LOCAL SUSTAINABLE ENERGY SYSTEM DEVELOPMENT IN AN INSULAR AREA : MUNICIPALITY OF VIS, CROATIA

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Promoting RES Integration for Smart Mediterranean Islands

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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 Vis 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 Vis 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 Vis 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.

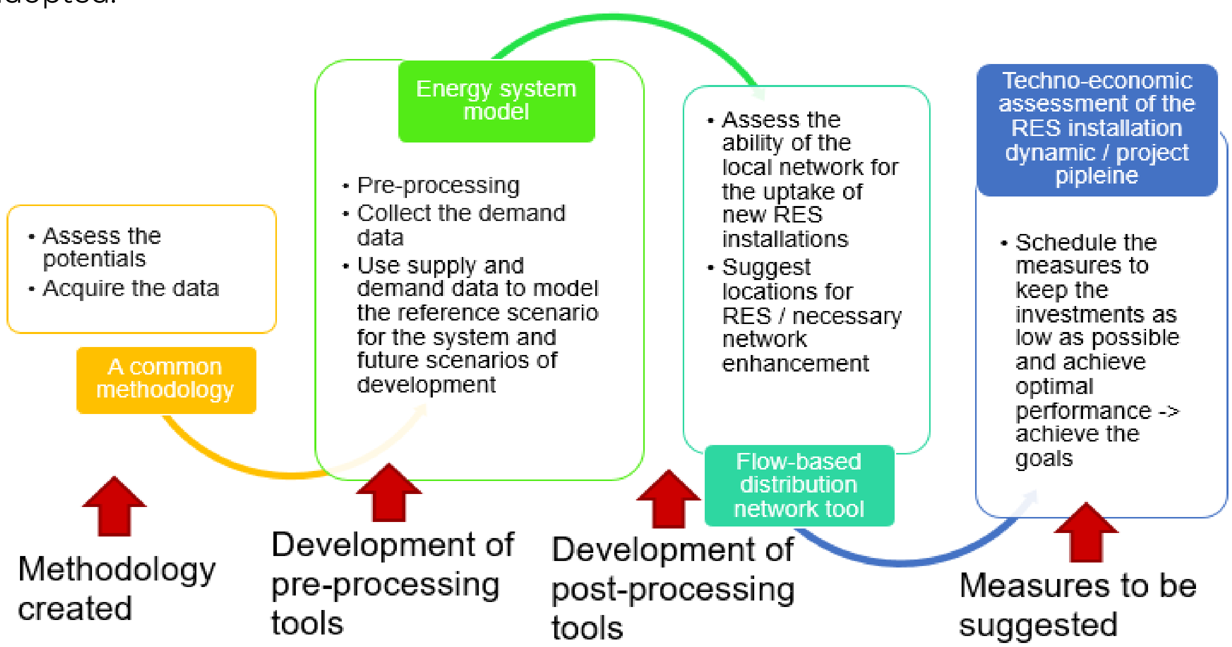

Figure 1 The PRISMI approach step by step

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

Mapping the energy needs of the island community

Vis 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 Vis indicated the following technologies: Photovoltaic (PV), Solar Thermal collectors (ST), Wind Turbines (WT), Electric Vehicles (EVs) and 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- Municipality of Vis Flagship Case (FC)

Vis is a small Croatian island in the Adriatic Sea, and it is the farthest inhabited island of the Croatian mainland, with a population of 3,617 in 2011. Vis has an area of 90.3 square kilometers. The highest point of the island is 587 meters above sea level. Once known for its thriving fishing industry in the late 19th and early 20th century, the main present-day industries on the island are agriculture and tourism. Concerning island's electrification, Vis currently depends on a submarine link with the island of Hvar. The electricity consumption of Island of Vis was 17.6 GWh in the year 2016.

Table 1 Mapping the needs of the island of Vis community

Needs	Level	Geographic distribution	Code
Electricity	Medium	concentrated	ElecMC
Heat	Low	dispersed	HeatLD
Cold	Low	dispersed	ColdLD
Transport fuel	Low	Long	Tran LL
Water	Medium	dispersed	WaterMD
Waste treatment	Low	dispersed	WasteLD
Wastewater treatment	Low	dispersed	WWTLD

Table 2 Mapping the resources on the island of Vis

Resource	Level	Code
Local primary energy		
Wind	Medium	WindM
Solar	High	SolarH
Hydro(Height)	Medium	HydroM
Biomass	Medium	BiomM
Geothermal	Low	GeothL
Energy import infrastructure		
Grid connection	Strong	GridS
Natural gas pipeline	No	NGplN
LNG terminal	No	LNGtN
Oil terminal/refinery	No	OilRN
Oil derivatives terminal	No	OilDN

Water		
Precipitation	Low	H2OPLL
Ground water	Low	H2OGL
Water pipeline	Yes	AquaY
Sea water	Yes	H2OSY

Technologies overview

Most relevant resource, with high potential, is solar. The surface of all residential area of the city Komiža, a city on Vis, is 108,630 m^2. After the methods of calculating the available surfaces of the roofs for solar PV from above, the possible surface is approximately 32,589 m^2. This surface gives the possible maximum nominal power for installed PVs of 5,000 kW in Komiža. The simulation takes also into account the 2 MW solar power plant that is planned on the island of Vis.

Other relevant resource is wind power, but the exploitation is made difficult due to the island being completely covered by the NATURA 2000 network and protected.

Biomass is used in households for heating and hot water in individual stoves. Solid biomass potential is too low for use in energy production, but potential can be identified for use in the degradable portion of waste for biogas production.

Water potential for pump hydro plants is restricted by the environmental protection regulations and it would be very challenging to prove its feasibility.

Other technologies, such as tidal energy and wave energy have not been sufficiently explored and mapped to be taken into consideration.

Division of scenarios

Energy system development of the island of Vis has been examined in three scenarios:

1. LowRES – following the same dynamics of RES use, as already proposed in actual SEAP-s
2. RES – Increase of RES use, with taking into consideration environmental constraints and legislative framework
3. HighRES – Modelling for a 100% RES energy system of the island

On the island of Vis, city of Komiža has developed an energy action plan similar to SEAP, however, the plan was not submitted to the Covenant of Mayors initiative [Vidović 2015]. Results of extrapolation [Pfeifer et. al 2017] are given in Figure 2 and general numbers for all scenarios are given in the table.

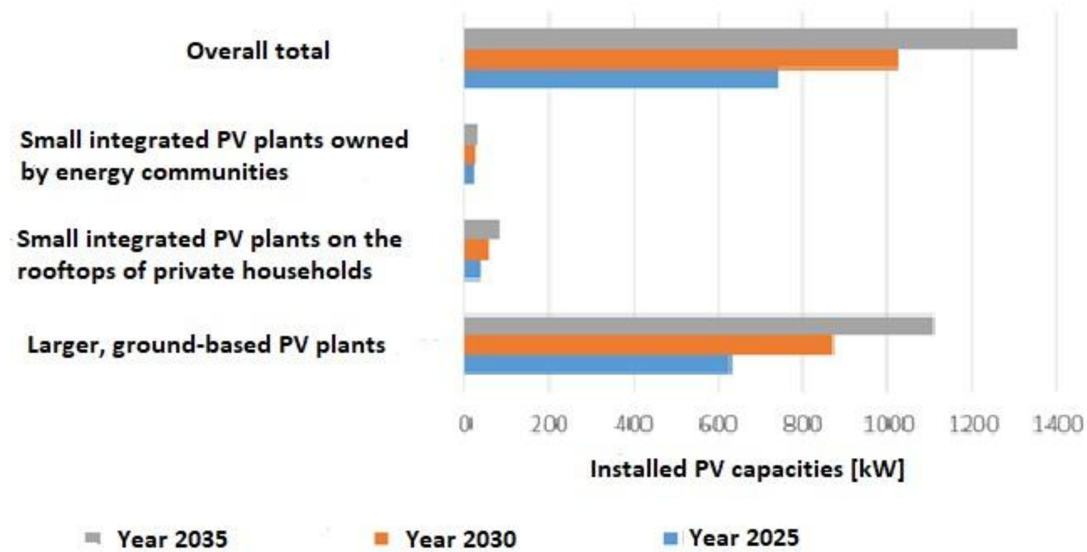

Figure 2 Results of data extrapolation regarding PV installations for the island of Vis

Table 3 Input data for scenarios of development of energy system of the island of Vis

2030	LowRES	RES	HighRES
PV [MW]	1.03	10.025	12.05
Wind [MW]	0	0	3.5
EV [no. of vehicles]	0	617	1234
EV connection [MW]	0	1.985	9.131
EV demand [GWh]	0	1.778	2.767
EV battery [MWh]	0	14.496	48.126

Further considerations will be elaborated having in mind the year 2030. For two scenarios, LowRES and HighRES, demand is different, and this difference is exactly the amount of demand for the electric vehicles.

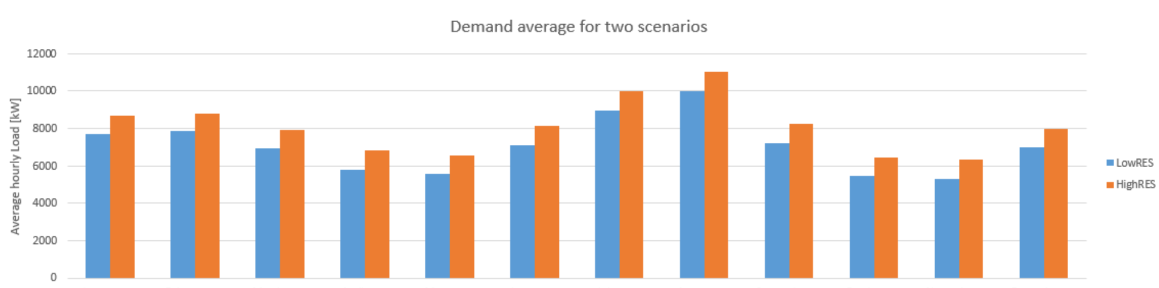

Figure 3 Monthly average hourly load for LowRES and HighRES scenarios for the island of Vis

2.1. Results of modelling and discussion

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

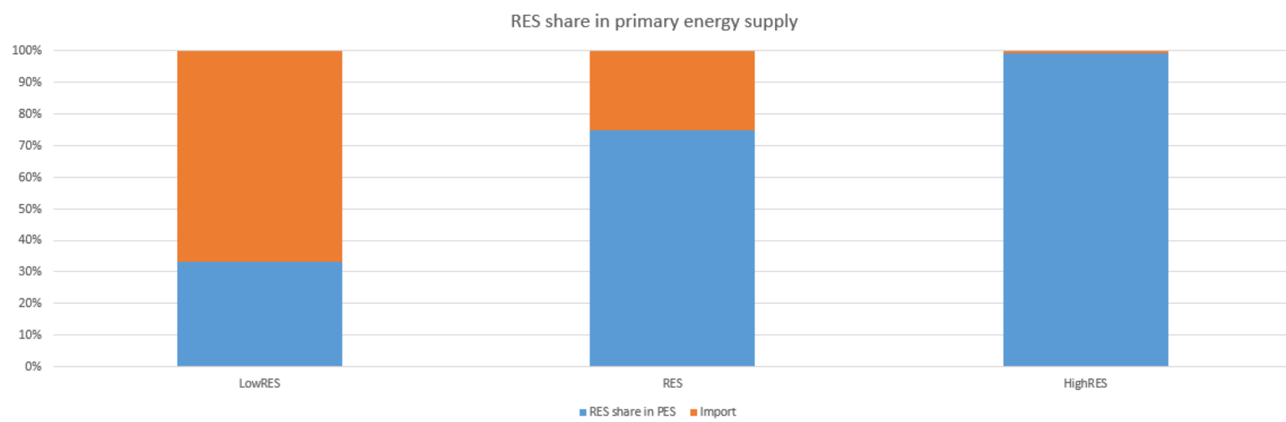

Figure 4 RES share in primary energy supply

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

Table 4 Results of modelling - RES production

LowRES		
RES prod.	1.61	GWh/year
Solar	1.61	GWh/year
Wind	0	GWh/year
Tidal and Wave	0	GWh/year
Hydro	0	GWh/year

RES		
RES prod.	15.62	GWh/year
Solar	15.62	GWh/year
Wind	0	GWh/year
Tidal and Wave	0	GWh/year
Hydro	0	GWh/year

HighRES		
RES prod.	23.28	GWh/year
Solar	18.74	GWh/year
Wind	4.63	GWh/year
Tidal and Wave	0	GWh/year
Hydro	0	GWh/year

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

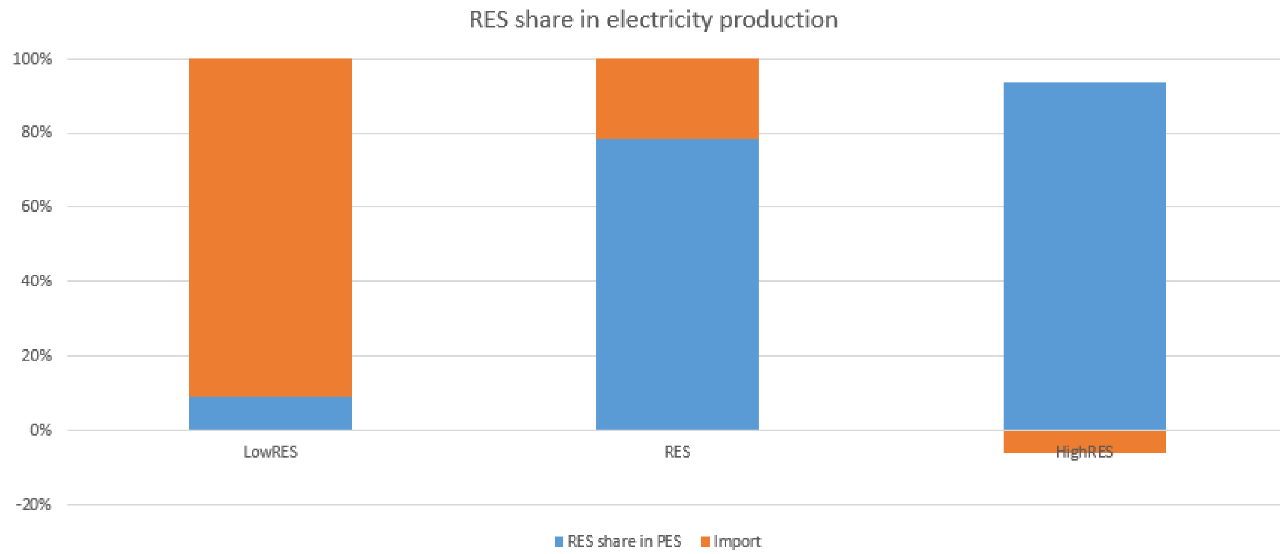

Figure 5 RES share in electricity production

It can be observed that the RES scenario already covers a very high percentage of energy production, due to the large solar energy potential on Vis, but share in primary energy supply is 20% lower. Therefore, in the HighRES scenario, all vehicles are substituted by electric vehicles. It can be observed that there is small Nett export amounting to 7% of electricity production.

In the following figures, the share of particular technologies in electricity supply is illustrated.

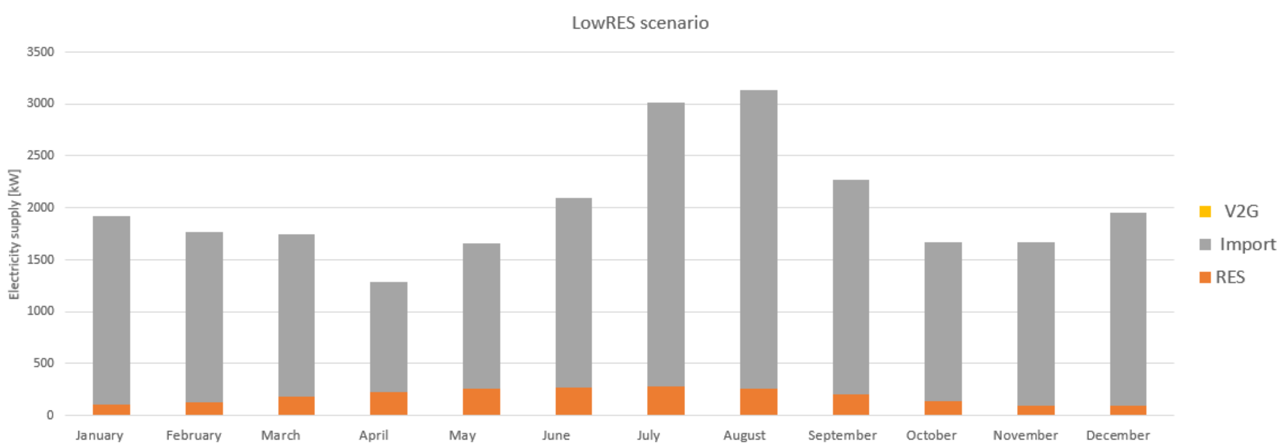

Figure 6 Share of RES in monthly average hourly production for the LowRES scenario

Vehicle-to-grid (V2G) represents the discharge from EV batteries, which is represented as additional supply in RES and HighRES scenario.

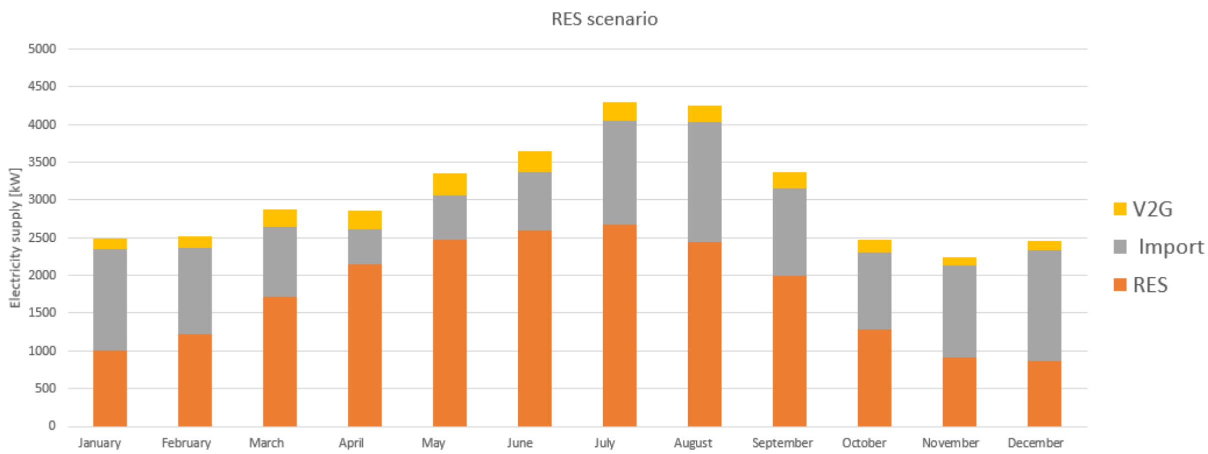

Figure 7 Share of RES in monthly average hourly production for the RES scenario

In HighRES scenario, wind energy is also added to achieve 99,3% RES system.

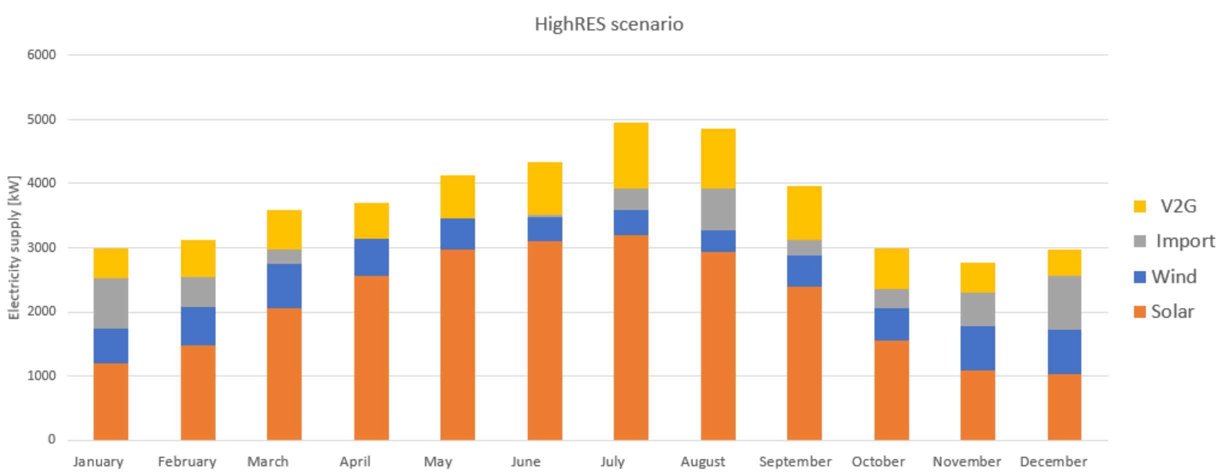

Figure 8 Share of RES in monthly average hourly production for the HighRES scenario

2.2. Socio-economic feasibility of adopted solutions

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

Table 5 Initial input data for techno-economic analysis

2030	Investment	O&M	Lifetime
PV [kEUR/kW]	1.1	2%	20
Wind [kEUR/kW]	1.375	3%	20
EV[kEUR/unit]	37.85	6,50%	10

Results of modelling for all scenarios, in terms of investment costs, are given in the following figures. In Figure 9, the share in costs for production technologies is given.

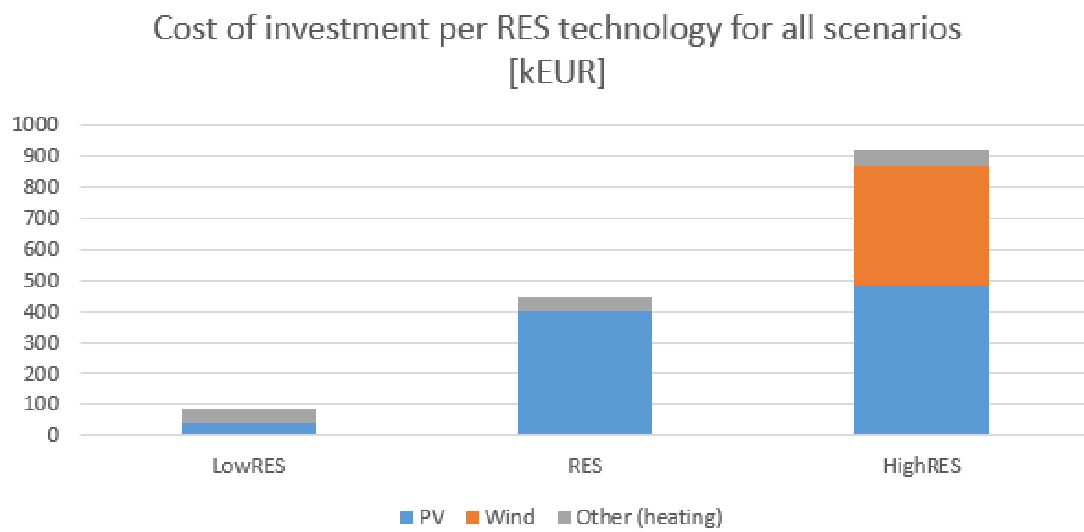

Figure 9 Share in costs for production technologies

In Figure 10, the cost of technologies for storage and balancing is given.

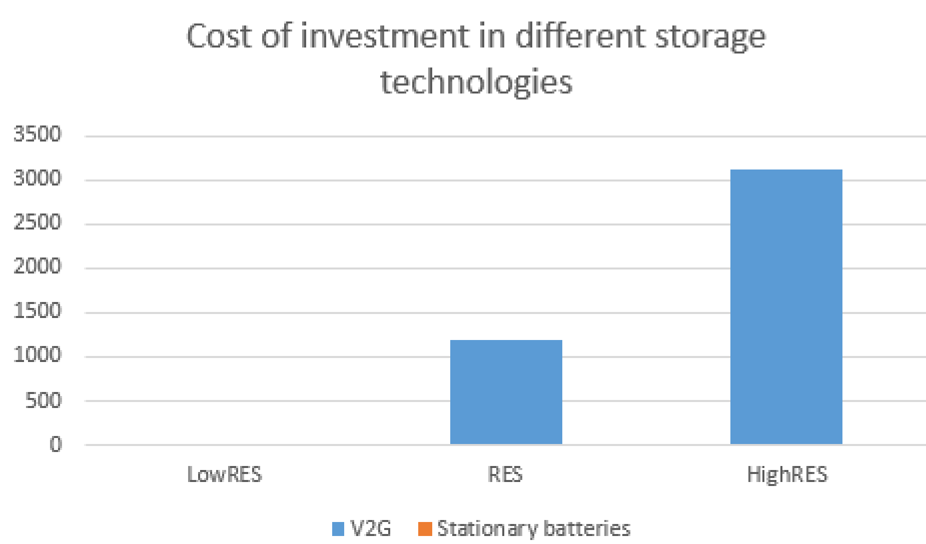

Figure 10 Cost of technologies for storage and balancing in kEUR

The next table shows the need for new jobs each scenario in the number of full time equivalents (FTEs).

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

2030	LowRES	RES	HighRES
Engineering	4	37	49
O&M	0	2	4
Instalation	3	26	36

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 10 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 5 jobs (FTEs), which would remain stable throughout this period.

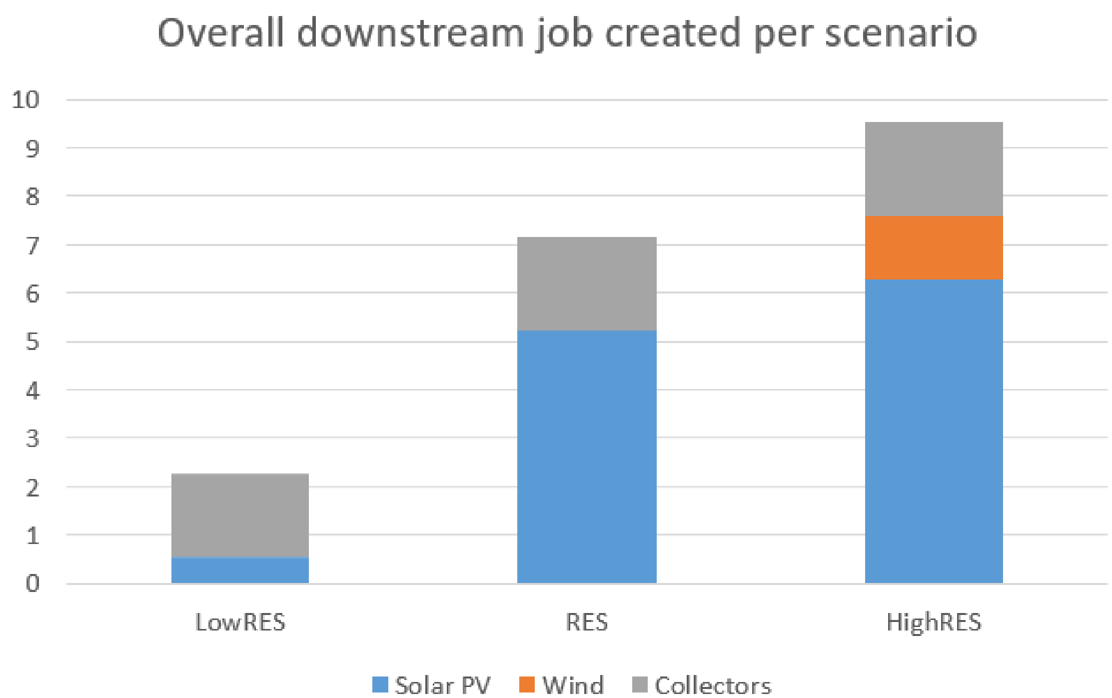

Figure 11 Full time jobs created per scenario

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

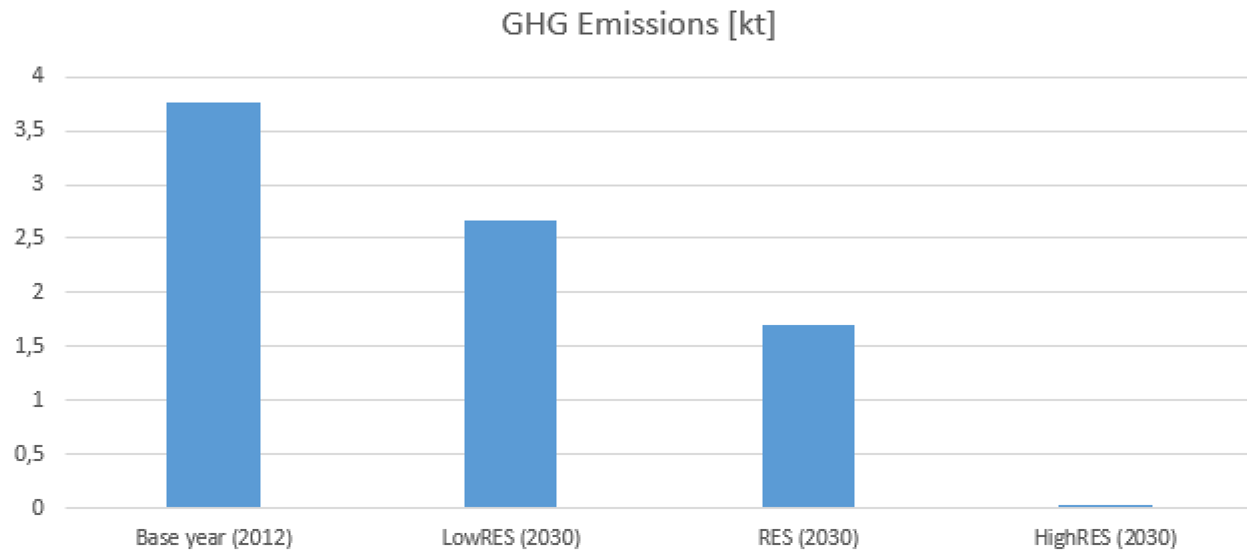

Figure 12 Comparison of emissions for all scenarios and compared to the base year

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 completely reduced.

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

Figure 13 illustrates that all the Vis island's area is included in NATURA 2000 network, which constraints the installation of any larger production facility.

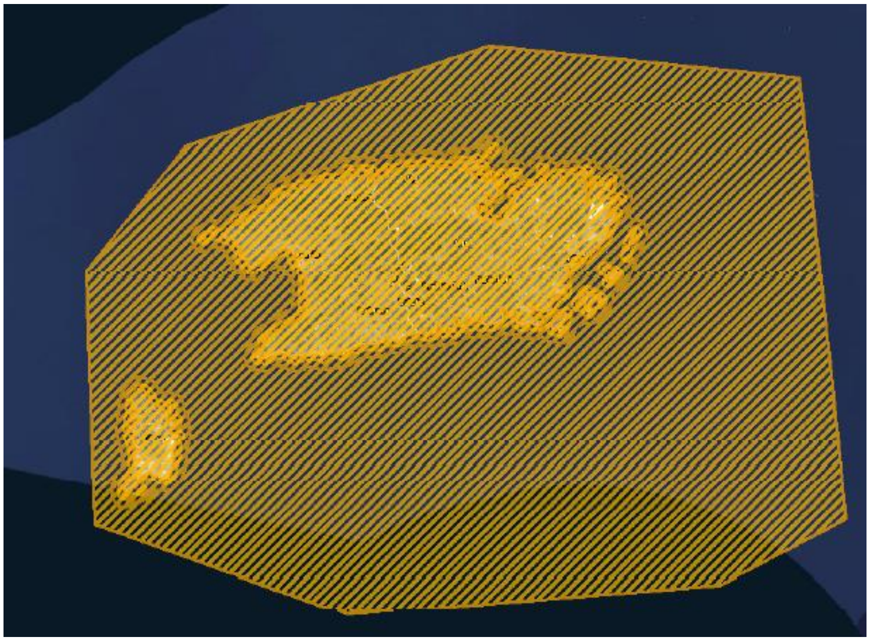
Figure 13 Natura 2000 network on the island of Vis

Although the protection of nature area on the island of Vis includes the whole island, in order to secure opportunities for local development, specific projects can be implemented. The new solar power plant Vis. The Spatial Plan of the Split-Dalmatia County provides for the construction of solar power plants on the territory of the county, including one location on the island of Vis under the name of Vis-Griževa Glavica (hereinafter referred to as Solar Power Plant Vis), whose location is shown in the figure below. The location is located about 3.6 km southwest of Vis and 4.8 km east of Komiža, east of the village of Glava, in the area of Podspilje.

Figure 14 Location of the Solar PV power plant on Vis

The project solution foresees the construction of the Solar Power Plant Vis only on cadastral plot 9887/1, total area 57 428 m^2.

Solar power plant construction is planned with a 2 000 kW power line connection, while the installed photovoltaic (FN) module power will be slightly larger to compensate for the losses. The contractor of the project is Končar - Renewable Resources d.o.o.. The estimated annual production of Solar Power Plant Vis can be expected to be around 2.800 MWh, corresponding to average annual consumption of approx. 550 households. Given the foreseen installed power and infrastructure conditions, construction costs can be estimated at approx. 2 500 000 €.

2.4. Suggestions for strategy of development

For Vis, as previously for Korčula, based on the above described scenario approach, a Joint SEAP would be advised. Such draft SEAP's should include new measures, which would support the conclusions of the analysis and foster the energy transition of the island:

- Installation of integrated PV on residential buildings (subsidized by local and regional government and national funds)
- Promotion of EVs
- Sharing of the electric bikes
- Construction of solar PV power plants on the island (support from local government)

3. Conclusion

In the current study, the scenario approach in energy systems modelling has been used to model the future scenarios for the Island of Vis. 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 ways to achieve it. A major step toward energy independence is the commissioning of the planned Power Plant Vis.To minimise emissions, replacing all fuel use in transport with EVs as well as replacing fuel oil and solid biofuels in households with solar thermal collectors is essential. 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. Refereneces

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