LOCAL SUSTAINABLE ENERGY SYSTEM DEVELOPMENT IN AN INSULAR AREA : MUNICIPALITY OF KORČULA, 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 the Island of Korčula 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 Korčula 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 Korčula 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.

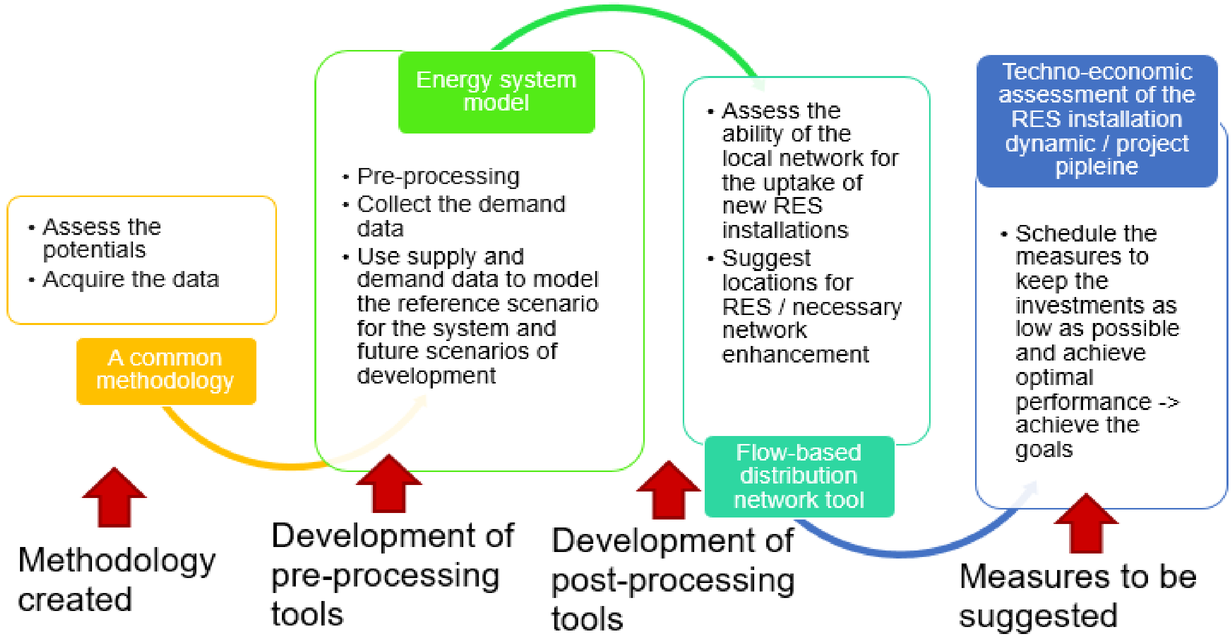


Figure 1 The PRISMI approach step by step

1.1. General framework method for devising the future development energy scenarios for the PRISMI 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 Korčula. Hence, the adapted methodology consists of the following actions:

Mapping the energy needs of the island community

Korčula 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. Island of Korčula indicated the following technologies: PhotoVoltaic (PV), Solar Thermal collectors (ST), Electric Vehicles (EVs), Wind Turbines (WT), 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 Korčula Flagship Case (FC)

Korčula is a Croatian island in the Adriatic Sea. It has an area of 279 km^2, 46.8 km long and on average 7.8 km wide and lies just off the Dalmatian coast. Its 15,500 inhabitants (2011) make it the second most populous Adriatic Island after Krk and the most populous Croatian island not connected to the mainland by a bridge. The island is largely covered with Mediterranean flora including extensive pine forests. Korčula Island is extremely fertile and is densely covered with evergreen conifers and pines, as well as Mediterranean plants and herbs. Two major settlements are the cities of Korčula, Blato and Vela Luka, while the island is administratively divided into four municipalities; Vela Luka, Smokvica, Lumbarda, Blato and the city of Korčula. Average electricity consumption for the Island of Korčula is about 55 GWh/year.

Table 1 Community needs – Island of Korčula

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 on the island of Korčula

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 step two of the method, one of the resources is rated as high potential: solar.

The initial step is to calculate the available area for solar PV installation. Calculations were made according to the total area size of all dwellings including dwellings for permanent residence, dwellings used occasionally and the ones for business activity only. Furthermore, it was assumed that on an average level, buildings have two floors; therefore, the total amount of square meters is divided in half. Apart from that, other restrictions were taken into consideration. Above mentioned area size was multiplied by a coefficient of 0.7 which represents the correction factor which includes buildings with more than two floors. In order to account rooftop objects such as windows, chimneys, slopes and antennas, which can reduce available space, a coefficient of 0.85 was used. The calculated surface was considered the net area for the installation of photovoltaic panels. The nominal power of 1 kW for PVs requires 6.5 to 7 square meters obtained surface. These conditions are applicable for the Croatian islands.

Other relevant resource is wind power, which is restricted in the terms of legislative framework (there is a law in force in Croatia, which prohibits wind turbine installations in the area which is less than 1 km from the coast). It is also difficult to implement due to the island being mostly covered by the NATURA 2000 network and protected. This is in particular true for the locations with some wind potential.

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 in use degradable portion of waste for biogas production.

Water potential for pump hydro plants can be observed but is restricted by the environmental protection regulations.

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

Division of scenarios

Final, fourth step of the method is the division of scenarios. Energy system development of the island of Korčula 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

Sustainable Energy and Climate Action Plans are currently being developed on three Croatian islands, i.e. island of Korčula for the municipality of Blato [Krajačić 2014], Smokvica [Krajačić 2014a], Vela Luka [Krajačić 2014c] and the city of Korčula [Krajačić 2014d]. Island of Vis (city of Komiža) has developed similar energy action plan, however, the plan was not submitted to the Covenant of Mayors initiative [Vidović 2015].
These action plans were used to acquire the basic data and then extrapolate the measures towards the year 2025, 2030 and 2035, using the same dynamic of implementation [Pfeifer 2017]. Considering possible PV installations, calculations based on this method are presented in the table.

Having in mind the method for solar power, described in the description of the study area and input data, the possible installed capacities of PV are calculated.

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

2030	LowRES	RES	HighRES
PV [MW]	4.59	44.59	42.05
Wind [MW]	0	0	10
EV [no. of vehicles]	0	1849	5222
EV connection [MW]	0	9.892	38.642
EV demand [GWh]	0	7.975	12.533
EV battery [MWh]	0	72.11	203.658

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

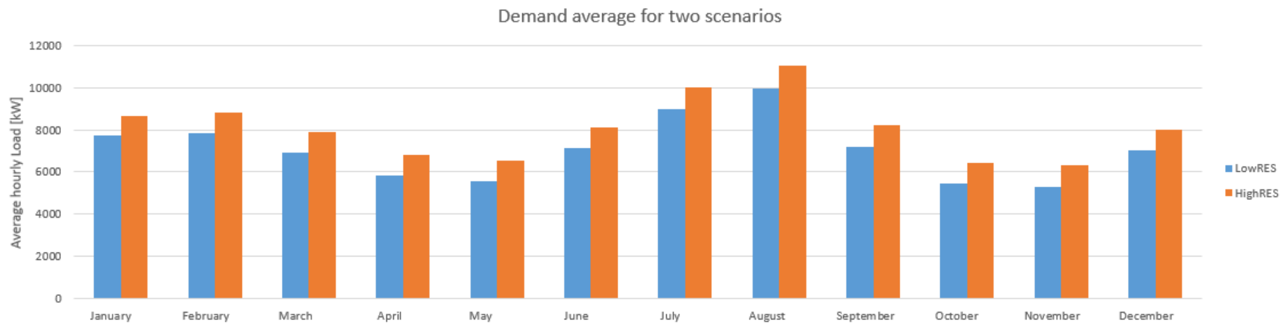


Figure 2 Average monthly load for the island of Korčula in 2030 for two scenarios

2.1. Results of modelling and discussion

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

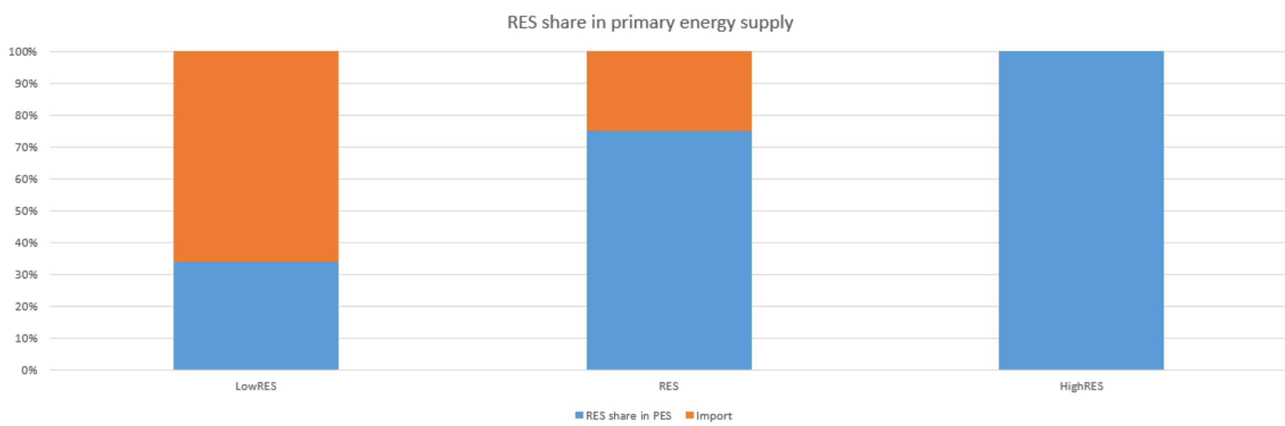


Figure 3 RES share in primary energy supply

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

Table 4 Results of modelling - production from RES

LowRES		
RES prod.	6.84	GWh/year
Solar	6.84	GWh/year
Wind	0	GWh/year
Tidal and Wave	0	GWh/year
Hydro	0	GWh/year

RES		
RES prod.	66.46	GWh/year
Solar	66.46	GWh/year
Wind	0	GWh/year
Tidal and Wave	0	GWh/year
Hydro	0	GWh/year

HighRES		
RES prod.	73.97	GWh/year
Solar	62.67	GWh/year
Wind	11.3	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.

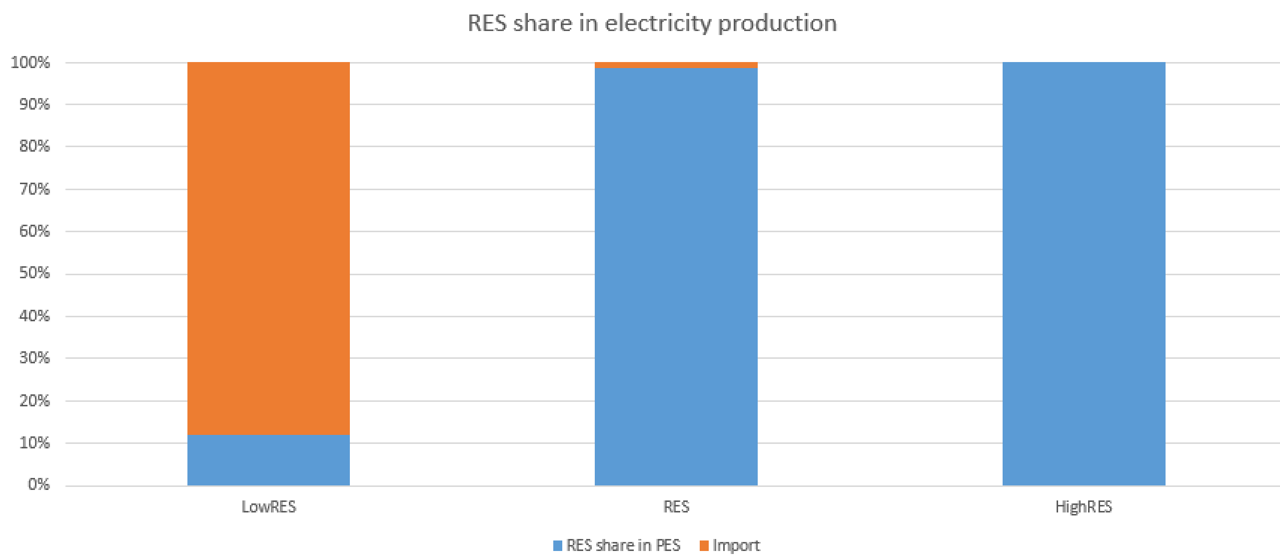


Figure 4 RES share in electricity production

It can be observed that RES scenario already covers a very high percentage of energy production, due to large solar energy potential on the island of Korčula but share in primary energy supply is 25% lower. Therefore, in the HighRES scenario, all vehicles are substituted by electric vehicles.

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

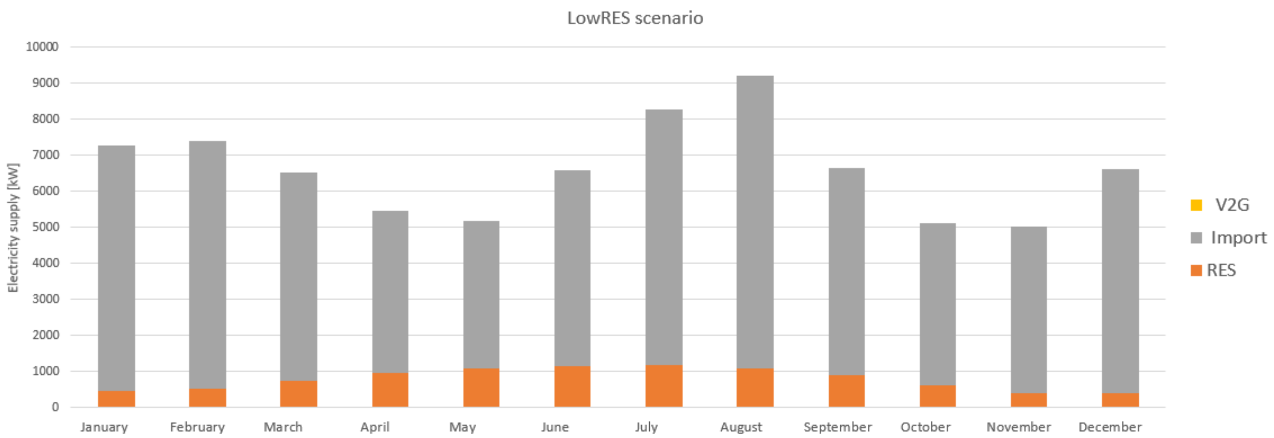


Figure 5 Share of RES in monthly average hourly production for the LowRES scenario

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

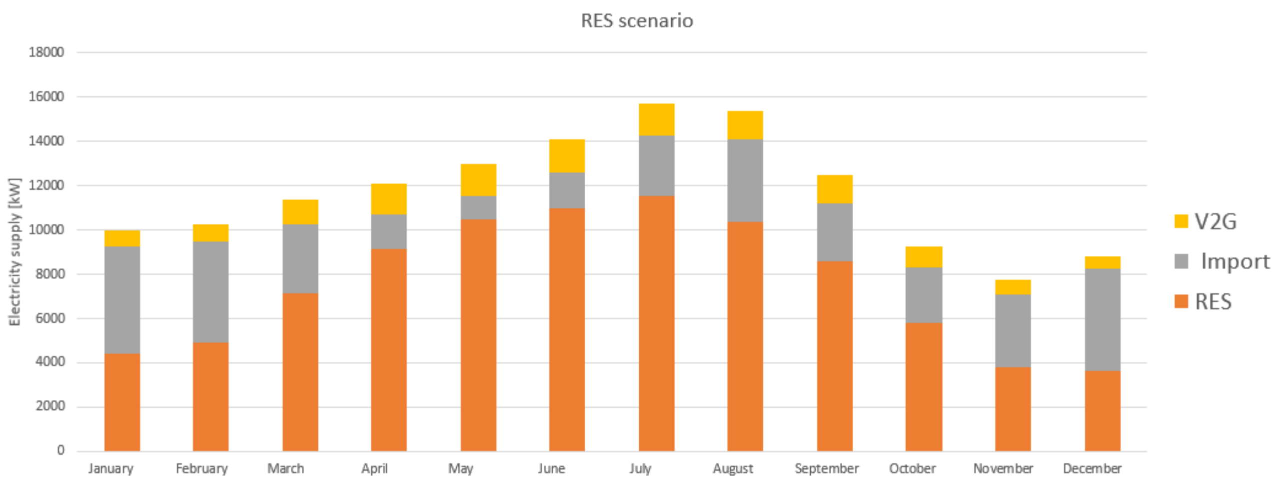


Figure 6 Share of RES in monthly average hourly production for the RES scenario

In HighRES scenario, wind energy is also added to achieve 100% RES system.

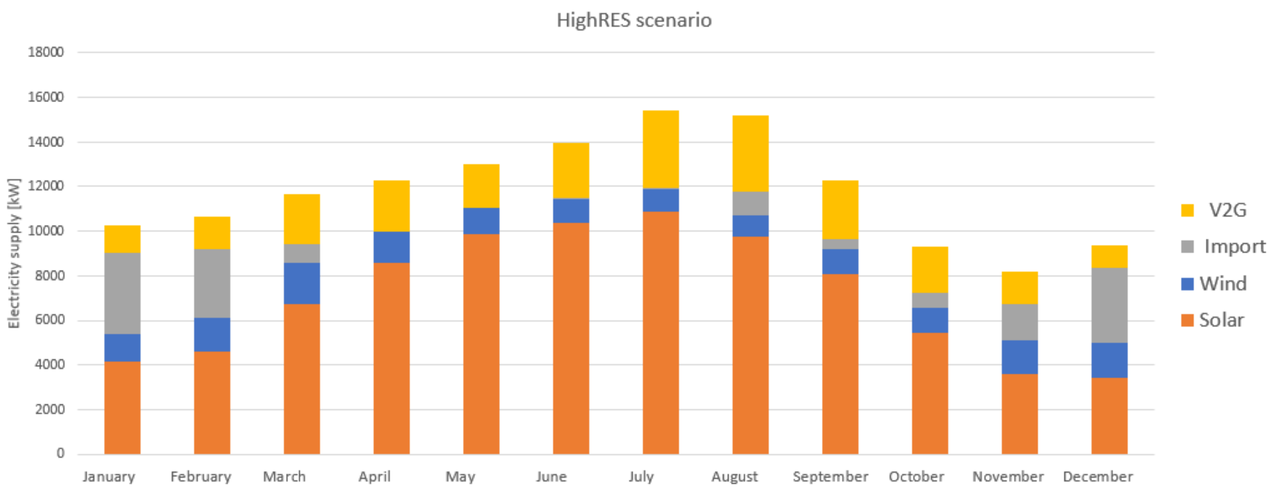


Figure 7 Share of RES in monthly average hourly load for the HighRES scenario

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 inputs 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 8, the share in costs for production technologies is given.

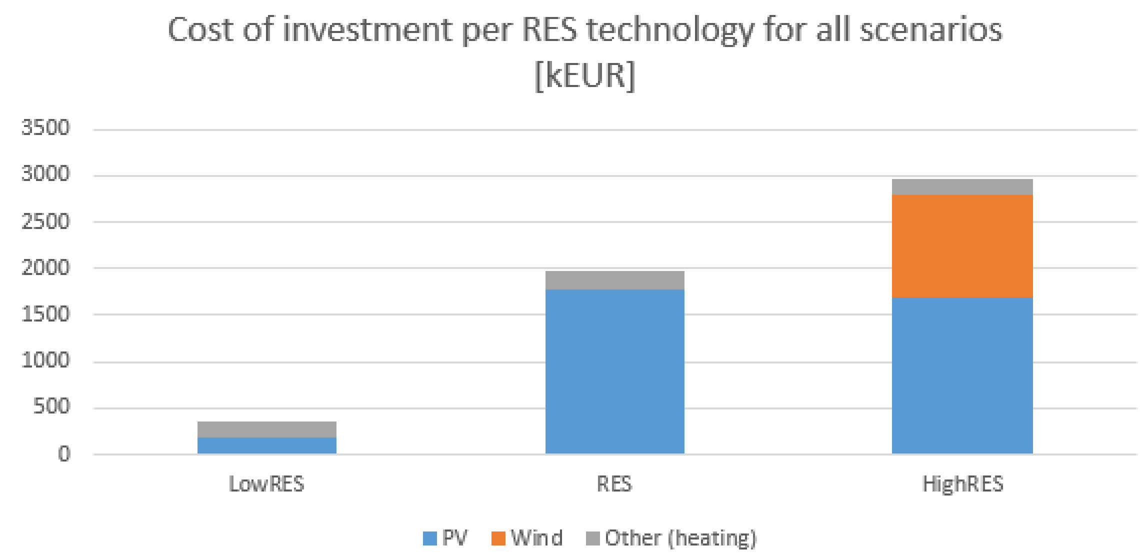


Figure 8 Share in costs for production technologies

In Figure 9 , the cost of technologies for storage and balancing is given. The cost of electric vehicles will most probably be covered by individual owners from the island which means it will not be directly cost of development of energy system. However, the cost of building of infrastructure for charging of EV and providing V2G services could be related to development of energy system, and they can increase community spending.

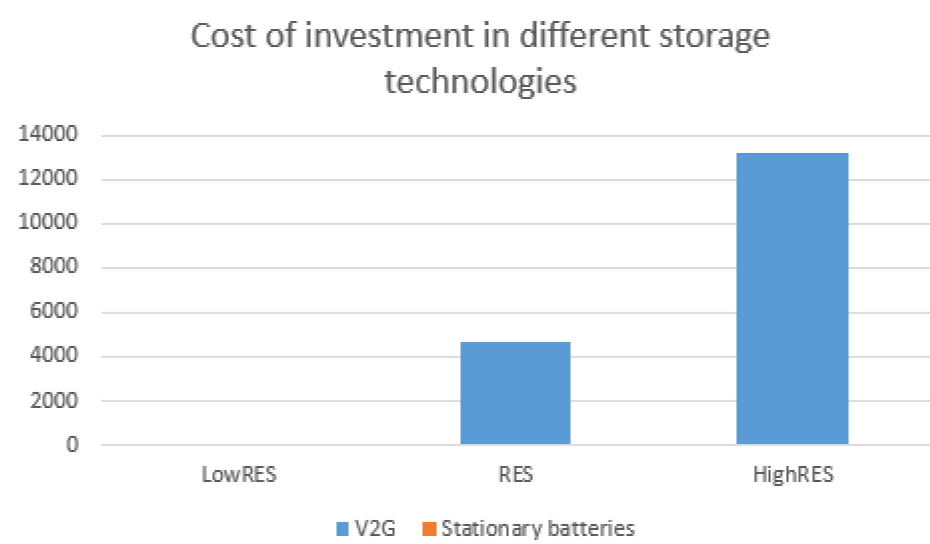
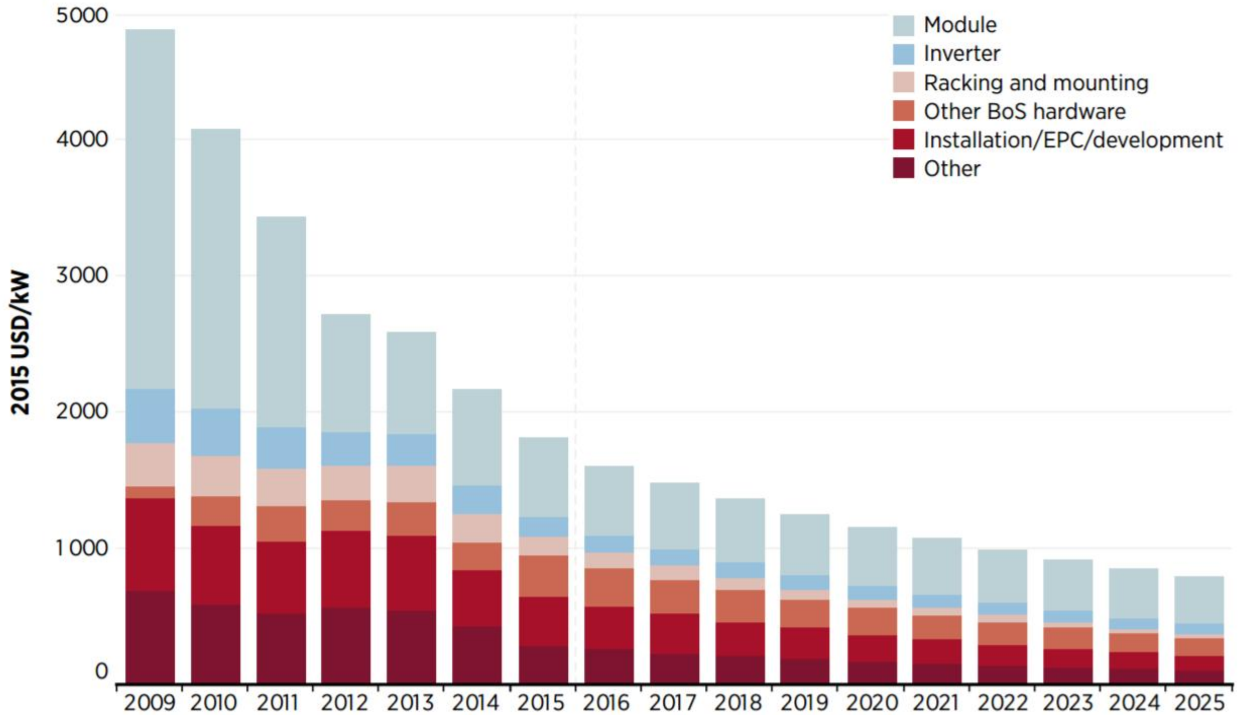


Figure 9 Cost of technologies for storage and balancing in kEUR

Rapid development of renewable energy sources, in particular solar and wind power, already caused the prices per kW of installed solar PV and wind turbines to fall drastically over the last 5 years. This trend is likely to continue, but even more interesting is the share of downstream jobs, such as installation and engineering, as well as O&M. These developments are illustrated in Figure 10.



Source: IRENA analysis and Photon Consulting, 2016

Figure 10 Price developments for the solar power and prediction towards 2025

Further on, in Figure 11 it is illustrated in more detail what is considered upstream and what a downstream job, with the visible emphasis on majority of jobs being downstream and local for the region which imports and implements the technology. This is relevant to the case study, which can create new local economy through energy transition.

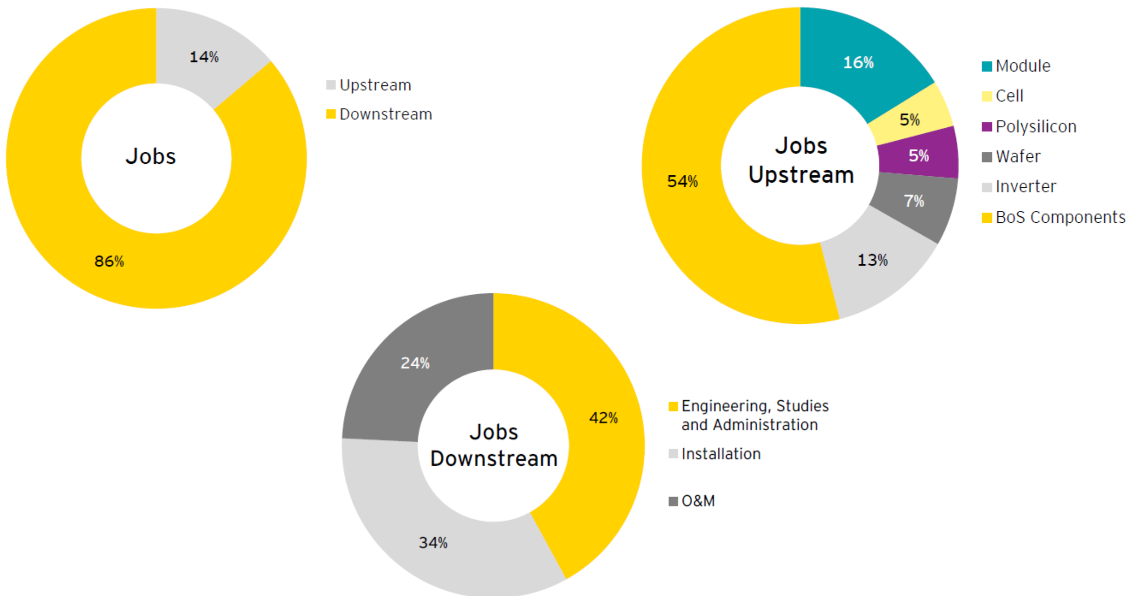


Figure 11 Upstream and downstream jobs in solar PV technology

One of the most important social parameters, which is investigated by the recent studies [2], is the number of newly created jobs related to the photovoltaic industry. The implementation of photovoltaics and wind turbines on the island of Korčula would create the need for new jobs, such as those related to the management and maintenance of these systems, as well as administrative-design and installation of the PV systems and wind farms themselves. The next table shows the need for new jobs for 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 Korčula

2030	LowRES	RES	HighRES
Engineering	17	164	167
O&M	1	11	13
Instalation	12	116	122

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 44.59 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 28 jobs (FTEs), which would remain employed throughout this period.

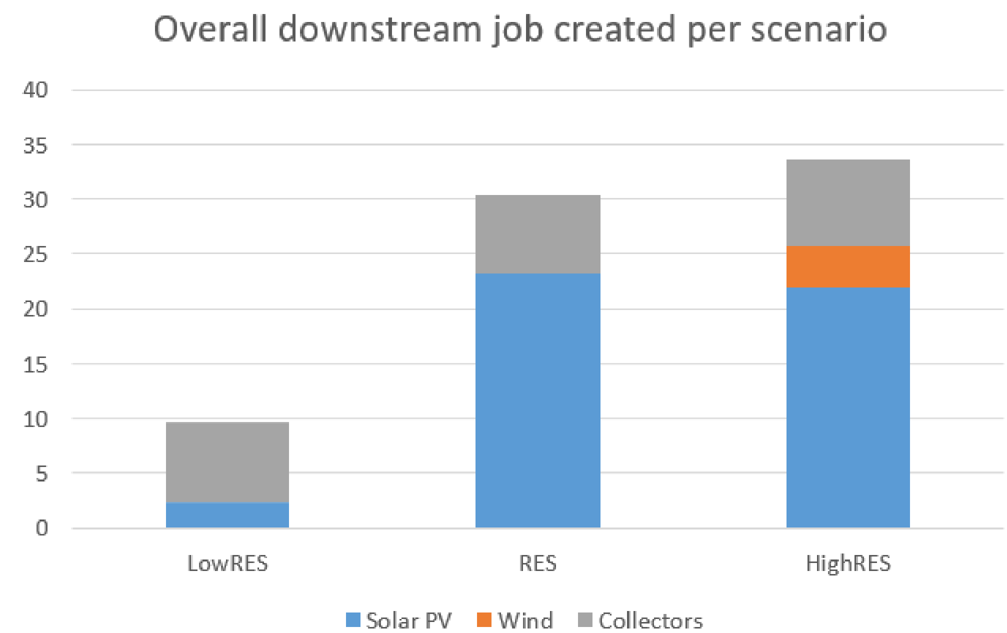


Figure 12 Overall downstream job creation per scenario on the island of Korčula

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 according to the dynamics set in motion in the period of this analysis).

2.3. Environmental considerations

1) Reduction of GHG emissions

In Figure 13, GHG emissions are presented, for each scenario. Also, for comparison, emissions in the base year are given.

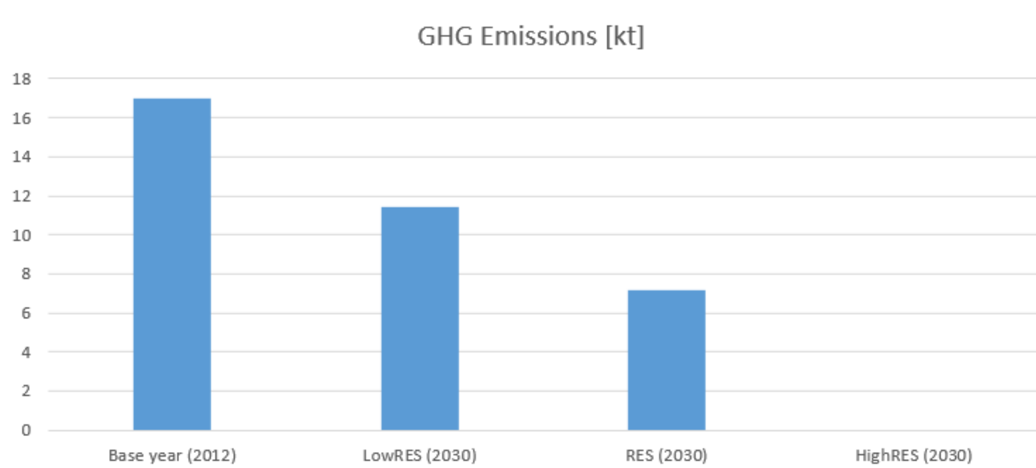


Figure 13 Comparison of emissions for all scenarios and compared to the base year

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

The Figure 14 illustrates how much of the area of island of Korčula is included in NATURA 2000 network, which constraints the installation of any larger production facility.

Figure 14 Natura 2000 network on the island of Korčula

Further limitations are considered, taking into account the recent Strategic study of Environmental Impact of the Plan for the Use of Renewable Energy Sources in the Dubrovnik-Neretva County[IRES, 2014].

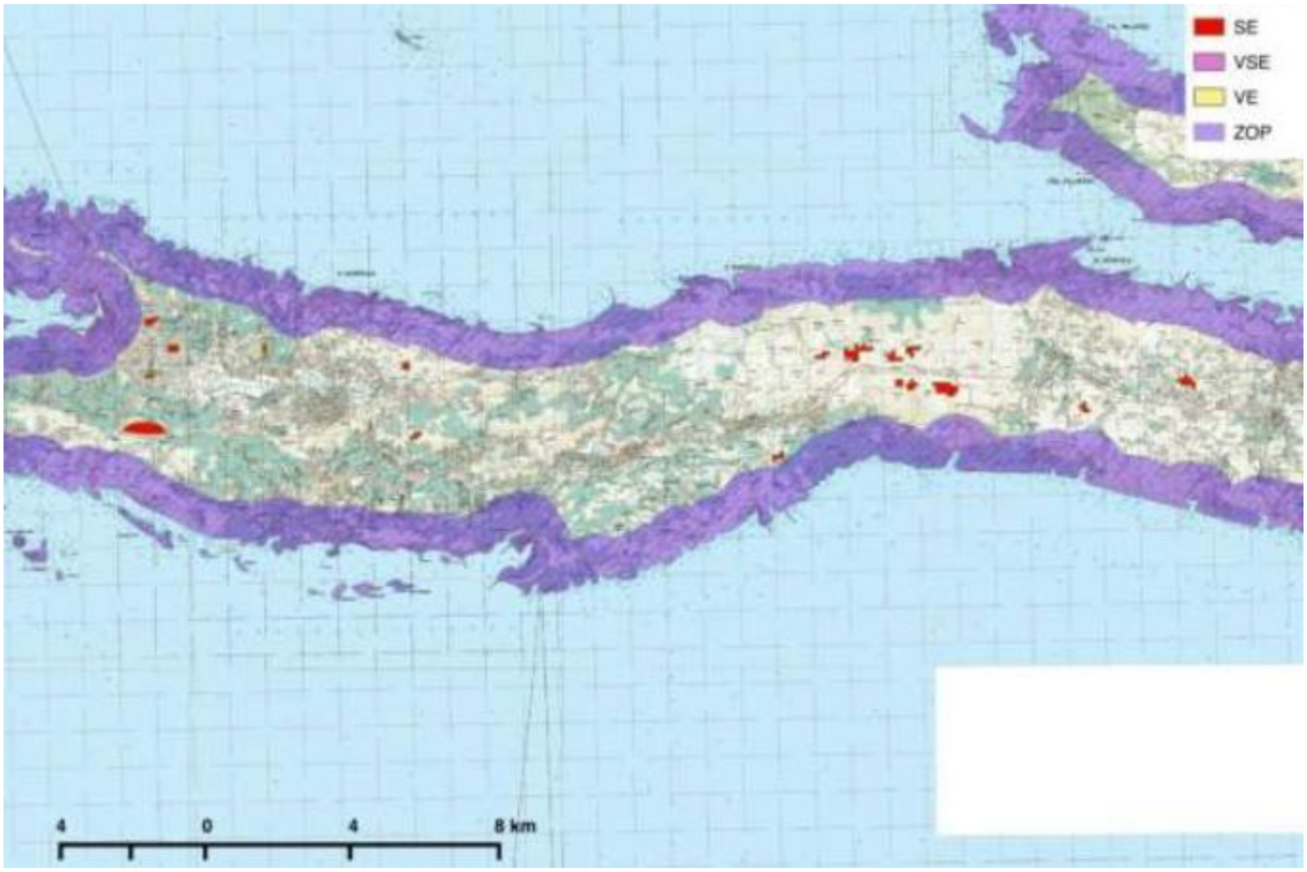


Figure 15 Illustration of coastal protected area and possible locations for solar power

From Figure 15, it is visible that there is a number of potential locations, in particular for PV power plants, which could be exploited.

Figure 16 Locations for PV which are suggested by the Strategic study

After all rigorous conditions have been examined in [IRES 2014], recommendation has been given for the locations presented in Figure 16. These locations remain in the plan for RES use and are available for investments.

2.4. Suggestions for strategy of development

For the island of Korčula, based on the above-described scenario approach, a draft Sustainable Energy Action Plan (SEAP) should be drafted, in the form of Option 2 of the Joint SEAP. Such draft SEAPs should for both islands include the following new measures:

- 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. Conclusions

In the current study, the scenario approach in energy systems modelling has been used to model the future scenarios for the Island of Korčula. 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. To achieve zero emissions, a transition to EVs and a V2G system has been identified as essential. As far as the heating sector is concerned, HPs and Solar thermal collectors represent viable solutions that should be analysed on a case-by-case basis. 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.

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