RES INTEGRATION METHODOLOGY IN A NEW RURAL SETTLEMENT

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ABSTRACT: This paper deals with an integration methodology of renewable energy sources in a new rural settlement, to be built in Thrace, Northern Greece. The specific settlement is designed so as to provide free housing for 300 families with energy conservation features and RES. The employment of the inhabitants is foreseen in agricultural activities and specifically in greenhouses, having their energy needs met by the utilization of locally available renewable energy sources.
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1. INTRODUCTION

The entire design is the result of research carried out within the JOULE2-CT93-0396. The layout of the settlement includes 300 houses and 7 public buildings in an attempt to plan for the social needs not only of the residents of the new town, but also of the surrounding communities as well. For the employment of the future inhabitants, greenhouse agricultural activities are foreseen in properly designed greenhouses (83 total of 2000m^2 each). For the design of the settlement a software tool was developed called "CRESCAD", that allows planners to produce architectural and urban planning with microclimatic criteria, taking in concern issues such as insolation and overshadowing of buildings and air flow around buildings; it also enables the evaluation of the thermal performance of the designed buildings with simulation. This tool is not presented here, but the heating and cooling needs of the settlement were determined with CRESCAD and subsequently used as input in the energy design methodology described below.

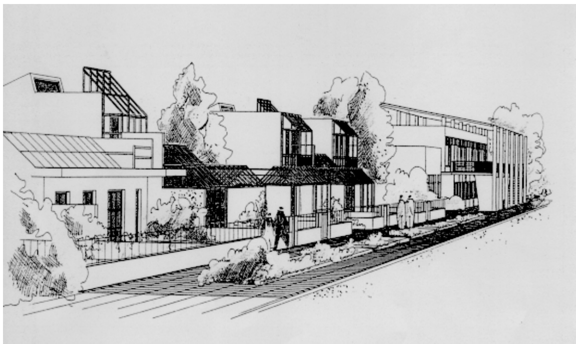

Figure 1: View of a street with typical residential buildings.

The energy design methodology is composed of two tools. The Decision Tool, that was developed to translate common sense principles into a methodology via a scoring system and assisting our initial decision on appropriate combined RE Systems, and the code RES-INTEGR developed for RE systems' performance evaluation through simulation. Annual results on an hourly basis is a typical deliverable of the simulation code and crucial factors such as, thermal and electrical energy production and deficit, cost of energy produced, capacity factors of each RES in the system and more, are calculated, aiming to assist the design engineer for the final system configuration. As a result, sized hybrid systems with high evaluation scores were obtained. Further evaluation was also necessary in order to verify the pre-selection technique.
The renewable energy sources that have been taken into consideration for investigation in this project are namely, solar energy, biomass, geothermal and small-hydroelectric power generation (see Table I). Regarding the wind resource of the region, the microclimate analysis have shown that the average mean speed is less than 3 m/s, therefore the conclusion that the wind energy is not exploitable has been reached.

Table I: Settlement and Greenhouse annual energy demand and locally available renewable resources.

Annual Energy Demand		**Local Renewable Resources**	
Settlement			
Heating	1.2 MWh (1352 kW)	Solar	1512 KWh/m^2 Global Hor.
Cooling	43.3 MWh (129 kW)	Biomass	-Agric. residues: 24.6 Mtons -Corn: 54 Mtons -Forest res.:35 Mtons
Electricity	900 MWh (245 kW)	Geo-thermal	-Geo. Field: 52-69°C at 320-350m -VEHE's 18-19°C at 30-80m
Greenhouses		Small Hydro	Nestos irrigation canal max capacity 25m^3/sec
Heating	28.2 GWh (33.2 MW)	Wind	Annual average 3 m/sec
Electricity	615 MWh (150 kW)		

The overall thermal load from the greenhouses was the determining factor for sizing the energy supply resources. All electrical and thermal loads in the settlement were analytically predicted with as much accuracy as possible, using known profiles[1] as well as assumed ones of similar existing settlements in Greece. The annual energy demand of 300 houses, 7 public buildings and 83 greenhouses are presented in Table I.

2. ENERGY DESIGN METHODOLOGY

The energy design methodology of the settlement has been developed along three strategic goals:

- minimization of the energy load and peak power demand with suitable urban planning and architectural design
- use of locally applicable renewable energy sources to meet the energy demand
- energy management in order to ensure optimum operation at both the demand and supply sides

For the applicability assessment of the locally available renewable resources, a methodology was developed, based on a scoring system with a number of **criteria:**

- availability and security of RE supply
- environmental and legal issues
- social effects
- capital cost
- difficulty of maintenance and operation
- spare parts and locally technical skills availability
- land or surface related availability etc.

2.1 DECISION TOOL

The evaluation and prioritization of all the above criteria is a troublesome process. For that reason, a Decision Tool was developed to translate the common sense principles into a methodology via the proposed scoring system. Objectivity is laborious to implement, because it mainly depends on who is to benefit. For example, the reduction of CO_2 emissions can be translated to avoided cost in the future and governments and financial institutions may be highly interested. Regional development is also very important for governments. In Greece, there is a capital subsidy of 55% for investments in the less developed areas, in order to create jobs and keep people to their homes.

The specific goals of each project, set the relative importance of **4 major issues**, by a percentage value that altogether add up to 100%.

Major issues : environmental, social, financial and other (defined case by case).

This provides also the possibility to vary easily the relative importance of a large number of criteria, that depend directly on one of these major issues, important to the subjective minded local user and/or investor. Each criterion receives a value between 0% and 100% (**weight factor**), that takes into account the relative advantages and disadvantages between all the RES being considered. A large value means a large advantage and a low value a large disadvantage. The criteria are related to one of the 4 major issues, being valued by the local user or investor.

The **criteria** can be distinguished into **beneficial** or **barriers** to the promotion and introduction of the considered RES technology. For example, an important benefit of a sizable biomass energy producing plant is the creation of several jobs. Job creation is a matter of high importance in under-developed, remote regions and recently even in the industrial world. On the other hand, modular PV systems can have a large value as demonstration systems, integrated onto building envelopes. As for barriers, we could mention the large capital cost investment, per kWp installed, for PV systems and the uncertainty of biomass supply for average and large CHP plants, due to year to year weather variations (drought), biomass fuel price uncertainty and other natural and socio-economic reasons (fire, strikes, ...).

A questionnaire was prepared, where in the first page the investor/user has to define the comparative importance of the 4 major issues of the project. The second page of the questionnaire concerns a comparative technology evaluation with respect to the criteria set. All these assumed values are being used in the RE systems evaluation, with the use of interlinked spreadsheets.

The Decision Tool is designed to assist our initial decision on appropriate RE Systems. As experience is gained, the Tool will incorporate the most agreed upon weighing factors for each major issue, criterion benefit/barrier for every RES under consideration.

2.2 SCENARIA SELECTION OF COMBINED RE SYSTEMS

The selection process of **combined RE systems** starts with the assessment of the locally available renewable energy resources and RE systems via the mentioned Decision support Tool. The estimated electric and thermal energy demand of the settlement provides the first dimension (variable) of the functions that are produced from the Tool. The percentage values of the major issues, that have been set as mentioned earlier, are multiplied with the weight factors of the criteria, to give an "absolute value" of benefit. These values are scaled according to their positive or negative impact with respect to the installed power production capacity, which in turn corresponds to the energy produced by the RE System. An example for one criterion is presented in figure 2.

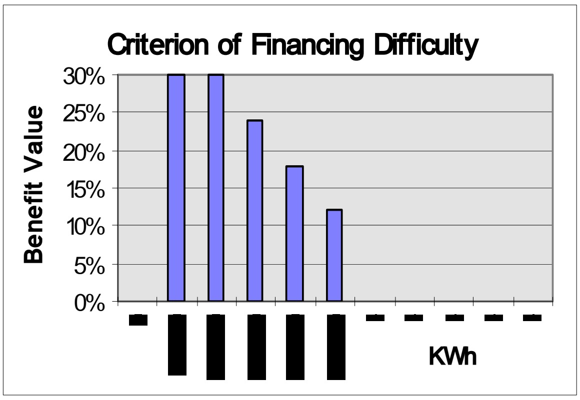

Figure 2: The benefit value variation of the criterion "Financing Difficulty" as a function of kWh produced annually, is presented for PV roof systems.

The scaling of the above benefit values is a very important task, as it has a major effect on the final results. The resulting value from each criterion is summed up with all the rest locally available RE systems, for all the energy (or power) steps up to the annually required energy. The energy axis can be different for the various RE Systems, since they do not all have the same potential for energy production. Then, a **merit value** as a function of the energy produced is delivered for each RE (see figure 3).

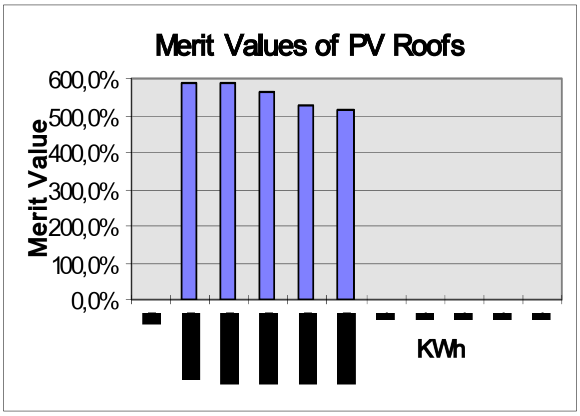

Figure 3: Merit value variation for all the criteria of PV roof systems' as a function of kWhs produced annually.

Finally, the energy (or power) axis of all RE Systems being considered are merged into the energy axis of the most productive RE system, to facilitate comparisons and the selection procedure of the energy supply scenaria.
A computational process follows, that produces all the possible combinations between the available RES and outputs a score. The merit value deduced for each energy step is summed up with the other RES merit values within each scenario, to yield the combined scenario score. The scenaria selection process is based on a common energy or power axis and the overproduction/underproduction or overcapacity/undercapacity of the energy supply system described by the scenario is penalized. Each scenario, whose sum of the total energy or peak power produced, is not approximately equal (within a range of ± 10%) to the demand, receives negative points (-3% of the total score, in this case).

Table II: The "top" 4 scenaria, as they were initially suggested by the Decision Tool.

			CHP Biomass			
Sce-nario	Photo-voltaics	Small Hydro	Electric	Thermal	GEO-thermal	Score
1	100	294	7000	28000	7000	1559
2	100	294	6300	25200	7000	1509
3	100	60	7000	28000	7000	1496
4	100	60	7700	30800	7000	1496

From these energy supply scenaria, we select the "top" 3 to 10 highest scoring ones for simulation and further amendments. A large number of scenaria is considered because the absolute performance of each one depends also on the RE Systems' complementarity in time and their operational control algorithms. Therefore, it is significant to include a few of the highest scoring scenaria in trial simulations.
Table II summarizes the "top" 4 scenaria, as they were initially suggested by the Decision Tool for the settlement in Thrace, sized for the peak thermal power demand (which in turn corresponds to an electric peak power) for the 307 buildings and the 83 greenhouses of the settlement. All the potential of geothermal power is being used in all the presented scenaria, without taking part in the scoring process, as it is characterized by a relatively lower energy production cost and lower capital investment than the other RES.

2.3 SIMULATION TOOL : RES-INTEGR v1.0

The initially selected RES nominal power capacities in the "top" scoring scenaria are entered into the code RES-INTEGR for performance evaluation through simulation. The final energy supply system is defined through an iterative process, that takes into account the existing energy demand and the expected energy production with RES, the supply and demand side management, as well as other variables - in order to meet the design requirements.
This code was developed for the project in concern. The performance of four locally available RES is simulated with RES-INTEGR using simplified performance models for each RES, namely:

- PV roof integration
- Biomass plants for thermal energy and Combined Heat and Power (CHP) production
- Small-hydro electricity generation plants
- Geothermal stations for thermal supply

The main simulation results provided by the code are:

- Energy delivered by the combination of RES systems
- Capacity factor of each RES
- Time series comparison between RES yield and load profile
- Excess energy production
- Levelized energy cost by each RES

3. PV ROOFS

Three options were available for the best technical and aesthetical integration of photovoltaics in the settlement.
1.Integration of photovoltaics on tilted roofs.
2.Integration of photovoltaics on metal grids connecting the houses of the settlement.
3.Integration of photovoltaics infront of buildings as shading devices and coverage of solar spaces.
A combination of the above three options was adopted in for the settlement. The photovoltaic modules will act as electricity generators, shading elements and linkage devices between the settlement houses.
A number of PV modules were assigned to each house type, as they are defined in the architectural designs.

All the available space offered by the architects on the houses' rooftops was covered with poly-crystalline silicon modules, of nominal power output of 51 Watts, at STC. The external dimensions of the selected modules are 44,5 cm by 99,5 cm. The frame of the modules is made of aluminum and in most of the cases, they will be placed on the metal supporting grid facing south at an inclination of 40 degrees, with respect to the horizontal. Except for the house type 5, where the inclination is 25 degrees and the orientation is 30 degrees southwest or 20,5 and 23,5 degrees southeast, according to the specific house location.

According to the architectural plans, there are 8 different building types to be constructed in the new settlement in Thrace. In volume 3, chapter 8 of the final report, all the house types with details about: the collection surfaces to be used, the number, type and electrical interconnection of modules, as well as the optimal operating current, voltage and power values fed to the suggested grid connected inverter of each individual house system, are presented. All the above information has been entered to a database (MS Access tables in the Appendix V, Vol.3 of JOULE project final report), where one has the option to select between various PV modules, electrical interconnections and the appropriate inverter type.

The electric energy produced from the PV roof systems is to be sold to the Public Power Corporation and each house should have each own inverter and energy measuring counter, in order to spread the benefits evenly between the inhabitants. The details for grid connected energy systems are governed and described by the Hellenic RES law 2244/94 and its regulations (in the form of presidential decrees). The energy production inequalities between houses, with regard to the installed peak power of the various PV systems, are unavoidable due to surface area variations. If the project policy is to equally divide the provided benefits, then there are other ways to achieve it.

The monthly energy from the grid-connected PV roof systems were calculated by taking into account the average system efficiency. Daily global insolation data on the inclined, were obtained from the statistical analysis between years 1966 and 1975 found in [2].

Two grid connected inverters have been selected due to their high measured performance, such as voltage stability, frequency stability, power factor, total harmonic distortions and low energy consumption in a stand-by status. The selected manufacturers are KRASCHNY which produces Solwex inverters and UFE which produces NEG inverters.

A survey of meters to measure the flow of electricity from PV systems into the grid, as well as the flow of electricity coming from the grid has been carried out. The final choice of an appropriate meter depends on the technical requirements of the utility.

4. RESULTS AND CONCLUSIONS

The integration methodology of RES systems at town level, designed so as to meet electrical and thermal loads of buildings and greenhouses has been reported in this paper. The energy design procedure takes into account bioclimatic, aesthetical, technical and social factors.

Preliminary results based on environmental factors and RES availability show that all electrical and a significant percentage of the thermal loads may be satisfied by RES in the Thrace settlement. The excessive electrical energy produced is sold to the Public Power Corporation for the benefit of the local community.

A general methodology that evaluates each RES has been developed. The Decision support Tool is based on a scoring system that takes into account weighing factors of beneficial and barrier aspects for each RES with respect to the other RES being considered. The scenario selection process is being used to identify scenaria for combined use of RES in order to satisfy a particular demand profile.

The code RES-INTEGR is then used to simulate the hourly operation of the systems on a year-round basis. In this way, the applicability and cost effectiveness of the proposed scenaria is evaluated using simplified performance models for each RES.

Despite all the impediments that legislative or other issues may impose in an integration plan of RES in the design of new settlements, the outcome of this project has created a new perspective in the concept of sustainability. The socio-economic benefit achieved from the installation of such energy systems, is an important factor that should be seriously considered. The profit made from the electric energy sales can be further invested in energy supply system applications and contribute in a financial and social development of the settlement (and the surrounding communities) and lead in sustainable rural communities.

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