LOCAL SUSTAINABLE ENERGY SYSTEM DEVELOPMENT IN A RURAL AREA : MUNICIPALITY OF BRDOVEC, CROATIA

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 Brdovec 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 Brdovec 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 Brdovec 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.

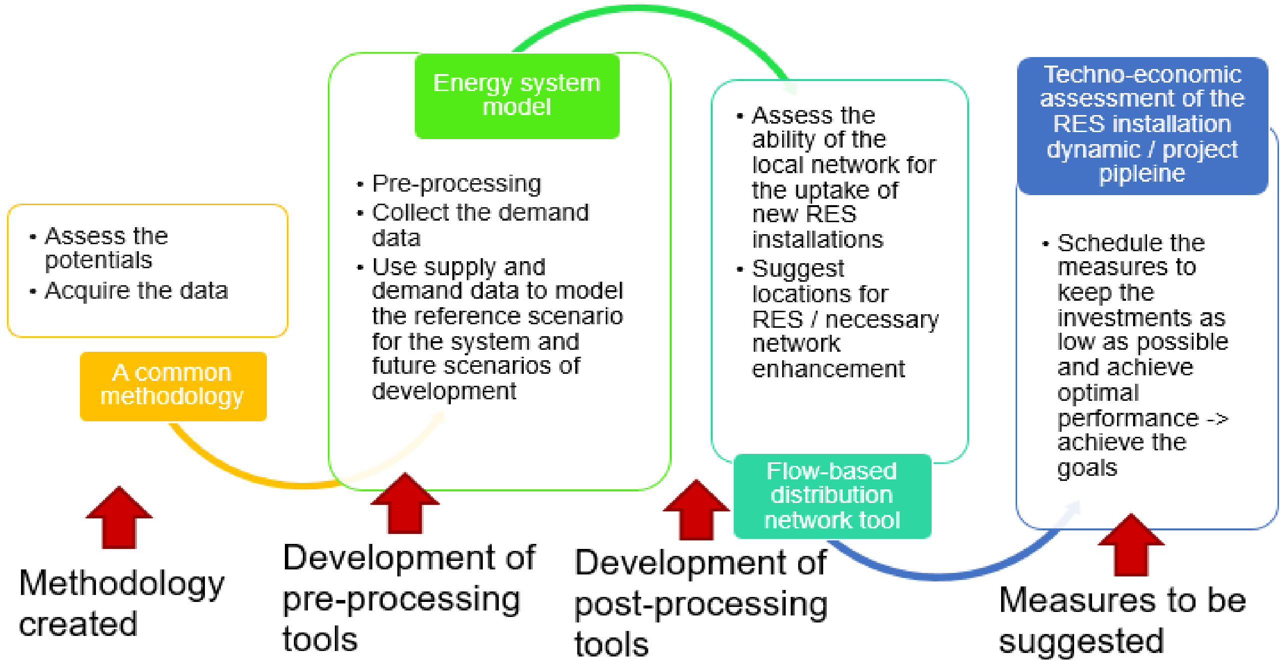

Figure 1 The PRISMI PLUS approach step-by-step

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

Mapping the energy needs of the local municipality

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

[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.

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. Brdovec 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) 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.

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

Brdovec is a municipality in Zagreb County, measuring 37.6 km^2 – the county's largest municipality. Municipality of Brdovec has signed the EU Covenant of Mayors initiative on November 15, 2011. Municipality of Brdovec has prepared Sustainable Energy Action plan (Further in the text: SEAP) as a part of Covenant of Mayors initiative and it was official approved by Municipality council on November 13, 2012. SEAP was prepared according to the Guidebook - How to develop a SEAP. The SEAP of Municipality of Brdovec includes 23 measures for reducing CO_2 emissions from buildings, transport and public lighting sector (Target – reducing the CO_2 emission by at least 21% in comparison with baseline year – 2009 year). According to the available data from SEAP the municipality's total energy consumption is roughly 90,000 MWh per year, with buildings consuming 78% of this total. Baseline emission Inventory of the Municipality of Brdovec is roughly 23 kt CO_2.[2] CO_2 baseline emission inventory of the Municipality of Brdovec covers direct CO_2 emissions occurring due to fuel burning, and indirect CO_2 emissions from electricity and thermal energy consumption from buildings, transport and public lighting sector.

SEAP of the Municipality of Brdovec in a nutshell:

- Date of formal approval: 13 November 2012
- Submission date: 2013-05-20
- Baseline year: 2009
- Energy consumption: 116,870.88 MWh
- CO_2 emissions: 23.59 kt CO_2.

Considering the facts that SEAP covers period until 2020 year it is time to go further. Municipality of Brdovecis interested to join the EU Covenant of Mayors for Climate & Energy. The EU Covenant of Mayors for Climate & Energy brings together thousands of local governments voluntarily committed to implementing EU climate and energy objectives. The new initiative covers period until 2030 year and signatories commits to prepare the Sustainable Energy Action and Climate plan (Further in text: SECAP).

In the first step of the PRISMI approach, demand modelling has been performed for the Municipality of Brdovec. Results of modelling include the base year demands, provided in the Table 1 .

Table 1 Energy demand of the Municipality of Brdovec in 2020[3]

Demand	2020
Households, services and industry	GWh
Electricity	60.76
Oil	7.79
Natural gas	34.33
Biomass	17.62
Total heating	59.73
Transport	GWh
Diesel	20.24

[2] Sustainable Energy Action Plan of the Municipality of Brdovec
[3] Based on the data received from HEP, GPZ, SEAP of the Municipality of Brdovec

Motor gasoline	12.34
LPG	1.08

The heating demand is observed in more detail, also with the help of GIS results of the research project RESFLEX, which was funded by the Croatian Science Foundation 2015-2017. Map of the heating demand, as well as the location of the Municipality are presented in Figure 2.

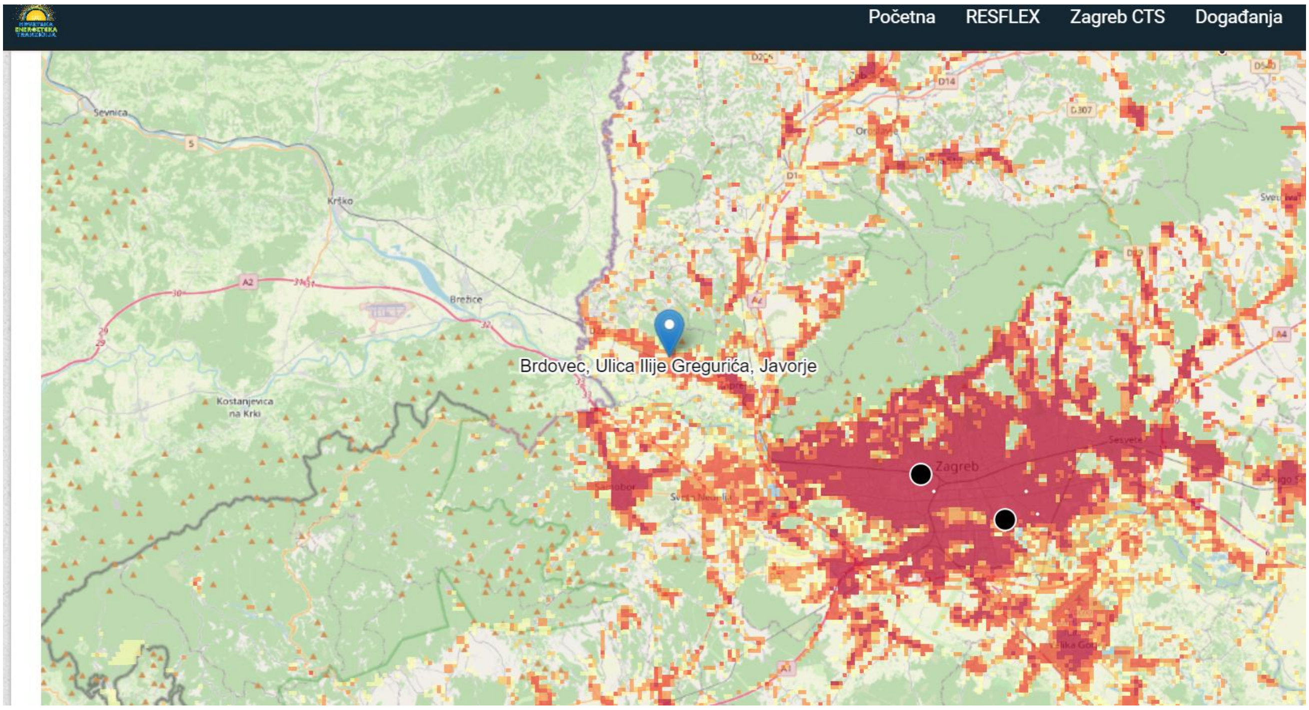

Figure 2 GIS map of needs for heating energy on the location[4]

In the second step, a mapping was performed of the locally available RES, and it can be derived that the solar energy potential is very significant, with the annual solar irradiation being in the levels of 1,500 kWh/m^2 [European Commission, 2021[5]]. Figure 3 depicts the hourly solar radiation variation, with the raw data time-series being retrieved from the web tool "*Renewables.ninja*" (link in the references).

[4] The RESFLEX project GIS results, http://het.hr/gis-karta/

[5] https://re.jrc.ec.europa.eu/pvg_tools/en/

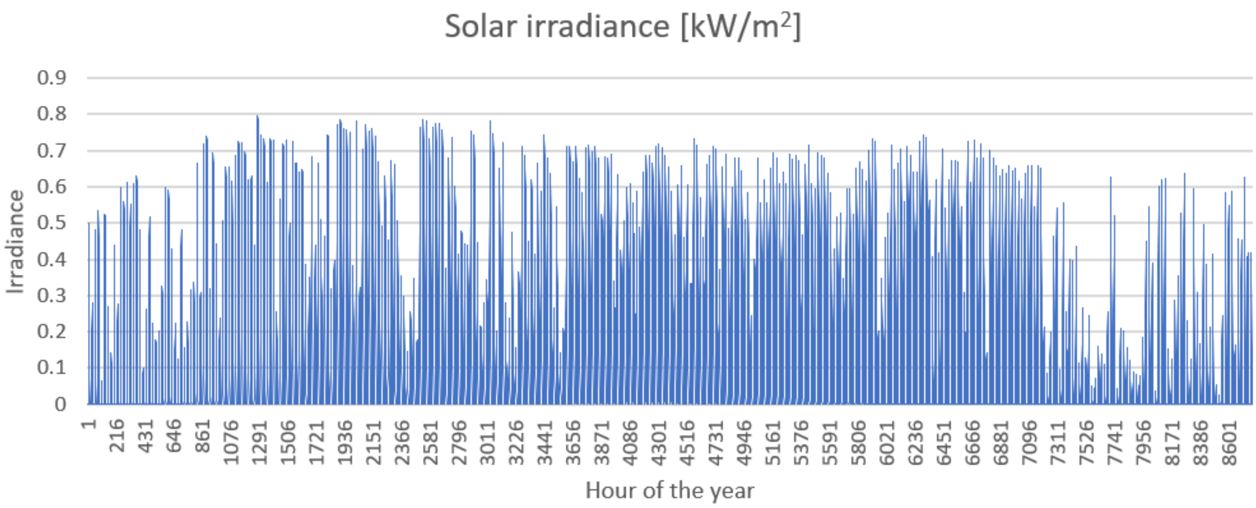

Figure 3 Solar Radiation on Horizontal Surface (kW/m2) in Brdovec

Potential for the use of biomass waste and green waste[6] was identified, as the Municipality is located in the area of Croatia with high potential for the use of waste portion of biomass. Figure 4 depicts the potential for such renewable source.

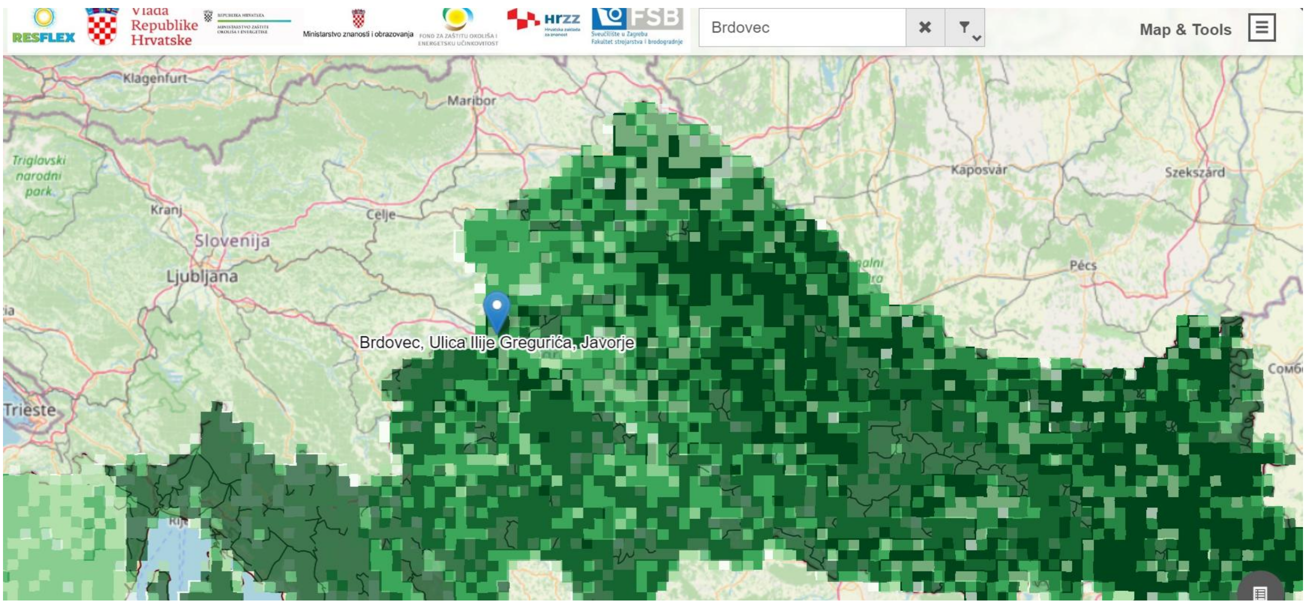

Figure 4 Potential for the use of waste biomass and agricultural waste

Geothermal mapping of Croatia[7] and recent research for the Zagreb County area[8] also underline the possibility of exploitation of geothermal energy for heating and, in a lesser degree, for electricity in the area of interest. Figure 5 represents the map of geothermal potential in the vicinity of the Municipality of Brdovec.

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[6] http://het.hr/gis-karta/

[7] https://geothermal-croatia.giscloud.com/

[8] Barkaoui A.E. et al., J. Mater. Environ. Sci., 2018, 9 (5), pp. 1411-1417

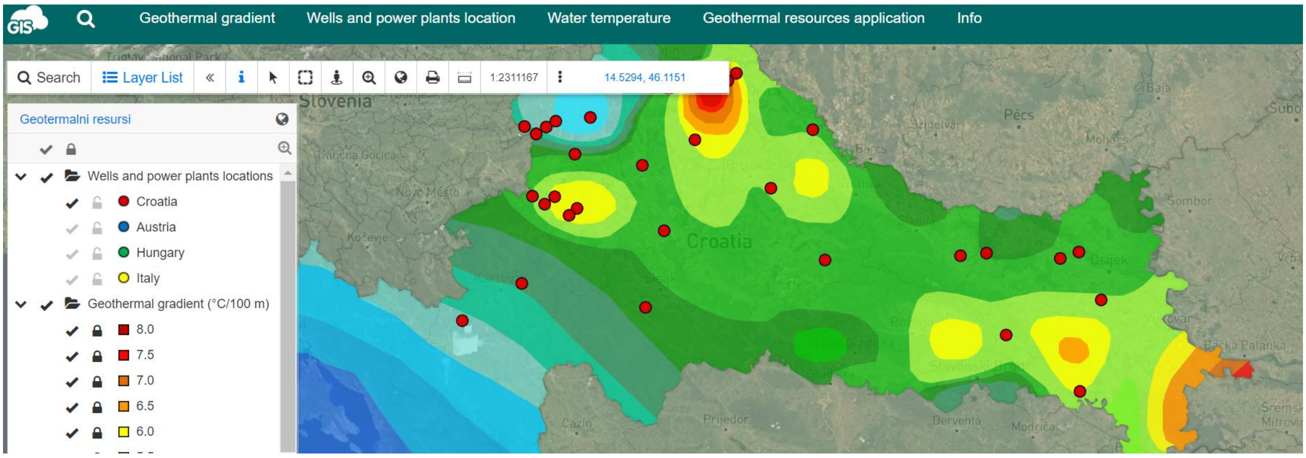


Figure 5 Geothermal potential in a GIS map of the continental Croatia

<u>Devision of scenarios</u>

The fourth step of the PRISMI PLUS method is the division of scenarios. The energy system development for the Brdovec municipality has been examined through the following these scenarios:
- one business-as-usual scenario until 2030 and two scenarios of the energy transition in 2030 and 2050.

Gradual transition scenario:

- Takes into account the gradual replacement of fossil fuels in heating with biomass, electricity (heat pumps). In transport, a gradual replacement of ICE vehicles with EVs is performed. In electricity supply, 50% of households instals PV systems by 2030 and 30% of the public building's rooftops is available for PV systems, which significantly raises the share of RES.

Fast transition scenario:

- This scenario is a step forward from the gradual one, in both technological and dynamic sense. In transport, smart charging is available by 2030 and vehicle-to-grid concept is used in 2050. In electricity supply, apart from majority of households installing PV and 90% of public buildings available for PV, additional ground based solar power plant with the installed capacity of 5 MW is installed, 5 MW of biomass power plant and 2 MW of geothermal power plant is added to complete the transition of the Municipality.

It is worth noting that the PV 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 Brdovec municipality

	Scenario BAU2030	Scenario RES2030	Scenario HighRES 2030	Scenario RES2050	Scenario HighRES 2050
PV installed capacity [kW_p]	0	6637.5	9961	19822	19822
GEO installed capacity [kW_p]	0	0	0	0	2000
Biomass installed capacity [kW_p]	0	0	0	0	5000
EV dump demand [GWh]	2.54	2.54	0.54	1	0
EV smart demand [GWh]	0	2	6	12	14
EV charging cap. [kW]	0	6577	15872	41751	41751
V2G [kW]	0	0	0	10751	41751
EV battery storage [MWh]	0	46.97	113.37	298.22	298.22

In the following figure, average monthly electricity loads are presented and the supply from different technologies is visible.

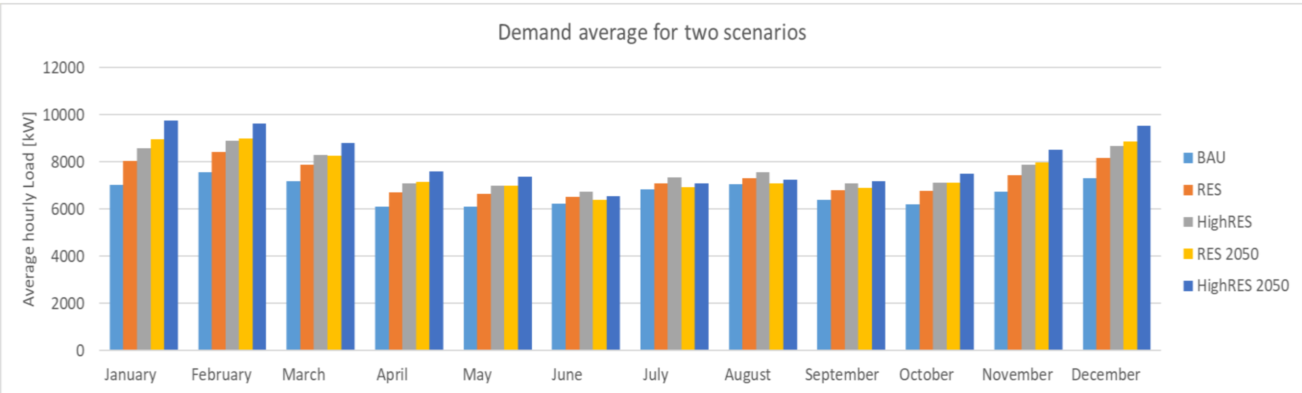


Figure 6 Municipal electricity supply scenarios with BAU and different RES scenarios

2.1. Results of modeling and discussion

In the following, the simulation (modelling) results are presented, in order to be easily understood and compared. Figure 7 shows the RES share in primary energy supply (PES). The combination of RES deployed for each scenario investigated is presented in Table 3.

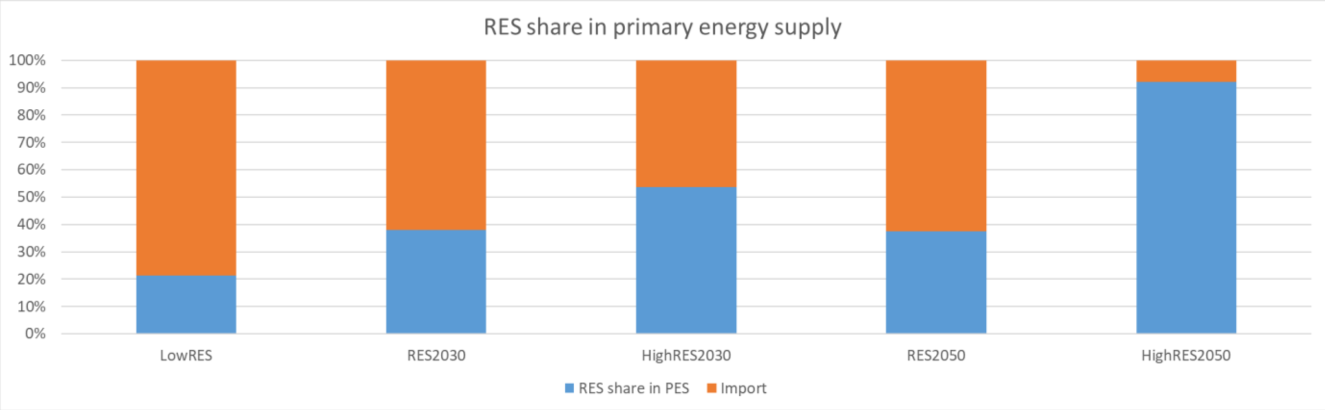


Figure 7 RES share in primary energy supply

For each scenario investigated, the combination of RES deployed is presented in Table 2.

Table 2 Results of modelling – energy generation from RES

GWh/year	RES 2030	HighRES 2030	RES 2050	HighRES 2050
RES production	8.66	12.99	25.97	68.42
PV households & ground	8.33	12.49	24.98	32.08
PV public	0.33	0.5	1	1
Biomass	0	0	0	17.77
Geothermal	0	0	0	17.57

Moreover, based on the previous amounts of energy generation, Figure 8 represents the RES share in electricity supply.

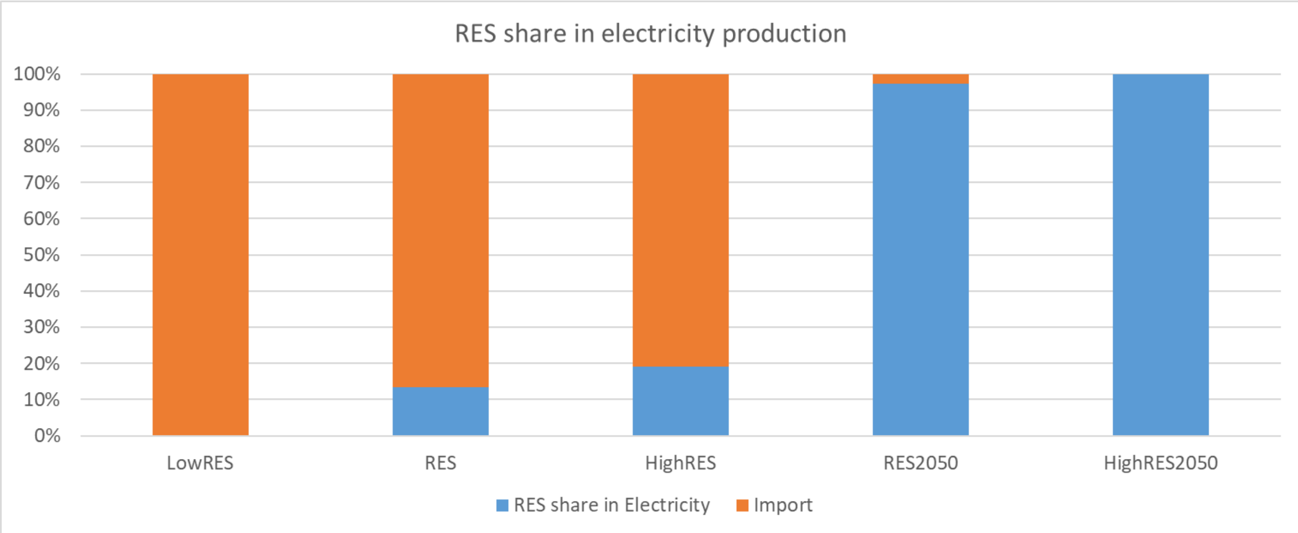
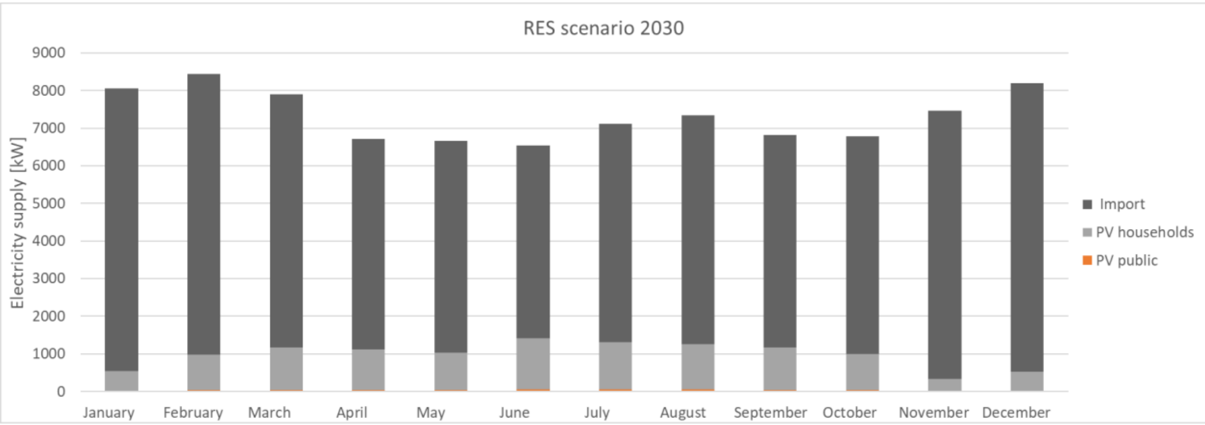


Figure 8 RES share in electricity supply

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 RES systems' output power are depicted for the scenarios investigated.



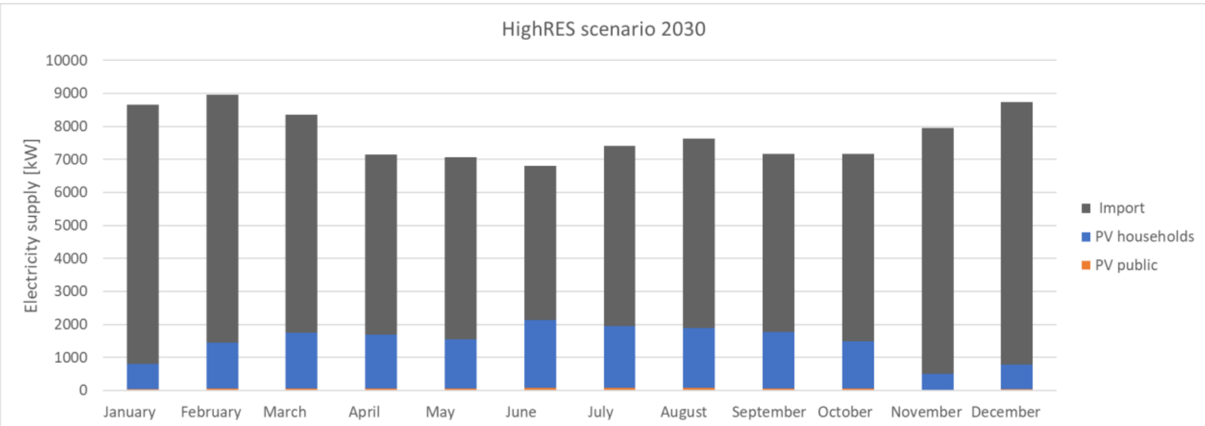
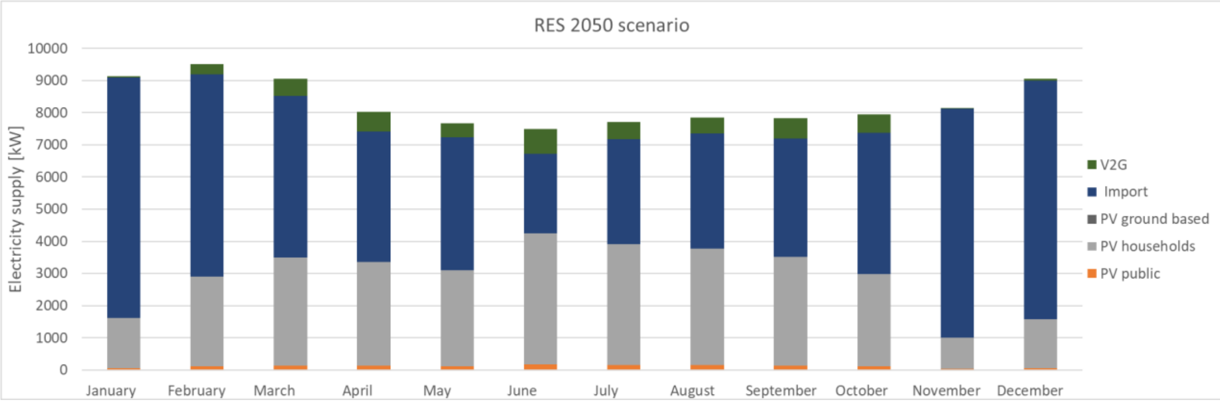


Figure 9 Average monthly output power values per scenario for Brdovec Municipality for year 2030



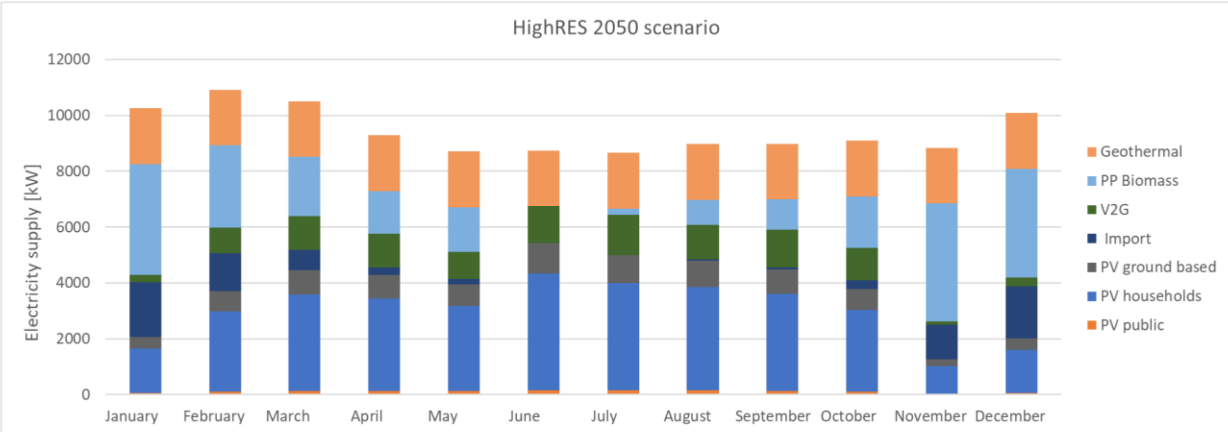


Figure 10 Average monthly output power values per scenario for Brdovec Municipality for year 2050

2.2. Socio-economic feasibility of proposed solutions

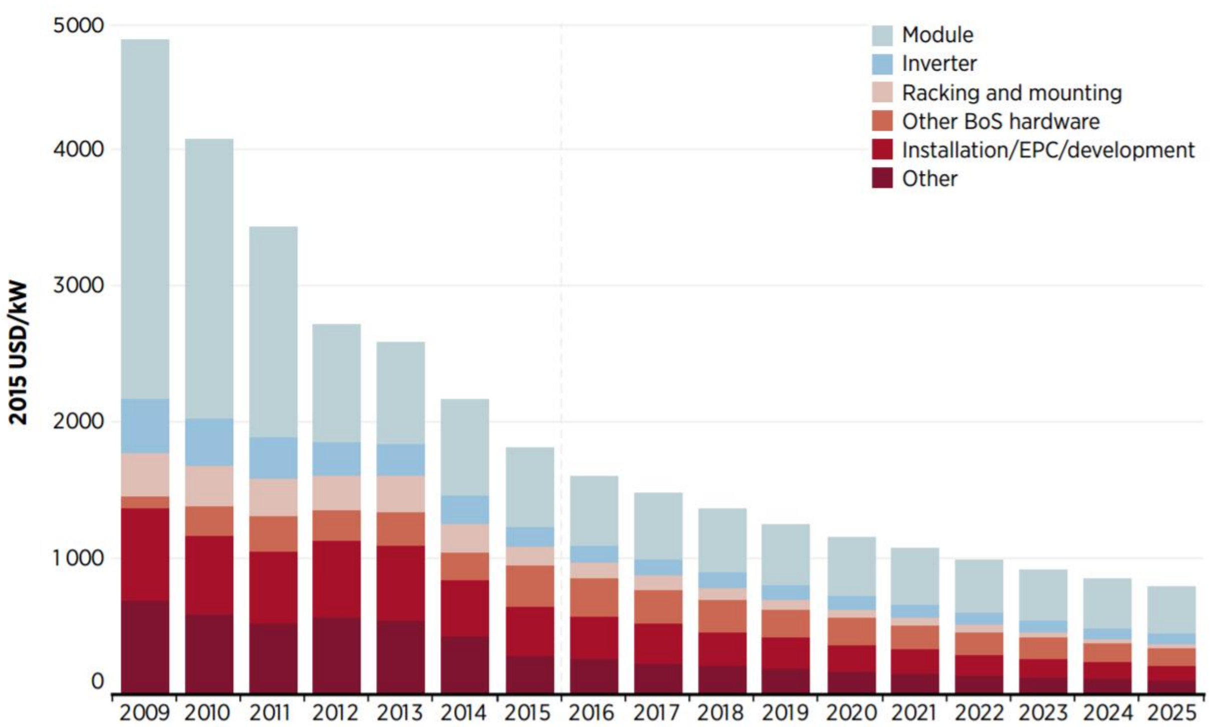
Input data for all three scenarios, regarding the prices of the PV and WT technology, are presented in Table 3.

Table 3 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 11 .



Source: IRENA analysis and Photon Consulting, 2016

Figure 11 Price development for the solar power and prediction towards 2025

In the same context, in Figure 12, 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.

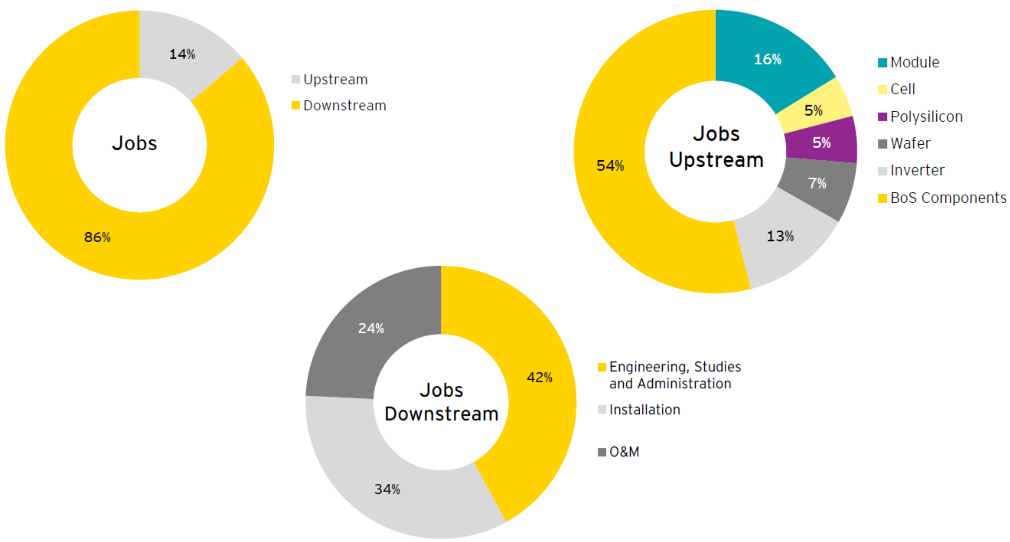


Figure 12 Upstream and downstream jobs in solar PV technology

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 Photovoltaic (PV) and Wind Turbine (WT) systems in the 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 13 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.

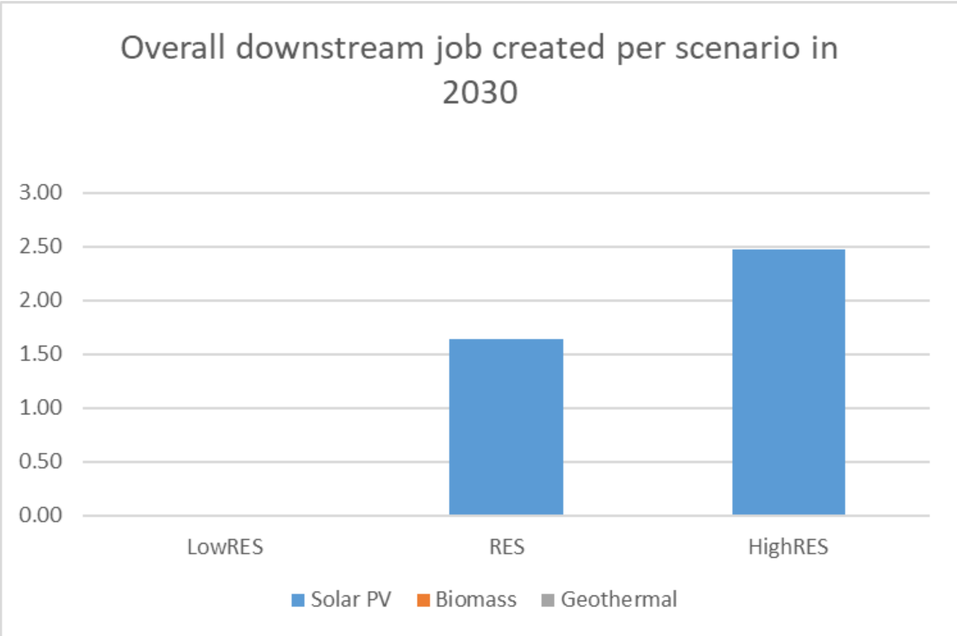


Figure 13 Overall downstream job positions creation per scenario for Brdovec Municipality for year 2030

In 2050 scenarios, however, the implementation of biomass and geothermal technologies kicks in. The calculated number of FTEs relies on the fact sheet published by the Environmental and Energy Institute in USA[9]. Figure 14 represents the number of downstream jobs locally due to the implementation of several RES technologies.

[9] S. Hettipola, Jobs in Renewable Energy and Energy Efficiency, November 2015, EEEI, www.eesi.org

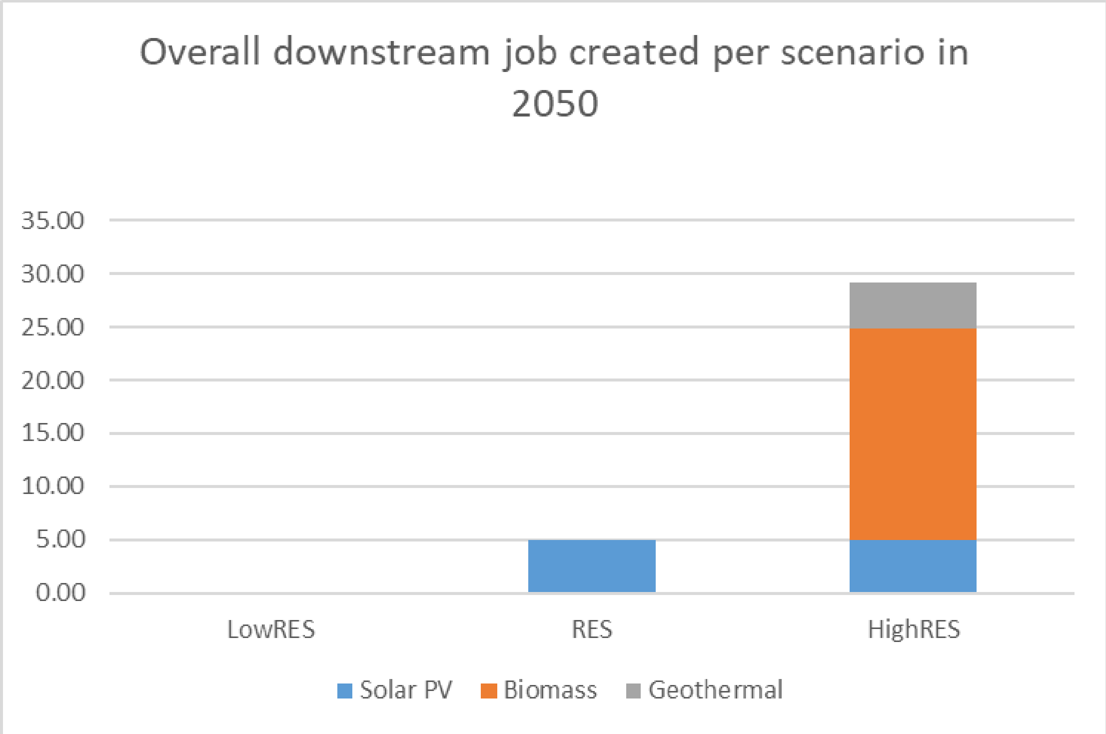


Figure 14 Overall downstream job positions creation per scenario for Brdovec Municipality for year 2050

2.3. Enviromental considerations

1) Reduction of Greenhouse Gases (GHG) emissions

Figure 15 presents the GHG emissions for each scenario investigated. Also, for comparison purposes, the GHG emissions in the base year are also presented.

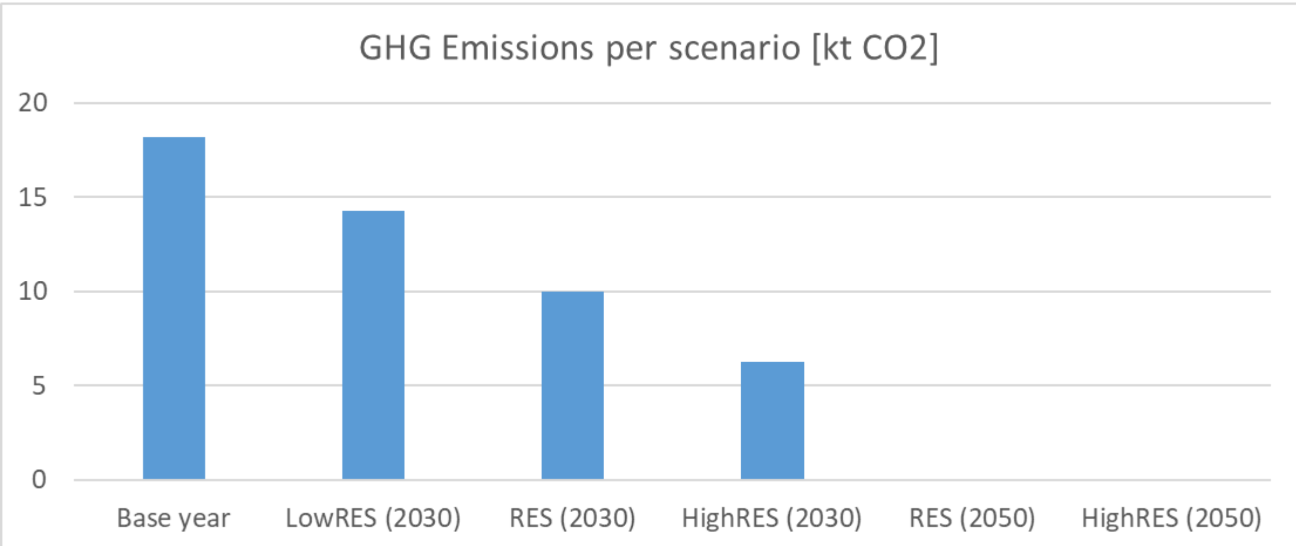


Figure 15 Comparison of GHG emissions for all scenarios as compared to the base year GHG emissions

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 Brdovec has an interesting solar, biomass and geothermal energy potential that is entirely 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 Municipality 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 (fostered by either the local and/or the regional government and possibly by national funds);
- identifying a location for the installation of biomass power plant, to exploit potential of waste biomass and lignocellulosic waste components of municipal waste streams;
- public awareness, informative campaigns and promotion of events for the adoption of energy efficiency measures, the use of HPs, Solar Thermal Collectors, and waste biomass, 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, establishing the Municipality as the leader in the implementation of energy system balancing technologies powered by the community;
- analyse the grid stability in the Municipality, the surrounding area and the whole region in order to avoid renewables curtailment;
- support of Municipality in investigation of the suitable fields for the geothermal energy use.

3. Conclusions

In the current study, the scenario approach in energy systems modelling has been used to model the future scenarios for the Municipality of Brdovec. 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 analyzed 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, biomass and geothermal 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 center of energy transition.

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