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THE ECO-GOZO CONCEPT:
FROM A SUSTAINABLE ENERGY PERSPECTIVE

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ABSTRACT:

The Eco Gozo 2015 Vision of the Ministry for Gozo aims at making the Island of Gozo eco-friendly, supporting a sustainable society, while improving the quality of life of citizens and reducing the Island's carbon footprint [1].

This paper aims at addressing the Eco-Gozo Concept from a sustainable energy point of view. Gozo, being a small island that fully depends on the main Island of Malta for the provision of energy supplies and electricity, would have to become more self-sufficient in terms of renewable energy generation, thus reducing power transmission losses and its associated carbon emissions, and increasing the island's autonomy and energy diversification.

Studies showed that for the immediate future, there is a good potential for the use of solar and wind energy systems on the island. The use of bio-energy and alternative fuels for vehicles would increase energy options for transport fuel, and in the longer run, there might be possibilities for using wave energy for electricity production. The paper also shows significant savings that could be achieved by applying roof insulation to buildings.

Although the paper has not exhaustively dealt with all energy saving, energy efficiency and renewable energy options, the results presented here should be useful to all entities who may be directly or indirectly involved in planning for the Eco-Gozo initiative, and may also support the formulation of sustainable action plans that would be necessary to achieve the full aims of the Eco-Island concept. This study also showed that the Island of Gozo could potentially even become a net exporter of green electricity.

1. INTRODUCTION

During the month of May 2010, the Institute for Sustainable Energy (ISE) of the University of Malta conducted a number of case studies related to the Eco-Gozo Concept, focusing on energy issues. These included solar thermal and solar photovoltaic potential, feasibility of a medium-sized wind farm, biofuels' potential for transport and the future potential of wave energy for power production.

This study was led by a team of experts from the ISE, and groups of students from James Madison University, Virginia, U.S.A., who spent one month employing different methodologies for determining the potential of alternative energy systems for the Island of Gozo.

This paper presents a synthesis of the following internal reports that were completed in June 2010:

1. *The Contribution of Solar and Heat Pump Water Heaters towards Sustainable Development on the Island of Gozo*, Gaertner E., Knoll A. and Oliver N., with Yousif C.
2. *Solar Photovoltaic and Wave Energy Potential of Gozo*, Draper, B., Johnson, J., Pugh, T., & Sabo, J., with Mule'Stagno L.
3. *Wind Energy in Kerċem, Gozo: A Case Study on Technical Feasibility and Social Acceptance*, Cochran K., Fox J., McHarg M. and Williams E., with Farrugia R.N.
4. *ECO-GOZO, Towards Zero Net Carbon Emissions: Biofuels for Transport,* Frankenfield S., Jennings R., Pearson C. and Smith E., with Weissenbacher M.
5. *Roof Insulation to Reduce the Carbon Footprint of Buildings in Gozo*, Miller G., Mills C., Rupnik B. with Fsadni M..

Sustainable Development may be described as the result of making the best of economic development, environmental protection and social inclusion. The United Nations Department of Economic and Social Affairs identified energy as the main factor that would affect sustainable development. Energy would have to be managed in such a way that the right balance is achieved between the need for using energy and the negative impact that such use may have on the environmen. For this reason, this paper has focused on the energy needs of the Island of Gozo and on studying the potential offered by alternative sources of energy and roof insulation.

2. WATER HEATING OPTIONS

Yousif C., Gaertner E., Knoll A. and Oliver N.

Maltese as well as Gozitan households extensively use electric boilers for heating water. The 2005 Census showed that 94.7% of households have a water heater installed [3]. The Household Budgetary Survey of 2008 had estimated the percentage of households that own an electric or gas heater at 93.7% [4].

In this section, the focus was on the potential of using solar heating and/or heat pumps to replace traditional electric water boilers, which may reduce a household's electricity consumption by 15% to 30%. In fact, the total amount of electricity that could be saved by heat pumps or solar thermal systems could range between 6,040 and 12,080 MWh per year. The precise figure depends on several factors including family size and lifestyle. Hence, water heating would be one of the important factors that could affect the overall consumption of electricity, as it was estimated to have amounted to between 8 and 16% of the total electricity consumed in Gozo in 2007.

The scope of this study may be summarized as follows:

- To determine the prevalence of solar water heating units in Gozo.
- To estimate the average area of roofing available for solar water heaters.
- To perform economic analysis comparing solar water heaters, heat pumps, and electric resistance water heaters.
- To establish the possible reduction of CO_2 emissions by using solar and heat pump water heaters.

The main reason for introducing heat pumps stemmed from the fact that certain households may have no access to a roof and therefore may not benefit from any Government grants for solar hot water heating systems. At the same time, the EU Directive on renewable energy 2009/28/EC has identified heat pumps as a possible source of renewable energy, provided that the energy delivered for heating is significantly higher than the primary energy consumed to drive the motor, as shown in Figure 2.1 [6].

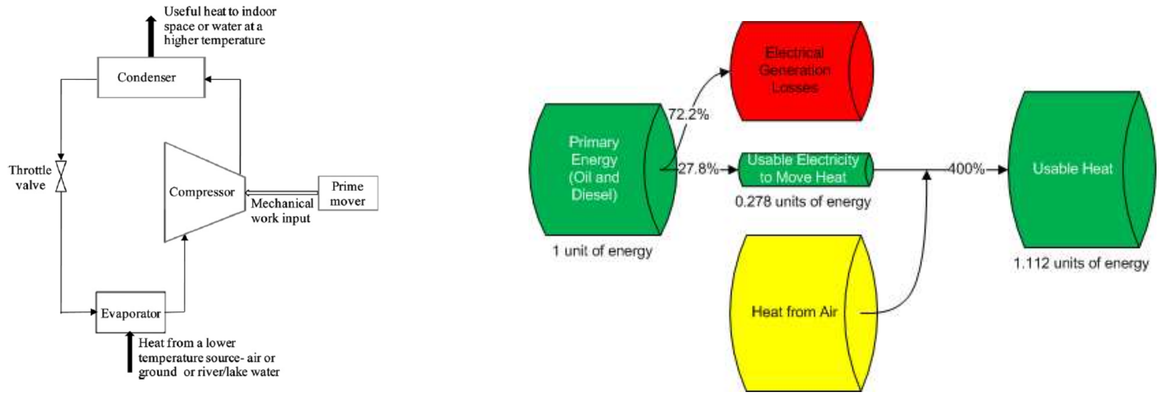

Figure 2.1: The heat pump cycle and the corresponding energy flow diagram drawn to scale for a heat pump with a COP of 4 [5].

When compared to an electric heater energy flow diagram (Figure 2.2), one would appreciate the positive impact that a heat pump would have on the environment, since it would provide 3 to 4 times more heat energy per unit of electricity consumed.

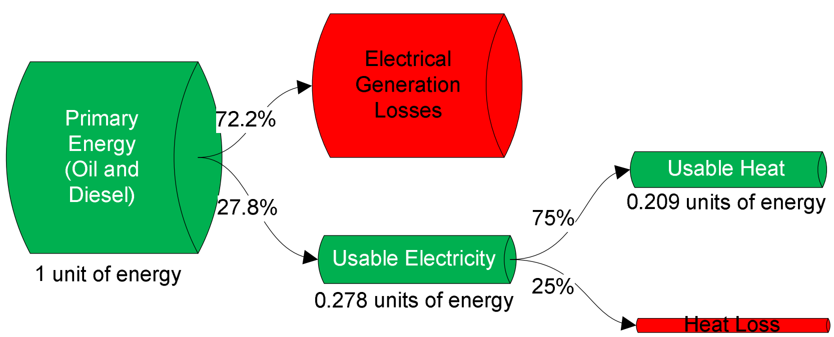

Figure 2.2: Energy flow diagram for a traditional electric boiler. The size of each box is drawn in proportion to the energy needed, produced, consumed or lost [5].

Therefore, it is recommended that heat pump technology for water heating should also be supported in proportion to its renewable energy generation contribution. Grants should be provided so that households that have no access to the roof would still benefit from funding schemes that encourage and support them to save energy and produce renewable energy for their needs, thus ensuring a more equitable social justice prevalence among all citizens.

It was considered necessary to gauge the potential of solar heating from a technical as well as a social point of view. For the technical part, two sites were sampled, namely *Victoria* (representing a community of predominantly terraced houses) and *Marsalforn* (mainly consisting of high rise buildings and apartments). Surveys, photographs and geographical imaging were all combined to provide an insight to the existing percentage of households owning a solar system, the potential for installing new systems and the percentage of households with no access or shaded roofs. From a social point of view, a sample survey was conducted among Gozitan households in both localities to gauge the level of popularity of solar heaters.

2.1 Technical Study

Vantage points were chosen from where a number of photographs were taken. A photo-combination exercise was then carried out to produce a panoramic overview of the sample area for sample buildings from *Victoria* (mainly terraced houses) and *Marsalforn* (mainly high rise buildings). By combining these photos and comparing them to GIS maps taken from Google Earth, it was possible to measure the unshaded areas on each roof within the sampled areas and at the same time count the actual number of installed solar heaters. Figure 2.3 shows the methodology adopted, whereby each household was numbered and identified in Google Earth. Dimensions were taken, shaded areas removed and net useable areas calculated.

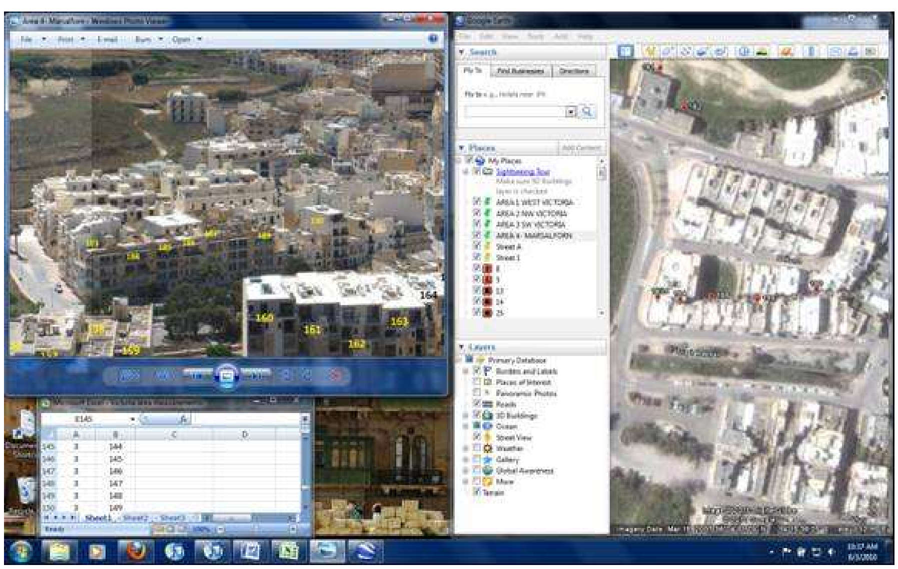

Figure 2.3: Photography and GIS Google Earth photos were combined to calculate the effective unshaded roof areas in *Victoria* and *Marsalforn*, Gozo [5].

Results have shown that the majority of rooftops in *Victoria* are accessible and there is sufficient space to place a solar water heater (26% of roof) without conflicting with the other traditional uses for the roof, such as laundry drying, gardening and other social activities. Around 90% of the dwellings there have adequate space for a solar heater. Meanwhile, in *Marsalforn* area, the roof availability amounts to 29% of the total roof area, but given that it will have to be shared among all apartments in the building (assumed to be 3 storeys high), only 26% of households would have sufficient roof space to place a solar heater, as shown in Table 2.1.

Table 2.1: Results showing the availability of rooftop area for the installation of a typical 200-litre solar water heater.

	Avg. rooftop area (m^2)	Avg. useable rooftop Area (m^2)	Avg. useable rooftop area (%)	Percentage of buildings having adequate space for ALL households within (%)
Victoria (terraced houses)	104	26	26%	91%
Marsalforn (Flats)	141	41	29%	26%

In order to generalize these results to the whole Island of Gozo, it was deemed necessary to divide the island into zones according to their prevailing building structures (terraced houses or apartments). Two villages were considered as predominantly consisting of apartments, namely *Marsalforn* and Xlendi; while the remainder of the island’s councils were considered as predominantly composed of terraced houses.

Based on this zoning exercise, an indicative estimate of the number of solar heaters in Gozo was carried out as well as the potential for solar heating and heat pump applications for the Island, making use of past Census data and the surveys that were conducted for *Victoria* and *Marsalforn*. It was concluded that about 12.5% of Gozitan households currently have a solar water heater, as compared to 10% in 2005 (as deduced from the 2005 Census). Furthermore, about 78% of households in Gozo have both the space and un-shaded requirements necessary to install a solar heating system. The remaining

22% would have to resort to a heat pump water heating system in order to reduce their electricity bill and contribute towards a better environment.

2.2 Social Study

The aim of the social study was to determine the implications or constraints for the installation of solar heaters in Gozo. The 68 surveys that were collected from *Victoria* and *Marsalforn* were analyzed and this resulted in the following statistical outcomes:

- Of those who had solar heating systems, 88% were satisfied with their performance and 71% have benefited from the financial government grant on capital cost.

- Of those who had no solar heating systems, 90% knew about the government's financial support scheme.

Several important conclusions can be made from these statistics. The first is that most people who have solar water heaters are happy with them. The second is that almost 3 out of 4 people took advantage of the government's subsidy, which would seem to suggest that the scheme is having some impact on the purchase of solar water heating units. The most important outcome from this sample was the fact that most domestic users who do not have solar water heaters are in fact aware that a government subsidy is in place. This suggests two important things; the first that information about the government subsidy is not a major cause for people not purchasing such units and the second that the current government subsidy alone is not enough to motivate the widespread application of solar heaters.

The next set of information addressed the reasons why people may not have solar water heating units. Figure 2.4 shows the reasons given by respondents for not having a solar water heating unit. These are grouped into several categories.

It is clear that the majority of respondents have an interest in purchasing a solar heater, but many of them are actually waiting until their electric boilers fail. While the result seems to be positive, the likelihood for these homes to purchase a solar heater is not guaranteed. More awareness and education would probably be needed to entice this group to opt for a solar heating system now, rather than waiting for a number of years. Here one needs to keep in mind the fact that when an electric boiler fails, the household would need to replace it immediately. In general, applying for a solar water heater grant takes time and this would discourage people from opting for this approach, since they would wish to reduce the time without a hot water supply source to a minimum, and would not afford to wait until their application is approved.

The second largest group responded that the capital cost was still high in spite of Government's financial support. This is due to the fact that the potential buyer has to pay a lump sum at the beginning, which is not always possible. This would seem to suggest that the Government's grant on capital expenditure is not enough to encourage the purchase of a solar water heating system for these people. It can also imply that solar heating systems are not really the top priority at this stage. The most recent Household Budgetary Survey of 2008 [4] has showed that on average, Maltese families manage to save 1,000 Euros per year. This would imply that average households cannot buy a solar heater that usually costs up to 1,700 Euros and therefore, solar heating is not high on their list of priorities.

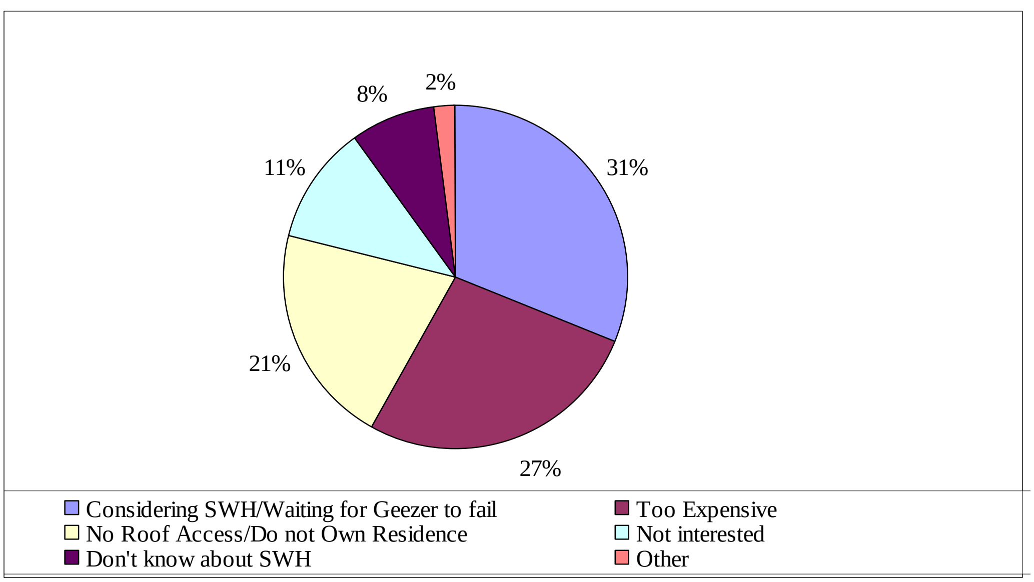

Figure 2.4: Pie chart of reasons why sample dwellings in Gozo do not have solar water heaters and their relative percentages.

The third largest group of people surveyed said that they did not have access to the roof for some reason or another, though for most people this is due to living in an apartment complex. This is the group that would benefit most from the development and implementation of an incentive program for heat pump technology.

The last few groups are small but probably the most difficult to deal with. While it is a small percentage overall, a number of people did say that they simply had no interest in getting a solar water heater for various reasons. An even smaller percentage said that they did not know much about solar water heaters. While it is positive that this and the other groups are small, it still may be worth looking into what can be done to help promote solar water heaters. In fact, the cumulative effect of the small groups adds up to an impressive 20% of the total potential of the domestic sector, which is quite significant.

The last part of the questionnaire gave an indication of the main motivations that the domestic sector would be interested in. The results are shown in Figure 2.5 and this fully agrees with the previous analysis carried out; i.e. that the present financial scheme is not sufficiently enticing to encourage the widespread application of solar heaters.

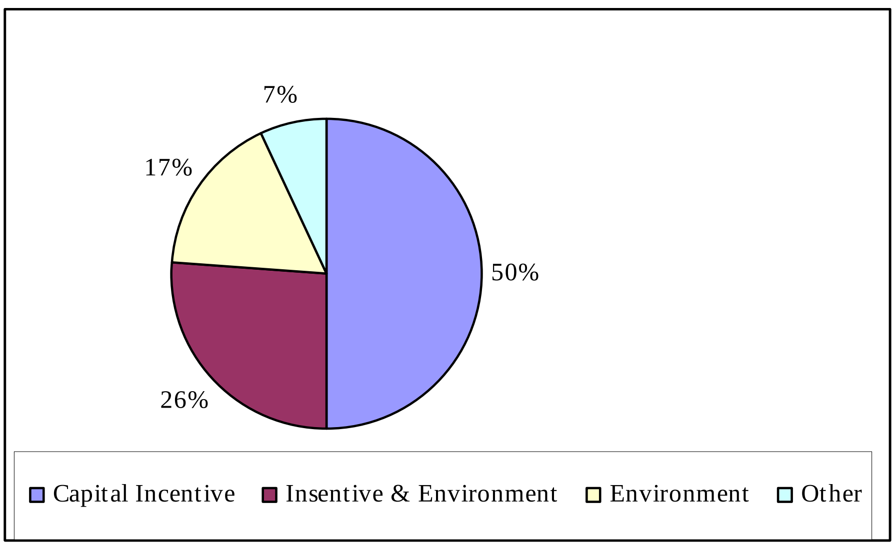

Figure 2.5: Pie chart of people’s primary motivation for buying a solar water heater [5].

This represents one of the most fundamental problems with environmentally-friendly practices. In order for people to adopt a technology such as this, it must be economically beneficial for them to do so. The fact that solar water heating technology is economically beneficial (due in part to the government subsidy), is something that must be conveyed to the public in order to generate interest. The economic analysis in the following section shows that purchasing a solar water heater can pay for itself in electricity savings in a few years. This means that using solar water heating technology is actually cost effective as well as being beneficial to the environment.

2.3 Life Cycle Costing Analysis and Environmental Benefits

An economical analysis based on life cycle costing was carried out for the three options of heating water, namely, the traditional electric boiler, a solar heater and a heat pump. Figure 2.6 shows the overall costs divided into capital and operational costs.

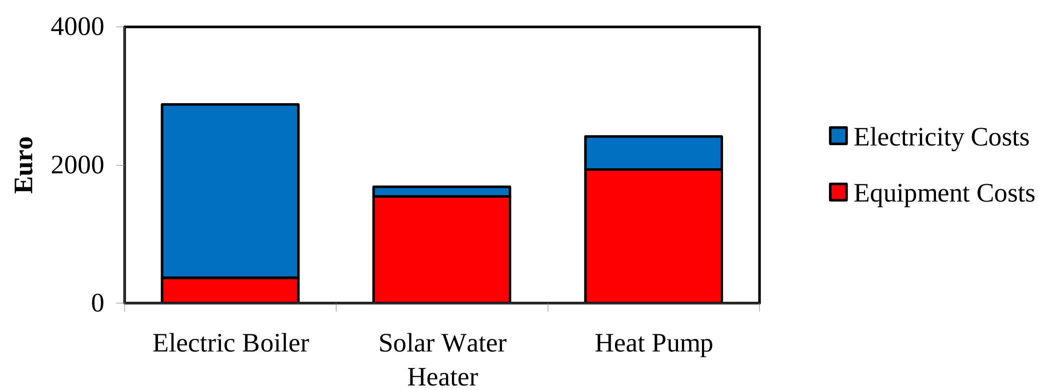

Figure 2.6: Life cycle costs for the three different options for heating water [5].

It is clear that although the capital costs are lower for a traditional electric boiler, the overall costs over a period of 10 years make it the most expensive option for heating water under the prevailing electricity tariffs of 2010. Solar heating offers the best option even without any government subsidy.

Naturally, a traditional boiler has no payback period because it only consumes energy, while a solar heater and a heat pump could pay back, since they essentially produce free energy. Table 2.2 shows a comparison of payback periods for a solar heater and a heat pump.

Table 2.2: Financial indicators and discounted payback periods for a solar heater (SWH) and a heat pump (ASHP) *without* government subsidy.

Heating Option	SWH	ASHP
Benefit – Cost (€)	1,189	466
Savings to Investment Ratio	1.97	1.25
Discounted Payback (years)	6	10+

If one were to include a Government subsidy on these two renewable energy technologies, it is realised that a reasonable payback period of 4 years may be reached if the Government subsidy is at least 60% of the total capital costs, as shown in Table 2.3.

Table 2.3: Effect of Government subsidies on the payback period of RE technologies.

	Solar Water Heaters			Air Source Heat Pumps		
Percent of Capital Cost (%)	Lifecycle Costs (€)	Benefit-Costs (€)	Payback (yr)	Lifecycle Costs (€)	Benefit-Costs (€)	Payback (yr)
0%	2,353	629	8	2,586	466	10+
20%	1,975	1,007	6	2,161	891	8
40%	1,598	1,385	5	1,736	1,316	6
60%	1,220	1,762	4	1,312	1,740	4

This is not farfetched since other countries are also investing heavily in subsidies to encourage households to use renewable energy technologies. In Australia for example, a subsidy of 1,000 Australian dollars are granted for a solar heater and 600 Australian dollars are provided for a heat pump [7].

With regards to environmental benefits, solar heating and heat pumps positively contribute to the reduction of the carbon footprint of households when compared to the present usage of traditional electric boilers, as shown in Table 2.4.

Table 2.4: Carbon dioxide savings of heat pump and solar water heating technologies, when replacing a traditional electric boiler.

Technology	Elect. Savings (kWh/year)	CO_2 Savings (kg CO2/year)
ASHP	1630	1432
SWH	1895	1664

2.4 Conclusions

The conclusions of this study may be summarized as follows:

- Solar heating is still very lightly utilised in Gozo (12.5% of households);
- The majority of households have adequate roof space to install a solar heater;
- Around 20% of households have no space or have shaded roofs and would therefore have to use a heat pump water heater, as an alternative to the traditional electric boiler;
- Both SWHs and ASHPs are economically and environmentally superior to traditional electric boilers
- Subsidies of at least 60% would be needed to bring the payback period of solar heaters and heat pumps to an acceptable level of 4 years (lower than the typical guarantee on the product of 5 years).
- Educational campaigns are needed to convince around 20% of households that are not interested in solar heating, to reconsider.

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3. PHOTOVOLTAIC SOLAR ENERGY POTENTIAL

Mule'Stagno L., Draper, B., Johnson, J., Pugh, T., and Sabo, J.

Photovoltaic (PV) technology is one of the proven technologies that can be implemented to reduce greenhouse gases. Advantages of PV electrical generation include the predictable output with respect to solar availability and the possibility of having modular systems that virtually fit in every area whatever the size may be. In such systems, there are no moving parts and therefore PVs are reliable and long lasting. Disadvantages include the relatively high capital outlay and the competition for roof space with other uses. There are several types of PV panels, but the most common ones (and those with the longest history) are those made from mono- or multi-crystalline silicon wafers. The main difference between the two is the slightly lower cost and lower efficiency of the latter – therefore requiring more roof space (typically 10-20% more) per kilo-Watt peak (kWp) installed. A third available type, thin film PVs, has the disadvantage of either lower yield (amorphous silicon), or of being relatively new technology with potential recycling issues at the end of the material lifetime (CdTe and CIGs). In the long term these latter materials might be attractive when these issues are resolved because they offer a lower cost per unit of electricity generated, but so far mono and multi-crystalline silicon panels are dominating the market, including that in Malta. Typically, these kinds of panels require about 15 m^2 of roof space per kWp (taking into account allowances to avoid cross-shading of one string of panels on the next group behind them).

Gozo, like the rest of Malta, has the highest level of insolation in the EU and over 1,400 kWh could be generated per unit kWp installed [1]. A typical household installation of 1.5-2 kWp will therefore generate 2,000 – 2,500 kWh per annum reducing around 2,000 kg of CO_2 emissions per year or the equivalent of that absorbed by about 100 trees [2]. It would therefore make sense to maximize the number of installations on homes and businesses. Since these installations would be relatively small (1-100kWp), the power generated should not disrupt the energy grid and transmission losses would be negligible since the power would be consumed close to where it is generated.

It was estimated that Gozo has 2-3 km^2 of available rooftop space. As mentioned earlier, the useful roof space is only that part that is unshaded for most of the day. Therefore, for example, on the typical Gozitan house the roof has a 0.83 m perimeter wall and the panels cannot be installed closer than 2 metres to the perimeter to avoid over-shadowing. Also, any higher buildings to the South, West or East of the roof in question will limit the productivity of any PV installation on that roof, making it uneconomical. Taking these factors into account for Gozo, the unshaded roof space available for PV installations is estimated to be closer to 1 km^2. This would put the theoretical maximum installed capacity in Gozo at 67 MWp, which would generate an estimated 100 GWh per annum compared to Gozo's total annual consumption is of 73 GWh in 2007 [4]. This means that Gozo's rooftops could generate enough electricity for the island and even export surplus to Malta.

A realistic target of installed capacity depends on various factors including the incentives available, the cost of the technology, the public's openness to these technologies and the important pre-requisites of having a solar water heater and becoming energy efficient. The former makes sense because a solar heating system is three times more efficient, and four times less expensive than an equivalent photovoltaic system producing the same equivalent amount of electricity to heat water. Naturally, one will need to leave space on the roof for installing such solar heaters. Hence, if one assumes that PVs could be installed on 10% of the available rooftop, this would result in a generation of approximately 10 GWh per annum, or 14% of Gozo's total power consumption. If appropriately incentivized, this level could be significantly higher.

Currently, the Government is offering a feed-in tariff of € 0.28 for electricity generated from PV systems installed in Gozo. At current PV prices the straight payback period (not taking into account cost of capital) for such an installation in Gozo, is under 5 years if the buyer obtains the 50% (€ 3,000 maximum) Government grant (Figure 3.1).

Without Government grant, even if prices continue showing some decline as they in fact appear to be doing, the payback period would still be on the order of 7 to 8 years. A more attractive feed-in tariff is probably needed to encourage more people to install PV panels on their roofs to approach the level of installations mentioned above. This is the trend that has been followed and successfully implemented by the majority of EU Member States.

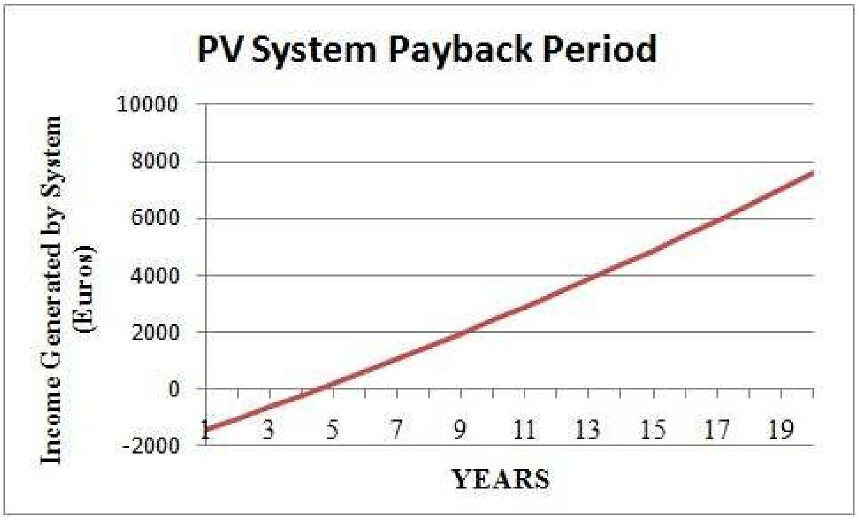

Figure 3.1: Income generated per year for a PV system installed in Gozo. Assuming 0.28c/kWh FIT, an average price of €3650/kWp and 50% Government grant on purchase price [3].

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4. WAVE ENERGY POTENTIAL

Mule'Stagno L., Draper, B., Johnson, J., Pugh, T., and Sabo, J.

While wave energy generation is not yet a mature technology, it is coming of age and there is currently an increased level of interest in this technology. Various pilot installations have been installed around the world and there are plans to expand to full full-scale wave-farms. While waves in the Mediterranean tend to be of lower intensity than those in other seas, there is still potential for testing new technologies in the field that could bring the cost per kWh down to a more competitive price, when compared with other renewable sources and possibly even with traditional fossil-fuelled electricity.. This is because the technology may be scalable – since the marine space is relatively large and the technology itself has a low visual and environmental impact. The main disadvantage is that most technologies are still new and fairly unproven, and are limited by sea depth (though these technologies can be installed in much deeper waters than offshore wind turbines)

There are currently dozens of companies working in this field. The technologies are broadly subdivided into four main categories, as follows:

1. Terminators are anchored to shore and capture or reflect the power of wave energy by moving perpendicular to the direction of the wave.
2. Attenuators float on and move with the waves, and generate electricity by offering resistance to the wave or by taking advantage of the change in height provided by the wave.
3. Point absorbers also float on the waves and generate electricity by taking advantage of the up-down motion, but they do so at a fixed point (like buoys) rather than by undulating with the waves like attenuators (which are more like hinged rafts).
4. An overtopping device has a large reservoir that becomes filled by incoming waves to a higher level than the surrounding sea or ocean. The water's energy is converted to electricity when it is then released.

The last three technologies could potentially be applicable in Gozo. Terminators, having to be anchored to shore provide both environmental and logistical issues since the likely best location for wave generation in Gozo has a cliff face.

A wave farm should ideally be positioned in shallow regions that are close to shore but at the same time, experience high waves. The best location in the sea around Gozo therefore seems to be the North-West region which has the highest waves closest to shore [1]. The land facing that direction of the sea is sparsely populated, while the earmarked area is far from any major shipping routes. Figure 4.1 shows the average height of waves around the Maltese Islands, where a given wave height (1 m, 1.5 m or 2 m) is exceeded at least10% of the time [1].

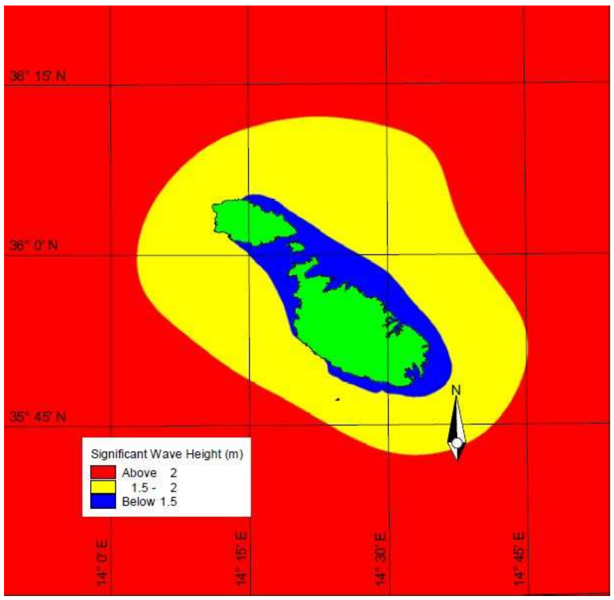

Figure 4.1: Average wave heights around the Maltese Islands (Blue – less than 1.5 m, Yellow – 1.5-2 m and red – greater than 2 m) [1].

The hurdle that would have to be overcome would be in power transmission since no high voltage power lines cross Gozo [2], as shown in Figure 4.2. However, if tests performed at this site prove that this technology is promising, this should not be an insurmountable problem.

Given that the technology is modular, and the space is not limited, it is conceivable to have a 5-10 MWp park or even larger. Since not much data is available it is difficult to predict the exact amount of electricity generated, but it is conceivable that such a wave farm around Gozo could produce 5 to 20 GWh or 7-28% of Gozo's total consumption. Photo-montages have been produced as shown in Figure 4.3 below.

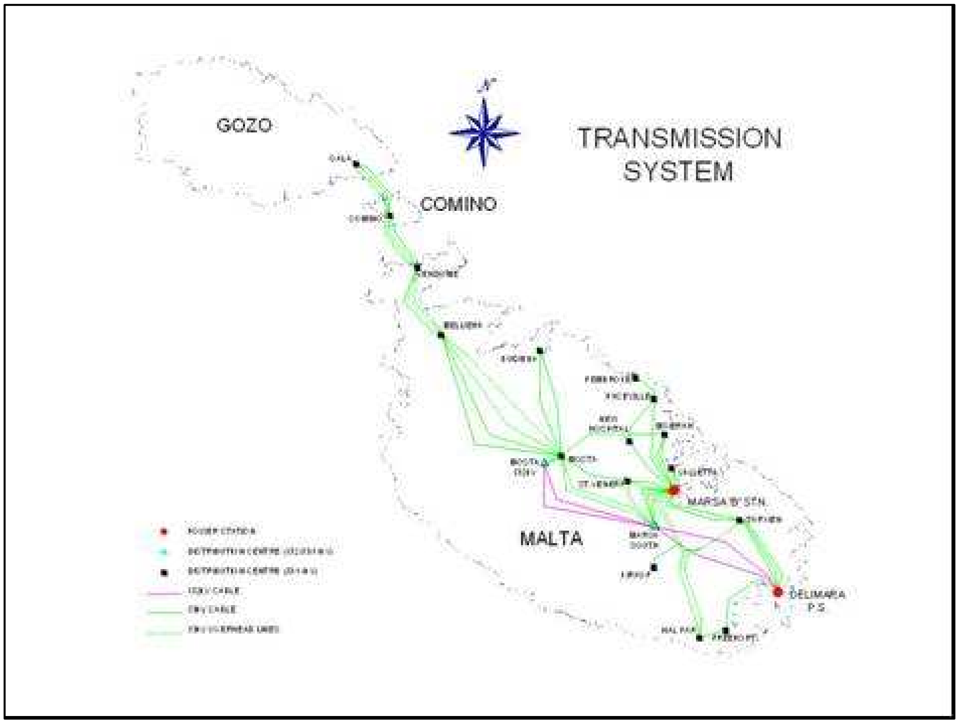

Figure 4.2: The main high voltage electricity transmission lines for the Maltese Islands [2].

Figure 4.3: Photo-montages of what different types of wave farms could look like at the North-western sea off Gozo [3].

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5. WIND POWER TO COMPLEMENT THE ECO-GOZO INITIATIVE: A CASE STUDY ON TECHNICAL ASPECTS AND SOCIAL PERCEPTIONS

Cochran K., Fox J., McHarg M. and Williams E. and Farrugia R.N.

5.1 Desk-based Research

The 2010 wind study commenced by identifying locations on Gozo that could be suitable for the installation of wind turbines. Two general areas were identified for further investigations, primarily due to their significant land area and due to their exposure to the regional prevailing winds. The first was an expanse of land on the south western end of the island of Gozo, roughly west of the villages of *Kerċem* and *Santa Lucia*. The other area was north west of the village of *Għarb*. At an early stage in the project study, a decision was taken to focus on the former site due to the availability of a wind parameters database from one of the ISE's wind monitoring stations on site.

The small scale of the Maltese islands, the high population density, intense land use and their cultural and historical backgrounds make them unique in their own way for such case studies. The research work focused on estimating wind resources, on current developments in the wind industry, on energy yield from selected wind turbines, and on issues that are typically related to wind project development. Likewise, local policies that may be applicable to the case study in question were noted.

5.2 Fieldwork: Identification of Ongoing Activities and A Constraints Mapping Exercise

In the initial phases, the research focused on field work at the site of interest. In cases where the case study is dealing with larger-scale wind projects, the students were not only taken on site, but were expected to venture further afield in order to get a broader perspective of the task at hand. During this phase, one is expected to identify key vantage points from which one may assess the extent of the site under consideration, to recognize current activities that are underway in the general area, and to earmark other points of interest. On completion of the first phases of fieldwork, the group then retire to map out all of these aspects in order to create a land use and constraints map. This exercise defines the boundaries and limitations for the hypothetical wind farm. During the visit to *Kerċem*, the group identified a number of ongoing activities with the main site characteristics outlined as follows:

- agricultural landscape with typical terraced fields surrounded by rubble walls interspersed with tracts of untended land;
- limestone quarrying and stone crushing for aggregate underway at two distinct and separate areas;
- urban areas: particularly the villages of *Kerċem* and *Santa Lucia*. The site was also visible from the main town of *Rabat* and from the *Ċittadella*, the old fortified citadel, amongst other more distant urban areas;
- a few farmhouses dotted the area; with the closest on the outskirts of *Kerċem* and in the nearby valley;
- the area may be considered one of natural scenic beauty with protected cliffs on the seaward boundary of the site. The site is also partly visible from *Dwejra*;
- a rock pool called *L-Għadira ta' Sarraflu* is classified as a protected area;
- historically significant remains exist at the farthermost western extremity of the site;
- a fireworks factory is located in the area;
- a VHF Omni-directional Range Navigation System (VOR) that allows aircraft to navigate safely from point to point was identified as one of the major constraints on the site.

The main activities (or constraints as appropriate) were then mapped out on a topographical map with buffer zones superimposed around towns and villages, industrial activities, cliffs and areas of historical/archaeological significance according to level of interaction or conflict with a hypothetical wind farm. The remaining 'available' area allowed for two wind turbine arrays with different-sized wind turbines to be prepared.

5.3 Quantification of Wind Resources

The site in the vicinity of *Kerċem* is located high on the cliffs of Gozo's south western coast, making the area particularly exposed to the prevailing north-westerly winds that dominate the central Mediterranean basin. A wind monitoring station managed by the ISE was operational at this very location some years ago and an earlier undergraduate dissertation [2] had explored different statistical techniques in order to present a wind climatological fingerprint for the area, with the main findings subsequently being published in a paper [3]. The 2010 wind group used the wind speed frequency distributions extrapolation methodologies developed by Fernandez Naveira [2] to estimate wind speeds at the hub heights of the wind turbine models earmarked as suitable for the 2010 case study at *Kerċem*. Three different wind turbines were shortlisted in order to have different-sized machines. Figure 5.1 shows the wind speed frequency distributions for various projected heights above ground level.

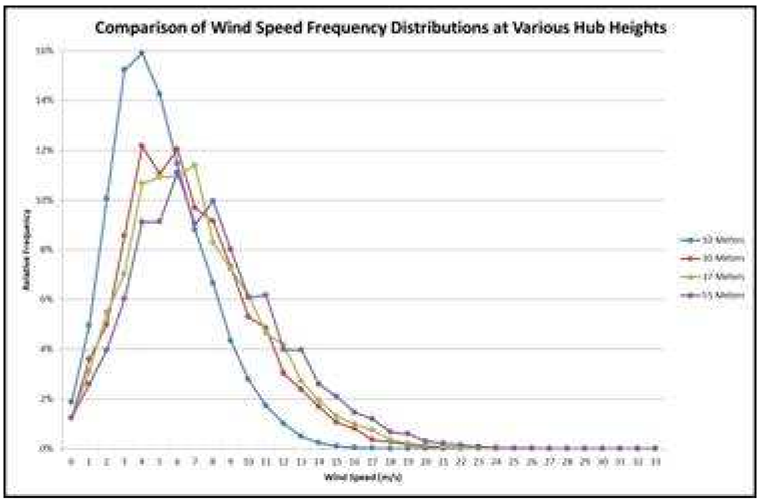


Figure 5.1: Wind speed frequency distributions generated for heights of 10, 30, 37, and 55 metres above ground level [1].

5.4 Wind Turbine Options

The wind team carried out a number of evaluative procedures on wind turbines rated at 100, 330 and 900 kW; these having hub heights of 30, 37 and 55 metres respectively. The main results of these analyses are illustrated in Table 5.1 below, that show two scenarios; one for an array of small turbines, the other for a smaller array with larger wind energy generators. A photomontage was also prepared to illustrate the general appearance of a particular wind turbine array in the landscape (Figure 5.2).

Table 5.1: Indicative annual energy yield and emission reductions coming from wind farms with small (100 kW) and large (900 kW) wind turbines assuming a 25% capacity factor. This factor was assumed to apply to all

machines in the arrays. The estimated CO_2 annual emissions reductions from such installations are also listed [1].

Turbine Rating [kW]	**Number of Turbines**	**Annual Energy Output (MWh)**	**Annual Reduction in CO_2 Emissions (tonnes)**
100	34	7,446	6,539
900	8	15,943	14,001

Figure 5.2: Photomontage showing a wind turbine array using the larger wind turbine version scaled on the *Kerċem* landscape. The photo was taken almost at the westernmost extremity of the site looking roughly towards the East. The cliffs and the entrance to *Xlendi*, a small seaside locality on the south coast, may be seen on the right hand side of the picture. The island of Malta is just visible in the far background [1].

5.5 Social Perceptions and Popular Awareness

5.5.1 Public Opinion Poll

Wind turbines are perceived to be futuristic, to generate clean energy from a renewable resource and to reduce CO_2 emissions. However, development comes at a cost and wind farms are no exception. Environmental issues such as visual impact, interaction with flora and fauna, and noise are amongst the more frequently-encountered topics that invariably crop up whenever wind project development is considered. Part of the Wind Team's task focused on public perceptions of a wind farm in the vicinity of *Kerċem* and the report also outlined a number of proposals to generate more awareness, to inform and disseminate information on the various benefits and impacts related to such a development.

Part of the study on public perceptions involved the preparation of a number of questions to feel the pulse of people in this respect. The poll was conducted at the ferry terminal at *Ċirkewwa* in Malta on persons waiting to cross over to Gozo; in this way sampling people visiting the island for a day or more. Other respondents were interviewed at the main square (*it-Tokk*) in Victoria so as to get feedback from Gozo residents. Finally, interviews were conducted at the *Ċittadella*; the respondents being mainly tourists visiting on a day trip to the island. The interviewees therefore included Gozitans, Maltese visiting the island as well as tourists. A selection of results is presented in the following section with the questions and responses from locals and tourists placed side by side for comparison purposes [1].

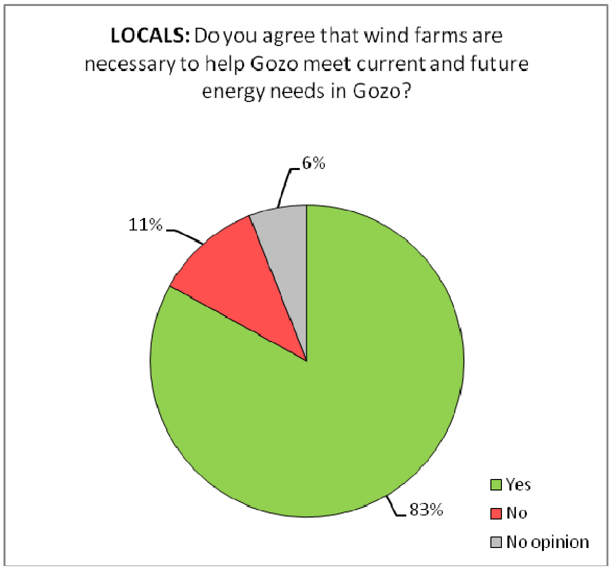


Figure 5a: When asked whether wind farms are necessary to meet Gozo's energy needs, the large majority of locals were in favour [1].

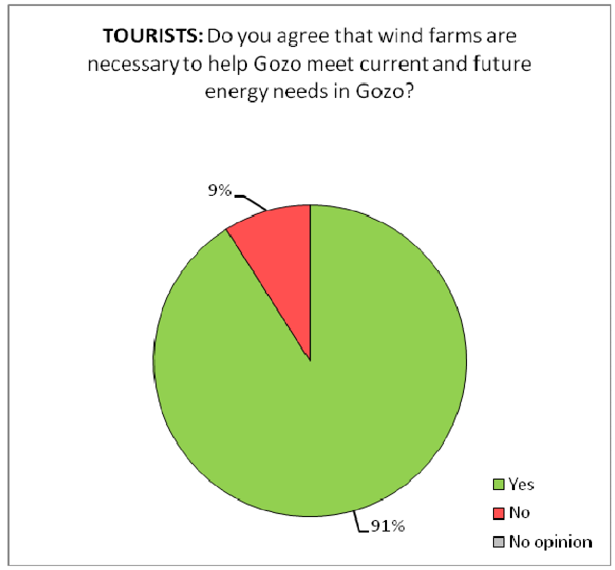


Figure 5b: A larger majority of tourists were of the same opinion [1].

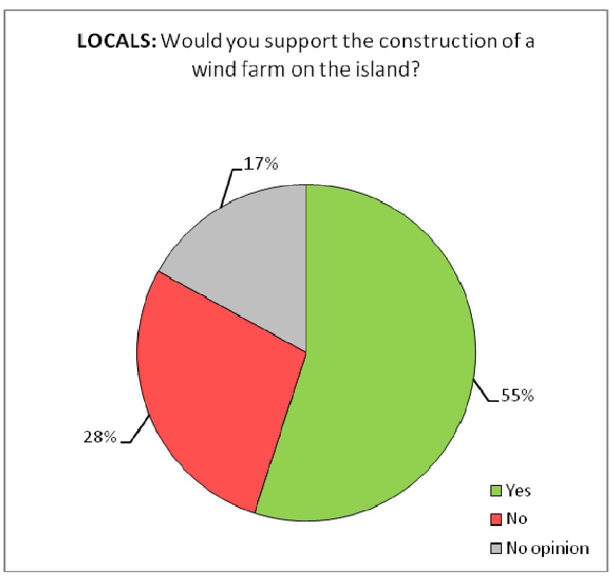


Figure 5c: 55% of all locals interviewed would support the construction of a wind farm on Gozo, whilst 30% were against. 17% had no opinion [1].

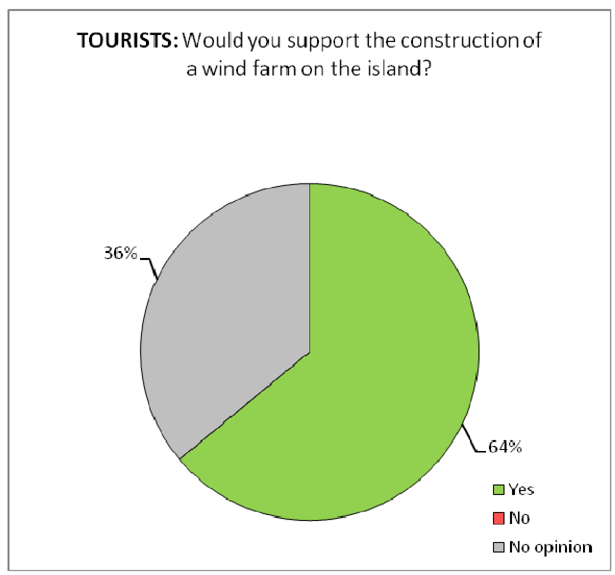


Figure 5d: Tourist response to this question resulted in 64% being in favour of WF construction on Gozo and 36% had no formed opinion; these generally agreeing that it was more important to gauge how the locals felt [1].

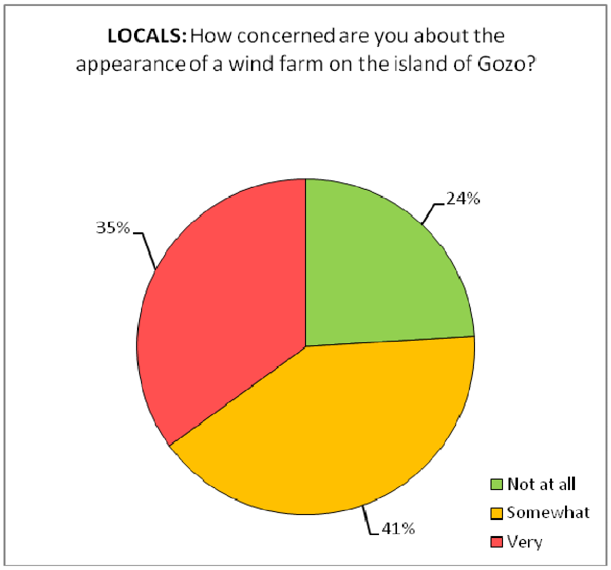
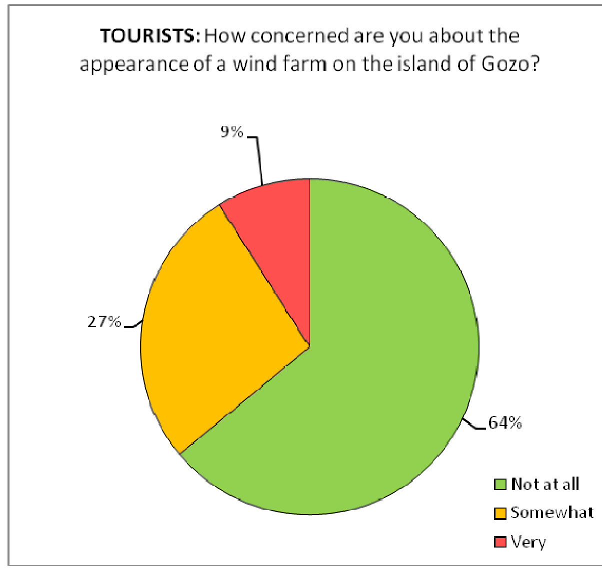


Figure 5e: Concerns about the visual impact of a wind farm on Gozo were explored with this question. 24% of respondents were not concerned, 41% were somewhat concerned and 17% had no formed opinion [1].



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gure 5f: The larger majority of tourists were not concerned about appearance, with a lesser percentage being somewhat concerned about such a development [1].

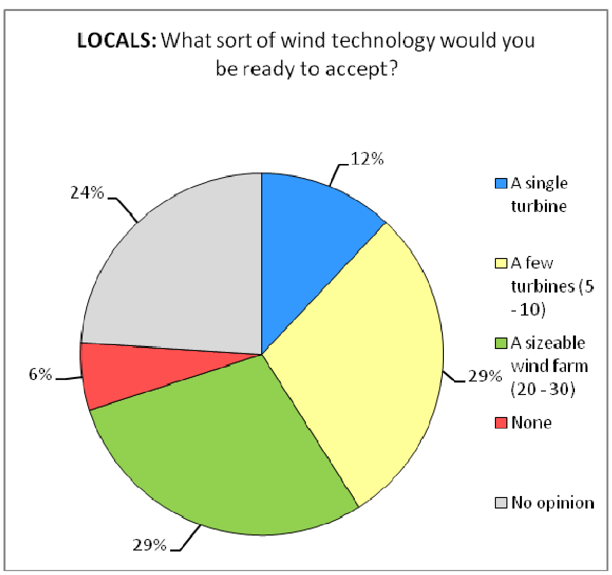

Figure 5g: The response of locals interviewed to gauge perceptions of acceptable technology penetration levels were in favour equally of a few turbines (5 to 10 machines) and a sizeable wind farm (with 20 to 30 machines). Only 6% were not ready to accept any turbines at all; although 24% had no formed opinion on the matter [1].

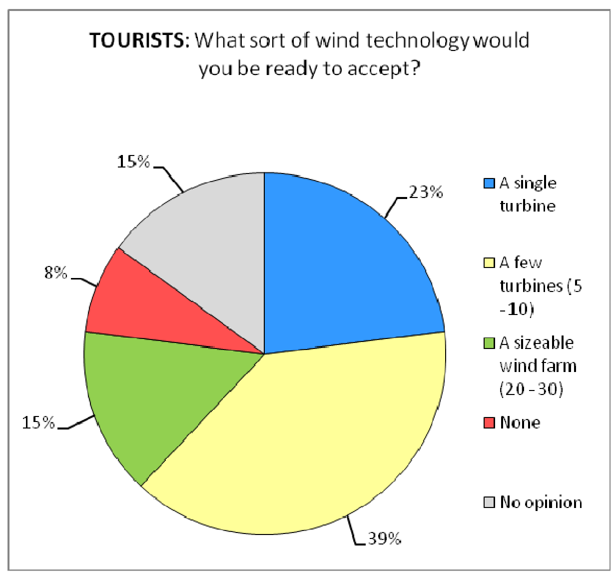

Figure 5h: As for tourists/visitors, the larger percentage were in favour of a few turbines, 23% were in favour of a single machine, and 15% a sizeable wind fam. 8% were not ready to accept any turbines [1].

5.5.2 Dissemination of Information

Creating awarenss on environmental responsibilities is essential if the general public is to be informed on the advantages and limitations of RE technologies; a prerequisite that is also true in the case of wind power technologies. The study identified different levels of dissemination of information targeting students and adults. Inclusion of information in school curricula was recommended at primary and secondary school levels to target students. Wind and environment-related projects and art competitions are two of the suggestions for the younger students. At secondary school level, group projects, essays, and other similar activities could be useful tools that generate awareness and more knowledge.

Informing the current generation of adults may be more demanding because their views are generally already formed and as they are also out of the formal educational system. The need to reach such citizens from different walks of life and in different age groups requires other tools such as brochures, websites, billboards and last but not least the media. One of the Wind Team members focused specifically on the preparation of a lesson plan for students and on the preparation of a brochure focusing on the *Kerċem* wind case study. This leaflet presented information on the role of wind energy in a diversified and sustainable energy mix, highlighting details on the benefits and challenges of wind energy projects as well as presenting results from the public opinion poll conducted by the group and presented earlier in this summary. An important aspect that is worth mentioning is that once a wind farm is operational, the need for information and education remains. At such a stage, tours to the wind farm could be one way of exposing and attuning the public to the technology.

5.6. CONCLUSIONS

This study had selected *Kerċem* as a candidate site for a number of wind turbine arrays. Different wind turbine sizes were selected and the arrays were designed according to the lie of the land and other site-specific conditions. The utilisation of the larger machines would appear more advantageous, although a number of technical and infrastructural challenges do exist such as the need for more detailed studies on the availability of specialised equipment for the wind equipment transportation, installation and operation. Site access and grid network capabilities are likewise very important and critical issues. The smaller turbines would redress some of these issues, although the energy generated would be approximately half of what their larger counterparts would produce. In view of the various constraints, particularly the presence of the VOR beacon, the road access constraints, and the electrical distribution grid, more detailed studies are required in order to determine the suitability of the site at *Kerċem* as a potential wind farm location for Gozo.

Acknowledgements

The 2010 Wind Team would like to acknowledge the support of Ing. R. Galea from Malta Air Traffic Services.

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6. BIOFUELS POTENTIAL FOR TRANSPORT

Weissenbacher M., Frankenfield S., Jennings R., Pearson C. and Smith E.

The purpose of the biofuels project was to estimate if the island of Gozo could sustain itself in terms of transport energy needs through the use of biofuels derived from materials on the island. Raw materials considered included plant biomass from dedicated fuel plants such as rapeseed, oil palm, hay, Chinese tallow, jatropha; livestock waste from cows and pigs; and waste cooking oil from restaurants and hotels.

Potential yields from these resources were in turn compared to Gozitan energy consumption in the transport sector. The project was a mix of a desk and a field study in which data retrieved from official reports and statistics as well as various academic journals have been combined with information obtained through interviews of Gozitan farmers, drivers, fuel station operators, and restaurant owners. The interviews with drivers and fuel station operators were to reveal the general attitude towards biofuels, including price expectations. The interviews with restaurant owners were to indicate the quantities of waste cooking oil available for biodiesel production. The interviews with farmers were to explore the entire energy and price structure of agricultural operations on the island, including electricity and fuel consumption as well as the extent of feed and fertilizer sourced locally compared to the quantities and price of imports.

Gozo occupies 67 km^2, of which about a third is considered arable land or land that is suitable for agricultural use, according to the National Statistics Office’s Agricultural and Fisheries Report of 2008. Population numbers have steadily increased during the past decades to reach some 30,000 permanent residents. Energy consumption for transport according to official figures of liquid fuels delivered to Gozitan petrol stations amounted to 6.1 million litres of gasoline and 7.0 million litres of diesel in 2008. This translates into an energy consumption of 524 million MJ.

The maximum theoretical biofuel supply from dedicated fuel plants has been estimated in case all arable Gozitan land were dedicated to biofuel production. Biomass yield per acreage figures were used as reported in academic journals for other settings, while any potential site-specific limitations (including nutrient and water supply, soil and climatic conditions) were ignored for this estimate. Yields per biomass in terms of output of bioethanol (to replace gasoline) or biodiesel (to replace fossil diesel), were estimated according to factors reported in journals, and the lower energy content of bioethanol compared to gasoline, and biodiesel compared to fossil diesel, was taken into account to assess the potential fossil fuel energy replacement.

Methane produced from livestock waste and biodiesel produced from waste cooking oil were included in this study to represent biofuels that can be made from resources already in existence. The National Statistics Office reports the total Gozitan cattle herd to count some 5,800 animals (distributed on nearly 60 farms), while there are about 4,500 pigs. Waste per animal and methane output per waste factors as reported in academic journals were used to estimate the total potential energy content of the final fuel. No reliable figures were available in terms of waste cooking oil generated on Gozo within this limited study. Based on information provided by individual restaurant owners, a scenario was chosen to estimate the energy potential of this resource by assuming that about 110,000 litres of waste cooking oil were available from hotels and restaurants. Conversion factors from waste cooking oil to biodiesel were used as reported in journal articles. Note that this entire study was an estimate of energy content in biofuels potentially produced from local resources, while energy inputs in biofuels production have not been taken into account.

Figure 6.1: Hay bales left wrapped up to ferment on a Gozitan farm. Cattle feed production of this kind would compete for raw material suitable for the production of second-generation bioethanol that serves as gasoline substitute [1].

Compared to the annual Gozitan transport energy consumption of 524 million MJ, it was estimated that the maximum theoretical energy content of biofuels yearly produced from local resources would be 161 million MJ for hay (second-generation bioethanol), 454 million MJ for oil palms (biodiesel), 114 million MJ for jatropha (biodiesel), 58 million MJ for livestock waste (methane), and 3.7 million MJ for waste cooking oil (biodiesel). The other oil-rich fuel plants under consideration would yield substantially less biodiesel than oil palms and jatropha.

The above figures indicate that current Gozitan transport needs cannot be fully met through biofuels produced from the local resources considered. Higher yields may be possible some time in the future through third-generation biofuels (produced from algae) or generally from aquatic resources.

Figure 6.2: Animal waste stored on a farm on Gozo. It is applied as fertilizer on the fields to minimize the import of expensive industrial fertilizers. Alternatively, such animal waste can be used to produce methane for transport or other energy purposes, but fertilizer imports would inevitably go up. Imported fertilizers are energy-intensive in terms of their production, and their increased application on the island would lead to a rise in energy consumption elsewhere [1].

6.1 Conclusions

While biofuels production and use would contribute to making Gozo a more sustainable place, this biofuels potential estimate also stressed the limitations of the concept of an “eco-island” as such. The defined physical borders of an island indicate more clearly than any national border between neighbouring countries that populations living in one area ultimately burden environments in other areas in a trade-connected world [2]. Gozitans import much of their food and devote much of their land to the production of hay and sorghum to feed dairy cows. The trade-off between using land to produce food, feed, textile-fibres, building materials or biofuels extends to areas far beyond the island itself and so does the impact of overall lifestyles enjoyed on Gozo. Even freshwater is being imported to somewhat help Gozitan farmers overcome what remains the most obvious limitation in terms of increasing the agricultural output. Fertilizers and animal feed are also partly imported, and if farmers would stop using animal waste as fertilizer (turning it into methane for energy consumption instead) such imports would increase. What is more, the transport of people, goods and materials to and from the island consumes a lot of energy, but was excluded in this study.

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7. THE POTENTIAL ENERGY SAVINGS FROM INSULATING RESIDENTIAL ROOFS

Fsadni M, Miller G., Mills C. and Rupnik B.

7.1 Introduction

Malta has adopted the goal of reducing CO_2 emissions 5% by 2020, and further by up to 80% in 2050 compared to the 1990 level [1]. It is estimated that 40% of primary energy in Malta (as it is in Europe) is used for heating and cooling of buildings. The use of air conditioning is increasing steadily leading to increased use of electricity with corresponding increases in emissions from power stations. The largest component of the heat exchange in buildings occurs through roofs, which can easily be reduced by insulation, to lower the overall heat exchange coefficient or U-value. The Technical Guidance F requires that roofs have a U-Value of 0.59 W/m^2K [2].

This project focused on the potential energy and economic benefits of installing roof insulation on residential buildings in Gozo in compliance with the new building regulations, while maintaining thermal comfort in the buildings.

7.2 Weather Conditions and Thermal Loading of Roofs

Weather conditions in Malta are such that some heating and cooling is necessary. For instance solar radiation reaches 8 kWh/m^2day in summer, resulting in roof surfaces heating up above 50^oC [4], which is far higher than ambient air. On the other hand, evaporative cooling of the roof surface as a consequence of dew or rain, especially in winter, results in surface temperatures lower than that of ambient air. This coupled with the large roof area contribute to high heat exchange, which can be decreased by reducing the U-value of roofs.

In previous work, analysis of the hourly thermal loading of a test roof in Malta showed that the air temperature inside the building is at the limit of thermal comfort [5]. In Malta people heat and cool rooms only when they are occupied, so it was then assumed that this was done for two hours in the morning, two hours at midday, and seven hours in the evening (referred to as ***partial*** value). Heating was assumed to take place from 1st December to 30th April and cooling from 15th June to 30th

September. The temperature differences were summed up for these intervals for each day within these periods. A summation was also done for the full day during the heating and cooling 'seasons' (*full a/c)*, representing the upper limit [4]. The results are given in the Table 7.1:

Table 7.1. Heating and cooling degree hours (Kh) [4]

partial a/c	full a/c
19000	37000

7.3 Roof Structure and Insulation

Buildings can be divided into vernacular and modern which have different roof structures. The heat exchange rate between the roof surface and the inside air was calculated to be 2.08 and 2.31 W/m^2K for modern and vernacular roofs respectively [5]. Assuming that 75 % of buildings are modern the average value for all buildings would be 2.14 W/m^2K.

Roofs are insulated by means of EPS board or spray-on foam. For this study it is assumed that existing buildings can be insulated with EPS board and an additional layer of screed to reach the required U-Value of the Building Regulations, i.e. 0.59 W/m^2K. In calculating the heat exchange between the roof surface and inside air, the value becomes 0.6 W/m^2K.

7.4 Residential Buildings and Estimation of the Total Roof Area

The total number of dwellings in Gozo is 10,719 of which 1,150 are flats, while 511 are maisonettes [6]. Preliminary estimates show that 2910 residences (flats, maisonettes etc.) may have no exposed roofs, which brings the total number of exposed roofs to 7809.

An estimate of the average roof area of one residence was made by examining aerial pictures from *Google Earth* for a number of towns in Gozo and using the inbuilt ruler to measure-up the plan area of a number of houses. The majority of roofs ranged from 12 x 6 m, to 24 x 6 m so that an average roof size was taken to be 18 x 6 m, or 108m^2 which are realistic dimensions for a terraced house with a frontage of 6m [8].

During an excursion to Gozo the built-up area surrounding the Citadel was observed and photographed. This showed that 40%, 60% and 20% of buildings had a washroom, shaft and internal yard respectively, which reduce the roof area for heat exchange. Effectively an equivalent area of 5m^2 had to be deducted from the representative roof area to bring it to 103 m^2. The total roof area in Gozo could then be estimated by multiplying the total number of roofs and the representative roof area. This would result in a total of 804,327 m^2 [8].

In view of the wide variation of individual roof areas, another method was used to calculate total roof area using aerial images in *Google Earth* and the ruler measurement tool of the program. The images of eleven towns were examined and the built-up areas were measured, block by block for the whole town. The resulting total area was 736,594 m^2. From these two estimates an average value of 770,460. m^2 was taken for further calculation [8].

7.5 Results and Cost analysis

The cost of installing insulation on all roofs was estimated from quotations, from local suppliers, giving the price of insulation material to be around 10€/m^2, while the cost of installing the insulation in the roof varied between 16.74 €/m^2 and 4.09 €/m^2 for the foil, screed, and labour.

The electricity consumption depending on level of air conditioning used were estimated. A medium tariff of 0.173 Euro/kWh [7], was assumed to calculate the total cost of electricity consumed for heating and cooling.

The cost of insulation, electricity consumed assuming a discount rate and an electricity escalation rate of 4% and a 20 year life cycle were used in the cost analysis. The benefit-cost (B-C), savings to investment ratio, and discounted payback time were calculated. The cost of insulation and installation for the two price value were calculated to be [8]:

low rate at 14.09 €/m^2	high rate at 26.74€/m^2
10,8532,289. €	20,597,370. €

The amount of heating and cooling needed to offset heat losses and gains through all roofs is the heat exchanged, obtained by multiplying the UA values by the total heating and cooling degree hours. The electricity needed by a/c units is given by the heat exchanged divided by the Coefficient of Performance (COP assumed to be 3) of the a/c units. The annual electricity use in MWh for heating and cooling are [8]:

roof	not insulated		insulated	
a/c	limited	full	limited	full
Total (MWh)	9,269	18,050	2,731	5,320

The total cost in Euro of the electricity needed at the rate of 0.173 €/kWh would amount to [8]:

roof	not insulated		insulated	
a/c	limited	full	limited	full
Year 1 (€)	1,603,549.	3,122,700.	472,625.	920,375.

The life cycle costs, benefit-cost and payback may then be calculated as [8]:

roof	not insulated		insulated			
insulation cost			low	high	low	high
a /c	limited	full	limited		full	
Life cycle cost (€)	32,070,992	62,434,013	20,305,791.	30,049,872.	29,260,793.	39,004,874.
B – C (€)			11,765,201.	2,021,120.	33,193,220.	23,449,139.
Payback (years)			10	19	5	10

The results are presented graphically as shown in Figures 7.1 to 7.3 below [8]:

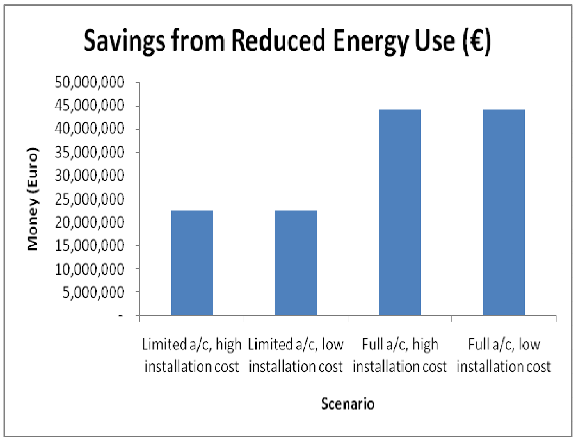

Figure 7.1: Total savings with insulation [8].

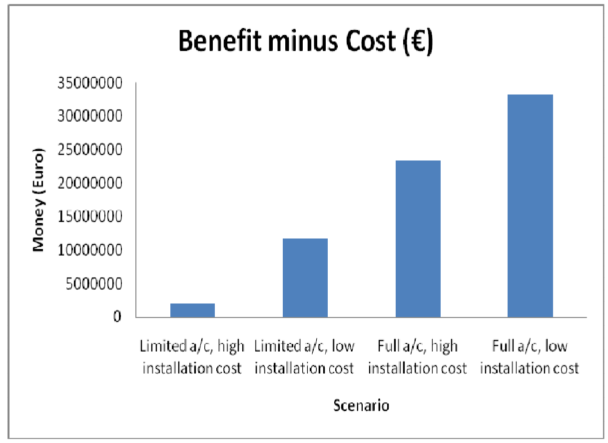

Figure 7.2: Financial feasibility of insulation [8].

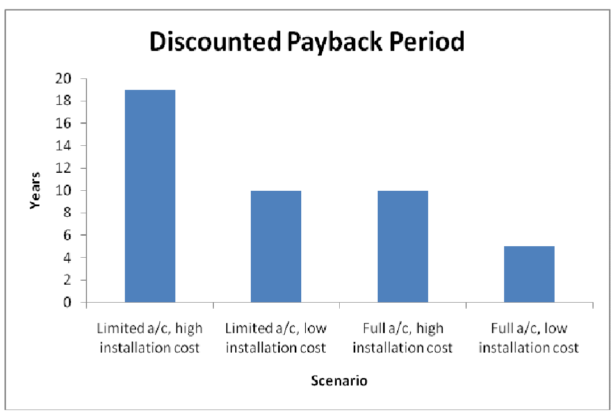

Figure 7.3: The payback periods of the cost of insulating the roofs [8].

7.6 Discussions and Conclusions

The results show that with limited a/c use and high installation costs the payback period is appreciably long at 19 years and the B-C value is low. Once the costs of installation are reduced, the payback period becomes more acceptable at 10 years and the B-C value also improves appreciably.

With full a/c use an acceptable payback period results even with high installation costs and the savings to investment ratio is appreciable. Of course with full a/c use and low installation-costs the shortest payback period (5 years), the highest B-C cost and highest savings to investment ratio is achieved.

The installation of insulation on the roof always pays back even if a wide range of periods result from the different scenarios investigated. On the level of the whole of Gozo the savings assume national importance both financially and environmentally.

It is recommended that:

1. a more accurate estimation of roof area should be carried out using detailed area plans,
2. a closer examination of the costs quoted by different suppliers and contractors should carried with a view of having more 'standard' values,
3. the role of government grants or incentives for installing roof insulation should be examined.

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8. CONCLUSIONS

This paper demonstrated that renewable energy can take a significant role in reducing the Island of Gozo's carbon footprint and thus contribute to a better and cleaner environment and a more sustainable lifestyle. Meanwhile, energy efficient measures such as rooftop insulation of dwellings could also lead to a better quality of life and a reduced energy bill.

Renewable energy sources need to be evaluated holistically, including technical, social, and economic aspects. Some technologies are commercially available today, others will mature to contribute in the future, and often different types of technologies complement, or substitute others. For instance, biofuels made from local resources may not be sufficient to meet all the needs for transport fuel on the island, but surplus electricity from photovoltaic and wind energy systems could be used to charge electric cars and hence reduce the need for fossil fuel the transport sector.

Energy efficiency measures must go hand in hand together with the introduction of renewable energy systems. Without energy efficiency, energy – even if it comes from a renewable source – could be wasted. On the other hand, a focus on energy efficiency alone would not be sufficient to make Gozo as an Eco-Island, because the concept implies that we should rid ourselves entirely from the limitations and environmental burden of fossil energy.

There is no one solution for achieving sustainability in an island scenario, but this paper indicates that much could be accomplished given a certain level of government determination. The next step would be to produce a roadmap towards a more sustainable Gozo, which would make the island a beacon of sustainable development in the Mediterranean region that has experienced different forms of over-exploitation and unsustainable depletion of its resources throughout history.