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LOCAL SUSTAINABLE ENERGY SYSTEM DEVELOPMENT IN AN INSULAR AREA : MUNICIPALITY OF RAGUSA, ITALY

February 2021

PRISMI PLUS

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

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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.

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Executive Summary

The PRISMI PLUS toolkit implementation for Ragusa 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 Ragusa 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 on. 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 city of Ragusa 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.

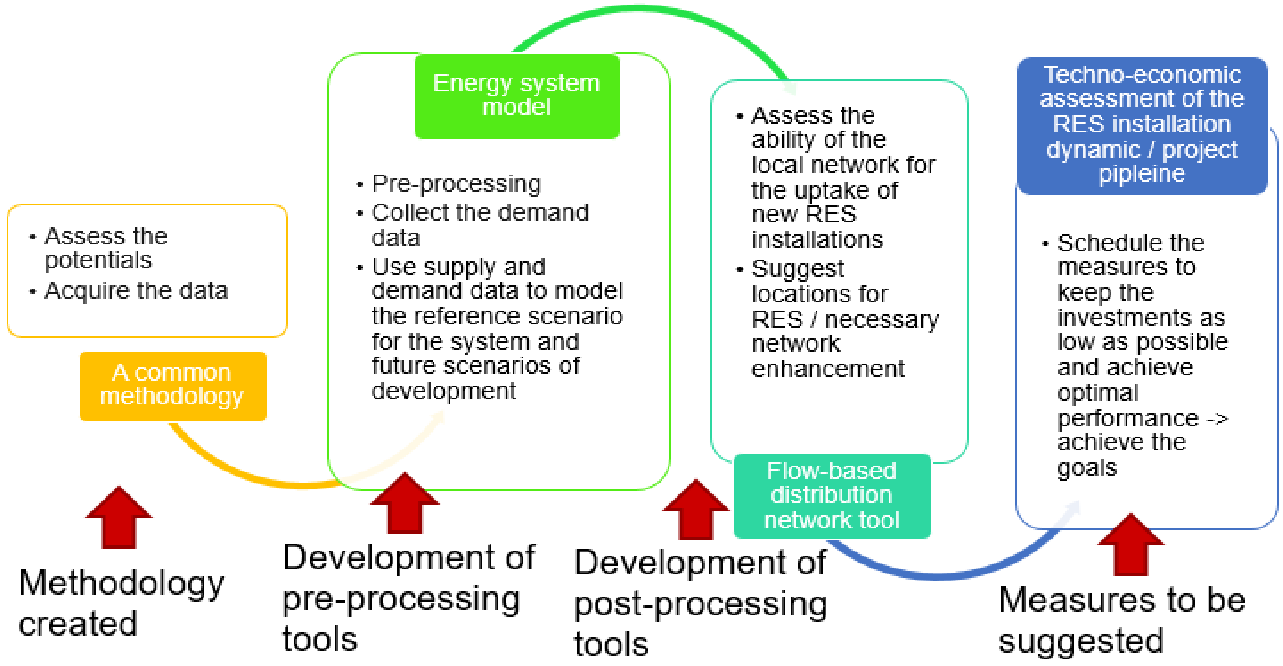


Figure 1 The PRISMI PLUS approach step-by-step

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

Mapping the energy needs of the local municipality

Ragusa 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.[1]

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 be exploited is solar power.

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'

[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.

analysis. Ragusa Municipality indicated the following technologies: PhotoVoltaic (PV), Wind Turbines (WT), Solar Thermal collectors (ST), Electric Vehicles (EVs), Heat Pumps (HPs), Battery Energy Storage (BES).

Division of scenarios

The energy system development is examined through three scenarios. 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 Ragusa Flagship Case (FC)

Ragusa is a Municipality in southern Italy; it is the capital of the province of Ragusa, on the island of Sicily, with 73,288 inhabitants in 2016. It is built on a wide limestone hill between two deep valleys, Cava San Leonardo and Cava Santa Domenica. Together with seven other cities in the Val di Noto, it is part of a UNESCO World Heritage Site. Concerning the electricity supply, the size of the cable has been assumed to be 26.55 MW by analyzing the peak power of the electricity load profile provided by the Ragusa Municipality itself that is equal to 22.13 MW that has been oversized by a factor 1.2 so as to obtain the value of 26.55 MW.

The city is strongly dependent on electricity imports, as the possibilities for local energy production are limited. Indeed, only a few distributed PV and wind units are installed in the city with a yearly production of 79.4 GWh/y and 18.46 GWh/y, respectively. Ragusa is also a popular tourist location, especially during summer. This results in intensive seasonal loads.

Table 1 shows the energy consumption subdivided in energy vector and energy-consuming sector as provided by the Ragusa Municipality itself.

Table 1. Consumption details

Consumption	Energy vector	Value	Unit of measure
Heating	Diesel	15270	MWh/y
	Coal	0	
	Biomass	25658	
	GPL	39294	
	Oil	16414	
	Natural gas	98077	
	Solar thermal	1364	
Transport	Gasoline	120793	
	Diesel	274412	
	GPL	20214	

	Biofuel	16615	
Industry and other fuel consumption	Oil	106872	
	Natural gas	50570	

Regarding the heating sector, no information on the use of HPs has been provided so the baseline does not consider this technology in the mix.

Following a dedicated mapping of the locally available RES, it can be derived that the solar energy potential is remarkably high, with the annual solar irradiation being in the levels of 1,900 kWh/m^2 [European Commission, 2021]. Figure 2 depicts the hourly solar radiation variation, with the raw data time-series being retrieved from the web tool "*Renewables.ninja*" (link in the references).

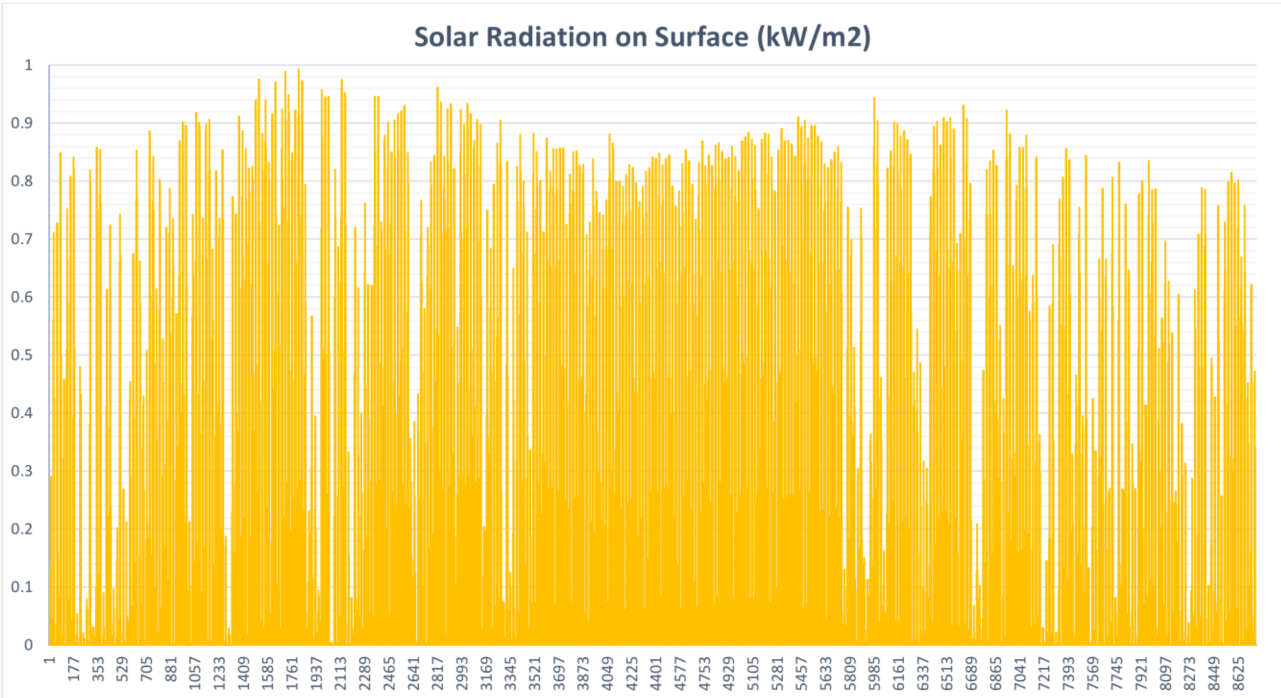


Figure 2 Solar Radiation on Horizontal Surface (kW/m^2) in Ragusa

Figure 3 shows the hourly capacity factor for PV panels in Ragusa "*Renewables.ninja*".

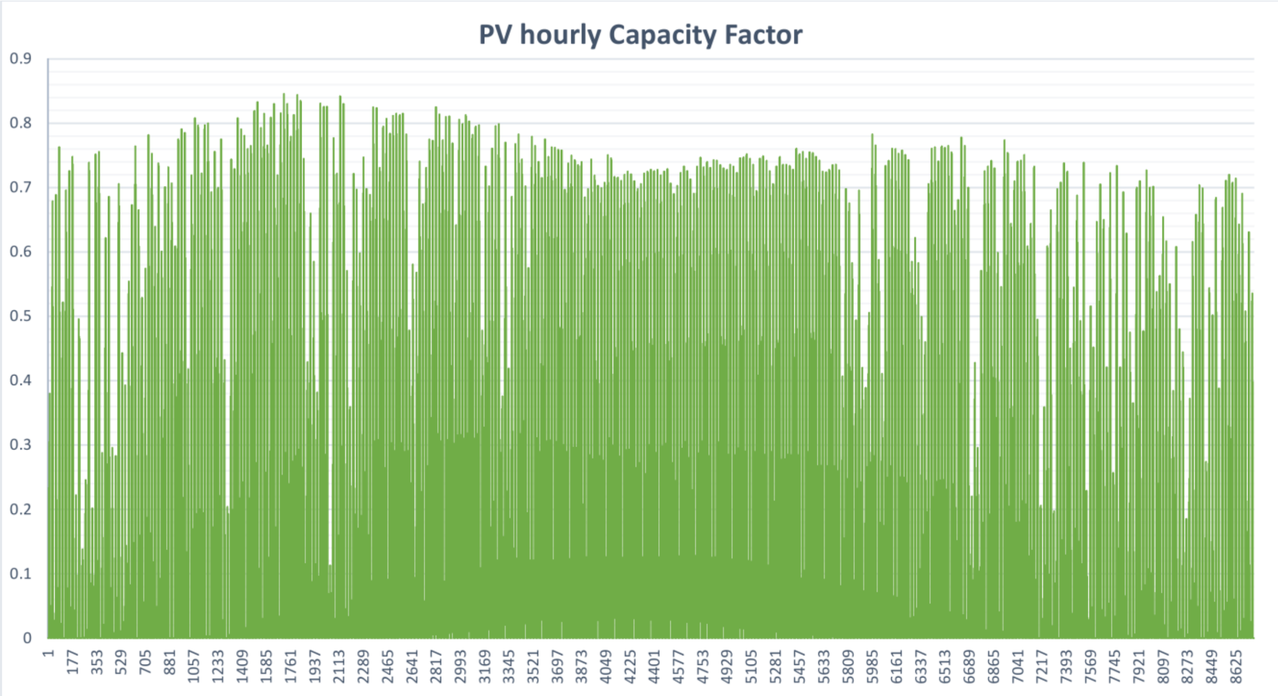


Figure 3 PV hourly Capacity Factor in Ragusa

Devision of scenarios

The fourth step of the PRISMI PLUS method is the division of scenarios. The energy system development for Ragusa municipality has been examined through the following three scenarios:

Scenario 1: During this scenario, the electricity consumption of the whole region, as provided by Ragusa Municipality itself, is considered. This scenario is used as a baseline scenario since no other installation/investment is analysed.

Scenario 2: During this scenario, the partial electrification (i.e. 50% of the total consumption) of the heating sector and the transport one is analysed by means of the installation of HPs and EVs, respectively. Also, the investment in PV, WT, and BES is analysed in order to reach a 50% RES share.

Scenario 3: During this scenario, the full electrification (i.e. 100% of the total consumption) of the heating sector and the transport one is analysed by means of the installation of HPs and EVs, respectively. Also, the investment in PV, WT, and BES is analysed in order to reach a 100% RES share.

In both scenarios 2 and 3, EVs are considered to be enabled only for smart charging, no Vehicle-To-Grid (V2G) is allowed. Further considerations will be elaborated on the basis of the year 2030. Table 2 shows the installed PV and WT capacity for the 3 scenarios while Figure 4 shows the electricity demand variation between the scenarios due to the increasing electrification of demands. It is worth noting that the PV and WT installed power have been evaluated in order to reduce the Critical Excess Electricity Production (CEEP) and thus to reduce the curtailment (i.e. waste of renewable electricity).

Table 2 Input data for the energy system scenarios in Ragusa municipality

2030	Scenario 1	Scenario 2	Scenario 3
PV installed capacity [kW_p]	50650	157700	383000

WT installed capacity [kW_p]	7096	23585	127000

The municipality of Ragusa provided all yearly data needed for calculations. However, since the hourly electricity distribution of Ragusa was not given, a reference hourly profile was employed.

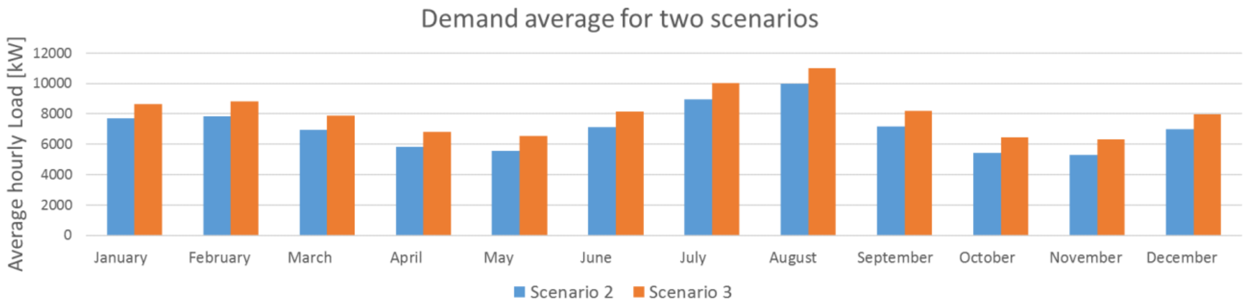


Figure 4 Average monthly load demand for Ragusa municipality in 2030 for scenarios 2 and 3

2.1 Results of modelling and discussion

In the following, the simulation (modelling) results are presented, in order to be easily understood and compared. Figure 5 shows the RES share in primary energy supply (PES). The combination of RES deployed for each scenario investigated is presented in Table 3.

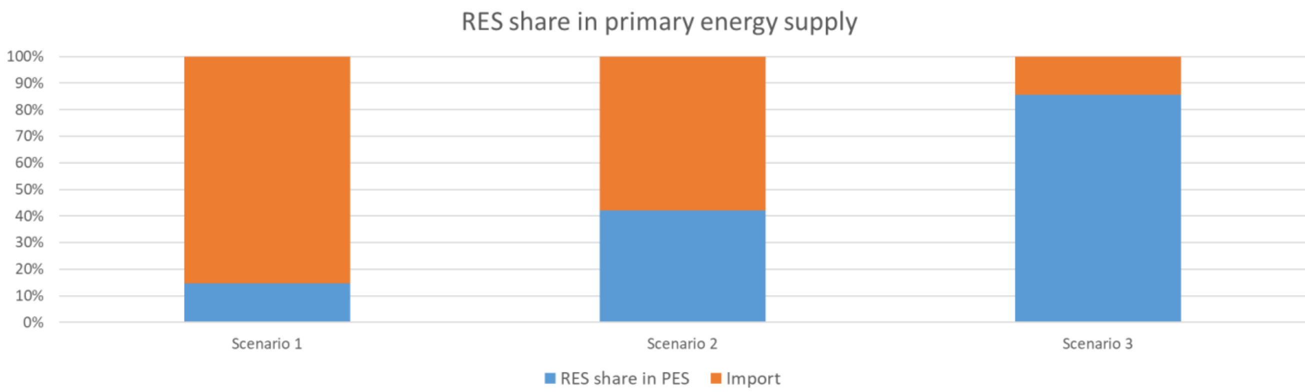


Figure 5 RES share in primary energy supply

For each scenario investigated, the combination of RES deployed is presented in Table 3.

Table 3 Results of modelling – energy generation from RES

	PV production	WT production	Unit
Scenario 1	79.42	18.46	GWh/year
Scenario 2	247.28	61.35	GWh/year
Scenario 3	600.56	330.34	GWh/year

Moreover, based on the previous amounts of energy generation, Figure 6 represents the RES share in electricity supply.

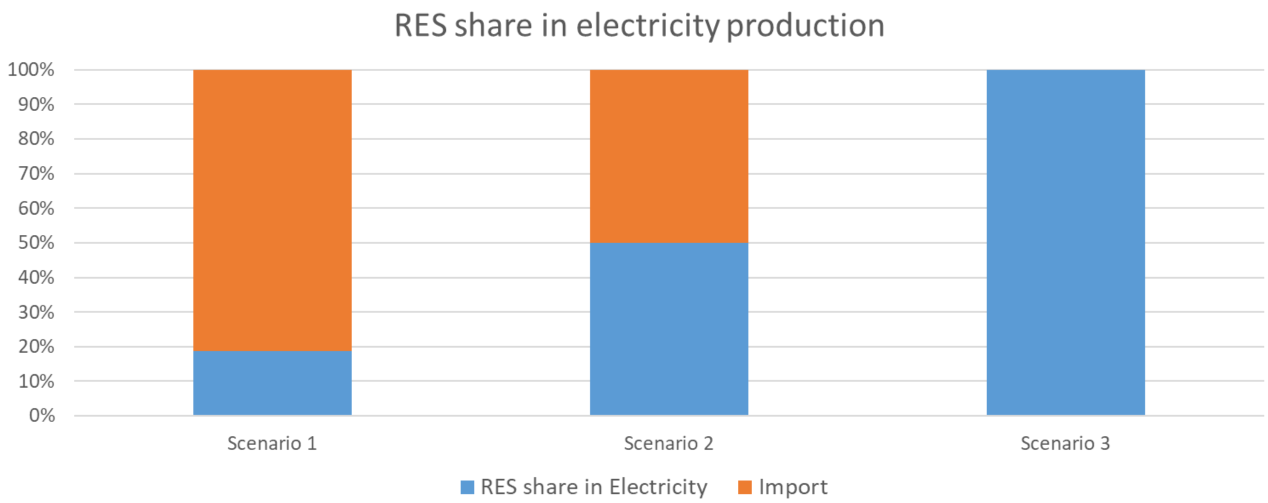


Figure 6 RES share in electricity supply

A great diversification can be noted in the percentages of the RES share in electricity supply.

In the following figures, the average monthly values of PV and WT systems' output power are depicted for the three scenarios investigated.

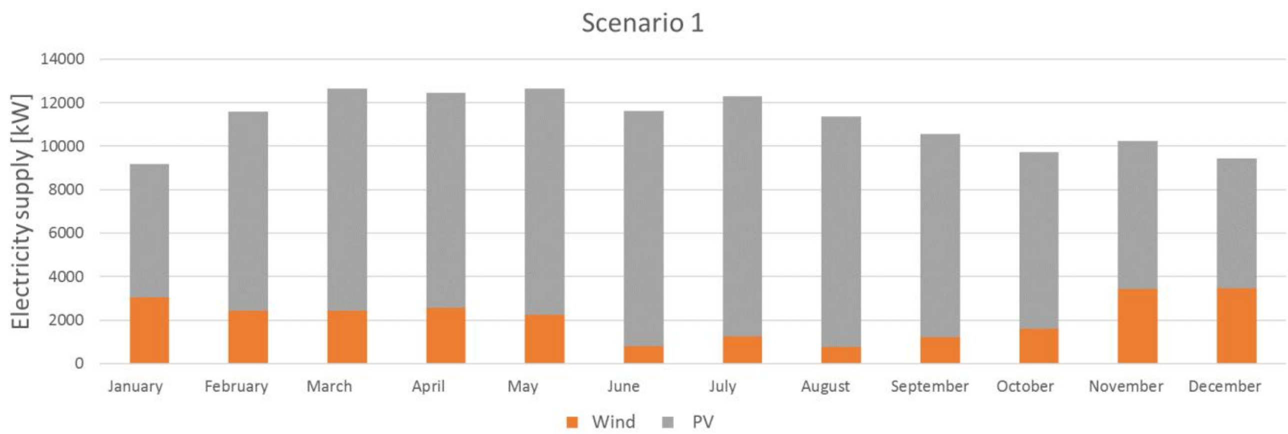


Figure 7 Average PV and WT systems' output power values for Scenario 1

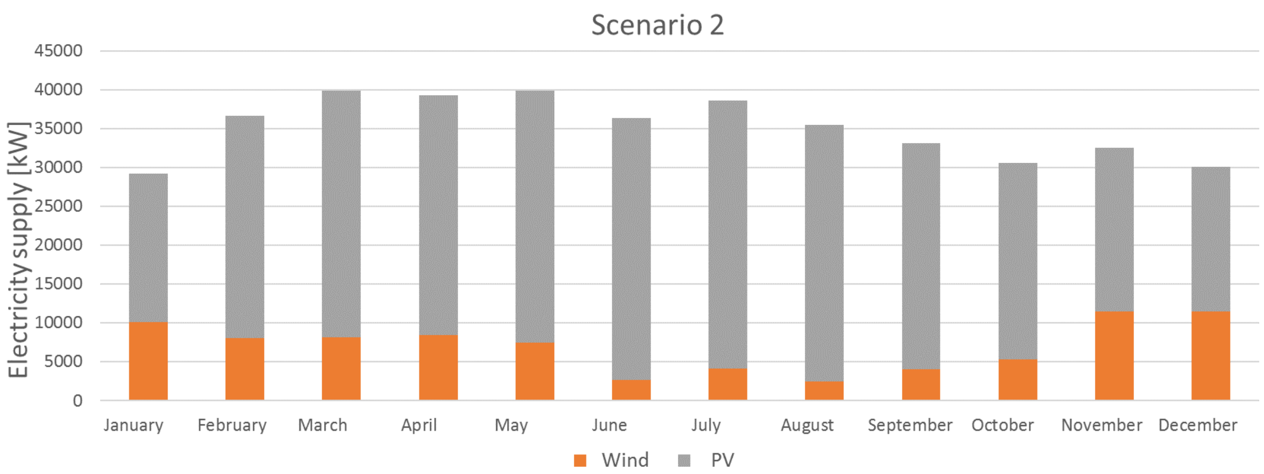


Figure 8 Average PV and WT systems' output power values for Scenario 2

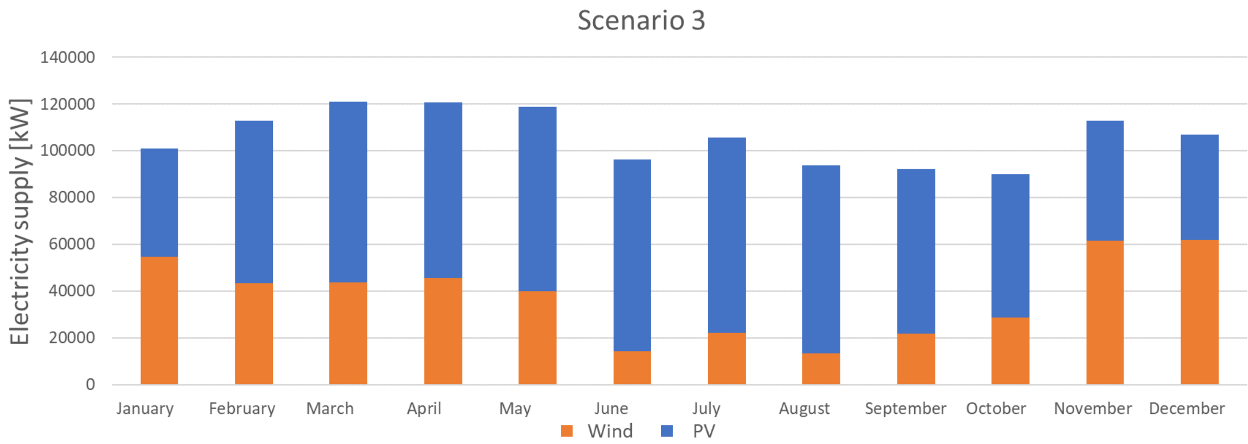


Figure 9 Average PV and WT systems' output power values for Scenario 3

Scenario 3 lead to a high value of Critical Excess Electricity Production (CEEP) equal to 75.39 GWh/y that is equivalent to 10% of the whole electricity consumption. Such percentage value is considered to be high. Indeed, the reference value of 5% is usually what a modeller should aim for. In order to avoid stability issues, the CEEP should be reduced by curtailment, thus wasting renewable electricity and leading to a renewable, usable, energy production equal to 298.2 GWh/y from Wind Turbines and 557.28 GWh/y from PV plants. This information suggests that additional flexibility strategies should be analysed as suggested in Section 2.1.4.

2.2 Socio-economic feasibility of proposed solutions

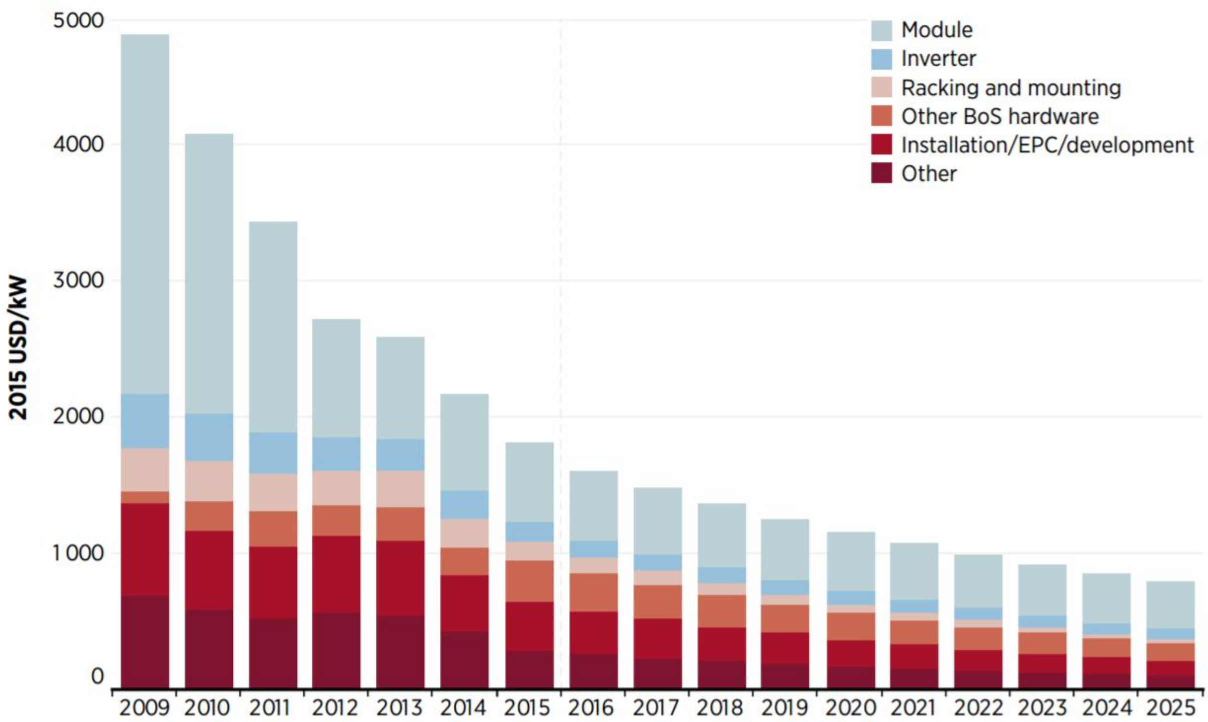
Input data for all three scenarios, regarding the prices of the PV and WT technology, are presented in Table 4.

Table 4 Initial inputs for techno-economic analysis

2030	Investment	O&M	Lifetime
PV [kEUR/kW]	1.07	1%	35
WT [kEUR/kW]	0.99	3.2%	27

Full-time equivalent jobs analysis – socio-economic parameter

The rapid development of RES, in particular solar and wind power, has already driven the prices per kW of installed PV systems and wind turbines to fall drastically over the last 10 years. The specific trend is likely to be continued, but even more interesting is the share of downstream jobs, such as in installation and engineering, as well as in O&M. These developments are illustrated in Figure 10.



Source: IRENA analysis and Photon Consulting, 2016

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

In the same context, in Figure 11, discrimination between upstream and downstream job positions is being carried out. Emphasis is put on the majority of jobs that are downstream and local for the region which implements the PV technology. This depends mainly on the case study investigated, as it can create new local economy through the energy transition.

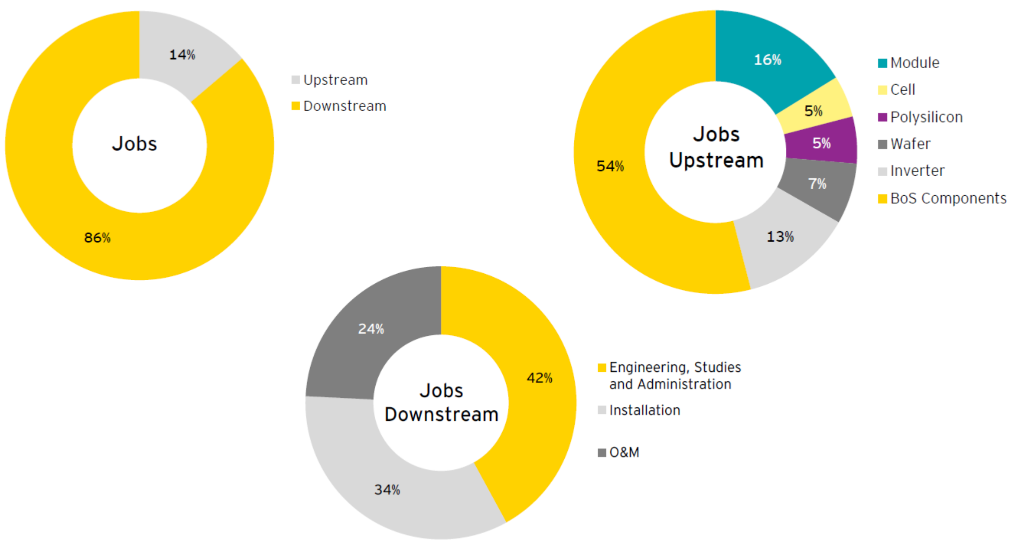


Figure 11 Upstream and downstream jobs in solar PV technology

One of the most important social parameters, which is investigated by recent studies, is the number of newly created jobs related to the PV industry [IRENA, 2020;

Ram et al., 2020]. The implementation of PV and WT systems in Ragusa municipality will create the need for new jobs, such as those related to the management, installation, and maintenance of these systems, as well as administrative tasks. It is worth noting that O&M jobs remain stable for the next 25-years' time-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).

Figure 12 presents the number of full-time equivalent (FTEs) jobs in each scenario investigated for 2030. Calculated for the last year of the analysis (2030), FTEs need to be also considered in the context of dynamics of the energy transition, which includes annual rates of installation for solar and wind power.

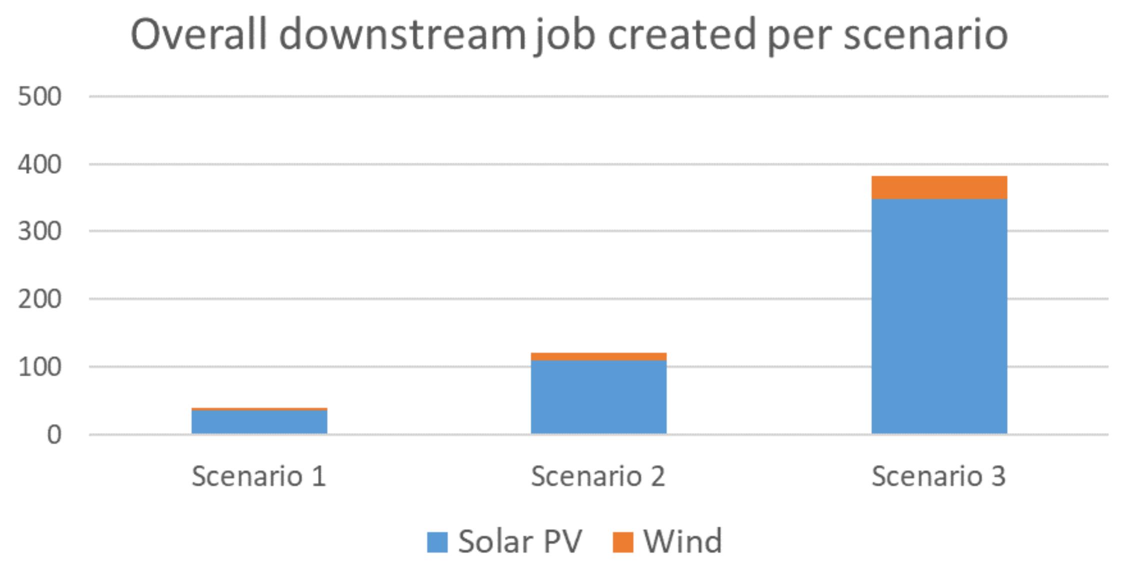


Figure 12 Overall downstream job positions creation per scenario for Ragusa Municipality

2.3 Environmental considerations

1) Reduction of Greenhouse Gases (GHG) emissions

Figure 13 presents the GHG emissions for each scenario investigated. or comparison purposes, the GHG emissions in the base year are also presented.

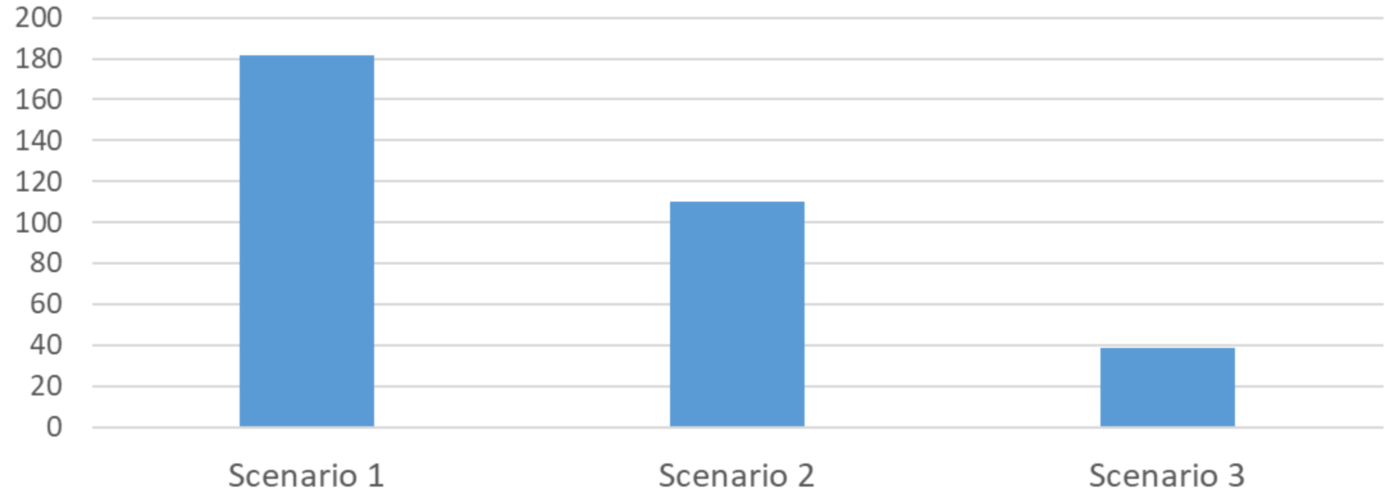


Figure 13 Comparison of GHG emissions for all scenarios as compared to the base year GHG emissions

Since the use of fossil fuels currently employed for electricity generation is partially substituted, the GHG emissions are to a great extent reduced.

2.4 Suggestions for the development strategy

The preliminary results obtained in the present study confirm that Ragusa has an interesting solar and wind energy potential that is largely unexploited. 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 developed by the PRISMI and PRISMI PLUS projects.

Thus, the future energy strategy of the region of Ragusa should revolve around some key concepts and ideas that could be deduced from the aforementioned results, which are:

- conceptualization of a thorough implementation plan for the integration of PV systems in the residential and the public buildings' rooftops (subsidized by either the local and/or the regional government and possibly by national funds);
- introduction of a special provision in new building permits for the aforementioned integration;
- identifying a location for installation of Wind farms;
- public awareness, informative campaigns and promotion of events for the adoption of energy efficiency measures, the use of HPs, Solar Thermal Collectors, and Wind Turbines, as well as Electric Vehicles;
- support and if possible incentivise the installation and upgrade of the required infrastructure (both physical and digital) for the introduction of Electric Vehicles enabled to provide flexible services to the grid;
- analyse the possibility to enable Vehicle-to-Grid (V2G) services in order to provide additional grid flexibility through demand response schemes;
- analyse the grid stability in the Municipality, the surrounding area and the whole region in order to avoid to rely on renewables curtailment;
- a detailed qualitative and quantitative analysis for the integration of other RES that would differentiate the energy mix of the region thus stabilising the energy supply and reducing the need for energy storage systems.

3. Conclusion

In the current study, the scenario approach in energy systems modelling has been used to model the future scenarios for Ragusa 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. Also, the need to shift to sustainable mobility in order to reduce the emissions to zero has been analysed underlining that EVs 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. 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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