CLEAN ENERGY TRANSITION AGENDA

SIFNOS ISLAND

Version October 2019

CLEAN ENERGY FOR EU ISLANDS

Secretariat • Rue d'Arlon 63, BE-1000 Brussels
Phone: +32 2 400 10 67 • E-mail: info@euislands.eu • Website: euislands.eu

Preface

The Island Clean Energy Transition Agenda is a strategic roadmap for the transition process towards clean energy. It is designed by the local community, for the local community. Starting from an examination of the current dynamics on the island, the Clean Energy Transition Agenda spells out a vision of the island that is shared by the members of the island community. The perspectives of different island stakeholders are aligned to work towards this common vision by identifying possible pathways, including common goals and effective strategies.

This Island Clean Energy Transition Agenda for Sifnos was developed jointly by the Sifnos Island Cooperative and the Municipality of Sifnos, with the support from the schools of Sifnos, the Port Authority of Sifnos and the Agriculture Cooperative of Sifnos. It was co-authored by the Clean Energy for EU Islands Secretariat who facilitated the writing of the document and provided some technical advice.

This document is the first version of the Clean Energy Transition Agenda for Sifnos which describes the current context in the island. It illustrates the strategies developed by the transition team to accelerate the energy transition. In case of new decisions agreed within the transition team, some modifications could be done at a later stage.

The Clean Energy for EU Islands Secretariat is an initiative on behalf of the European Commission aimed at catalysing the clean energy transition on EU Islands. The Secretariat is managed by Climate Alliance, REScoop.eu and 3E, and collaborates with a wide range of local stakeholders, authorities, academia and citizens. The work done by the Secretariat is done in close collaboration with local, regional, national and international partners, with particular support from the Technical Educational Institute of Crete and the University of the Balearic Islands.

Table of contents

Part I: Island Dynamics

1. Geography, Economy & Population

Geographic Situation

Sifnos Island is part of the Cyclades island group, in the region of South Aegean Sea in Greece. Sifnos is located around 130 km from Athens mainland which represent a journey of around 3 to 5 hours.

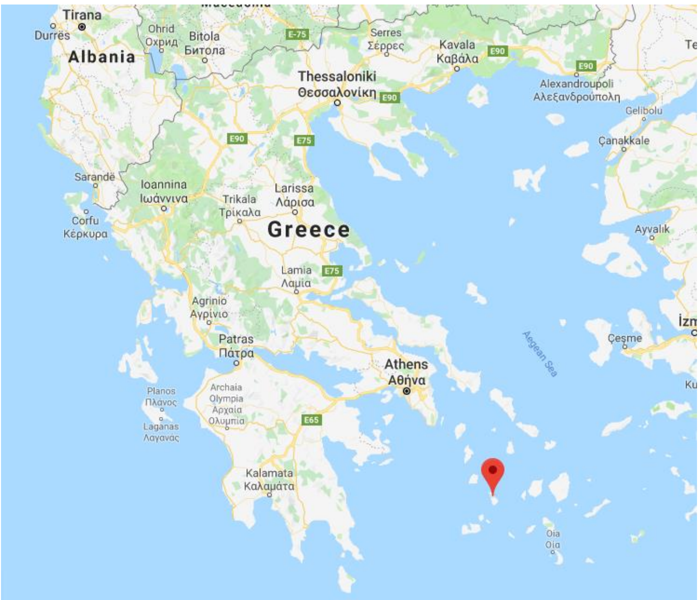


Figure 1 Localisation of Sifnos at the country level Taken from Google Maps

Sifnos has an area of 74 km², it is about 15 km long and 7.5 km wide, and it has a shoreline of 70 km. More than 25% of Sifnos territory belongs to the Natura 2000 European Network of Nature Protection Areas. In addition, the traditional Cycladic architecture and the environmental and cultural wealth of the island have led to Sifnos being a Landscape of Outstanding Natural Beauty since 1976.

Figure 2 Map of Sifnos Taken from Google Maps

Its permanent population is 2,625 of which 438 are students, one of the highest per capita ratio in Greece. During high season, in July and August, the population peaks up to 16,000 with the tourist visitors.

Other challenges besides the lack of clean energy as mentioned by different local stakeholders are: basic medical care (no general practitioner), sewage and waste water treatment, solid waste management, availability of drinking water, high energy consumption of public lighting and low quality of road infrastructure.

Local Government

Sifnos is an island municipality. The Island is Governed by the 17 members of the Municipality Board, headed by the Mayor of Sifnos, elected every five years.

Economic Activities

The main source of income in the island comes from tourist services provided to approximately 90,000 visitors annually, averaged in the last five years. Other sources of income include pottery, agriculture, livestock farming, fishing and beekeeping.

Connection to the mainland

There is no road connection, neither electrical interconnection, between Sifnos and mainland Greece and with the surrounding Cyclades islands.

2. Energy System Description

The scope of the description of the island's energy system includes the demand and generation of electricity, heating, transport on the island, and transport to and from the island. The analysis is carried out by considering the breakdown of the final energy consumption per fuel type and sector.

The energy consumption data for Sifnos is based on data retrieved in 2018 from energy companies and on estimated values in those cases where no data was available. The Hellenic statistics authority, the Hellenic Coast Guard of Sifnos, the Public Power Corporation, the Regulatory Authority for Energy, the Sifnos Island Cooperative and shipping companies participated in providing information.

The total electricity consumption data is provided by the Public Power Cooperation. Then, consumption associated to transport on the island is estimated based on the number of vehicles and an average number of kilometres covered annually. Consumption due to ferry transport is estimated according to the quantity of arrivals and departures provided by the Hellenic Coast Guard of Sifnos, the average consumption of the vessels communicated by two ferry companies, the average distance of trips and an appraisal of the percentage of participation.

Figure 2 gives the annual energy consumption breakdown. The highest energy consumption is due to transport to and from the island, 529,733 MWh per year, which adds up to 88% of the final energy consumption. The largest share of energy is consumed as diesel and fuel oil. Renewable energy, for both heat and electricity, makes up only a small share of the energy sources.

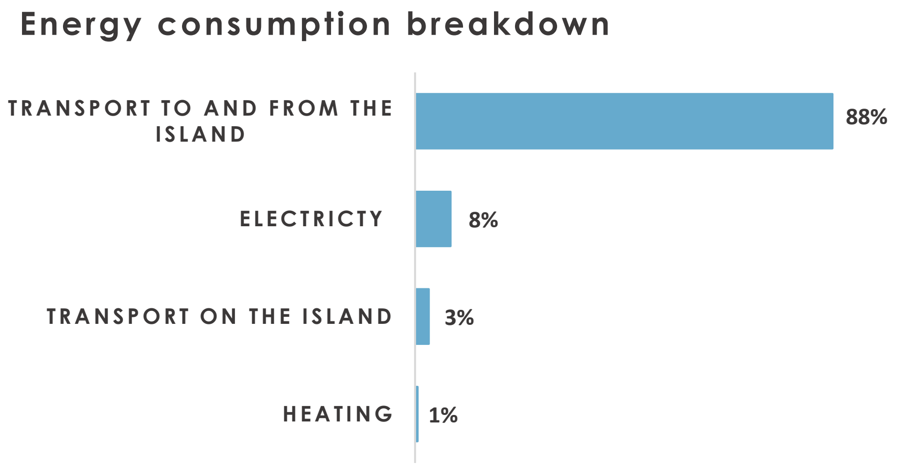


Figure 3 Annual energy consumption breakdown

The sections below give a discussion per energy vector.

Transport to and from the island

The transport to and from Sifnos represents the major share of the island's energy consumption with 88% of the yearly total energy consumption, 529,733 MWh. The island is only connected to the mainland by ferries, there are no plane connections. The frequency of ferries is characterised by seasonality. During high season, around 25 to 30 ferries travel to and from the island per week compared to only 3 connections per week during the rest of the year. In total, 1,966 ferries arrived on Sifnos in 2018.

Three ferry companies connect Sifnos with the main land and neighbouring other islands: Sea Jets, Aegean Speed Lines and Zante Ferries. The ferries are using both diesel and marine diesel oil to power the vessels. According to the ferry companies, the average consumption of the diesel and the marine diesel oil vessels are respectively consuming 154 liters of diesel per nautical mile and 190 liters of marine diesel oil per nautical mile. In 2018, almost 2.5 million liters of diesel and 5 million liters of marine diesel oil were consumed to power the ferries from the port of Piraeus to Sifnos. The total emission is about 141,968 tCO_2eq/year which represents 89% of the island's total annual emissions.

Electricity

The share of electricity consumption per sector is shown in Figure 3. The results highlight the high electricity consumption from the tertiary non municipal buildings which gathers businesses, offices and mainly hotels. The high standards hotels of Sifnos are equipped with devices which are consuming significant amount of energy like AC cooling systems or lighting. Around 60% of the total electricity consumption on the island comes from hotels. Tourism is the main source of income on the island which has an important impact on its economy. The rest of the electricity is consumed in residential and municipal buildings and only a few is consumed for agriculture, forestry and fisheries.

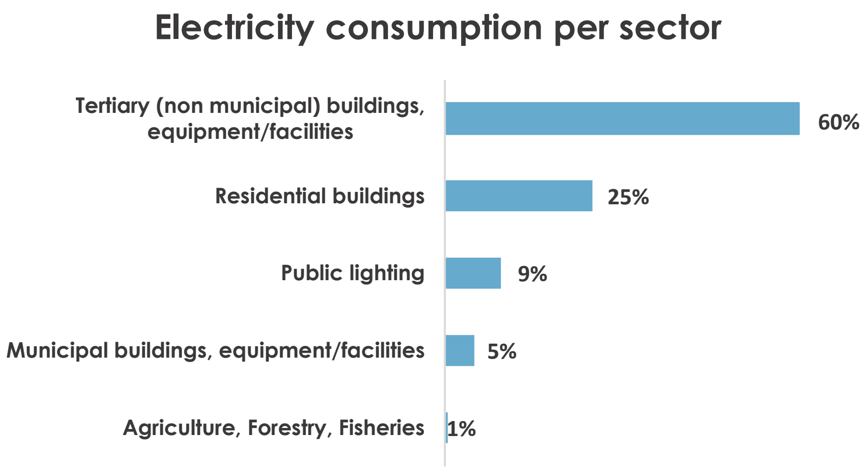


Figure 4 Annual electricity consumption per sector

The island is not electrically inter-connected to the other Cyclades islands. The total installed capacity is 11.5 MW, which is mainly generated by the diesel power plant in Plakoto owned by Public Power Corporation (PPC). A picture of the power plant is shown in Figure 4. It utilizes nine synchronous generation units of 1.1 MW each. The annual diesel demand for power generation is more than 4 million litres (which represents a primary energy demand of 44,982 MWh) and it is used to produce 18 GWh of electricity. This demand includes electricity consumption for the desalination of sea water for the supply of 90% of the fresh water requirements of Sifnos. The annual consumption for the desalination of the water in Sifnos is 372 MWh which represents 2% of the total annual electricity consumption.

Figure 5 : PPC's diesel power plant in Plakoto, Sifnos with exhaust pipes of seven fixed gensets (centre), fuel tanks (centre and lower right), two containers with mobile gensets (centre and left) and the 1.5 kV distribution lines (left)

Besides the fossil-fuel based generation, Sifnos counts with 335 kW of photovoltaics generators distributed over 25 residential and two small commercial installations. The photovoltaic installations produce 589 MWh of electricity per year. Early in 2019, the national Public Power Corporation installed 2 wind turbines with a total capacity of 1.26 MW on the island. This project was supported by the local community energy initiatives to address the concerns of the residents regarding wind turbines.

Table 1 Sifnos sources of electricity generation

Technology	Primary energy demand MWh/yr	Final energy production MWh/yr	Share of total
Diesel	44,982	18,704	80.8%
Wind power	-	3,863	16.7%
Solar Power	-	589	2.5%

The final energy produced by the wind turbine shown in Table 1 is an estimation, assuming a capacity factor of 0.35 according to the value found in the 'Hybrid Power Plant on Sifnos Island - Technical Description' report.

Figure 5 shows the estimated electricity demand curve in 2020 in Sifnos. It highlights the significant seasonal variation in the electricity demand due to tourism, with a maximum peak demand of 6 MW in summer compared to 3 MW in winter.

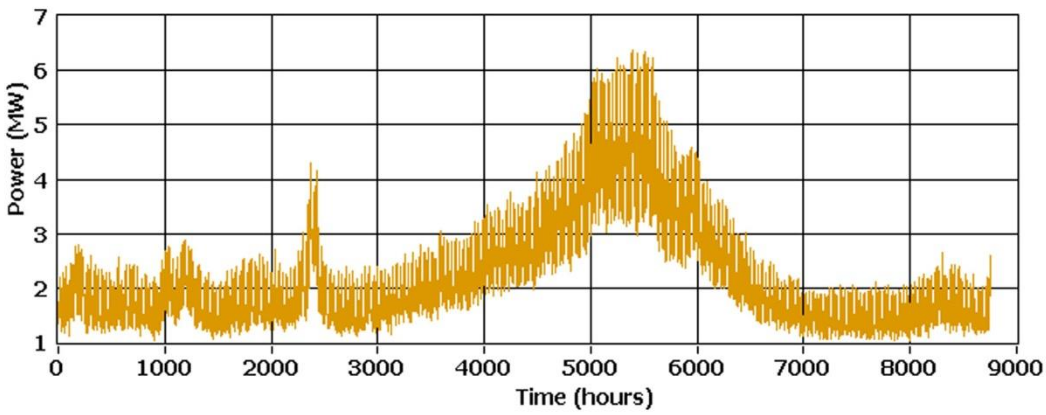


Figure 6 Electricity demand curve in 2020 in Sifnos

Transport on the island

When converted to primary energy equivalents, the energy consumption on the island used for internal transportation is 17,281 MWh, coming from diesel and gasoline. This represents 3% of the island's yearly total energy consumption and includes vehicles used on road transport - mainly cars, buses and moto-cycles.

There are several bus lines on the island, served by two municipal and three privately owned buses that connect the individual villages with Apollonia, the main village. The average distance between two connection points is 7 km. The tourist offices also offer mini-van and coaches to transport the tourists. Another alternative is the taxi, with ten taxi vehicles operating on Sifnos.

The last green transport mode in Sifnos is the bicycle. However, due to the rolling countryside, bicycles are not really used on the island. Few hotels offer the possibility to rent an electric bike which allow tourists to visit the island in a more carbon-neutral way.

Heating

Heating represents a small share of the energy consumption per year, 2.8 GWh. This is due to high winter temperatures in Sifnos, around 10°C. Heating-oil which is predominantly used for heating in the residential sector. Sifnos counts 1,002 households, 20 hotels and 10 public buildings. Some solar thermal devices are also installed in some buildings which produce 628 MWh additional heat per year for use in households and hotels.

3. Stakeholder mapping

Civil society organizations

Sifnos Island Cooperative

In January 2014, the Sifnos Island Energy & Development Cooperative (SIC) was founded in accordance with the International Co-operative Alliance principles.
The Sifnos Island Energy & Development Cooperative's main objective is the development of renewable energy installations capable of securing the energy autonomy of Sifnos Island. In order to achieve this objective, Sifnos Island Cooperative has signed a Memorandum of Collaboration with the Municipality of Sifnos and has conducted a full project study, the Sifnos Hybrid Station, and applied to the Regulatory Authority of Energy (RAE) in Greece, for a production permit for a Hybrid Power Station.

Contact: Sofia Armeliniou

Businesses

Production Supervisor in Sifnos Public Power Corporation Thermoelectric Power Station

The Public Power Corporation is involved in the energy transition in the island. At the beginning of the year, the Public Power Corporation installed two wind turbines in Sifnos which increased the share of renewables on the island.
According to the Sifnos Island Cooperative, the Public Power Corporation is interested in the Sifnos Hybrid Station as its operators working in the thermal power plant could work in the Hybrid Power Plant.

Contact: Apostolos Diaremes

Association of Professionals & Merchants

The association is positive towards sustainability; however, the members feel a bit sceptical about the Sifnos Island Cooperative regarding the size of the project.

Rental House Association

The association is positive towards sustainability in general and is supporting the Sifnos Island Station project. The members of the association don't understand the hesitation regarding the integration of the Sifnos Island Station, and they would like more information about the Sifnos Island Cooperative's activities.

Public Sector

Governmental Actors

President of Sifnos Municipality Board

The Municipality of Sifnos has signed a collaborative agreement with Sifnos Island Cooperative in October 2014 and since, the Mayor of Sifnos joined the Sifnos Island Cooperation representatives on their visits to the Ministry of Energy, RAE, HEDNO etc.
On the 12th of October 2018, the Municipality Board of Sifnos unanimously decided to fully support the project of the Sifnos Hybrid Station presented in detail by the Sifnos Island Cooperative. In addition, the Sifnos Municipality decided to become a member of Sifnos Island Cooperative once the Sifnos Island Cooperative will change its statue into Energy Community in accordance to the new law.

Contact: Konstantinos Soulis

Greek distribution system operator (HEDNO)

HEDNO in general is supportive to the energy transition of the Greek non-interconnected islands through hybrid (i.e., generation & storage) power plant concepts. Several representatives emphasize the need to prioritize public resources and efforts and they recommend giving priority to islands that may not become connected to the mainland in the medium-term future.

Greek Regulatory Authority for Energy (RAE)

The Greek Regulatory Authority for Energy is currently processing the Sifnos Island Cooperative's application for a power production permit with the Sifnos Hybrid Station. The application was submitted in September 2016 and complemented in April 2017. According to the Sifnos Island Cooperative, the Regulatory Authority of Energy signalled in November 2018 that the application had passed the technical evaluation and entered the financial evaluation.

Schools and Academia

Primary Education

Kindergarten

In the kindergarten and schools of primary education in Sifnos, environmental education is implemented within school hours in which all students are involved. Some of the themes are pollution, recycling, biodiversity, waste management, renewable energy sources etc. Teachers are raising awareness among the pupils about climate change and to make them aware of their responsibilities recycling, energy waste, overconsumption and renewable energy recourses.
Few years ago, all schools of Sifnos (kindergarten, primary, secondary) were involved in a project reducing plastic bags on the island, co-organized with the Sifnos Island Cooperation.

Contact: Evangelopoulou Maria

Secondary Education

Gymnasium-Lyceum of Sifnos

The Sifnos Secondary Education provides environmental education and raises awareness among students. The objective of this program is to educate the students to become sustainable citizens which respect their environment.

Contact: Nikos Mpelios

University

Technical Educational Institute of Crete (TEIC)

The Sifnos Island Cooperative has been closely collaborating with the TEIC since December 2015. The TEIC supported them with the technical description of the hybrid power plant and the application for the power production permit.

4. Policy and Regulation

Non-Interconnected Island policy and regulation

According to the Ministerial Decision 8295/95, "*the total penetration of installed capacity of wind, solar and small hydroelectric power plants connected to the Public Power Corporation network and independent producers on isolated islands or interconnected one to another, shall not exceed 30% of peak hourly demand (in MWh) for the last year in which there are officially published Public Power Corporation data*."

National policy and regulation

Greece has access to renewable energy sources such as hydro-power, wind, solar energy and biomass. Almost 61% of Greece's primary energy needs are fulfilled through imports, mainly fossil fuel (99.6%), with the remaining 39% being covered through domestic energy sources, mainly lignite (77%) and RES (22%)(1). Greece is making strong efforts as it nearly doubled its share from RES, from 6.9% of gross final energy consumption in 2004, to 15.5% in 2017(2). Over the period 2000 to 2015 the energy efficiency for final consumers improved by 33%. The larger decrease was registered to transport sector with a decrease of 40% over the period, then to industry with a decrease of 29% and to household with a decrease of 28%(3).

a. Targets

The government's declared policy is to diversify energy sources and reduce the carbon dioxide (CO2) intensity of the economy while increasing energy security and implementing energy market reforms to make the sector more competitive(4).

Greece's NECP is based on three pillars(5):

- In terms of renewable energy, the target for 2030 is set at a share of 31%. To achieve this goal, the plan foresees a radical transformation of the electricity sector, as renewable energy will substitute fossil fuels with over 55% of final electricity consumption.
- Increasing energy savings with one-third of current consumption by 2030. This practically means, among others, renovating and replacing 10% of residential buildings by 2030 with new near-zero energy consumption.
- The reduction of energy poverty, by ensuring equal and unhindered access to basic goods and services for all.

Greece's 2030 target for greenhouse gas (GHG) emissions in the non-ETS sector, is to reduce it by16% compared to 2005. In the NECP Greece also aims to reduce dependence on lignite power and provides the framework for investments totalling EUR 35 billion.

Greece has made steps towards the promotion of energy democracy and boosting citizens participation. With the Act N4513/2018(6), the concept of energy communities was introduced in Greece and is defined as urban partnerships to strengthen the sub-economy and innovation in the energy sector. The law aims to enable citizens, local actors such as municipalities and regions and small and medium-sized local businesses to participate in the energy transition and energy planning through their direct active involvement in energy projects, with priority being given to RES. Energy communities can produce, distribute and supply renewable energy from plants up to 1 MW.

b. Sector regulation

- The Ministry of Environment and Energy (YPEN) has the responsibility for the definition and implementation of the national energy policy as well as the coordination of the energy sector, including the promotion of RES(7).
- The Regulatory Authority for Energy (RAE) is an independent administrative authority, with financial and administrative independence under the supervision of YPEN.
- RAE monitors the operation of the energy markets, including electricity from RES(8).
- The Operator of the Electricity Market (LAGIE) has the responsibility for the operation of the electricity market(9).
- The Independent Power Transmission Operator S.A. is the Transmission System Operator for the Hellenic Electricity Transmission System(10).
- The Hellenic Electricity Distribution Network Operator S.A. (HEDNO/DEDDIE) is tasked with the operation, maintenance and development of the power distribution network in Greece(11).
- The Centre for RES and Saving (CRES) is a national entity for the promotion of RES, rational use of energy and energy conservation(12).

European policy and regulation

1. Energy and climate action

Energy is one of several shared competences between the European Union (EU) and the Member States. EU policy is currently based on three pillars (known as the "energy trilemma"):

- Competition;
- Sustainability;
- Security of supply

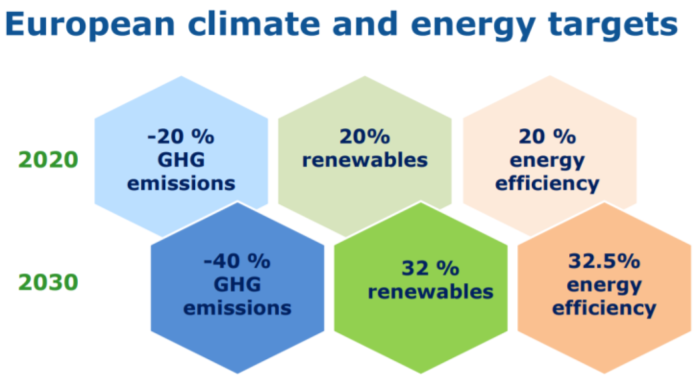
Through policy and regulation, the EU promotes the interconnection of energy networks and energy efficiency. It deals with energy sources ranging from fossil fuels, through nuclear power, to renewables (solar, wind, biomass, geothermal, hydro-electric and tidal). Three legislative packages were adopted to harmonise and liberalise the internal European energy market between 1996 and 2009. These addressed issues of market access, transparency and regulation, consumer protection, supporting interconnection, and adequate levels of supply.

For a while now, the EU is actively promoting Europe's transition to a low-carbon society and is regularly updating its rules to facilitate the necessary private and public investment in the clean energy transition.

A variety of measures aiming to achieve an integrated energy market, the security of energy supply and a sustainable energy sector are at the core of the EU's energy policy:

- Renewables Directive: mandatory targets, national plans grid rules…
- Emission Trading Scheme (ETS), reflecting a carbon price to achieve the cap.
- Energy Union: secure, sustainable, competitive and affordable energy
- 3rd energy package: unbundling, harmonised grid operation rules, network codes etc.
- Energy Efficiency Measures
- Institutional measures: ENTSOs, ACER, CEER…
- Development of the longer-term framework: 2020, 2030, 2050,

As the EU is on track to meet it's 2020 targets, the EU leaders agreed in October 2014 on new climate and energy objectives for 2030 following a proposal put forward by the European Commission. The 2030 framework aims to make the European Union's economy and energy system more competitive, secure and sustainable. It will increase certainty for investors, especially for long-term infrastructure projects, and give guidance to EU governments in preparing national policies.



A centrepiece of the 2030 framework is the binding domestic target to reduce greenhouse gas emissions by 40% below 1990 levels by 2030. This will put the EU on the most cost-effective path towards its agreed objective of an 80-95% reduction by 2050. EU leaders also agreed on raising the share of renewable energy to at least 32%, and an indicative energy efficiency target of at least 32.5% by 2030. The proposed framework will bring multiple benefits: reduced dependency on imported energy, a lower bill for imported energy, greater innovation, economic growth and job creation, increased competitiveness and better health through reduced air pollution.

2. Latest legislation package

On 30 November 2016, the European Commission published its so-called "Winter Package" with eight proposals to facilitate the transition to a "clean energy economy" and to reform the design and functioning of the European Union's electricity market. This package of proposals can be divided into three categories:

- proposals to amend the existing energy market legislation;
- proposals to amend the existing climate change legislation;
- proposals for new measures.

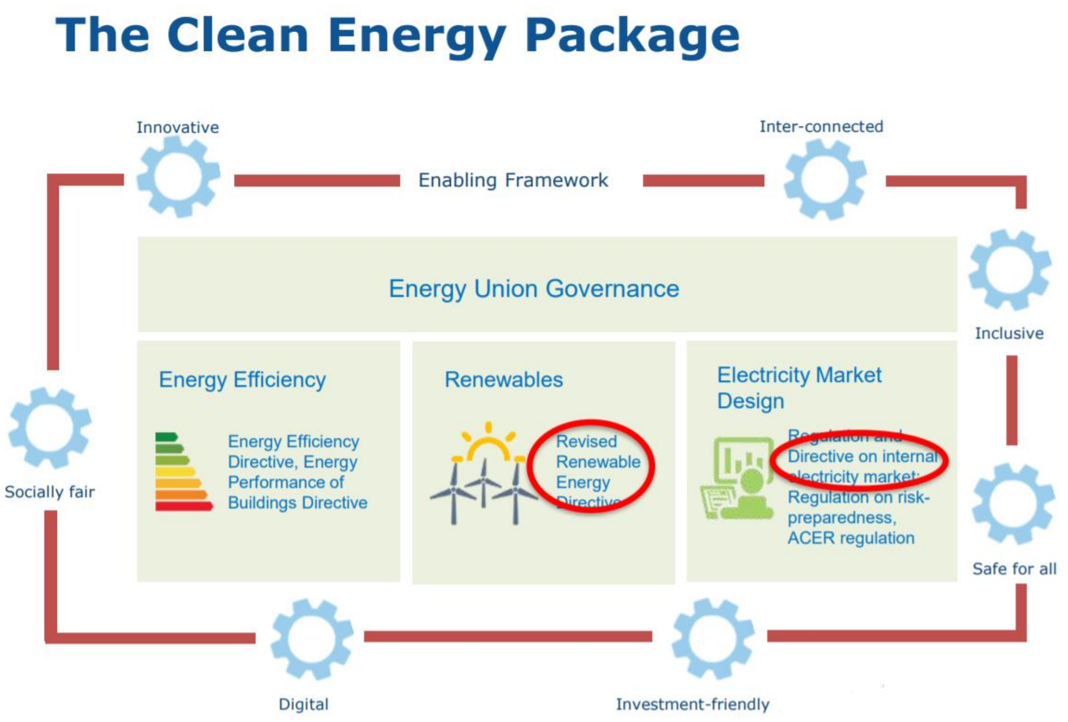
In the autumn of 2018 and spring of 2019, several directives were adopted under the Clean Energy for all Europeans Package. The eight legislation measures can be placed in four groupings:

1. Energy Efficiency:
    - The Energy Efficiency Directive; and
    - The Energy Performance in Buildings Directive
2. Internal Energy Market Reform:
    - The Internal Electricity Market Design Regulation;
    - The Internal Electricity Market Design Directive;
    - The Agency for the Cooperation of Energy Regulators (ACER) Regulation; and

- The Risk Preparedness in the Electricity Sector Regulation.

3. Renewable Energy:
   - The Renewable Energy Directive;
4. Governance:
   - The Governance of the Energy Union and Climate Action Regulation.

These new Electricity Market Design (EMD) rules make the energy market fit for the future and place the consumer at the centre of the clean energy transition. The new rules are designed to empower energy consumers to play an active role in driving the energy transition and to fully benefit from a less centralised, and more digitalised and sustainable energy system. The new rules enable the active participation of consumers whilst putting in place a strong framework for consumer protection.



3. Energy communities

For EU Islands the most important new rules are those that empower citizens and small producers under the new concept of Renewable (REDII) or Citizens (EMD) Energy Communities. These are groups of citizens, social entrepreneurs, public authorities and community organisations participating directly in the energy transition by jointly investing in, producing, selling and distributing renewable energy.

What?

- Generation of energy from renewable resources and technologies, which are partly or wholly owned by local communities

Who?

- Groups of citizens, social entrepreneurs, public authorities and community organisations participating directly in the energy transition by jointly investing in, producing, selling and distributing renewable energy

What can they do?

- Produce, consume, store and sell renewable energy, including through renewable power purchase agreements;
- Share, within the renewable energy community, renewable energy that is produced by the production units owned by that renewable energy community;
- Access all suitable energy markets both directly or through aggregation in a non-discriminatory manner

It is noticed throughout the EU that the participation of local citizens and local authorities in renewable energy projects through renewable energy communities has resulted in substantial added value in terms of local acceptance of renewable energy and access to additional private capital which results in local investment, more choice for consumers and greater participation by citizens in the energy transition. Therefore, the RED II and the EMD state that the Member States should ensure that renewable energy communities can participate in available support schemes on an equal footing with large participants. To that end, Member States should be allowed to take measures, such as providing information, providing technical and financial support, reducing administrative requirements, including community-focused bidding criteria, creating tailored bidding windows for renewable energy communities, or allowing renewable energy communities.

It is up to the Member States to set the fees and tariffs to be borne by the CEC. They can allow the CEC to be a distribution system operator (DSO) or a closed distribution system operator (CDS), and they must facilitate the roll-out of RECs by removing market barriers and taking account of RECs in support mechanisms.

Part II: Island Transition Path

Sifnos Island has actively undertaken a path to achieve 100% renewable energy generation. Their specific chosen path, its impact and alternative choices are discussed in more details in this section.

1. Transition Governance

The transition team of Sifnos, charged with spearheading the Clean Energy Transition Agenda, is mainly driven by the Sifnos Island Cooperative, the Municipality of Sifnos, with the support from the faculty and the schools of Sifnos, the Port Authority of Sifnos and the Agriculture Cooperative of Sifnos, which gather people willing to participate in the energy transition of the island.

The members of the transition team have been working together to develop a vision for Sifnos. The Sifnos Municipality with the Sifnos Island Cooperative signed the Memorandum of Understanding where the parties agreed on their responsibilities towards the development of the Clean Energy Transition Agenda.

The transition team had carried out together activities to raise sustainability on the island. A relevant example is the action implemented to reduce the use of plastic bags on the island. The action was led by the Sifnos Island Cooperative and supported by both the Municipality of Sifnos and the public schools who organized educational activities to raise awareness among the students.

Since 2013, the members of the Sifnos Island Cooperative have done lots of strategizing in order to develop a strong vision for their islands.

The Sifnos Island Cooperative has developed in collaboration with the Technical Educational Institute of Crete an energy project study to install a Hybrid Power Station combining wind turbines and a hydro pumped storage system. The project has been submitted to the Regulatory Authority of Energy (RAE) in Greece, and since the Sifnos Island Cooperative is waiting for the approval of the project. The project is still currently under revision by the Greek Regulatory Authority for Energy which caused a delicate situation on the island.

2. Vision

The vision developed by the transition team is to turn Sifnos into an energy independent island thanks to predominant local renewable sources. The main objective behind it, is to protect the island community and its economy.

In order to produce 100% of renewable energy by 2030, the electricity will be generated from renewable sources installations jointly owned by the inhabitants of Sifnos and private investors.

3. Pillars of the Energy Transition

The core pillars of the energy transition represent the energy-related areas where improvement should be addressed for the energy transition. For each of the pillars of the Local Energy Transition, a general objective is identified and a strategy, including organisational structures and relevant technologies, are described. These pillars link the vision of the transition with the current island reality. If developed, the pillars will include the financing concepts that have been considered.

Pillar 1 – Electricity generation and storage

Objective: To take ownership of electricity production on the island in order to bring economic benefits and local employment to the island communities.

There have been studies that investigated possible solutions for achieving energy independence, these solutions are divided into one strategy and two technology alternatives.

Strategy I	To build and operate the Sifnos Hybrid Station - Wind potential assessment
Technology Alternative I	To install PV panels combined with electric batteries
Technology Alternative II	To use deep sea storage system

Each of these solutions were investigated and the values provided are directly taken from the following reports:

- Technical description of a Hybrid Power Plant guaranteed Power 8 MW in Sifnos Island, developed by the Sifnos Island Cooperative in collaboration with the Technical Education Institute of Crete in 2016
- Optimization of the energy supply system of the island Sifnos, submitted by the Fraunhofer- Institute for Energy Economics and Energy System Technology in 2018.
- CellCube – a storage system based on the vanadium redox flow technology submitted by TESCO engineering in 2016

Strategy 1: **To build and operate the Sifnos Hybrid Station**

The first strategy that the island is considering is a combination of wind and hydro pumped storage. Their intention is to completely remove the usage of diesel for electricity generation by implementing these two technologies.

The Sifnos Hybrid Station was conceptualised based on 3 principles.

1. **De-carbonization**: The Sifnos Hybrid Station project aims at 100% Renewable Energy Sources electricity generation and gradually replacing oil for heating and transport (electric vehicles, boats, hydrogen fuelled ferry) rendering Sifnos 100% RES self-sufficient by 2030.

2. **Sustainable development**: The Sifnos Hybrid Station is a long-term infrastructure project fully protecting and substantially enhancing the touristic character of the island for the present and for generations to come.
3. **Innovation**: The employment of sea water for Hydro-storage combined with renewable energy sources could be the first hybrid system of its kind installed in Europe which will be an example for EU islands and maritime territories.

Technology description

The proposed technology is based on wind generation combined with a pump hydro storage system described as follows in the Sifnos Island Cooperative feasibility report:

> Technical description of a Hybrid Power Plant report
>
> "*The Sifnos Hybrid Station is composed of several wind turbines and a hydro pumped storage system. The hydro storage systems use an upper reservoir to pump up water when there is excess power generation and a lower reservoir to drain the water through hydro generators when energy is demanded. The innovative component of the proposed project is to use the sea as a lower reservoir, providing immense water capacity, compared to the scarce fresh water available on islands and lowering the costs of building a lower reservoir.*"

The Sifnos Island Cooperative, supported by the municipal council, is developing the Hybrid Power Plant Project which consists of a wind park of 11.5 MW and a Pumped Hydro Storage Plant with a Hydro Power capacity installed of 8 MW. The capacity was based on the annual power peak demand which is 6.37 MW in order to cover 100% of the annual electricity consumption. The feasibility study has been published in 2016 and the project is still currently under revision by the Greek Regulatory Authority for Energy - REA.

> Technical description of a Hybrid Power Plant report
>
> The guaranteed power from the hydro-turbines and during a 24-hour period implies guaranteed energy output, on average, per day, equal to 42.46 MWh. Accordingly, the effective capacity of the upper reservoir to produce guaranteed energy is for 18.69 days, starting for fully filled and without any energy storage during this period. This autonomy period of the system ensures its sufficiency and ability to continuously meet the power demand from the hybrid power plant safely.

Maturity of the technology

Both wind energy and pumped hydro storage are mature technologies. Pumped hydro storage is an attractive solution for medium-term storage system which is relevant for islands with high seasonal differences in electricity demand. Moreover, pumped hydro storage has a relatively high round trip efficiency of around 80-85%.

The innovative component of the proposed project is to use seawater instead of fresh water. This requires some precautions. Firstly, sea water is very corrosive due to its salty composition. The materials chosen for the construction of the reservoir, the penstocks and the turbine are determinant to ensure the durability of the components. For instance, it won't be possible to use steel but FRP material could be a good alternative(13). Second, the potential infiltration of seawater inside the soil will have a harmful impact on the surrounding ecosystem. It is important to use highly efficient impermeable liners to avoid infiltration. Last, it is necessary to build a proper energy dissipation system in order to avoid damages when the water is discharged into the sea.

According to the Sifnos Island Cooperative, "*although the use of sea water seems complicated, marine grade equipment and machinery for pumping effectively sea water have been widely used by marine vessels for decades and all sea water corrosion aspects have been successfully addressed. The potential infiltration of seawater inside the soil which will have a harmful impact on the surrounding ecosystem will be excluded thanks to the double layer sealing foreseen by the study for the construction of the sea water reservoir. The first (lower) sealing layer will made using Bentonite from the nearby Island of Milos. The second (upper) sealing layer will be the same as the one used in the sea water reservoir in Okinawa, Japan, with a perfect service record of 17 years. The Sifnos Hybrid Station solutions to use sea water will be an example for the following worldwide projects.*"

<u>Assessment of grid balancing benefit</u>

On a general aspect, a hydro pumped storage system, according to its capacity, can allow a high renewable penetration while maintaining the island grid balanced. Hydro turbines can be ramped up relatively quickly which gives to the technology a fast time response. Hydropower can store electricity over weeks, months or seasons according to the size of the reservoir and the water evaporation.

Grid congestion is currently one of the main barriers of increasing the penetration of renewable electricity generation in Sifnos. The storage system of the station presents the advantage to increase the grid absorption capacity for renewables.

<u>Market</u>

<u>Technical description of a Hybrid Power Plant report</u>

The results of the Sifnos Hybrid Station financial analysis show an estimation of EUR 37,255,000 for the total cost of the project. It states that the most expensive components of the project the wind park and the upper reservoir which represent respectively 35% and 25% of the total investment cost. According to the study, the investment's revenues for the Sifnos Hybrid Station will come from the sale of guaranteed electricity and the sale of guaranteed power.

The Sifnos Island Cooperative highlighted that they "*expects to find the required equity for this project mainly from citizens (residents and sympathizers) as well as a minority share from the contractor. In addition, the Cooperative is planning to apply for financial help from the European Investment Bank to finance the Sifnos Hybrid Station which offer loans with low interests. On the income side, the feasibility study estimates a required feed-in tariff of 324 EUR/MWh. The Sifnos Island Cooperative's is now waiting for a power production permit from the Greek energy regulator RAE.*"

<u>Examples of previous projects or case studies</u>

- Tilos is a small Greek island with a total permanent population of 500 inhabitants during the winter and approximately 3,000 in summer. Currently, Tilos is supplied by an underwater cable which is not reliable and caused several blackouts in the past. The new renewable energy system developed through an EU Project, is a hybrid system which combines batteries with a total capacity of 2.88 MWh and a nominal power of 800 kW, that are recharged by an 800 kW wind turbine and a photovoltaic park of 160 kWp. In case of emergency, a diesel genset is connected to the grid. The electricity generation is optimized by Smart Metering and Demand Side Management tools. TILOS received EUR 11 million of funding under the EU's Horizon 2020 programme and the total cost of the project is EUR 15 million. This project is the first battery-based Hybrid Power Station in Greece and issuance of all relevant permits, including the firs PPA, which disrupted the local energy market and paved the way for system replication.

- El Hierro is a small volcanic island in the Canary archipelago. Until recently, electricity was generated by diesel generators. In 2014, a hybrid power system consisting of five wind turbines of 2.3 MW and pumped-storage hydropower system was installed with a total capacity of 10 MW. The total cost of the project was EUR 82 million, and the project has been criticized for its high capital and operational cost. A main difference between the El Hierro project and the Sifnos Hybrid Power system is that El Hierro was a project based on a top-down approach whereas the HPS project in Sifnos is developed by the Sifnos Island Energy & Development Cooperative (SIC) that works according to a bottom-up approach.

- In Okinawa, in Japan, the Yanbaru plant was an experimental Seawater Pumped Hydro Storage Station installed in 1999. The total capacity of the station was 30 MW and the Philippine Sea is used as the lower reservoir. The inner surface of the reservoir was covered with an impermeable liner to avoid seawater infiltration and the fibre-reinforced tubes are used instead of steel tubes to prevent corrosion. Last, the turbine is made of stainless-steel resistant to sea water. The Japanese operator could not put the power station into practical use because the electric demand in Okinawa had not grown as predicted, and the plant was not profitable as a business. For this reason, the power plant was dismantled in 2016.

- In Chile, Espejo de Tarapaca, is a proposed 300 MW pumped hydro storage plant that operates with seawater. The goal of this project is to eliminate the intermittency issues of a 561 MW photovoltaic solar plant. The construction of the plant should begin in 2020.

<u>Key stakeholders to engage for further development</u>

- Greek Regulatory Authority for Energy
- Civil work company
- TSO
- Sifnos Island Cooperative
- Local authorities
- Power grid operator (IPTO/ADMIE)
- Public Power Company (PPC)

Wind potential assessment

An initial wind assessment study was conducted using available data from various measuring stations around Sifnos.

Technical description of a Hybrid Power Plant report

The results from the Sifnos Hybrid Station study show a mean wind speed of 5.1 m/sec at an altitude of 74 m. The installation of the 2,000 kW wind turbine, located at 78m above ground level, will provide around 7 GWh per year taking into consideration the shading, hysteresis and transmission losses. Taking into consideration the annual electricity consumption in Sifnos, 18 704 MWh, 3 wind turbines of 2,000 kW will cover the future demand.

Assessment of grid balancing benefit

Integrating wind generation into the grid affects the power system's security and stability due to the intermittency of the generation. In Sifnos, it is currently not possible to inject more electricity into the grid due to the little available grid capacity. Combining renewable generation with a storage solution could solve this situation.

Market

The cost of electricity from wind is falling. In December 2018, Wind Europe published an article highlighting that the price of onshore wind turbine had decreased compared to July 2018 from EUR 68-72/MWh to EUR 55-65/MWh, according to the results from the second onshore wind auction. The low-price can be explained by the participation of investors with large wind portfolio in Greece which put pressure to decrease prices. These results are promising for the future of wind energy in Greece.

However, it is important to note that the balancing cost (storage cost) must be considered together with the cost of wind power. Without the necessary infrastructure for grid balancing it is impossible to increase the number of wind turbines in the island grid.

Examples of previous projects or case studies

- The Public Power Corporation installed in Sifnos two wind turbines of 1.26 MW capacity at the beginning of 2019.

The Sifnos Island Cooperative underlines that "*wind measurements begun in 1989 and they had to wait 30 years the installation of wind turbines. In addition, during the installation of the two wind turbines, the crew erecting the wind turbines quoted that Sifnos was the first island in Greece they faced no opposition of any kind while transporting the wind turbines from the port to the erecting site*. "

Key stakeholders to engage for further development

- Local community
- Power grid operator (IPTO/ADMIE)

- Public Power Company (PPC)

<u>Alternative Transition Paths</u>

Concentrating the electricity generation on one renewable source to generate electricity could present a risk due to the unreliable characteristic of renewable sources. A solution to prevent this risk could be to diversity the sources of electricity generation. For the Sifnos Hybrid Station, the integration of both solar and wind resources combined with a storage mechanism could balance much better the grid and ensure a more reliable system.

The Sifnos Island Cooperative believes that "*combining wind turbines and PVs for the electricity generation in Sifnos Hybrid Station present significant advantages. Especially due to the apparent climate change, the regular Northern winds that have always been blowing in the Aegean Sea during July and August, could not blow for several consecutive days. Therefore, the employment of 2 MW PV at the expense of a wind turbine is gaining momentum among the Sifnos Island Cooperative's technical team. Final decision will be made after the issue of the requested Production Permit, in accordance to the existing regulatory framework in Greece.* "

Another important aspect in the integration of renewables in a non-interconnected island like Sifnos, is the existing limitation of penetration. According to the Ministerial Decision 8295/95, "*the total penetration of installed capacity of wind, solar and small hydroelectric power plants connected to the Public Power Corporation network and independent producers on isolated islands or interconnected one to another, shall not exceed 30% of peak hourly demand (in MWh) for the last year in which there are officially published Public Power Corporation data*."

The total installed capacity in Sifnos of both wind 1.26 MW and solar PV 335 kW, has almost reached the 30% of peak hourly demand. The integration of renewable won't be possible without combining it with system storage.

Technology Alternative I: **To install PV panels combined with electric batteries**

<u>Technology description</u>

- Photovoltaic systems convert solar radiation to electricity, which is then either directly consumed locally or fed into the electricity grid. As power production depends on the presence of sunlight, generation is highest during midday and there is no production at night. 335 kW of PV panels have already been installed on the island. They produce about 2.5% of the island's annual electricity consumption. By increasing the number of PV modules on public building, hotels and private housing, the percentage of renewables in the electricity mix can increase and the island's dependence on fossil fuel decreased. Moreover, as suggested by the Sifnos Island Cooperative, diversifying the energy sources with a large Solar Plant will bring more reliability to the gird.

- Several types of electric battery technologies exist on the market. The most widely utilised for utility scale energy storage systems is lithium-ion technology. In general, this technology exhibits a high average storage cycle efficiency of 80-90%.

Potential of the technology

The geographic situation of Sifnos is favourable for solar power, as the average horizontal solar irradiance on the island is 1825 kW/m^2.

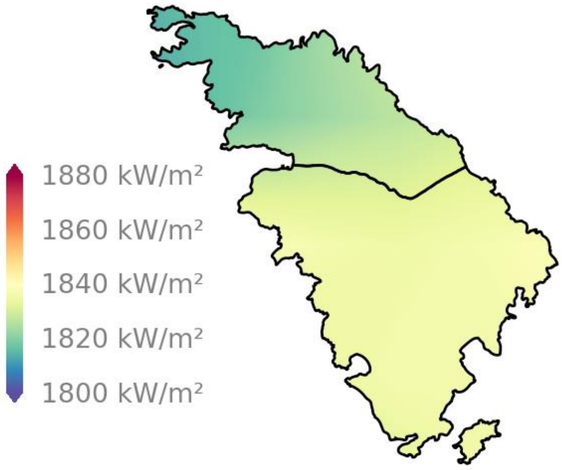


Figure 7 Repartition of the Horizontal Solar Irradiation in Sifnos

The rough terrain and the traditional architecture on the island do not favour large-scale PV project nor small-scale on the flat roofs of buildings as they would severely damage the high aesthetic the traditional house settlements present as a tourist attraction.

Nevertheless, in the open call for proposals addressed when examining alternatives for the Sifnos Energy Autonomy Project, Tesco Engineering in collaboration with Gildemeister Energy Solutions, offered three scenarios for large scale PV combined with Vanadium redox flow energy storage systems.

CellCube – a storage system based on the vanadium redox flow technology report

The three proposals presented by Tesco Engineering after closely analysing the daily energy demand in Sifnos over the past five years, were the following:

A. 63% RES in the Sifnos demand mixture with 9MWp PVs and 15 CellCubes 200kW-800kWh at a cost of 27,367,500 euro
B. 83% RES in the Sifnos demand mixture with 15MWp PVs and 25 CellCubes 200kW-800kWh at a cost of 44,362,500 euro
C. 89% RES in the Sifnos demand mixture with 15MWp PVs and 25 CellCubes 200kW-1600kWh at a cost of 59,227,952 euro

All three proposed installation had an expected life of service of 20 years, an estimation of 1650 kWh/kWp electricity generation and a prerequisite that the existing diesel generating Station of Sifnos will remain in service in order to supplement the small amounts of energy required by the proposed systems. The following table shows the result of the TESCO Engineering study:

Component	Solution 1 basic	Solution 2 advanced	Solution 3 supergreen
PV	9 MWp	14MWp	14MWp
Generator	5,5MW	5,5MW	5,5MW
CellCube	200-800 * 15	200-800 * 25	200-1600 * 25
Renewable Fraction	63%	83%	89%
Capital cost €	27,367,500	44,362,500	59,227,952
LCOE/kWh €	0,272	0,239	0,254
LCOE (2%inflation, 7% interest rate)/kWh €	0,323	0,321	0,326
	Recommended scenario		

Maturity of the technology

Over the past 20 years, solar PV has developed into a mature technology with a large track record across the world. Components, expertise and trained personnel are available throughout Greece, which has one of the highest per capita solar PV capacity in the world. Sifnos already has a small share of PV installations on roofs.

The battery technology improved significantly the past few years. Currently, it is one of the highest energy densities which means that more energy can be stored with less weight. The technology has a low self-discharge rate around 1.5-2% per month and requires low maintenance. However, the technology presents some disadvantages like its tendency to overheat and a potential auto-damage at low voltage.

Market

After obtaining the results from the Tesco Engineering study, the Sifnos Island Cooperative emphasised on the high cost of electrical batteries storage systems that does not compete with the price of the pumped hydro storage system.

Assessment of grid balancing benefit

Simultaneity of electricity production and consumption is important, in particular for island grids. Considering the demand side of households, the first peak of consumption occurs in the morning between 7 and 9am before people go to work, the second peak happens between 6 and 9pm when people come back home. However, the peak of solar power production generally happens around midday and the electricity consumption and electricity production therefore exhibit low simultaneity

The simultaneity can be increased by two means. First, with the integration of energy storage system connected to the PV panels, the electricity could be stored and released during high demand. Batteries are particularly a good solution to tackle grid instabilities due to their fast-electric response and can participate in the frequency regulation. Another aspect of the technology is its role to increase the grid capacity. In case of a shortage, the batteries can supply electricity meanwhile the correction of the system.

Second, through demand side management, electricity demand can be shifted to times of high PV production. Consumers that focus on self-consuming PV production can contribute to reducing the grid peak when production and consumption occurring at the same time. For instance, demand from electrical cooling during the high season can be used to this effect. Moreover, local generation and consumption reduce the power system losses and increases system efficiency.

Examples of previous projects or case studies

- In 2012, in Crete, the Bali Paradise Hotel installed solar PV on its roof with a total capacity of 80 kWp. The annual energy production is 112 MWh/year and is saving 67.2 $CO_{2,eq}$/year. The total cost of the project was EUR 203,500 which represents EUR 2.54/Wp installed. The electricity is fed into the grid and the retail price was EUR 0.441/kWh paid by the Public Power Corporation under the Feed in Tariff scheme.

- On Pellworm Island, located off the North Sea coast of Germany, lithium-ion batteries where implemented for the SmartRegion Pellworm project. The project had the objective to increase the integration of renewable resources into an already congested distribution grid. By installing 560 kWh of energy storage, the level of self-consumption increased, the grid was better controlled, and more renewables were implemented. This project also created a strong community engagement (14).

- On the Greek island Tilos, the Technology Innovation for the Local Scale, Optimum Integration of Battery Energy Storage (TILOS) project is testing the integration of an innovative local-scale, molten-salt battery (NaNiCl2) energy-storage system in the real grid environment. The prototype battery-storage system will improve micro-grid energy management and grid stability, increase renewable energy use and provide services to the main grid. If successful, this energy storage technology could be widely replicated on islands to complement and encourage the use of variable renewable energy sources. The total capacity installed is 2.8 MWh.

Key stakeholders to engage for further development

- Power grid operator (IPTO/ADMIE)
- Battery lithium-ion manufacturer
- Solar PV installers & retailers
- Local community (hotel owners)
- Local turbine owners (PPC)

The study for "CellCube – a storage system based on the vanadium redox flow technology" submitted by the Tesco Engineering was introduced to the General Assembly of the Sifnos Island Cooperative, *"which unanimously voted in favour of the proposed Sifnos Hybrid Station incorporating the wind park and the pumped hydro storage system*."

Technology Alternative II: **To use deep sea storage system**

The Fraunhofer Institute for Energy Economics and Energy System Technology conducted a study from January to March 2018 on the "Optimization of the energy supply system of the island Sifnos". The report presents several energy scenarios combining electricity generation and storage. The potential of a novel Pumped Hydro Storage system was assessed, the StEnSea, Storing Energy at Sea.

Optimization of the energy supply system of Sifnos Island report

The Sifnos Island Cooperative's request for better alternatives to the proposed Sifnos Hybrid Station, the Fraunhofer-Institute For Energy Economic and Energy System Technology was employed to conduct a study on the Optimization of the energy supply system of Sifnos Island, in order to find the optimal renewable energy sources to supply the Sifnos electricity grid, also examining the use of a novel energy storage system using specially constructed deep sea bulbs named StEnSea.

Fraunhofer IEE has developed a software, which finds the optimal mix of renewable energy sources and storage capacity to supply a defined area with electrical energy. The software OptMix aims towards the minimization of the levelized costs of energy (LCOE) to identify the most economically profitable solution. The software has been developed for the German market and is equipped with a related default data set. In this project, data from the Sifnos Hybrid Station report were used to adjust the software for the Greek island Sifnos.

Fraunhofer IEE final report examined 10 different renewable energy sources scenarios also including partial diesel generation, in order to minimize the required renewable energy installation cost. The report provides to the Sifnos Island Cooperative's technical team high detailed information on the possible advantages of mixing wind and solar energy for the required production.

Description of the technology

The StEnSea (Storing Energy at Sea) system uses the sea itself as the upper storage reservoir. A hollow concrete sphere is installed at the bottom of the sea and represents the lower storage reservoir. The storage system is fully charged when the hollow sphere is empty and discharged by filling the sphere with the surrounding seawater. The inflowing water drives a pump turbine, which consequently feeds energy into the grid.

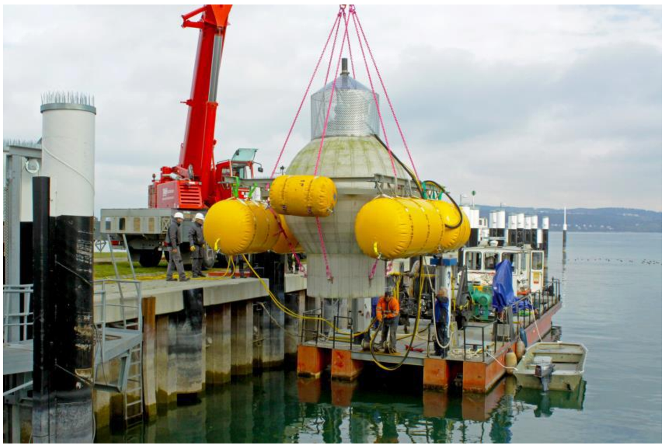


Figure 8 Scaled prototype of the StEnSea system

Maturity of the technology

The StEnSea storage system is not a mature technology yet as mentioned in the Fraunhofer report "the StenSea system is the most promising one regarding the investment costs. It is necessary to make further analysis to identify an installation site. Additionally, it must not be neglected that the StEnSea system is currently in development and the full-scale system is not yet commercially available".

A decision has been made by the Sifnos Island Cooperative Board, to install for actual operational testing, one bulb of the StEnSea system, complementary to the pumped hydro storage system, if adequately financed by the interested party.

Pillar 2 – Energy demand for heating

Objective: **To facilitate the conversion of buildings on Sifnos to be more sustainable in their energy usage.**

The objective of the energy transition is in the first place to reduce the heat requirements as much as possible by implementing energy saving measures and improving the buildings envelop. Secondly, renewable sources of heat are preferred over non-renewable sources. Finally, non-renewable sources are used as efficiently as possible, ideally in devices that have a high coefficient of performance.

Strategy I	To improve the envelop performance of buildings and implement sustainable construction
Strategy II	To use heat pumps for space heating
Strategy III	To install solar thermal to heat domestic water

Strategy I: **To improve the envelop performance of buildings and implement sustainable construction**

Sifnos is one of the very few islands in Aegean Sea that have been continuously inhabited since 2,400 B.C. until today. Though the main reason for the other island's dissertation was piracy, the sustainability characteristics of the Sifnian society also affected architecture. The traditional architecture of Sifnos Island is synonymous to what we nowadays call "Bioclimatic Architecture". Over 50 cm thick external walls, small windows on the out-side of the wall, never on the north side of the building, white colour for minimum attraction of the sun rays during summer and cistern to collect rain water. Internal wall and roof insulation with canes, sea wheat and lime mortar. However, the houses built in the last 30 years, all use concrete frames and 20-22 cm thick cavity walls with organic insulation, the same structure used in Athens and most major cities in Greece. These constructions are not well insulated and required a high energy consumption.

The energy demand in buildings mainly depends on the insulation performance of the building. Improving the insulation of the envelope is the first step to improve energy efficiency which means reduce the heat losses and ensure summer comfort. According to a testimony of the previous Mayor of Sifnos, the major problem on the island is the old buildings which can't insulate heat. In order to improve the envelop of the buildings, the first steps are the following:

- Insulation of external walls, roofs, lofts and floors
- Replacement of windows and doors
- Draught proofing
- Installation of solar shading systems
- Employment of natural ventilation technique (15)

In a later stage, the Sifnos Island Cooperative is willing to train builders and general public to return to sustainable methods of construction. However, this action requires a certain amount of time which will be allocated the next few years.

Strategy II: **To use heat pumps for space heating**

Technology description including organisation

A heat pump is a device which can provide both heating and cooling in one integrated unit. Heat pumps can be used in households for residential uses and are scalable for larger buildings.

Maturity of the technology

A heat pump is a mature technology which consume less primary energy than boilers to produce heat. Different factors are mainly used to evaluate the performance of the device, the main one is the Coefficient of Performance (COP). It is defined as the ratio between the useful heat transfer for heating/cooling and the required driven energy.

In order to operate a heat pump in the most efficiently way, when choosing the device six factors have to be considered: climate, temperature, auxiliary equipment, technology, size and control system.

Market

According to the European Heat Pumps Association, since 2014, the heat pumps market has increased by 14% percent each year in Europe to reach in 2018 EUR 1.3 million of sales. The price of a heat pump depends mainly on the size of the energy needs. For the device and its installation, the cost starts from around EUR 10k for a residential application which can be a significant investment, but the operating costs are 75% lower than operating a fossil fuel boiler. Thanks to the high operating efficiency, the payback time is often very short.

Examples of previous projects or case studies

- In Imerovigli in the Santorini island, the Andromeda Villas which is a luxurious hotel, installed an energy saving system. Heat pumps were installed to replace an oil boiler, for heating the water and the swimming pools of the hotel. The oil boiler was consuming 12,000 liters of fuel per year which represents around EUR 16,000. Currently, thanks to the heat pumps, the annual energy consumption to heat the water is 14,300 kWh with a cost of EUR 2,145 per year. Regarding the technical performance, the owners of the hotel are satisfied with the investment they made since the system allowed to save more energy than it was plan.

Key stakeholders to engage for further development

- Heat pumps manufacturer
- Local government
- Hotel owners

Strategy III: **To install solar thermal to heat domestic water**

Technology description including organisation

A solar panel is a simple device which collects heat from the sun and uses it to heat up water which is stored in a hot water tank. The solar water heating panel is mounted on the roof. Sifnos has already installed some solar thermal units to heat water. Currently, the installed solar panels are providing 638 MWh per year.

Maturity of the technology

Solar heating water panels are a mature technology. The efficiency of the device depends on the geographic location and the solar resource. The installation of solar heating water panels in Sifnos and more precisely for hotels could reduce significantly the electricity bills.

Market

Usually, a solar water heating system is more expensive than a conventional water heating system. However, in the long term, a solar water heating panel will allow to save money and even more in island as the cost for conventional fuels like heating oil is high.

According to the Greek solar water heater provider Andrianos, the price of a device starts around EUR 900 for a capacity of 120 liters and an area of 2 m2.

In Sifnos Island, there are three well trained water panel contractors and there are several houses that have replaced their 12-16 years old water panels with new ones.

Examples of previous projects or case studies

- Sifnos has already installed several solar heating water panels on roofs, many of them connected to the central heating systems of the house in order to save on diesel for heating during the winter.

Key stakeholders to engage for further development

- Local community (hotel owners, citizens)
- Solar heating water panels installers & retailers
- Local Authority

Pillar 3 - Transport on the island

Objective: **To decarbonise the island's transport system by focusing on public transport and electric mobility**

Strategy I**: To develop a Sustainable Island Mobility Plan (SIMP) for Sifnos**

Sifnos is involved in the **Sustainable Island Mobility Plan (SIMP)**, which aims to evaluate the problems and challenges that an island faces related to mobility and the provision of sustainable mobility solutions on transport and land-use planning, mobility management, pricing policy and logistics. It addresses several issues, such as boosting public transport, ensuring that vehicles can move around and park on the island safely, promoting environmentally-friendly modes of transport (cycling, walking), providing accessibility for vulnerable groups (elderly, children, mobility impaired), etc. The SIMP gathers those issues and supports to make collaborative decisions on how they are going to be solved in the most efficient, environmentally-friendly and socially beneficial way. At the same time, it will constitute an important tool for the municipality to seek funding, in order to bring about the necessary changes that will decisively improve the quality of life for everyone.

The project started in Sifnos at the beginning of September 2018 and the first meeting was held on the 12th of March 2019. This project involves different stakeholders including the residents, professionals and visitors of the area, in collaboration with specialised scientists and the Municipality which all have a role to play.

Currently, the Sustainable Island Mobility Plan team is analysing the situation of the Municipality thanks to online surveys which gather questions regarding the needs, habits, preferences and problems of the trips made by visitors and permanent residents.

Different actions that can be proposed in the SIMP are:

- Assist Sifnos Municipality in finding funding at regional, national and European level to invest in an electric bus that covers the entire island.
- In collaboration with Municipality, create incentives for local auto-motto rental businesses replace their fleets with electrical vehicles.
- In collaboration with Municipality, create incentives for local goods transporters replace their lorries with electrical ones.

Pillar 4 - Transport to and from the island

Objective: **to decarbonize ferry transport by switching to a low carbon transport solution to connect the Cycladic islands**

Strategy I	**To acquire a hydrogen fuelled all-weather passenger vessel through European funding**

Sea transport with the ferry is the major single energy demand related to the island. Around 90% of the islands' CO_2 emissions are due to maritime transport. Three companies are connecting Sifnos which are Sea Jets, Aegean Speed Lines and Zante Ferries. The distance between Athens and Sifnos is about 130 km which represents around 3 to 5 hours trip according to the vessel. Sifnos is also connected to other Greek islands with a high rate trip during the summer. All the ferry connections and the far location from the mainland of Sifnos, are the main factors for the high CO_2 emissions.

Replacing ferry vessels requires a significant investment and low-carbon alternatives are also still very expensive. Fuelling is an important challenge, especially considering the significant distance between Sifnos and Athens and the variable weather conditions of the Aegean Sea. Replacing the ferries with a low-carbon alternative is therefore a particularly cost-intensive undertaking.

The Sifnos Island Cooperative suggests implementing a hydrogen ferry inside the Cyclades Islands which will connect Sifnos to the international airports of the surrounding islands of Paros, Mykonos and Santorini.

<u>Technology description including organisation</u>

Few technologies exist to replace fossil fuels to power maritime vessels. Hydrogen is one of them but is it still an immature technology which has not been showed case on a large scale yet.

Hydrogen can be produced using diverse resources including fossil fuels, such as natural gas and coal, biomass, non-food crops, nuclear energy and renewable energy sources, such as wind, solar, geothermal, and hydroelectric power to split water. It is possible to classify three types of hydrogen:

- Grey hydrogen, which is produced using fossil fuels which is the major hydrogen produced in the world today
- Blue hydrogen, which meets the low carbon threshold but is produced using non-renewable energy sources like nuclear
- Green hydrogen, which is generated using renewable energy sources

Currently, two types of technologies exist for hydrogen ferries. The first one is a ferry using hydrogen as a direct fuel. The direct combustion of hydrogen powers the motor to drive the vessel. The second technology uses a hydrogen fuel cell which converts compressed hydrogen gas into electricity to power electrical motors. In order to power the engines, the ferry will carry onboard tanks filled in by pressurised gas. The advantage of hydrogen is its lower density which allow to produce more energy in a smaller volume and the possibility to store it for long periods. In Sifnos case, the long distance between the mainland and the island requires a solution capable of storing enough fuel to power the engines during the entire journey which makes hydrogen a potential alternative. Then, if the hydrogen is produced on the island by renewables, an electrolyser will be installed to convert the electricity produced into hydrogen. The hydrogen will be stored into a tank which will be connected to a Hydrogen Refuelling Station which will fill the onboard tanks with hydrogen.

Maturity of the technology

The first hydrogen ferry was launched in 2015 by the Scandlines company and since the company keeps on manufacturing more ferries. A hydrogen boat is still an innovative technology which needs more experience to become mature at both the technical and economic levels. The efficiency of the cycle from production to consumption of the hydrogen can be improved and the devices like the electrolyser and the fuel cell are still very expensive. For instance, in many cases boats need a backup diesel in case their fuel cell breaks in the middle of the sea.

However, with the development of future hydrogen projects, the technology seems promising. Hydrogen present several advantages like its versatility. It can be used not only in shipping but also it can balance the variability of renewable energy sources, it can be used in industrial processes or in the road transport sector.

Market

Hydrogen ferry are more and more present on the market but there are still being developed under pilot projects to keep on improving the efficiency of the technology.

Fuel cells remain expensive devices, not well established on the market and require refuelling infrastructure. This is the chicken and egg problem; the fuel cells are not well developed due to the lack of refuelling stations and refuelling stations won't be installed if there are no engines. According to a study made by Roland Berger, a fuel cell powered ferry with a fuel cell stack, a hydrogen tank, battery and electric motor present a capital cost of approximately EUR 255,000 (16). The hydrogen ferry is not competing yet competing with conventional ferries.

The Sifnos Island Cooperative will try to fund the project by Horizon 2020 which aims to achieve smart, sustainable and inclusive economic growth.

Examples of previous projects or case studies

- In Scotland, inside the HySeas project consortium, the company Ferguson Marine is building a renewable hydrogen powered ferry using Ballard fuel cells and it is expected to be launched in 2021.
- In Orkney, a different project has been developed with a stationary fuel cell installed in the harbour. It provides electricity on demands for ships and the heat produced by will be piped into nearby buildings.
- The EVERYWH2ERE project aims at demonstrating the potential of Fuel Cell gensets. The device is composed of a fuel cell stack, a power electronics battery and a hydrogen storage and presents the advantage to be used in mobile applications. In Greece, 8 x 25 kW containerised plug and play hydrogen gensets will be deployed for quayside power for ferries.

Key stakeholders to engage for further development

- Research structures
- Local, regional and national government
- Ferry companies
- Cycladic islands governments

Solution	**Technology maturity**	**Lifetime (year)**	**Capital cost (€)**	**Overall suitability**
Hydrogen ferry	Semi-mature		255,000	Medium
Fuel cell	Semi-mature	Transportation 5,000h Stationary 40,000h	- 2,000-10,000	Medium
Electrolyser	Semi-mature	60,000h	500	Medium

(17)

Complementary path: **Hydrogen storage**

Technology description including organisation

As presented in the previous section, the integration of a hydrogen ferry will require the production of hydrogen, refuelling stations and a hydrogen storage tank. All the development of these infrastructures could be an opportunity to use the hydrogen in a "power to hydrogen" system. The hydrogen stored inside the tank could be convert into electricity and then injected inside the grid.
If Sifnos replaces its ferries by hydrogen ones, the island will need to develop all the necessary infrastructures to produce, store and use the hydrogen. Once the devices will be installed in the island, it could be financially interesting to combine the need to power the ferries with the need to produce electricity. In a case of a sufficient hydrogen production, the gas could be stored into tank during the winter and then used to power the grid in summer, when the electricity demand increases.

Maturity of the technology

The technology isn't well developed yet due to the high cost of the technology to compress the gas in order to store it. However, some pilot projects are already implemented which allow to increase the efficiency of the technology. Compared to chemical batteries, hydrogen storage and fuel cells do not self-discharge, which is a significant parameter for seasonal storage. In the long term, stationary fuel cells combined with hydrogen storage, could replace diesel generators which require more maintenance and emit a huge amount of CO_2 emissions.

Market

Currently, hydrogen storage is not economically competitive due to the high price of generation, transportation and distribution. The CAPEX is very high compared to alternative solution like pumped hydro or battery storage. Manufacturers recently communicated the price for the electrolyser and its installation at around EUR 500/kW (18). The price of the fuel cell highly depends on the technology used and can be range between EUR 2000 to 10000/kW (19). In specific location like island, where the electricity cost is very high due to the price of diesel, the integration of hydrogen storage combined with renewables presents a potential niche market. In this case, long-term hydrogen storage may become an economic reality (20) .

Examples of previous projects or case studies

- Orkney is a group of islands to the north of Scotland with a big potential of wind, tidal and wave resources. In the island of Eday, an 0.5 W electrolyser has been installed which is power by the electricity produced from both, the wind and tidal turbine. The hydrogen is produced by the electrolyser and stored as compressed gas in a tank. Then, the hydrogen shipped to Kirkwall, Orkney's capital, where people are developing systems to make use of hydrogen.

Key stakeholders to engage for further development

- Universities
- Electrolyser manufacturers
- Power grid operator (IPTO/ADMIE)
- Local authority
- Local renewables operator

4. Identified pathways

Completing the previous chapters permitted to define three different energy pathways which are illustrated in the following figure. [2]

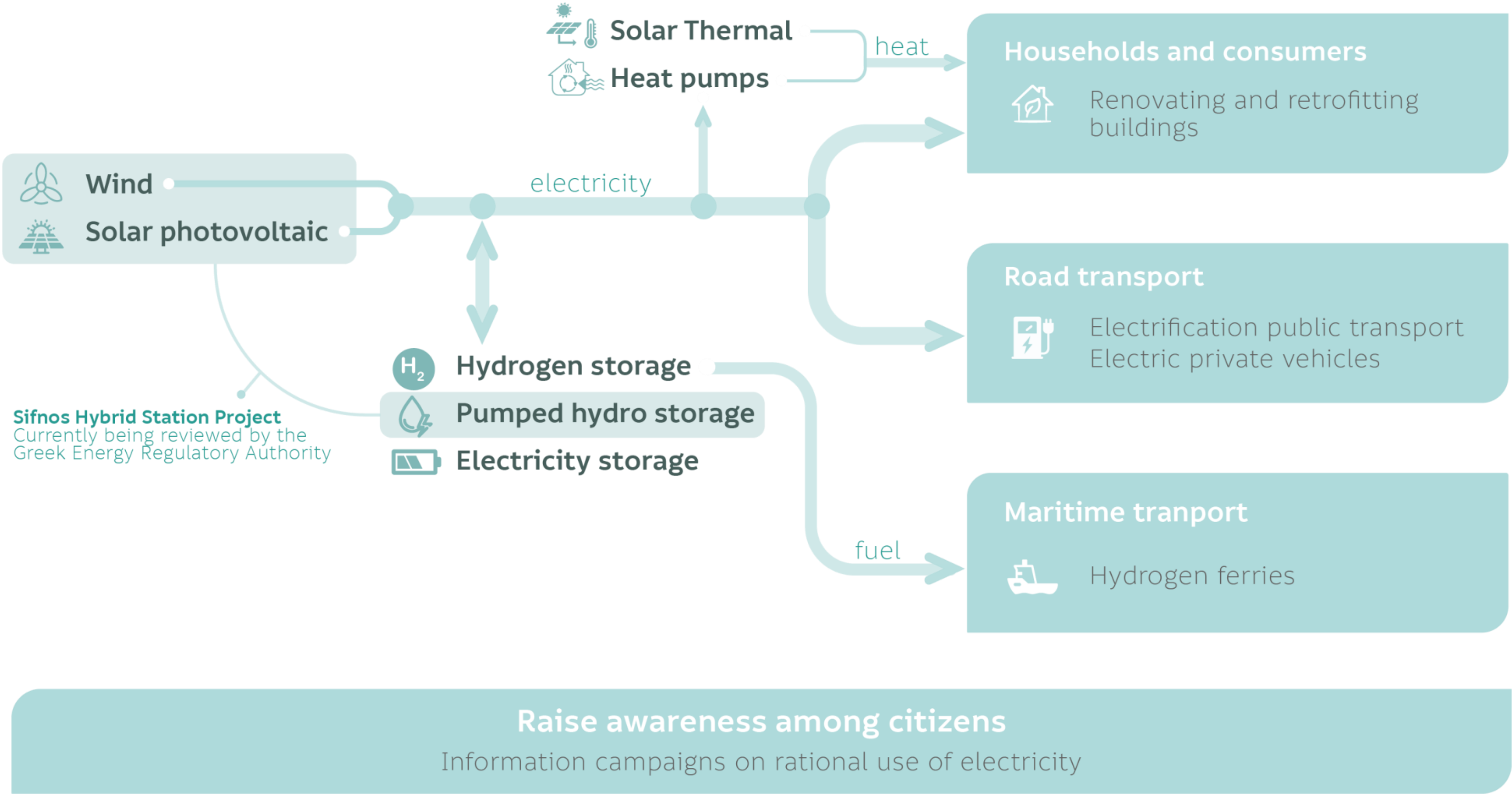


Figure 9 Identified energy pathways for Sifnos

In order to reach energy autonomy and 100% renewable generation, Sifnos will need to implement several actions that will both reduce the energy demand and increase the penetration of renewables.

Sifnos island will reduce the energy demand thanks to the replacement of outdated and polluting devices like oil heating boilers by more efficient alternatives such as heat pumps and solar thermal collectors. These actions will allow to have a reduced energy demand profile which makes easier the replacement of conventional energy generation by alternative technologies.

The diversification of energy sources will be essential to increase the reliability of the system generation. Renewable energies are not dispatchable which means they cannot be turned on and off according to the grid's needs. Both, wind turbines and solar panels are already installed on the island and more devices will be implement in the future. A grid with high integration of renewables needs flexibility, different ways of smoothing and balancing out the fluctuation in wind and solar. In order to optimize and secure the energy generation from renewables, it will be favourable to install energy storage systems. The excess electricity will be stored inside the storage systems and when electricity is not produced, the stored electricity will be injected inside the grid to cover the demand.

Three pathways will be considered according to the selected storage system technology:

1st pathway

The Sifnos Hybrid Station will be implemented. The excess of electricity produced will be used to pumped water from the sea up to the reservoir. When, electricity demand won't be covered by the wind turbines, the water will drive the hydro turbines to produce electricity and power the grid.

2nd pathway

The excess of electricity will be converted into hydrogen by an electrolyser. The hydrogen produced will be stored inside a hydrogen tank. Then, according to the quantity of hydrogen produced, the hydrogen will be used in two sectors. First, the hydrogen will be converted to electricity by a fuel cell and then injected into the grid to cover the demand. Second, the hydrogen will be used to power a hydrogen ferry in order to replace the current conventional ones and reduce the GHG emissions of the island.

3rd pathway

The exceed electricity will be stored in an alternative storage system like a deep-sea water system or electric batteries.

In the three scenarios, renewable generation is combined with an innovative storage system. The Sifnos Island Cooperative is supporting the first pathway which is still waiting for a permit approval from the Regulatory Energy Authority. The second pathway has not been studied in details and the results from the third pathway are presented in the Fraunhofer report.

5. Monitoring and dissemination

Monitoring is an important part of the learning process of any transition. The Clean Energy Transition Agenda therefore monitors both the transition itself and the way that that the process is managed. This forms the basis to determine the next steps. Monitoring happens based on Transition Indicators that acknowledge the transient character of the transition process and address the need for regular re-adjustment. Since transition processes are uncertain by nature, the Island Clean Energy Transition Agenda cannot be a static document. Through periodic reporting it is revised and adjusted to accommodate changes of circumstances.

The transition indicators span nine areas that cover different dimensions of the clean energy transition on the Aran Islands. An annual self-assessment is made by the transition team as experts of the situation on the island. This analysis helps to direct the strategic focus of the transition agenda and can be used as an indicator for the next steps.

The transition indicators for Sifnos were evaluated in September 2019. This section provides the results from the self-assessment exercise realised by the island transition team.

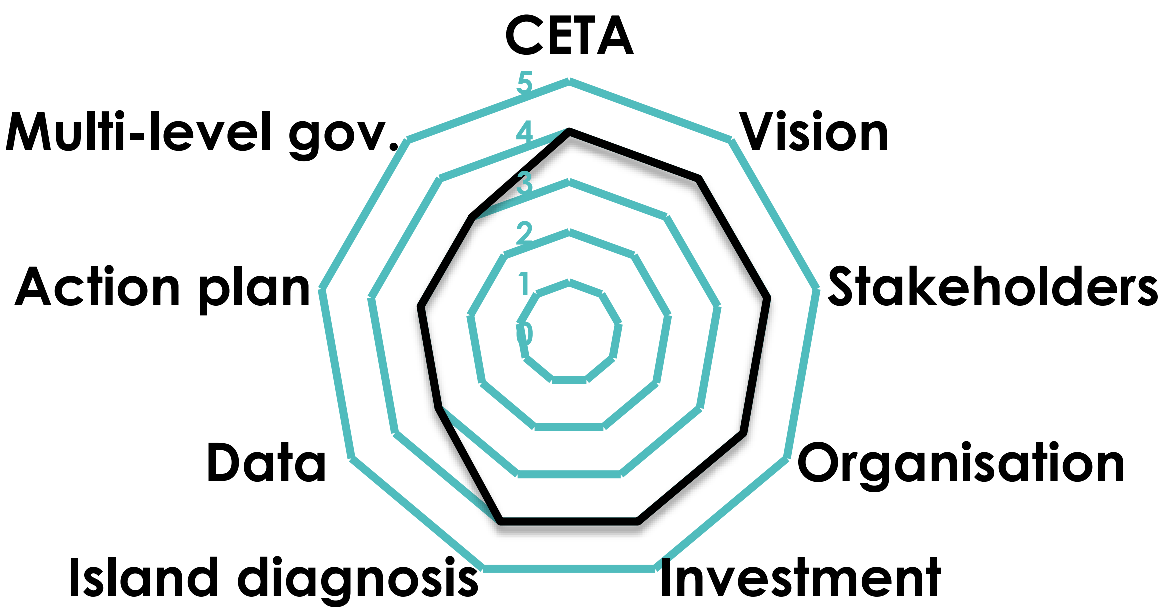


Figure 10 Transition Indicators Evaluation September 2019

Indicator: Clean Energy Transition Agenda

4

The transition team indicates that there is a Clean Energy Transition Agenda authored by the transition team in collaboration with the Clean Energy for EU Islands Secretariat. Some work remains in order to complete the document. The Sifnos Island assesses itself as 4 for this category.

In order to reach level five in this category, Sifnos island will submit a Clean Energy Transition Agenda to the Clean Energy for EU Islands Secretariat. They foresee to do this in Fall 2019.

Indicator: Vision

4

The Sifnos Island Cooperative has a well-developed vision that includes clear objectives: energy autonomy, energy innovation and sustainable development. In addition, there is a long and medium-term island-wide vision on clean energy with explicit targets which has been approved by the Sifnos municipality.

In order to reach level 5, the transition team is waiting the approval by the relevant authority, the Regulatory Authority of Energy.

Indicator: Community Stakeholders

4

All the stakeholders on Sifnos are strongly committed to the clean energy transition and have signed the Clean Energy for EU Islands Pledge. The Different pathways to move forward the transition have been discussed and considered. After discussing the potential solutions with the members of the transition team, the stakeholders decided on which transition paths are worth pursuing.

This commitment will be formalized at an island level when the Clean Energy Transition Agenda will be delivered and then presented to the newly elected Municipality Board.

Indicator: Community organisation

4

The stakeholders are actively working on the clean energy transition. The Sifnos Island Cooperative is supported by actors from multiple stakeholder groups that drives the energy transition. In the past, the Sifnos Island Cooperative has initiated different sustainable activities like the campaign to reduce plastic bags, the promotion of local products outside the island and the technical study for the Renewable hybrid power plant.

In order to reach level 5, the transition team is waiting for the approval of its Sifnos Island Station project by the relevant authority and the newly elected Municipality Board.

Indicator: Financing concept

4

The transition team, in order to implement the Sifnos Hybrid Station is waiting for the "Production Permit" from the Relevant Authority of Energy (RAE) which will also determine the price of the power generated by the facility. Once the final prices will be announced, the Sifnos Island Cooperative will define and formalized the funding schemes.

In order to reach level 5, the transition team is waiting for the price of the electricity generated by the Sifnos Hybrid Station delivered by the Relevant Authority of Energy.

Indicator: Decarbonisation plan – Island diagnosis

4

A technical and economic analysis of the island energy system was conducted and submitted in 2018 by the Fraunhofer Institute for Energy Economics and Energy System Technology. The report presents a final energy consumption breakdown for electricity and several energy scenarios combining electricity generation and storage.

The electricity generation plan has been done, currently a Sustainable Island Mobility Plan (SIMP) is developed in Sifnos and the heating solutions will be look at a later stage.

Indicator: Decarbonisation plan - Data

3

An inventory of electricity consumption exists per sector. Regarding the transport, thanks to the information provided by the relevant organisations, the consumption of maritime transport was determined. The Sustainable Island Mobility Plan is currently collecting information in order to provide detailed data.

The transition team assessed itself as 3 in this category.

Indicator: Decarbonisation plan – Action Plan

3

The main action plan developed by the transition team is the implementation of the Sifnos Hybrid Station. In order to reach level 4, the project has to be approved by the newly elected Municipality Board and the Production Permit of the Sifnos Hybrid Station will allow to move to level 5.

Indicator: Multi-level governance

3

The municipality of Sifnos with the Sifnos Island Cooperative signed the Memorandum of Understanding where the parties agreed on their responsibilities towards the development of the Clean energy Transition Agenda. The Sifnos Municipality is supporting the Sifnos Island Cooperative in their actions. The transition team assesses this category as 3 and they are hopping to reach level 4 when the new Municipality Board will approve their vision. References

References

1. Statistics | Greece - Total Primary Energy Supply (TPES) by source (chart) [Internet]. [cited 2019 Aug 28]. Available from: https://www.iea.org/statistics/?country=GREECE&year=2016&category=Energy%20supply&indicator=TPESbySource&mode=chart&dataTable=BALANCES

2. Greece - Renewable Energy | export.gov [Internet]. [cited 2019 Aug 28]. Available from: https://www.export.gov/article?id=Greece-Renewable-Energy

3. Greece energy efficiency & Trends policies | Greece profile | ODYSSEE-MURE [Internet]. [cited 2019 Aug 29]. Available from: https://www.odyssee-mure.eu/publications/efficiency-trends-policies-profiles/greece.html

4. Energy Policies of IEA Countries - Greece Review 2017. 2017;143.

5. fernbas. National Energy and Climate Plans (NECPs) [Internet]. Energy - European Commission. 2019 [cited 2019 Aug 26]. Available from: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans

6. WIPOLex [Internet]. [cited 2019 Aug 27]. Available from: https://wipolex.wipo.int/en/legislation/details/17737

7. ΥΠΟΥΡΓΕΙΟ ΠΕΡΙΒΑΛΛΟΝΤΟΣ ΚΑΙ ΕΝΕΡΓΕΙΑΣ [Internet]. [cited 2019 Aug 27]. Available from: http://www.ypeka.gr/Default.aspx?tabid=37&locale=en-US&language=el-GR

8. REGULATORY AUTHORITY FOR ENERGY [Internet]. [cited 2019 Aug 27]. Available from: http://www.rae.gr/site/en_US/categories_new/about_rae/intro.csp

9. Home | ΛΑΓΗΕ [Internet]. [cited 2019 Aug 27]. Available from: http://www.lagie.gr/nc/en/home/

10. Home | ΑΔΜΗΕ [Internet]. [cited 2019 Aug 27]. Available from: http://www.admie.gr/nc/en/home/

11. StartPage [Internet]. HEDNO. [cited 2019 Aug 27]. Available from: https://www.deddie.gr/en/

12. CRES [Internet]. [cited 2019 Aug 27]. Available from: http://www.cres.gr/cres/index_uk.html

13. Pandey P, Kulmi P, Prasad AK. Sea Water Pumped Storage Power Plant-Concept Paper. 2016;17.

14. Union PO of the E. Li-ion batteries for mobility and stationary storage applications : scenarios for costs and market growth. [Internet]. 2018 [cited 2019 Jul 30]. Available from: https://publications.europa.eu/en/publication-detail/-/publication/e65c072a-f389-11e8-9982-01aa75ed71a1

15. ECONOMIDOU M. Energy renovation [Internet]. 2015 [cited 2019 Sep 3]. Available from: https://e3p.jrc.ec.europa.eu/articles/energy-renovation

16. Pratt JW, Klebanoff LE. Optimization of Zero Emission Hydrogen Fuel Cell Ferry Design With Comparisons to the SF-BREEZE. [Internet]. 2018 Jan [cited 2019 Jul 30]. Report No.: SAND2018-0421, 1513454. Available from: http://www.osti.gov/servlets/purl/1513454/

17. Fuel Cells [Internet]. Energy.gov. [cited 2019 Sep 3]. Available from: https://www.energy.gov/eere/fuelcells/fuel-cells

18. Hart D, Lehner F, Jones S, Lewis J, Klippenstein M. The Fuel Cell Industry Review. 2018.

19. Weidner E, Ortiz Cebolla R, Davies J. Global deployment of large capacity stationary fuel cells – Drivers of, and barriers to, stationary fuel cell deployment. 2019.

20. Hydrogen from renewable power: Technology outlook for the energy transition. :52.

The role of the EU Islands Secretariat was to advice the islands transition team and to facilitate the written agenda.

Published by the
Clean Energy for EU Islands
Secretariat