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Large-scale integration of renewable energy sources an action plan for Crete

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This paper presents a general methodological framework for the formulation of an action plan for the large-scale integration of renewable energy sources (RES). The action plan is the output of a four-stage procedure: (a) identification and ranking of RES technologies according to various criteria, (b) formation of candidate sets of RES technologies that satisfy the goal of minimum interventions to the energy system and the balanced regional development through site selection rules of RES projects, (c) technical and economical analysis, and (d) social acceptance of the proposed action plan. The method is applied to the autonomous energy system of Crete and three alternative action plans are proposed.

Keywords: Energy policy; Renewable energy sources; Action plan

Introduction

Formulation and implementation of energy policies were until recently a central level decision-making process which considered only national priorities and needs. The basic guidelines, as dictated either by the Ministries of Energy or the various Energy Utilities, were the minimisation of energy cost under the constraint of a secured supply. All the energy policies adopted by governments after the two oil crises gave special emphasis on the utilisation of indigenous fossil fuels (such as coal, lignite and hydrocarbon fuels) and large hydropower units. As a result, the reduction of oil imports and the diversification of both energy suppliers and primary fuels mixture (eg with the introduction of natural gas into the energy systems of many countries such as Italy, Spain, Portugal and now Greece) have been achieved. Nonetheless, the resulted increase of environmental pollution, the hesitant progress of Renewable Energy Sources (RES) and the centralisation of the decision-making procedures have had negative impacts on the regional development.

It is now realised that this single approach is inadequate for handling contemporary complex energy problems. The implementation of an energy project has to satisfy not only the criterion of cost minimisation but also the need of environmental protection at a local and global level (eg reduction of CO_2 emissions).

A major change in the planned (or already introduced) liberalisation of the energy market is the entrance of private-owned production firms and the unbundling of vertical and/or horizontal monopolies. Current tendencies in energy planning favour (a) the competitiveness of the energy market through liberalisation and price transparency, (b) the security of supply through diversification of suppliers/fuels and interconnection of networks, and (c) the environmental protection by the introduction of new emission targets, environmental taxes and improvement of energy efficiency.

Renewable energy sources (RES) can considerably contribute to progress in this direction. The extensive and large-scale exploitation of RES satisfies the security of supply through the diversification of primary energy sources, the protection of the environment through the use of clean energy sources, and the competitiveness of the energy market through projects that can be implemented by private-owned firms and limited funding.

Investments on RES projects can also have a positive impact on unemployment and on regional development.

Despite its significant advantages, RES utilisation has a rather low contribution to the primary energy requirements in the majority of the EU countries. Although RES were extensively used for energy production in the previous century in Greece, their present-day share in final energy consumption is now minimal. The reasons for this are cost, technological difficulties, which make difficult the large-scale integration of RES with other conventional energy technologies as well as the inefficiencies of the existing legal framework. The restructuring of decision-making procedure and the formulation of an action plan will boost RES utilisation. (European Community, 1994; Nacfaire *et al*, 1993).

The objective of this paper is the development of a methodological framework for the formulation of alternative regional action plans for the large-scale penetration of RES. Action plans are formed on the basis of three objectives, that is the *minimisation of energy production cost*, *minimisation of environmental pollution* and the *provision of annual* (and maximum hourly) *energy supplies*. The proposed methodological framework is then applied to the autonomous energy system of Crete and three action plans are formulated to meet the final energy demand.

Methodological framework

The formulation of an action plan for the large-scale integration of RES is based on a four-stage iterative procedure (Figure 1) which is presented in the next paragraphs.

During the first stage, the most significant RES technologies are identified and ranked according to the maturity of RES technology, the cost of energy production and the RES potential. Answers to the following questions should be given:

1. What is the potential energy demand that can be satisfied by using RES?
2. What is the exploitable supply of RES?
3. Which RES technologies are currently available at a commercial level and can be economically used to satisfy the final energy demand?
4. Which are the most appropriate sites for the installation of a specific RES plant?

The most important criteria for the selection of a specific RES technology to be included in the candidate set are:

- RES technologies should be technically mature and economically viable not only with the current level of relative prices, but in the future, too.
- For the siting of RES projects, one should consider the spatial spread of the RES potential (taking into account the morphology of the ground, accessibility of the site, land uses, cost of land, etc.) and the consumption of energy at the urban centres (in order to minimise the transportation and distribution losses).
- Non-continuous availability of RES potential poses constraints on RES penetration into the maximum hourly production of electricity.
- Reliability and stability of the electrical system demands for appropriate interventions to the transportation network and improvement of the technical characteristics of the whole electrical system. These interventions should be planned in time in order to assure the maximum penetration of RES into the electricity production sector.
- Some pilot projects should be installed before the commercial exploitation of RES start in order to study the performance of RES plants under various conditions of energy demand, and the problems caused by integrating RES plants with conventional thermal plants.

The previous analysis determines the priorities for singling out the appropriate RES technologies and formulating an action plan, which will integrate RES technologies with existing conventional technologies of an energy system.

During the second stage, a candidate set of RES technologies is formed by selecting the appropriate sites for the RES projects which will (a) minimise energy production cost (b) minimise interventions into the existing energy system, and (c) maximise regional development.

The candidate set is formed both as an output of the first stage and as a requirement of combining various RES technologies to form an integrated energy system which will be able to overcome constraints posed by the variable and stochastic power production of RES (eg wind energy is available at random time periods and its massive exploitation in hours of minimum load or its non-existence in hours of maximum load pose serious problems to the management of the electricity system). The parallel use of pumping hydropower units with large storage tanks and wind farms may solve these problems and improve the operational characteristics of an electrical system. Wind farms can be used for pumping the water to the storage tanks in hours of minimum electricity load and the stored hydroelectric energy can be used to produce electricity in hours with maximum load.

During the third stage, a technical analysis of the proposed action plan is undertaken. The goal is to solve specific technical problems before integrating RES technologies with conventional technologies. The basic steps of the technical analysis are (see Figure 2):

1. Estimation of the maximum hourly electricity consumption.
2. Satisfaction of the maximum hourly electricity consumption.

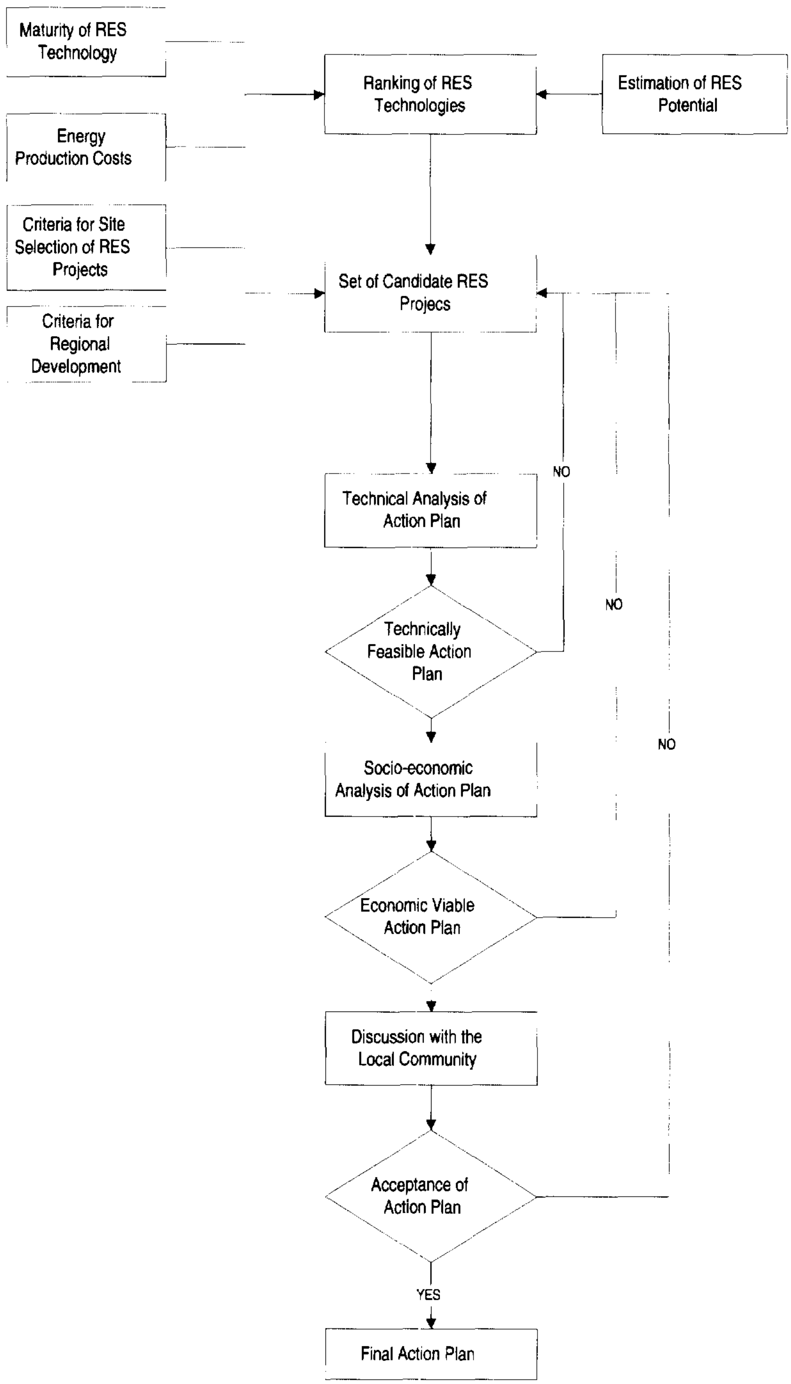

Figure 1 Flow chart of the methodological framework for the formulation of action plans

3. Estimation of the annual electricity consumption.
4. Satisfaction of annual electricity consumption.
5. Planning of the required interventions to the electrical system.
6. Combined satisfaction of annual and maximum hourly electricity consumption.

Satisfaction of energy demand on an annual basis is a first-priority goal of every energy plan. RES potential is usually abundant but technical constraints set limits to its exploitation. Simulation of the operation of the system should be undertaken at both steady state and unsteady state conditions. At steady state, the load flow is analysed for the whole transmission network. Active and reactive power of every transmission power line and of every transformation centre should be estimated and the ability of the transmission network to transport the extra load that the RES plants pose on the system should be examined. At unsteady-state conditions, the impacts on the frequency and the voltage of the system, caused by a sudden loss of a RES plant, are analysed. The objective is to assure the normal operation of the electrical system

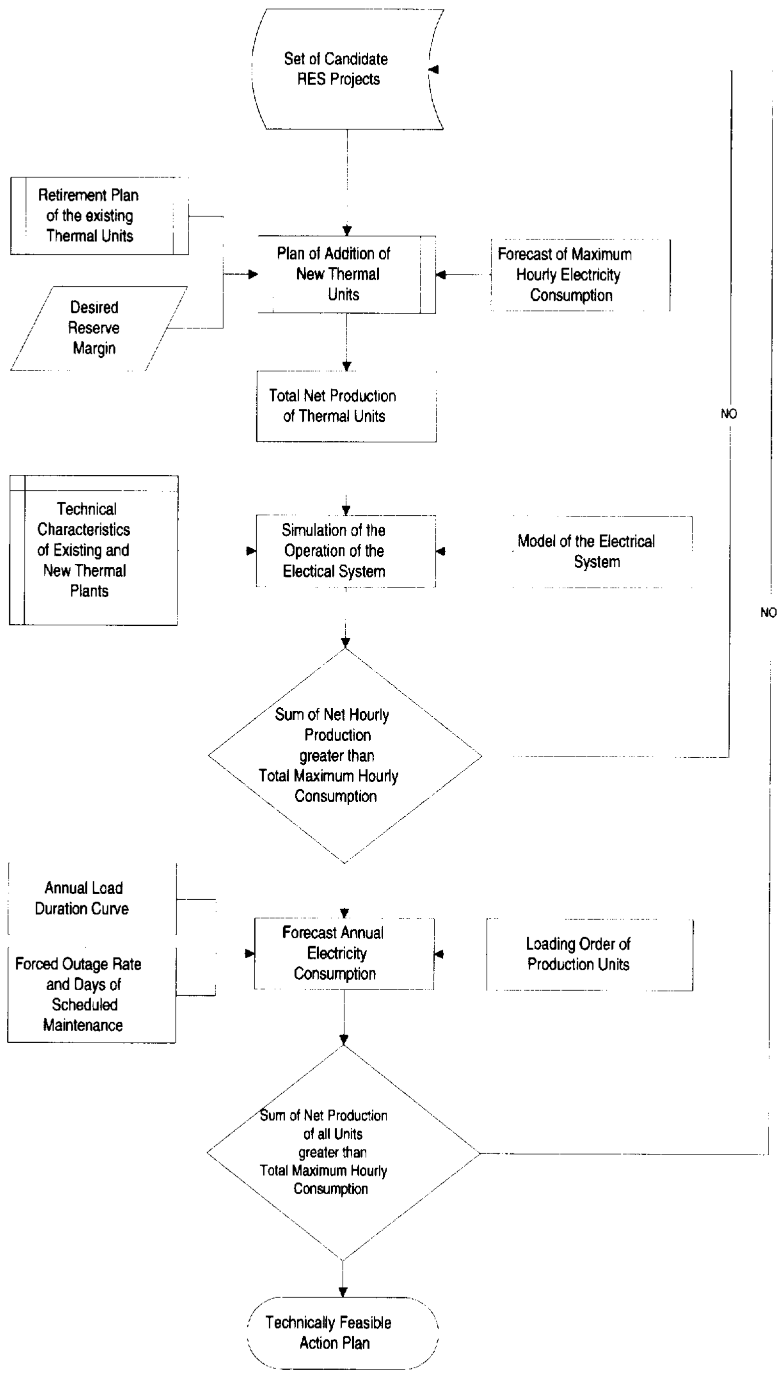

Figure 2 Flow chart of the technical analysis of action plans

and the continuous supply of electricity to final consumers.

By repetitively applying the six steps of the technical analysis, the candidate set is modified in order to include those RES technologies that can concurrently satisfy the annual and maximum hourly energy demand.

If the action plan is not technically feasible, the candidate set of RES technologies is changed and the technical analysis is repeated.

At this stage, an economic analysis is also applied to assure that the proposed action plan is economically viable. Investments in RES technologies improve general social welfare by internalising costs that are not taken into account by the analysis of economic factors (for example, the cost of protecting the environment).

During the fourth stage, an extensive dialogue with the local community will be implemented to ease the acceptance of the proposed action plan. A dialogue with the local authorities will affirm that the proposed action plan is in accordance with the priorities of the local community and fully accepted by the local investors and regional authorities who will be implementing the specific actions.

An important condition for the success of an action plan, which gives emphasis on RES technologies, is the analysis of the existing legal framework and the removal of the barriers that hinder the diffusion of these technologies. Being technically feasible, economically viable and socially acceptable, the action plan is transferred to the implementation phase. Otherwise, the candidate set is modified and another application of the procedure is considered.

The generality of the proposed methodological framework makes possible its applicability to every energy system either at the national or regional level. The European Commission financed the application of this methodological framework in the case of Crete, which is summarised in the following paragraphs.

Action plans for the integration of RES into the energy system of Crete

The current situation

The gross regional product of Crete has increased in the last ten years at a higher rate than that of the national average. The economic development of the island is based on tourism and, during the last decades, there was considerable urbanisation. The synergetic effects of these two phenomena resulted into an increased consumption of energy with rates higher than the average rates occurring for the national energy system.

A similar pattern applies in the case of electricity consumption. Figure 3 presents the trend of electricity consumption in Crete and on the mainland. The annual rate of increase of electricity consumption in Crete is equal to 9.2%, whereas the corresponding rate of increase in the case of the electrical system of the mainland is only 4.6%. The rate of increase of the maximum hourly electricity consumption in Crete is 7.5%.

Furthermore, the electrical system of Crete is autonomous and, as the island has no reserves of fossil fuels, its operation depends completely on oil imports from the mainland. Interconnection of the electrical system of Crete with the national grid faces serious technical problems (sea depths of more than 1200 m between Peloponesse and Crete and a fault seismic line northern of Crete).

RES can be considered as an alternative solution for the energy problem of Crete because:

1. There is a high exploitable potential of RES and there are currently many commercially available technologies to harvest this potential.
2. There is now an attractive legal framework regarding RES (Law 2244/94) in Greece and there are significant funds available to support RES projects (Community Support Framework).
3. There are many local investors seeking to invest on RES technologies (there is already one wind farm constructed in Crete and there are many applications for new wind farms of 200 MW in total).

The case of Crete, as regards its energy system, is a challenge for the formulation of an action plan that should be governed by technological, social and economic criteria. The proposed solutions have to (a) support high standards of living for the local population and tourists, (b) secure the supply of energy and (c) respect the international treaties that Greece has signed in order to lower its national emissions.

Application of the proposed methodological framework

The proposed methodological framework was used for the formulation of three action plans for RES integration

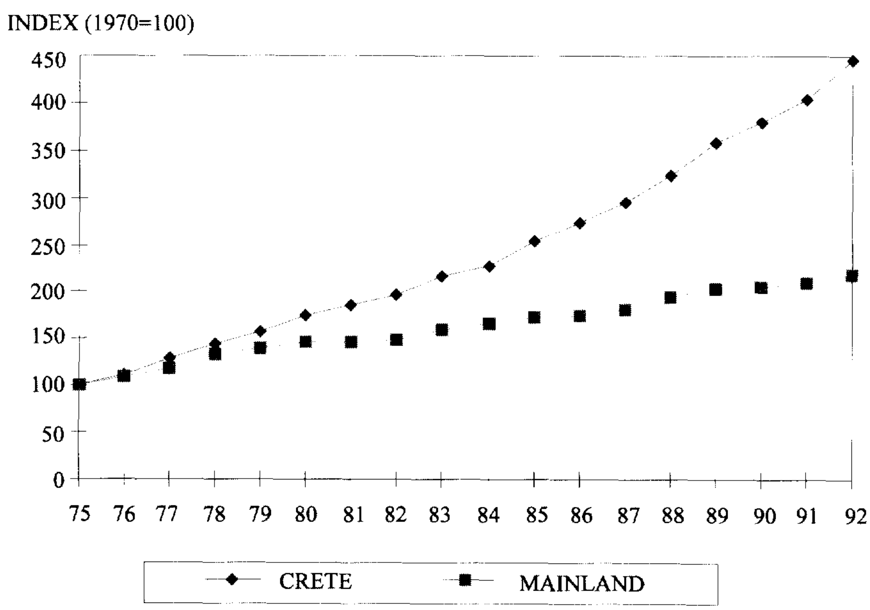

Figure 3 Electricity consumption of Crete and of the mainland's system

Table 1 **Potential of RES that is economically exploitable**

RES	Primary energy (GWh)	Installed capacity (MW)
Wind energy	1235	470
Small hydro-units	25	7.5
Pumping systems	500	300
Agricultural by-products	1455	175
Energy plantations	2715	330
Solar energy for electricity production	1165	100

into the energy system of Crete. At the first stage (identification and ranking of RES technologies), the potential supply of RES was estimated. Maturity of the existing RES technologies and the RES potential for Crete restrict the possible renewable energy sources to four candidates: (a) wind energy, (b) small hydro-units, (c) biomass energy, and (d) solar energy. Table 1 presents the economically exploitable potential as it was estimated in a detailed study of the energy system of Crete. (NTUA, 1996; Kyriakidis and Papadakis, 1992; Flagsol, 1995; Public Power Corporation, 1992; Vournas and Garyfallakis, 1989; Zervus *et al*, 1992).

At the second stage, a set of candidate RES technologies was formed. The most appropriate RES technologies in the case of Crete are: (a) wind farms, (b) small hydro units, (c) biomass plants using agricultural by-products and energy plantations, (d) solar-thermal stations for electricity production, (e) photovoltaic stations, and (f) pumping hydro units. These RES technologies have been selected according to their maturity, the cost of energy production and the morphology of the island for the installation of the RES projects.

For the site selection of the RES projects, precise site-rejection rules have been used, such as proximity to archaeological sites, military areas or cultivated zones, sharp change of altitude, etceteras. The most important criteria for the distribution of RES projects over the island were: (a) the high RES potential, (b) the uniform distribution of the sites all over the island in order to achieve an even development of the regions, (c) the minimisation of interventions to the electrical system, and (d) the minimisation of transmission losses. Figure 4 presents the proposed sites for the installation of RES projects in Crete.

At the third stage, a technical analysis of the candidate set was undertaken. The first step, was to forecast annual net electricity production on the basis of simple logistic models. Figure 5 depicts the trend of the net electricity production in Crete. Furthermore, an estimation of the maximum and minimum hourly net electricity production was attempted based on the estimation of the annual net electricity production and the expected load factor trend (assuming that specific demand-side management techniques will increase its value from 55 to 60%), Fig. 6.

The scheduling of the new production units to satisfy maximum hourly electricity demand and the plan for the withdrawal of existing thermal units was carried out in the next step. Emphasis was given on the use of RES technologies whenever this was possible because of their environmental advantages and the significant decentralisation of the electrical system that is achieved through the use of many scattered production units (a decentralised versus a centralised production system offers many advantages, such as lower transportation costs, more security of supply, and higher reliability).

The rule for the installation of a new production unit is that the sum of the net summer hourly production of all the production units should be greater than the maximum hourly electricity demand plus a reserve margin. This margin is taken equal to 20% and is covered by thermal units that are kept in cool reserve in order to handle emergencies (such as unscheduled maintenance of other units, problems with the transportation grid, etc.).

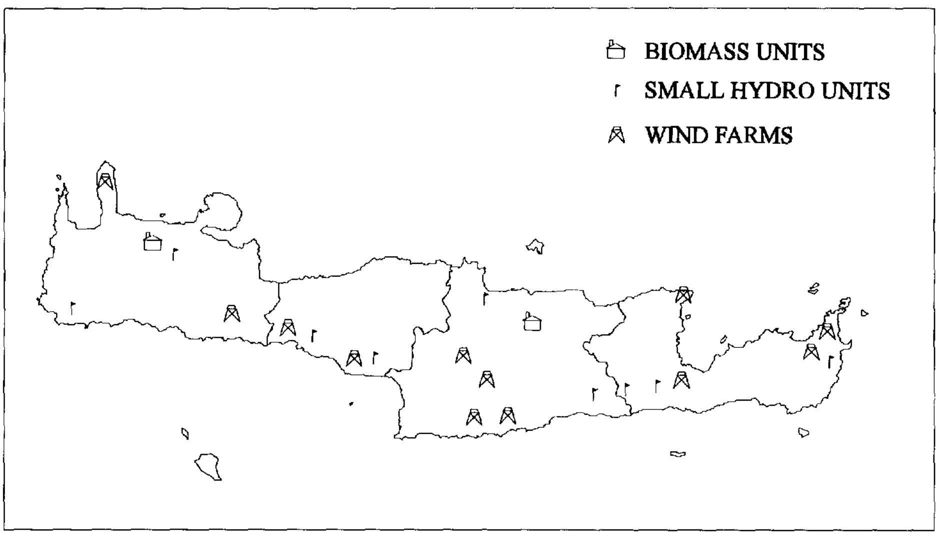

Figure 4 Sites of Renewable Energy Sources plants in Crete

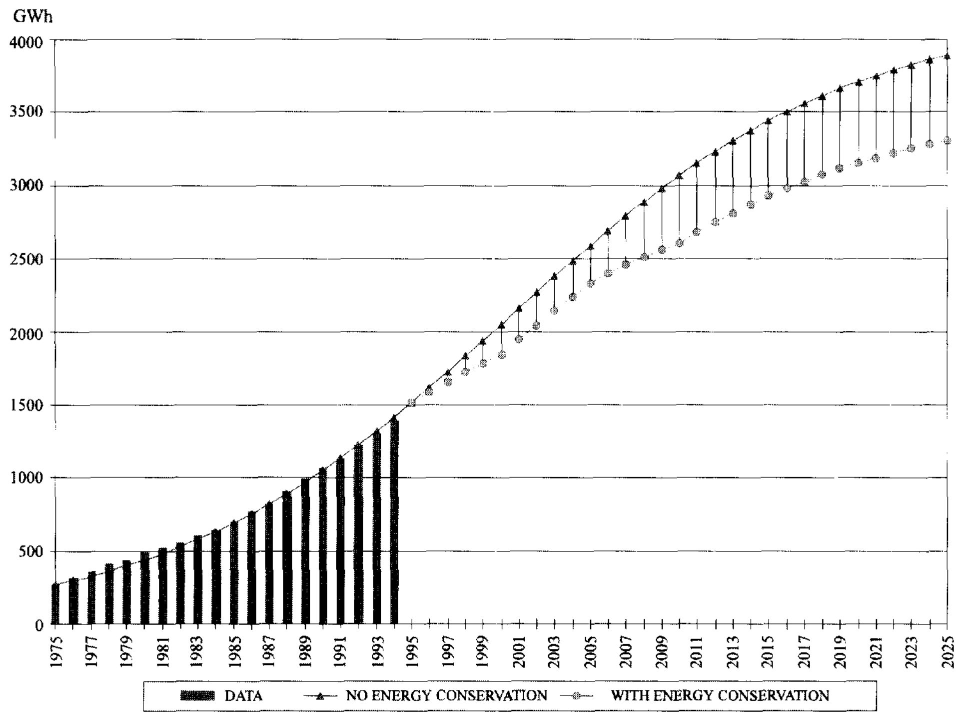

Figure 5 Forecast of electricity net production in Crete

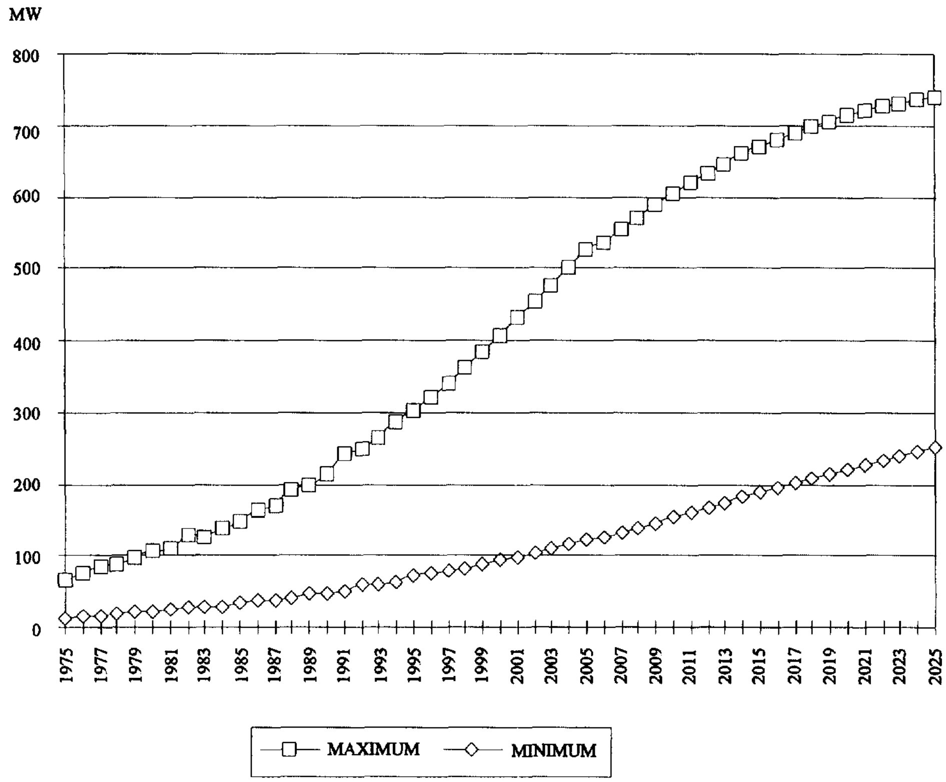

Figure 6 Forecast of maximum and minimum hourly net production of electricity in Crete

It is worth mentioning that the maximum hourly electricity demand occurs during summer (due to the significant increase of tourists; more than 2 million tourists visit Crete in summer) and that the total net electricity production is lower during summer due to the extensive use of gas turbines. For the above reasons, the technical analysis of the electrical system of Crete is performed for the summer period.

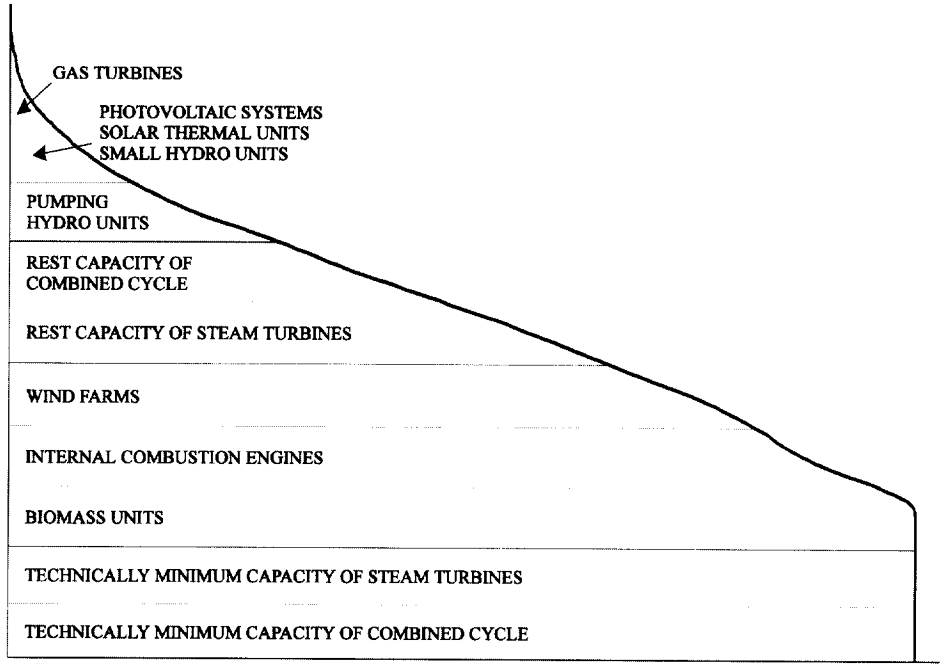

Figure 7 Disposal of the electricity production units under the load–duration curve

Figure 7 presents the order in which the production units are used to satisfy the electricity demand. Conventional thermal units operate at their technical minimum capacity (conventional thermal units cannot be shut down and turned back on after a few minutes; therefore they are always left operating on minimum capacity to avoid their fast obsolesce). Then, biomass units and internal combustion units are used. Wind farms are used to meet intermediate loads, whereas the remaining capacity of the conventional thermal units is used to cover intermediate loads. Finally, pumping hydro units, solar-thermal plants, photovoltaic systems and gas turbines are used to cover peak loads.

Technical analysis highlights the problems that have to be solved in order to integrate RES technologies with conventional thermal units, that is (a) the need for a pumping hydro-power unit to handle situations of maximum production by RES units and minimum electricity demand, (b) the required interventions in the electrical system, and (c) the formation of standards for wind engines so that they can operate even with significant reductions of the frequency of the system (the majority of the wind farms are asynchronous and they are aroused by the electrical system; a significant reduction of the frequency of the system will not sustain the operation of the wind engines and, therefore, a black-out is possible). Simulation of the operation of the electrical system of Crete is done by using a special model, developed for the case of Crete, which provides the load flow (steady-state analysis) and the frequency and voltage of the electrical system (unsteady-state analysis).

The technical analysis of the electrical system of Crete is used to modify the candidate set of RES technologies. The sum of the net electricity production of all the units must simultaneously satisfy the annual electricity consumption and the maximum hourly electricity consumption. This requirement, together with the potential supply of RES, suggests the combination of new RES production units that should be installed and their respective capacity. The combined analysis of the energy and power demand is handled through a deterministic model, developed for the case of Crete, which simulates the operation of the electrical system and provides the electricity production and fuel consumption of each unit.

Description of the three proposed action plans for the integration of RES into the energy system of Crete is given in the next paragraphs. (NTUA, 1996). Economical analysis of the action plans shows that the proposed action plans are economically viable. At the last stage, a dialogue with the local authorities indicated that the three action plans are also socially accepted.

It should be mentioned that for the three action plans examined, some energy conservation measures are also proposed to increase the load factor of the electrical system from 55 to 60% (NTUA, 1996). The use of solar boilers for hot water production can reduce electricity consumption, as Crete has significant solar radiation all over the year. Photovoltaics on buildings for electricity production and bioclimatic design of the buildings themselves can significantly reduce annual and maximum hourly electricity consumption. Furthermore, significant reduction of maximum hourly electricity demand can be achieved through: (a) the use of technological applications (use of ice-banks at hotels and replacement of inefficient incandescent bulbs with new energy-efficient fluorescent bulbs), and (b) the application of a new

Table 2 Satisfaction of the annual net production of electricity by adopting the RES-intensive exploitation scenario

	1995		2000		2005		2025	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Existing thermal stations	404	1470	524	1422	524	1238	524	931
New thermal stations								
Wind farms	7	6	77	200	207	511	407	985
Biomass plants			30	184	60	370	120	744
Small hydro-units			2	9	6	26	6	26
Solar-thermal stations							50	82
Photovoltaic stations							50	52
Pumping systems					125	225	300	490
Non-interruptible units	404	1470	556	1615	715	1859	950	2191
Interruptible units	7	6	77	200	207	511	507	1119
Total	411	1476	633	1815	922	2370	1457	3310

pricing policy with which the consumer will be charged more during peak hours and less during off-peak hours throughout the day.

Scenario of RES-intensive exploitation

The *RES-intensive exploitation* scenario aims at the maximum penetration of RES into the electrical system of Crete. Under this scenario, all the new electricity demand after 1995 will be satisfied by RES electricity. No new conventional thermal unit will be required after 1995. Satisfaction of maximum hourly electricity demand will be achieved using biomass plants and pumping-storage-hydro units.

Under this scenario, two biomass plants is proposed to be installed after 1995. These units would burn agricultural by-products to produce electricity. By the year 2025, the installed capacity of the two units would reach the 120 MW (using also energy-intensive crops). Biomass units are used to satisfy base loads. In order to satisfy the rest of the base loads, it is proposed to install pumping-storage-hydro units. In the year 2005 the installed capacity of these units is estimated to reach 125 MW whereas in the year 2025 it will reach the level of 300 MW (this is the maximum capacity of pumping-storage-hydro units that can be installed in Crete). The installed biomass units and pumping-storage-hydro units can satisfy the additional maximum hourly electricity demand up to the year 2025 and, therefore, the installation of a new conventional thermal unit can be avoided. Installation of the pumping storage hydro units is vital for the operation of the electrical system of Crete because these units can transform the variable production of wind farms (due to the stochastic nature of wind energy) to a uniform production at pre-selected hours of operation (usually at peak demand).

On the island the potential of small hydro units is limited. Up to the year 2025, it is estimated that only 6 MW of small-hydro units can be installed. The installed capacity of wind farms can reach the level of 77 MW in the year 2000 and the 207 MW in the year 2005 (7 MW have been already installed at Toplou Abbey). This capacity, together with the production of the biomass plants, the small-hydro units and the pumping-storage-hydro units, is adequate to meet the additional annual electricity demand after 1995. In the year 2025, the installed capacity of wind farms can be doubled and reach the level of 407 MW. Such a high penetration of wind energy will not pose any problem to the electrical system of Crete due to the existence of the pumping-storage-hydro units. Finally, it is estimated that a solar thermal unit and a photovoltaic unit will be installed after the year 2005 with 50 MW capacity each (the capacity of these two units is related by the exploitable potential of the corresponding RES). Table 2 and Figure 8 present the production units for the satisfaction of both annual and maximum hourly electricity demand of the RES-intensive exploitation scenario.

Scenario of RES-constrained exploitation

The *RES-constrained exploitation* scenario aims at the optimum penetration of RES, taking into account technological and financial constraints. The share of the additional electricity consumption that is covered by RES is equal to 60%. Under this scenario, it is estimated that a new conventional thermal station should be installed to contribute to the maximum hourly electricity demand. This station will have two steam turbine units of 60 MW each and two internal combustion units of 20 MW each (total installed capacity of 160 MW).

The extra maximum hourly electricity demand will be satisfied by a new pumping-storage-hydro unit to be installed after 2005 with a total capacity of 250 MW. Additionally, two biomass plants, using agricultural by-products, are to be installed after 1995. In the year 2025, the installed capacity of the two units would reach the 60 MW.

In the year 2025, it is estimated that only 6 MW of small-hydro units can be installed. The installed capacity

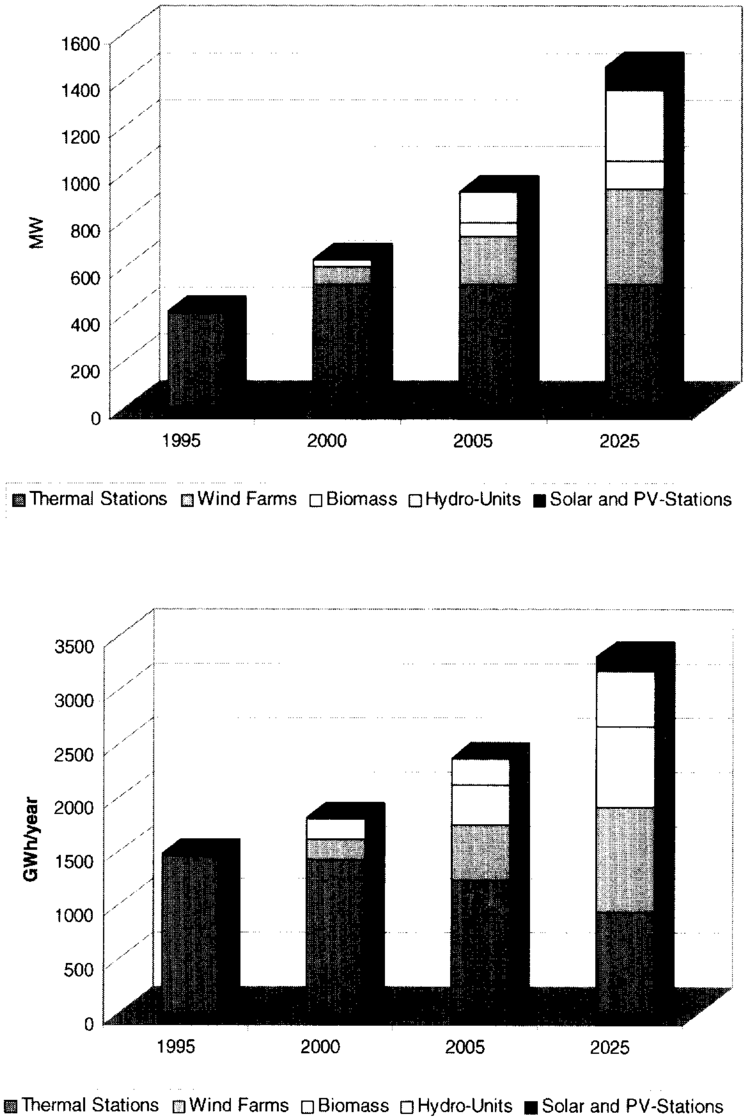

Figure 8 Satisfaction of annually and maximum hourly electricity production under the scenario of RES-intensive exploitation

Table 3 Satisfaction of the annual net production of electricity by adopting the RES constrained exploitation scenario

	1995		2000		2005		2025	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Existing thermal stations	404	1470	524	1299	524	1090	524	904
New thermal stations			40	270	160	705	160	780
Wind farms	7	6	57	145	157	372	307	750
Biomass plants			15	92	30	177	60	368
Small hydro-units			2	9	6	26	6	26
Solar-thermal stations							30	45
Photovoltaic stations							25	22
Pumping systems							250	415
Non-interruptible units	404	1470	581	1670	715	1998	1000	2463
Interruptible units	7	6	57	145	157	372	362	847
Total	411	1476	638	1815	922	2370	1362	3310

of wind farms could reach the level of 307 MW in the year 2025. Table 3 and Figure 9 present the production units needed to meet both annual and maximum hourly electricity demand of the RES-constrained exploitation scenario.

Scenario of RES-limited exploitation

The most important difference between the *RES-limited exploitation* and the *RES-constrained exploitation*

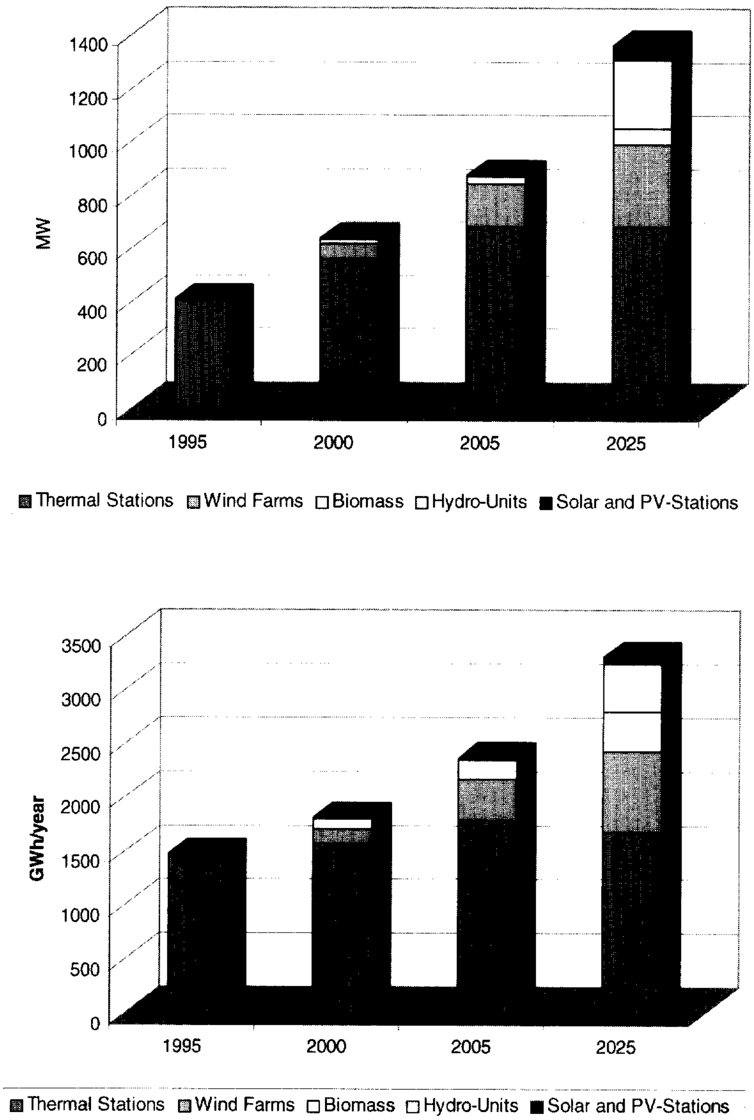

Figure 9 Satisfaction of annually and maximum hourly electricity production under the scenario of RES-constrained exploitation

Table 4 Satisfaction of the annual net production of electricity by adopting the RES-limited exploitation scenario

	1995		2000		2005		2025	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Existing thermal stations	404	1470	524	1299	524	1090	524	991
New thermal stations			40	270	160	705	410	1473
Wind farms	7	6	57	145	157	372	167	385
Biomass plants			15	92	30	177	60	368
Small hydro-units			2	9	6	26	6	26
Solar-thermal stations							30	45
Photovoltaic stations							25	22
Pumping stations								
Non-interruptible units	404	1470	581	1670	715	1998	1000	2858
Interruptible units	7	6	57	145	157	372	222	452
Total	411	1476	638	1815	872	2370	1222	3310

scenario is the installation of a second thermal power station instead of a pumping-storage-hydro unit. Furthermore, due to the absence of the pumping-storage-hydro unit, the installed capacity of wind farms can only reach the level of 167 MW in the year 2025. The maximum installable capacity of wind farms is constrained by the stability consideration of the electrical system (the installed capacity of all the interruptible units should not

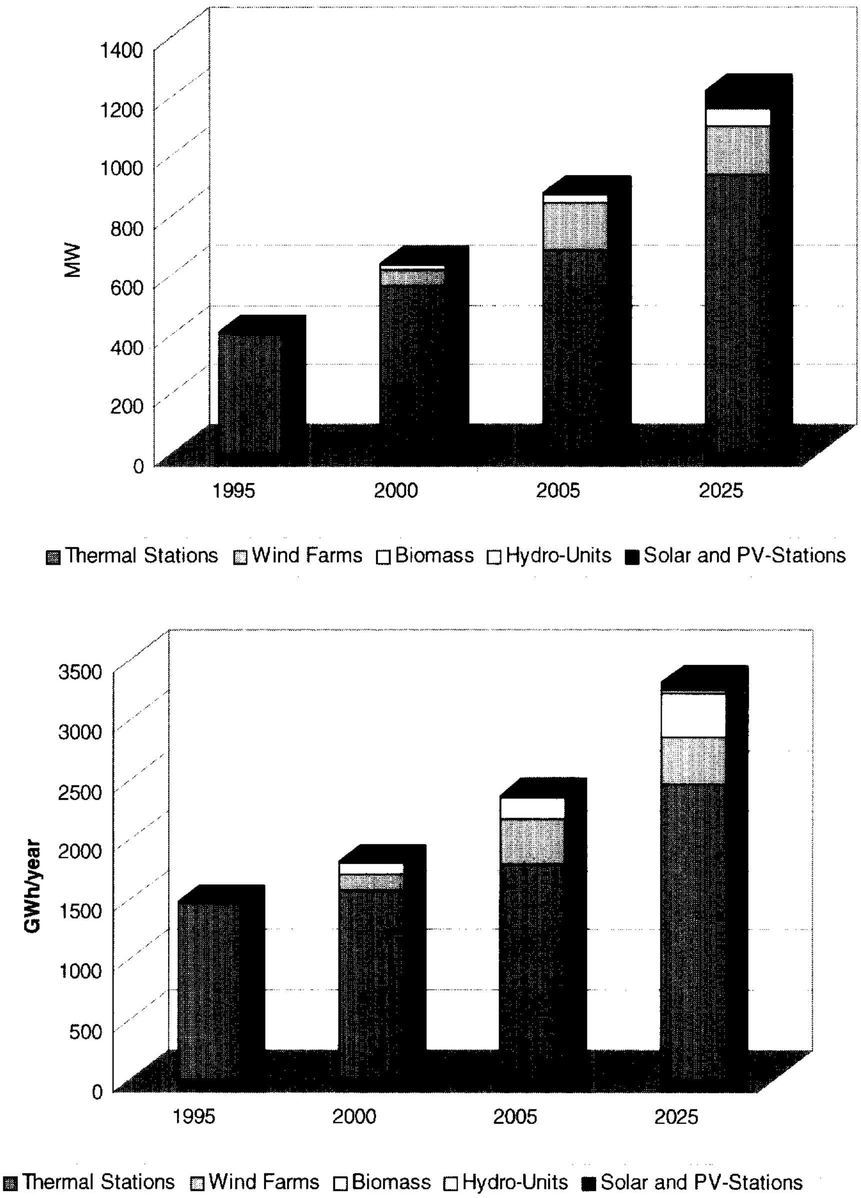

Figure 10 Satisfaction of annually and maximum hourly electricity production under the scenario of RES-limited exploitation

exceed the 30% of the maximum hourly electricity consumption occurred in the previous year). Table 4 and Figure 10 presents the necessary production units to meet both annual and maximum hourly electricity consumption in the RES-limited exploitation scenario.

Socio-economic analysis of action plans

A cost–benefit analysis of the three proposed action plans is attempted by using socio–economic criteria. The use of RES technologies for electricity production and electricity substitution for residential uses is compared to the use of fossil fuels (mainly fuel oil and diesel oil) for electricity production. Furthermore, the social benefit that is achieved through the avoidance of pollution reducing technologies is also incorporated in the analysis.

Figure 11 depicts the results of the analysis. The internal rate of return, in the case of the RES-intensive exploitation scenario, is equal to 9%, whereas in the case of the RES-constrained exploitation scenario is 12%. It is worth-noticing that with a discount rate of 6% the two scenarios yield the same results. By adopting a discount rate smaller than 6%, the RES-intensive exploitation scenario is preferred, whereas with a larger discount rate, the RES-constrained exploitation scenario is most favourable.

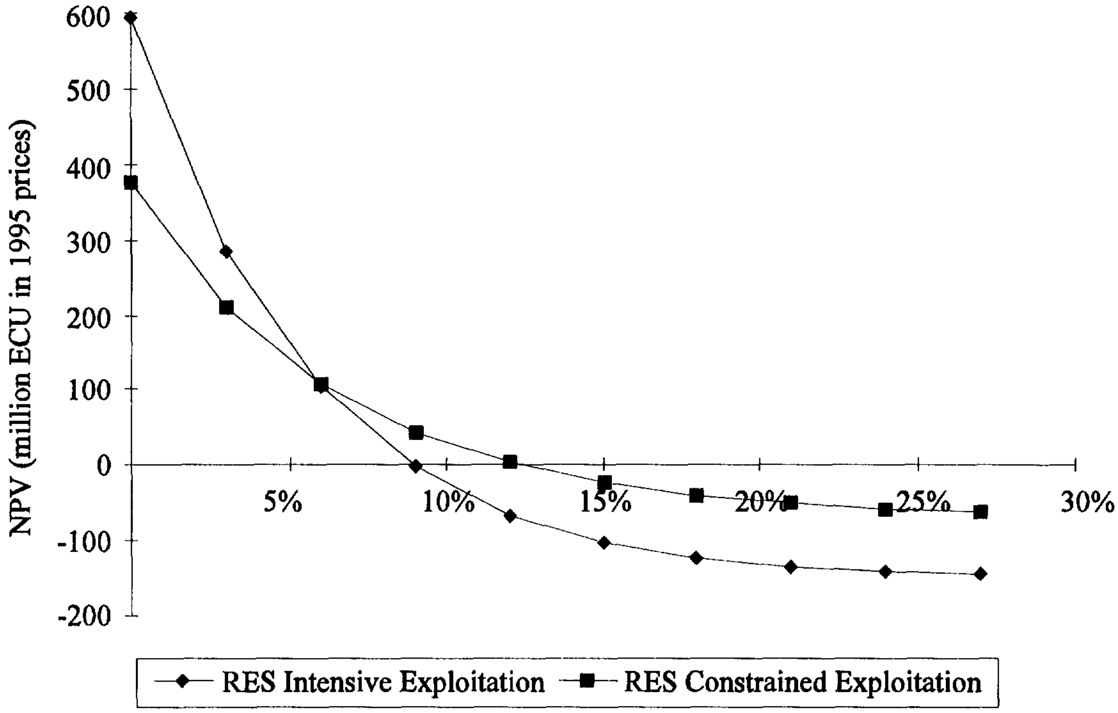

Figure 11 Results of the socio-economic analysis

Conclusions

A large-scale introduction of RES technologies into an energy system should be based on an energy policy different to that adopted up to now. Priorities should be given to technologies that both reduce the impacts of energy use on the environment and increase the participation of regional authorities in the decision-making procedures.

This paper presented a methodological framework for the formulation of action plans to integrate RES technologies with conventional technologies present in any energy system. An important step in the application of the methodological approach is the specification of ranking criteria for the RES technologies that must reflect the priorities of the local community. An action plan is formulated by following a procedure of four single stages, the most critical being technical analysis. At this stage, it is required that the proposed action plan simultaneously satisfies annual and maximum hourly energy demand. At this stage, various RES technologies are combined in order to eliminate the problem of stochastic energy production that characterises some forms of RES (eg wind energy).

This methodological framework has been applied in the case of the energy system of Crete. Three different action plans have been formulated which differ in the degree of penetration of RES technologies to the electrical system of Crete. Socio-economic analysis of the action plans proved that all three plans are economically viable and they increase the social welfare of the local community. Technical analysis identified some problems that have to be overcome for the safe integration of RES technologies with the electrical system of Crete (eg specification of standards for wind engines, interventions into the electrical system, etc.). Finally, the extensive dialogue with the local community showed that there is a strong interest from investors and a good investment environment.

References

EUREC (1996) *Renewable Energy for Europe.* EUREC Agency Position Papers, Executive Summary.

European Community (1994), *The European Renewable Energy Study: Main Report.* EC, Luxembourg.

Nacfaire *et al* (1993) *An Overview of the Status and Potential of RE Sources in the European Community.* World Summit, Paris.

National Technical University of Athens (NTUA) (1996) *Developing Decision-Making Support Tools for the Utilization of Renewable Energies in Integrated Systems at the Local Level.* DG-XVII, Athens.

Kyriakidis, S and Papadakis, M (eds) (1992) *General Management Plan For the Forest Related Development of the Department of Chania.* Forest Service of the Department of Chania (in Greek).

Flagsol (1995) *Preliminary Study for Solar-Thermal Unit in Greece.* Development Agency of Western Crete.

Public Power Corporation, Department of Exploitation and Transportation (1992) *Administration for Engineering Construction of H.E.P. Service for Preliminary Designs and Investigations: Reconnaissance Report.* Crete.

Vournas, C and Garyfallakis, S (1989) *Wind Farm Generation Loss Analysis for the Electric Grid of Crete.* EWEC, Glasgow Scotland.

Zervos, A, Rados, C and Voutsinas, S (1992) Application of the w.p.-opt code to the optimal design of a wind park of 17 300 kW machines in Crete Island', *Proc EWEA, Special Topic Conf.*, Denmark.