LOCAL SUSTAINABLE ENERGY SYSTEM DEVELOPMENT IN AN INSULAR COMMUNITY: VENTOTENE, ITALY

February 2021

PRISMI PLUS

Transferring a toolkit for RES Integration in Smart Mediterranean Islands and rural areas

Deliverable title	RES feasibility study
Related Work Package:	WP 3 - Transferring
Related Activity:	Toolkit application in receiver territories
Start date of the Project:	16 February 2021
Duration:	16 months
Authors	Daniele Groppi, Davide Astiaso Garcia, Adriana Scarlet Sferra and Daniele Bruschi - Sapienza University of Rome
Reviewers:	---
Abstract:	Energy scenarios will be defined, modelled and simulated, emphasizing the different solutions that can be adopted, thus providing potential energy strategies. In the same framework, environmental and techno-economic feasibility analysis will be outlined.

Table of contents

List of Figures

List of Tables

Executive Summary

The PRISMI PLUS toolkit implementation for Ventotene Municipality Flagship Case (FC) is integrated with the current feasibility study and comparative analysis. The specific analysis renders available both the documents to guide the strategic energy planning actions of Ventotene as well as the modeling and the pre-and post-processing tools. Current and foreseeable energy scenarios have been developed and compared on the basis of the local RES potential data, also presented in detail, by means of the Programme's simulation tool (EnergyPLAN model), innovative energy production technologies have been considered.

The general definition of approach is shortly described in Section 2. Nevertheless, a detailed definition of the approach, as well as a definition and description of the tools which includes pre-processing tools, such as the wind speed and output power calculator and solar energy tools, simulation tool, that, is EnergyPLAN model, and the post-processing tool can all be found on the PRISMI PLUS website (link).

The current feasibility study is presented in Section 3, in which the modeling and simulation results for the energy scenarios devised are presented. The presentation includes the different adopted technology solutions and provides potential energy planning strategies and techno-economic feasibility analysis. The elaborate includes the description of the case study and the input data, the results of modeling with discussion, the socio-economic feasibility of adopted solutions, the environmental considerations, and the feasible strategy for the case study's area development.

At the end of the document, conclusions are drawn and suggestions for the future energy strategy of the Municipality of Ventotene are made.

1. General Definition of Approach

The PRISMI PLUS approach is comprehensively outlined in Figure 1, that describes the flowchart of using the PRISMI PLUS toolkit and the overall approach that should be adopted.

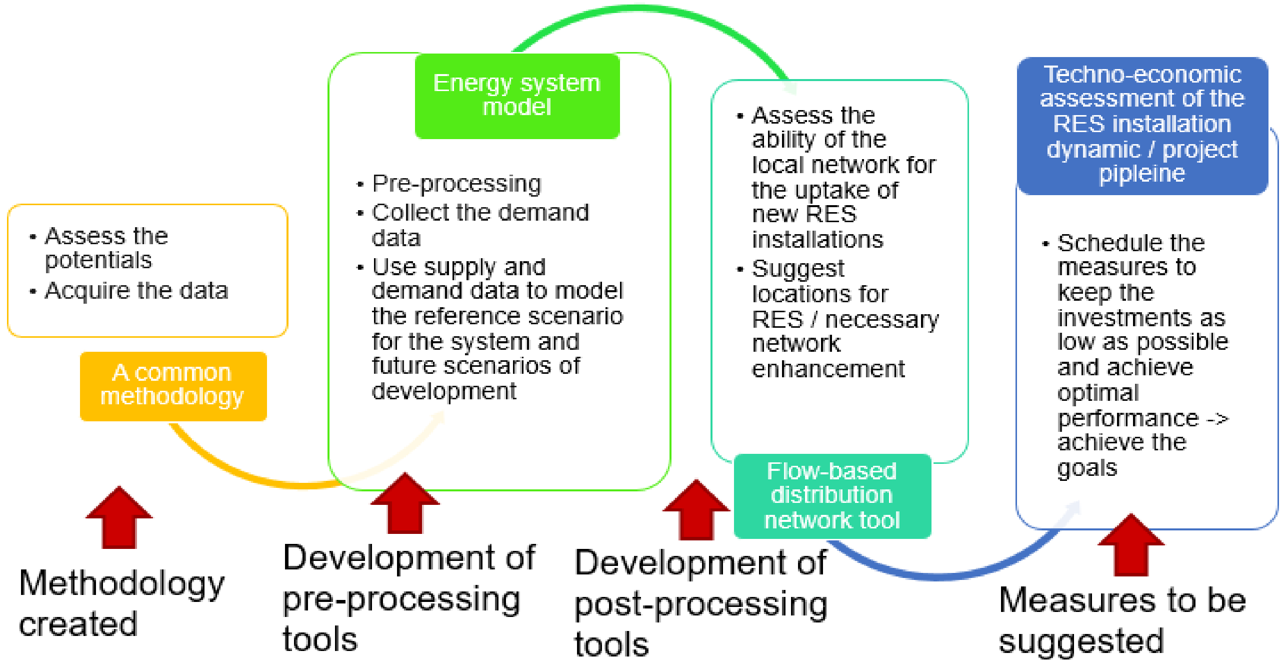

Figure 1 The PRISMI PLUS approach step-by-step

1.1 General framework method for devising the future development energy scenarios for the PRISMI PLUS case study considered

As the first step to devise the scenarios, the methodology (described in D3.1.1 of the PRISMI project) should be followed, dedicatedly adapted to Ventotene. Hence, the adapted methodology consists of the following actions:

Mapping the energy needs of the local municipality

Ventotene and REGEA (Horizontal project partner) provided the available data about energy consumption for electricity, heating, and transport with as much detail as possible about the subdivision in used energy vectors.

Mapping the locally available renewable energy resources

The data for the potential of locally available Renewable Energy Sources (RES) are collected in a form appropriate for analysis, in the context of providing a systematic overview for further research and deployment. This part of the process is also aided with the dedicated web tool "*Renewables.ninja*[1]" since the major renewable source that can

[1] Stefan Pfenninger, Iain Staffell, Long-term patterns of European PV output using 30 years of validated hourly reanalysis and satellite data, Energy, Volume 114, 2016, Pages 1251-1265, https://doi.org/10.1016/j.energy.2016.08.060.

be exploited is solar power. Other identified resources include biomass and geothermal energy but are not yet sufficiently mapped and investigated.

Technologies overview for bridging the gap between energy needs and energy resources

Appropriate technologies, which can exploit the locally available RES and are feasible for use on the location of the local municipality, are considered for the scenarios' analysis. Ventotene Municipality indicated the following technologies: PhotoVoltaic (PV), Solar Thermal collectors (ST), Electric Vehicles (EVs), Heat Pumps (HPs), Battery Energy Storage (BES), biomass electricity generators (BIO), geothermal electricity generators (GEO).

Division of scenarios

The energy system development is examined through three scenarios (LowRES, RES and HighRES). In such a way, the case study examined will have a short overview of available energy resources, present energy needs, and available technologies as the basis for devising the corresponding scenarios.

2. Case study examined – Municipality of Ventotene Flagship Case (FC)

First known as Pandataria, Ventotene island is, with Santo Stefano island, the eastern part of the Pontinian archipelago which comprehends also Ponza, Palmarola and Zannone. The island, 33 km far from Cape Circeo, has a maximum altitude of 139 m above sea level and a surface of 1,247 km^2. The climate is the typical Mediterranean one, as shown in Table 1, with mild winters and hot summers, high values of relative humidity, and consistent wind speed.

Table 1 Ventotene typical weather conditions

Month	Temperature (°C)	Solar radiation (MJ/m^2)	Wind speed (m/s)	Relative humidity (%)
January	12	6.4	6.1	66
February	11	10.2	6.3	65
March	11	14.0	6.1	65
April	14	17.9	6.0	68
May	16	22.1	4.4	71
June	20	23.5	4.4	69
July	24	23.3	3.6	68
August	24	21.6	4.0	67
September	23	16.9	4.3	63
October	20	12.4	5.3	66
November	15	8.4	6.1	65
December	13	6.0	6.4	67

From the demographic point of view the island's population varies from a maximum of 4,350 people in August to a minimum of 580 people in November, mainly due to the tourist vocation of the island and to the commuter residents. From the power generation viewpoint, Ventotene is not connected to the national grid. The energy production is provided by six diesel generators, respectively, a primary system, with a total peak power of 1.6 MW, and a back-up system, with two diesel generators (total peak power of 500 kVA). The primary system is oversized with respect to the winter minimum load around 150 kW but also to the maximum summer peak power load of about 1 MW. The fuel consumption trend, almost constant along the year for residential uses, undergoes remarkable variations in the nautical activity and the energy production, especially during summertime. The 60% of the distributed liquid fuel supplies the electricity generation system, while the other final uses are strictly related to the transport and nautical applications. It is remarkable that the low consumption of gaseous fuel for room heating applications is related to the high penetration of electric heating systems. The annual distribution of the electric load demand presents a marked summer peak confined in the July–August period with a maximum load around 1 MW, but mostly around 700 kW, while during the remaining portion of the year the power demand is below 400 kW.

As far as the water demand is concerned, in Ventotene, water is produced by the recently installed (2017) reverse osmosis desalination plant near the new port. After the desalinization process, the water is distributed to seven compensation reservoirs displaced along the island, for a total capacity of 2,800 m^3. The water adduction grid to the reservoirs is 2,600 m long, while the grid to the users has a length of 3,400 m. The hourly water consumption curve has been normalised from the electricity consumption curve with a corrective factor based on yearly consumption taking into consideration the Legambiente Report for sustainable Island 2021. The following graph (Figure 2) shows the electricity demand for the year 2019. Finally, it should be specified that, given the large increase in summer load due to the island's tourist vocation, the desalination plant requires an additional diesel unit to generate electricity. Since this additional load is not supplied by the public network, it does not appear in the annual load shown below.

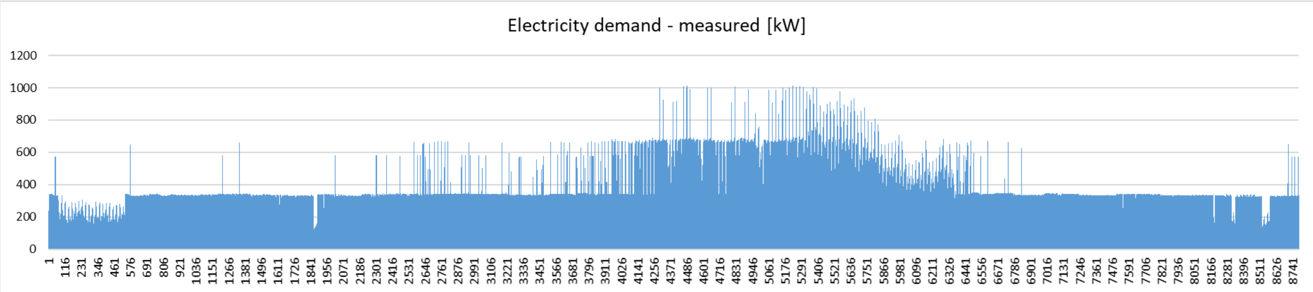

Figure 2 Ventotene power supply 2019

It should be noted that the stepped trend of the electricity generation curve is due to the recent installation (2015) of a 600 kWh electrical storage unit, which has significantly increased the efficiency of the island's thermal power plant.

Division of scenarios

The division of scenarios for the island of Ventotene followed the typical PRISMI methodology, starting initially with the base case study (the island's current energy situation). Secondly, a scenario in 2030 was evaluated with the objective of reaching a 50% renewable energy source (RES) penetration (RES Scenario). Finally, the most virtuous case was analysed aiming at 100% RES share (High RES scenario) and analysing the related issues in terms of grid stability. The different scenarios also had an increasing electrification of the transport sector and in particular the RES scenario considered only the option of smart charging while the HighRES scenario also included the possibility of Vehicle-To-Grid (V2G).

Table 2 Division of scenarios

2030	LowRES	RES	HighRES
PV [KW]	98	1300	2000
Biomass [KW-e]	0	0	400
Electrical storage [MWh]	0,6	2	2
EV not V2G mode [no. of vehicles]	0	177	0
EV in V2G mode [no. of vehicles]	0	0	354
EV connection [MW]	0	0	2,5
EV demand [MWh]	0	0	167
EV battery [MWh]	0	0	11,4

Most of the integration of renewable energy on the island will have to be achieved through the installation of new photovoltaic power (1.3 MW for the RES scenario and 2 MW for HighRES). However, this will not rely on large ground-mounted installations. The problem of available space when it comes to one of the smallest islands in the Mediterranean protected by a nature reserve (where there is an absolute ban on ground-mounted photovoltaic installations) is something to be seriously addressed. Photovoltaic can be integrated on the roofs of residential and public buildings, but since large ground-mounted installations cannot be considered, they cannot exceed a certain threshold. A biomass plant, on the other hand, has a much higher ratio of installed kW to required square metres. Moreover, Ventotene is an island with a strong agricultural sector, so it could produce agricultural waste in adequate quantities and reuse the waste from the electricity production process as agricultural fertiliser.
The wind resource, although present as on almost all islands, remains absent in the planning of Ventotene both because of the above-mentioned problem of space and because of the important characteristic that makes Ventotene one of the islands of passage for migratory birds. Many studies have confirmed that various types of wind turbines could disturb this transit. Thus, also offshore plants are not considered.
The increase in the island's electricity demand due to the transition to 100% electric mobility is illustrated below. Using the V2G (High RES Scenario) the increase in demand goes hand in hand with the increase in storage capacity.

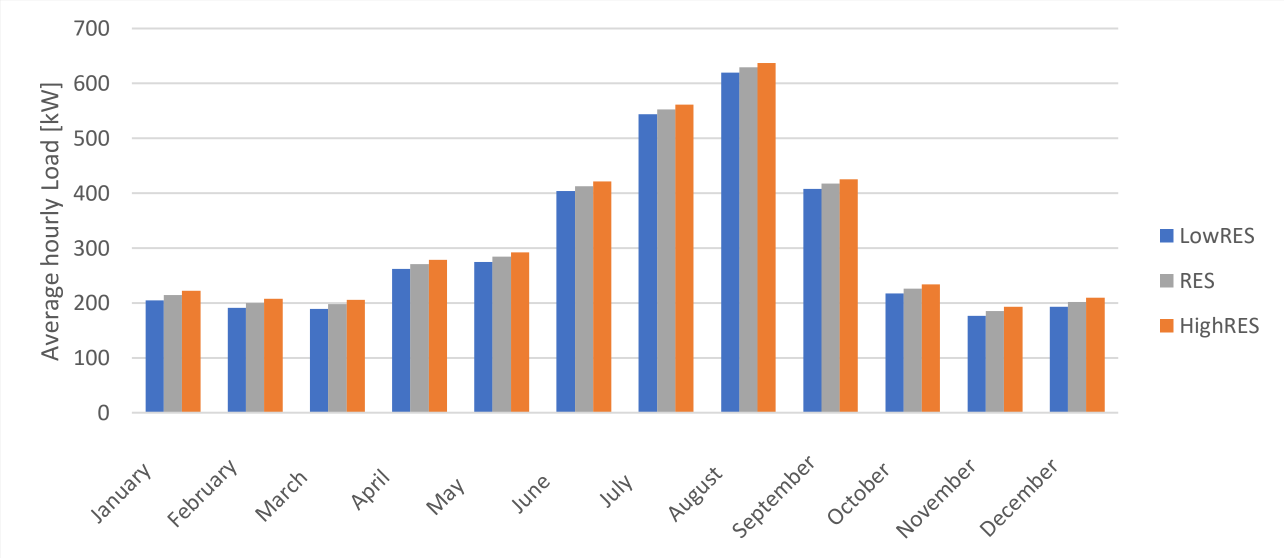

Figure 3 Demand average for each scenarios

In this graph, the consumption of the desalination plant is not included. Nevertheless, in all the simulations and analysis, the desalination plant has been considered to be connected to the power grid in order to exploit the flexibility potential that it could offer. At the same time, in order to control grid problems due to the integration of the photovoltaic source (which is non-dispatchable), the increase in generation was followed by an increase in the size of storage, which was necessary in order not to exceed the critical threshold (5%) of the so-called CEEP (Critical Excess in Electricity Production).

Table 3 Critical Excess in Electricity Production

Scenarios	LowRES	RES	HighRES
CEEP (%)	0	3,9	2,3

2.1 Results of modelling and discussion

Results of modelling are presented in Figure 4 and Figure 5 in terms of RES share in PES and in electricity, respectively.

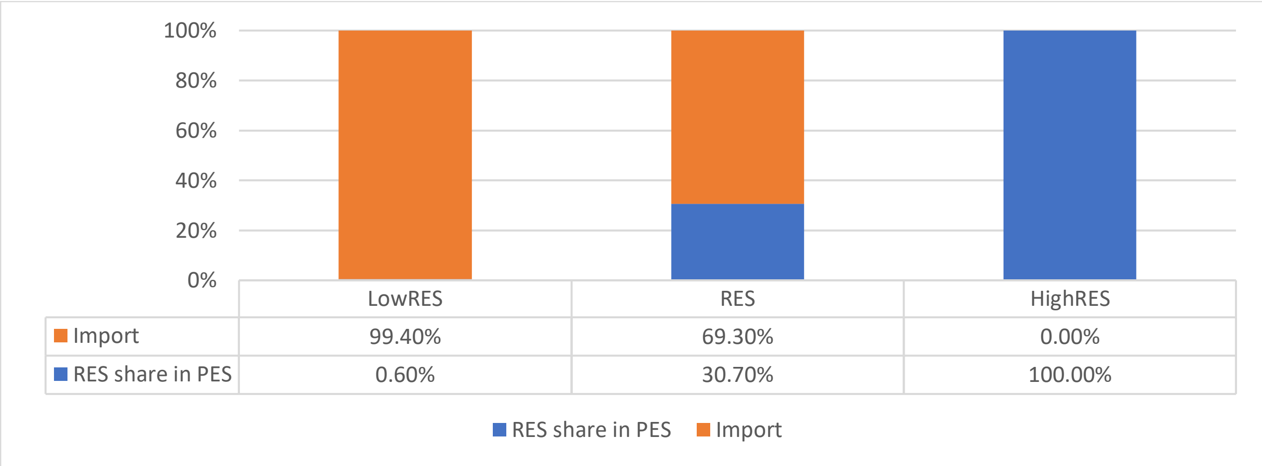

Figure 4 RES share in primary energy supply

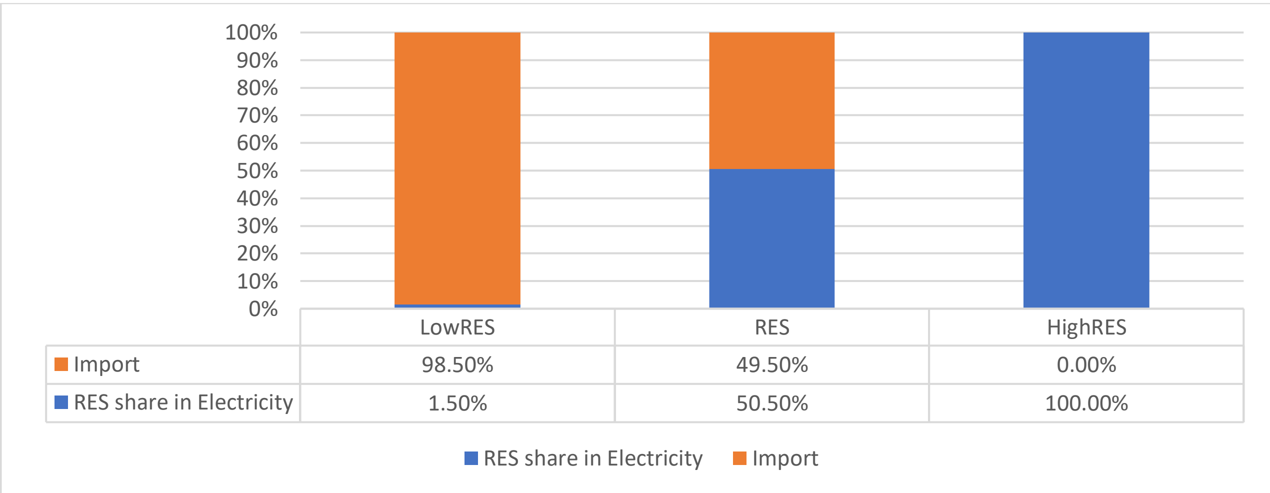

Figure 5 RES share in electricity production

Figure 5 clearly shows the increase in the RES generated electricity. In the case of RES, the increase is exclusively due to the newly installed PV for a total of 1.3 MW. In the HighRES scenario, 100% independence from fossil fuels is achieved by replacing the current fuel with biomass (partly produced locally and partly imported from neighbouring areas) and increasing the PV installations by 700kW compared to the RES scenario for a total PV installed power of 2 MW.

Table 4 RES percentage of RES penetration

Scenario	RES share in PES	Import

LowRES	0.6%	99.4%
RES	30.7%	69.3%
HighRES	100%	0%
Scenario	RES share in Electricity	Import
LowRES	1.50%	98.5%
RES	50.50%	49.5%
HighRES	100%	0%

The following two graphs analyse the monthly trends of the different energy sources that would make up the island's energy mix in the medium (RES) and long term (High RES). In particular, Figure 6 considers the High RES case in which all energy is produced from renewable sources. In this situation, the contribution of V2G is fundamental as it allows the use of biomass to be reduced in the intermediate seasons (for example, it can be seen that there is no need for biomass in March). The latter remains however fundamental to cover the summer peaks due to tourism and the winter difficulties due to the few hours of sunshine.
The importance of V2G to ensure adequate grid flexibility is confirmed by the analysis in Figure 7 where we have graphed the energy mix of the RES scenario. In this case the contribution of the diesel generator remains significant and exceeds 50% of the consumption in the summer months. Ultimately, we can say that Smart Charging helps to optimise the uptake of renewables, but V2G is needed to achieve higher RES shares and avoid too high CEEP (Critical Excess in Electricity Production) values.

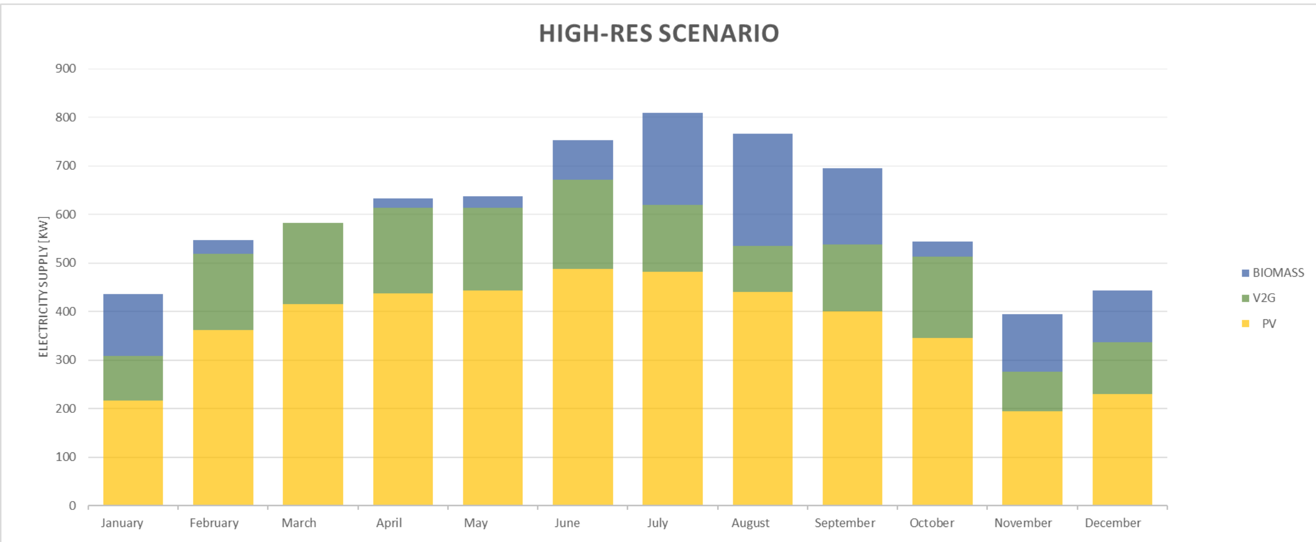

Figure 6 Monthly electricity supply HighRES scenario

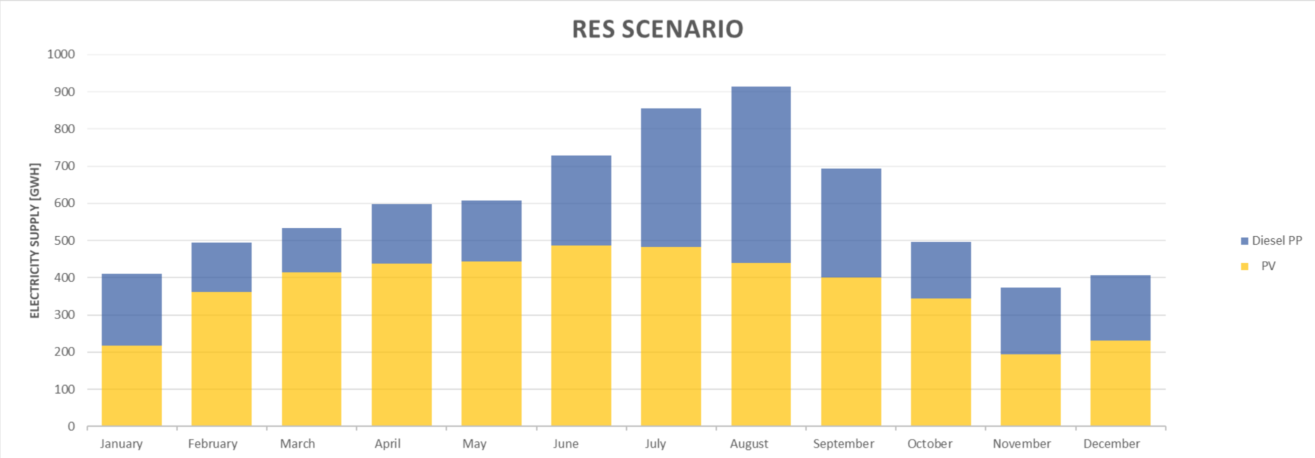

Figure 7 Monthly electricity supply RES scenario

2.2 Socio-economic feasibility of adopted solutions

As can be seen from the table below (Table 5), the largest expenditure is on EVs, but thanks to that expenditure the need to increase storage remains limited to 2 MWh. The use of V2G in the HighRES scenario makes it possible to keep the size of electrical storage unchanged compared to the RES case while at the same time increasing the PV park. In terms of grid flexibility, therefore, the use of V2G makes feasible to limit the use of batteries and expand renewable generation while keeping CEEP under control.

Table 5 Technology costs

Technology	Investment	O&M	Lifetime
EV [kEUR/unit]	30	6.50%	10
Biomass [kW-e]]	1.5	3%	15
PV [kEUR/kW	2	2%	20
Storage (kEUR/kWh)	0.5	2%	15

Cost of investment per RES technology for two scenarios [kEUR].

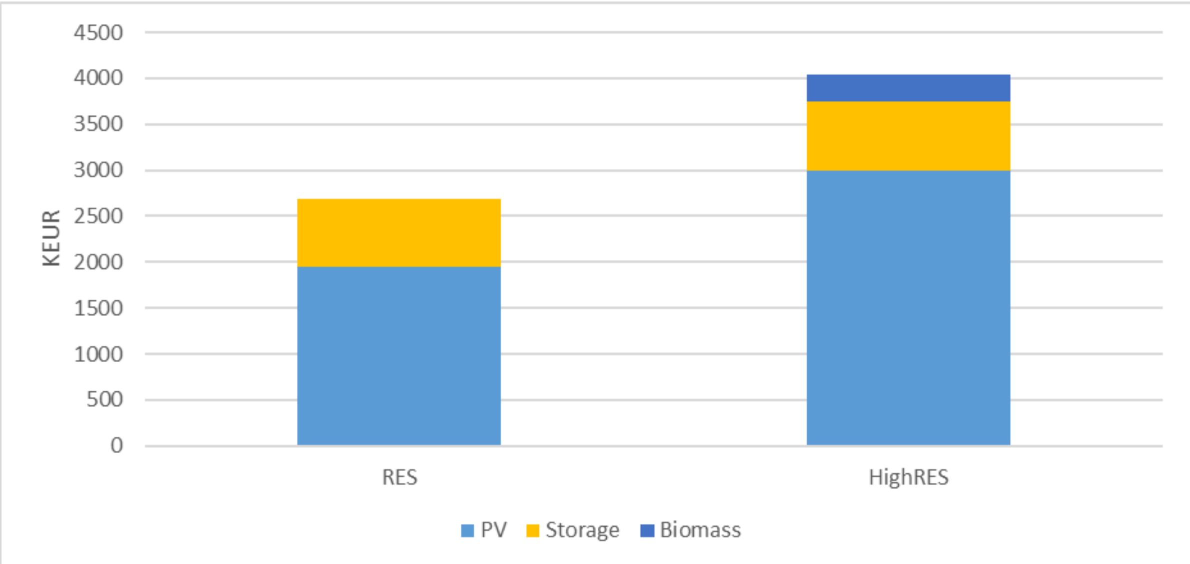

Figure 8 Cost of investment per RES technology for two scenarios

Considering both the cost of electric vehicles (graphed in Figure 9) and the cost of power generation technologies, we can see that the cost of switching from the current to the RES scenario is about the same as the cost of switching from the RES to the HighRES scenario.

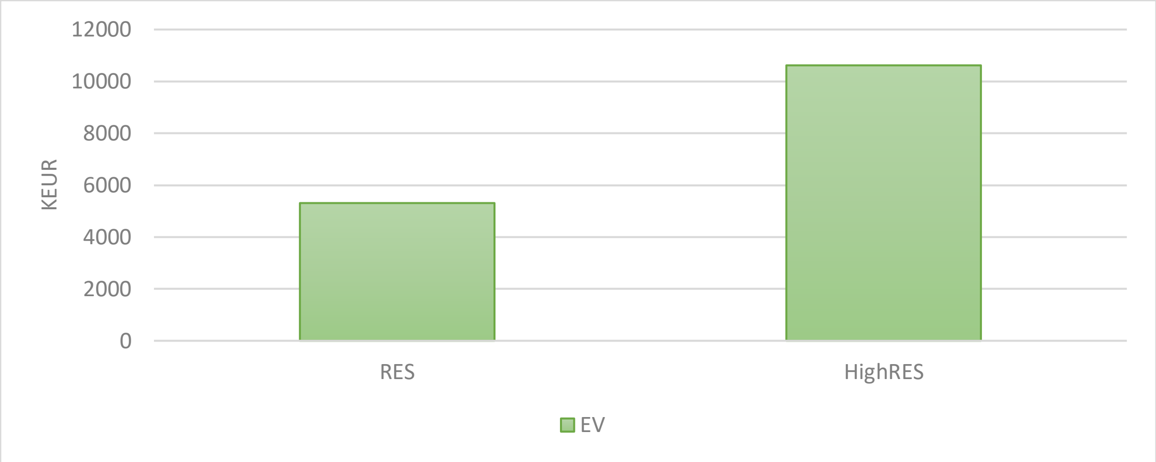

Figure 9 Cost of investment for Electric Vehicles

Although they are among the highest costs, EVs are also the most incentivised and quickest to pay back. Also, in the National Recovery and Resilience Plan (NRRP) for green islands there is a chapter of incentives to facilitate private individuals in the transition to electric mobility.

As regards the employment impact of these interventions on the island's fabric, we can say that the installation of 1.2 MW of photovoltaic power could lead to the creation of a small team of 2-3 people responsible for the routine maintenance of the new (and existing) installations. At present, in fact, maintenance work for private individuals is extremely expensive due to the distance between them and the companies responsible for the maintenance of these installations, which sometimes makes the investment unprofitable. At the same time, the introduction of a small biomass plant could, on the one hand, convert the work of the operators of the existing diesel power plant and, on the other hand, create additional jobs in the sector of agricultural waste collection and fertiliser redistribution.

2.3 Environmental considerations

From an environmental point of view, the reduction of polluting emissions on the island of Ventotene is even more important as it is a marine and terrestrial nature reserve. Figure 10 shows the map of the Marine Protected Area.

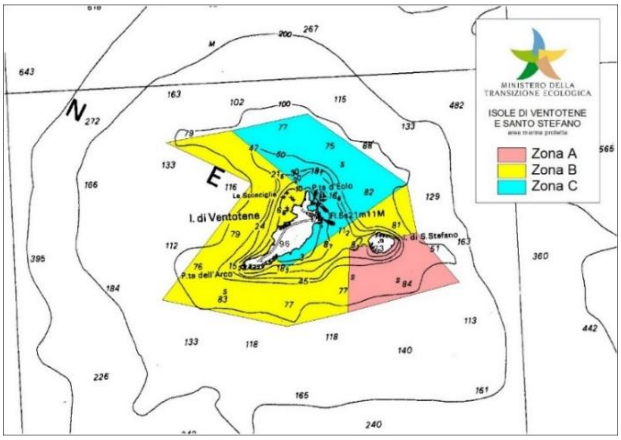

Figure 10 Ventotene Marine Protected Area

Founded in 1999, the marine and terrestrial reserve aims to preserve the island's typical marine and terrestrial flora and fauna through targeted environmental protection measures. The installation of technologies for the production of energy from RES has undergone several difficulties over the years due to their size and visibility. Installing technologies such as wind and wave power plants, although promising, has never yet been proposed because they could disturb the native fauna. This is why this study has chosen PV as the main technology to invest in.
In Figure 11 and Table 6, we noted the positive impact in terms of Greenhouse Gas (GHG) emissions obtained thanks to the increased energy production from RES and the electrification of the transport sector.

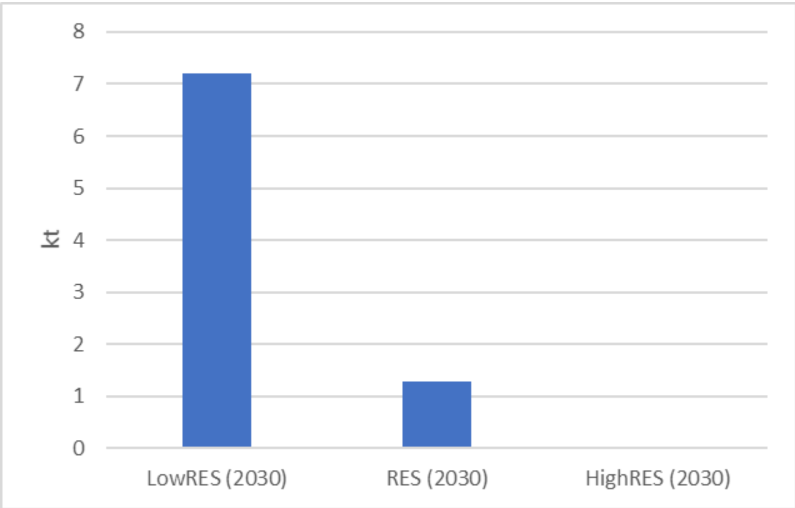

Figure 11 GHG emission for each scenario

Table 6 GHG Emissions

Scenario	GHG Emissions [kt]
LowRES (2030)	7.20
RES (2030)	1.27
HighRES (2030)	0

2.4 Suggestions for the development strategy

In light of the obtained results the following suggestions can be made. The island of Ventotene still has great unexplored potential for electricity generation from renewable energy sources. However, the design and integration of such technologies in the area is not easy and requires a thorough analysis of the resources and an intimate knowledge of the territory. This is why the recent establishment of the Ventotene Energy Community could be a solution both to the problem of knowledge of the territory and to the active participation of citizens. If the municipality firmly supports such a community, it could ensure the widespread integration of photovoltaic technology on almost all the island's roofs within a few years, thus avoiding the installation of large photovoltaic systems that are harmful both from an aesthetic and environmental point of view.

To accelerate the energy transition, energy policies should go hand in hand with residential and tourism policies. The most difficult challenge from an energy point of view is precisely that of having to satisfy two very different demands: a summer demand with peaks of 5.000 inhabitants and a winter demand with just over 300 inhabitants. The seasonal adjustment of the tourist offer is therefore something that both the island's economy and its electricity network need.

Another accelerator of the transition can also be the proper allocation of the PNRR[2] funds for the Green Islands, which are aimed precisely at making the island's electricity system more efficient. Although the integration of large plants is unthinkable (nor desirable) thanks to the rules of the nature reserve, Ventotene could benefit from widespread micro-generation by aiming to make all residential homes and municipal buildings as energy self-sufficient and efficient as possible. The integration of 1.2 MW of photovoltaic power proposed by this study is therefore not to be understood as a large photovoltaic park but as hundreds of small public and private installations spread throughout the territory. The integration of such a widespread photovoltaic park will take time and can only be accelerated by targeted private incentive policies, which is why it is assumed that the medium-term scenario (RES) and long-term scenario (HighRES) can be reached in 2030. In order to solve the space problems that the island certainly suffers from, small solar floating spots could also be considered if they are compatible with the Marine Protected Area.

A final important theme that emerged from this study is the need for electrification of transport. Making Ventotene an island with only electric vehicles would, on the one hand, reduce GHG emissions into the atmosphere and, at the same time, allow easier integration of the solar source without damaging the flexibility of the grid thanks to Vehicle to Grid system.

In conclusion, it seems certain that real territorial cohesion and co-planning on these issues, bringing together the Municipality and the Community, will be the key to a profound transition.

[2] The National Recovery and Resilience Plan (PNRR)- provides EU-funded financial support to member states for post-pandemic economic recovery, reforms, and sustainable growth

3. Conclusions

In the current study, the scenario approach in energy systems modelling has been used to model the future scenarios for Ventotene Municipality. Moreover, the EnergyPLAN model has been identified as the main simulation tool for energy scenarios, owning to its user-friendliness and performance, proved through past research works. For the purpose of facilitating the future use of the PRISMI PLUS toolkit, various renewable energy sources were identified and modelled in the most ambitious scenario, as well as several energy system flexibility options (V2G, heat pumps). Thus, the subsequent development of an energy strategy is to great extent facilitated.

The methodology that has been applied includes the description of the case study and input data, the results of modelling accompanied by dedicated discussion, the socio-economic feasibility of adopted solutions as well as potential environmental considerations. All the energy scenarios analysed the diversification of RES production to serve the corresponding energy needs. From this study, interesting measures have been identified and then proposed as suggestions for the development of strategic energy planning documents.

Recapitulating, the present study has demonstrated the possibilities to increase integration of locally available renewable energy sources (more precisely, solar energy and biomass) and ways to achieve it without disturbing the island's native fauna. Considering the limited space which can be used for energy production and storage, EVs and V2G technology represent an interesting opportunity since they could also support the energy system through flexible services that could avoid the need for large energy storage systems.
Such energy transition can lead the considered Municipality towards the sustainable and energy self-sufficient city concept and create new local job opportunities, putting the end-users in the centre of energy transition.

4. References

Department of Development and Planning, Aalborg University, n.d. *EnergyPLAN: Introduction*. Available from: https://www.energyplan.eu/ (Accessed at October 2021).

European Commission, 2021. *Photovoltaic Geographical Information System (PVGIS)*. Available from: https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html (Accessed at October 2021).

European Commission, 2020. *Natura 2000 data and maps*. Available from: https://natura2000.eea.europa.eu/ (Accessed at October 2021).

European Commission, 2018. *Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP)'*. Available from: https://e3p.jrc.ec.europa.eu (Accessed at October 2021).

International Renewable Energy Agency (IRENA), 2020. *Renewable Energy and Jobs – Annual Review 2020*. Available from: https://www.irena.org (Accessed at October 2021).

ISTAT, 2019. Statistiche ISTAT [WWW Document]. URL http://dati.istat.it/?lang=en Pfeifer, A; Dobravec, V; Pavlinek, L and Krajačić, G., 2017. Integration of renewable energy and demand response technologies in connected island systems – Case study of islands of Vis, Lastovo, Korčula, Mljet and Pelješac. *SDEWES 2017*, Dubrovnik, Croatia (4-8 October).

Ram, M., Aghahosseini, A. and Breyer, C., 2020. Job creation during the global energy transition towards 100% renewable power system by 2050. *Technological Forecasting and Social Change* **151**(3): 119682, pp. 1-19.

Renewables.ninja, n.d. Available from: https://www.renewables.ninja/ (Accessed at October 2021).