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Review Article

Energy Transition in Sifnos; A Patter for Economic and Social Development: A Review

Dimitris Al. Katsaprakakis*, Eirini Dakanali, Apostolos Dimopoulos, Giannis Gyllis

Department of Mechanical Engineering, University of Hellenic Mediterranean, Heraklion, Greece

ABSTRACT

Energy transition constitutes a major challenge for the whole planet. Once implemented following an effective, rational and fair approach, it can be the lever for sustainable economic and social growth for all citizens, especially for regions with high Renewable Energy Sources (RES) potential. The present article focuses on the effort of the Sifnos Energy Community (SEC) towards this direction. Typically, as all Aegean Sea islands, Sifnos has been blessed with remarkable wind potential, available on constant basis during the whole year (average wind velocity at 9 m/s). The intensive land morphology favors the installation of seawater Pumped Hydro Storage systems (PHS), with large storage capacity and minimized set-up cost. A Hybrid Power Plant (HPP) has been proposed for the island by SEC, as the main energy transition project in Sifnos. It consists of a 12 MW wind park and a seawater PHS with 860 MWh of storage capacity. The achieved storage capacity offers an autonomy operation period of 15 days. The PHS set-up cost, through its proper design and siting, is kept as low as 30 €/kWh of storage capacity. The HPP is capable to cover 100% electricity demand in Sifnos, including the anticipating additional load from the transition to e-mobility. The excess electricity production during the low power demand season (from October to May), can be absorbed for potable water production through reverse osmosis desalination plants and hydrogen production with an electrolysis unit. The potable water annual availability can be doubled, compared to the current annually consumed water amount, enabling the development of additional professional activities on the island, such as biological stock-farming and agriculture, assisting, in this way, the local economy to reduce its strong dependency on tourism. The produced hydrogen can be used to power a 200-passenger vessel and ensure secure and daily maritime interconnection of Sifnos with the neighboring larger islands in the Cyclades complex, solving once and for ever the issue of insularity in Sifnos. The plan of energy transition in Sifnos can constitute a pattern for social and economic development for all islands in the world.

Keywords: Energy transition; Hybrid power plant; Seawater pumped storage; Energy communities

INTRODUCTION

The Sifnos island

Sifnos is a small island located at the western part of the Cyclades complex, in the Aegean Sea, Greece, with a population of 2,625 and a total area of 73.9 km² (Figure 1).

The main occupations in the island are directly or indirectly connected with tourism. According to the Hellenic Statistical Authority, economy in Sifnos is more than 75% based on tourism. The island accepts more than 100,000 tourists every year, mainly from June to September. The strong dependence on tourism makes the local economy quire vulnerable and creates constantly a sense of insecurity in the local islanders.

Figure 1: The map of Sifnos and its geographical location in Greece.

Correspondence to: Dimitris Al. Katsaprakakis, Department of Mechanical Engineering, University of Hellenic Mediterranean, Heraklion, Greece, E-mail: dkatsap@hmu.gr

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Energy transition in Sifnos-The Sifnos energy community

With the term "energy transition" we refer to the substitution of the traditionally consumed fossil fuels for electricity and heat production and in the transportation sector with Renewable Energy Sources (RES) and the adoption of a pattern of Rational Energy Use (RUE). Energy transition has been introduced by the European Union as an essential objective for the Member States and has been in detail described, through the achievement of specific target in two main directives [1,2].

The initiative of Sifnos Energy Community, with main project the Hybrid Power Plant (HPP), vividly demonstrates the tensions in the European Union's efforts for Economic and Social Transition and Development. The initiative was ignited by the European Commission's call to the European citizens to be engaged in the urgently required energy transition of the European Union, back in 2012, for the rapid development of RES generated power as a cure to Europe's dependency on imported hydrocarbons, also contributing to climate change.

REScoop.eu, the European federation of citizen energy cooperatives, wholeheartedly responded to this call, pledging to fully support each and every citizen initiative towards the European Energy Transition goal and among them the initiative of the people of Sifnos who were particularly concerned on the island's 100% energy dependency on imported oil.

Indeed, so far, the onshore transportations in the island are exclusively based on liquid fossil fuels (diesel oil and gasoline). Electricity demand is more than 90% covered by eight diesel generators, of 1.1 MW nominal power each, installed in the local autonomous thermal power plant. The electricity production is integrated with a wind power of two wind turbines of 1.26 MW each and small, decentralized photovoltaic stations, with a total power of 335 kWp. The electricity production levelized cost was calculated, according to official data provided by the local utility, at 344.07 €/ Wh in 2015. During the current energy crisis, this feature should have been configured higher than 450 €/MWh.

Being aware of the energy transition necessity, the high dependency of the island on imported energy sources and the remarkably high energy cost, a core of citizens in Sifnos founded in 2013 the Sifnos Island Cooperative, transformed to Sifnos Energy Community (SEC) in 2020. The ultimate objective of SEC is to approach a fair, rational and effective energy transition in Sifnos, by achieving the maximum possible energy independency and ensuring, at the same time, energy democracy.

Hand in hand with REScoop.eu, after three years of volunteer dedicated team work, the Sifnian citizens and the friends of Sifnos managed to device a comprehensive and fully bankable plan for the Energy Autonomy of Sifnos through RES, in full compliance with the relevant legal and technical framework in Greece. The main energy transition project is a hybrid power plant, described more in detail in the next section. The application for the licensing of the first required permit for this project was submitted to the Regulatory Authority of Energy (RAE) in September 2016. This was not a small task, bearing in mind the particularities of an independent micro grid in a Non-Interconnected Island (NII) to the mainland grid with energy requirements decimal to the requirements of the mainland and consequently extremely few energy planning specialists were concerned with such niche markets.

LITERATURE REVIEW

The hybrid power plant of Sifnos

The proposed hybrid power plant (HPP) by SEC consists of a wind park and a Pumped Hydro Storage system (PHS). Wind Park was selected instead of photovoltaic as the RES unit of the HPP, due to the higher power density, which leads to minimum land occupation, and the remarkably high wind potential at the selected installation site, which imposes annual capacity factor above 40%, more than twice higher than the same feature of a photovoltaic plant at the same region. This practically means that with the same set-up cost (roughly at 1,000–1,200 €/kW), the wind park will produce more than twice higher electricity annually than the photovoltaic plant.

The annual average wind velocity at the wind park's installation site was calculated at 9.0 m/s at 10 m height above ground, according to the executed annual certified wind potential measurements. What is also highly important is the constant availability of wind potential through the whole year and particularly during summer, when the power demand maximizes due to the tourist season, unlike photovoltaic, which produce more than 60% of the annual production from May to September.

PHS was selected as the storage technology of the HPP, since it combines low levelized set-up cost with regard to the offered storage capacity (at the range of 50 €/kWh), storage capacities at the range of hundreds of MWh, long life period, at the range of plenty of decades, on the condition of proper maintenance, and maximized added value for the local economic, social and natural environment [3-5]. The proposed PHS for Sifnos should operate with seawater, given the low annual rainfalls with regard to the required water amount in the plant [6].

Similar plants have been widely studied and constitute a quite popular topic in the scientific literature. They have been proposed for both insular and mainland electrical grids [7-11]. The most common investigated issues are the maximization of RES penetration, the ancillary services provided by the PHS systems and their contribution to the electrical grids dynamic security and stability, the economic viability of the required investments etc.

Following the computational simulation of the HPP's annual operation and the ultimate objective of the sizing process to achieve clear 100% annual electricity coverage [12], the size of the HPP's components is summarized below:

- Wind park: Four (4) Enercon E-82/4 wind turbines with nominal power 3,000 kW each, giving a total wind park's power of 12 MW.

- PHS: Upper reservoir with storage capacity of 1,106,057 m^3 and absolute altitude of its free surface at its upmost position of 332 m, giving a total storage capacity of 860 MWh.

Hydroelectric power plant with four (4) Pelton hydro turbines with nominal power of 2.185 MW each, namely with a total plant's capacity of 8.74 W. A pump station with twelve (12) centrifugal pumps with nominal mechanical power of 0.857 MW each, namely with a total station's nominal mechanical power of 10.28 MW.

A couple of pipelines exclusively for the transportation of water from the upper reservoir to the hydroelectric power plant and another couple exclusively for the transportation of the pumped water from the sea to the upper reservoir, constructed with Glass Reinforced Polyester (GRP), with inner diameter of 1 m.

The annual electricity consumption, with the full transition of the onshore transportation sector to e-mobility, is estimated at 20,500 MWh, which gives a daily average consumption of 56.2 MWh. Given the achieved storage capacity of the PHS plant (860 MWh), it comes that the proposed HPP offers a 15 days autonomy operation period (full coverage of the power demand), starting from full charge level and without any intermediate storage during this period. This feature is extremely important with regard to the energy supply security of the insular system.

With the adopted size of the proposed HPP's components, the achieved annual electricity production and storage are summarized in Table 1. As seen in this table, the ultimate objective for 100%, clear electricity production is Sifnos, including also the anticipated future electricity consumption for e-mobility, has been achieved with the proposed HPP and the specific sizing (Table 1).

Table 1: Analysis of the annual electricity production in Sifnos in 2021.

Magnitude	Amount
Total initial annual production from the wind park (MWh)	44,961.40
Annual direct electricity penetration from the wind park (MWh)	4,627.80
Annual electricity production from the hydro turbines (MWh)	13,946.90
Annual electricity production from the existing wind park (MWh)	1,524.70
Annual electricity production from the existing photovoltaic (MWh)	257.3
Total annual electricity production (MWh)	20,356.70
Annual electricity consumption coverage from RES (%)	100
Annual electricity storage (MWh)	21,649.90
PHS system total average annual efficiency (%)	66
Annual electricity production from the wind park surplus (MWh)	23,311.50
Annual electricity surplus percentage over the wind park's production (%)	51.8

However, as also seen in Table 1, with the proposed sizing we have considerable electricity production surplus from the wind park. This result comes as a direct consequence of the over-dimensioning of the HPP, so as it will be able to undertake the increasing power demand during the summer months. This requirement leads to considerable electricity surplus during the rest period of the year, namely from October to May and it appears during periods of full upper reservoir of the PHS. Although this considerable electricity surplus features as a major drawback of the adopted plant and sizing, as it will be shown in the next section, it can be turned into a lever for sustainable social and economic development in the island, by being absorbed in activities aiming to heal essential problems in the island, such as the shortage of potable water or the inadequate maritime connection during winter.

The siting of the HPP was designed at the northeast coastline of the island and is depicted in Figure 2. Both the wind park and the PHS are sited at the same area, an achievement quite important for the minimization of the required infrastructure works (e.g. access roads), the captured land, the impacts on the natural and anthropogenic environment and, consequently, the minimization of the project's set-up and maintenance cost. It should be mentioned at this point that the installation position was selected from the scientific team together with the founding members of SEC. The aforementioned positive features reveal the potential when the technical expertise of well-experienced consultants is combined with the deep knowledge of the available territory, supplied by the local citizens, and their interest for the optimum possible results of their initiative (Figure 2).

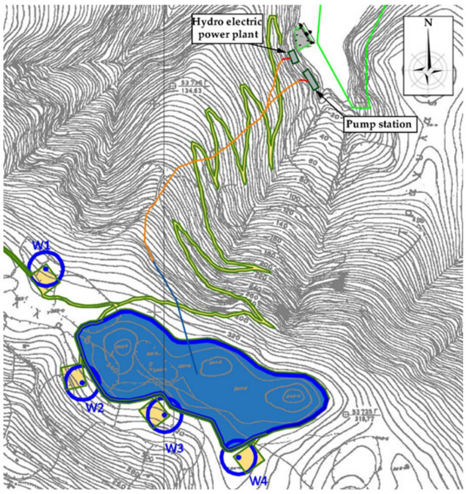

Figure 2: The siting of the hybrid power plant.

The proposed HPP in Sifnos exhibits three global innovations:

- It will be the first HPP of a wind park and a seawater PHS.
- It will be the first RES project which will clearly cover 100% the electricity and the transportation demand of an island.
- It will be the first RES project in an island aiming at 100% onshore energy coverage, implemented and owned by a local energy community.

DISCUSSION

Far more than an energy transition project, the proposed HPP is foreseen as a major infrastructure for holistic social and economic development for all islanders in Sifnos and a pilot initiative for all European Islands. This can be approached with the exploitation of:

- The anticipating project's profits for the implementation of essential infrastructures in the island.
- The electricity surplus for the operation of these infrastructures.

For example, a major problem of small islands like Sifnos in Greece, not equipped with an airport, is their maritime connection with the neighboring larger islands and the mainland country, particularly during winter. It has been shown that with the annual exploitation of approximately 6,900 MWh of the electricity surplus for the production of hydrogen through electrolysis, a daily cycling voyage of a 200 passenger vessel can be totally fueled, starting from the marine of Platis Yialos at the southern coast of Sifnos, passing from the marine of Pollonia at the northeast coast of Milos and then the port of Paroikia in Paros and the port of Ermoupoli in Syros (capital of the Cyclades Prefecture) and then back to Platis Yialos in Figure 3 [12]. In this way, the maritime connection of Sifnos with the neighboring large islands is ensured during the whole winter, all of them administrative centers in the Cyclades complex and equipped with airport (Figure 3).

Figure 3: Map of the potential cycling voyage for the daily maritime connection of Sifnos with the neighbouring islands.

Another crucial issue, common also for all southern islands in Greece and in the Mediterranean basin, is the low annual rainfalls, inadequate in most cases to cover even the essential demand for water supply in the settlements [13]. Currently, the annual potable water consumption in Sifnos is 600,000 m^3 , with 90% of this amount covered by municipal desalination plants. By assuming a specific electricity consumption of 4 kWh/m^3 in a reverse osmosis desalination plant, with the absorption of 5,000 MWh from the HPP's electricity surplus, 1,250,000 m^3 of potable water can be additionally produced. This practically increases more than twice the current availability of potable water in the island and offers the possibility for the development of new professional activities, such as biological agriculture and stock-farming, currently totally absent in Sifnos, which will enable the reduction of the local insular economy dependency on tourism.

Beyond the obvious direct benefits from the implementation of the aforementioned activities, it is also conceivable that all these additional electrical loads in the insular grid will increase the electricity demand and the finally penetration electricity from the HPP, eventually strengthening its economic viability.

CONCLUSION

The European Commission highly appreciated the proposed Sifnos Hybrid Power Plant project and elected Sifnos as the first Pilot Island in the "Clean Energy for E.U. Islands". Furthermore, it also invited the Sifnian people to represent European citizens in the "Energy Day" event, held in Katowice, Poland, in the United Nations organized COP24 summit to fight climate change. However, despite the broad acknowledge of the efforts of SEC in European level, SEC has not received so far the anticipated support from the Greek State.

In human history we observe an ever going straggle of people trying to gain the power to decide on their own affairs and governance systems trying to deny it. Whenever rules were laid for individuals who were allowed to struggle to bear fruit in accordance to these rules, sciences, arts, commerce, industry and even the military flourished, and wealth and prosperity reigned in these societies. On the other hand, whenever greed and control obsession prevailed, societies' achievements were minimal, in comparison. The current developments in the energy section in Europe, speak for themselves.

Sifnos, with only 2,500 inhabitants and 19 GWh electricity requirements, may seem small. But the effect that the non-progress of the Sifnos Hybrid Power Plant project bears on all those watching and deciding not to struggle to bear fruit, as it appears that there is no point in trying, is not so small. Nevertheless, the project is still alive, even though it is not kicking.

It is agreed, by most energy planning experts that the most effective method for seriously developing RES produced energy is in combination with large scale hydro storage systems. Hydro storage systems provide the cheapest and most sustainable energy storage capacity over lengths of time unseen by electrochemical batteries. Their only constrain is that they require large amounts of water, over a long period of time.

With climate change, drying of rivers and lakes is not just foreseen, it is already happening. It will not be long before the energy systems specialists realize that the only possibility for securing hydro storage systems and subsequently RES deployment, in the long run, is the seawater. At this point a viable prototype using sea water hydro storage system will be in great demand. And the engaged citizens of Sifnos will be there, ready to oblige.

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