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LOCAL SUSTAINABLE ENERGY SYSTEM DEVELOPMENT IN AN INSULAR AREA : MUNICIPALITY OF GOZO, MALTA

June 2018

Project co-financed by the European Regional Development Fund

PRISMI

Promoting RES Integration for Smart Mediterranean Islands

Deliverable title	D3.4.2 RES feasibility study and comparative analysis
Related Work Package:	WP 3 - Studying
Related Activity:	PRISMI toolkit development – Energy scenarios modelling
Start date of the Project:	1 November 2016
Duration:	18 months
Authors	Antun Pfeifer, University of Zagreb, Faculty of mechanical engineering and naval architecture – UNIZAG FSB Goran Krajačić, UNIZAG FSB Neven Duić, UNIZAG FSB Milan Vujanović, UNIZAG FSB Boris Ćosić, UNIZAG FSB Tomislav Novosel, UNIZAG FSB Viktorija Dobravec, UNIZAG FSB Filip Jurić, UNIZAG FSB Giannis Kanaris, CEA Harris Kordatos, CEA Erika Massa, MIEMA Daniele Groppi, SAPIENZA Daniele Bruschi, SAPIENZA Davide Astiaso Garcia, SAPIENZA Christoforos Perakis, CRES Georgios Nomikos, PUAS Emilia Kondili, PUAS Ioannis Kaldellis, PUAS
Reviewers:	Christoforos Perakis, CRES
Abstract:	Energy scenarios will be defined, modelled and simulated emphasizing the different adopted

	solutions and providing potential energy strategies. Moreover, environmental and techno-economic feasibility analysis will be outlined

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Executive summary

The PRISMI PLUS toolkit implementation for the Island of Gozo 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 Gozo 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 Island of Gozo are made.

1. General definition of approach

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

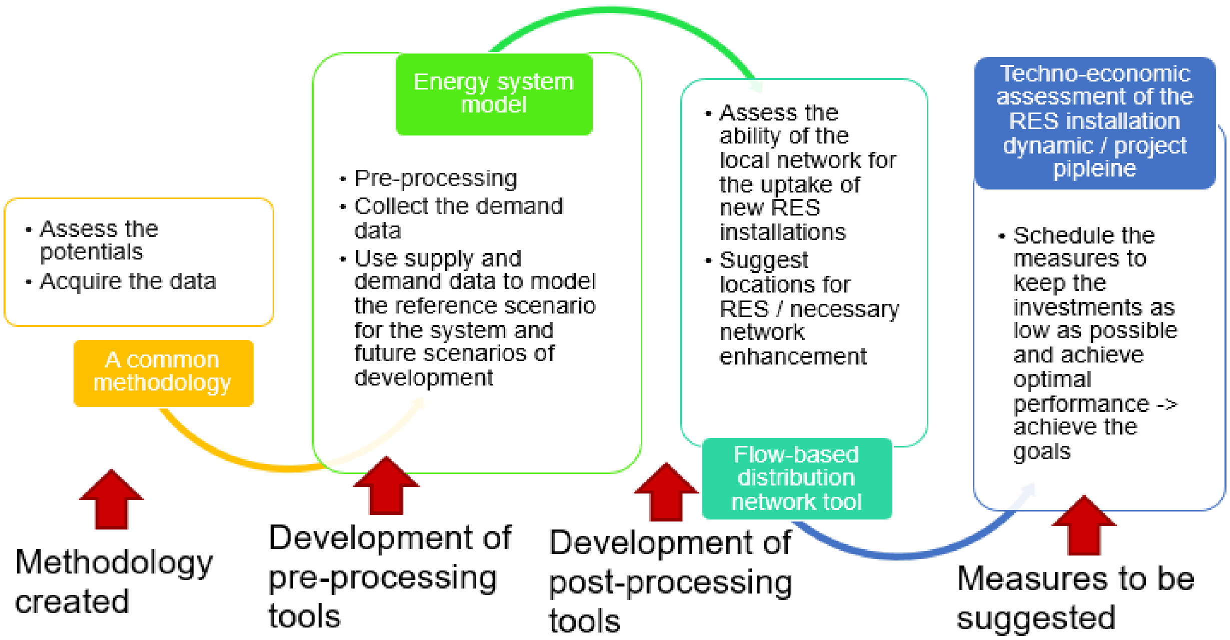

Figure 1 The PRISMI approach step by step

1.1. General framework method for devising the scenarios of future development for PRISMI case study areas

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 Gozo. Hence, the adapted methodology consists of the following actions:

Mapping the energy needs of the island community

The island of Gozo 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 the 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 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. The Island of Gozo indicated the following technologies: Photovoltaic (PV), Solar Thermal collectors (ST), Electric Vehicles (EVs), Heat Pumps (HPs), Wind Turbines (WT), Wave and Tidal energy, Vehicle-to-Grid approach (V2G)

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.

[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.

2. Case study examined- Island of Gozo Flagship Case (FC)

Gozo is an island in the Mediterranean Sea pertaining to the Maltese Archipelago which includes the islands of Malta, Gozo, Comino as well as several little islets. The total area of Gozo Island is about 69 km^2 and, according to the census of March 2014 the population is considered to be about 37,300 inhabitants representing approximately 8% of the entire national Maltese population, with a density of 540 inhabitants/km^2. Gozo has separate environmental and cultural assets, whose sustainable exploitation could be used productively for the development of the island region as well as the national economy.
The main land use in the islands of Malta, as in Gozo, is agriculture, which covers almost half the land area, while the other half is covered by Natural habitats and urban/developed areas. Consequently a large proportion of the population of Gozo deals with farming and agriculture. In general, 32% of agricultural land is found within Natura 2000 sites throughout the Maltese Islands. Gozo has significant protected areas, which include two Areas of Ecological Importance / Sites of Scientific Importance (AEI/SSI), one Special Area of Conservation (SAC) of International Importance and one Special Protected Area (SPA).
Concerning the electricity production, there are no power stations in the Gozo Region and the area is supplied with electricity from Malta via three submarine cable circuits which pass over the island of Comino. Average electricity consumption for the Island of Gozo is about 420 GWh/year.

In accordance with the PRISMI method, 4 steps of energy planning are observed:

Table 1 Mapping the needs of the island community - Gozo

Needs	Level	Geographical Distribution	Code
Electricity	Medium	Concentrated	ElectMC
Heat	Low	dispersed	HeatLD
Cooling energy	Low	dispersed	ColdLD
Fuel for transportation	Low	Short dist.	TranLS
Water	Medium	dispersed	WaterMD

Processing waste	Low	dispersed	WasteLD
Wastewater treatment	Low	dispersed	WWTLD

Table 2 Mapping the resources available – Gozo

Resources	Level	Code	Resources	Level	Code	Resources	Level	Code
Local primary energy			Infrastructure for energy imports			Water		
Wind	Medium	WindM	Network connection	Normal	GridN	Rainfall	Low	H2OPL
Solar	High	SolarH	pipeline natural gas	n/a	NGplN	Groundwater	Low	H2OGL
Water potential (altitude drop)	Medium	HydroM	Terminal LNG	n/a	LNGtN	Water supply	Yes	AquaY
Biomass	Medium	BIOMM	Oil terminal / refinery	n/a	OilRN	Seawater	Yes	H2OSY
Geothermal potential	Low	GeothL	Terminal petrol. production	n/a	OildDN			

Technologies overview

From the step two of the method, one of the resources is rated as high potential: solar. From a RES potential point of view, Gozo is inserted in the context of a country with the highest overall solar irradiation in Europe. PV accounts almost exclusively for all RES power production on Malta so far, and is anticipated to be the most relevant contribution to the achievement of Malta's country specific decarbonisation targets. From the statistics of 2015 of the National Statistics Office of Malta, it is shown that the stock of PV installations by district in the last few years have increased significantly. Thus, it can be said that solar energy is the most exploitable RES in the island. For this energy simulation the available area for solar PV installation was calculated. For Gozo being a small Municipality, the calculation of available area took in consideration the introduction of large PV installations on the rooftops of dwellings located in the main industrial district of the study area of Gozo. The rooftop area available is calculated to be approximatively 26.780 m2 and the installation will result in a range of 25 MW (with 6.5 m2/kW).

Although wind power is not only temporarily ruled out by any regulation in Malta, it represents another interesting resource for the island. Wind power however in the long term, could be utilized only to a limited extent due to geographical constraints and the environmental constraints, which presently prohibits the wind turbine installations.

Similarly, biomass has an average potential although the potential of solid biomass is too low for effective energy production. However, biomass produced inland remains underutilized. On the other hand, biodegradable waste is beginning to be used on Malta's main island, where the existing waste plant processes the degradable portion of waste for biogas production.

Although there are many pilot projects considering the implementation of tidal and wave energy in Malta, because of the undeveloped technology, they are only taken in consideration in most ambitious case.

Division of scenarios

The fourth step of the method is the division of scenarios. Energy system development of the island of Gozo has been examined in three scenarios:

1) LowRES – following the same dynamics of RES use, as already proposed in actual SEAP-s, adding PV to 50% of rooftops available
2) RES – Increasing the use of RES, taking into consideration environmental constraints and legislative framework
3) HighRES – Modelling for a 100% RES energy system of the island

In the first scenario Business As usual, BAU, (LowRES), besides adding a significant share of PV, it will also consider solar thermal technologies for households and probable support electrification of transport in a limited way. This latest can be prescribed through SEAP-s, as for instance the adoption of electric bicycles, dump charge vehicles, etc).
In the second scenario (RES), it is envisioned the replacement of all heating in households with heat pumps and solar collectors and 50% of the transport on smart charging and vehicle-to-grid concept. In addition, all available rooftops and ground-based PV plant will make up for a total addition of 25 MW of PV).
Finally, in the last scenario (HighRES), Gozo goes towards 100% renewable system. This includes the RES scenario with wind, wave and tidal as well as, 100% electrified transport.

Currently, Sustainable Energy and Climate Action Plans were developed on 6 localities of Gozo, i.e. municipality of Ghajnsielem [2010], Gharb [2011], Xewkja [2010], Victoria [2012], Qala [2012], Xaghra [2010]. These action plans were used to acquire the basic data from the baseline inventory.

Table 3 Input data for modelling of development of Gozo energy system

2030	LowRES	RES	HighRES
PV [MW]	9.5	32.5	32.5
Wind [MW]	0	0	15
Offshore wind [MW]	0	0	20
Tidal [MW]	0	0	2
Electricity demand [GWh]:	175	175	175
Total electricity demand [GWh]:	193.29	208.29	224.96

Although the SEAPs are not very up to date, it was possible to assess the proposed measures and energy and use them as a starting point for energy planning. Based on this approach, calculations for potential PV installations are presented in the table. Considering the method for solar power shown in the description of the study area and input data, the possible installed capacities of PV have been calculated.

2.1. Results of modelling and discussion

Results of modelling are presented in single figures for all three scenarios, to be easily comparable.

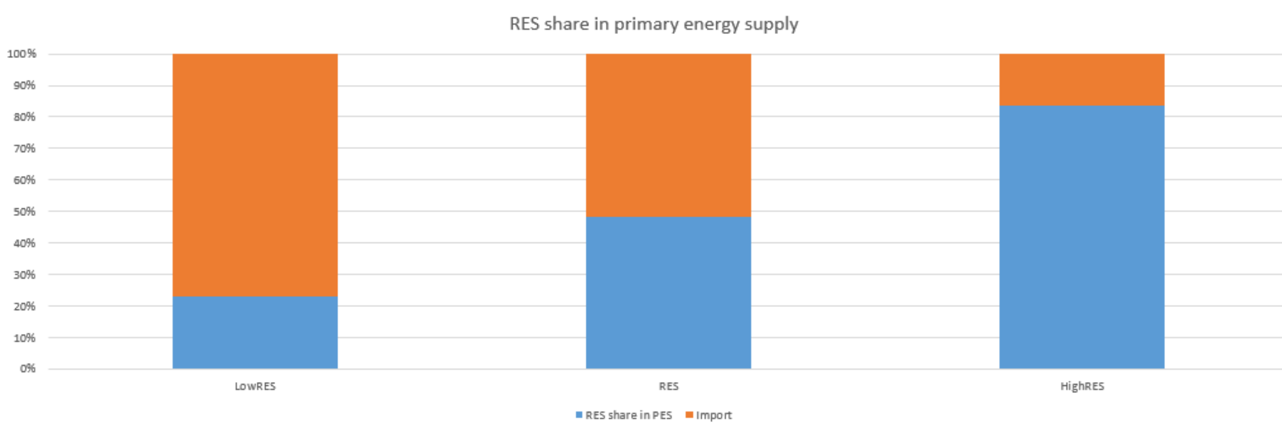

Figure 2 RES share in primary energy supply

For each scenario, the combination of RES sources is used, as presented in table 4.

Table 4 Results of modelling - RES production

LowRES			RES			HighRES		
RES prod.	17.11	GWh/year	RES prod.	58.52	GWh/year	RES prod.	170,3	GWh/year
Solar	17.11	GWh/year	Solar	58.52	GWh/year	Solar	58.52	GWh/year
Wind	0	GWh/year	Wind	0	GWh/year	Wind	44.4	GWh/year
Tidal and Wave	0	GWh/year	Tidal and Wave	0	GWh/year	Tidal and Wave	0.82	GWh/year
Hydro	0	GWh/year	Hydro	0	GWh/year	Offshore	59.2	GWh/year

Also, following these amounts of generated energy, the following figure represents the RES share in electricity production.

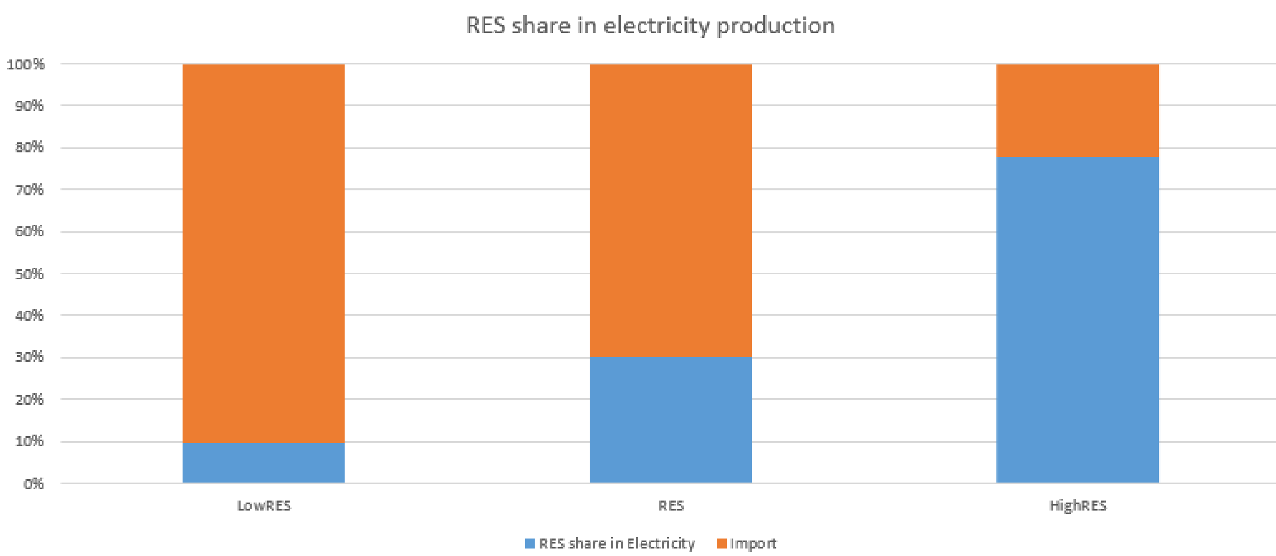

Figure 3 RES share in electricity production

In the following figures, the share of particular technologies (in this RES scenario, only PV) in electricity supply is illustrated.
For the LowRES scenario, Figure 4, the impact of minor addition of new PV power plants on electricity supply is visible. The dynamics of implementation of measure does not lead to significant change in the status quo.

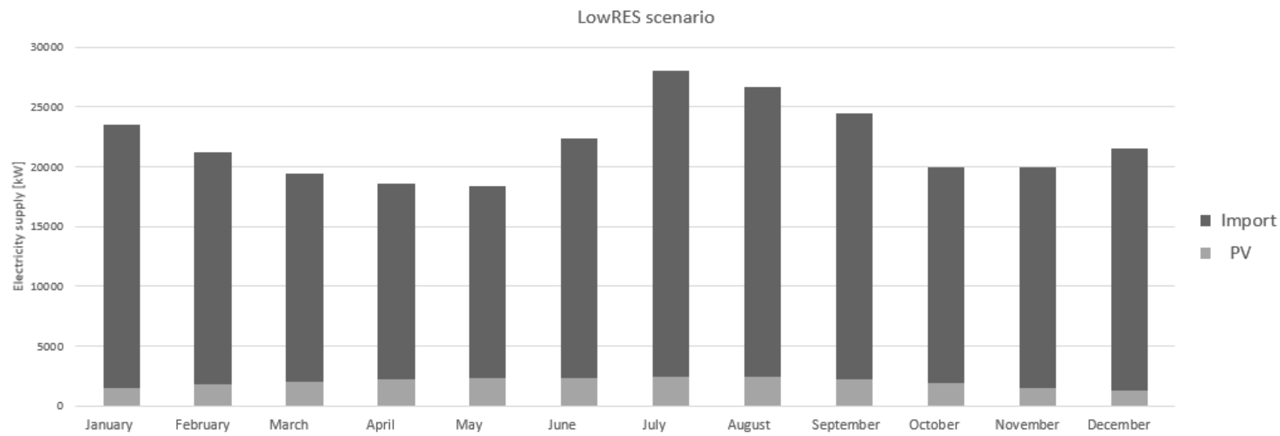

Figure 4 Monthly average hourly production for LowRES scenario in 2030

In RES scenario in 2030 (Figure 5) the influence of PV integration is significant, while V2G discharge to the grid is hardly visible. This is due to very low number of hours in which discharge is needed to balance the supply and demand, since the production from RES is still well under the demand.

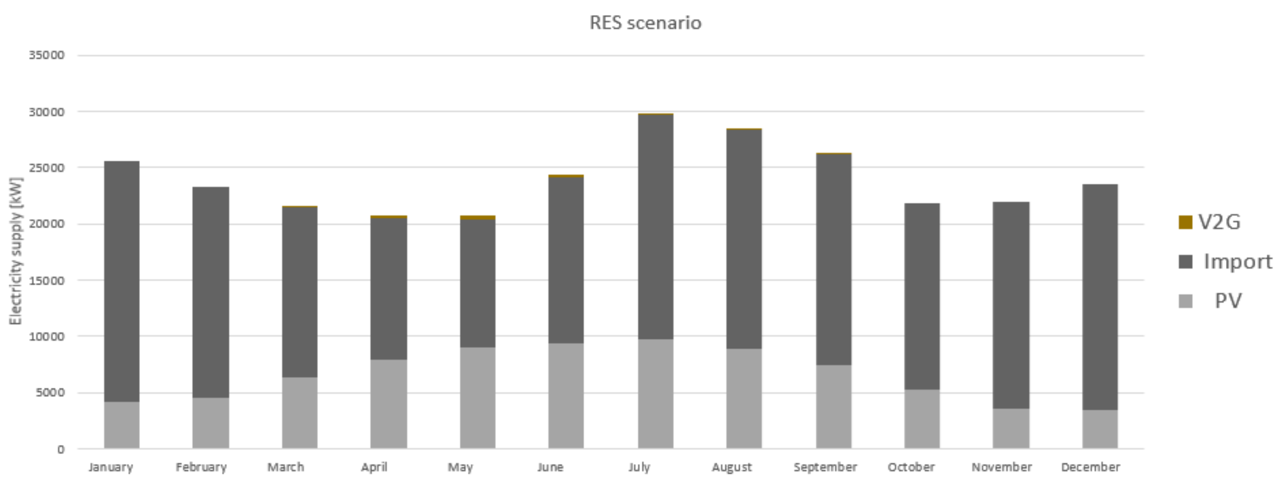

Figure 5 Monthly average hourly production for RES scenario in 2030

In last, HighRES scenario (Figure 6), various technologies are used to represent the potential future investments on Gozo. The scenario represents high penetration of onshore and offshore wind locally, also potential exploitation of wave and tidal energy, which proves, in this calculation, to be of minor importance and potential, but needs to be further investigated. Comparatively, onshore and offshore wind is of great importance and might prove to be an important factor in future considerations for development of the Gozo energy system.

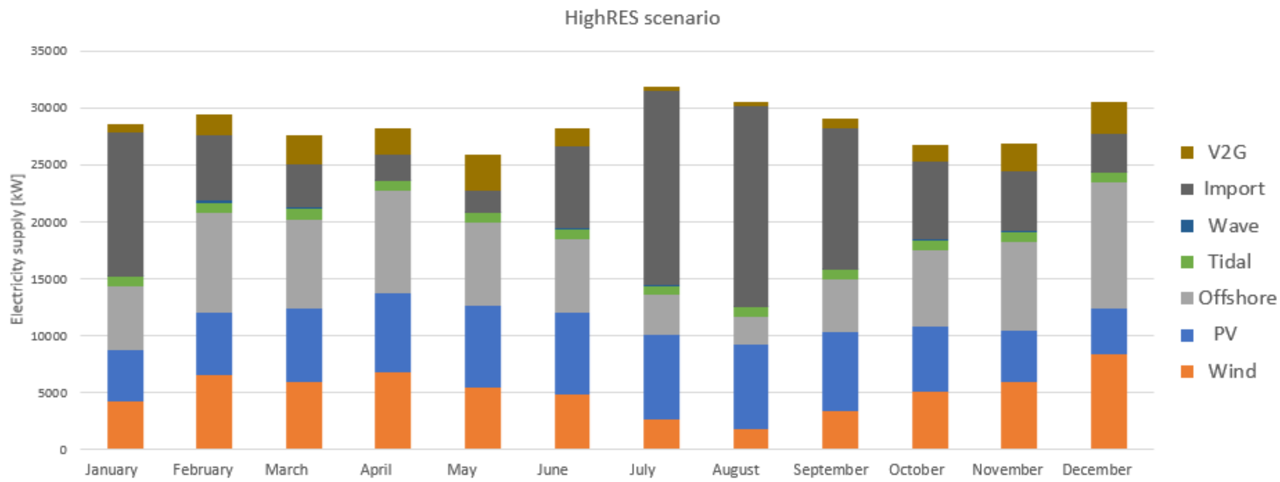

Figure 6 Monthly average hourly production for HighRES scenario in 2030

Consequence of increased electrification of transport and investment in heat pumps in households is also increased electricity demand, but according to Figure 7, this increase is comparatively not exhaustive.

As a consequence of all the measures, CO2 emissions are reduced in all scenarios, with the differences demonstrated by Figure 8.

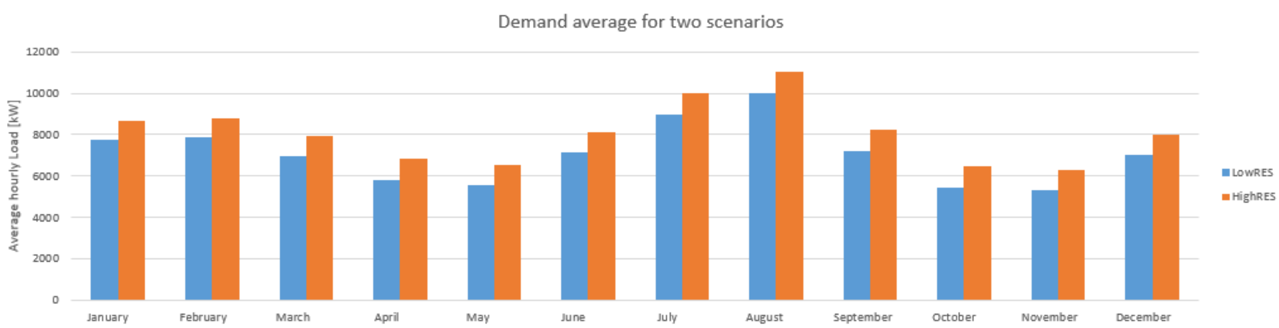

Figure 7 Monthly averaged electricity load difference between LowRES and HighRES scenarios

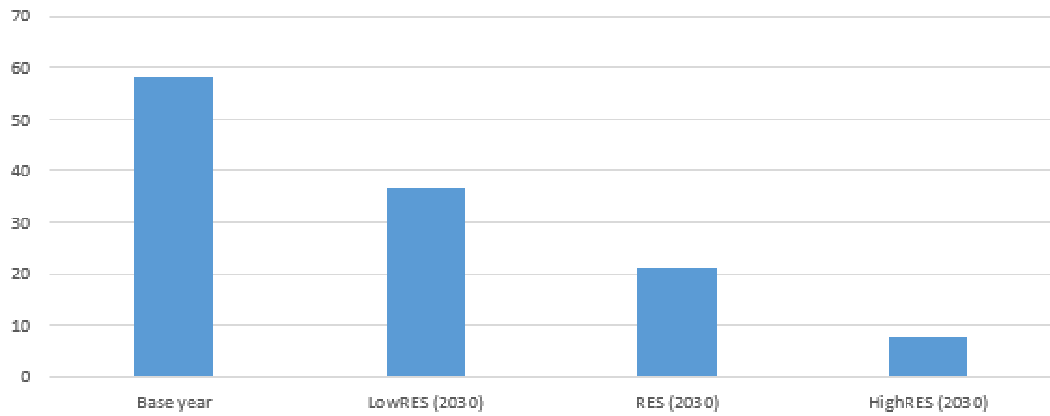

Figure 8 CO_2 emissions reduction in scenarios

2.2. Socio-economic feasibility of adopted solutions

The results of the economic analysis are divided according to the proposed scenarios. In all cases, it has been considered a real interest rate of 3%, a lifetime of 20 years and 25 years for RES technologies and an electricity price of 54€/MWh. Furthermore, operating costs have been considered only for RES technologies.
The first scenario (LowRES) is accountable for a set of initial investments in PV technology (with the generation of a solar farm on the roofs of the industrial areas), Heat Pumps, Solar Heaters, Electric boilers mainly for residential and EVs mobility.
The second scenario (RES) includes more investments in PV technology (with the generation of a solar farm on the roofs of the industrial areas), Heat Pumps, Solar Heaters, Electric boilers and significantly more investment in EVs.
The HighRES scenario includes further investments in PV technology, Heat Pumps, Solar Heaters, Electric boilers. In addition, it is foreseen an investment in Wind, Offshore Wind, Tidal and Wave energy. Furthermore, the scenario includes that all passenger cars will be EVs. The investment costs according to each scenario are shown in the graph in Figure 9, while the annual costs are displayed in the graph in Figure 10.

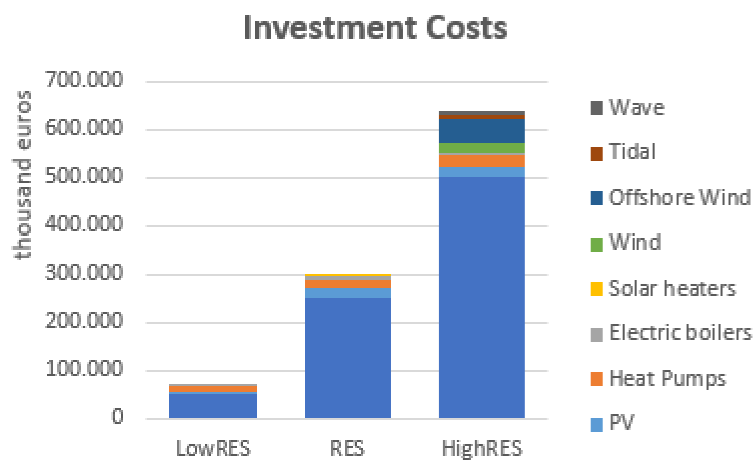

Figure 9 Investment costs for LowRES, RES and HighRES scenarios

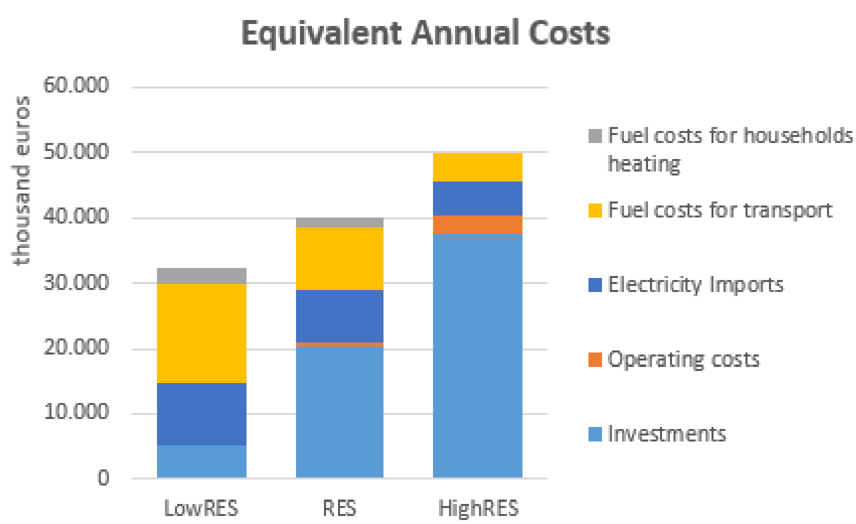

Figure 10 Equivalent annual costs for LowRES, RES and HighRES scenarios

Input data for High RES scenarios, regarding the prices of technologies implemented, are given in the table.

Table 5 Overall costs of installations on Gozo

2030	Investment	O&M	Lifetime
PV [EUR]	21.775.000	544375	25
Wind [EUR]	18.000.000	540000	25
EV[EUR]	500.000.000	1.000.000	20

The next table shows the need for new jobs for each of the scenarios in the number of full time equivalents (FTEs). This is calculated on the basis of solar PV and onshore wind power.

Table 6 Number of full time equivalent jobs per scenarios of development of the energy system on the island of Gozo

2030	LowRES	RES	HighRES
Engineering	9	92	111
O&M	1	6	10
Instalations	7	65	84

Calculated for the last year of the analysis, 2030, FTEs need to be also taken in the context of dynamics of the transition, which includes yearly rates of installation for solar and wind power. For example, if 25 MW of solar PV are to be installed by 2030, with dynamics of roughly 10% being installed yearly from 2020 to 2030, local community would create roughly 16 jobs (FTEs), which would remain stable throughout this period.

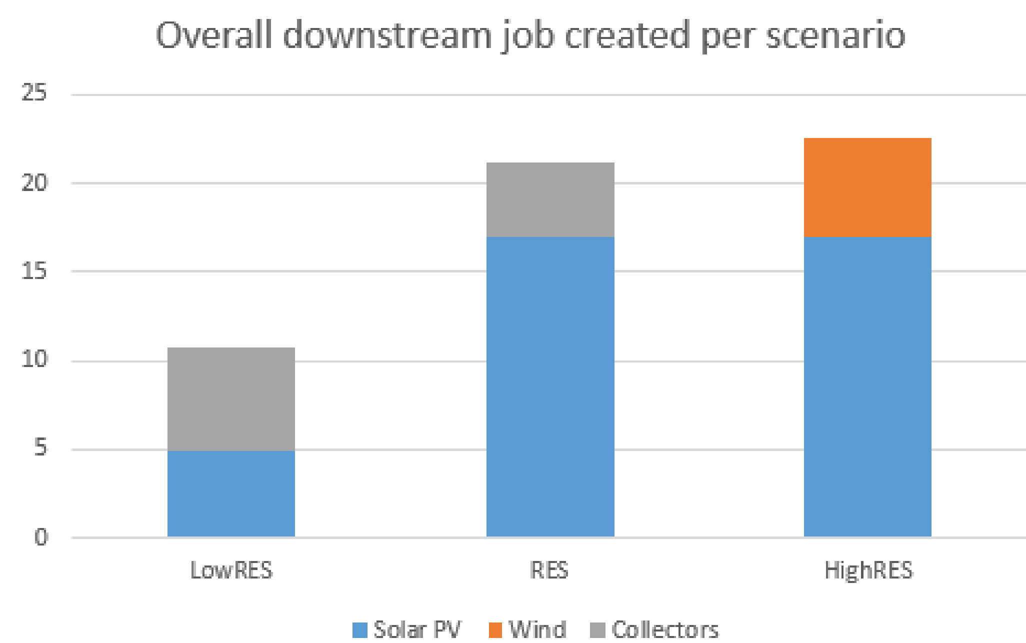

Figure 11 Overall downstream job creation per scenario

Further on, O&M jobs remain stable for the next 20 years period, with engineering and installation jobs occurring again during the repowering period (and also according to the dynamics set in motion in the period of this analysis).

2.3. Environmental considerations

1) Reduction of GHG emissions

In Figure 12, GHG emissions are presented, for each scenario. Also, for comparison, emissions in the base year are given.

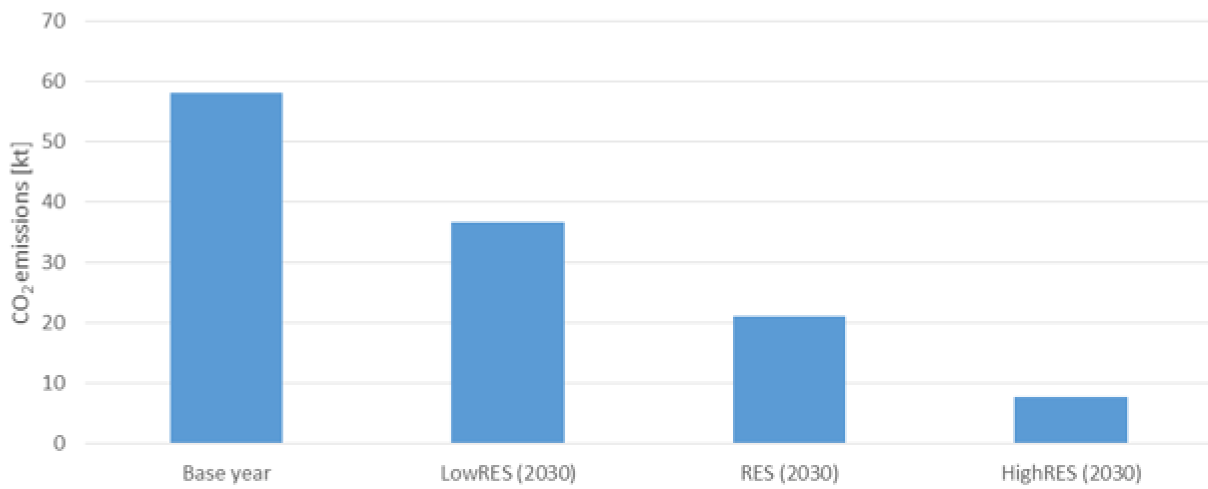

Figure 12 Comparison of emissions (Kt) for all scenarios and compared to the base year

Since all fuel use in transport is replaced with electricity use for EV's and solar thermal collectors replaced the use of fuel oil and solid biofuels in households and services, the emissions in HighRES scenario are significantly reduced.

2) Environmental constraints in the case study area, which influence the feasibility of scenarios

Figure 13 and Figure 14 illustrate how much of the area of the Island of Gozo is included in NATURA 2000 network, SAC, SPA and other marine protected areas which constraints the installation of any large solar or wind farms. For this reason, the most reasonable scenario is the one in which all roofs of dwellings are used to produce energy from PV panels and the industrial areas are exploited for extensive production from solar systems. With regards to wind power, the reality of a vulnerable landscape, the issues that derive from its protection and the high density of urbanisation, creates barriers to the introduction of wind power to a large scale. However, as it is shown in the HighRES scenario, the presence of wind turbines would give a relevant contribution to the share of energy from RES to the island of Gozo.

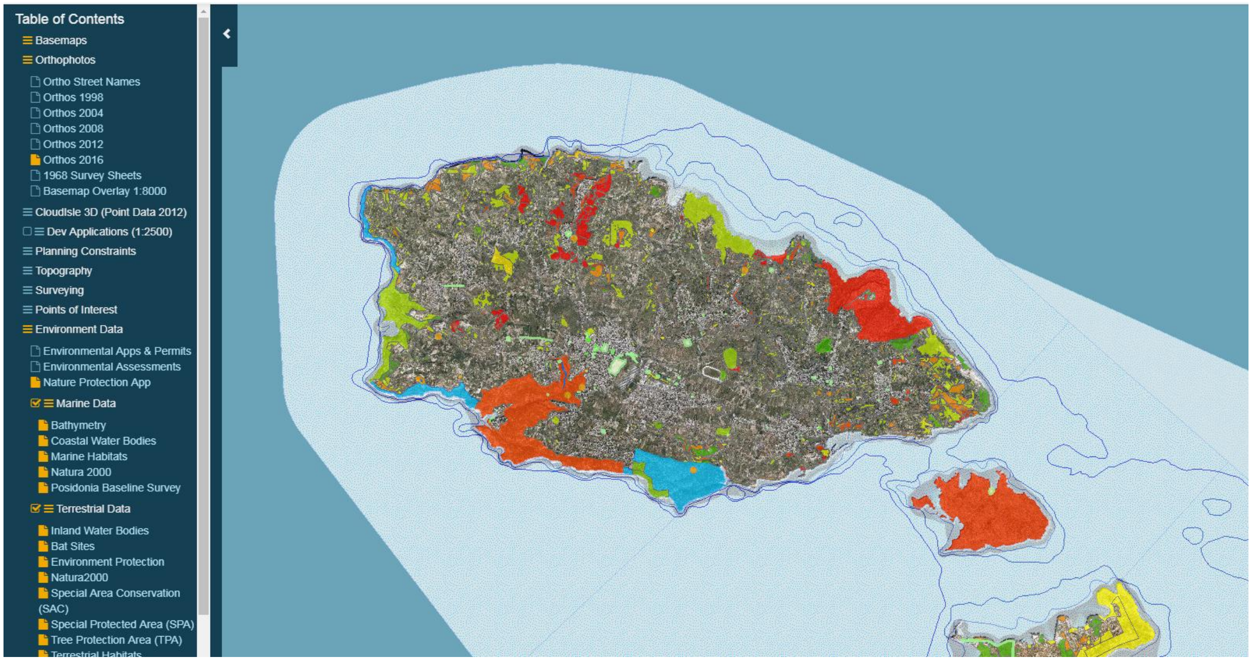

Figure 14 Enviromental Protected sites in Gozo

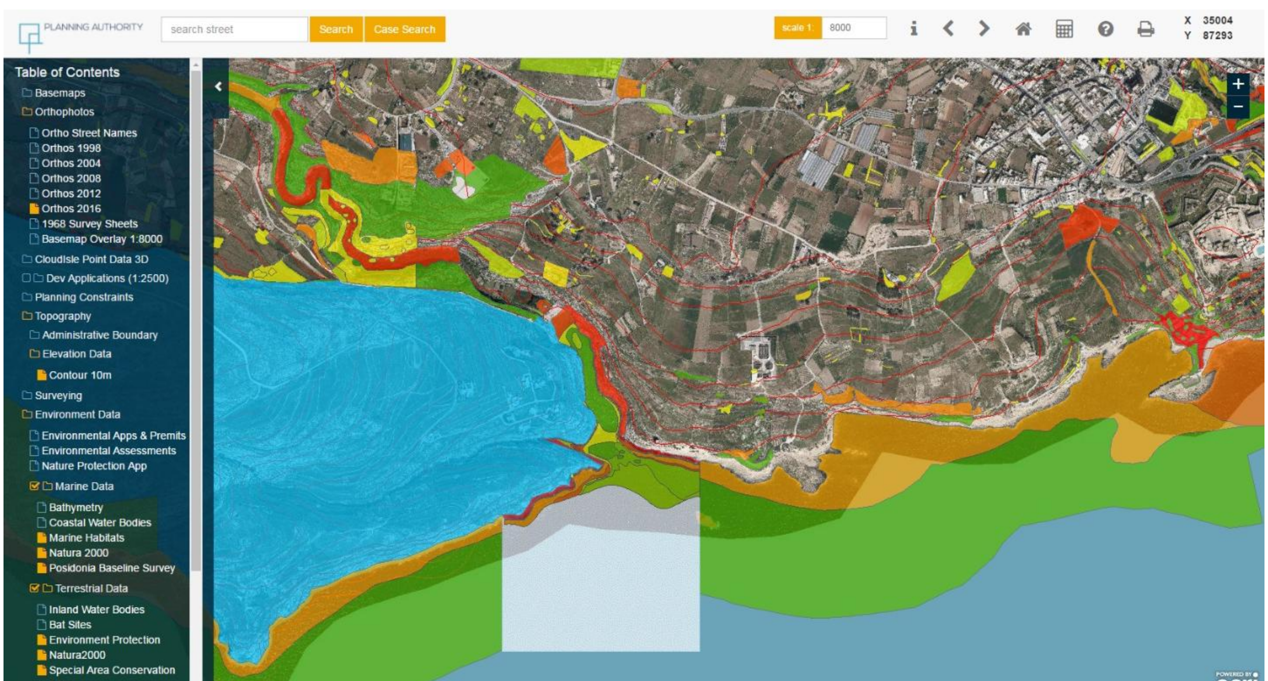

Figure 13 Enviromental and Marine Protected sites in Gozo

2.4. Suggestions for strategy of development

The scenarios and calculations presented show very interesting hints of what can be achieved with strategic energy planning and the use of tools as the ones created by the PRISMI project. Although the economic factors related to the path towards sustainability of Gozo have been developed, a more detailed quantitative analysis shall be run in order to fully understand the economic efforts that sustainable energy planning will entail. Furthermore, the political decisions towards RES still have to take significant steps in order to make these scenarios possible. In particular the exclusion of wind power from the future midterm scenarios for Malta’s energy system due to environmental, visual impact and space constraints (although in some ways understandable) is preventing higher shares of RES in the energy system.

3. Conclusion

In the current study, the scenario approach in energy systems modelling has been used to model the future scenarios for the Gozo 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 and wind energy) and ways to achieve it. Onshore and offshore wind is of great importance and, even taking into account a more complicated implementation because of the surrounding nature, might be an efficient solution for energy planning of Gozo. The strategy shows that investing in Electric Vehicle (EV) mobility can be an asset for the island, since a great amount of energy consumption derives from transportation, which relies on fossil fuels and contributes to CO_2 emissions. Given also that so little progress towards a sustainable energy system had been made so far in Malta, the strategy and the above illustrated results represent a feasible set of opportunities for Gozo islands to become more energy self-sufficient.

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