What role for renewable energy systems in domestic energy use? Meeting the demands of the Mediterranean islands.

Buildings are the most energy-consuming sector, while at the same time they offer a great potential for the application of energy efficiency techniques and technologies. The environmental challenges that buildings currently face call for immediate action and particularly those, which are located in insular communities, are the most vulnerable ones. Therefore, the introduction of the appropriate sustainable energy systems to the insular communities through the exploitation of the local natural energy resources can contribute to face local environmental and global warming issues, the security of energy supply and volatile energy prices, achieving a stable, self-sufficient and sustainable development (EC 2009).

This paper is a part of a study, whose aim is to assess the transformation of the conventional energy supply system of the building and transport sectors of a Greek island to a sustainable system of zero emissions (Chatzivasileiadi 2011). However this paper basically focuses on the part related to the household sector. The research work has produced a methodology that allows us to produce results suggesting the most efficient and advantageous renewable energy technologies, distributed or centralized, or a combination between them.

The investigation is carried out for Ios island in the Cyclades complex. Electricity demand, space heating and cooling loads and domestic hot water needs are estimated for a baseline and a sustainable future scenario in the medium term. In the first scenario, the "business as usual" approach is taken into consideration. In the other scenario, renewable energy sources are introduced to power the building sector, while energy efficient techniques and technologies are applied there.

The first step of the research is to assess the energy demands over the year for the household sector of Ios in the next 10 years, transforming it from oil-based to RES based. Then, the potential renewable energy technologies to meet the demands are investigated and the most advantageous ones for each type of use are selected. The paper carries on with the brief presentation of the results extracted from the simulations regarding the design of a RES energy system, focusing on the application of PVs in the household sector. Storage and demand-side management techniques are also briefly discussed.

Electricity based on oil is currently the main energy carrier of Ios and is associated with buildings, while oil has a small direct contribution mainly for space heating in winter. Solar, wind and biomass, currently provide a small contribution to the island's energy needs. Although solar energy is abundant and well-corresponding to the energy demands, only a small part of the DHW needs and space heating are covered by solar thermal collectors and biomass correspondingly. A part of the electricity demand on the island, about 18%, is covered by wind energy at present, while no electricity is generated by solar PV. Electricity presents high demands in summer for the building sector with a peak demand of about 7MW in the middle of August and a total annual demand of 18GWh for 2010. Especially for the household sector, the total annual demand for 2010 is 5,396 MWh.

Due to the high potential for energy savings in buildings, the methodology used in this research study assumes improvements in domestic energy use of at least 25% in the medium term. This figure relates to measures applied to the buildings' envelope, the introduction of energy efficient appliances and the adoption of a sustainable behaviour by the locals. In addition, an increase in energy demand of about 26% above the figures of 2010 is assumed to occur over the 10-year period (Katsikeas and Dimeas 2011).

Space heating and cooling demands during the year are assumed to be covered by using electrically driven GSHP or WSHP in the coastal areas with COP>4 (IEA 2011), instead of oil. Solar collectors will be used for the preparation of DHW with a small contribution by heat pumps for some days in winter. The estimated figures for energy demand in the household sector are presented in Figure 1.

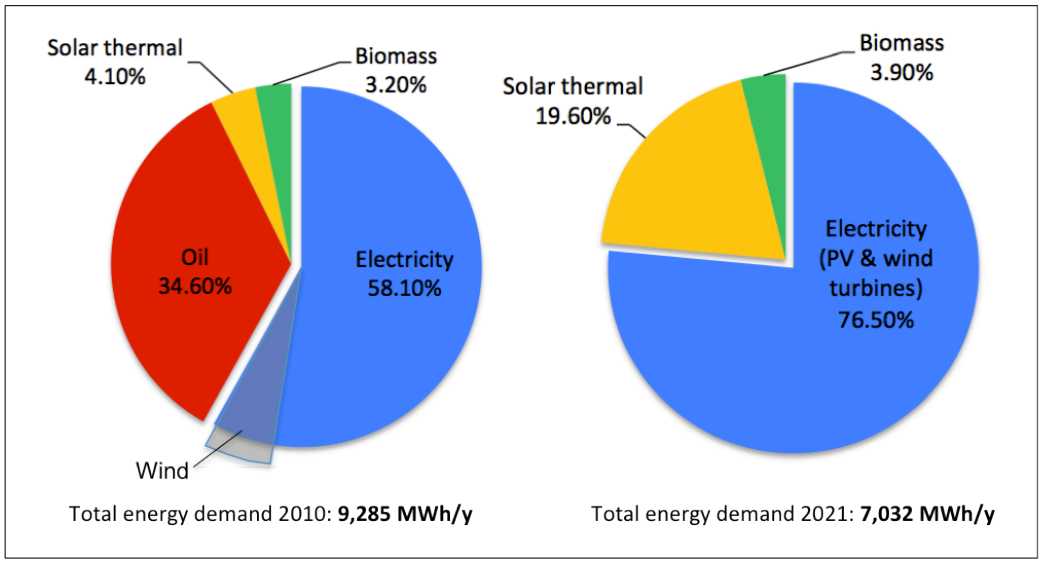

Figure 1: Energy consumption by energy carriers in 2010 and 2021 (100% RES) for the household sector in Ios island. In the baseline scenario the energy consumption is estimated to 11,700 MWh/y with the same structure as in 2010.

The abundant solar radiation in Greece is a really motivating factor for solar energy exploitation through solar thermal collectors and solar PV. Solar thermal collectors constitute a simple, direct and inexpensive technology for DHW production, providing high efficiency, reliability and a rather rational use of the energy source (IEA 2011). Regarding GSHP, their introduction for space heating and cooling constitutes a highly sustainable approach. GSHP could also contribute in supplementary heat production during some cloudy winter days for DHW production. As regards electricity generation, solar and wind are rather complementary energy sources, so a combination of both seems to be beneficial in terms of generating electricity on a 24-hour basis over the year.

Based on the above, advanced GSHP or WSHP powered by RES electricity are assumed to be used for residences' space heating and cooling, while solar thermal collectors are assumed to be covering nearly 100% of the energy demand for DHW. The introduction of such systems will result to a significant reduction of the energy

consumption, without affecting the comfort level of the users. A small contribution from biomass will continue.

In the electricity sector, the exploration was performed considering the overall building and transport sectors through the use of linear programming (Dantzig and Thapa 2003), with the aid of a software tool developed in Excel (Chatzivasileiadi 2011). The criteria under which the optimization was performed are the total minimum installed capacity, storage losses of 10%, the minimum surplus energy, the annual capacity factor of the system and the specific power generation per kW installed. The optimization was a three-stage process and the final results suggested that the solar PV installed capacity should be 12,114kWp (77%), while the wind installed capacity should be 3,628kW (23%).

The arrangement of the systems takes into account technical, social, economic, environmental and aesthetic parameters. The PV modules are distributed in dispersed PV systems in the urban environment and three centralised plants. This will result to higher reliability and lower aesthetic impact. As regards the residential buildings, considering the special conditions of the traditional settlements and the percentage of the owners who would be interested in installing RES systems on their houses, a capacity of 1,440kWp in 360 households is estimated for integration by 2021.This capacity constitutes about 12% of the total installed capacity projected for the island. The color of the PV modules and the supporting structures is suggested to be cobalt blue, like the color of the window frames, the shutters, the doors of the buildings and the sea. Thus, polycrystalline silicon PV modules are suggested.

Distributed storage with batteries in each household or by using the battery pack of the electric cars (Emandi 2011), and a central storage of advanced technology -chemical or pump storage- seems to be the best combination for the electricity system. The flexibility of demand and advanced control strategies for the management of the system, as well as the introduction of weather forecasting models are considered.

The undertaken research achieves the goal of establishing sustainability through the introduction of RES in an island of the Mediterranean in a very focused manner. The household sector is highly addressed, as actions within this sector can raise social awareness and alert the local community.

References

Chatzivasileiadi, A. 2011. *Distributed or centralized energy systems? Towards sustainable development of the islands.* MSc Thesis, Cardiff University.

Dantzig, G.B. and Thapa, M.N. 2003. *Linear Programming 2: Theory and Extensions*. New York: Springer.

Emandi, A. 2011. *Transportation 2.0.* IEEE/Power&Energy magazine vol. 9 (4), pp. 18-29.

European Commission (EC) 2009. *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of RES.*

International Energy Agency (IEA) 2011. *Technology roadmap. Energy efficient buildings: heating and cooling equipment*. Paris, France: IEA Publications.

Katsikeas, P. and Dimeas, A. 2011. Data provided by the Public Power Corporation, Greece.