Customer European Commission

Subject Final report

Contract SRSS/S2017/048

Notes

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Issue date 29/11/2019

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REVISIONS HISTORY

Revision number	Date	Protocol	List of modifications and/or modified paragraphs
0	30/11/2019	19011668	First issue

1 INTRODUCTION

This document is the final report foreseen by the Grant Agreement:

- *"Technical support to improve the penetration of renewable energy sources and energy efficiency in Cyprus"*

In the following, the results of the activities carried out within each of the four work packages composing the work plan are synthetically described.

2 WORK PACKAGE 1 - "REVIEW AND AMENDMENT OF THE TRADE AND SETTLEMENT ELECTRICITY MARKET RULES"

The main objective of the work package was to provide support to MECIT by reviewing and proposing suitable amendments to the CERA's approved Trading and Settlement Rules v. 2.0.0 (according to CERA Decision no. 84/2017, dated 12/5/2017) in order to ensure compliance with the Proposal for a revised electricity regulation ("Regulation Recast") and the Proposal for a revised electricity Directive (Directive Recast).

In the following the actions implemented by RSE for each of the Technical Activities foreseen in the work plan and the results obtained are described. Ultimately, all the Technical Activities have been completed and MECIT has been provided with the expected results.

C1 – Collection of data

The following documents were collected and analyzed:

- Cyprus Transmission System Operator: *"Trading and Settlement Rules (TSRs) version 2.0.0 - May 2017"*, as approved by CERA with its Decision no. 84/2017, dated 12/5/2017;
- Council of the European Union: *"Proposal for a Directive of the European Parliament and of the Council on common rules for the internal market in electricity (recast)"*, Interinstitutional File 2016/0380 (COD), 15886/17, 20 December 2017; Council of the European Union: *"Proposal for a Regulation of the European Parliament and of the Council on the internal market for electricity (recast)"*, Interinstitutional File 2016/0379 (COD), 15879/17, 20 December 2017
- the Transitional Regulation for the Operation of the Electricity Market until TSRs v2.0.0 become commercially operational (Regulatory Decision No. 04/2017 Κ.Δ.Π.223/2017 30/6/2017, Decision 120/2017 26/6/2017, Decision 121/2017 26/6/2017).

Other reference documents taken into account were the deliverables foreseen by the contract *"Technical and policy/regulation support to the Ministry of Energy, Commerce, Industry and Tourism ('**MECIT**') with regard to its participation in the process [lead by the Cyprus Transmission System Operator ('**TSO-Cy**')] for amending the existing Trade and Settlement Electricity Market Rules ('**TSRs**')"*, that are:

- RSE: *"Detailed document(s) with MECIT's proposed amendments to the TSRs to be submitted to TSO-Cy before the 2nd AC Meeting"* – Revision no. 1, 14/06/2017.
- RSE: *"Progress and Recommendations Report"* – Revision no. 1, 14/06/2017.

C2 – Revision and preparation of amendments to the TSRs v.2.0.0

The main issues arising from a comparison between the Directive and the Regulation with the TSRs and the Cyprus market design were pointed out and commented. The main topics initially dealt with are:

- Aggregation
- Energy communities
- Storage systems
- Intraday market
- Imbalance settlement period
- Balancing market data publication
- Technical bidding limits

With respect to such topics, amendments to the Trading and Settlement Rules (TSRs) and to the Cyprus market design were proposed and the results were described in the draft deliverable D.1.1, submitted to MECIT for approval.

Subsequently, on the basis of further discussions with MECIT, two more topics were analyzed:

- Capacity mechanisms
- Priority dispatch of RES and CHP

On the basis of the analysis of the aforementioned documents, the following amendments to the Trading and Settlement Rules (TSRs) and to the Cyprus market design were proposed:

- **Aggregation**
  - Allow for aggregation of (flexible) demand, renewable as well as conventional generating units and storage systems, in particular for the provision of balancing services.
  - Possibly, start with aggregation pilot projects to gain experience (generation aggregation, load aggregation and finally the most complex case, generation / load /storage aggregation).
  - Do not impose upper limits on the aggregate size, unless in case of excessive market concentration.

- **Energy communities**
  - Set up a legal and regulatory framework supporting the implementation of energy communities.

- Include in the TSRs this new kind of market player, that must be subject to the same rights and obligations as the other players according to the different roles it can play (generator, supplier, final customer, self-consumer, aggregator, DSO).

- **Storage systems**
  - Regulate the participation of storage systems to the different market segments at all levels to foster the integration of growing shares of renewable sources, amending CERA's Regulatory Decision no. 1/2015, the TSRs and the Transmission and Distribution Rules – TDRs.
  - Possibly, to gain experience start with storage system pilot projects for the provision of ancillary services, possibly through aggregation, including Vehicle-to-Grid (V2G) applications.
  - Assess the opportunity of requiring high performance ancillary services to be provided by storage systems, possibly remunerated according to a "pay-for-performance" scheme.

- **Intraday market**
  - Consider the introduction of an auction based Intraday Market before the interconnection of Cyprus with Greece via the EuroAsia interconnector, currently expected in December 2023 (the auction based scheme is more efficient than the continuous trading and does not cause coordination problems with the ISP), in case a sufficient liquidity can be expected.
  - After the interconnection with Greece, implement a continuous trading Intraday Market with gate closure one hour before delivery, in line with the EU Target Model, taking into account the necessary coordination with the Integrated Scheduling Process.
  - In case the Intraday Market is not implemented from the beginning, assess the feasibility of a delay of the gate closure of the Day-Ahead Market and, in turn, of the Integrated Scheduling Process, to reduce their distance from the delivery.

- **Imbalance settlement period**
  - After the interconnection of Cyprus with Greece, carry out a cost-benefit analysis of moving to a 15 minute imbalance settlement period and, in case of a negative result, ask for a derogation or for an exemption, according to the results of the analysis.

- **Balancing market data publication**
  - Comply with the Regulation requirement concerning the publication as soon as possible, but not later than 30 minutes after real-time, of the information on the current system balance and on the estimated balancing energy prices.

- **Technical bidding limits**
  - Establish an estimate of the Value of Lost Load (VoLL) in Cyprus and take it into account when setting the value of the *Administratively Defined Energy Offer Cap* or of a possible technical clearing price cap.

- **Capacity mechanisms**
  - Carry out adequacy assessment studies to assess the necessity of strategic reserve in short / medium / long term development scenarios of the Cypriot power system, in order to have the possibility of deciding on a quantitative basis how much strategic reserve capacity will be necessary and for how long.

- **Priority dispatch of RES and CHP**
  - Include in the TSRs provisions concerning priority dispatch of RES and CHP, meaning that RES and CHP offers (both Day-Ahead and upward balancing offers) should be cleared before offers of other sources with the same price, in line with Article 11 of the Regulation.
  - Do not limit the acceptance of downward energy balancing bids of RES only to situations when system constraints cannot be satisfied.
  - CERA should define a negative Administratively Defined Lower Limit for Downward Offers, to provide incentive to RES to participate to downward balancing.
  - Set up procedures to pre-qualify RES aggregates (or more general aggregates) to enjoy priority dispatch, when composed by units each having priority dispatch.

C3 – Preparation of a timetable for applying proposed amendments

As far as activity C3 is concerned, a two days meeting has been held at MECIT's premises on 12 and 13 July 2018 in order to analyze and discuss with MECIT, SRSS, CERA, TSOC and DSO needs and opportunities to harmonize the TSRs and the Cyprus market design with the provisions of the Directive and of the Regulation on the internal electricity market, in particular with reference to the above mentioned topics.

The aim of the discussions has been to define the main requirements and a tentative timeline for the harmonization implementation for each issue deemed relevant. The minutes of the meetings, prepared by RSE, have been submitted to MECIT for comments and integrations, and then circulated to the meetings participants that, in turn, have provided their comments and suggestions.

Subsequently, on the basis of the above discussions, a tentative schedule for the implementation of the actions identified has been circulated among the involved stakeholders that, again, have provided their comments and suggestions.

Taking into account all the information collected during the above described work, as well as additional information provided by MECIT, RSE finalized Deliverables D.1.1 and D.1.2, that were approved by MECIT in March 2019.

The proposed schedule of the different actions specified in D1.2 are reported in the following.

- **Aggregation**

A provisional agreement on the Directive and on the Regulation has been reached among the Commission, the Council and the Parliament during the 6th and final "trilogue" on 18-19 December 2018. The final text including the revised Annex IV of the Directive, defining the time limits for its transposition into national law, is not available yet. Nevertheless, a compromise was reached on Article 70 of the Directive, explicitly stating that several articles (Articles 2, 3, 5, 6(2), 9(2), 10(2), 11 to 24, 26, 29, 31 to 34, 36, 38(5), 40 42, 51, 54, 57 to 59, 61 to 63 and Annexes I to III) should be transposed into national laws, regulations and administrative provisions by 31 December 2020, i.e. in coincidence with the start of the Net Pool market, assumed here for January 2021. The aforementioned articles include the provisions concerning aggregation and "citizens energy communities".

If this will be the case, in principle, the market should start in a form fully compliant with the already transposed Directive, while, as above mentioned, the tender for the procurement of the Market Management System (MMS) is based on the current version of the TSRs, based on Decision no. 1/2015 by CERA, that do not comply with the extended concept of aggregation defined in the Directive. Therefore, it is not realistic to hypothesize, at this stage, a stop of the current tender, a quick revision of Decision no. 1/2015 and of the TSRs, the start of a new tender for the MMS and its put in place by end of 2020.

Nevertheless, on the basis of the above assumptions, at the beginning of 2021 the MMS, the Meter Data Management System (MDMS), the Distribution Management System (DMS) and a first batch of Smart Meters should be already installed and in operation, therefore a sufficient infrastructure to enable to carry out at least a few aggregation pilot projects, to gain valuable experience, should be in place and should progressively grow in the following months.

For example in Italy, the Regulatory Authority, in view of a more comprehensive reform of the Dispatching Services Market to enable the participation of Distributed Energy Resources (DERs), even in an aggregated form, decided to set up different kinds of experimental pilot projects. To this aim, on May 5, 2017 the Authority issued the Decision no. 300/2017/R/eel defining the so-called Virtual Enabled Units (UVA), consisting of aggregates of distributed flexible loads (UVAC), production units (UVAP) and of a mix of the two, including storage systems and Vehicle to Grid installations (UVAM). UVAx are aggregates of DERs enabled to provide Replacement Reserve and balancing services.

The Italian TSO TERNA, after a consultation process, issued the technical regulations for the implementation of the UVAC projects on May 30, 2017, of the UVAP projects on September 22, 2017 and of the UVAM projects on September 25, 2018. In the second half of 2017 and in 2018 UVAC projects amounting to 516 MW and UVAP projects amounting to 116 MW have been implemented. The first auction for UVAM projects held on 19 December 2018 assigned 350 MW.

Of course, the short time needed from the regulation to the implementation of UVAC and UVAP projects benefitted from the fact that in Italy the electricity market has been up and running for several years, while this is not the case for Cyprus. Therefore, it is advisable for Cyprus first to gain experience from the normal operation of the market in the currently foreseen configuration, then to implement some aggregation pilot projects in order to test on field both regulatory and technical solutions, and, finally, carry out a comprehensive reform to enable a full scale participation to the market of aggregations of DERs.

Thus the proposed schedule could be the following:

- wait for the first year of operation of the market (January – December 2021)
- in the first half of 2022, assess the availability of Distributed Energy Resources and of aggregators to participate to pilot projects; in case of a positive assessment, define the regulatory (by CERA) and the technical (by TSOC) framework
- start with the pilot projects in the second half of 2022 and carry out them for at least one year (till the second half of 2023)
- in the course of 2023, revise the regulatory framework (RD 1/2015 by CERA) to increase the scope of aggregation, as well as the TSRs and the Transmission and Distribution Rules – TDRs (by TSOC), taking also into account the results of the ongoing pilot projects (this final revision process could be speeded up by a preliminary revision process to be based on the provisions clearly stated in the Directive and in the Regulation, that could be started at once)
- in the course of 2024 implement the appropriate modifications to the Market Management System – MMS (by TSOC)

In such a case, at the beginning of 2025, five out of seven smart meters installation phases should have been completed and the Distribution Management System (DMS), in operation for more than four years, should have extended its control to most of the distribution network, thus possibly enabling a significant amount of distributed resources to participate in aggregation.

It is remarked here again that this proposed timeline is not compliant with the 31 December 2020 deadline for transposition of the relevant Directive provisions into national laws, regulations and administrative provisions. It is also worth noting that RSE, in its previous consultancy activity for the benefit of MECIT, already in 2016 highlighted the necessity to amend CERA's regulatory decision no. 1/2015 and the TSRs in order to extend the concept of "aggregation" in a way that would have been compliant with the Directive, but this has not been done. At this stage, stopping the tendering process for the procurement of the Market Management System (MMS), amending CERA's regulatory decision no. 1/2015, the TSRs and the TDRs and starting a new tendering process would introduce additional, probably unacceptable, delays in the start of the Net Pool market. Therefore, in any case, it would not be possible to have by 1 January 2021 an electricity market up and running and fully compliant with the Directive.

- **Energy Communities**

Similarly to aggregation, and taking advantage of the experience gained with the aggregation pilot projects, the revision of the regulatory framework to account for Energy Communities could be carried out in the course of 2023, together with the consequent revision of the TSRs and of the TDRs.

The same issues concerning the non-compliance with the Directive deadline for transposition (31 December 2020) previously highlighted hold here.

- **Storage systems**

- RSE does not agree with the proposal of TSOC to delay the participation of storage systems to the Net Pool market after two or three years of market operation, both for their prospective importance for the Cypriot power system and to ensure as far as possible the compliance with the Directive transposition deadline.
- RSE therefore assumes that the finalization of the Regulatory Decision 03/2018 takes place in the very first months of 2019, following the consultation phase, and that the consequent revision by TSOC of the TSRs and of the TDRs takes place by the end of 2019, as requested by the Decision itself.
- Since the tendering process for the procurement of the Market Management System has been restarted and is based on the current version of the TSRs, a re-definition of the software specifications on the basis of the revised TSRs would be necessary in the course of 2020, in order to

allow for the participation of storage systems to the different market segments, if not from the very beginning of market operation, assumed to take place in January 2021, at least as soon as possible.

- As far as the provision of non-conventional ancillary services like synthetic inertia and fast primary regulation (that can be provided by storage systems) is concerned, it is recommended that TSOC carries out a study to assess the related system needs in prospective scenarios characterized by a significant development of intermittent renewable sources (in particular in the scenario(s) included in the National Energy and Climate Plan).
- On the basis of the results of such a study, it will be possible to plan the timeline of the definition by CERA of the regulatory framework for the provision of such services, of the consequent modifications by TSOC of the TDRs and of the TSRs, and of the implementation of the corresponding markets by TSOC (for example, yearly auctions for capacity).

As far as Article 32 of the Directive is concerned, in case Cyprus does not apply for a derogation the DSO should have the possibility of procuring flexibility services, including congestion management, in its service area, from distributed generation, demand response or storage. In principle, the same distributed resources that can take part in aggregation could provide flexibility services to the DSO but, to solve a specific local problem on the distribution network a very limited number of resources can be effective, thus a potential market would be subject to the possibility of exercising an excessive market power. In such a case, the few effective resources could be awarded a fair remuneration defined by the Regulator for their redispatching, being resources essential for the security of the system.

- **Intraday market**

After the beginning of the operation of the new electricity market assumed for January 2021, monitor market participation to assess the level of liquidity that could be expected in an intraday market. As soon as such a level is deemed sufficient, set up the regulatory framework, amend the TSRs and implement an auction based intraday market. It must also be taken into account that in CERA's Regulatory Decision no. 1/2015 it is stated that an Intraday Market should be implemented at *"the latest within 24 months from the date the market starts operation under the new arrangements"*, that would be by beginning 2023 under the assumptions of the present report. Then, right after the interconnection of Cyprus with Greece via the EuroAsia interconnector, *implement* a cross-border intraday market with a continuous trading up to one hour before delivery, ensuring the necessary coordination with the Integrated Scheduling Process.

- **Imbalance settlement period**

  - Define the specifications for all the components of the Advanced Metering Infrastructure and for the smart meters to be deployed so that they can easily support a switch from a 30 minute to a 15 minute measurement time interval.
  - After the interconnection of Cyprus with Greece, carry out a cost-benefit analysis[1] of moving to a 15 minute imbalance settlement period and, in case of a negative result, ask for a derogation (at most extended to 1 January 2025) or for an exemption, according to the results of the analysis.

- **Technical bidding limits**

After the interconnection of Cyprus with Greece via the EuroAsia interconnector, currently expected by December 2023, Article 9 of the Regulation applies to Cyprus, requiring that limits on clearing prices for day ahead and intraday markets are defined taking into account the maximum Value of Lost Load. It would therefore be advisable for CERA to carry out a study to estimate the VoLL in Cyprus providing results before the interconnection of Cyprus with Greece. The sooner such a study is completed and the sooner its results are taken into account to set the Administratively Defined Energy Offer Cap or a possible technical clearing price cap, the better.

- **Priority Dispatch of RES and CHP**

  - To this regard, CERA recently stated that *"Regarding the implementation of the provisions of the "Priority Dispatch of RES and CHP" it is noted that no amendment of the Regulatory Decision 1/2015 is required and CERA under the Electricity Market Regulation 2003-2018 will give direct instruction to the TSOC to change the Market Rules."*
  - CERA should also define a negative Administratively Defined Lower Limit for Downward Offers, to provide incentives to RES to participate to downward balancing.
  - The Market Management System should of course be implemented accordingly.

[1] See for example:

- https://docstore.entsoe.eu/Documents/Network%20codes%20documents/Implementation/CBA_ISP/ISP_CBA_Final_report_29-04-2016_v4.1.pdf
- https://www.copenhageneconomics.com/publications/publication/finer-time-resolution-in-nordic-power-markets-a-cost-benefit-analysis
- https://www.fingrid.fi/globalassets/dokumentit/fi/sahkomarkkinat/varttitase/final_15_min_isp_derogation_report_poyry.pdf

- **Balancing market data publication**

Provided that the provision of the Regulation becomes binding after the interconnection of Cyprus with Greece, it is advisable that CERA, as market evolves and as a result of its market monitoring activity, assesses the opportunity of anticipating the enforcement of the provision to foster market transparency and efficiency.

3 WORK PACKAGE 2 – "DELIVERY A SOFTWARE TOOL TO CERA[2] FOR THE OPTIMUM DESIGN OF SELF-CONSUMPTION PV SYSTEMS FOR ENTERPRISES"

The main objective of the work package was to develop and provide MECIT with a software tool, in an easily accessible form, to be used for the optimum design of self-consumption PV systems by taking into account a number of defined and agreed variables.

In the following the actions implemented by RSE for each of the Technical Activities foreseen in the work plan and the results obtained are described. Ultimately, all the Technical Activities have been completed and MECIT has been provided with a tool complying with all the foreseen requirements.

C1 – Review the existing reports to be provided by CERA[2]

Activity C1 has been carried out, through the review of the documents containing the description of RES support schemes (sent to RSE on 23 May 2018 and on 17 July 2018), that have been taken into account in order to build the SW tool.

C2 – Identification of consumption curves

Activity C2 has been successfully completed. MECIT provided RSE with a set of measured data corresponding to some Cypriot end-users, categorized by typical consumption profiles: residential, commercial, industrial. The profiles have been integrated in the tool, maintaining their shape, but with the possibility of rescaling, so as to change the total annual energy consumption.

C3 – Identification of the main parameters for the final model

On 8 May 2018 a first draft of a schematic and simplified description of the software capabilities (inputs / outputs / control logics) has been shared with MECIT. The expected features of the software tool were further discussed during the kick-off[3] web conference. RSE and MECIT opted not to include the diesel generator as an extra input, and therefore consider only PV generations. On 15 June 2018, based on the above discussions, a new schematic draft of the SW graphic interface (inputs / outputs / control logics) was sent to MECIT and a positive feedback was received. A few e-mail exchange followed, for clarifications on several technical aspects, and the identification of the main parameters was then completed. MECIT and RSE identified MATLAB as the best programming language for the development of the tool, for two main reasons: the first was the expertise of RSE in this language, and

[2] In the course of the project it was agreed that the main beneficiary would have been MECIT instead of CERA, therefore CERA has been no longer involved in the activities.

[3] A new kick-off was necessary, since MECIT took over CERA.

the second was the possibility of obtaining a web application with a relatively small effort through the WebApp Compiler toolbox.

The final list of software parameters agreed between RSE and MECIT is shown in the following table.

Parameter and description	Entry mode	Basic user - Simulation mode	MECIT / Consultant - Optimization mode
GENERAL SETTINGS			
Simulation time-step	field	☒	☑
Project life-time	field	☑	☑
First year	field	☑	☑
WACC	field	☒	☑
VAT	field	☒	☑
Connection Type	select	☑	☑
Approved electric load	field	☒	☑
INCENTIVE SCHEME			
Incentive scheme choice	select	☑(limited)	☑
Billing period	select	☑	☑
Net metering duration	edit	☑	☑
Energy price options	select	☒	☑
Energy buy price	edit	☑	☑
Energy sell price	edit	☒	☑
Increase rate of energy price	edit	☑	☑
Incentive scheme parameters	edit	☒	☑
LOAD PROFILE			
Option 1 Typical load profile	select	☑(limited)	☑
Option 1 Monthly energy consumption	vector (12 values)	☑	☑
Option 2 Import CSV file (full year)	CSV file	☒	☑
Option 3 Hourly energy consumption (two typical days for each month, weekday, weekend)	vector (2*12 x 24 values)	☒	☑
ENERGY EFFICIENCY MEASURES			
Energy efficiency measures	select	☒	☑
PV GENERATOR			
Surface available for installation	field	☑	☑
Roof type	select	☒	☑
Module technology	select	☒	☑
Efficiency	edit	☒	☑
Nominal power	edit	☒	☑
Inverter conversion efficiency	edit	☒	☑
Inverter calendar life	edit	☒	☑
Monthly Performance Ratio	edit	☒	☑
PV subsidies	edit	☑	☑
PV modules orientation/inclination (tilt and azimuth values):			
Option 1 Use optimal values	select	☑	☑
Option 2 Manual input	field	☒	☑
Size (rated power on the DC side):			
Option 1 Manual input	field	☑	☑
Option 2 Optimized	select	☒	☑
CAPEX/OPEX (PV and Inverter)			
Option 1 Use default values	select	☑	☑
Option 2 Manual input	field	☑	☑

STORAGE SYSTEM				
Size (storage capacity, charge/discharge power):				
Option 1	Manual input	field	☑	☑
Option 2	Optimized	select	☒	☑
Storage parameters (CAPEX, OPEX, Cycle life,Calendar life, DoD, RTE, Self discharge)		edit	☒	☑

C4- Evaluation of existing open source software

In order to get a comprehensive picture of what was already available, RSE carried out a review of the most representative SW tools for energy systems simulation and optimization, through literature and web search and analysis. In the following, a list of the analyzed open source and commercial software tools is reported together with a brief description of their main strengths and weaknesses.

- OSEMOSYS

PROs: completely open source, high number of active users, a lot of documentation and case studies available, flexibility, a web interface can be implemented.
CONs: not user friendly, no components size optimization, a minimum knowledge of the SW programming languages is required in order to modify it.

- RETSCREEN

PROs: vast database of commercial products and meteorological data, detailed/powerful financial analysis, easy to use (Excel), good amount of documentation, available in almost 40 languages.
CONs: limited inputs (no import of time series data), low time-resolution, monthly averages (low precision).

- SAM

PROs: user friendly, components/weather database embedded in the software, good amount of documentation/literature available, active users community.
CONs: no storage, only one generation technology per simulation (no hybrid energy systems), main focus on the U.S. context.

- Hybrid2

PROs: user friendly, detailed simulation of a specific system, many electrical load options, custom dispatch algorithms can be implemented.

CONs: not working on Windows versions later than XP, lack of flexibility, limited access to parameters, password needed to install demo version.

- EnergyPLAN

PROs: the simulation time-step is one hour, while the energy system can be modelled up to one year period; it encompasses the whole national or regional energy system including heat and electricity supplies as well as the transport and industrial sectors.
CONs: it is disseminated as freeware but the source code is not open; the key objective is to model a variety of options so that they can be compared with one another, rather than model a single ‘optimum’ solution based on defined pre-conditions.

- HOMER PRO (Commercial)

PROs: user friendly, efficient graphical input/output, low computing time, possibility of carrying out sensitivity analyses, constantly updated (many users) and improved over the years.
CONs: “simple” equations (first degree linear equations), “black box” code used.

- TRNSYS (Commercial)

PROs: modular approach (high degree of flexibility) makes it suitable to analyse from simple to very complex energy systems, user friendly (graphic interface, drag&drop of single components), web-based library of additional components and frequent downloadable.
CONs: no components size optimization.

- iHOGA (Commercial)

PROs: multi and mono objective optimization, low computing time.
CONs: free educational version has limited capabilities.

- LEAP (Commercial)

PROs: user friendly graphic interface (input and output), wide range of modelling methodologies (bottom-up, end use, top down macroeconomic), low input data requirements for starting the analysis.
CONs: no optimisation, no detailed simulation of a specific energy system (no single project analysis).

Most of the software tools identified in the analysis have been developed specifically for scenario / complex energy systems analysis on a medium or long term timeframe.

An open source simulation model easily adaptable to the purpose of WP2 has not been identified. Considering the purpose of the requested tool (simulation, optimization, specific incentive schemes, etc.) and some specific requests (e.g. available on-line), and also taking into account RSE's expertise in specific programming languages, RSE agreed with MECIT that a new/custom-made software tool would have been developed in MATLAB, specifically tailored to MECIT's needs.

C5 – Development and delivering of the first draft of the Final Model

The first complete version of the software tool was sent to MECIT on 15 March 2019. The draft of the software manual (English version) was also shared; after including the feedbacks received from MECIT, RSE completed its translation into Greek language.

C6 – Delivering the Final Model

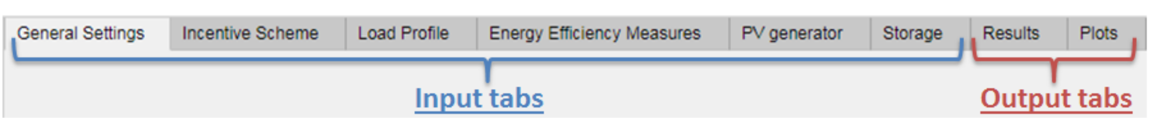
The final version of the SW tool, for both Linux and Windows operating systems, was sent to MECIT after the training session in Nicosia, so as to include all the requested, minor, modifications. The structure of the tool and its main functionalities are summarized below.

Software structure

Tabs

The software is structured into different tabs, each one regarding a specific aspect of the project, which can be divided into two main classes:

1. Input tabs: where the user can specify all input parameters necessary to run a simulation
2. Output tabs: where the user can evaluate the results of the simulation



Blue help buttons

Most parameters are correlated with a "help button" (blue button with a question mark). When clicked, a text box appears, containing a more detailed explanation of the corresponding parameter.

Summary

On the right side of the screen a "Summary" box is located, containing a synthetic list of the main input parameters set by the user. Each coloured box contains a summary of the parameters set in the corresponding input tab. Whenever a parameter is changed, the summary automatically updates its information.

RUN button

In order to run a simulation, the user has to click the "Run" button, located in the bottom-right side of the screen, and then to click "Yes" in the following confirmation box.

User classes

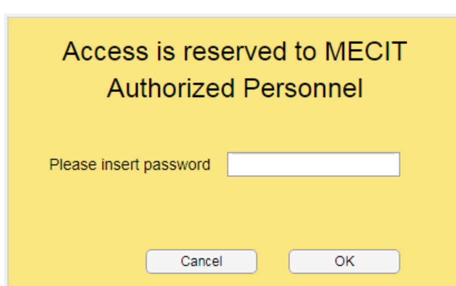
There are two main user classes:

1. "Basic User" – *simulation mode*: it is the standard mode, active whenever the software is launched. Its main purpose is to allow a residential end-user to perform the simulation of simple energy systems and to evaluate their technical and economic feasibility. It is therefore characterized by a simplified set of input parameters and limited choices.
2. "Super User" – *optimization mode*: it is the "professional" mode to be used by relevant parties (MECIT, enterprises, energy consultants, etc.) in order to perform both simulation and optimization of the main components sizes and evaluate the impact on the end users' electricity bill of different scenarios (e.g. electricity prices, RES installation and operation costs, etc.) and of different parameters regarding RES incentive schemes.

When operating in *simulation mode* the components sizes are set by the user, while in *optimization mode* the optimal system's components sizes are determined by the SW tool from a finite number of possible values (matrix of possible combinations of PV and storage sizes).

The optimization criterion consists in the maximisation of the project's Net Present Value.

In order to access the "Super User" mode, it is necessary to click on the "Menu" (top left corner of the screen), click on "Switch to Super User mode", insert the password provided by MECIT in the following window and then click "OK".



In the following we describe the functioning of each tab in the “Super user” mode, since in this option all the possible parameters are editable.

Software description by tabs

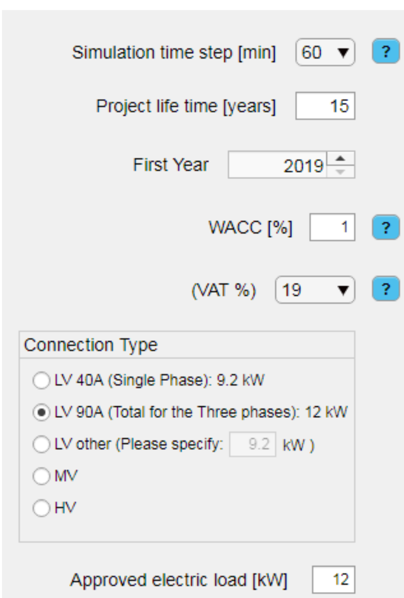
When the “Super User” mode is activated, all options (e.g. load profile input modes, incentive schemes, etc.) and parameters (e.g. PV generator and storage characteristics) are selectable and editable by the user.

Moreover, it is possible to run the software in “*optimization mode”*, where the optimal system’s components sizes are determined by the SW tool from a finite number of possible values. The SW tool will investigate each possible combination (e.g. 10 sizes of PV and 10 sizes of storage system → 10 ✕ 10 = 100 possible system configurations).

The “*Optimization mode”* can be activated by clicking the “Optimize!” buttons in the photovoltaic and storage sizing tabs, as it will be explained in detail in the corresponding section. The optimization criterion consists in the maximisation of the project’s Net Present Value.

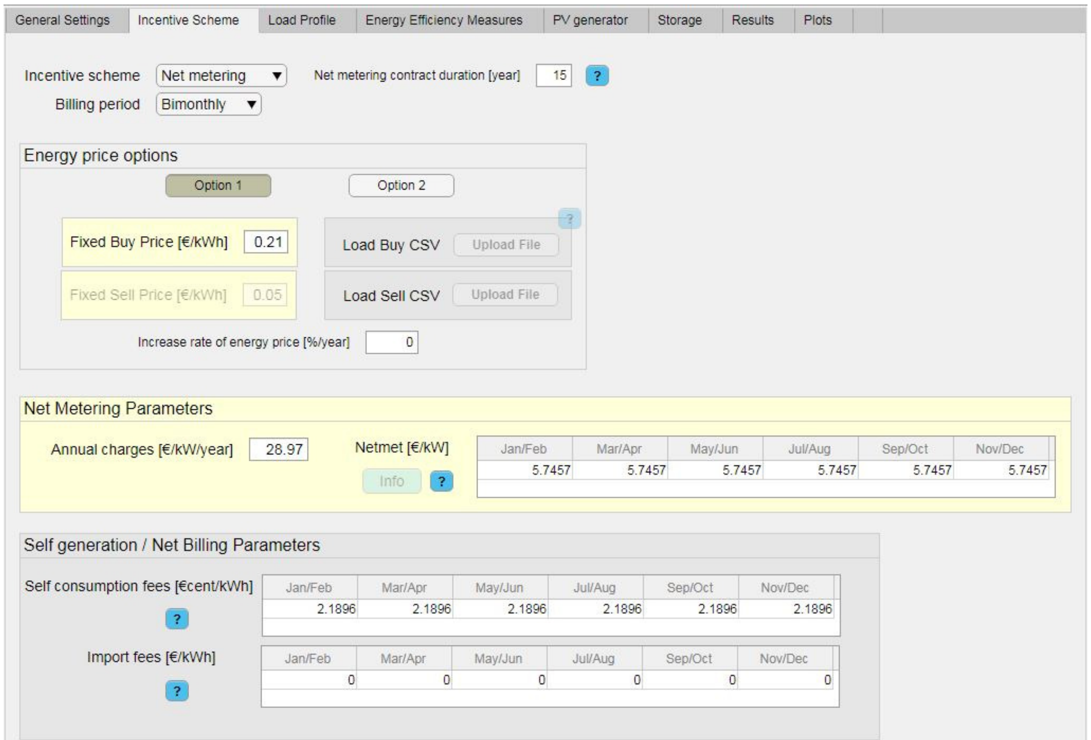
Every option and parameter editable in “Super User” mode is described in the following paragraphs.

- General Settings tab



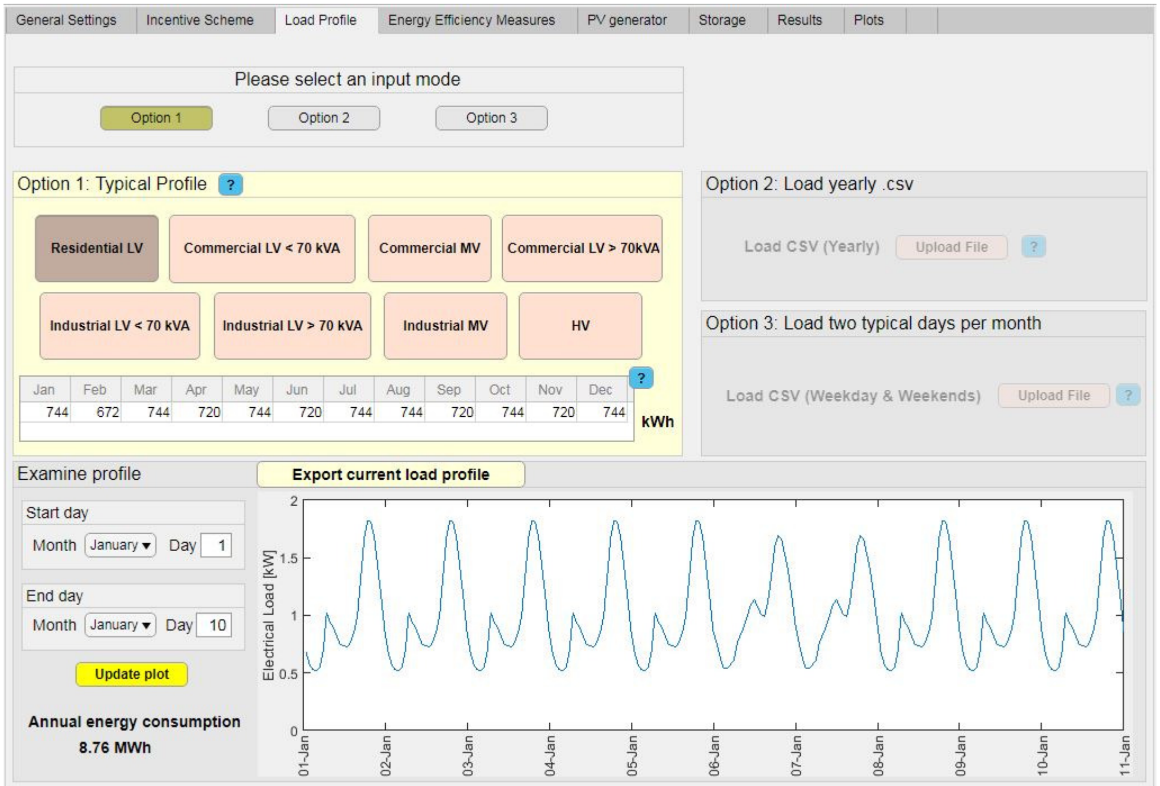
In the “General Settings” tab the user can set general inputs regarding the software simulation, general financial parameters, and general electric load features.

- Incentive Scheme tab



In this tab the user can specify the incentive scheme to be applied to the project and its relative parameters, the cost of energy (fixed, or loaded via .csv files) and the billing period (either monthly or bimonthly)

- Load Profile tab



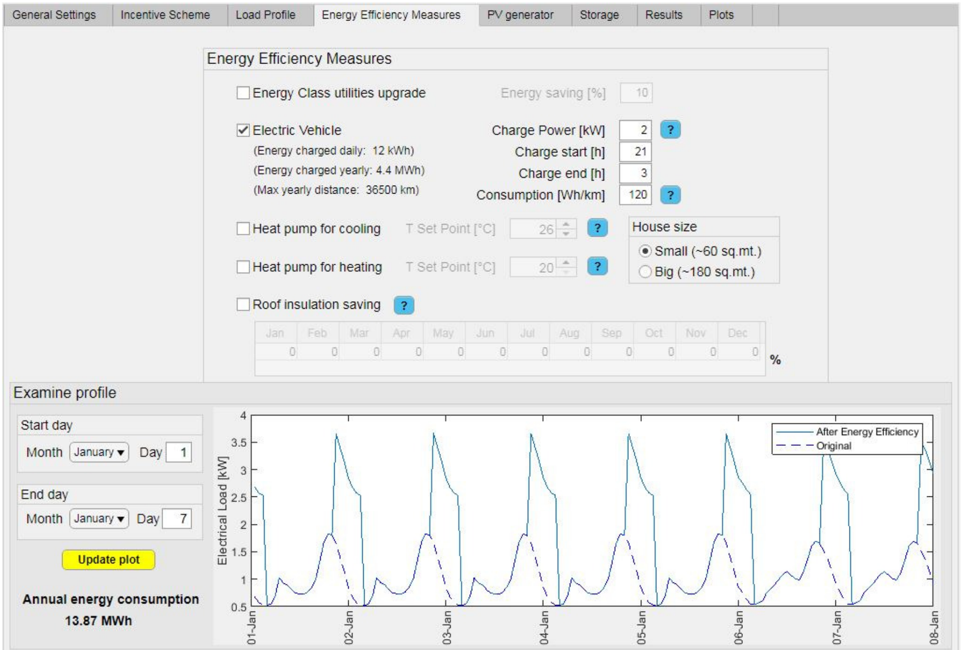
In this tab, the user can define the electrical load profile. Three options are available:

– Option 1: select from a predefined set of typical load profiles (Residential, Commercial, Industrial, etc.)

– Option 2: load a yearly profile from a .csv file

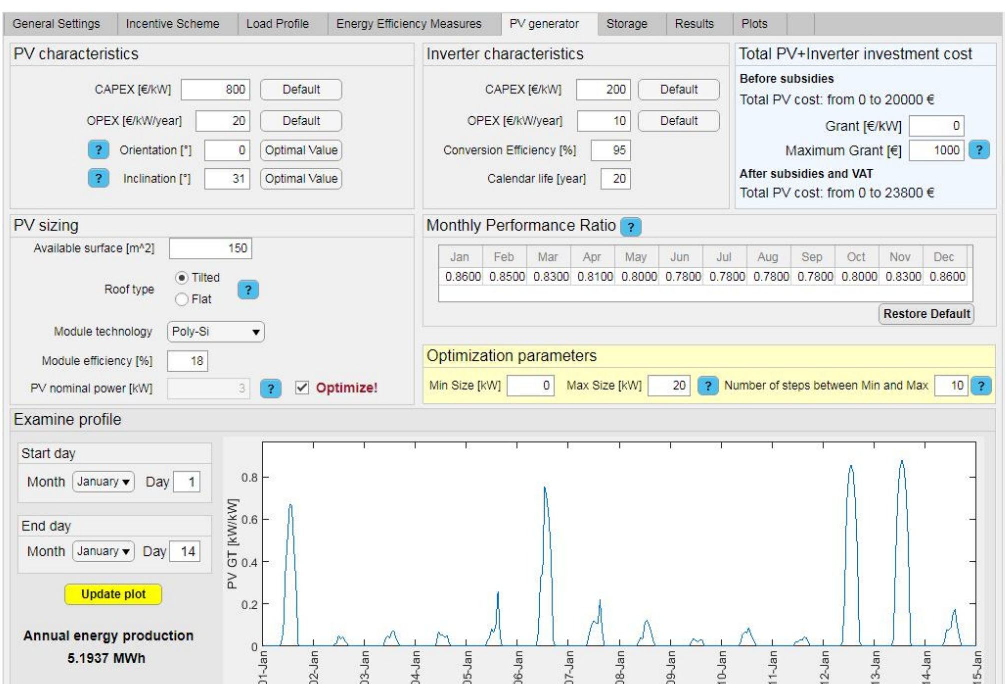
– Option 3: load a .csv file containing weekly profiles, that are then processed to obtain the year sequence

- Energy Efficiency Measures



In the "Energy Efficiency Measures" tab the user can select one or more energy efficiency measures by checking the corresponding box. The load profile is modified accordingly by the software.

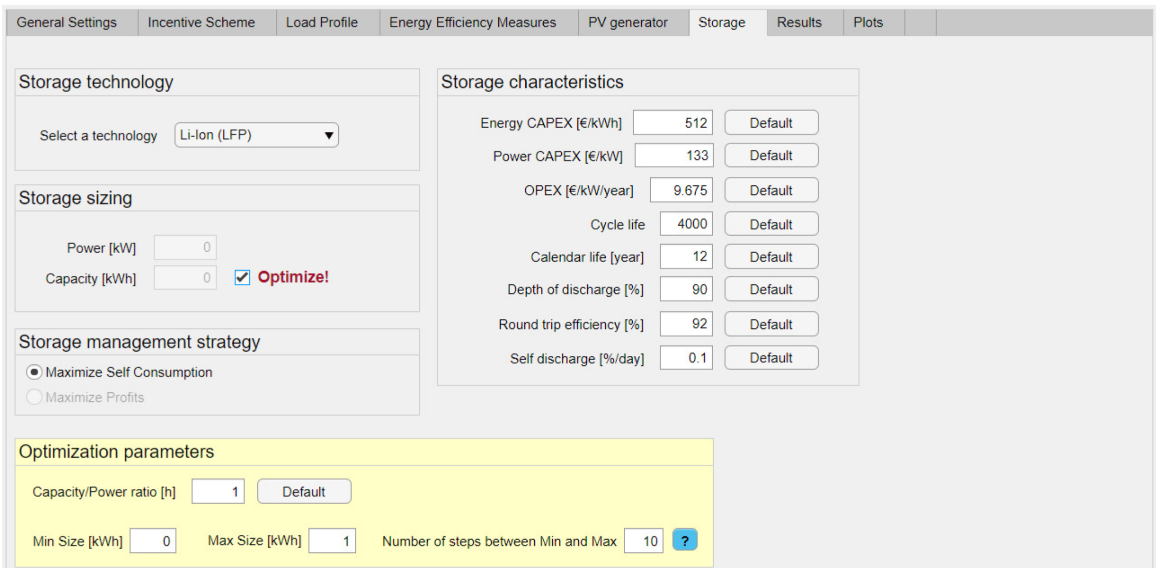
- PV Generator tab



In this tab the user can edit both technical and economic parameters relative to the PV plant.

Optimize!: when the "Optimize!" box is checked, an "Optimization parameters" box appears, where the user can specify the range of PV sizes that will be analysed/simulated by the SW calculation engine.

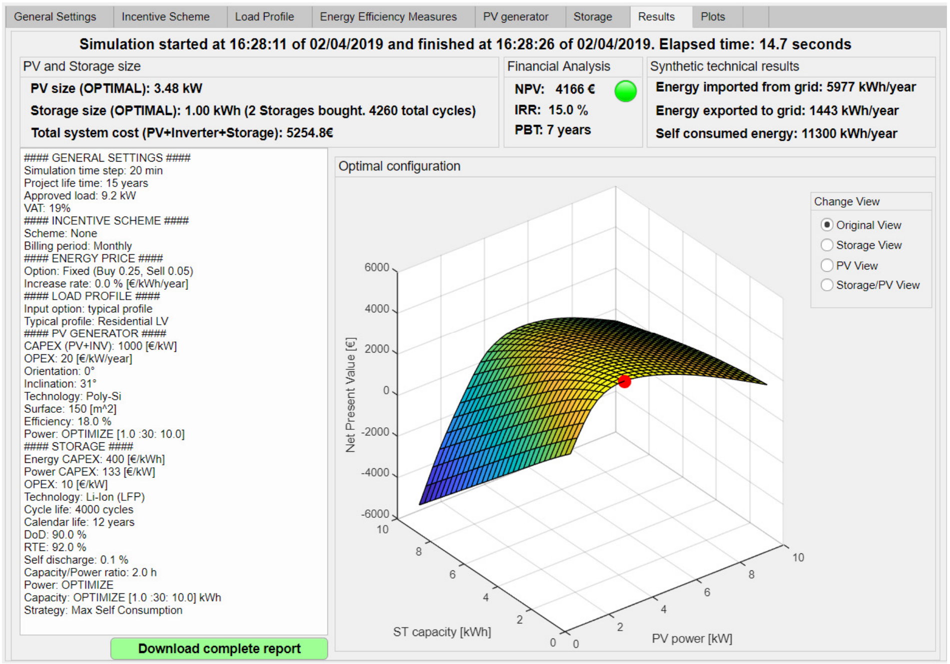
- Storage tab



In this tab the user can edit both technical and economic parameters relative to the Storage.

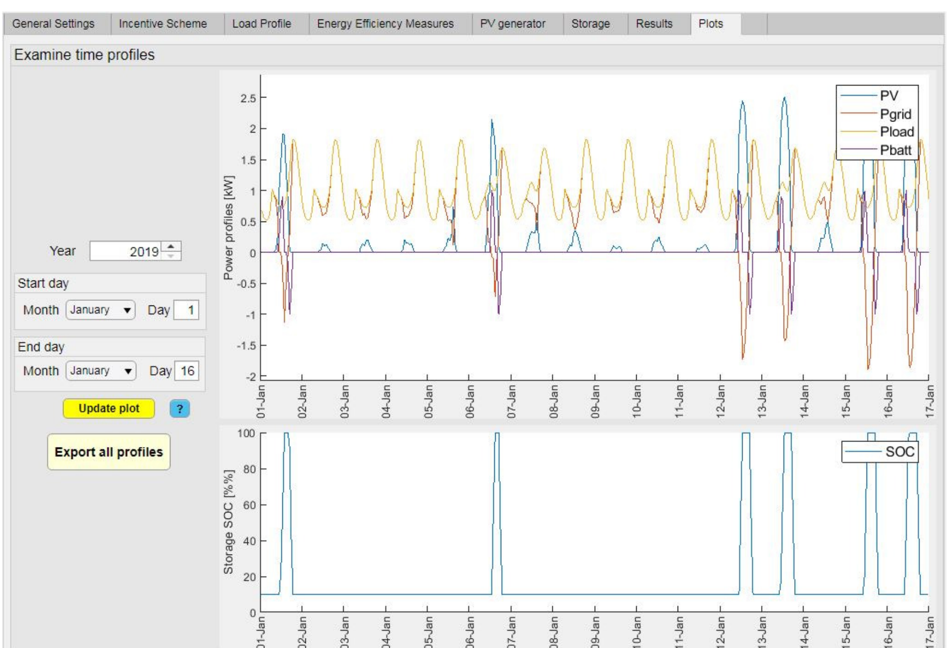
Optimize!: when the "Optimize!" box is checked, an "Optimization parameters" box appears, where the user can specify the range of storage sizes that will be analysed/simulated by the SW calculation engine.

- Results tab



In this tab the economic results of the simulation are shown. The optimal PV/Storage configuration is marked with a red dot on the 3D plot showing the sizing on the X-Y axis and the NPV on the Z axis.

- Plots tab



In the “Plots” tab it is possible to visualize the time series of the most representative electrical quantities:

- PV: power generated by the PV plant
- P_{GRID}: power imported/exported from/to the grid
- P_{LOAD}: power absorbed by the load (= load profile set by the user)
- P_{BATT}: charge/discharge power of the storage system (if present)

If a storage system is present, a second plot shows the battery State Of Charge (SOC).

C7 - Training on the final model

The training day (10/05/2019) took place at the MECIT Energy Service Building in Nicosia, and was articulated in two sessions: one in the morning and one in the afternoon.

First session:

The first session was dedicated to the demonstration of the software tool features, as well as to its architecture and user interface.

No training material has been used since it was considered more efficient to use directly a laptop (linked to a projector) to show in real time the software features to the attendees.

During the presentation, RSE showed the different tabs available in the user interface (general settings, incentive schemes, load profile, energy efficiency measures, PV generator, storage, results/plots), going through each option that can be selected by the SW end-user and all parameters taken into account by the software calculation engine.

The back-end of the SW was illustrated as well, together with how to optimally exploit the software functionalities and to obtain meaningful and useful results.

During the session, MECIT formulated a few requests of minor changes in the software tool:

- e.g. adding “roof insulation” as an energy efficiency measure;
- minor bugs to be fixed;
- small editorial changes in the field names or in the corresponding help buttons’ text.

The requested changes have been included in the final version of the software delivered to MECIT.

Second session:

The purpose of the second session was to examine with more detail the structure of the back-end code of the software, so as to make MECIT personnel capable of implementing modifications.

Particular attention was dedicated to the following editable aspects:

- user interface: e.g. how to add new components (buttons with hyperlinks to external resources) and to edit the different fields and the corresponding help buttons;
- incentive schemes: how to adapt the currently implemented ones so as to cope with possible future variations in support schemes for renewables and energy efficiency.

Finally, RSE implemented the last minor modifications requested during the training session, and on 26/07/2019 provided MECIT with the final version of the software (activity C6), both for Windows and Linux operating systems.

4 WORK PACKAGE 3 – "DETERMINATION OF THE ACTUAL ENERGY DEMAND OF A STATISTICALLY SIGNIFICANT PERCENTAGE OF DIFFERENT TYPES OF BUILDINGS AND PROCESSES"

The main objective of this work package is to assist MECIT to establish a methodology to estimate the actual energy consumption for different types of buildings and processes of residential, tertiary and industrial sectors in Cyprus. Through the results of this work package, MECIT will be better positioned to set up appropriate energy efficiency strategies and targeted energy policies.

The study aims to provide a qualitative and semiquantitative description of the heating and cooling demand in the residential, tertiary and industrial sectors. Developing and evaluating efficiency strategies for heating and cooling applications depends on understanding their prevalence, varied usage patterns and energy demand information.

In the following the actions implemented by RSE for each of the Technical Activities foreseen in the work plan and the results obtained are described. Ultimately, all the Technical Activities have been completed and MECIT has been provided with the expected results.

C1 – Energy analysis method and data collection

To pursue the objectives of activity C1, RSE:

- carried out a literature review and a collection of data about energy efficiency statistics in Cyprus;
- signed of a contract with a local company (OEB - Cyprus Employers and Industrialists Federation) in order to have a support for the data collection;
- carried out a segmentation of domestic, tertiary and industrial sector energy consumption and an identification of the buildings and plants to be audited/metered;
- defined the analysis methodology for all the sectors.

The methodology and, above all, the selection of buildings to be metered and establishments to be audited, was fully agreed with MECIT. Due to time and budget constraints, it was agreed to reduce the number of audited establishments for the tertiary and industry sectors to 48 and 23 establishments respectively.

The list of buildings belonging to the tertiary sector is the following:

Hotels and other accommodation establishments

Grecian Park Hotel	Ayia Napa
Hilton Cyprus	Nicosia
Ajax Hotel	Limassol
Alexander the Great Beach Hotel	Paphos
1-2 of *** smaller hotels	3* Hotels

Schools (public and private)

Heritage Private School	Limassol
Kindergarten of Anthoupoli	Lakatamia
Elementary School of Lykabittos	Nicosia
The English School	Nicosia
Kindergarten "Mia for ki enan kairo"	Strovolos

Universities (public and private)

University of Cyprus + Halls	Aglantzia
University of Nicosia + Halls	Nicosia
European University Cyprus	Engomi

Public office buildings

Department of Labour	Nicosia
Department of Public Works	Nicosia
Larnaca department of lands and surveys	Larnaca
Limassol department of lands and surveys	Limassol
Accounting Office Building of MCIT	Nicosia

Sport facilities

19 Fitness	Nicosia
Komanetsi Aquatic and Fitness Center	Strovolos
Poseidonio Health Spa and Fitness center	Paphos

Airports

Paphos International Airport	Paphos

Supermarkets

Poplife Electric Shops Ltd	Nicosia
Lidl Cyprus	Larnaka
C.A.C. Papantoniou Trading Ltd	Paphos
Ch. A. Papaellinas Commercial Public Co. Ltd (Alphamega)	Nicosia

Hospitals and clinics (public and private)

Ippokrateio	Nicosia
Evangelistria	Nicosia
Papapetrou	Nicosia
Areteio	Nicosia
Limassol Polyclinic Ygeia	Limassol

Coffee shops and Restaurants

Costa coffee or coffee island	Nicosia
KFC	Nicosia
Mc Donald’s	Nicosia
Voici la mode	Nicosia

Private offices

Deloitte	Limassol
HQ Hellenic bank	Nicosia
PWC	Nicosia

Retail shops and malls

Mango	Nicosia
Small retail shop	Nicosia
Marks and Spencer	Nicosia

Laundries

Arizona Laundries Famagusta Ltd	Paralimni
Leathermaster	Stovolos

Theaters

Thoc	Nicosia

Bakeries

Sigma Bakeries Ltd	Limassol
Zorbas	Nicosia
Pandora	Nicosia

Other (museums)

Leventis Gallery	Nicosia

For the industry sector, the selected establishments are:

Mining and quarrying

Hellenic Copper Mines Ltd	Nicosia

Water supply

Water Development Department- pump station	Tersephanou
Desalination (KWh/lt water desalinated)	Ammochostos

Food and Beverage Industry

Frou Frou Cyprus	Kokkinotrimithia
KEO PLC	Limassol
Alambra	Nicosia
Alantika Gregoriou	Nicosia
Charalambides Christis	Nisou

Textiles

Famipo Nimatourgia	Latsia

Wood

H.H. Furnishings Ltd – Prima Kitchens	Strovolos
Takis K. Marangos & Sons Ltd	Agios Athanasios

Paper and pulp

Power of art	Dali

Chemicals

Spyros Stavrinides Chemicals	Xylofagou
Unilever PMT Ltd	Engomi
Metochemie	Nicosia
Remedica	Nicosia

Plastic products

Lordos United Plastics Public Ltd	Limassol
Elysee Irrigation Ltd	Ergates

Other non-metallic minerals

Nicolaides & Kountouris Metal Co. Ltd	Geri
Muskita Aluminium Industries	Limassol

Cement industry

Vassiliko Cement Works PLC	Mari

Machinery and equipment

Houtris	Larnaca

Other industry

Cyprus Employers & Industrialist Federation	Nicosia

In this first part of the project, the only difficulties encountered were small delays in the collection of data. This was solved by agreeing with MECIT and SRSS to slightly delay the issue of the first deliverable, that was then approved by all the involved parties.

The collection of data was performed by the subcontractor (OEB), that had more local contacts and access to databases also in Greek language.

The above described activities led to the achievement of "Output 3.1- Energy analysis method and data collection", with the official issue of the first version of deliverable D3.1 on 26 April 2018.

C2 – Determination of the actual energy demand

Activity C2 started with the procurement, the setup and the delivery of the needed material for smart metering of the residential sector and with the auditing of the industry and tertiary sectors.

The smart metering kits procurement was one of the first issues encountered, because it was difficult to find them with UK-type plugs and because there were several pieces with different delivery times, and moreover they needed to be configured and assembled before shipping to Cyprus for installation.

The 20 smart metering kits are composed of:

- the EnergyNote kit with 6 smart plugs, a display and a bridge, produced by GEO;
- a router, produced by Huawei;
- data cables to connect the bridge to the router;
- a 4G SIM Card.

The first idea was to use local SIM cards in order to reduce the costs, but it was very difficult from a bureaucratic point of view. At the end, Italian SIM cards with roaming options were chosen. However, they were made available later than the other parts of the kit, so the configuration and the shipping to Cyprus were delayed to the first week of June 2018 and, after this, the local subcontractor installed them by the end of June, ensuring at least 6 months of measurements.

In parallel, the local subcontractor contacted the companies of the tertiary and industry sectors to start with the auditing activities. The plan was to complete 2-3 audits each week, except in August.

Subsequently, some minor technical issues that were encountered with the metering kits were solved and the auditing the companies of the tertiary and industry sectors proceeded.

Concerning the residential sector:

- all the smart metering kits were installed in 20 residential households, selected in accordance with MECIT, being representative of “average buildings” in the 4 climatic zones of the Republic of Cyprus;
- questionnaires were collected for all 20 households, in order to have input data about the building envelope, the heating system, the available electric appliances and inhabitants habits and behaviours (e.g. set temperature of AC, use of different electric appliances, etc.).

However, some minor issues have been encountered:

- not all the interviewed households had their electricity bills for the last year(s): the local subcontractor tried to solve this issue by obtaining the data from the Electricity Authority of Cyprus;
- for 2 households, there was an issue with the smart metering kits, that were installed too far from the main electricity meter, not allowing to record the overall consumption (that could be, however, extracted from the electricity bills);

- for 1 household, the installed kit had some technical issues, and the recording started on 19 August, instead of the beginning of July 2018: however, some similar households were metered and the questionnaire was filled.

Every month, consumption data from the online EnergyNote cloud were downloaded for each of the 20 buildings.

With regards to the tertiary sector and industry, the auditing activity started and some issues were encountered: on one hand, some companies refused to cooperate and be audited, on the other hand, collection of data took longer than foreseen.

To solve the first issue, an attempt was made to find similar companies to audit, but this wasn't always possible. This meant that the scope needed to be reduced. This was defined and agreed during the progress meeting held in Cyprus with the local subcontractor, RSE and MECIT:

- for the tertiary sector, out of the initially foreseen 49 companies, 29 were to be audited and analysed;
- for the industry sector, out of the foreseen 23 companies, 15 were to be audited and analysed.

Regarding the second issue, the main problem was that, even if the auditors from the local subcontractor made appointments and anticipated questionnaires before visiting the companies, in most cases the documents about equipment and energy consumptions were not available, and further visits and calls were needed in order to complete the audits. This implied that, for each establishment, the auditing process took at least 2-3 months.

Due to the abovementioned issues, an extension of the deadline was agreed with MECIT, in order to be able to complete all activities. This would have allowed also to collect metering data up to a later date than December 2018, in order to extend the validity of the experimental campaign.

Then, the collection of the last energy bills was completed, metering data were downloaded from the cloud and the results were elaborated.

As for the tertiary and industry sectors, the collection of the audits was completed and the results were elaborated.

Both for the residential and for the tertiary and industry sectors, there were further issues that slowed down the study:

A. for the residential sector:
   - A1. most households disconnected the metering kit at the end of December 2018, therefore with no extension of the metering period;
   - A2. moreover, in some cases, the monitored equipment covered only a small part of the overall electricity consumption of the household: this was due to the constraints in the choice of the metered appliances, e.g. due to the large size of the smart plug that couldn't fit everywhere;

A3. the lack of weather data, with the needed detail to simulate the building with RSE's software, about the different climatic zones in Cyprus;

B. for tertiary and industry sectors:

B1. there was a further delay in the collection of audits, and the activity was completed on 28 February 2019: this implied a further postponement of the final analysis;

B2. some data were missing in the audits, so they were requested to the local subcontractor, that contacted the companies, but the data resulted not always available;

B3. the collected data in the audits were not the same for all the companies, even in the same subsector.

In order to solve these issues, several actions have been put in place:

A. for the residential sector:

B1. assumptions were made based on the data collected up to the point where the metering kit was disconnected;

B2. calculations on the consumption of other appliances were done using the collected questionnaires and the results were compared with the overall consumption collected with the meters;

B3. after the local subcontractor tried in any way to get the data, we used those contained in another energy simulation software; however only for two climatic zones it was possible to retrieve the data with enough detail to be used in RSE's model;

B. for the tertiary and industry sectors:

B1. the start of the analysis was delayed and a delay in the delivery of D3.2 was agreed with MECIT;

B2. for the retrievable data by the local subcontractor, it was decided to wait to analyse the concerned audits; for the others, assumptions and simplifications were made, even if this led to the loss of significance of some KPIs for few establishments in the tertiary sector;

B3. a deeper analysis was done, in order to try to align the categorization into services and process phases in all the audits; this took a longer time than foreseen, that was considered in agreeing with MECIT the delay in issuing D3.2.

Finally Deliverable D3.2 was completed and sent to MECIT at the beginning of August 2019. MECIT provided its comments on 30 September and they were taken into account to provide the final version of D3.2 on 19 October.

Summarizing, as above mentioned, part of the scope of the work changed in agreement with MECIT, but a more detailed analysis was carried out on the available data.

"Output 3.2 - Determination of the actual energy demand" was therefore achieved for the three analysed sectors, and policy recommendations were inserted into the deliverable to support the Republic of Cyprus in the development of a regulation related to the support of energy efficiency projects.

Some examples of the main results are reported in the following.

Residential sector

The wide differences in the collection of data and monitored appliances for each type of building and climatic zone, makes it difficult to build a significant comparison among them.

An attempt of comparison has been made by using Key Performance Indicators, as described in Deliverable D3.1.

For the residential sector, the choice has been to use the following KPIs:

- electricity consumption per square meter;
- fossil fuels consumption per square meter;
- primary energy consumption per square meter;
- CO_2 emissions per square meter;

for the whole building. When possible, also a split by service has been done, e.g. to evaluate the specific consumption for heating and/or cooling.

The calculation has been performed with the following boundaries:

- for overall electricity consumption, the results obtained with the measurements in households (available for all users except #2, #3, #12, that had only the single appliances measurements due to technical issues) have been averaged with what contained in the energy bills (available for all users for at least 1 year between 2017 and 2018, and for most users for both years) and the total electricity consumption has been calculated;
- for heating and cooling, the declared data in the questionnaires have been used to calculate the consumption of electricity and other fuels, by setting average efficiencies of the equipment in the households; electricity consumption for heating, also when heating is done with fossil fuels, takes into account also the needed auxiliaries;
- for DHW, all the selected households had solar thermal systems, so it was impossible to calculate the need; however, they are already using efficient technologies;
- for lighting, the consumption was calculated from the power and usage factor declared in the questionnaires;
- for appliances, the data from direct measurement, energy bills (overall consumption minus heating, cooling, lighting) and what declared in the questionnaires were compared and averaged.

In the figures below, it is possible to see the final and primary energy consumption for each service (heating, cooling, lighting, appliances) for each user.

For most of the users, the largest consumption comes from heating (red bar) and appliances, both in final and primary energy terms. However, since most of the users heat their houses (partially or completely) with fossil fuels, the share is lower in terms of primary energy. The choice of showing both final and primary energy results (that has been done also for tertiary and industry) has been made in order to be able to sum-up and compare the consumption from different fuels.

Cooling is however significant in most cases, while lighting represents only a small portion of the overall consumption.

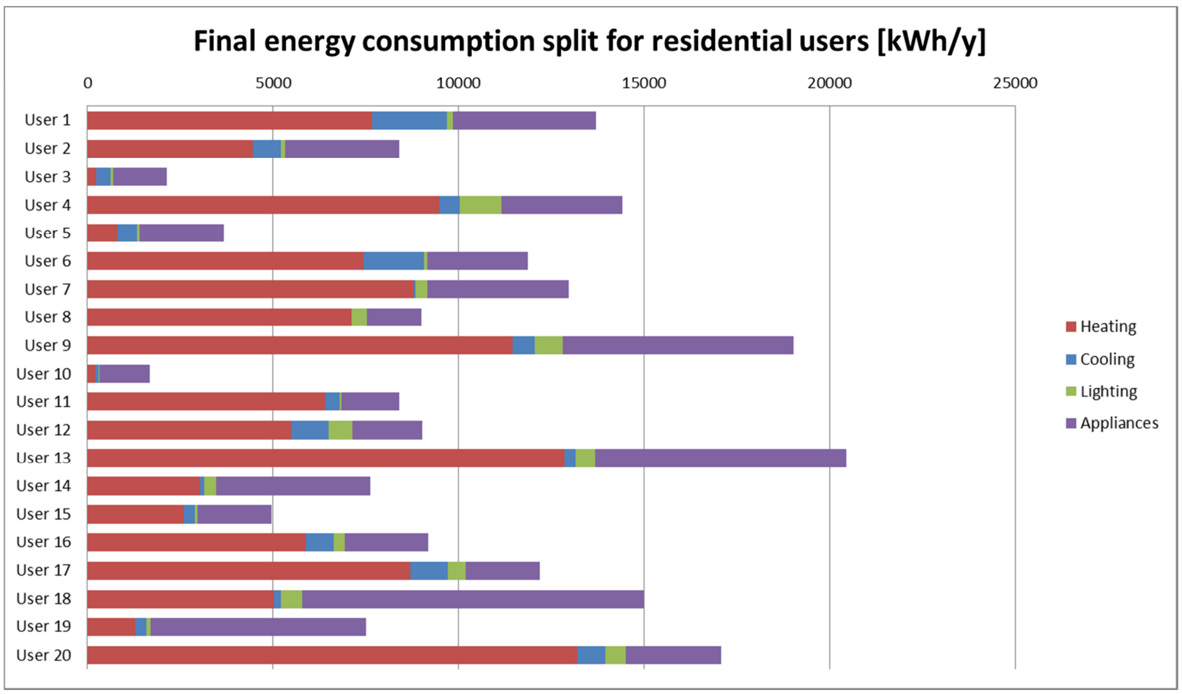


Figure 3-1: Final energy consumption per service.

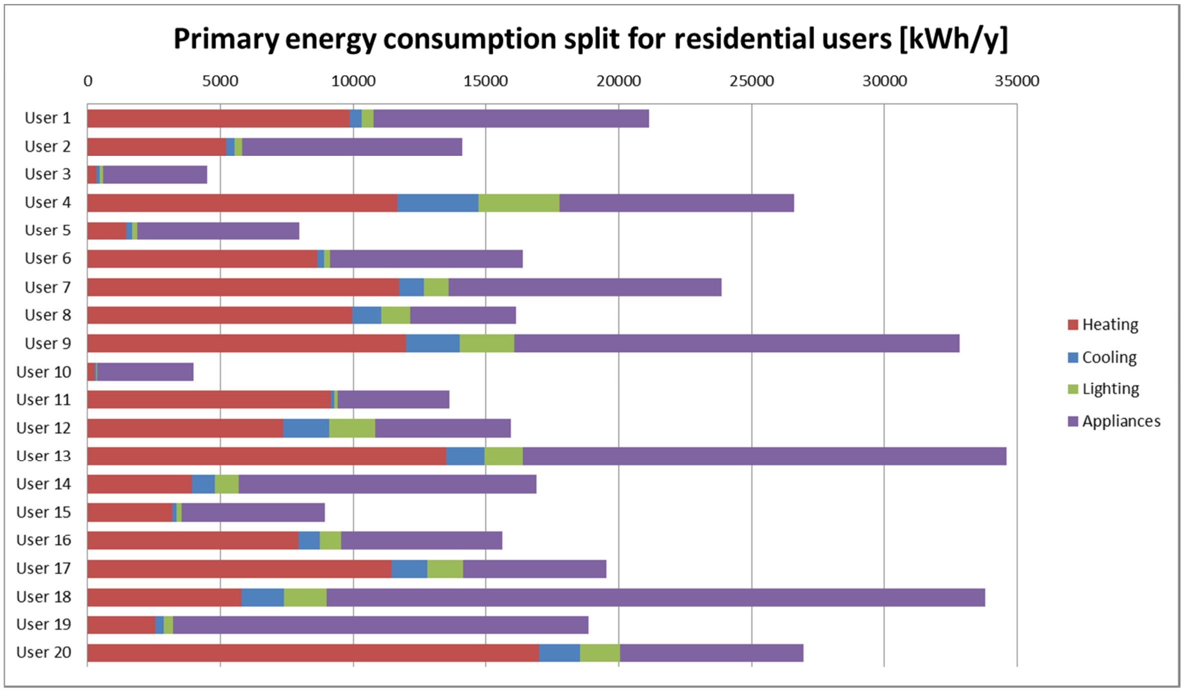


Figure 3-2: Primary energy consumption per service.

The results in terms of KPIs is reported in the below.

Table 3-1: KPIs results for residential sector - minimum, maximum, average, median.

KPI	Min	Max	Average	Median
Electrical intensity [kWh/m^2]	16	40	26	25
Fossil fuels intensity [kWh/m^2]	0*	96	25	16
Primary energy intensity [kWh/m^2]	56	172	96	91
CO_2 intensity [kgCO_2/m^2]	37	105	68	69

*four households do not use fossil fuels

Tertiary sector

The large variety of activities in the tertiary sector made it difficult to compare the results among different companies. Also the use of KPIs, although significant in comparing the performances in each subsectors, is difficult to standardize across all the sector.

Also in the same subsector, large differences exist between companies with similar scopes but different sizes.

An attempt of comparison has been made based on the KPIs, reported in the table below.

Table 3-2 KPIs comparison for the tertiary sector.

KPI	Min	Max	Average	Median
Energy intensity per company – kWh_{final}/unit	2	102,255	11,117	306
Energy intensity per square meter - kWh_{final}/m^2	34	5,113	827	212
Primary energy intensity – kWh_{prim}/unit	5	145,131	17,979	583
Primary energy intensity – kWh_{prim}/m^2	63	7,257	1,525	471
Energy cost intensity - $€_{energy}$/unit	0.4	10,556	1,303	39
CO_2 intensity – kg_{CO2}/y/unit	2	67,824	9,781	435

Anyway, the only comparable data are those referred to the KPIs in red, specific to the area of the building, since the others are specific to different units (clients, employees, guests, etc.).

Also these parameters show the high variety of the sector and how the specific characteristics of the company can affect energy performances.

For each subsector, the specific consumption per service has been calculated. The two most consuming services, in all cases, are process and cooling, while sometimes also transport can be relevant.

Industrial sector

The large variety of activities in the industrial sector made it difficult to compare the results among different companies. However, here there is an advantage when compared to the tertiary sector, because the way of calculating KPIs is the same across all sub-sectors.

However, it has to be considered that, also in the same subsector large differences exist between companies with similar scopes but different sizes.

An attempt of comparison has been made and it is reported in the table below.

Table 3-3 Industry KPIs analysis

KPI	Min	Max	Average	Median
Final energy intensity (kWh/k€)	297	67,415	14,040	5,069
Primary energy intensity (kWh/k€)	532	121,356	26,006	7,995
Carbon intensity (kg_{CO2}/k€)	316	73,724	16,076	4,053
Energy cost intensity (€/k€)	39	8,854	2,231	519

According to this analysis, the best performing sectors in terms of energy efficiency seem to be chemicals, wood and paper production, with very low intensities. Around the average values (but above the median) there are food and plastic sectors, while mining is slightly above the average. The worst performing sector is non-ferrous metals, with all the KPIs equal to the maximum, meaning a very high energy intensity but also very high costs of energy. Especially in terms of Energy cost intensity, all sectors but this one, are performing well.

For each subsector, the specific consumption per service has been calculated. Like general KPIs, since the area was not available for many establishments, the specific consumption was calculated based on k€ of production value.

As expected, there is a very high specific consumption related to process, followed by transport, while the other services are not very relevant.

It has however to be reminded that this study cannot be considered exhaustive in terms of representativeness of the energy efficiency status of the different sectors in the Republic of Cyprus, since it was impossible to collect data and energy audits for a statistically significant number of buildings and establishments.

A further development of the work could be to improve the auditing system, collecting more data about production and other parameters (consumption of each process phase, description of the business, implemented energy efficiency projects, etc.) and presenting a deeper analysis of the situation, for a larger number of plants. However, to do so, both a longer time and full cooperation from all the companies are needed.

Conclusions and recommendations

For both the residential and the tertiary sector, the first recommendation is related to cooling and heating, that in both cases represent significant shares of the overall energy consumption of the buildings. In the residential sector questionnaires, it has been noticed that there were unusual temperature set-points in several houses. This, coped with the results obtained when calculating KPIs, where the households with high set-points in winter and low set-points in summer had the worst performances, independently of the age of the building. For the tertiary sector, this information is not available in the audits. However, also during the visit to Cyprus we noticed very low cooling temperature set points in restaurants, hotels, shops and offices, so we assumed that the choices are similar. Thus, there is a strong need of setting general recommendations or rules about temperature set-points for heating and cooling. In Italy, for example, in the Decree of the President of the Italian Republic n.74 - 16/04/2013, article 3 there is the statement that, for heating, temperature set-points shall not be above 20°C (with +2°C tolerance for particular cases, up to 22°C), while for cooling the minimum temperature shall be 26°C (with -2°C tolerance for particular cases, down to 24°C) and the

Italian national energy agency suggests not to cool the building more than 5°C less than the external temperature, in order not to damage the health of the inhabitants or employees (in case of companies). As shown in the dynamic simulations reported in the deliverable, increasing or decreasing the temperature of few degrees can lead to significant energy savings.

Moreover, there should be a set of rules on how many hours heating and cooling systems can be on at maximum (minimum in the case of cooling) set-point temperature and how many hours they need to be at set-back temperature, based on the climatic zone (e.g. in mountain areas people could be allowed to have heating at maximum set-point for 14 hours, while in coastal areas for 6 hours – the opposite for cooling).

One of the most interesting points is that both private households and companies are producing DHW mostly with solar thermal systems: this is rational, considering the weather in the country, and it is a good practice that should be incentivized. However, the use of electrical heaters as a supplement or a back-up should be discouraged, unless electricity is produced with PV or other renewable sources.

Both in the tertiary and industry sectors, we noticed that halogen lamps are still used in several activities. A campaign and incentives to switch to more efficient technologies can be useful to reduce energy consumption in the buildings.

For what regards process equipment in industry, there wasn't enough information to understand which were the most efficient and less efficient ones. However, a type of incentive (related to an obligation scheme) that has proven to be working in several EU countries are the White Certificates. In Italy, for example, for standard technologies there are simplified rules to obtain White Certificates, while for more complicated projects it is necessary to prove that there are actual energy savings and the procedure is more complex. In order to increase the adoption of efficient technologies, it is suggested to put in place such schemes, that take however into consideration also the structure of the sector in the Republic of Cyprus.

One of the things that were noticed, for food industry, is the low penetration (at least in the audited companies) of biofuels to produce heat: in Italy, several food companies have installed biodigestors that transform wastes into fuel, that is then used as a replacement for LPG, methane or oil in boilers. In some other cases, waste biomass is directly used as a fuel, without any conversion in biogas.

In general, we noticed, in the audited tertiary and industrial buildings, a low penetration of PV systems. The same was noticed on residential buildings during our short visit to Cyprus (for the audited residential buildings one of the requirements was no PV system, because it would have been impossible to compute actual energy consumption with the smart metering). One of the main points on which subsidies shall intervene, considering also the weather in the country, is actually the incentivization in the adoption of such technologies, that can be then integrated with heat pumps for the production of both heating and cooling. Heat pumps are suggested also for those households where heating is performed with speed heaters or electrical stove, with a very high energy waste.

5 WORK PACKAGE 4 – "DEVELOPMENT OF FORECASTING TOOL FOR VARIABLE RENEWABLE ENERGY SOURCES"

The main objective of this work package is to develop and test variable renewable sources (RES) production forecasting tools for different forecast horizons, after a study on the current RES forecasting systems adopted in Cyprus, the evaluation of the state of art in this field, taking into account the peculiarities of the climatic conditions of the Island.

The activities foreseen for WP 4 suffered from a significant delay due to the difficulties experienced by MECIT during the data collection. According the work plan schedule, the data collection was supposed to end three months after the beginning of the project, i.e. in mid-April 2018. The data collection concerns renewable forecasting methodologies already adopted in Cyprus and a set of forecast and actual energy generation, both for wind and solar plants. At the beginning of 2019 the data collection was not finished yet, despite all the efforts by MECIT. Therefore, RSE agreed with MECIT the following variation of the work plan:

- with regard to the activity C3 "Assessment of the current status of VRE Forecasting in Cyprus", because of the lack of information on the tools and the incomplete data collection, especially for the solar production, an assessment in the form of statistical analysis of current forecasting vs actual production for the wind generation, using the data set with forecast and actual production already made available, will be supplied;
- with regard to the activity C4 "Assessment of the current "Weather to Energy" Models used by VRE producers", RSE was supposed to conduct an assessment of Weather to Data models/methodologies and best practices utilized worldwide and make a comparison between the best practices/models and the current models/practices used in Cyprus". Since RSE was not provided with documentation on the models used in Cyprus, an exhaustive up to date state of the art of the most recent methodologies devoted to the power production forecast, both for wind and solar, with different time horizons, will be supplied.
- activity C5 "Preparation of a holistic model for VRE forecasting" could not be undertaken without an exhaustive data set with the areal production for wind and solar in Cyprus, both forecasted and measured. For this reason, considering MECIT's interest in the nowcasting horizon for the solar production, two different tools for the forecasting of the solar power production will be supplied. The first tool allows to forecast the power production for six hours ahead with a time step of fifteen minutes, while the second one performs the hourly production forecast for three days ahead. These systems can be used to estimate the production of each single power plant.

In the following the actions implemented by RSE for each of the Technical Activities foreseen in the amended work plan and the results obtained are described. Ultimately, all the Technical Activities have been completed and MECIT has been provided with the expected results.

C1 – Preparation of forecasting assumptions

The needs and the expectations concerning the forecasting tools have been explored through a preliminary meeting on 6 February 2018 via a conference call between RSE and MECIT. During the meeting, MECIT stressed, in particular, the problem of dust storms that affects the solar production and put in evidence the lack of a link between the meteorological forecast for PVs (impact on the DSO) and the power forecast for wind (impact on the TSO).
A continuous exchange of e-mails between RSE and MECIT for the duration of the project has made it possible to finalize and customize the forecasting tools according to the key requirements of MECIT and on the basis of the available data, necessary to develop the tools themselves.
In addition, a kick-off meeting was organized by MECIT on 7 June 2018, with a first part held at the Cyprus Institute premises, and a second part held at the MECIT premises. The attendees were from the following institutions: CYI, DOM, EAC-DSO, MECIT, RSE, SRSS-EC. The meeting was an opportunity to better understand the needs of the stakeholders, to present RSE's experience in RES forecasting and to describe the data necessary to implement the forecasting tools. Furthermore, in that occasion, MECIT described the urgency of having reliable renewable power forecasts, not only day ahead, but mainly for "nowcasting" (0÷6 hours ahead), with rapid updating, in order to better manage the dispatching of energy.

C2 – Collection of data

RSE prepared a list of the data to be collected in order to develop the project. The data collection focused on:

- forecasting models used by RES producers;
- forecasted and actual energy produced for specified periods;
- meteorological data.

In order to analyze the current forecasting models used in Cyprus, RSE asked for a description of the RES production forecasting tools. MECIT supplied two reports, one related to the solar forecasting and another one related to wind forecasting, that RSE analyzed.
In order to perform the statistical analysis on the current power forecasting models used in Cyprus and to develop the power forecasting tools, a dataset of power measurements and corresponding power forecasts was requested.

Considering wind data, a complete dataset, made up of observed and forecasted power data was made available. In particular, for a 24 hours (ST) forecast horizon, two datasets of almost one year were made available, while a period of around two months was made available for a three hours (NOW) forecast horizon.

Regarding solar power data, a period of only two months with corresponding forecast and observed data was available. The period was too short in order to carry out a meaningful statistical analysis for this source.

However, different solar power measurements, with different time frequency and referred to plants with different size were collected. Using these data, it was possible to implement and test the two solar forecasting tools for nowcasting and short term forecasting, described in the following.

The last data request referred to a meteorological dataset. Most of the modern RES generation forecast models are based on the weather forecast supplied by a Numerical Weather Prediction (NWP) Model.

Also the forecasting tools proposed by RSE are based on the prediction of some meteorological variables affecting RES production. In particular, RSE has developed a direct approach to forecast the future production. With this approach the power is estimated through a statistical technique that directly links the meteorological variables affecting the PV production with the production itself.

In order to develop this kind of algorithm, an historical dataset of power measurements together with the associated weather forecast was required.

The Numerical Weather Prediction (NWP) Model used by the Department of Meteorology (MetDep) of Cyprus is the Weather Research and Forecast (WRF) model, run twice a day using the High Performance Computing Facility of CYI. A dataset of the WRF weather forecast on Cyprus was supplied. The dataset covered the period January 2017 ÷ October 2018.

In order to extract the WRF forecast in correspondence of the sites of the renewable plants, RSE developed specific decoders.

In addition to WRF data, RSE also downloaded a dataset of atmospheric components forecast, in order to produce specific indicators of the air transparency, strictly affecting the solar production. The dataset was made available by Copernicus Atmosphere Monitoring Service (CAMS). RSE collected and decoded all the runs at 12 UTC with a time horizon of 60 hours, a spatial resolution of 0.4° and a temporal resolution of 3 hours since 2017.

C3 – Assessment of the current status of VRE Forecasting in Cyprus

On the basis of the data collection carried out in the activity C2, a statistical analysis has been performed by RSE for some wind farms installed in Cyprus, with different nominal capacity and located over different complex terrains. The analysis has been related to the day-ahead forecast and to the intra-day forecast, taking into account the grid compliance obligation for Cyprus.

In the following the main conclusions of the analysis, related both to single plants and to the aggregation of all the plants, are reported.

The performance evaluation for single plants showed that the current models are in line with the results reported in the literature for wind power plants located in flat or fairly flat terrain. The forecast related to a specific site, the Ayia wind farm, gained worse results than the other plants and its performance is more in line with the reported literature regarding wind farms located in complex terrain. Further investigation is therefore needed for this wind farm, in order to discriminate the possible cause.

Considering TSOC regulation, each plant exhibits different levels of performance depending on the month. In particular, Orites and Alexigros showed fluctuating results with generally better performance during the warm seasons and higher values of error for the remaining months, while Koshi and Aeolian always exceeded the 10% accuracy limit, both in terms of NMAE_month and NRMSE_month, according with the error definition proposed by.

The total wind production forecast was always under the 10% accuracy limit, both in terms of NMAE_month and NRMSE_month, due to the compensation effect given by the aggregation.

A short analysis for the intra-day forecast was also performed. Even if the period of available data was very short, the 3-h forecasts demonstrated to be able to improve the results over a 1-month verification for all the 3 available power plants, showing less level and phase errors in identifying the wind production.

It would have been possible to go into more detail in the analysis in presence of wind measurements in correspondence of the wind farms or using wind information derived from model reanalysis data, when available. This kind of information could help both in the validation of the power measurements and also to detect local patterns in the wind regimes that could affect the power forecast performance. In this case particular post-processing techniques could be applied to reduce systematic errors in the forecast.

C4 – Assessment of the current "Weather to Energy" models used by VRE producers

In this activity, RSE analysed the state-of-art of “Weather to Energy” models reported in literature up to now. RSE produced a deliverable with a section devoted to the description of the most recent weather forecasting models, since the main current power forecasting systems make use of numerical weather prediction models.

Another chapter described the different power forecasting techniques developed so far and a section on the comparison with the current models used in Cyprus was also provided. In this regard it is important to point out that it is very difficult to compare different models when applied in diverse climatic conditions and when the errors of the models are normalized with different values, such as nominal power or the average of the observations or the maximum of the observations. Sometimes the same approach can gain the best results for a plant, but not for others, because of local features or due to a different quality of the training dataset, therefore it is inappropriate to look for the best model for every plant and in every place. Likewise the analysis of the state of art puts in evidence that model performances change according to the time horizon (from few minutes to many days) and depending on the time frequency (from quarterly-hour time step to hourly or daily time step).

Another observation drawn from the study of the state of art is the tendency in preferring the use of direct approaches both for the nowcasting and the short-term horizon with respect to the indirect ones, based on a physical model of the plant, eventually fed by some meteorological inputs. In fact, in order to build a physical model of the plant, a deep knowledge of the technical characteristics of the plants and details on the installation are needed, and therefore the indirect method is very difficult to apply especially for the PV distributed generation, due to a lack of information of each single small plant.

Taking into account the previous remarks, the comparison with the current models used in Cyprus showed that the forecast for the wind generation is in line with the state of art. In particular, for the short term, the use of the weather forecast derived from different NWP models should lead to a reduction of the final uncertainty, because of the error compensation achieved by means of the combination of different models. Also the post processing used to link the weather information to the power production forecast showed performances very similar to the ones reported in literature.

With respect to the nowcasting, the improvement obtained by means of using update power measurements is also evident and compliant with the literature even if short series of power data and corresponding forecasts were available for the analysis.

For the PV production forecasts, the methods implemented by RSE and described in detail in deliverable D4.5 are in line with the state of art.

C5 – Preparation of solar production forecasting tools for multiple time horizons

RSE in activity C5 worked on the implementation of two algorithms to derive the PV profile both for the short-term (ST) and for the nowcasting (NOW) horizon.

The tools have been developed taking into account the specific characteristics of Cyprus, i.e. the weather variability due to sudden formation of cloudiness and the presence of dust storm events, strongly affecting the PV production. Considering the state-of-art of the renewable power forecast, RSE implemented two direct approaches to forecast the production on the basis of the existing relationships between the environmental conditions and the PV production itself and exploiting the information contained in the historical time-series of the past production of a plant.

The short term forecasting is based on the statistical technique Analog Ensemble (AnEn). AnEn estimates the probability distribution function of the future generation using the measured production registered in the past when the weather scenario looked very similar to the current forecasted one. With this approach, the statistical technique directly links the factors affecting the PV production with the production itself, with no use of a physical model of the plant. In this way it is not necessary to know all the details of the installation, such as system size, module and array type, tilt and azimuth, system losses, inverter efficiency and so on, except for the geolocation of the plant. The geolocation is mandatory because the algorithm needs some predictors, calculated in correspondence of the plant, used as inputs of the AnEn scheme, in order to derive the predictand, that is the PV power generation.

The ST tools supply the future PV production with a time resolution of 30 minutes up to two days ahead. In order to learn the relationships between predictors and predictand, AnEn needs a training period, made up of a set of past predictors and corresponding observed predictands. The longer the training period, the better is the training of the algorithm.

The algorithm has to be trained for each plant, in order to identify the specific relationships between the production of that plant and the predictors in correspondence of the plant site.

Two different configurations of the AnEn have been implemented in this study, differing for the variables used as predictors.

The first configuration is called CONF A, and it is based on the following predictors:

- future Sun position (solar zenith and azimuth angles)
- predicted Global Horizontal Irradiation (GHI)
- predicted panel temperature (affecting the yield)

The second configuration is called CONF B, and it is based on the following predictors:

- future Sun position (solar zenith and azimuth angles)
- predicted Global Horizontal Irradiation (GHI)
- predicted panel temperature (affecting the yield)
- DNI in clear-sky conditions
- DNI with according to the parameterization proposed by Ruiz-Arias

Regarding CONF A, all the predictors are provided by the Numerical Weather Prediction (NWP) model Weather Research and Forecasting (WRF), supplied by the Meteorological Department of Cyprus (MetDep) in collaboration with the Cyprus Institute (CYI).

As regards CONF B, the predictors are calculated on the basis of some information on the atmospheric components obtained from a global forecasting model, made available, operationally, by Copernicus Atmosphere Monitoring Service (CAMS). Therefore this configuration can be activated only in presence of the CAMS forecast.

A flow chart describing the process to derive the short term forecasting according to the configuration A is reported in Figure 4-1, while Figure 4-2 represents the operational chain implemented for configuration B.

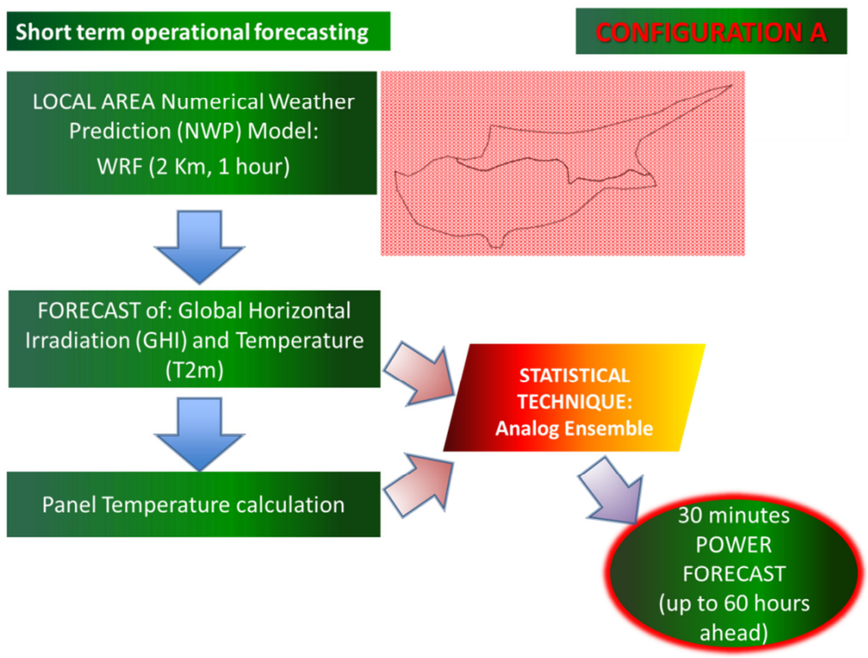


Figure 5-1: Flow chart of the PV short term forecasting with the configuration A.

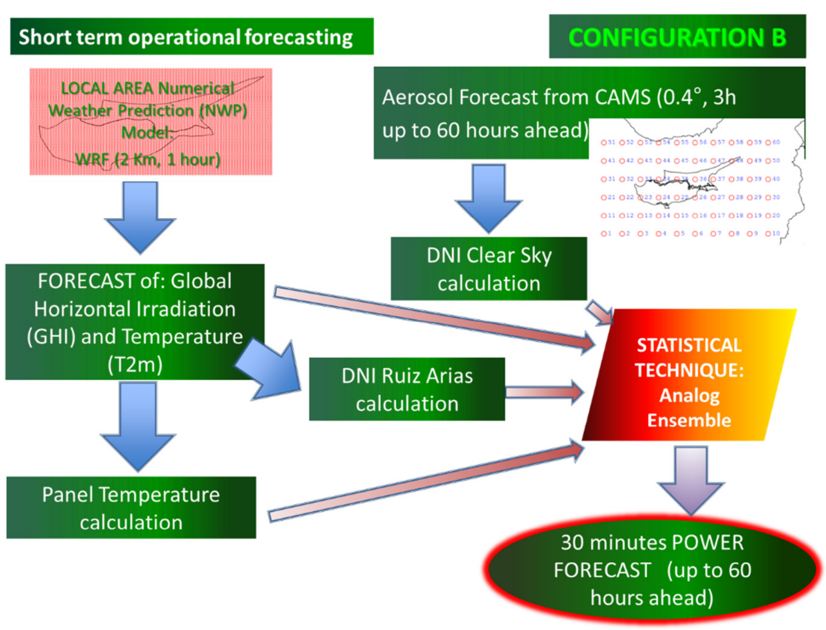


Figure 5-2: Flow chart of the PV short term forecasting with the configuration B.

In addition to the ST one, an algorithm to forecast the PV production in the next six hours, with a time resolution of thirty minutes, based on an Auto-Regressive Integrated Moving Average (ARIMA) algorithm, has been implemented. The tool to generate the NOW forecast is based on a real-time updating of the production measurements and on the output of the ST forecast.

A flow chart, describing the data flow of the nowcasting is presented in **Errore. L'origine riferimento non è stata trovata.**:

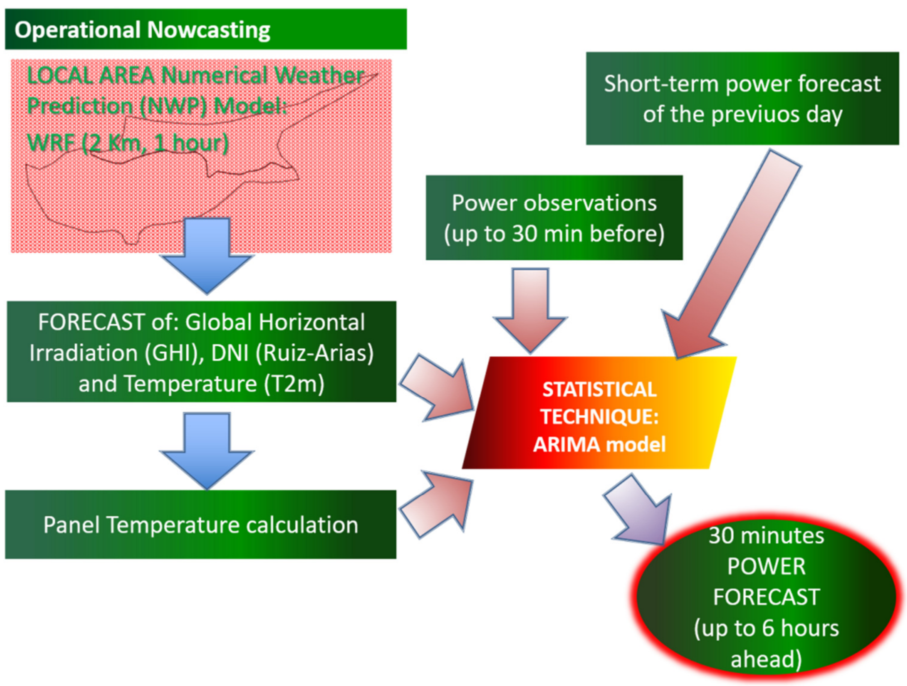


Figure 5-3: flow chart of the nowcasting tool

The performances of the tools have been evaluated against the smart persistence, used as a benchmark, on different Cypriot plants, using the time series of one year of half-hourly production measurements. All the errors have been normalized with respect to the average of the measured production.

Considering the ST, the developed algorithm outperforms the smart persistence in terms of correlation, rMAE and rRMSE. The configuration B always gains better results than configuration A. This finding underlines the importance of better characterizing the state of the atmosphere in order to improve the quality of the direct forecasting methods. In particular, further improvements might be expected using an update version of WRF that can provide all the components of the irradiation.

Summing up, in terms of rMAE the best result is achieved by means of the configuration B with a relative error of 16.6%, together with the lowest value of rRMSE, corresponding to 29.4%. The higher registered improvement with respect to the benchmark is of six percentage points in terms of rMAE and of 10 percentage points as regards the rRMSE.

A general overestimation, represented by the rBIAS error, can be noticed for all the plants. The main causes of this behaviour can be sought in a general overestimation of the irradiation by the NWP, causing a consequent overestimation in the PV production or in the short length of the training dataset. For this last reason, the AnEn could not be able to find enough cases in the past similar to the current weather situation, bringing to errors in the final forecast.

The NOW was tested on the same year of the ST and, in particular, the improvement with respect to the ST was evaluated. The results obtained in this analysis show that the NOW is beneficial in the horizons up to one and a half hour ahead, while after this time, the forecast of the ST, supplied the day before, is more accurate than the NOW. The study on the NOW has nevertheless shown the importance of using exogenous variables in the autoregressive methods, such as the forecast of the different components of the irradiation, in order to improve the accuracy of the NOW, with respect to use only recent production data in the model. This result suggests that an improvement in the ARIMAX could be probably obtained using update irradiation measurements in correspondence of the plant. In absence of solar measurements close to the plant, also irradiance estimations, obtained using data derived from meteorological satellites could be used. In particular, the estimation in real-time of the movement of the clouds, that are the main factor affecting the PV production, could be considered in the model, in order to recognize the changes in the irradiation underway.

The software to generate both the ST and NOW forecast has been installed in a reserved area on Cy-Tera. The ST tool can run in operative mode, on the condition that the weather forecast is supplied day by day. In this case it produces the half-hourly generation profile in the two following days on a selection of Cyprus plants, defined through a registry file. It can also be used to reproduce past forecasts or to build the information necessary when the user wants to produce the forecast on plants not yet included in the registry, or using a different configuration from the one settled by default.

The tool to generate the NOW forecast is based on a real-time updating of the production measurements and on the output of the ST forecast. Both the ST and NOW forecasting can be visualized through a graphical user interface, specially developed for this purpose.

The script that drives all the steps to obtain the forecast is written in Perl5 language. This tool manages the execution of some Fortran90 codes, for the analysis and decoding of WRF and CAMS data and to calculate the ST using the AnEn technique and some R scripts to execute the ARIMA algorithm and for generating images to be visualized interactively.

The graphical user interface (VIS) is written using the Tk module of Perl5, that is a GUI program for managing with widgets. The visual interface that opens when the Perl script is executed, is shown in Figure 4-4, as an example.

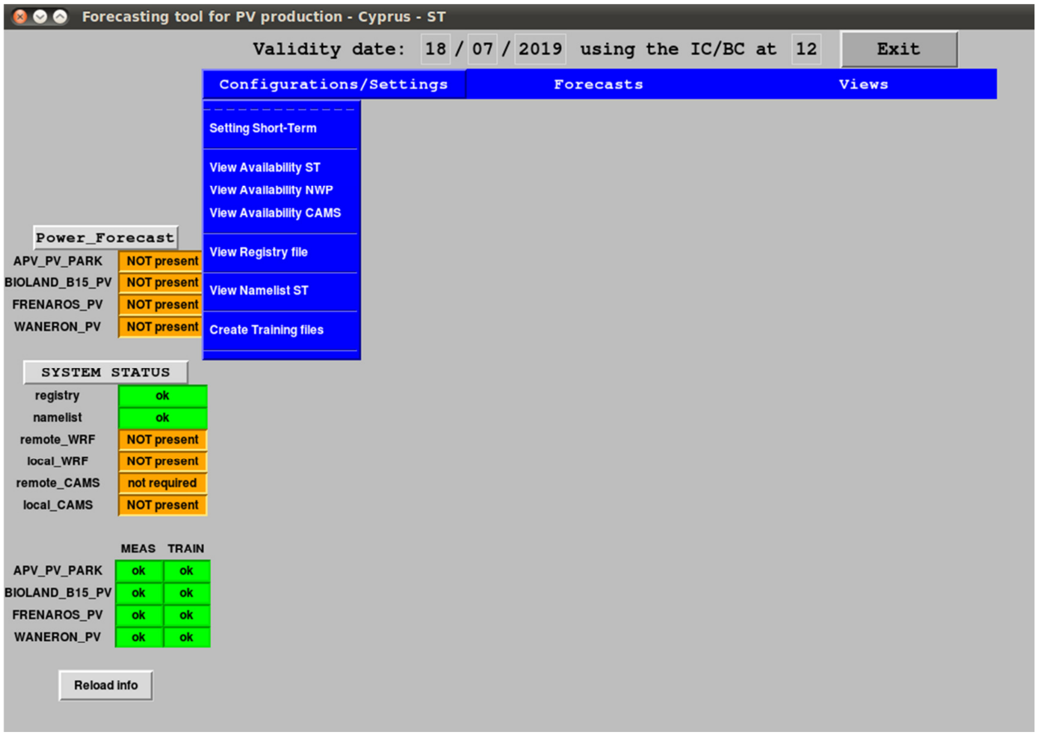


Figure 4-4: graphical interface to visualize the ST forecasting.

C6 – Recommendation and next steps

All the phases of WP4 focused on an in-depth understating of the specific features of the renewable sources in Cyprus, in order to develop useful RES forecasting tools, able to meet the needs of the stakeholders. The statistical analysis on the wind forecasting tools currently used in Cyprus, together with the study of the state-of-the-art of RES forecasting, showed that the used tools are in line with the state of the art. Also the short analysis related to the wind intra-day forecast has produced results in line with the literature and showed the importance of updating the day before forecast, by means of production measurements, supplied in real-time.

For PV, the continuous exchange of information between RSE and MECIT has brought out the necessity of having forecasting tools with different time horizons and customized to forecast the solar production in specific weather conditions, such as during dust storms events.

Considering the ST horizon, the validation of the tool on one year of measurements on different Cyprus plants showed the importance of characterizing as well as possible the weather conditions and the air transparency, using all the available information on the components of the irradiation and characterizing the atmospheric components affecting the air transparency and, consequently, the PV production.

The study on the NOW tool stressed the importance of using exogenous variables in autoregressive algorithms, in order to forecast the PV production in the very short term.

Both the studies on the ST and the NOW also brought out the importance of using validated power measurements in the training phase of the models.

These considerations, together with a detailed description of the work carried out by RSE in the WP4, have been discussed during a final meeting, organized on 23 July 2019 at MECIT premises.

Thanks to the participation at the meeting of MECIT, the stakeholders, the DepMet and the CYI, important technical aspects have been discussed in order to use in operative mode the tools.

A further step towards the best integration of RES could result from the comprehensive forecast of the production of wind and solar plants. In fact, it happens very often that, in an area, the wind production has the opposite trend of the PV production during the same day, due to the fact that, for example, adverse weather conditions, responsible for reduction in the irradiation and finally in the PV production, are also often windy, causing an increase of wind production.

This balance effect could result also in a balance of the forecasting errors. It would be worth exploring the matter more in depth, to quantify the advantage in using a comprehensive forecast with respect to forecast the production from the different sources separately.

Finally, in accordance with a request from MECIT, RSE organized a web-conference, on 13 November 2019, to discuss in detail about some aspects of the forecasting tools developed by RSE.

MECIT, CYI and RSE took part in the meeting. In particular CYI asked for some clarification on the data flow behind the power forecasting tool. RSE described the fundamental steps in the forecasting process and also proposed alternative systems for data transfer.