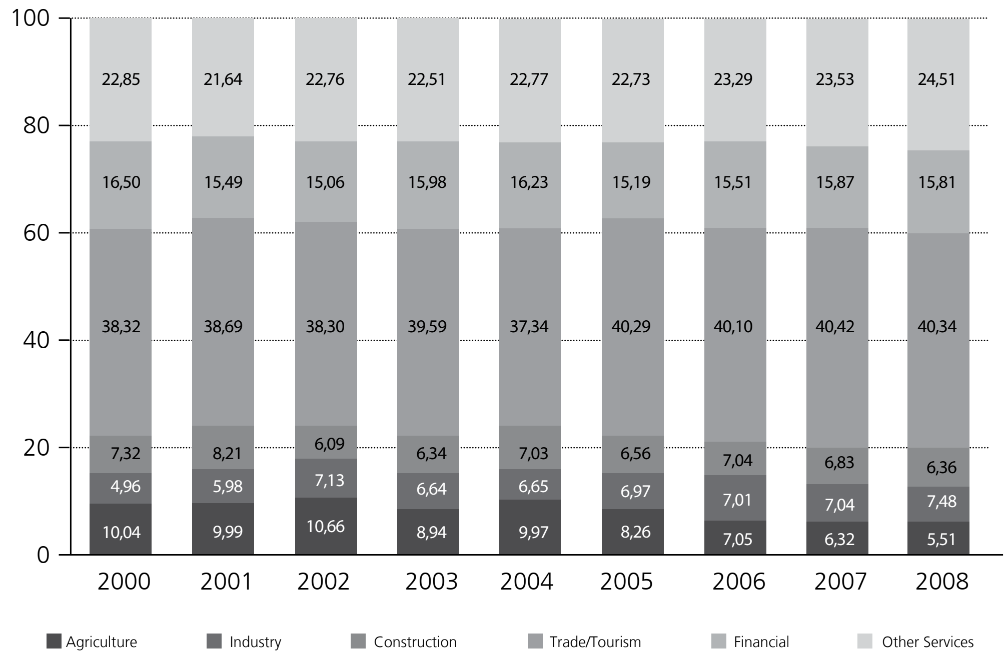
B6. The economic activities in the Greek Islands.

In order to further understand the energy needs in the Greek islands the economic activity should be analyzed. The main economic activities in the Greek islands are:

- Tourism
- Agriculture (olive oil, Viticulture, other) & Livestock (including dairy product)
- Services (transportation, health care, education)

As an example, the economic activity in the island of Crete is illustrated in the following figure:

Table 10: Economic activity in the island of Crete, 2000-2008



Source: ELSTAT 2012

C. Technical Enablers to Increase RES Penetration

C1. Introduction

The different technical enablers distinguish themselves mainly by the different technologies involved, the level of RES penetration, which can be achieved and the cost parameters of each option. Some technical enablers are generic, given that the optimal scenario for each NIIPS in Greece - in terms of technology, security of supply, reliability and cost - highly depends on the unique characteristics of each island (load profile, size, RES availability, local weather conditions, local power generation profile, touristic season parameters etc).

C2. Installation of advanced EMS

The levels of solar and wind can be increased, by smartly controlling the electricity generated by both thermal and renewable energy sources. This is done in a way, which ensures that the diesel generators still run safely and the grid stability of the island system is not jeopardized. In these systems it is accepted that some share of the renewable energy generated will be curtailed and, hence, not used. However, due to the fact that the energy generated by the renewable sources is less costly than the energy generated from the diesel, significant savings of between 20-30% can be achieved, depending on the island and load curve. This approach could lead to immediate savings compared to the current cost of diesel generated electricity.

In practice, the installation of island tailored EMS need to be installed that optimize the island operation by maximizing RES penetration, minimizing costs and ensuring the dynamic stability of the system in case of disturbances caused by the intermittency of the RES or system faults. Efficient load and RES forecasting methods and optimized dispatch of the diesel gens need to be applied.

It may be advisable to also review the operating minima applied by the operators of the diesel generator stations on the islands, which at the moment are relatively high, (40-50% of the rated capacity of the diesel generators). Some Genset manufacturers have studied minimum load requirements of the their Gensets and now accept significantly lower levels of minimum loads without expecting significant negative effects on fuel consumption, operation and maintenance, as well as aging of the generators. These lower minimum load regimes would allow for higher RES penetration.

C3. Energy Storage

Storage is an important technology for intermittent RES, especially in NIIPS. In the Greek energy legislation, this is foreseen in the form of Hybrid stations, which combine a RES with a form of storage (e.g. battery, pumped hydro, flywheel, etc.) and can provide guaranteed, firm capacity. According to the Law 3468/2006, a Hybrid Station is defined as electricity power plant which:

- Utilizes at least one type of RES technology

- The total annual energy absorbed by the system is no more than 30 % of the total energy consumed for the full charging of the storage system of the station

- The nominal capacity of all RES units in the station cannot exceed the 120 % of the installed capacity of the storage facilities of the station

NIIPS are often congested in terms of absorbing energy produced by non-dispatchable RES units, which is leading to limitations regarding increased RES penetration. The Hybrid Stations are considered as important means for connecting new RES power plants in the congested island grids by utilizing the curtailed production. The legislation defining the operation of the Hybrid Stations in the Greek NIIPS is described in the following official articles: Law 3468/2006, Public Consultation Text of RAE (8/2008), Non-Interconnected Island Code - RAE 39/2014.

Storage is certainly the way to go in the future and to achieve very high levels of renewable energy shares, initially up to 50-60% and combined with desalination and other demand side and energy efficiency measures, even up to 80%. However, due to their high cost and limited experience in remote sites, like the Mediterranean islands, they are regarded as a follow-on step after increasing the shares of renewables via hybrid control systems.

C4. Desalination

Desalination has been related to large integration of RES in NIIPS in several pilot projects, which aim towards a high penetration from RES. Availability of mature technologies provides with the capability to create synergies between RES electricity production and water production and management in areas where fresh water scarcity remains a challenge even today.

Desalination infrastructures, which separate dissolved salts in seawater or brackish water, are energy demanding; according to Kalogirou (1996) production of 1000 m^3 fresh water per day requires 10.000 tons of oil per year. Integration of RES in NIIPS could be further developed via hybrid systems with wind, solar and hydro. Desalination could play a perfect balancing role being activated during the hours of high availability of solar irradiation or wind with storage of water being significantly cheaper than installing expensive electricity storage systems. The main goal of combined desalination-RES systems is the coordinated operation of the two sectors in order to ensure secure operation of the local grid especially during peak load periods.

D. Competitiveness, Job Creation and Economic Development

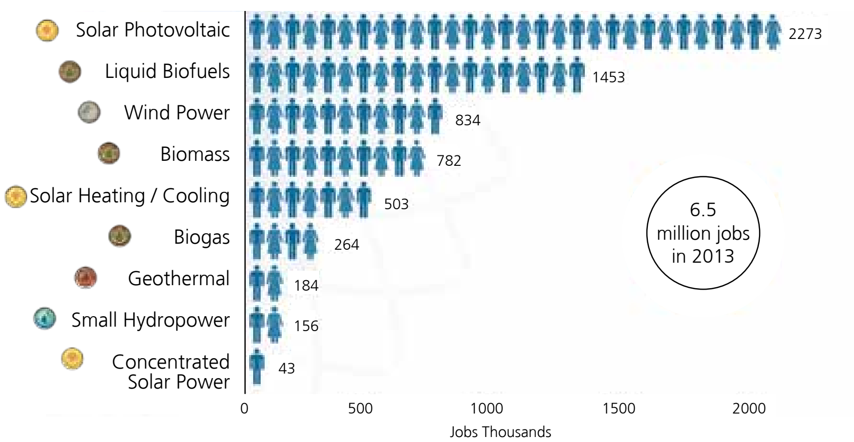
D1. RES and employment

During the last two decades, several declarations, e.g. Canary Islands (1998), Palma de Majorca (1999), Azores (2000), Cagliari (2001) and Chania (Crete-2001), as well as international meetings e.g. the Small Island Developing States on Mauritius (BPoA+10 - 2005), have promoted a global process, emphasizing the key role of RES in the strategy of sustainable development for NIIPS and their relation with long-term economic development and quality of life of island populations.
The financial crisis in Europe and Greece is posing significant challenges in the economic development of rural areas and islands. Sustainable development in NIIPS requires a combination of political will, complex

innovation strategies, industrial policy and technology development in order to coordinate several economic sectors and counter fight consequences from external dynamics, such as the national and European stagnation. NIIPS, as mentioned before in this paper, can provide with the necessary social and geopolitical laboratory to work on energy sustainability and develop large RES integration, not as complementary option as it is today, but rather as the core aspect of a new economic development strategy.

Increasingly energy becomes a decisive factor of the development model and the key production mode of any island activity. Water production and management, waste management, tourism, small-medium enterprises, agricultural production and services among other vital island economic sectors are deeply influenced by the energy cost and the availability of diversified energy sources. A massive tourist development model, in contrast to location-specific, environmentally sustainable small and medium scale touristic model, cannot be strategically beneficial for a sustainable mode of development based on RES. The RES sector has constantly increased its capacity worldwide, expanding the number of job positions, both direct and indirect, created within its several sectors - manufacturing, installation, related services, planning, R&D, operation, maintenance, environmental studies etc. During the slow recovery period in the global and European economy, labor markets have been under significant pressure with high levels of unemployment especially in Southern Europe. Greece suffers from extremely high unemployment, especially among the highly-skilled young population with a technical and/or scientific education. The potential of the RES sector to boost employment, although recognized, needs to be further analyzed in the specific context of each country and region. The International Renewable Energy Agency (IRENA) has conducted several relevant studies, which should be taken into account. According to the annual 2014 review, manufacturing and installation of RES infrastructure are the main sources of job creation in the sector. Declining prices of basic equipment (solar, wind) shift employment towards installation, operation and maintenance, which is more relevant to cases of countries and regions such as the Greek NIIPSs. Global RES employment data and fields of expertize within each main RES sector are given by IRENA as follows:

Figure 4: Global RES employment and fields of expertise



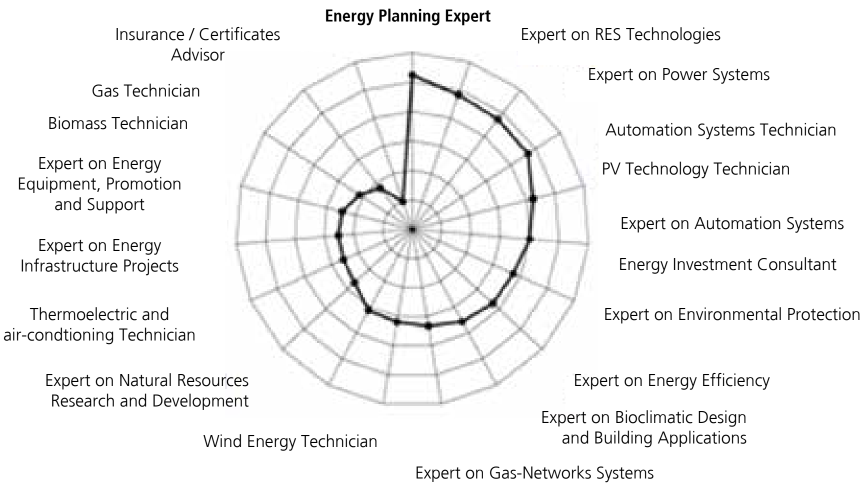
Sector	Job Positions
Wind Energy	Project developers, Technicians, Data analysts, Electrical-Computer-Mechanical-Construction Engineers
Solar Energy	Installation of PV solar thermal infrastrcture, Maintenance, Building Technicians
Hydropower	Electrical, Perations and Maintenance Engineers, Technicians, Trades
Geothermal Bioenergy	Trainers, Geothermal Engineers, R&D, Technicians, Trainers

Source: www.irena.org/Publications/rejobs-annual-review-2014.pdf

In order to plan large RES integration in NIIPSs in relation to employment creation, the value chain of the RES sector needs to be analyzed based on other production infrastructure available in different types of NIIPSs so that increased synergies among the local economy sectors can be supported. Skill shortage is still an issue for the RES sector worldwide, which means that human and technical capacity building should be addressed from the beginning of any future strategy regarding NIIPSs.

According to a recent policy statement of the Hellenic Federation of Industries in May 2014, these are some fields of professional expertise related to the development of the RES sector, which will be needed in Greece in the near future, listed by priority:

Figure 5: Fields of professional expertise in the greek RES sector



D2. Industry Policy Recommendations for Greece focusing on NIIPS

Islands provide the necessary territorial, social and resource foundations for a new model of development. In order for Greece to ensure prosperity in the future, economic activities e.g. industry, agriculture and related services need to strengthen. The ratio imports/exports has been extremely high, even before the financial crisis burst out in 2008. Seen from this perspective, deficits and debt should only be conceived as consequences of much wider structural flaws in the Greek economic and productive process, and therefore, a long-term development model cannot be based on such imbalances in the import-export balance. Given the intrinsic features of the Greek economy, the following criteria can provide the necessary prioritization over different sectors in the production matrix to be supported through public policy instruments and which should be related to the development of the RES sector in NIIPSs:

- Sectors with price inelastic products. Products with high price elasticity impose direct competition towards labor cost instead of competition in the fields of quality, innovation etc.

- Sectors with short time intervals between conception-prototype-production phases of development. The energy sector in Greek NIIPSs appears to support small-medium enterprises, opening up the space for niche markets, which are suitable for a new mode of development in Greece.

■ Sectors of medium technology level and high added value

■ Sectors with high potential of R&D activities

■ Sectors with high intermediate consumption

■ Transversal activities which are not organized in sectors, e.g. design, development and production of management systems, electronic control systems which can be utilized in many different sectors etc. can increase synergies among various economic sectors, i.e. tourism, agriculture, water treatment, energy management etc. These activities use mostly technology driven management methods.

Public policy in the RES sector in NIIPSs should emphasize the territorial aspect instead of location advantages. The strategy should target at creating the necessary financial-policy-knowledge ecosystems in NIIPSs, which can support the long-term prosperity of small-medium enterprises and ensure their viability through continuous support of innovation and flow of technical and institutional knowledge. These ecosystems may include research centers, universities, local administrational branches, specialized labor power and other social actors who can cooperate efficiently, analyze the specific conditions of each NIIPS and apply institutional, market and technical solutions in order to support a strategic large integration of RES in the local grids. Joint venture cooperation schemes should be prioritized in order to involve public-private-social entities in the process of planning, decision-making, ownership, investment and operation of the local power system. Moving away from traditional forms of incentives, subsidies and funding towards individual business actors, a new and efficient strategy of promoting this shift in energy technology paradigm should invest on cooperation networks, which ensure optimized utilization of existing infrastructure and human capacities.

Synergies among electricity production and management and other local activities, e.g. recycling, water treatment and management, eco-touristic activities, logistic activities, agricultural production units should be planned, supported and developed through coordination of the various actors active in NIIPSs. Public policy should aim its support instruments towards activating such networks, facilitating this process and ensuring the necessary regulation and legal transparency in order to maximize cooperation activities. NIIPS offer a privileged space to apply a circular economy model, which contributes to economic and environmental sustainability.

Circular Economy Model: The term refers to production and consumption of goods and services, including a transition from fossil fuels to RES, and diversity as a roadmap of resilient and productive systems; a model for industrial economy which is restorative and in which material flows are of two types, biological nutrients, designed to reenter the biosphere safely, and technical nutrients, which are designed to circulate at high quality without entering the biosphere. [Walter Stahel, "How to Measure it", The Performance Economy second edition - Palgrave MacMillan, page 84] [http://en.wikipedia.org/wiki/Circular_economy#cite_note-1]

According to OECD studies, the positive effects of RES deployment in rural areas can be defined as follows:

■ New sources of state revenues through expansion of the tax base.

■ New job and business opportunities can be developed, direct and indirect, depending on the type of RES deployed.

■ Operation and maintenance can be fields of priority for local employment. This could require adaptation of existing knowledge and technical capacity to specific needs attributed to RES technologies.

■ Human capacity building locally should be performed in parallel to the installation of RES on the islands.

■ Inclusive governance; In contrast to top-down approach the "islanders" should be involved in the process of decision making and deployment to ensure local support.

■ Security of supply and protection against price volatilities; developing local RES potential replaces significant conventional fuel imports, which might be a burden to economic development, not only locally but on the national level as well. Electricity and heat can be produced with new RES facilities reducing the necessity for continuous expansion of the traditional, diesel-based electricity production system.

D3. RES and Tourism

The local economies of most islands in Greece are based on tourism and services sector during the last decades. Tourism produces the load pattern described in Section B, increasing the risks for energy shortages and load shedding during peak summer periods. Increased levels of reserves require on average additional cost for the operator. According to the International Scientific Council for Island Development (INSULA) there is a list of factors which creates serious burden in the large integration of RES in touristic infrastructures and regions; skill shortage, lack of cooperation frameworks of related professionals, e.g. architects, engineers, consultants, hotel managers, inhabitants etc., policy gaps and flaws, funding and credit mechanisms.

Since tourism represents an important economic driver for island economies, dependency on oil products makes the tourism sector vulnerable to oil price volatility and environmental risks. The basic energy needs in island touristic facilities include transportation, lighting, air conditioning, cooking and water heating. According to IRENA, there are four key technologies, which contribute significantly to a sustainable energy supply model for islands via the touristic sector:

- Solar water heating (SWH) systems: solar heat to warm up domestic water, replacing electric water heaters

- Solar air conditioning (SAC) systems: solar heat to provide cooling and heating

- Sea water air conditioning (SWAC) systems: cold water from the ocean depths to provide air conditioning in hotel rooms and facilities

- Solar photovoltaic (PV) systems: producing electricity to the grid or installed in remote-autonomous buildings.

According to the same study, these four technologies have proven to be cost-effective with reasonably attractive payback periods. Attraction of eco-friendly travelers is also considered a significant side-effect of large RES integration in local island systems, given the benefits in environmental conditions by replacing old, fossil-fuel based facilities.

In Crete, which is the major island of the Aegean Archipelagos, significant steps have been made towards a diversified expansion of RES applications. Further development strategies could set high priority on small scale wind, solar or solar hot water systems accustomed to small type touristic accommodations in villages or for domestic needs. Energy-saving mechanisms via demand side management and direct measures like replacement of street-lighting infrastructure, passive and hybrid technologies for cooling in hotels, bungalows, residences etc. can be incorporated in this strategy with multiple benefits. The potential of Demand Response programs in the island of Crete is very high, since the difference in variable cost between cheap and expensive units is big (more than 100€/MWh) and the curtailed RES energy on yearly basis is around 14%. Studies performed by NTUA within the EU funded Project "Smart House/Smart Grid" conclude that controlling the Air Conditioning units in only 20% of the households in the island (~66,000 households) results 1.4% fuel cost reduction (yearly profit 47.2€ per household)

The fact of renewable resources being used for energy generation could also play a major role in advertising Greece as a tourism destination. This could include its positive effects on environmental protection and conservation at large. And in the island context more specifically the reduction of air pollution, reduction of coastal and beach pollution by the shipping of diesel fuel and, last but not least, cleaner water.

D4. RES and Desalination

Integration of RES in NIIPSs could be further developed by combining them with desalination infrastructures, which separate dissolved salts in seawater or brackish water. These include thermally driven distillation processes based on solar energy flat plate collectors and hybrid systems with wind, solar and hydro. The main goal of combined desalination-RES systems is the coordinated operation of the two sectors in order to ensure secure operation of the local grid especially during peak load periods and a viable, sustainable model of waste management. Both of these two key resources, energy and water, account for a large capital expense in the touristic and agricultural sectors' balances, therefore any efficiency improvement has multiple benefits in the overall development of the local economies.

D5. RES and Research & Development (R&D)

Since a long time, islands have been considered as ideal pilot test beds for the development of Research and Development activities related to RES. This is due to the high costs of electricity production and the familiarity of the inhabitants with the use of RES for marine, irrigation and other applications. Kythnos is a characteristic example of the application of RES technologies from their early development. During the last decades, Greek Universities and Research Centers have been actively involved in European research involving island energy systems.

As a result, Greek Universities and Research centers have developed remarkable know-how and competence in the area of islands with high RES penetration, including:

- advanced EMS systems for optimal operation of high RES NIIPS with advanced forecasting and optimization functions and on-line dynamic security capabilities and

- dynamic simulations of island systems with conventional thermal generation stations and RES power electronic interfaces with advanced ancillary service functions (e.g. droop control and synthetic inertia), etc.

These can play a leading role in Europe in RES-island R&D. Good examples are the experiments of islanded operation carried out at the laboratory microgrid of NTUA, which comprises several controllable power electronic interfaced DER with droop control capabilities. Moreover, hardware DER are incorporated in virtual islanded systems with the use of real-time hardware-in-the-loop simulation which allows very realistic analysis and testing. It is the right time now to move from pre-industrialized Research to pilot installations and in the most advanced of them to commercial products HEDNO S.A. since 2015 has taken the initiative to promote cooperation with Universities and Research Centers in order to promote technology know-how development and innovation in several fields, including planning, operation and management of NIIPSs. Cooperation between the main institutional stakeholder of the islands in the electricity sector, HEDNO S.A. and the Greek and international research community is expected to produce soon significant technical and scientific knowledge, which can be applied in the Greek islands and abroad.

E. Policy Recommendations and Technology Requirements

Based on international development experiences and general planning guidelines for local-rural development, there are some key parameters which need to be addressed within any long-term strategy design for RES integration:

- Subsidy mechanisms for RES projects should avoid repeating flaws of the past decade, i.e. RES integration being explicitly based on very high subsidies leading to negative impacts on land use and other local activities. These contradictions have contributed to a generally negative public conception of RES projects in several Greek rural communities. Hybrid systems of subsidy could be applied to those RES projects, which are viable in market terms and have multiple effects on the local development strategy. Distinction between pilot-innovative projects, which aim at improving current available technologies, control systems and efficiency, and market projects, which aim at immediate revenue for the project developer, could support a differentiated support mechanism.

- The type of RES infrastructure and technology, which could be applied in each NIIPS, should be chosen based on a set of criteria, including local social-landscape-economic conditions. Apart from the resource availability, which is a key design factor of any new RES project, synergies of the specific RES production system with the rest economic activities on the island should be taken into account, e.g. desalination needs, transportation, waste-water management etc.

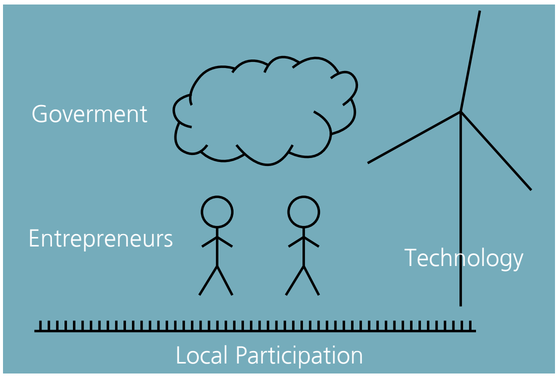
- Using microgrids as the cell structure of the NIIPS grid and targeting towards aggregation of several smaller microgrids has proven to be an efficient way to increase RES penetration, especially on small NIIPSs. Investments on transmission systems are currently under pressure worldwide and microgrids can provide an alternative way of integrating RES in the current grids.

- Apply inclusive governance practices involving local social and institutional actors; several delays in the RES installation process in Greek NIIPS have been linked by relevant studies to broad feelings of social discontent against investments for projects related to RES.

As mentioned in the technology chapter, increased penetration of RES in island systems would require adoption of innovative RES facilities:

- Advanced EMS
- Energy storage
- Desalination

The four success factors of Samso RES island project, according to Jan Jantzen, Samso Energy Agancy:



T for Technology
G for Goverment
E for Entrepreneurs
L for Local Participation

Concluding we can distinguish among three sets of recommendations, based on the already existing experience from the Greek NIIPS' operation as well as successful examples from abroad; technical, policy and business, social. These recommendations lead us to a set of priority actions for any social-institutional actor who aims at setting the next steps ahead for a change in the technology paradigm of NIIPS in Greece.

E1. Technical Recommendations

- Energy Planning aiming to maximize RES penetration in islands including Demand Side Management and Storage facilities. Planning should include operational considerations in order to maximize RES and reduce costs. Application of advanced technologies including longer term RES forecasting modules and Use of Geographical Information Systems for RES siting and sizing in local planning.

- Operation based on advanced EMS system optimized for the NIIPS. The EMS is aiming to increase RES penetration and reduce costs, maintaining the security of the system. The EMS will manage the island system taking into account the RES, biomass and controllable loads (waste treatment, desalination units, greenhouses, residences etc) This involves the application of short-term Weather/RES forecasting methods and the exploitation of the control capabilities of RES currently available and possibly enhanced for island conditions.

- Reducing the 'technical minima' of the diesel generators, taking into account their age, to levels of 20-25% which could allow increased RES participation, without affecting significantly the performance of the generators. A study could be performed to prove to the island operators about the limited effect on the generators.

- Investments in Smartgrids technologies including the installation of Smartmeters, in order to allow full exploitation of the RES control capabilities and Demand Side or storage flexibility avoiding unnecessary investments in new generation and local distribution/ transmission systems.

- Investment in R&D activities on RES and smart grid technologies including pilot projects aiming at a very high penetration of RES in islands and aiming at a future total decarbonization of energy production in mainland.

E2. Policy and Business Recommendations

- Provision of initial support to feasibility studies and demonstration projects, with a very clear short-term path to cost savings and not requiring additional subsidies.

- Institutional innovation in RES business - credit schemes, capital cost reduction policies via lower cost loans, tax incentives, limited initial grants.

- Circular economy strategy promoting synergies of local production facilities with the RES sector development. Provide increased possibilities for decentralized, local decision making by enhanced local authorities.

- Remove any regulatory barriers that make hybrid projects aiming to a very high penetration of RES (close to 100%) financially unattractive.

E3. Social Policy Recommendations

- Involvement of local population in the decision making - vital role of local authorities and other citizens' initiatives.

- Training, education and job creation for the local communites.

- Best-practice demonstration projects combined with a strategy to raise public awareness and technical expertise.

Appendix

AP1. R&D projects for NIIPS

Integration of RES in island systems for a high penetration of renewables in their operation

1996-1998, Potential for the Development of Renewable Energy in the Power System of Cyprus, General Secretariat of R&T in Greece and Cyprus

2003-2006, Renewable Energy Sources Promotion and Integration for the sustainable development of insular Regions of Europe RESPIRE NNE5-2001-00740

2004-2007, RISE-RENEWABLES FOR ISOLATED SYSTEMS - ENERGY SUPPLY AND WASTE WATER TREATMENT INCO - Integrated Project Contract No FP6 - 5091610

Several studies for the limits of RES integration in the non-interconnected islands financed by PPC, HEDNO, and Operator and Regulatory authorities of Cyprus

Development of Advanced Control Technologies to allow operation of insular system with high penetration of Renewables

1997-1999, CARE - Advanced Control Advice for Power Systems with Large Scale Integration of Renewable Energy Sources

1998-2000, Dissemination of the Advanced Control Technologies for Isolated Power Systems with Increased RES Penetration, EC - THERMIE Contract DIS/01625/1998-GR

2000-2003, MORE CARE MORE ADVANCED CONTROL ADVICE FOR SECURE OPERATION OF ISOLATED POWER SYSTEMS WITH INCREASED RENEWABLE ENERGY PENETRATION AND STORAGE Contract ERK5-CT1999-00019

Development and Application of Advanced Wind Power Forecasting Technologies

2002-2006 ANEMOS "Development of a Next Generation Wind Resource Forecasting System for the Large-Scale Integration of Onshore and Offshore Wind Farms

2008-2011 ANEMOS Plus - Advanced Tools for the Management of Electricity Grids with Large-Scale Wind Generation, Contract No.: ENK5-CT-2002-00665

2008-2012 SafeWind—Multi-scale data assimilation, advanced wind modelling and forecasting with emphasis to extreme weather situations for a secure large-scale wind power integration

Microgrids: Research on NIIPS has naturally contributed in developing competitive know-how and European leadership of Greek research in Microgrids

2003-2005 MICROGRIDS Large Scale Integration of Micro-Generation to Low Voltage Grids ENK 5-CT-2002-006100

2006-2009 MORE MICROGRIDS – Advanced Architectures and Control Concepts for More Microgrids Contract No: SES6 -019864

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