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# LOCAL SUSTAINABLE ENERGY SYSTEM DEVELOPMENT IN AN INSULAR AREA : MUNICIPALITY OF AKAMAS, CYPRUS

June 2018

Project co-financed by the European Regional Development Fund

# PRISMI
## Promoting RES Integration for Smart Mediterranean Islands

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| 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 |
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| Abstract: | Energy scenarios will be defined, modelled and simulated emphasizing the different adopted |

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| | 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 Akamas 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 Akamas 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 Akamas 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.

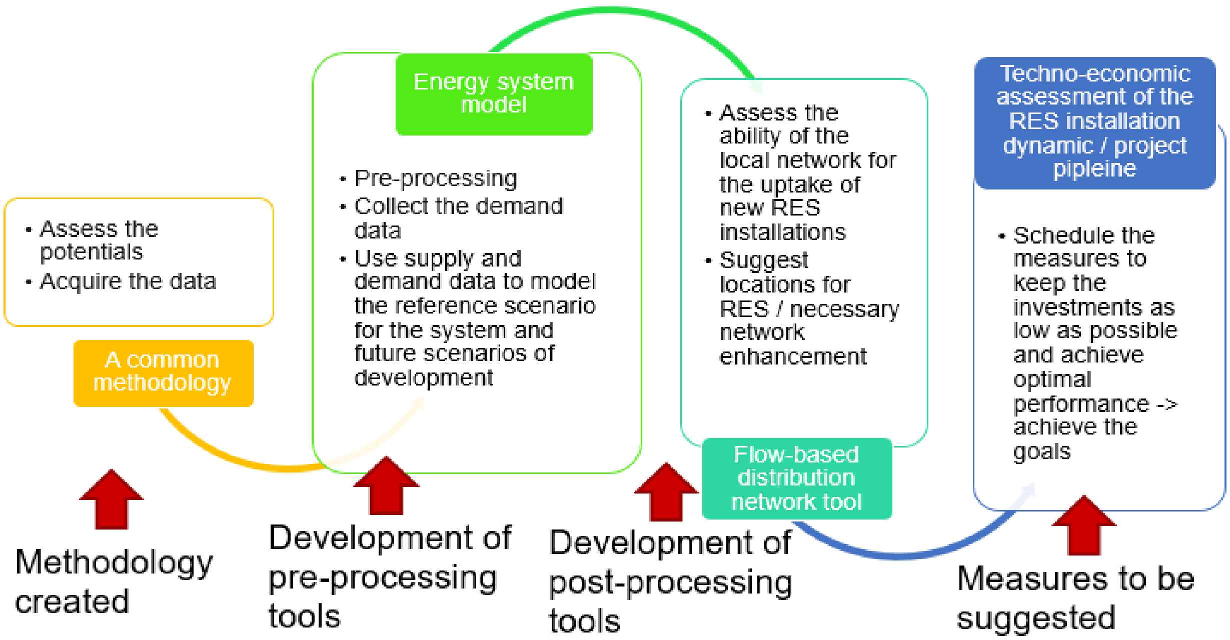


**Figure 1 The PRISMI approach step by step**

## 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 Akamas. Hence, the adapted methodology consists of the following actions:

**Mapping the energy needs of the island community**

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

**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 Akamas Flagship Case (FC)

Akamas Peninsula is located on the northwest end of Cyprus and is defined by the administrative boundaries of eight local authorities: the municipality of Peyeia and the village-communities of Kathikas, Pano & Kato Arodes, Ineia, Drousheia-Pittokopos, Androlikou and Neon Chorion and the abandoned village of Fasli. The total area of the peninsula is 230 square kilometers (Cyprus area: 9.251 square kilometers) and is one of the least inhabited places on the island with 6000 inhabitants (census 2011). The mountainous nature of the peninsula there contributes to the fact that there are not any streets running through her heart and some roads highlighted in the Cypriot road maps of the area are not asphalted. In addition, half of the terrestrial part of the peninsula is part of the European network - NATURA2000. Average electricity consumption for the local authorities of Akamas peninsula is about 40 GWh/year.
In accordance with the PRISMI method, 4 steps of energy planning are observed:

**Table 1 Mapping the needs of the Akamas peninsula community**

| Needs | Level<br>*(Low, medium, high)* | Geographical Distribution<br>*(Dispersed, concentrated)* | Code |
|---|---|---|---|
| Electricity | Medium | Dispersed | ElectMD |
| Heat | Low | Dispersed | HeatLD |
| Cooling energy | Low | Dispersed | ColdLD |
| Fuel for transportation | Low | Short distance. | TranLS |
| Water | High | Dispersed | WaterMD |
| Processing waste | Low | Dispersed | WasteLD |
| Wastewater treatment | Low | Dispersed | WWTLD |

### Table 2 Mapping the resources available

| Resources | Level | Code |
| --- | --- | --- |
| **Local primary energy** | | |
| Wind | Low | WindL |
| Solar | High | SolarH |
| Hydro (height) | n/a | n/a |
| Biomass | Low | BiomL |
| Geothermal potential | n/a | n/a |
| **Infrastructure for energy imports** | | |
| Network connection | Normal | GridN |
| pipeline natural gas | n/a | NGplN |
| Terminal LNG | n/a | LNGtN |
| Oil terminal / refinery | n/a | OilRN |
| Terminal petrol. production | n/a | OildDN |
| **Water** | | |
| Precipitation | Low | H2OPL |
| Groundwater | Low | H2OGL |
| Water supply | Yes | AquaY |
| Seawater | Yes | H2OSY |

*Technologies overview*

From the second step of the process, only solar energy has been rated as a high potential, while wind and biomass have been rated as low potential.

In Cyprus, solar power is generally used for two reasons, the production of electricity using photovoltaics and the production of hot water through solar thermal panels. In fact, the government provides incentives to citizens and businesses that want to install photovoltaic systems while the use of solar thermal panels is a mandatory basis. For Cyprus, a PV system with an optimal angle (25-30 °) and optimal orientation (south) produces an average of around 1,200-1,600 kWh / year / $kW_p$ and the required space is 7-8 $m^2$. On the other hand, for solar thermal panels is recommend that the collector angle be equal to the latitude of the area (for Cyprus is 35°) producing about 650-700 kWh / $m^2$ / year.

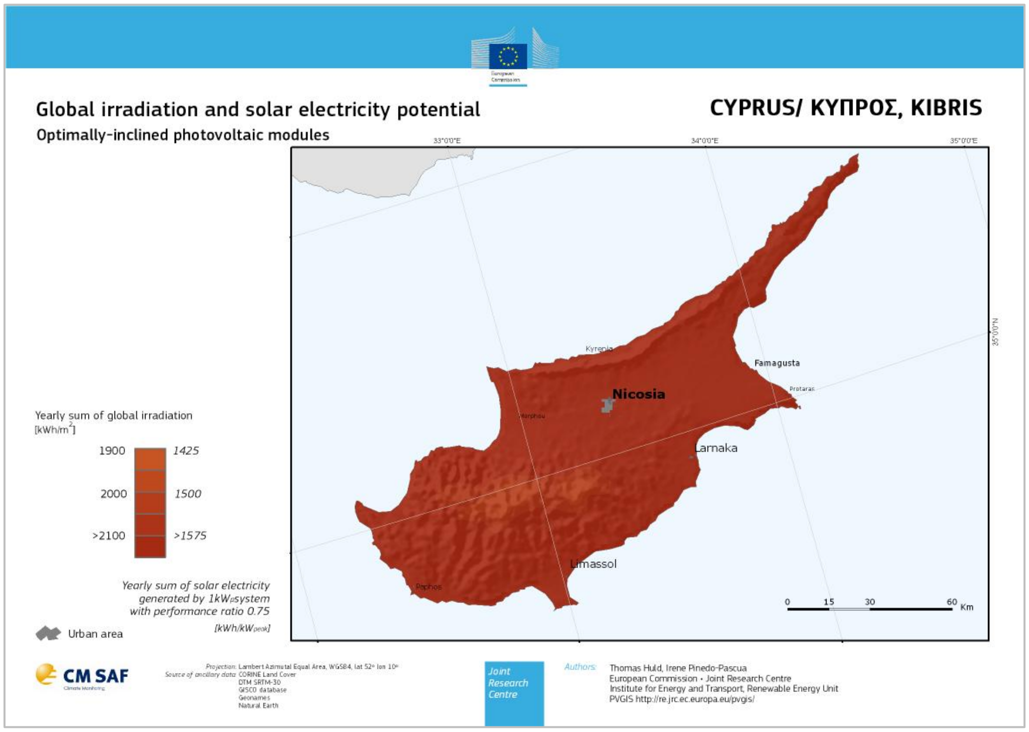


**Figure 2 Solar irradiation and solar electricity potential, Cyprus**

Another resource is wind energy from wind turbines located in non-urban areas. Outside the deployment limit, wind turbines of up to 10 kW and a maximum height of 18 m can be installed, while for wind systems of 30 to 100 kW, an environmental study is required. As a result, the creation of wind farms in the wider area of the Akamas peninsula is limited since most of it is part of the NATURA 2000 network.

Biomass is mainly used in households in fireplaces for space heating and hot water. There are several small farms in the area which might, if they cooperate, create small biomass units in the future.

*Division of scenarios*

The final, fourth step of the method is the division of scenarios. Energy system development of the Akamas peninsula has been examined in three scenarios:

1) LowRES – This scenario can represent the "business as usual" case
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 peninsula

The data extracted from the above scenarios will greatly assist local authorities of the Akamas peninsula in developing a joint Sustainable Energy and Climate Action Plan (SECAP) and submitting it to the Covenant of Mayors for approval.

**Table 3 Input data for scenarios of energy system development on Akamas peninsula**

| 2030 | LowRES | RES | HighRES |
|---|---|---|---|
| PV [MW] | 0.45 | 20 | 20 |
| Wind [MW] | 0 | 0 | 20 |
| EV [no. of vehicles] | 0 | 1000 | 3000 |
| EV connection [MW] | 0 | 5.348 | 22.198 |
| EV demand [GWh] | 0 | 4.313 | 7.201 |
| EV battery [MWh] | 0 | 38.99 | 117.12 |

For two scenarios, LowRES and HighRES, demand is different, and this is presented in the figure below.

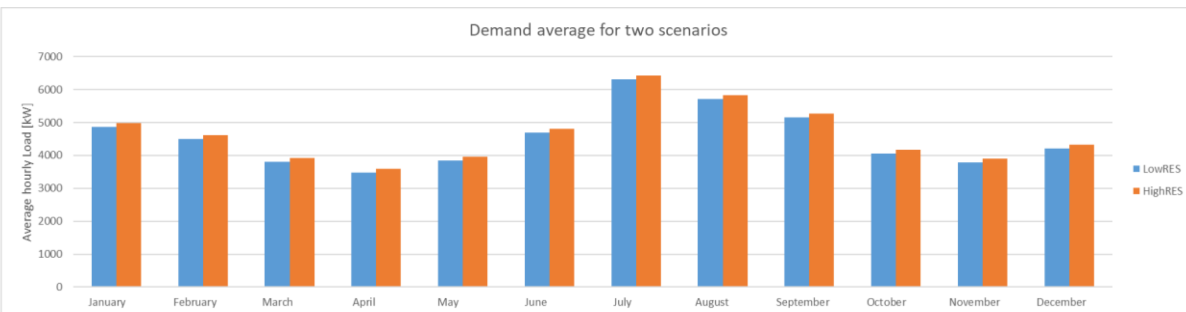


**Figure 3 Monthly average hourly load of Akamas peninsula in 2030 for two scenarios**

The necessary electricity demand data was collected from the Cyprus Transmission System Operator. However, the data provided to us had fifteen minutes distribution and it was for the whole island. Therefore, based on some data we already had in our database, we made some assumptions in order to get hourly data for the 6 local authorities in Akamas peninsula so that they can be entered in EnergyPLAN. In addition, the data requested for solar and wind energy were extracted with the help of the SODA solar radiation tool and the PRISMI wind power calculator respectively.

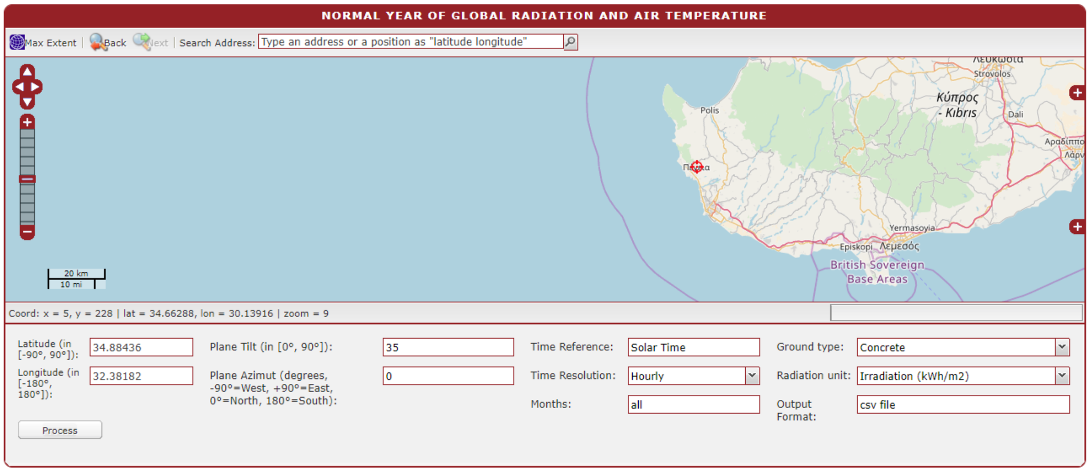


**Figure 4 SODA solar radiation tool – screenshot**

## 2.1. Results of modelling and discussion

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

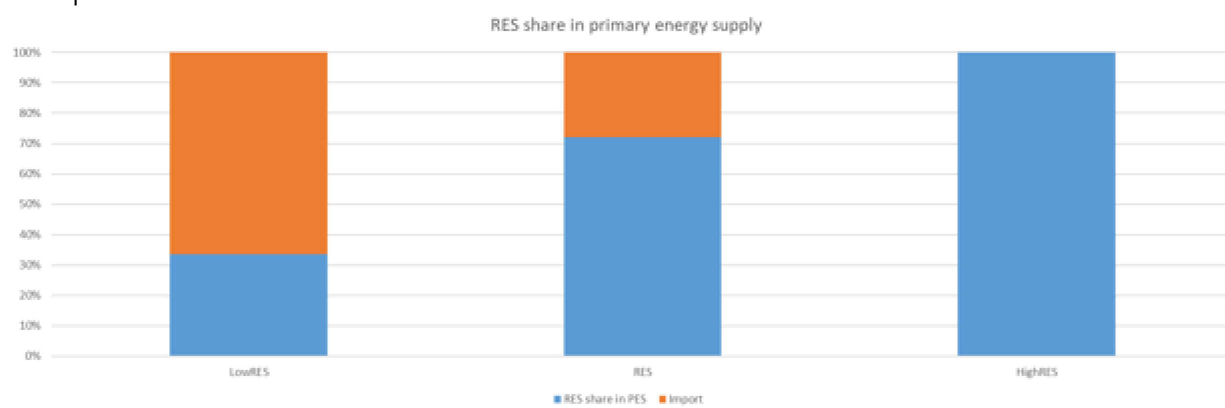


**Figure 5 RES share in primary energy supply**

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

**Table 4 Results of modelling - RES production**

| LowRES | | |
|---|---|---|
| RES prod. | 0.66 | GWh/year |
| Solar | 0.66 | GWh/year |
| Wind | 0 | GWh/year |
| Tidal and Wave | 0 | GWh/year |
| Hydro | 0 | GWh/year |

| RES | | |
|---|---|---|
| RES prod. | 21.75 | GWh/year |
| Solar | 21.75 | GWh/year |
| Wind | 0 | GWh/year |
| Tidal and Wave | 0 | GWh/year |
| Hydro | 0 | GWh/year |

| HighRES | | |
|---|---|---|
| RES prod. | 37.53 | GWh/year |
| Solar | 21.70 | GWh/year |
| Wind | 15.83 | GWh/year |
| Tidal and Wave | 0 | GWh/year |
| Hydro | 0 | GWh/year |

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

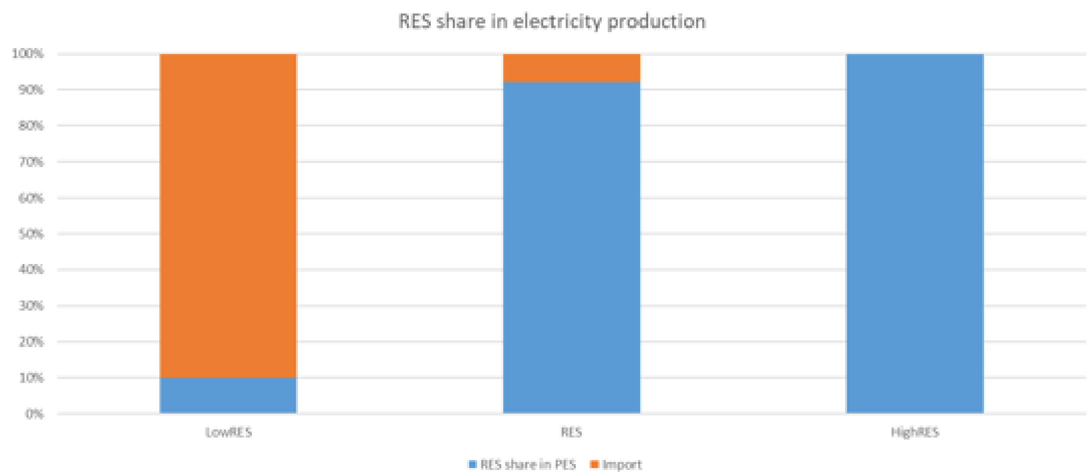


**Figure 6 RES share in electricity production**

It can be observed that RES scenario already covers a very high percentage of energy production, due to large solar energy potential in the Akamas peninsula area but share in primary energy supply is 20% lower.

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

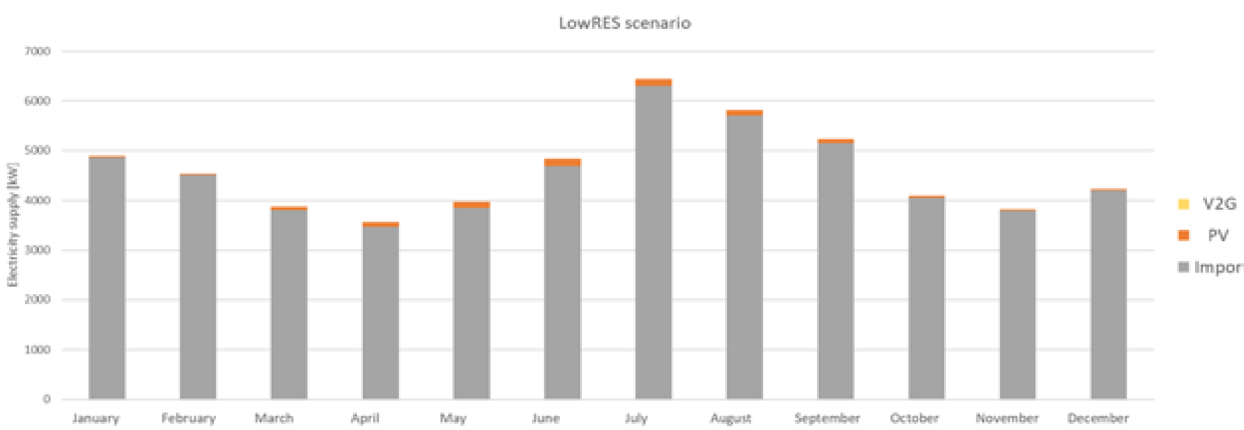


**Figure 7 Share of RES in monthly average hourly production for the LowRES scenario**

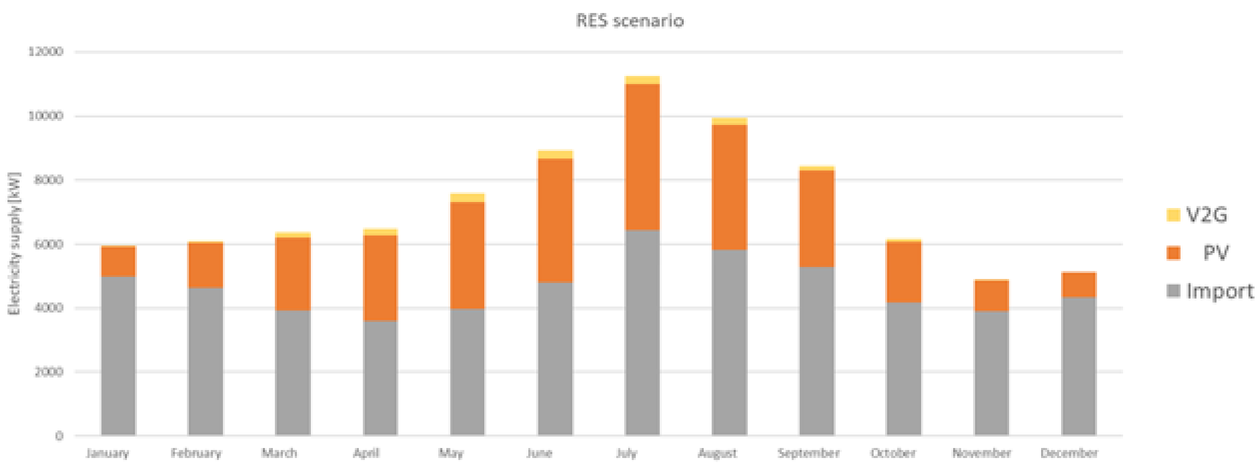


**Figure 8 Share of RES in monthly average hourly production for the RES scenario**

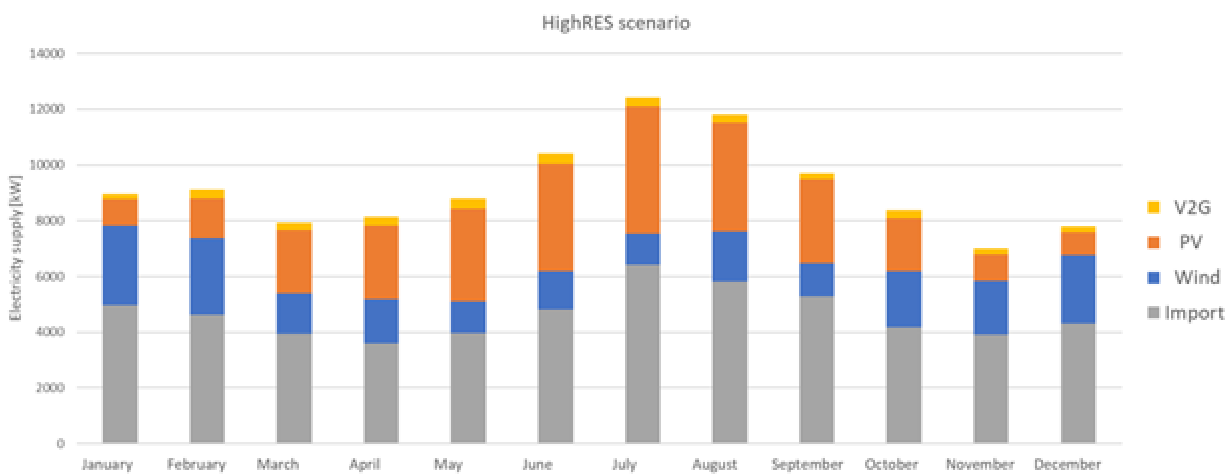


**Figure 9 Share of RES in monthly average hourly production for the HighRES scenario**

## 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 inputs for techno-economic analysis**

| 2030 | Investment | O&M | Lifetime |
|---:|---:|---:|---:|
| PV [kEUR/kW] | 1.2 | 4% | 20 |
| Wind [kEUR/kW] | 3 | 4% | 20 |
| EV[kEUR/unit] | 30 | 4% | 10 |

Results of modelling for the three scenarios, in terms of investment costs, are given in Figure 10, where the share in costs for production technologies is given.

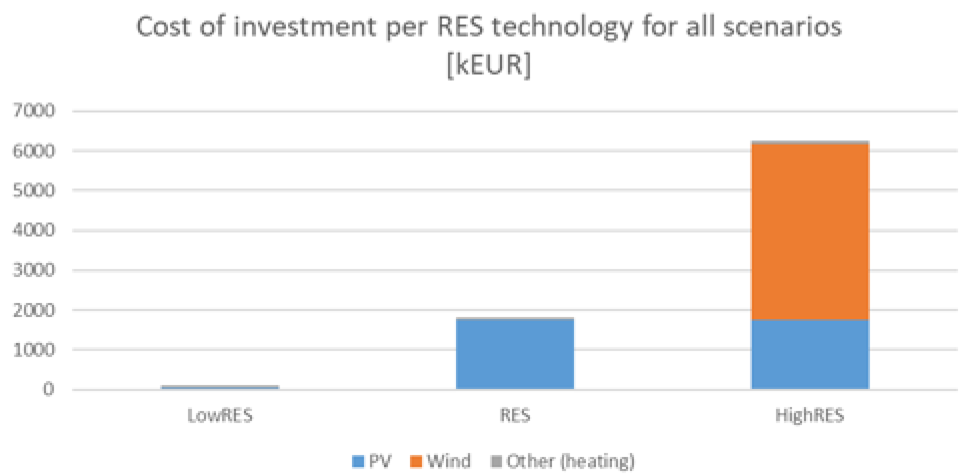


**Figure 10 Share in costs for production technologies**

In Figure 11, the cost of technologies for storage and balancing is given.

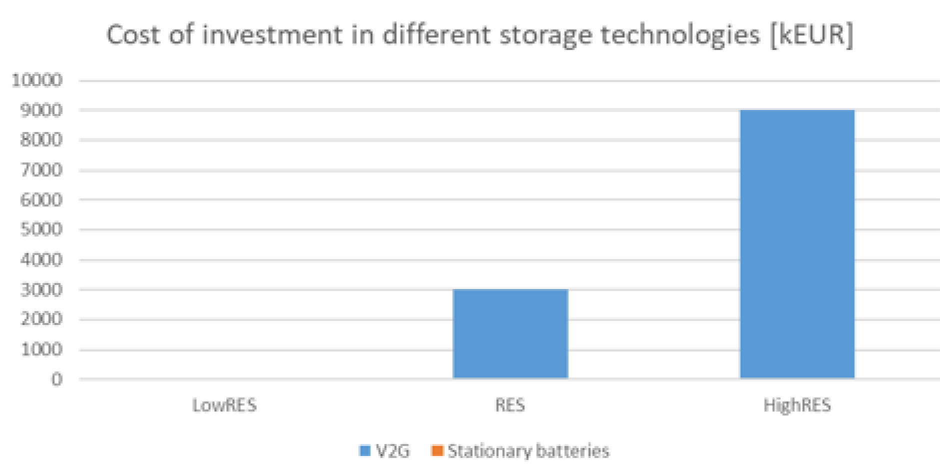


**Figure 11 Cost of technologies for storage and balancing**

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 year for each scenario of development of the energy system on Akamas peninsula area**

| 2030 | LowRES | RES | HighRES |
|---|---|---|---|
| Solar PV | 0 | 10 | 10 |
| Wind | 0 | 0 | 7 |
| Solar collectors | 3 | 3 | 4 |

The above table shows the jobs to be created per sector in the three scenarios. These jobs of course depend on the installed power of each sector. If, for example, we make them up to 2030, which is the planning date for the third scenario, then we have about 120 jobs for solar power, 84 jobs for wind power and 48 jobs for hot water solar collectors.

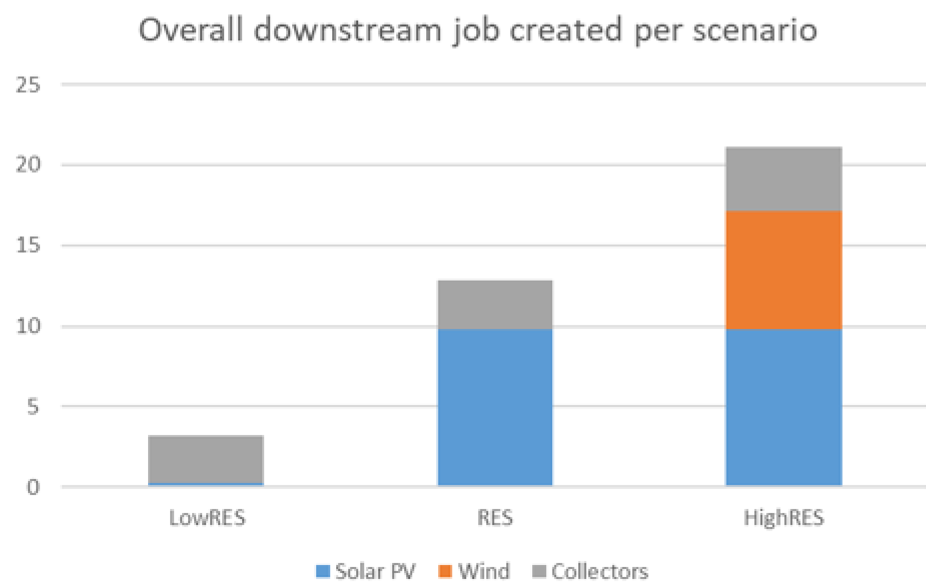


**Figure 12 Overall downstream job created per scenario**

## 2.3. Environmental considerations

Basic outline of influence of scenarios on environment, on two levels:

1) Reduction of GHG emission

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

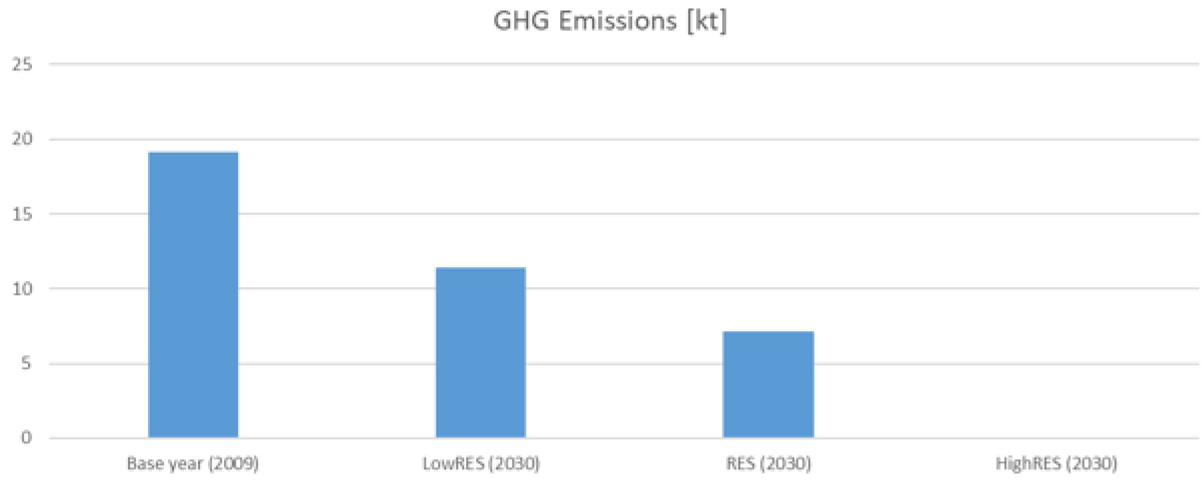


**Figure 13 Comparison of emissions for all scenarios and compared to the base year**

Since all fuel use in transport is replaced with electricity use for Electric Vehicles (EVs) and solar thermal collectors replaced the use of fuel oil and solid biofuels in households and services, the emissions in HighRES scenario significantly reduced.

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

Figure 14 illustrates how much of the area of the Akamas peninsula is included in NATURA 2000 network. Akamas peninsula area presents a comprehensive and complete picture of the characteristic vegetation of the coastal and lowland areas of the island in good physical condition and presents a rich marine ecosystem. Akamas Peninsula is one of the most important areas of Cyprus for migratory birds and the European Environment Agency noted that it was one of only 22 areas of endemicity in Europe.

**Figure 14 Natura 2000 network in the Akamas peninsula area**

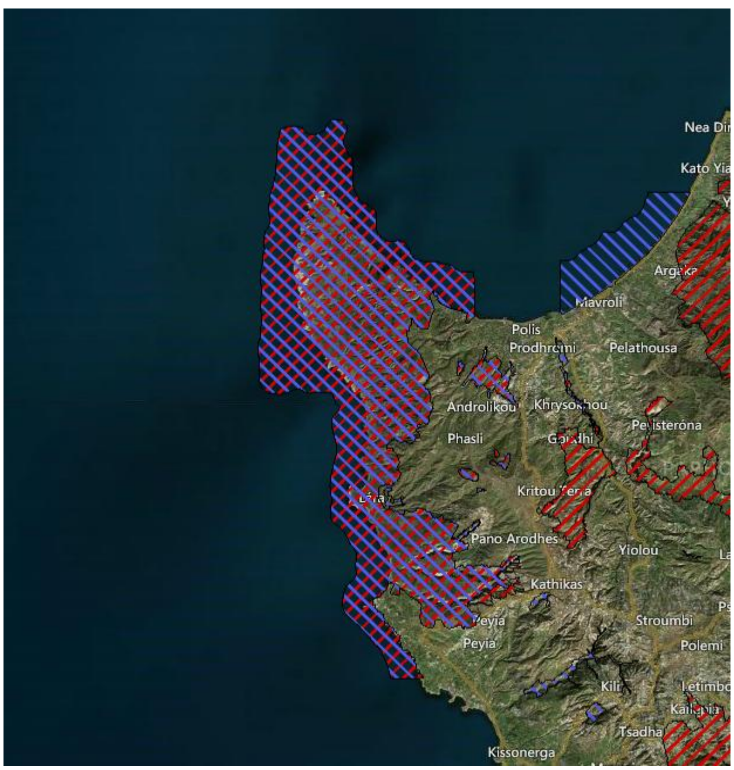


**Figure 15 Coastal protected area through the online tool "The Natura 2000 Viewer" [natura2000.eea.europa.eu]**

Figure 16 below shows the geographical distribution of licensed power plants using RES for the whole island with a capacity of more than 20 KWp.

Cyprus Energy Regulatory Authority – CERA, in the framework of the NER300 program and the Individual Support Measure approved by the Council of Ministers granted in 2016:

- a licence to construct and operate a Solar Thermal Park with a capacity of 50 MWe, storing thermal energy and consisting of small towers and mirrors,
- a licence for the construction of a Solar Thermal Power Station of a capacity of 50 MWe with Stirling machines storing electrical energy

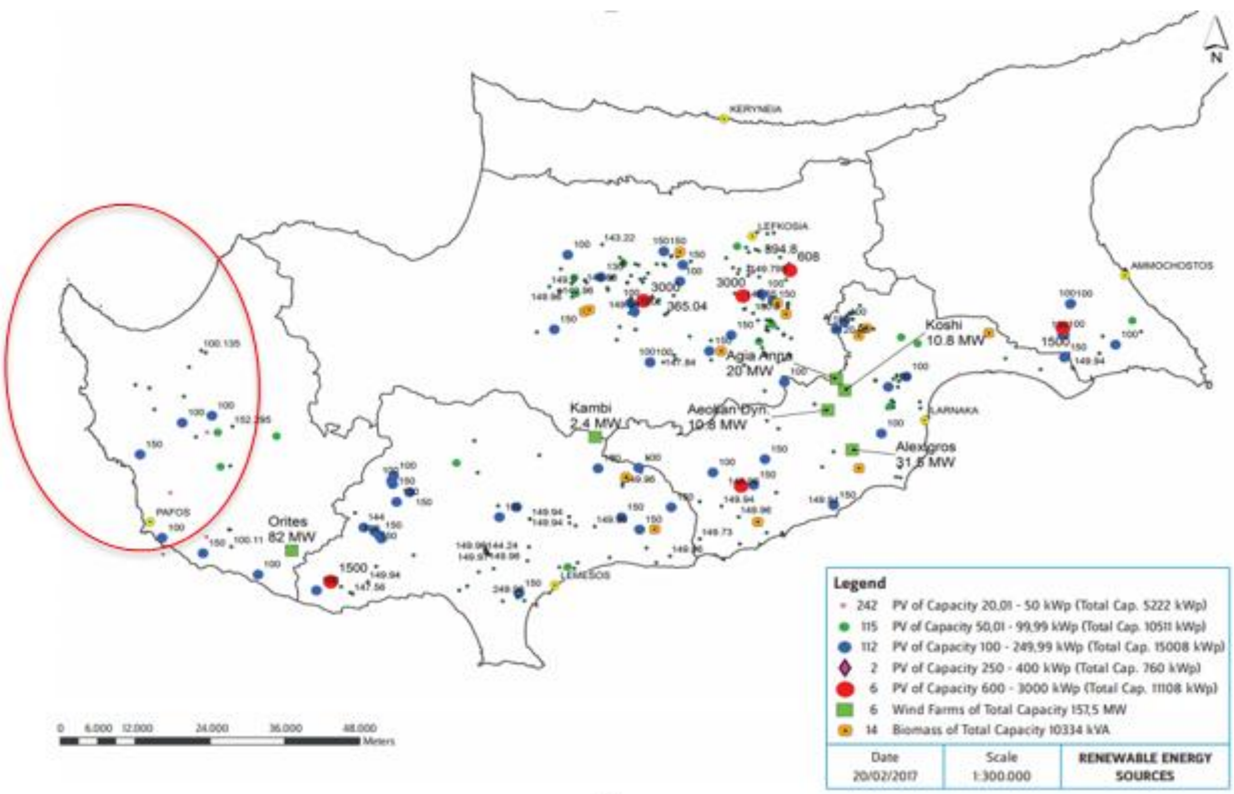


**Figure 16 Geographical Distribution of Licences for RES Units by 2016 in the study area [Cyprus Energy Regulatory Authority, annual report 2016]**

## 2.4. Suggestions for strategy of development

The above scenarios will help the local authorities of Akamas peninsula to develop their joint Sustainable Energy and Climate Action Plan. Local authorities will plan their actions by 2030 and even further, until 2050, aiming to become energy-independent in line with the HighRES scenario. The measures included in SECAP will concern:

- Events promoting electric vehicles, free parking for electric cars in public spaces electric vehicle charging stations
- Installation of photovoltaic systems in Local Authorities buildings
- Construction of charging point for Electric Vehicles in new buildings (Special provision in building permit)
- Construction of bicycle parking spaces in squares, parking areas, bus stops and parks

# 3. Conclusion

In the current study, the scenario approach in energy systems modelling has been used to model the future scenarios for Akamas 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. 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 solar thermal) 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, Solar thermal collectors represent a viable solution for replacement of fuel oil and solid biofuels in households.
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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