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Research Article

The Renewable Energy Potential of the Maltese Islands

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Summary. *The potential of renewable energies is presented for the territory of the Republic of Malta. These are in the main sun, wind and biogas. Taking the base year 2003 for comparing the percentage contribution of electricity generated from renewables to that generated from fossil-fuelled power stations, it was found that rooftop solar photovoltaic systems could produce 9.1%, onshore wind farms could offset 5.4% and the offshore wind potential lies in the region of 3.4%. Energy from waste could contribute another 5.6%, while widespread solar water heating in domestic buildings could offset 4.8%. Economic analysis of applying renewable energy power systems under the present constraints is carried out. A range of barriers to the use of renewable energy devices is described. The currently available incentives are listed and a number of measures that could be implemented to allow widespread applications of renewable energies are suggested*

Keywords: *renewable energy, potential, widespread, barriers, incentives, islands.*

The Solar Potential

Since 1993, solar radiation has been continuously monitored at the Institute for Energy Technology (IET) of the University of Malta. This is the only site in Malta that is currently operating in this field; but the only long term data available is that taken by the Royal Air Force at Qrendi over the period 1958-1972.

Figure 1 shows the mean daily global horizontal solar radiation for each month over Malta in kWh/m²/day. It is clear that the peak radiation occurs in summer and reaches a maximum of almost 8 kWh/m²/day, while in winter it drops to a minimum of 2.5 kWh/m²/day. This data compares favourably with other sites around the Mediterranean region and southern Europe (Palz 1984, Yousif 2005).

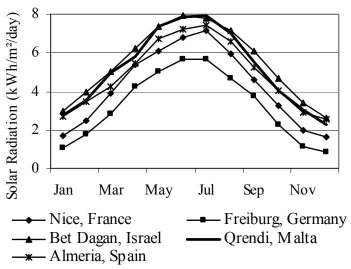

Figure 1: Long term mean daily global horizontal solar radiation for different sites in southern Europe and the Mediterranean.

Several studies on solar radiation potential in Malta have been carried out (Akiwale 2003 and Scerri 1982). A summary description of the weather conditions is shown in Table 1 (Akiwale 2003) where,

G = Global horizontal solar radiation;
H_0 = Extraterrestrial radiation;
G/H_0 = Clearness Index.

Sky Description	Range	Occurrence (%)
Cloudy	$G/H_0<0.2$	2.9
Partly Cloudy	$0.2<G/H_0<0.6$	34.5
Clear	$0.6<G/H_0<0.75$	61.9
Very Clear	$G/H_0>0.75$	0.7

Table 1: Summary description of the Clearness Index of the sky conditions over Malta.

It follows that more than 62% of the year enjoys an abundance of sunshine, while only 11 days (3%) may be considered as very cloudy days.

Performance Of Solar Photovoltaic (PV) Systems

Since 1996, IET has carried out performance tests on a number of grid-connected solar photovoltaic (PV) systems. One of the main conclusions reached was that a typical stationary grid-connected PV array, inclined at 30° to the horizontal and facing the true geographic

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South would produce a daily mean electric output of 3.6 kWh/kWp of solar module capacity (Ribeiro, Yousif 2004).

Potential Of Power Generation From Grid-Connected PV Systems

The fact that Malta enjoys an abundance of sunshine and mild temperatures, coupled with other factors such as the existence of flat roofs as the standard way of building and the recent trend of increased power consumption in summer due to air conditioning, all favour the application of solar photovoltaics on a wide scale.

In order to reach a realistic assessment that reflects the potential of solar PV applications, one has to appreciate the fact the solar PV systems would ideally be decentralised rather than large ground-based systems, due to the scarcity of suitable land. Hence, one would consider the availability of rooftop areas in domestic, industrial and public buildings. The commercial sector in Malta may be excluded, as most of the establishments do not have their own rooftop. There is also some potential for façade cladding and building integration of photovoltaics, but this could not be quantified at this stage.

a. Domestic Buildings

The categories of local households as identified in 2003 are given in Table 2 (National Statistics Office 2005).

The *effective* number of dwellings that may be considered as providing roof space for installing PV systems is also included in the Table based on the following facts and constraints:

- Terraced, semi-detached, fully detached and farm houses as well as maisonettes would have a factor of 1 for calculating their effective rooftop availability;
- Ground floor tenement may have a factor of 0.5 as these dwellings may or may not have other floors on top of them;
- Apartments/Flats are on average built in blocks of 3 storeys. Hence, a factor of 0.3 may be applied for the effective rooftop area;
- Other parameters that could affect the availability of roof space for the installation of photovoltaic systems may be summarised as follows:
    - Use of solar water heating systems;
    - Satellite dishes and television antennas;
    - Water storage tanks;
    - Unusable areas due to shading.

It is essential to take into consideration the aesthetics of buildings. Moreover, legislation stipulates that retrofits should be placed away from façades and the existence of 1 metre-high perimeter walls at roof level would further reduce the area available for solar photovoltaics. Hence, a realistic *utilisation* factor of 30% may be introduced to cater for these additional constraints.

Type of Dwelling	**Number**	**Effective Number**
Terraced	63,980	63,980
Semi-Detached	2,770	2,770
Fully-Detached	1,490	1,490
Farmhouse	1,110	1,110
Ground Floor	14,120	7,060
Maisonette	20,010	20,010
Apartments	23,810	7,937
Other	680	0
Total	**127,970**	**104,357**

Table 2: Distribution of Households by Type of Main Dwelling.

Taking a conservative average roof plan area of 80 m^2 per household and considering that a factor of 0.6 would be used to cater for spacing between the different rows of solar modules to avoid shading, the effective potential for each roof would accommodate a 2 kWp PV system. The overall potential for photovoltaic installations would then amount to 213 MWp that is capable of producing an annual mean output of 280,000 MWh.

Considering the high capital cost of installing PV systems, a realistic scenario could be a 1.2 kWp per roof, costing around Lm 3,500 (8,000 €). In this case, the potential would be 125 MWp that produces a mean annual output of 164,250 MWh.

b. Industrial Zones

Eight industrial zones have been identified in Malta and Gozo. The majority of the buildings have flat rooftops with minimum shading of one building on another. Based on available survey sheets (Malta Environment and Planning Authority (MEPA) 1988 and 1994), the roof areas were calculated for each zone as shown in Table 3.

Zone	**Area (000 m^2)**	**Reference Year**
Bulebel	152.5	1994
Hal Far	76.7	1988
Kordin	46.6	1988
Marsa	149.5	1988
Mosta Technopark	28	1988
Mriehel	57.5	1994
San Gwann	86	1988
Xewkija	24	1988
TOTAL	**620.8**	

Table 3: Rooftop areas in industrial zones.

In many cases, cooling towers and other appliances would be installed on the roof. Hence, assuming that 50% of the roof areas are available and taking into consideration spacing between modules to avoid shading, one would conclude that the potential area available amounts to 186,000 m^2. It follows that this area would be sufficient to install at least 26 MWp of solar modules rated at 12% efficiency and inclined at 30° to the horizontal. The estimated annual energy output would then amount to 34,164 MWh.

c. Public Buildings

i. Schools and University

A demonstration solar photovoltaic system may be easily fit on the flat rooftops of schools. A realistic first stage introduction of 5 kWp systems could be feasible. Smaller systems of 2 kWp may be placed on the English Language schools and other educational centres, due to their limited space. The available roofs at the University of Malta could accommodate 63 kWp (Yousif, Scerri 1996).

Table 4 lists the number of schools and educational centres available in Malta (Ministry of Education, Youth and Employment 2005). Hence, the total installed capacity would amount to 1.44 MWp or an electricity production of 1,896 MWh per annum.

School	State	Church	Private
Primary	77	30	15
Secondary	37	20	9
Tertiary	23	3	3
Special	6	0	0
English Language	0	0	42
Others	0	0	87

Table 4: Listing of Number of Schools and Educational Centres in Malta.

ii. Hospitals and Retirement Homes

There are four public and two private hospitals having substantial roof areas, with another large public hospital coming into operation in mid-2007. A number of three-star hotels and some church hospitals have also been converted to retirement homes. The overall potential for installing PV systems on these rooftops could amount to 600 kWp or a generating output of 788 MWh per annum.

iii. Hotels

In Malta there are 120 established hotels (Malta Tourism Authority (MTA) 2005), that would each accommodate a 5 kWp PV system without encroaching on space needed for other machinery that may be installed on rooftops. This would result in a potential of 600 kWp or an equivalent production of 788 MWh per annum.

Hence, the overall potential of rooftop solar PV systems amount to 153.64 MWp with the bulk contribution coming from the domestic sector. The resulting output would reach 201,883 MWh per annum, which is equivalent to about 9.1% of the total electricity generated from the power stations in 2003 (Enemalta 2004).

The Wind Resource

(1) Introduction

Wind characteristics depend upon numerous factors such as topography, site elevation above sea level, surface roughness and location exposure to any prevailing winds. Wind speed increases with height above ground level at the specific site itself, calling for wind speed measurements at a height representative of a wind turbine hub height. Based upon current wind turbine technology, the first 100 m of the lower atmospheric boundary layer is the prime area of interest.

(2) Background

Wind data was collected at different heights above ground level at a number of locations on the central Mediterranean Maltese Archipelago and analysed in a series of research studies (Farrugia 1998 and IET 2005).

In order to evaluate the local wind resource potential in a tangible manner, wind records gathered at one of these sites have been analysed. *Bahrija* (Site 3) is located on the south western coastal escarpment of the main island of Malta as shown in Figure 2. Other onshore prospective sites are numbered as appearing in the text.

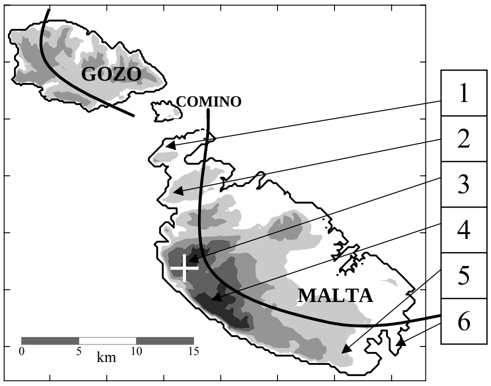

Figure 2: Schematic showing the location of *Bahrija* on the main island of Malta (indicated by a cross) and other onshore prospective sites.

The wind monitoring equipment was installed on a 45-metre lattice-type communications mast with effective anemometer heights of 10 and 45 m above ground level. Wind direction was monitored at 10 m above ground level. The data analysed covered 36 consecutive calendar months commencing in March 2002.

(3) Wind Characteristics

An analysis of the mean monthly wind speeds over the discussed time frame exhibited trends similar to those displayed at other locations around the islands i.e. higher wind speeds during the colder season and lower than average wind speeds during the hotter months (Farrugia 1998 and Darmanin 1995).

These characteristics become particularly important when evaluated with respect to the electricity generation potential of wind turbines as illustrated in Figure 3, which shows the theoretical monthly average energy yield for a typical medium-size wind turbine subject to site-specific wind conditions at *Bahrija* over a 12-month time frame.

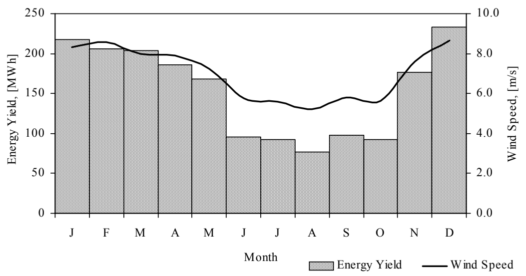

Figure 3: Mean monthly wind speeds and mean monthly theoretical energy yield for a medium-size wind turbine at *Bahrija*, 45 m above ground level.

The marked prevalence of winds blowing from the north westerly sector is evident in the wind direction frequency distribution at this site, which once again substantiates results from other locations (Farrugia 1998 and Darmanin 1995).

(4) The Wind Resource Potential and Other Indicators

Site mean wind speed and average power density are two frequently-encountered indicators of location wind resource potential. In the case of Bahrija, the range of values listed in Table 5 is based upon measured records at 10 m and 45 m above ground level. Wind speeds at other levels have been calculated using the Power Law and a site-specific wind shear exponent of 0.18. Calculated values for mean wind speed and average power density were derived, by assuming a standard air density of 1.225 kg/m3 and a Rayleigh distribution.

Height Above Ground Level [m]	Mean Wind Speed [m/s]	Average Power Density [W/m^2]
10	5.0 – 5.5	150 – 200
30	6.5 – 7.0	300 – 350
45	7.0 – 7.5	350 – 400
50	7.0 – 7.5	400 – 450

Table 5: Mean wind speeds and power densities for different heights at *Bahrija.*

Research (Manwell et al. 2003) suggests that sites having average power densities of 300 to 400 W/m^2 at 50 m above ground level are suitable for wind energy development with turbines having high towers (e.g. 50 m hub height) and that sites having average power densities ranging between 400 to 500 W/m^2 or more are considered suitable for most wind turbine applications.

The Potential for Wind Power Generation

(1) The Onshore Wind Power Generation Potential

Locations exposed to the prevailing winds, having high elevations above mean sea level and enjoying comparable roughness characteristics to those of *Bahrija* could have winds of similar quality. Generally, such areas are expected to lie south west of imaginary lines running across the two main islands as depicted in Figure 2. These areas are also less urbanised making them more suitable for wind generation technologies. Candidate sites falling within a category similar to that of *Bahrija* are *Marfa Ridge* (Site 1), *Mellieha Ridge* (Site 2) and an expanse of land running south of the village of *Dingli* (Site 4). Sites expected to have a lower potential are also included namely *Hal Far* (Site 5) and *Delimara* (Site 6). A number of these locations have been addressed in various studies ([a]Borg 2000 and Farrugia, Miles 2003). Other research work (Farrugia, Scerri 1999 and Leddin 2003) estimated the onshore wind resource potential using correlation techniques as well as mathematical models.

In this analysis the wind data measured at 45 m above ground level as specified was used as input to the Wind Atlas Analysis and Application Program (WA^{S}P) (Landbergh et al. 1987-2004), in order to generate wind resource maps for the islands. If areas expected to have average power densities of 300 W/m^2 or higher as depicted by the orthographic projections are taken as a baseline condition for wind power generation suitability, the cumulative area of land available for such a technology amounts to a circa 153 km^2 for the three main islands. This estimate is referred to as the *theoretical* area available for wind power generation technologies as it does not take technical, social and environmental constraints into consideration. Other research (European Wind Energy Association (EWEA) 2005), assumed that only 4% of the total *theoretical* area would eventually be accessible for wind power generation as a result of practical constraints. Applying such a proviso in the Maltese context results in a cumulative *practical* land area of about 6 km^2.

Wind farm array design is very important in determining optimised machine performance. Studies (Manwell et al. 2003) have indicated that the downwind - with respect to any prevailing winds - spacing between wind turbines is typically between 8 and 10 rotor diameters, whereas the crosswind spacing is 5 rotor diameters. If a crosswind spacing of 5 rotor diameters and a downwind spacing of 9 rotor diameters are assumed, then the area required by an average-sized machine (1 MW wind turbine with a 55 m rotor diameter) is 0.136 km^2, leading to an indicative installed capacity of 7.4 MW/km^2. Utilising the *practical* land area as defined previously implies that the potential for onshore wind generation could reach some 45 MW. Assuming wind turbine capacity factors of 25% to 30% (EWEA 2005) leads to the conclusion that the total energy generated would supply from 4.5% to 5.4% (Farrugia 2005) of the total annual electricity generated by Enemalta Corporation in 2003 (Enemalta 2004).

(2) The Offshore Wind Power Generation Potential

On a small island archipelago crosscutting issues, particularly those of a social and environmental nature, would limit the penetration levels of onshore wind generation facilities. Developments in the international wind energy sector over the past decade or so have seen this technology also going offshore. Sea depth, the wind resource and the site-to-shore distance are key factors that affect offshore wind project technical feasibility. The wind resource off the coast is more attractive due to lower surface roughness, resulting in higher wind speeds closer to sea level. Likewise, lower turbulence intensities also contribute towards higher energy yields when compared to machines operating onshore (Harrison 2000).

A number of areas have been identified that could be of interest for the offshore installation of wind machines (Farrugia and Scerri 2000), as depicted in Figure 4. An area off the north coast of Gozo (Site A), *Sikka l-Bajda* (Site B), an area offshore from *Marfa Ridge* (Site C), an area off the coast between *Salina Bay* and *St. George's Bay* (Site D), *Sikka tal-Munxar* (Site E), *Benghajsa Reef* (Site F) and *Hamrija Bank* (Site G) are the outstanding shallow zones, categorised as areas having sea depths of 20 m or less (The Hydrographic Office 1983) and are considered attractive for multi-megawatt wind turbine installations. Hurd Bank lies slightly more than 15 km off the north eastern Maltese coast but sea depths are in the 35 to 50 m range and the area is not evaluated in this study. The main offshore areas as identified and having sea depths of 20 m or less cumulatively account for 13.5 km^2 of marine space.

Sikka l-Bajda (Site B) is possibly the only truly offshore reef in Maltese coastal waters having appreciable dimensions. Lying 1.5 km off the north eastern extremity of *Marfa Ridge*, this reef has an approximate area of some 2 km^2 (Farrugia et al. 2002). In the case of offshore installations, if 7.9 MW/km^2 (for a 2MW turbine with a 75 m rotor diameter) is taken as a realistic measure for installed capacity, one such wind farm could generate from 1.6% to 1.9% of the total electricity generated in 2003.

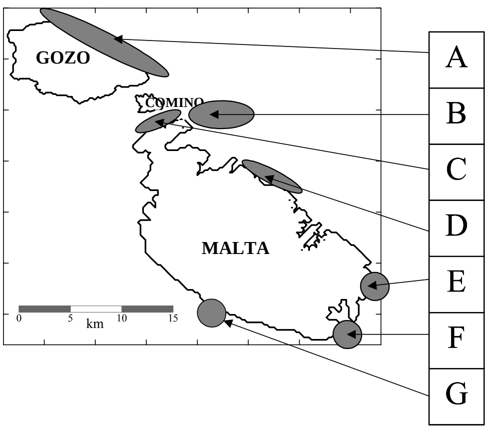

Figure 4: Schematic showing the Maltese Islands and some of the shallow areas around the coast having sea depths of 20 m or less as identified in the coastal zone.

If a second reef such as *Sikka tal-Munxar* (Site E) is also considered, the marine space could support an installed capacity of about 14 MW, having an equivalent electrical energy yield of 1.4% to 1.6% of the annual electricity generated by the fossil fuelled power plants on the islands in 2003.

It follows that the practical onshore and offshore wind resource potential could supplement almost 9% of the country's electricity generation.

Potential of Electricity Production from Waste

Three sources of methane (CH_4) are considered in the Greenhouse Gas (GHG) Inventory (Government of Malta 2004). The sewage treatment plant at *Sant' Antnin* produces a considerable amount of sludge, originally intended to go into the compost being produced on site. However, due to the presence of heavy metals, the sludge is not being used for this purpose.

A second source is animal waste from pigs, cattle and poultry, a fraction of which is applied to agricultural land as manure (cattle and poultry), while the rest (pig slurry) is disposed of into the sewage system.

A third source resides in the organic component of municipal solid waste, which is being deposited in a landfill at present.

For the year 2000 it was estimated that some 15 Gg of methane was produced from solid and liquid waste treatment and from animal husbandry. With proper treatment of the whole of the material available, one could reach 20 Gg of CH_4 per annum. This represents 1.11 x 10^9 MJ over a year, equivalent to 308,333 MWh_{th} and, in a 40% efficiency turbine, 123,333 MWh_e representing some 5.6% of total electricity generated in 2003.

Potential of Solar Water Heating Technologies

In a recent evaluation of the currently installed solar thermal applications in Malta, based on partially available information and correlation with statistical data of different types of installed solar water heaters in Malta, it was estimated that the currently installed area is in the region of 15,000 m² (10.5 MW_{th}) of flat plate collectors and 132 m² (92.4 kW_{th}) of evacuated tube collectors (European Solar Thermal Industry Federation (ESTIF) 2005). The cumulative installed areas currently cover only 8% of the potential of solar systems in houses ([c]Borg et al. 2005).

Solar thermal applications do not produce electric power but rather offset electricity generation from fossil-fuelled power plants, as the main source for heating water for domestic use is electricity. By adopting the same number of *effective* roofs as that for the PV system analysis shown in Table 2, knowing that only 70% of those dwellings are inhabited at the moment and assuming that each household would have a 150-litre flat-plate solar system (each having a 2.5 m² collector), one would reach to a potential of 182,625 m². Knowing that the mean global horizontal solar radiation is 5 kWh/m²/day and assuming an overall system efficiency and a utilisation factor of 40% and 80% respectively, it would be possible to offset 106,653 MWh per year, which is equivalent to 4.8% of the total electricity generated in 2003.

Economics Of Selected Resources

(1) Photovoltaic Systems

In the case of PV installations, the typical capital, installation and commissioning costs for small systems (1 - 3 kWp) in Malta would be Lm 3/Wp (7 €/Wp) installed. The life cycle costing, based on 4% net discount factor and a 20-year lifetime span, could then be calculated to be between 14.5 and 17 cents (34 - 39 € cent) per kWh produced from the solar PV system. With the 2006 state Budget subsidy of 20% of capital cost capped at Lm 500 (1,150 €), the cost of electricity would drop to about 28 to 37 € cent per kWh. At present the power utility, Enemalta Corporation, applies net metering, provided that the generated PV electricity is below the total consumption within the billing period. Under these circumstances, a small PV system would have a payback time just within its 20-year lifetime only if it was restricted to 1kWp, so making optimum use of the state subsidy and all electric output is sold to Enemalta at a preferential rate of 12 cents (28 € cent), as compared to the present peak rate of 6.2 cents (14 € cents). One may then conclude that, under the current market prices of PV systems, a decent payback period of 10 years may be achieved in Malta only if the selling price of PV electricity to Enemalta is set at 22 cents (50 € cent)/kWh or the state's subsidy on capital is increased to 70%.

(2) Wind Energy

Studies (EWEA 2005) have estimated the approximate costs for onshore wind-generated energy as a function of wind regime based upon a new onshore 850 to 1,500 kW capacity turbine, investment costs ranging between 900 and 1,100 €/kW, O&M costs of about 1.2 € cents/kWh over the turbine's 20-year lifetime and an annual discount rate of 7.5% (2003 calculations). At sites having low wind speeds (average wind speed of 5.4 m/s at 50 m a.g.l.) the cost of electricity ranges from about 6 to 8 € cents/kWh. At good coastal sites (average wind speed of about 6.9 m/s), the cost of energy ranges from approximately 4 to 5 € cents/kWh.

In the case of offshore wind development, costs derived (BWEA 2000) from limited experience typically stood at an indicative level of 1,600 €/kW for near-shore installations. This is approximately 60% higher than the mid-range cost of onshore machines at 1,000 €/kW installed.

Arguably, the cost of wind energy in the local context, with its specific conditions, may be expected to be higher than that on mainland Europe. Constraints on wind turbine size, the small grid and logistics are some aspects that will contribute to higher overall costs.

(3) Domestic Solar Water Heaters

Domestic Solar Water Heating systems fare now much better than before, as government is offering a subsidy of Lm 100 (230 €) for first-time buyers. The daily consumption of hot water by a family of four persons between autumn and spring (9 months) may be conservatively estimated to be 80 litres at 60 °C, requiring about 1,000 $kWh_{thermal}$. Hence, the life cycle costing may be calculated to be 5.2 cents (12 € cents)/kWh as compared to 6.5 cents (15 € cents)/kWh, if electric heating is used instead. The payback period would then be about 4.5 years which is lower than the expected lifetime of a typical solar water heater of 10 years. Without government subsidy the payback period would rise to 7 years.

(4) Energy Generation from Waste

Confining ourselves to existing plans to convert the methane content of landfill gas to electricity to be transmitted to the grid through a 1km. cable, an efficiency of 40% would yield a unit cost of 0.65 cents (1.5 € cent). O & M, which must include gas purification prior to burning, would add 0.2 cents (0.5 € cent); gas collection and power transmission losses, and safe disposal of small amounts of hazardous waste from gas purification would add some 0.08 cents (0.2 € cent). Total unit cost would then lie in the range 2.5 – 3.5 € cent. Real costs, which must include initial waste collection as well as landfill engineering costs would probably bring the cost close to 4.3 cents (10 € cent) per kWh generated.

Barriers and Incentives

The major physical barrier to widespread use of renewable energy (RE) is the fact that all such sources have a low energy intensity per unit area. The very limited land area (316 km^2), around 21% of which is built-up, and a high population density (1,273 persons per km^2), set tight limits on the potential from land-based RE generators.

The inclusion of sea areas suitable for offshore wind generators increases potential but puts up installation and other costs. In the case of PV and SWH installations, the general presence of flat house roofs normally used for a variety of domestic purposes ranging from drying clothes to roof gardening, does provide space for small installations, basically serving one household. On a larger scale there is area available as factory roof and on top of major public and private buildings.

The original Structure Plan (SP) (MEPA 1992) was written well before RE appeared on the local planners' horizon; so there was no mention of RE installations in the section on "Utilities". The current Utilities Topic Paper, part of the on-going SP revision, does give RE some mention. But apart from an initial and continued absence of planning policies, other factors have worked against RE development. There is as yet no national energy policy and still less a policy for RE development. Local interest in promoting energy conservation and use of RE has been confined to academics and a few individuals and firms outside the University ─ very far from the critical mass required for a good RE take off.

Information on RE devices has not been easily available to the general public and to small firms and commercial establishments with limited human resources, whereas the advertising and information apparatus for conventional devices is very well developed. Capital costs have also proved to be a powerful deterrent; but cost has a strong relative element.

Long years of subsidy on electricity prices from transport fuel sales tax have engendered strong expectations in the public mind that such a service is a low cost one. As a result, public or private investment in energy conservation and renewable energy has suffered from low social esteem, in marked contrast to the private car market, for instance. A short amortization period and a rapid money return is also expected from RE products.

On the other hand, energy-saving and RE technologies, quite apart from prices on European markets, are locally over-priced due to import duties (now diminished or removed on the basis of EU internal market rules), value-added tax, and high dealer mark-ups arising from low volume sales by too many importers in a small market. The combination of high prices and low electricity unit costs makes for long pay-back times and reinforces a general tendency to minimize capital cost even if this entails comparatively high running costs.

In the case of domestic water heating, there was a switch from gas to electricity between 1985 and 1995 (census years). By the latter year there was some public interest in the purchase of SWH, but in 20% of the cases, inadequate technical backup leading to poor performance has generated low level of customer satisfaction ([b]Borg 2004). The common social habit of asking for advice from one's friends rather than from technical experts reinforces customer dissatisfaction (Sudhakara Painuly 2004).

Preoccupation with satisfying public demand for low priced electricity has discouraged firm action in the RE field. The wholly state-owned provider – Enemalta – has been plagued by low investment leading to low productivity and inefficient conversion. Fragmented ministerial responsibility led to disjointed and sometimes even counter productive measures.

The prospect and now the reality of EU entry is ushering in a sea change. An energy regulator—the Malta Resources Authority (MRA) - has been set up; Enemalta has renounced its generating and fuel importation monopoly, but retained ownership of the electricity distribution network. Perhaps more important from an efficiency point of view, the finances of the various divisions of Enemalta have been unbundled, so that each must now operate profitably. This should drive Enemalta towards unsubsidised tariffs, reflecting the real costs of generation.

(1) Solar Water Heaters

In fact planning policy treating SWH falls under Part 13 of Development Control Policy and Design Guidance (MEPA 2005). The "guidance" is a little uneven, appearing to treat SWH rather leniently in comparison to PV. There are also some technical lacunae, as in the suggestion that siting the storage tank within adjoining washrooms can mitigate adverse visual impacts from SWH. Meanwhile the first incentives for RE use have appeared. Since June 2003, Enemalta has offered a waiver of the installation fee of electricity meters amounting to Lm 70 (161 €) for new customers, provided that a SWH system is installed on the premises beforehand (Enemalta 2005). Government has conceded a once-only payment of 25% of CIF value, up to Lm 100 (230 €) of a solar system for households (Department of Information 2005).

It is probable that other events may prove more important in promoting widespread use of SWH. Prices for SWH models have been coming down quite perceptibly; good quality evacuated tube absorbers are currently selling at around Lm 500 (1,150 €) for a 150 litre system. On the other hand, a more "educated" public is now evaluating costs, maintenance and installation more critically, which should lead to a higher customer satisfaction, signally lacking to date. Yet, what may eventually turn out to have provided the strongest push is the surcharge (17%) on electricity and water bills included in the 2005 National Budget, which was trebled just before the 2006 Budget. Domestic hot water, almost completely supplied by electric immersion heaters, accounts for 25%-35% of the annual electricity consumption. As the surcharge is tied to movements in the total fuel bill for generation, it is unlikely to disappear or even decrease appreciably in the short-to-medium term. This could lead to households looking more closely at SWH, as these would now have payback times of 3-4 years, well short of the SWH lifetime.

(2) Photovoltaic Systems

Planning policy for PV systems also falls under Part 13 of Development Control Policy and Design Guidance (MEPA 2005). The PV modules must not "have a significant visual impact". Such a statement could act as a disincentive to prospective developers. While the guidelines say that "solar voltaic cells can be incorporated….in the form of simple panels or even cladding", to date there has not been any proposal for building-integrated PV systems.

As far as PV is concerned, a formal protocol for mains connection has been worked out between MRA and Enemalta Corporation. The 2006 Budget offered a 20% on capital costs of the installation, capped at Lm 500 (1,150 €). A system below 3.7 kWp needs only to be registered at MRA, while an authorisation would be required for larger systems. Provided the PV power generated does not exceed total household consumption over a billing period, Enemalta accepts net metering. Generated units in excess of household consumption over a billing period are paid at 3 cent (7.3 € cent).

(3) Wind Turbines

Wind turbines have not yet been the subject of serious planning legislation. In the MEPA Design Guidance, they are declared to be "encumbered by physical constraints, which are predominantly related to visual intrusion". An existing proposal for a wind farm on *Marfa Ridge* has raised mixed reactions — all unofficial, as MEPA has not given any ruling on the proposal — ranging from visual intrusion to high noise levels and disruption of migratory bird routes to radar interference. In the specific setting of the Gozo and Comino Local Plan (MEPA 2001), wind turbines – other than very small ones on individual farmhouses – are banished to at least 100 m offshore.

The restriction to offshore raises further barriers: intrusion into areas of shallow water staked-out by other economic activities; increased construction and connection costs; increased cost of work directed to solutions of problems associated with the interaction of a wind farm with a small grid (Fsadni, Mallia 2006). The scale and cost of a wind farm will almost certainly require private investment, with its inevitable demand for an attractive rate of return (Meilak 2004). It is unlikely that anyone would invest in any wind farm until such problems are resolved. And they cannot be finally resolved without trials with a land-based wind farm of modest dimensions.

Elements of a Renewable Energy Policy

The present shortcomings in the approach to RE use suggest various lines of action, preferably within the framework of a National Energy Policy. That Policy will condition planning regulations for both large and small-scale applications. For instance, new or amended building regulations, similar to those adopted by several Spanish cities (ESTEC 2005) could be designed to stimulate the solar thermal market, whereby solar heating caters for a significant percentage of the thermal load in buildings. Actual incentives could be tied to installed area of absorber, a method that has been very successful in Germany. It is important that such measures drive home the point that SWH, with their lower cost and high conversion efficiency (ESTIF 2005) are the best prospect for rapid take-up, with a significant displacement of generated electricity.

The installation of PV poses a different set of problems. At present its more "glamorous" image compared to SWH cannot gainsay high capital cost and low efficiency (15%). As initial demand is likely to come from systems to be incorporated in existing structures, sensible planning parameters are required, keeping in mind available forms and costs of PV. There are then the further considerations of incentives on the two levels of capital cost and feed-in tariffs. To date we have none of the first and little of the second.

Germany has run a number of "PV-roof" programmes, which involved a 70% capital offset and a feed-in tariff of 90% of that for fossil-fuel units. At the close of the last programme at the end of 2003, capital grants were abolished but the feed-in tariffs were pushed up to the range 45–62 € cent/kWh (some 3 to 4 times the average rate for fossil fuel units), leading to a strong surge in the installation of PV systems, to actual shortages of silicon in the latter half of 2004 and to a total installed capacity of 794 MWp (Systemes Solaires 2005) by the end of that year. The UK and Italy, both new comers to the PV market, have provided capital cost offsets of 50-70% and 'net-metering' i.e. barter of units.

As far as wind energy is concerned, there is not a single commercial installation of any size feeding energy into the grid. There is lack of policy, planning, legal and technical instruments in this area. In this particular situation, these elements would need to be integrated into a coherent whole, which will do justice to each element.

The methods used in Germany, the European country with the highest installed wind turbine capacity, bear looking at. Wind turbines were described as facilities for public electricity supply, and as such could be erected in open country (Knight 1997). Apart from a well-funded R&D programme, grants up to 25% of initial investment (capped at 46,000 € per turbine) were provided, together with a €c 4/kWh premium on units fed to the grid. Germany had an installed capacity of 16,000 MW at the end of 2004 (Grotz, Fouqet 2005).

The U.K. has devoted the major share of its RE effort to wind energy. Two Non-Fossil Fuel Obligation (NFFO) orders issued in 1990 and 1991 were intended specifically for wind energy, with the rates of €c 8.7/kWh and €c 16/kWh being set for the two years (against 4-6 € cent/kWh for fossil fuel generation). The cut-off year of 1998 was subsequently removed, and in the year 2000 NFFO orders were replaced by Renewable Obligation Certificates (ROC). At the end of 2003, wind customers were paying 9.6 € cent/kWh. Planning issues were usually decided at the local level, but there were cases where local decisions, generally negative ones, were overturned by the Secretary of State for the Environment (Elliot 1997). Recently one major offshore farm has come into operation, bringing the total installed capacity to 890 MW. A large number of sites off the east coast of the U.K. have been leased as wind farm sites.

Italy had 1100 MW of installed wind power at the end of 2004. Grants amounting to 30-40% of eligible costs were provided, but there was a long process before selling prices were fixed in 1998 at around 10 € cent/kWh for the first 8 years of operation. In 2003, customers were paying 13 € cent/kWh. The multi-tiered Italian administrative set-up has led to disagreements about siting and size of wind farms. But in late 2004, four private companies were granted permits to set up a

63 MW wind farm in Troia, in northern Puglia. All forty-two 1.5 MW turbines were expected to be operational by the start of 2007.

Incentives and Measures

A number of possible measures intended to increase the take-up of renewable energy devices were published (Yousif, Scerri 1996 and Fsadni 1994). These, together with other initiatives are presented below:

- Publication of the National Energy Policy;
- Setting a national renewable energy target and a National Plan (Short, Medium and Long-term) to attain it;
- Formation of a technical body to certify the quality of imported or locally manufactured renewable energy systems, according to the national and international operating standards;
- Fiscal incentives for installing renewable energy systems;
- Formation of a Renewable Energy Fund that is supplemented by a "renewables or carbon/pollution surcharge" on transport fuels;
- Use of the Renewable Energy Fund to subsidize public RE projects in schools, hospitals, etc.
- Allowing grid-interfacing of all RE electricity generating systems;
- Provision of soft loans for installing RE grid-connected systems;
- Purchasing of extra power produced by RE systems by Enemalta at preferential rates, bearing in mind that the total effect on Enemalta's financial situation would be negligible due to the small percentage of renewables in the energy mix;
- Encouraging the local manufacturing of components that may be required for RE systems;
- Training in RE installations to ensure effective implementation and to create new jobs;
- Setting up of a monitoring entity that would ensure the adequate performance of RE systems, collate information on the state of affairs of RE applications and development in Malta and propose measures to boost their effectiveness.

Conclusions

An island scenario with limited land area and a small isolated grid favours the application of as wide a mix of RE technologies as possible. This would serve two distinct purposes. The first is to attenuate the effects of variability and intermittency of RE sources; and the second is to obtain as good a match as possible between supply and demand. In the Malta case, the cumulative contribution of solar, wind and biomass to power production could reach 24% of the total electricity generated in 2003. Furthermore, solar water heating could save an additional 4.8%.

It is high time that immediate and effective measures are taken at all levels to kick-start use of these energy sources that have remained practically untouched to date. Such measures should be accompanied by a determined drive for increased energy efficiency, which will itself enhance the RE contribution. The spiralling costs of fossil fuels as well as the current levels of pollution and greenhouse gas emissions make such a course of action imperative.

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References:

Akiwale A. (2003), *Solar Radiation over Malta*, unpublished M.Sc. dissertation, Centre for Renewable Energy Systems Technology (CREST), Loughborough University, UK, in collaboration with the Institute for Energy Technology, University of Malta, Malta.

[a]Borg S. (2000) *The Feasibility of Wind Energy in Malta*, unpublished B.Acc. (Hons.) dissertation, Faculty of Economics, Management and Accountancy, University of Malta, Malta.

[b]Borg S. P. (2004), *A Technical Examination of Solar Water Heaters in Malta*, unpublished M.Sc. dissertation, Centre for Renewable Energy Systems Technology (CREST), Loughborough University, UK, in collaboration with the Institute for Energy Technology, University of Malta, Malta.

[c]Borg S. P., Yousif C. and Farrugia R.N. (2005), *Investigation of Domestic Solar Water Heating Installations in Malta*, Proceedings of the Seminar: "Renewable Energies in Malta and Beyond" 19th September 2005, Salina, Malta, pp. 30-38 , organised by the Institute for Energy Technology, University of Malta.

BWEA 2000, The British Wind Energy Association, "Prospects for Offshore Wind Energy". Report written for the EU (Altener contract XVII/4.1030/Z/98-395) by the BWEA. Available online at: http://www.bwea.org consulted December 2005.

Darmanin P.J. (1995), *The Feasibility of Using Wind Energy in Malta*, unpublished Diploma in Environmental Science dissertation, International Environment Institute, University of Malta, Msida, Malta.

Department of Information (2005), www.doi.gov.mt/EN/press_releases/2005/03/09.asp Press Release No. 0354, 9th March 2005, consulted 2nd May 2005.

Elliot D. (1997), Energy, Society and Environment, Routledge, London, pp. 154-156.
Enemalta (2004), *Enemalta Annual Report 2004 and Financial Statements 2003*, Enemalta Corporation, Church Wharf, Marsa, Malta.
Enemalta (2005), Press Release of 27th June 2005, www.enemalta.com.mt/page.asp?n=pressarchive, consulted 30th June 2005.
ESTEC (2005), *Solar System Legislation: An Idea Takes Hold in Spain,* www.newsletterpage.de, consulted 1st June 2005.
ESTIF (2005), *Solar Thermal Markets in Europe: Trends and Market Statistics 2004*, www.estif.org, consulted 1st July, 2005.
ESTIF (2005), *ST Energy: Solar Thermal: A Leading Technology*, www.estif.org, consulted 1st June 2005.
EWEA (2005), *Wind Energy – The Facts*, in collaboration with the European Commission's Directorate General for Transport and Energy (DG TREN), www.ewea.org, consulted 12th June 2005.
Farrugia R.N. (1998), *Wind Resource Assessment for Malta,* unpublished M.Phil. dissertation, Institute for Energy Technology, University of Malta, Malta.
Farrugia R.N. and Scerri E. (1999), *A Wind Resource Assessment for the Maltese Islands*. 1999 European Union Wind Energy Conference and Exhibition, Nice, France, 1st – 4th March 1999.
Farrugia R.N. and Scerri E. (2000), *Offshore Wind Potential of a Central Mediterranean Archipelago*, OWEMES 2000 - Offshore Wind Energy in Mediterranean and Other European Seas, Syracuse, Sicily, Italy, 13th –15th April 2000, pp. 481-488.

Farrugia R.N., Miles J.J., et al. (2002), '*Sikka l-Bajda*' - *A Case Study for Offshore Wind Power,* unpublished paper in the Enemalta 25th Anniversary Conference on Energy and the Environment, Mediterranean Conference Centre, Valletta, Malta, 18th – 19th October, 2002.
Farrugia R.N., Miles J.J. (2003) *A Multi-Disciplinary Approach to University-Level Renewable Energy Education.* ISES 2003 Solar World Congress, Göteborg, Sweden, 14th – 19th June 2003.
Farrugia R.N., (2005), *Assessing the Prospects for Wind Power Generation in Malta*. Proceedings of the Seminar: *"Renewable Energies in Malta and Beyond"*, Salina, Malta, 19th September 2005, pp. 47-52, organised by the Institute for Energy Technology of the University of Malta.

Fsadni, M. (1994), *Incentives to Promote the Application of Energy Conservation and of Renewable Energies,* unpublished internal report presented to the Ministry of Finance and Infrastructure, Institute for Energy Technology, University of Malta, Malta.

Fsadni M. and Mallia E.A. (2006), *The Interaction of Wind Power Generation with Electricity Demand in the Context of a Small Grid,* Renewable Energy, 31, pp. 811-819.
Grotz C. and Fouquet D. (2005*), Fixed Prices Work Better,* New Energy, No.2, April 2005, pp. 18-21.
Harrison R., Hau E. and Snel H. (2000), *Large Wind Turbines – Design and Economics*, John Wiley and Sons Ltd. U.K.
IET (2005), home.um.edu.mt/ietmalta, consulted 5th June 2005.
Knight S. (1997), *Liberalisation Law Puts Cap on German Wind Output,* Wind Power Monthly, Dec. 1997, pp. 23-28.
Landbergh L., Mortensen N.G. et al. *Wind Atlas Analysis and Application Program (WA^{S}P), V. 8.01.* Risø National Laboratory, Denmark, 1987 – 2004.
Leddin B. (2003), *WA^{S}P in a Mediterranean Island Climate,* unpublished M.Sc. dissertation, Centre for Renewable Energy Systems Technology (CREST), Loughborough University, UK in collaboration with the Institute for Energy Technology, University of Malta, Malta.
Manwell J.F., McGowan J.G. and Rogers A.L. (2003), *Wind Energy Explained - Theory, Design and Application,* John Wiley & Sons Ltd., U.K.
Meilak J. (2004), *A Case for a Maltese Offshore Wind Farm: Challenges and Opportunities,* Bank of Valletta Review, No.30, Autumn 2004, pp. 47-61.
MEPA (1988, 1994), Mapping Survey Sheets of Industrial Zones, MEPA, Floriana, Malta.
MEPA (1992), *A Structure Plan for the Maltese Islands*, www.mepa.org.mt, under *Official Manual/*, consulted 25th May 2005.
MEPA (1999), www.mepa.org.mt under *Local Plans/,* consulted 1st June 2005.
MEPA (2001) www.mepa.org.mt, under *Local Plans/*,consulted 1st June 2005.
MEPA (2005) *Policy and Design Guidance April 2005*, www.mepa.org.mt, consulted 1st June 2005.
Ministry for Education, Youth and Employment (2005), www.education.gov.mt, consulted 24th June 2005.
MTA (2005), Malta Tourism Authority, www.visitmalta.com, consulted 24th June 2005.
National Statistics Office (2005), *"Distribution of Households by Type of Main Dwelling"*, www.nso.gov.mt/docs/household_table2.pdf consulted 4th July 2005.
Palz W. (Editor) (1984), *European Solar Radiation Atlas, Vol. 1: Global Radiation on Horizontal Surfaces,* Commission of the European Communities, Verlag Tuv Rheinland.
Ribeiro F., Yousif C. (2004), *Analysis of Photovoltaic Projects in a Mediterranean Island*, 19th European Photovoltaic Solar Energy Conference, 7th-11th June 2004, Paris, France, pp. 2842-2845.
Scerri E. (1982), *The Radiation Climate of Malta*, Solar Energy, Vol. 28, No. 4, pp. 353-356, Pergamon Press.
Sudhakara Reddy and Painuly J.P. (2004), *Diffusion of Renewable Energy Technologies —Barriers and Stakeholders' Perspectives,* Renewable Energy, Vol. 29, No. 9, pp. 1431-1447.

Systemes Solaires (2005), *Photovoltaic Energy Barometer, Table 2,* No. 166, March-April 2005, page 39.

The Government of Malta (2004), *The First Communication of Malta to the United Nations Framework Convention on Climate Change*, pp. 20-45.

The Hydrographic Office, Taunton, U.K., (1983), *Mediterranean Sea, Maltese Islands* – Charts 2537 and 2538. Admiralty Charts and Publications.

Yousif C., Scerri E. (May, 1996), *The Solar University of Malta,* unpublished proposal for funding under the Fifth Italo-Maltese Protocol, Institute for Energy Technology, University of Malta, Malta.

Yousif C., Scerri E. (1996), *Photovoltaic Solar Energy Applications in Malta*, unpublished proceedings of the 3rd Biennial Conference of the Malta Council for Science & Technology, Valletta, 4th – 5th June, 1996.

Yousif C., (2005), *Contribution Of Solar Applications Towards Achieving A Renewable Energy Target For Malta*, Proceedings Of The Seminar: *"Renewable Energies In Malta And Beyond",* 19th September 2005, Salina, Malta, Pp. 17-21, Organised by the Institute for Energy Technology, University of Malta.