LifeMedGreenRoof Project
Socio-Economic Report

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LifeMedGreenRoof Project - Assessing the potential socio-economic impact of adopting Green Roofs in Malta.

Executive Summary

The main goal of the LifeMedGreenRoof Project is summarised in the Project's Title:

"Constructing two demonstration green roofs to illustrate the potential of meeting environmental and energy targets."

The purpose of the Demonstration Green Roofs is to show to policy makers, architects, and other professionals, students and the general public what a green roof could look like and to highlight the benefits that they are able to provide. Recent studies carried out abroad have indicated that significant socio-economic benefits can derive from the installation of green roofs and there is no reason to suppose why similar advantages would not benefit Malta.

However, this report asserts that in contrast to many other countries, the interest in green roof technology in Malta has been minimal prior to the commencement of the LifeMedGreenRoof Project. It is suggested that this is due to a lack of awareness of green roofs and the potential benefits they could deliver in a Mediterranean context. This report also describes misconceptions about green roofs that have possibly created barriers to the adoption of the technology in Malta. A brief history of green roofs in other countries and an account of recent, worldwide research into the performance of green roofs is given. The report also describes the benefits of green roofs in terms of ecological, economical and advantages to human wellbeing that could potentially materialise if green roof technology were to be implemented to a significant extent in Malta.

An attempt is made to estimate the potential area of retro-fitted green roofs that theoretically could be installed within the built environment of Malta. The three main components of this built environment are identified as:

- Domestic or Residential housing
- Industrial & Commercial properties and
- Buildings within the Public Sector.

In the context of this appraisal, the question was posed, "What are the elements that are most likely to influence people's decision or ability to consider installing a green roof?" Three main factors were identified:

Availability – the number of Maltese homes or other buildings that have suitable roofs

Affordability – the percentage of the population that would have sufficient disposable income to invest in the technology

Affinity – number of people who have empathy with environmental concerns

The assessment made is speculative and a number of constraints and assumptions are recognised. Nevertheless the exercise does provide a broad indication of the potential area that could, theoretically be available in Malta for the establishment of green roofs.

1. Introduction

This report attempts to identify the social and economic benefits that would result from the wider adoption of green roofs in Malta. Its intended audience are Policy Makers, Architects and others involved in the Construction Industry and general members of the public.

The overriding goal of the LifeMedGreenRoof Project is to construct two demonstration green roofs to illustrate the potential of meeting environmental and energy targets. One of the demonstration green roofs has been constructed at the University of Malta while the second green roof is established at Fondazione Minoprio, Italy. The Project does not aspire to establish the resources or industrial infrastructure required to construct green roofs in Malta. Rather, the Project was set up to achieve three main objectives namely:

1. To determine a standard technology suitably adapted to the particular climatic conditions experienced within the Maltese islands
2. To investigate and record the behaviour of green roofs in terms of thermal performance and water management
3. To disseminate the information gathered from the two above actions and to highlight the Environmental, Social and Economic benefits that the installation of green roofs would bring to Malta

The aim therefore is to provide information to others in anticipation that individuals and organisations will be empowered and inspired to establish a significant network of green roofs on the islands. Malta is uniquely suited to the establishment of green roofs in that most building have flat roofs and these roofs are generally over-engineered and can safely take the additional weight involved. In addition, environmental problems such as urban flooding, air pollution and overheating are increasingly being experienced in Malta. Research carried out within a variety of countries has established that significant socio-economic benefits can be derived from the installation of green roofs and there is no reason to suppose why similar advantages would not benefit Malta.

As there are virtually no green roofs constructed in Malta at present, it stands that the assessment of any social or economic benefits to the country will be speculative in nature. This study attempts to establish and quantify as far as it is possible the likely impact that the installation of a significant number of green roofs will have on the socio-economic well-being of Malta.

In meeting environmental and energy targets green roofs will inevitably impact on the economic and social aspects of Maltese society. In particular, the following socio-economic factors have been identified and discussed in this study:

- Health, well-being and recreation
- Reduction in antisocial behaviour
- Property values
- Tourism
- Job creation
- Education
- Food production
- Renewable energy

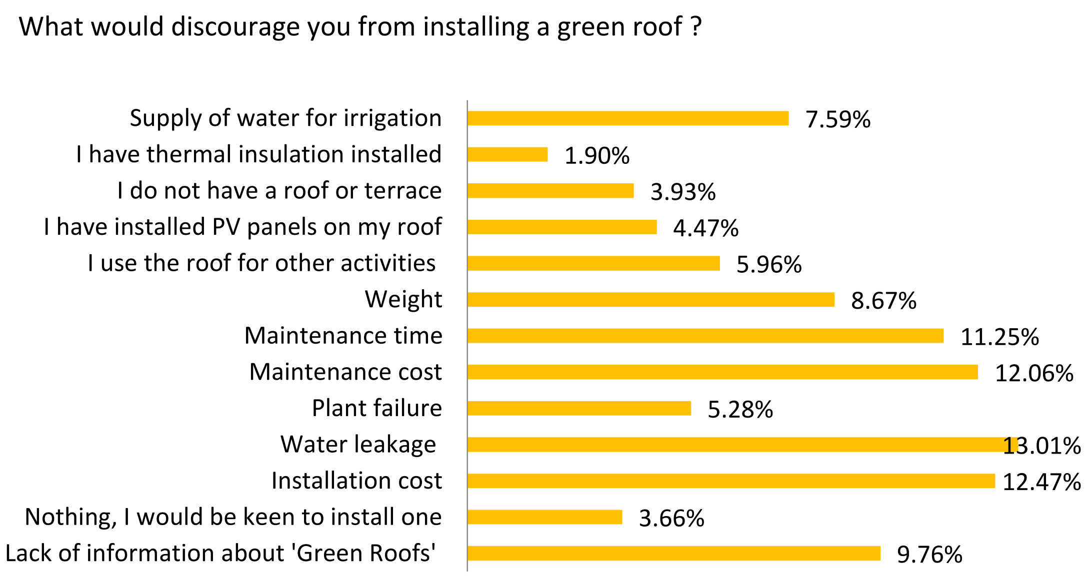
2. Project aims and perceived barriers to the adoption of green roofs in Malta.

The aim of the LifeMedGreenRoof Project based at the University of Malta is to encourage the adoption of green roofs more widely within the Maltese archipelago. Although green roof technology is well established in other European countries little has been developed in Malta. As an illustration of this divergence, Italy has established standards for the construction of green roofs since 2009 while Malta is only now in the process of publishing its own standards code through the cooperation between the Faculty for the Built Environment at the University of Malta and the Malta Competition and Consumer Affairs Authority (MCCAA) as part of the LifeMedgreenRoof Project. It was assumed that the reason for this lack of progress in Malta was due to misconceptions surrounding the following aspects:

- Lack of specific technical information about green roof construction
- Climatic conditions would not favour the establishment of plants
- Potential damage to the roof structure and waterproof membrane
- Prohibitive cost of installation and maintenance

In order to assess the general opinions and preconceptions of green roofs of the inhabitants of the islands, the LifeMedGreenRoof Project team has carried out a number of questionnaire surveys across the social spectrum of the population. The findings of these surveys are summarised in the following table:

***Table 1** Survey of the possible barriers to installing a green roof in Malta*



The six highest scoring reasons given for not considering the installing a green roof in Malta do indeed confirm the initial presumed objections. For instance, the lack of technical information (9.76%), damage to the roof structure through extra weight (8.67%) or water leakage

(13.01%), the initial cost (12.47%) and subsequent maintenance costs (12.06%) and maintenance time 11.25%).

However, the worry of plant failure was not a major concern (5.28%) although the supply of water for irrigation during the long, hot summers was more significant (7.59%).

The initial objectives of the LifeMedGreenRoof Project were twofold. Firstly the project would develop a databank of technical knowledge in order to inform the correct installation standards and procedure for green roof construction in Malta and secondly the project would investigate the performance of green roofs and then disseminate the information and also highlight green roofs in terms of their environmental, economic and social benefits.

In disseminating the information it is hoped that these misconceptions will, over time, be revised. For example, it has been demonstrated within the green roof areas at the University of Malta that maintenance demands are minimal, once the plants have had time to establish, and amounts to a few hour a month. It should be noted that the green roof areas at the University benefit from an automatic irrigation which eliminates the need for time consuming hand watering. The location, makeup of the substrate and the choice of plants can also

3. Brief history of green roofs.

Since early times, there have been many examples from various parts of the world of people covering the roofs of their shelters with living plants. These are commonly referred to as 'sod roofs' (Figure 1). They were often constructed in latitudes that experienced severe winter conditions. The soil and vegetation helped to insulate the living space beneath and to a large extent they protected the occupants from the vagaries of the weather.

Figure 1. *Sod roofed church in Hofskirkja, Southwest Iceland, built in 1884. (Köhler, 2006)*

To modern day sensibilities, the dampness and the threat of collapse by burrowing animals encouraged most civilisations to explore other solutions to solve the problem of providing a roof over their heads.

Modern day 'Green roof technology' can be said to have begun in the early 1980's in Germany when the first green roof systems were developed and commercially sold on a relatively large scale. The initial research carried out was in response to the occurrence of serious storm-water issues that made many German cities think about innovative solutions involving 'green technology'. German research developed into a modern green roof technology with high performance, lightweight materials utilized to grow hardy vegetation even on roofs that were not originally designed to take heavy loads. In the 1980's modern green roof technology was common knowledge in Germany while it was practically unknown in any other country in the world. In contrast to early, primitive 'sod roofs' the German systems offered a proven technology that consisted of reliable irrigation systems and reassuringly for the owner, a protective layering that prevented ingress of roots and moisture. At this time, that is in the late 1980's, it became increasingly acknowledged that green roofs were valuable, not only in alleviating local flooding but also in the restoration of wildlife habitats lost to urban sprawl and also in terms of their energy saving potential at a time when oil prices were fluctuating wildly. The German government between 1983 and 1996 launched incentive programmes to promote green roofs particularly in city centres. This support reduced the cost of green roofs considerably (N. Dunnett, 2008) . It is estimated that today, 10% of all German roofs are green, with about 10,000,000m² of new green roofs being constructed each year. (Köhler, 2006)

The German Landscape Research, Development and Construction Society (FLL) has issued guidelines for green roof technology. Their 'Guideline for the Planning, Execution and Upkeep of Green-Roof Sites' (FLL-guidelines) reflects the latest developments in German acknowledged state-of-the-art technology. These guidelines have been adopted and modified by many countries both in Europe and in America (Philippi, 2002). Standards applicable to Malta are currently being drafted through a collaboration between the Faculty for the Built Environment, University of Malta and the Malta Competition and Consumer Affairs Authority (MCCAA) as part of the LifeMedGreenRoof Project (LifeMedGreenRoof, 2016). The popularity of green roofs is increasing and they have become the subject of much scientific research. A number of European countries have very active associations promoting green roofs including Germany, Switzerland, the Netherlands, Norway, Italy, Austria, Hungary, Sweden, the UK and Greece. These individual associations have come together to form a European Federation to promote research, to disseminate information and encourage the installation of green roofs. (Efb., 2016).

4. Recent research into the performance of green roofs

In terms of academic study of the performance of green roof within Europe there are some notable examples. Research at the University of Natural Resources and Life Sciences in Vienna, Austria (Scharf, et al., 2012) investigated the effectiveness of green roofs in protecting a building's envelope from heat gains. They looked at three extensive roof greenings with substrate depths of 120mm and one intensive green roof with a deeper substrate of 300mm.

A number of studies focus on the use of computer modelling in order to predict the performance of green roofs. The advantages of modelling various scenarios against experimental methods are obvious. Experimental work can be expensive, time consuming and the results are specific to the location and therefore cannot be straightforwardly generalised. Research carried out at the Centre for Sustainable Energy Technologies (CEST) within the University of Nottingham aims to describe the methodologies for the development of databases that include data inputs that could be used within building simulation programs in order to appraise the performance of green roofs.

Beyond Europe, much research has been undertaken in North America. In one investigation carried out at the Carnegie Mellon University in Pittsburgh, USA, researchers aimed to quantify the effect on heat transfer of two green roofs located on two separate buildings on the University Campus. Temperature sensors were placed within different layers of the green roofs. The readings taken from the thermal sensors was combined with information about the thermal properties of the layers in order to quantify the conductive heat transfer through the systems. The conductive heat transfer through the two green roof systems was compared to the performance of conventional concrete slab roof areas located adjacent to the green roof areas. In comparing a green roof with a conventional roof they found that the green roof gained on average 75% less heat than the control roof in the cooling months of summer. (Becker & Wang, 2011)

Austin in Texas USA has a markedly different climate to the more northerly Pittsburgh. It is characterised as having a humid subtropical climate with very long, hot summers, warm transitional seasons and short mild winters. An investigation into the hydrological and thermal performance of six different extensive green roofs was carried out by the University of Texas around Austin. The researchers suggest that the potential of green roofs to retain storm-water and to lower the thermal loading on buildings were attributes that could be particularly useful in subtropical climates such as Texas and for that matter Malta, which experience high temperatures and intense rain events. The six, extensive green roofs were planted with native plants and their performance was compared to a non-reflective, black roof and a white, reflective roof. The results showed that there was little difference between the six designs of green roof and that the highest green roof temperatures were cooler than the conventional roofs by 38^{o}C at the roof membrane and 18^{o}C inside temperature.

5. Green roof research in the Mediterranean Region

Apart from the research carried out by the LifemedGreen Project at the two selected locations in Italy and Malta there are a small number of institutions within the central Mediterranean zone that have researched the performance of green roofs with regard to the existing climatic conditions.

The climate of Ancona in north eastern Italy is humid subtropical . The aim of the research, led by the Marche Polytechnic University was to assess the energy related benefits of green roofs in a Mediterranean climate by recording the thermal performance and energy efficiency parameters and comparing them with those recorded on a conventional slab roof. The study focused their data collection in summer when cooling of living spaces is most crucial. The experimental results showed the green roof's ability to moderate the fluctuations of the heat flux during summer and the report makes the point that the green roof has clearly outperformed the conventional roof in terms of reducing and moderating daily heat flows. Therefore, the potential for reducing the daily energy demand, particularly during the Mediterranean summer could be significant. However, the report concludes that further research needs to be undertaken on green roof technology within the Mediterranean region:

"The many technical solutions available for the construction of green roof systems based on various layers, materials, thickness and vegetation species also require that more comprehensive datasets are provided to report quantitative information about the observed performance for the different technologies adopted." (R. Fioretti, 2010)

A second Investigation carried out within central Mediterranean involved the appraisal of the energy and environmental performance of a green roof installed in a nursery school in Athens, Greece.

The climate of Athens, is similar to that of Malta in that both are classified as hot summer Mediterranean climates (Köppen- Geiger climate classification Csa). As with all urban areas, it suffers from the heat island effect where the ambient temperature is raised above that of suburban areas. In terms of the nursery school building itself, the simulations carried out by the study show that green roofs can make a significant contribution to building energy efficiency and that there is the potential to make remarkable and significant energy savings achieved through reduction of the summer cooling load. Therefore, the implementations of green roofs has the potential to enhance personal comfort by ameliorating the ambient air temperature and this also should result in a significant reduction in the use of conventional air conditioning and associated energy costs.

6. The Benefits of Green Roofs

The benefits of green roof can be categorised into three groups as follows:

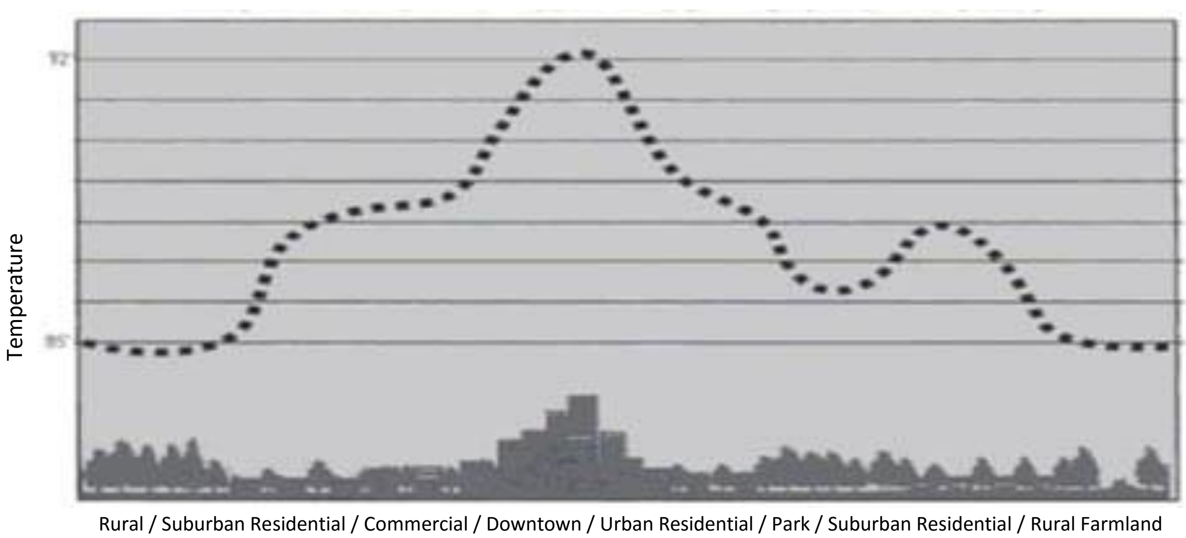
A. Ecological benefits
B. Economic benefits and
C. Benefits to human wellbeing.

A. Ecological benefits.

a) Reduction of the Heat island effect

The phenomenon of 'heat island' was first described by meteorologist more than a century ago (Howard, 1833) and is well documented as a phenomenon of climatic modification (M. Santamouris, 2001). It has been recorded that the temperatures of high density urban areas can be considerably higher than the surrounding sub-urban (Figure 2).

Figure 2. *Sketch of a typical 'heat island' urban effect. (M. Santamouris, 2001)*



One of the most important causal factors is recognised as being the absorption of sensible heat during the day by typical urban materials such as buildings, hard landscaping and roads.

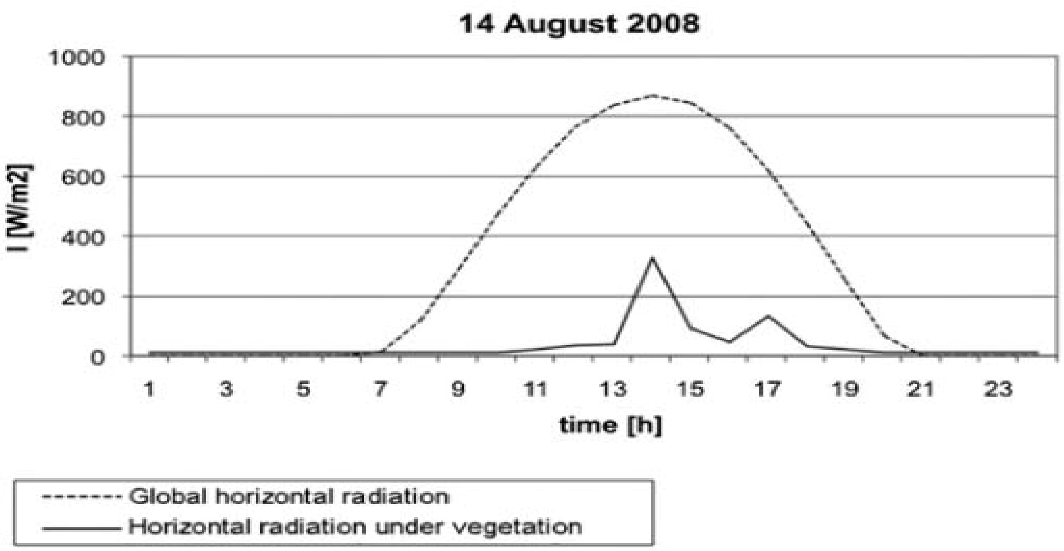
This stored sensible heat is released into the atmosphere at night and can have a negative impact on thermal comfort levels. The increase in temperature encourages the use of mechanical air conditioning systems which, in themselves increases the energy demand and also adds to further increasing temperatures.

The absence of vegetation is another aspect which has been found to increase the heat island effect as the lack of green vegetation eliminates the cooling effect of plant transpiration and evaporation (latent heat). Plants also have the effect of shading surfaces thus further reducing heat gain.

In addition, moisture is evaporated from the surface of the planting media which again through the absorption of heat required to change the state of liquid water to a gas (latent heat of vaporisation) effects a further reduction to the ambient temperature. Evidence gathered from experiments carried out by Fioretti et al (2010) on a green roof located in Ancona, Italy show that the vegetation layer diminished the solar radiation incident on the roof. This is illustrated in Figure 3 below which compares the solar radiation monitored on the horizontal surface and below the foliage observed on the 14th August 2008 at the green roof of the Regional Council of Marche, Italy.

Within the complex structure of the urban setting, there are other factors that contribute to the 'heat island effect'. For a more detailed account of the more important factors influencing heat island see Oke et al (Oke, et al., 1991).

Figure 3 *Comparison between solar radiation monitored on the horizontal surface and below the foliage observed at the green roof of the Regional Council of Marche (Italy) [Fioretti et al 2010]*



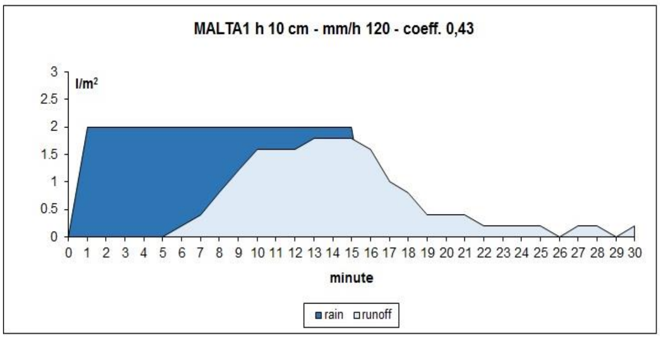
There have been a number of studies that have attempted to calculate the cooling effect that green roofs would have on the heat island effect. Through computer modelling, Bass et al (Bass, 2003) found a 1% reduction in ambient air temperature for a 50% green roof coverage in Toronto. And planning officials in Tokyo expect a 0.83^{o}C reduction of ambient temperatures with a green roof coverage of 1,200ha (Peck, 2001)

b) Prevention of Localised Flooding

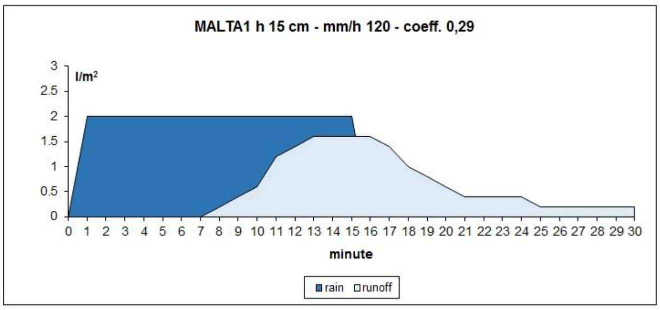
In an urban environment the dominance of buildings and hard surfaces means that heavy rain events are not absorbed and the run-off can often cause localised flooding. This is a particular problem in Malta where acute and heavy rain events are a common occurrence in the winter months. This has become an increasing problem and the Maltese Government has recently spent €55 million on an elaborate flood defence system (Government of Malta, 2012). Introducing green infrastructure into the urban environment can help alleviate flooding events as they absorb the initial down-pour and release it gradually over time. In addition, the plants will also absorb this water and through evapo-transpiration mechanisms dissipate the moisture to the ambient air and having the additional benefit of also reducing the heat Island effect.

Experiments on the effectiveness of green roofs to reduce the run-off rate following a significant rain event have been simulated by the LifeMedGreenRoof team at Minoprio Analisi e Certificazioni s.r.l., Italy. Here a rain chamber was used to investigate the performance of the Maltese (Mix1) substrates under laboratory conditions. Each substrate was saturated and left to drain for 24 hours prior to the commencement of the tests. The media were then subjected to an intense rain event which consisted of the application of 120mm/hr. for 15 minutes. The coefficient of discharged was then calculated. The coefficient of discharged refers to the relationship between the run off volume and the rain volume applied. The lower the coefficient, the more effective is the substrate at reducing run-off. The graphs provided in Figure 4 below illustrate the results. The coefficient of a conventional roof is in the region of 0.95. It can be seen from the graphs in Figure 4 below that this is significantly reduced by the inclusion of a green roof substrate layer. As would be expected, it also shows that the deeper the substrate the more effective is the control of run-off.

Figure 4. *Run-off test results. Graphs illustrating the volume and duration of the 'rain' applied (dark blue) and the resultant run-off (light blue)*



Run-off test results:
Substrate Malta1
Depth of substrate: 100mm
Rain intensity: 120mm/hr (from saturation)
Coefficient achieved: 0.43



Run-off test results:
Substrate Malta1
Depth of substrate: 150mm
Rain intensity: 120mm/hr (from saturation)
Coefficient achieved: 0.29

Investigations have also been carried out on the effect of green roofs on storm water management by the team at the LifeMedGreenRoof Project at the University of Malta. In contrast to the investigation in Italy the Maltese experiment has been carried out on an actual green roof set up. A record of the amount of rain falling on a green roof simulation of $1m^2$ was kept. The precipitation data was collected via a rain gauge adjacent to the area of green roof. The rate of run-off was measured by a Kipp 100 trip counter. Early results show that the Maltese green roof at a depth of 150mm possessed a better coefficient than was observed using the rain chamber. The more efficicient result was due to the frequency of rain events. Between rain events water evaporates from the substrate which thereby never reaches saturation levels, Figure 5 below shows the experimental set up at the University of Malta used for the investigation.

Figure 5. *The experimental set-up at the University of Malta used to monitor the storm water management performance of a green roof.*

The amount of rainwater falling on the $1m^2$ 'green roof' sample area is calculated from readings taken by the adjacent weather station. The run off is collected and piped to the Kipp 100 tip counter located below. This in turn is linked to a computer that records volume and rate of discharge.

c) Increasing biodiversity and the benefits of ecosystem services

The general urban sprawl and the practice of 'garden grabbing' which increases building density and eliminates green spaces obviously will lead to the deterioration of biodiversity. The lack of plants means that there is a knock on effect of depriving insects, birds and other animals from obtaining food and shelter. The presence of plants and wildlife also provides certain benefits to the human population. These are termed ecosystem services. These can include pollination of garden fruit and vegetables and the absorption by plants of airborne pollutants. The installation of green roofs, particularly those of an intensive construction can do much to increase habitats for wildlife and to re-establish ecosystem services.

Figure 6. *The Maltese Swallowtail Butterfly (Papilio machaon, melitensis) has bred in increasing numbers on the green roof at the University of Malta during the past three years.*

d) Lowering the heat accumulation within buildings

The mass of a green roof construction acts as an effective heat insulator which reduces roof surface temperatures and heat flux rates. The effect of this is to reduce heat gain in summer and heat loss to the external environment in winter. Research carried out at the Trent University, Ontario, Canada, found that on a typical summer's day with an ambient air temperature of 18.4^{o}C a normal roof surface temperature reached 32^{o}C while that under a green roof was 15^{o}C (Strain, 2014). This reduction of internal heat gain in summer would be very beneficial to Malta and would reduce energy costs of mechanical air cooling and increase thermal comfort.

Experiments carried out by Fioretti et al [2010] compared the thermal performance of a green roof with that of a conventional roof located at the public building of the Regional Council of Marche. Marche is situated on the central eastern coast of Italy between the Apennine Mountains and the Adriatic Sea. It should be noted that although this location is within the Mediterranean region it experiences a different climate to that of Malta which, to some extent, is harsher with greater heat and longer, drier summers. The thermal insulation benefits experienced in the living space beneath, resulting from the presence of the green roof was investigated by Fioretti and his team. The daily heat flow through the roof surface was measured and a comparison made between the performance of the green roof with that of a conventional roof slab

The data obtained provides a better understanding of the energy fluxes between the building envelope and the surrounding environment, leading to potential energy savings and an improvement in quality of life in the urban setting.

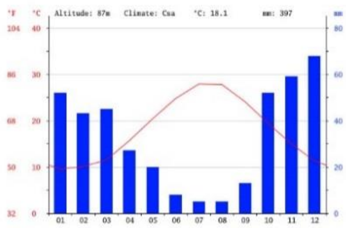
Another example of research being carried out on the energy and environmental performance of green roof in the Mediterranean region was carried out by the University of Athens, Greece in 2007. The researchers selected a nursery building with a newly constructed green roof located in the centre of the city of Athens (Santamouris M. et al.2007). The results of the research show that green roofs can indeed reduce energy requirements significantly.

The study was carried out in two phases. During the first phase, an experimental investigation of the green roof system efficiency was made and analysed. During the second phase the energy savings were examined through a mathematical approach by calculating both the cooling and heating load for the summer and winter period for the whole building as well as for its top floor. The energy performance evaluation showed a significant reduction of the building's cooling load during summer. This reduction varied for the whole building in the range of 6–49% and for its top floor in the range of 12–87%. The modification of the building fabric for the reduction of the cooling often results in an increase in its heating load, however this was not the situation in the case of this green roof and its influence on the buildings heating load was found to be insignificant.

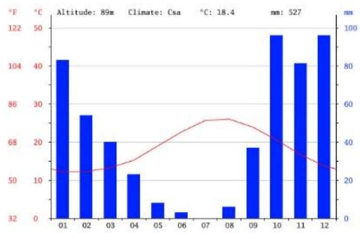
According to the above results therefore, the installation of the green roof system significantly contributed to the building energy efficiency. A remarkable energy saving was reportedly achieved due to the reduction of cooling load during the summer period after the installation of the green roof system. This resulted in a significant reduction of conventional air-conditioning use. In comparison, the impact of the green roof system on the heating load during the winter period was regarded as insignificant.

The results of the Athens' study has important significances for Malta as both geographical locations have a similar climates characterised by particularly hot, dry summers as can be seen in the climate graphs shown in Figure 7 below:

Figure 7. Climatic graphs of Athens, Greece and Birkirkara, Malta



Athens, Greece



Malta (Birkirkara)

e) Reducing Noise and air pollution

The thermal insulation effect of green roof resulting from the mass of the construction method as described above is also effective in reducing noise within the living space beneath. Of course this is affected by the depth of the planting medium, the deeper the layer the more effective is the noise attenuation. However, it has been shown that the moisture content also has an effect on sound reduction with higher moisture content providing greater noise attenuation.

It is being increasingly realised that the deteriorating air quality experienced in Malta is having an alarming effect on the incidents of respiratory illnesses such as asthma, particularly in children and the elderly within the population. This is thought to result from the high numbers of road vehicles on such a relatively small island and to dust caused by construction and industrial activities. The rapid loss of fields and green infrastructure given over to building activity over the last twenty years has also probably exasperated the situation for, as explained above, plants have the ability to absorb air pollutants. Therefore the development of green roof on the urban buildings of Malta would have some beneficiary health effects. However, to be realistic, the cause of the problem needs addressing rather than any attempt at ameliorating the symptoms. Perhaps the health problems caused by air quality on the island would be better resolved by changes in life style and transportation priorities.

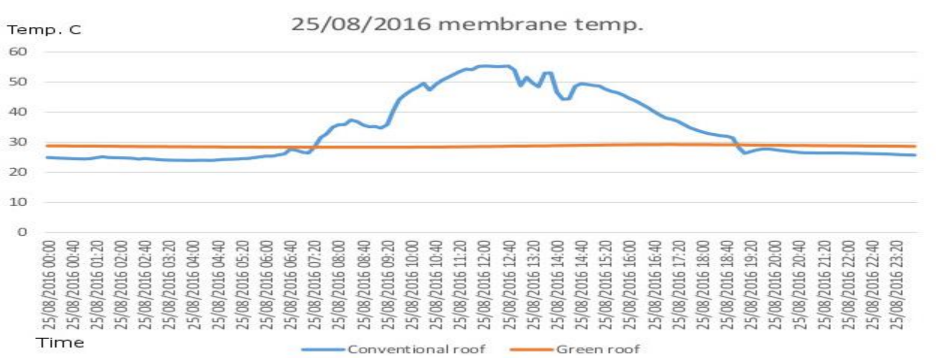
B. Economic benefits.

a) Reduction in Energy Cost

Probably the most significant economic benefit would be the savings to the building owner from savings in energy use. As said previously, green roof can make a significant difference to heat gains experienced within the living space beneath. This means that personal comfort can be obtained with a lower use of mechanical air conditioning thereby reducing energy bills. However it has been pointed out that it is older properties that would benefit more from the installation of green roofs. This is because they generally have lower levels of insulation than is now demanded by modern building regulations (Castleton, et al., 2010). In 2010, the University of Michigan USA, carried out a valuation study comparing a 2,000m² conventional roof and a green roof (Getter, et al., 2011). They concluded that over its estimated lifespan of 40 years, a green roof would save about $200,000 (€179,284), of which nearly two-thirds would come from reduced energy costs. However, a point is made that variables such as the green roof design, its geographical location and surroundings and the building itself could have a significant effect on this cost saving estimate.

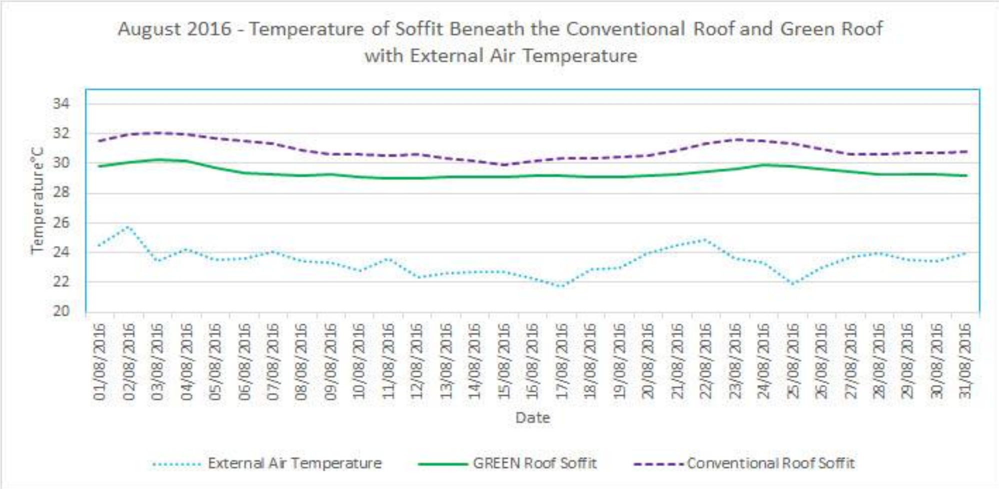
Investigations by the LifeMedGreen Roof at the University of Malta into the thermal performance of green roofs has begun to provide evidence that the potential to save energy during the cooling months of summer could be substantial. In one experiment, a thermal sensor was attached to the damp-proof membrane beneath a 200mm deep green roof and a second sensor was attached to a conventional roof membrane adjacent to the green roof. The graph below (Figure 8) shows that the diurnal variation in temperature of the conventional membrane varied by almost 30°C while the membrane beneath the green roof remains constant. Apart from reducing heat gain within the slab, this stability would prevent the expansion and shrinkage of the membrane and the concrete slab beneath thus prolonging their life and reducing replacement/maintenance costs.

Figure 8 Graph of the diurnal temperature range of the membrane of the conventional roof and on the membrane under the green roof during the cooling month of August in Malta



A second investigation involved attaching temperature probes to the soffit, one sensor beneath a conventional roof and another beneath a 200mm deep green roof. The graph below (Figure 9) shows that the soffit beneath the green roof was consistently cooler than that beneath the conventional roof during the cooling month of August. When the conventional soffit temperature recorded its highest point (32.17°C) the temperature of the soffit beneath the green roof was some 5.8% cooler (30.3°C)

Figure 9 *Temperature of Soffit Beneath the Conventional Roof and Green Roof with External Air Temperatur-August 2016.*



It has been shown by other studies, that green roofs are more effective in reducing heat gains in the cooling months than heat loss in winter (Liu, 2003). This is an important consideration in Malta which experiences a prolonged cooling period. Therefore in terms of reducing heat gains in the cooling months it was shown that the addition of the green roof consistently reduced the temperature recorded at the soffit as compared to beneath the conventional roof during the cooling month of August. However, the maximum reduction of heat gain was in the region of 1.87°C. This, as shown, represents a 5.8% reduction in heat gain in cooling months compared to the conventional roof. Although this signifies a potential positive result in terms of saving of energy resulting from employing mechanical means of cooling space, it does seem quite modest when compared to other similar studies. For instance, researchers at the Carnegie Mellon University in Pittsburgh, USA recorded a 75% reduction in heat gain in the cooling months (Becker & Wang, 2011). Similar research carried out in Austin, Texas, which experiences a comparable sub-tropical climate to that of Malta, found that the inside air temperatures as measured beneath the green roof was 18^{o}C cooler than under the conventional roof (Simmons M. T., 2008).

In order to explain this rather modest result it was decided to investigate the structure of the conventional concrete slab which is continuous under the green roof. Its construction was unknown as architectural plans of the building were not available. However, following the drilling of a core it transpired that it had a measured thickness of 550mm (Typically roof thicknesses range from 200mm to 250mm). It was decided to take a sample core through the slab to ascertain its composition. It was found that in addition to the substantial concrete component (410mm) , which in itself has a high thermal mass, the slab contained a 50mm layer of expanded polystyrene and a 90mm layer of local 'torba' or limestone gravel, both known to have significant insulation properties. The actual degree of potential thermal resistance of the slab is therefore substantial and would have a significant dampening effect on the performance of the green roof in this case. Further investigations are now being undertaken to achieve a truer picture of the likely performance of a more conventional Maltese roof slab and thereby provide an estimate of the likely savings in energy costs involved in cooling during Malta's prolonged and hot summers..

b) Extending the life of the roof waterproofing layer

The standard lifetime of a conventional bitumen based membrane is 12-20 years on average (Progressive materials, 2016). The layers of the green roof not only shade the waterproofing membrane from the harmful solar exposure but its insulator characteristics, as described above minimises the fluctuation of temperature and therefore there is less movement due to expansion and contraction. Both these actions mean that the lifespan of the waterproofing membrane is estimated to be extended by over 200% (T. Carter, 2008). Furthermore, researchers at the Penn State University's Green Roof Research Centre, Pennsylvania, anticipate that the lifespan of a roof will increase by as much as three times after greening the roof (Penn, 2008).

c) Increasing Property value

The availability of green spaces within the urban environment in becoming increasingly rare. In the case of new build, developers are offering smaller plots and with the increase in high level apartments, access to private gardens or green space is becoming rarer. This places properties that do have access to green space at a premium within the housing market. The importance of having access to green space is more and more being valued. It has been shown in a number of recent studies that getting in touch with nature can have a significant effect on ones wellbeing and can help prevent depression (Bushak, 2013).

Apart from the benefits of being in contact with greenery and nature, the additional space provides an area for relaxation or for social interaction which is important to the quality of life. It has been estimated that access to a green roof can increase property value by as much as 15 percent. (Deneen, 2016).

d) Increased water retention.

The ability of green roof to act like sponges and delay run-off following heavy rain events has been described above. In addition green roof structure can act both as a filter, thus improving the quality of the excess water and as a temporary storage within the drainage layer. This layer can be configured to act as a storage facility for water. Excess run-off can be diverted to a water reservoir thus providing a useful supply of secondary water that could be used to irrigate the green roof in the summer months.

e) Opportunities for Green Employment

In countries such as Germany the Government has actively supported the installation of green roofs through financial grants and support for research and development. As a result it is estimated that 10% of roofs in Germany are covered by a green roof. Other countries such as France have recently passed legislation that all new commercial buildings must either have photovoltaic panels or a green roof installed. Similarly, the City of Toronto has recently approved a new by-law that requires green roofs on all new residential buildings over 2,000m^2 and 6 stories high. These initiatives open up the sector to lots of new opportunities for green employment and economic development. Ranging from research and development jobs to installation and maintenance there is great potential to create employment and stimulate the economy.

C. Benefits to human wellbeing.

a) Psychological benefits

It is well known that contact with nature is a deep seated human need. A number of studies have provided evidence that being in contact with nature can bring health benefits. Research carried out at hospitals in Pakistan concluded that contact with vegetation plays a vital role in health and wellbeing of patients through various physical, psychological and social interactions.

The results of the research revealed that 76.7% of patients reported improved mental health while it was shown that 62.5% of patients recovered faster from illness as a result of contact with greenery (Aslam, et al., 2016)

In other studies, it has been shown that hospital patients who had only a view of trees or the natural environment through the window recovered more quickly compared to patients who had only a view of a wall (Taylor, et al., 2001).

Contact with nature has been shown to be particularly important for children's overall development:

> *"Nature experiences are important for encouraging imagination and creativity, cognitive and intellectual development, and social relationships." (Kahn Jr. P.H., 2002)*

It has also been shown that children with psychological problems (e.g. Attention deficit disorders, ADD) also benefit from being in touch with nature in that the contact has a calming effect and helps concentration (Taylor & Kuo, 2009).

As well as benefiting children's psychological condition, contact with nature has also been shown to be of benefit to elderly people particularly those suffering from Alzheimer's disease which is a type of dementia:

"*Studies have found that nature experiences can be of particular benefit to dementia patients. Exposure to gardens can improve quality of life and function of dementia patients by reducing negative behaviours by up to 19%*." (Mooney, 1992)

One study found that workers with workstation views that included green elements were more satisfied at work and had more patience, less frustration, increased enthusiasm for work, and fewer health problems. (Kaplan, 1993.) The positive effect that contact with green infrastructure has on people's mental health in general is explored in a recent study conducted by researchers from the University of Essex and published by the mental health organization Mind (UK). The study found that taking a walk in nature reduced depression scores in 71 percent of participants (Gladwell VF, 2013).

b) Reduction in antisocial behaviour

Attractive, natural places in which to live in have been shown by various studies to reduce the incidents of anti-social behaviour (Kahn Jr. P.H., 2002). In the increasingly urban areas of Malta the inclusion of green roofs could offer the potential to provide such places.

c) Air quality

As mentioned above, green roof have the ability to absorb and hold air particulates that are a contributory fact to many respiratory diseases. This is a particular problem in Malta as the statistics show an alarming increase of such respiratory conditions such as asthma, particularly in young children. A recent study of 5 to 8 year old Maltese children showed an increase in the prevalence of chronic wheezing from 19.15% to 30.2% over 10 years (Montefort, 2009).

7. Estimating the Potential Uptake of Green Roofs within various sectors of the Maltese built environment.

The aim of the LifeMedGreen Roof project is to demonstrate the feasibility of setting up green roofs in Malta, to disseminate information about the technology involved and evaluate the potential environmental benefits. Through the publication of the Maltese Standard for Green Roofs and the contacts the Project has made with policy makers, entrepreneurs and others it is hoped that support for the installation of green roofs within the Maltese archipelago will be encouraged.

There are three sectors of the potential market for green roofs. They are:

i. Domestic
ii. Industrial and Commercial
iii. Public Sector

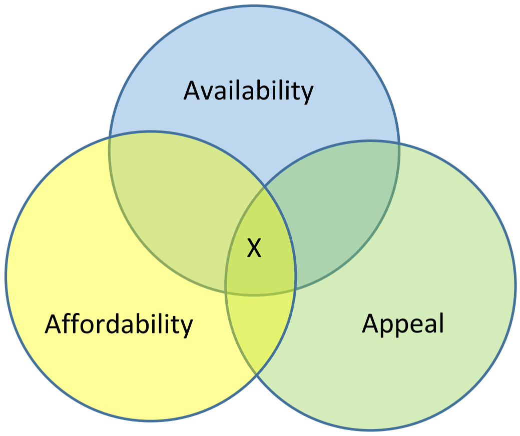
i. Domestic

In order to gauge the potential for the uptake of green roofs within the Domestic sector it is necessary to attempt to estimate of the potential number of households that could realistically accommodate green roofs. The ability to predict the potential uptake of green roofs in Malta is difficult as many factors could have an effect however, a speculative attempt is made here.

The perceived barriers in peoples' minds to the adoption of green roofs has been discussed above but what other limiting factors may exit that could affect the potential uptake? Three main factors have been identified:

1 Availability - Number of Maltese homes that have suitable roofs
2 Affordability – People with the sufficient disposable income
3 Appeal - To environmental ideals   *(See Fig. 10 below)*

Figure 10. Factors that could potentially affect the uptake of green roofs in domestic buildings. 'X' represents the theoretical number of Green Roofs that could potentially be installed in Malta



Availability - Number of Maltese homes that have suitable roofs

The 2011 Maltese census records that the number or households in Malta stood at a total of 152,980. Of these, 71,080 were vacant with 29,848 dwellings being occupied seasonally but with 41,232 households being completely vacant. More than 75% of all vacant dwellings were in a good state of repair, however almost 7,000 households were either dilapidated or in need of serious repairs. Despite being vacant all the households with suitable roofs have the potential of having green roofs installed so they will not be discounted in this assessment. Interestingly, it has been shown that installing green roofs on older or renovated homes has greater potential to save energy and therefore money (Castleton, et al., 2010). The reason being that older properties normally have lower insulation values than modern homes built according to higher building regulation standards.

Of the 152,980 total households, how many are likely to have access to suitable roofs? Traditionally, Maltese residential buildings consisted of two storeys with each household having access to a roof. However, over the last twenty or so years there has been an increase in the number of apartment blocks of three or more floors with only the upper apartment having access to the roof. In addition, the popularity of Penthouse flats has further reduced potential roof space. In order to achieve an approximate number of potential household with available roofs it is reasonable to divide the total number of households by five or 20% giving an approximation of households with potentially available roofs estimated at around 30,600. This assumes that all the roofs are sufficiently robust, structurally to accept the weight of a green roof.

Affordability – People with the sufficient disposable income

Affordability is another potential limiting factor that has been identified. The cost of installing a green roof in Malta has been estimated at being in the region €120 per m^2. This is not an insignificant cost and it would be reasonable to conclude that only households with a level of disposable income would be able to install a green roof. However, the affordability of green roofs could be made more attractive if financial grants were to be made available. Recently in Malta, photovoltaic units were promotion via Governmental financial grants.

Nevertheless, assuming that no grants are to made how many households would have sufficient disposable income to potentially afford the installation and maintenance?

The National Statistics Office of Malta report in their 'Labour Force Survey: Q3/2015' published on the 23rd December 2016 reveal that a total of 193,893 adults were in employment during the third quarter of 2016 (July-September 2016). Of this 40% are classified as being within the top three of the Major Occupation Groups as defined by the International Standard Classification of Occupations (ISCO). The three groups consist of Group 1 - Managers, Group 2 - Professionals and Group 3 – Technicians and Associate Professionals Within Malta, this group of occupations earn in excess of 18K Euros. Although not an absolute indicator of the potential disposable income, it is assumed for the purpose of this exercise that this group consisting of some 78,379 individuals or 40% of the workforce are more likely to be able to afford to implement green roofs. However, these individuals may well live in a family unit and therefore may not represent households. Therefore it is prudent to halve this figure to around 39,000 or 20% of the workforce in order to indicate the number of household that could potentially afford to install green roofs.

Appeal - To environmental ideals

Included within the LifeMedGreenRoof Project's questionnaire was the question:

"How important would you think it is to increase the number of Green Roofs in Malta?"

Of the 720 respondents to the questionnaire 75% responded that they thought that it would be "Very Important" to increase the number of Green Roofs in Malta. It can be assumed that this would represent the percentage of Maltese people who would be minded to consider the installation of a green roof on any property they owned. However, this conclusion needs to be tempered, to some extent as many (67%) of those who responded did so as a result of visiting the projects website and could therefore be deemed to have had a predisposition to favour green roofs. If we were to reduce the figure of households who would favour installing a green roof by 10% (the percentage of green domestic roofs in Germany) then perhaps this would better represent a truer indication.

Calculation.

It has been estimated that around 30,600 households in Malta have access to a suitable flat roof. With an average floor area for a three bedroomed apartment being in the region of 100m² (Times of Malta, 2012.) it would suggest a potential total area for domestic properties suitable to accept a green roof be in the region of 3,060,000m².

However, there would be constraining factors acting on this total figure. The estimated number of households that possess sufficient disposable incomes to be able to afford green roofs would represent 20% of the total suitable households that is 20% of 30,600 which equals 6,120. Of these, if 10% were inclined to favour the installation of a green roof this would represent around 612 potential residential green roofs in Malta.

Accepting that the average area of a typical three bedroomed house is 100m² (Times of Malta, 2012.) then it would suggest a potential total area for domestic properties to be in the region of 61,200m² or 6 hectares. This represents 20% of the total area of suitable residential roofs and 0.4% of the total number of all households in Malta.

ii. Industrial and Commercial

Industrial Estates

Figure 11*. Aerial view of Bulebel Industrial Estate near Zejtun*

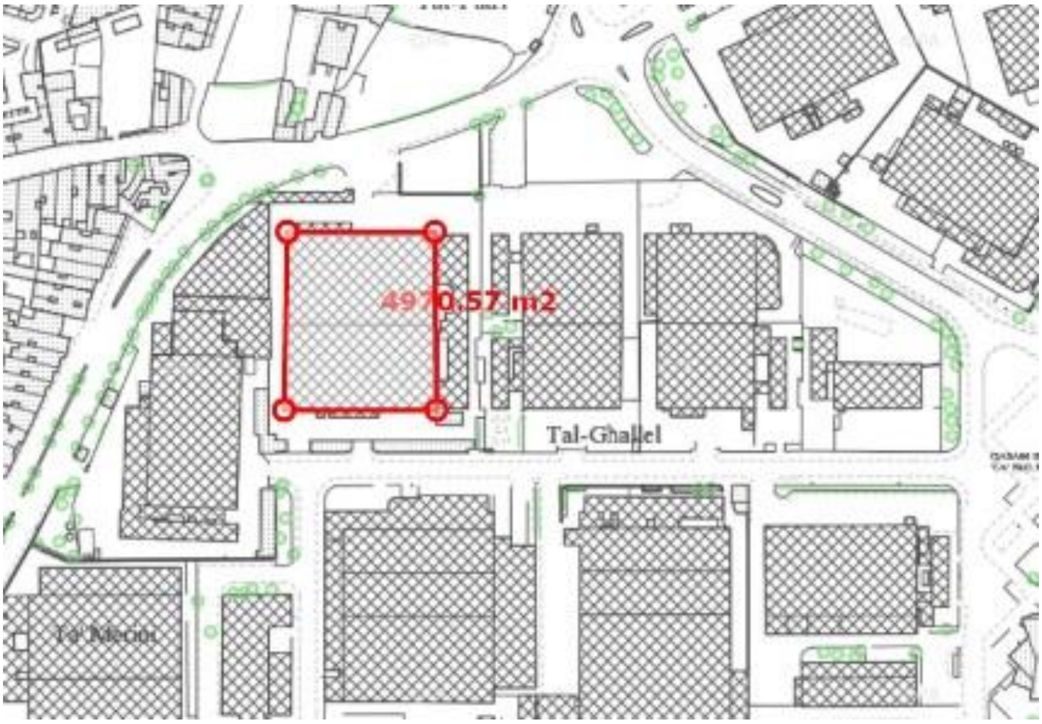
There is a wide range of commercial property located in Malta, both from the private and public sectors. Malta also has a number of existing Industrial Estates. Table 2 below lists the 14 largest Industrial Estates and the approximate overall area of each estate.

Table 2*. Main Industrial Estates of Malta*

Main Industrial Estates in Malta	Approximate floor area in m^2
Bulebel near Zejtun	600,000
Marsa	500,000
Mriehel near Qormi	466,033
San Gwann	270,000
Kordin near Paola	250,000
Albert Town, Marsa	191,771
Xewkija Gozo	172,000
Tal-Handag, Qormi	133,076
Hal Far near Birzebbuga	130,000
Luqa	100,000
Mriehel near Qormi	100,000
Ta'Qali, Attard	75,333
Mosta Industrial Estate	60,000
Ta' Maggi at Zabbar	22,650
TOTAL =	3,070,863

In order to find an approximation of the potential available area of suitable roof space within the Industrial Estates of Malta it was decided to examine one particular estate. Bulebel, the largest industrial zone at just under 600,000m² was selected. Using information from aerial photographs, Google Earth and MEPA's 'Mapserver' internet site an estimate of the possible flat roofs available for Green Roofs was made.

Figure 12.. Using MEPA's 'Mapserver' Internet facility to measure the area of roofs within Industrial Estates.



It was calculated that there was a total area of 93076m² of available flat roofs. Of these 15,880m² were extensively covered with photovoltaic panels.

***Figure 13**. Photovoltaic panels located on the roof of Baxter Limited's factory, Malta.*

Although green roofs and photovoltaic panels can co-exist and in fact, be mutually beneficial the density of coverage would be problematic in terms of also installing a green roof, therefore, it has been decided to subtract the areas of extensive photovoltaic cover from the total area of flat roofs. This leaves a potential area of approximately 77,220m² for the implementation of green roofs on industrial buildings within the Bulebel zone. This figure assumes that the structure of these roofs would be able to support the weight of a green roof.

If the total area of Bulebel industrial zone is divided by the potential area for green roofs then this give a ratio of 7.8 to 1.Therefore for every 7.8m² of total zone area there would potentially be 1m² available for green roofs. Or, put another way, 13% of the total area of the industrial estate represents the potential area that could, theoretically be converted to green roofs. This assumes that the density of the buildings is similar and that the proportion of suitable roofs is the same. However, if these assumptions are accepted it is possible to predict, approximately, the likely area available for green roofs for each zone. Table 3 shows the results:

***Table 3**. Estimated area suitable to install Green Roofs in m² for each selected Main*

Main Industrial Estates in Malta	Approximate floor area in m²	Estimated area suitable to install Green Roofs in m²
Bulebel near Zejtun	600,000	77,220
Marsa	500,000	64,350
Mriehel near Qormi	466,033	59,979
San Gwann	270,000	34,749
Kordin near Paola	250,000	32,175
Albert Town, Marsa	191,771	24,681
Xewkija Gozo	172,000	22,136
Tal-Handag, Qormi	133,076	17,127
Hal Far near Birzebbuga	130,000	16,731
Luqa	100,000	12,870
Mriehel near Qormi	100,000	12,870
Ta'Qali, Attard	75,333	9,695
Mosta Industrial Estate	60,000	7,722
Ta' Maggi at Zabbar	22,650	2,915
TOTAL =	3,070,863	**395,220**

Therefore there is a potential to install almost 400,000m² or 40 hectares of green roofs within the main Industrial Estates of Malta. However, as with the calculation of the potential available area of domestic roofs there would be a number of constraints on this figure. The ability of companies to afford the cost and their commitment to green technology are likely limiting factors. Therefore if this total, predicted area is reduced by 10% (as was the case with the domestic calculations) then this would give approximately 40,000m² or 4 hectares of industrial roof area.

The Demonstration Green Roof at the University of Malta has hosted a number of interested industrial and commercial groups including the APS Bank of Malta and services manages from Baxter Limited, Malta. (Figure 14 below)

Figure 14 *Representatives of the service management team from Baxter Limited, Malta visit the Demonstration Green Roof.*

Technology parks

In addition to the existing Industrial Estates, a number of new industrial clusters are still being developed. These are generally targeted at specific industries. A prime example is SmartCity Malta. This is a planned technology park located in Kalkara, Malta. The project, unveiled in September 2007, is estimated to cost around €275 million when it is fully completed in 2021. However, many of the offices have already been operating for a number of years. When fully complete, SmartCity will cover an area of 360,000 square metres. Again there is a great potential to incorporate green roofs into the proposals. However, as the artist's impression below illustrates, green roof have unfortunately not been considered as yet.

Figure 15*. Artist's impression of SmartCity Malta.*

Retail and Entertainment buildings.

There is also a considerable number of retail and entertainment properties in Malta. They are mostly scattered within high traffic pedestrian areas, such as Sliema, St Julians, Valletta and other popular town centres. This distribution pattern makes the estimate of potential roofs within this sector difficult to estimate. In addition, retail and similar properties often utilise the lower floors for business and rent the upper stories including the roof space to residential housing space. Nevertheless, the so called 'big-box' type of store is becoming more popular on the island and these would have the potential of offering large areas of float roofs if they roof structure were designed to do so.

***Figure 16**. Lidl's 'Big Box' store in Xewkija. It has a sales area of about 1,000 square metres (Times of Malta, 2016)*

It would be difficult to achieve estimates of the total potential for installing green roofs on these commercial building but it could be significant.

iii. Public sector

Schools

Since the establishment of the Demonstration Green Roof, there has been a considerable and increasing interest shown by schools in the Green Roof project and many have brought groups of pupils to visit the roof (Figure 17 below).

***Figure 17.** Pupils from Zeitun Secondary School during a visit to the Demonstration Green Roof*

In addition a group of Educational Officers and Heads of Department came to a presentation describing the benefits of Green Roofs and were interested in seeing for themselves what a green roof could look like in Malta.

A number of schools have shown real interest in establishing green roofs at their school and many more would be keen if financial assistance were available. His Grace, the Archbishop of Malta, Mgr. Charles Scicluna has also recently visited the Green Roof Project and was very interested in the social benefits that green roofs could bring to the people of Malta.

***Figure 18**. His Grace, the Archbishop of Malta, Mgr. Charles Scicluna shows great interest in the benefits that green roofs could provide in terms of peoples wellbeing and society in general.*

The Church in Malta manages around 50 primary and secondary schoolsThe statistics show that there are a total of 224 schools in Malta. It has been calculated that they have an average roof area of around 3,000m². This gives a total area of 672,000m². However, there would be constraining element that are likely to reduce this figure such as structural integrity, affordability and commitment to green ideals. As with previous calculations it would be prudent to reduce this total roof area by 10%. This gives a final potential area of 67,200m² or 6.7 hectares.

Therefore, it can be seen that within the educational sector there is potential to install a significant area of green roof that would not only provide the environmental benefits previously described but also be an opportunity for Maltese children to have a direct connection to the natural world while also providing a valuable educational resource.

Public and Governmental Buildings

The Government of Malta is by far the largest land-owner in the country. It owns a wide variety of property ranging from office buildings, commercial premises, stores, garages, residential premises, fortresses, towers even war-time pillboxes and public conveniences. Given this diverse portfolio of buildings, it would be difficult to calculate a total area available for the installation of green roof but it is likely to be significant. A conservative estimate would place the figure close to that calculated for Schools that is around 50,000m² or 5 hectares.

Figure 19 *The Maltese Government Minister for Transport and Infrastructure, the Hon. Joe Mizzi visits the Demonstration Green Roof.*

In promoting a sustainable, green national attitude it would be encouraging if the Government were to set an example and investigate the feasibility of installing green roofs on appropriate buildings in their care. The Demonstration Green Roof has to date, hosted three senior ministers of the Maltese Government namely the Minister for Transport and Infrastructure, the Minister for Education and Employment and the Minister for Sustainable Development, the Environment and Climate Change. All have shown great interest in the Green Roof Project.

8. Estimated total area of roofs in Malta that could facilitate the installation of Green Roofs

The various categories of buildings that could host the installation of green roofs in Malta are listed below. For each group, the potential area the roof areas that could be available for green roofs is given:

Table 4. *Potential area of roof available for installing green roofs in Malta.*

Category of building	**Potential area available for green roofs**
Domestic/Residential	61,200m²
Industrial /Commercial	40,000m²
Retail/Entertainment	?
Public Buildings	50,000m²
Schools	67,200m²
TOTAL =	218,400 m² (approx.. 22 hectares)

It must be remembered that the total of 218,400m² of potential roof area available to implement green roofs is very speculative and has been calculated by adopting many assumptions and approximations. However, a cautious approach has been taking in estimating the figures and the actual potential could be greater than that presented. Nevertheless, the estimated total figure does demonstrate that with a determined commitment to developing sustainable green infrastructure in the form of green roof technology, there is much potential in Malta.

9. Conclusions

The Demonstration Green Roof installed above the Faculty of the Built Environment at the University of Malta has attracted much interest from many sectors of Maltese society. Representatives of these groups have included Planners and Designers, Industrial Manages, School Teachers and Pupils, Representatives of the Church, Members of Financial Institutions and Government Ministers. This proves that there is a wide interest in the potential benefits that could accrue from the installation of green roof technology within Malta.

This speculative study has also shown that there is great scope for the installation of green roofs in Malta and that significant benefits to the environment, society in general and the economy would result from the wider adoption of green roofs within the islands. With the increasing urbanisation, the island’s population is becoming increasingly more disconnected from nature. It has been shown that contact with green infrastructure is important for maintaining mental health. Green roof can provide valuable places for people to entertain, relax, and meditate and to be in immediate contact with the natural world. There is also evidence that people’s ability to concentrate and therefore their productivity in the workplace is improved due to contact with nature.

It has also been shown that green infrastructure can improve the quality of the air we breathe and thereby reduce the increasing incidents of respiratory problems such as asthma, particularly in children and the elderly. Apart from purely health benefits, studies have shown that the incidence of antisocial behaviour is lower in areas that are green and attractive.

Green roofs can make properties more attractive to potential buyers and therefore tends to raise their value.   One of the reasons is that the insulation property of green roofs helps increase the energy efficiency of the building and reduces energy costs. As less and less properties have the luxury of adjacent gardens in Malta’s urban areas any home that has access to outside recreation space would attract a premium in terms of resale value.

Although not directly connected to the tourism industry, green roofs have the capacity to enhance views and offer attractive amenity spaces. Hotel roofs and spaces above underground car parks would be ideal opportunities to create areas used for relaxation and entertainment. The enhanced experience is likely to encourage an increase in the tourism trade and revenue.

It has also been suggested that the adoption of green roofs could result in the creation of a number of related jobs. These may include researchers and trainers, landscape designers, plant nursery staff, landscape contractors and maintenance staff. The benefits that the establishment of green roof in schools has also been highlighted. Green roofs could provide opportunities for pupils to learn not only about horticulture and nature but also about the weather and the wider environment. Within schools and the wider community, green roof spaces could be used for the production of vegetables, herbs and fruit thus providing a local, sustainable source of food.

Malta has in recent years encouraged the installation of photovoltaic units in order to increase the percentage of renewable energy used. It has been stated that the coexistence of green and photovoltaic panels could have benefits in that the plants, by means of evapotranspiration cool the ambient air thus enhancing the efficiency of the panels. Furthermore, the insulating benefits of a green roof also provide a saving of energy required and therefore reduce energy bills.

Flooding in some parts of Malta regularly causes damage to vehicles, homes and infrastructure. It also causes distress to those affected. The Maltese government has recently spent a considerable sum in attempting to solve the problem. The ability of green roofs to regulate storm runoff would help in alleviating the damaging and costly effects of flooding.

This study has shown that the nature of Malta’s urban built environment is ideally suited to the retro-fitting of green roofs and that, in addition it has significant areas of roof that could potentially accommodate green roofs. It is hoped that those who are in the position of influencing the planning and design of Malta’s urban communities will consider implementing green roofs and other green infrastructure for the many potential benefits they would give to the social and economic wellbeing of the Maltese people.

References

Aslam, A. et al., 2016. Effect of Hospital Landscaping on the Health and Recovery of Patients. *Adv. Agric. Biol.*, 5 4, pp. 86 - 88.

Athanasios, D. & Sarantopoulos, M., 1977. *Hellenic National Meteorological Service, Division of Climatology & Applications, Department of Control and Processing of Climatological Data.* [Online]
Available at: http://wmo1.asu.edu/europe-highest-temperature
[Accessed 23 August 2016].

Bass, B., 2003. *The impact of green roofs on Torontos unrban heat island,* Toronto: s.n.

Becker, D. & Wang, D., 2011. *Green Roof Heat Transfer and Thermal Performance Analysis,* Pittsburg: Carnegie Mellon University.

Bushak, L., 2013. *Benefits Of Ecotherapy: Being In Nature Fights Depression, Improves Mental Health And Well-Being.* [Online]
Available at: http://www.medicaldaily.com/benefits-ecotherapy-being-nature-fights-depression-improves-mental-health-and-well-being-261075
[Accessed 8 Agust 2016].

Castleton, H., Beck, S., 2010. Green Roofs; building energy savings and the potential for retrofit. *Energy and Buildings,* Issue 42, pp. 1582 - 1591.

Deneen, S., 2016. *Living Green - Green Roof.* [Online]
Available at: www.thedailygreen.com/living-green/definitions/green-roof
[Accessed 8 August 2016].

Efb., 2016. *European Federation of Green rof Associations.* [Online]
Available at: http://www.efb-greenroof.eu/
[Accessed 12 August 2016].

Getter, K., Rowe, D., Andresen, J. & I.S., W., 2011. Seasonal heat flux properties of an extensive green roof in a Midwestern U.S. Climate. *Energy and Buildings,* Issue 43, pp. 3548 - 3557.

Gladwell VF, 2013. The great outdoors: How a green exercise environment can benefit all.. *Extreme Physiology and Medicine, 2:3*.

Government of Malta, 2012. *http://www.timesofmalta.com/articles/view/20151231/local/work-on-national-flood-relief-project-concluded.597334.* [Online]
Available at: https://mti.gov.mt/en/Pages/WASD/PROJECTS/ Rainwater-Flood-Relief-Project aspx
[Accessed 07 October 2016].

Howard, l., 1833. In: *The Climate of London, Vols. I-III.* s.l.:London.

Kahn Jr. P.H., 2002. *Children and Nature: Psychological, Sociocultural, and Evolutionary Investigations.* Cambridge MA.: MIT Press, Cambridge MA..

Kaplan,., 1993.. The Role of Nature in the Context of the Workplace.. *Landscape and Urban Planning* , 4 February, pp. 193-201.

Köhler, M., 2006. *Urban Habitats,* 4(1), pp. 3 - 26.

LifeMedGreenRoof, 2016. *Lifemedgreenroof Project.* [Online]
Available at: http://www.lifemedgreenroof.org/
[Accessed 31 August 2016].

Liu, K. B. B., 2003. *Thermal performance of green roofs through field evaluation.* Ottowa, Canada, Proceedings for the First North American Green Roof Infrastructure Conference, Awards and Trade Show, Chicago, IL., May 29-30, 2003, pp. 1-10 .

Santamouris, M., 2001. In: M. Santamouris, ed. *Energy and Climate in the Urban Built Environment.* s.l.:James & James (science Publishers) Ltd, 35-37 William Road, London NW1 3ER, UK.

Montefort, S., 2009. Increasing prevelance of asthma, allergic rhinitis but not exima in 5-to 8-yr-old Maltese children (ISAAC). *Pediatric Allergy Immunology*, Feb, pp. 67-71.

Mooney, P. a. P. N., 1992. Mooney, P., and P.L. Nicell. 1992. The Importance of Exterior Environment for Alzheimer Residents: Effective Care and Risk Management. Healthcare Management Forum. *Healthcare Management Forum 5*, pp. 23-29.

N. Dunnett, N. K., 2008. *Planting Green Roofs and Living Walls.* 2nd ed. s.l.:Timber Press Inc. London.

Oke, T., Johnson, D. & Steyn, I. L. M., 1991. Simulation of Surface Urban Heat Island under 'Ideal' Conditions at Night - Part 2: Diagnosis and Causation. *Boundary Layer Meteorology*, pp. 339 -358.

Peck, S., 2001. Tokyo begins to tackle urban heat with green roofs. *Green roofs Infrastructure Monitor,* 3(2).

Peck, S., 2008. *Award Winning Green Roof Designs.* s.l.:Schiffer Publishing Ltd. Pennsylvania.

Peel, M. C., Finlayson, B. L. & McMahon, T. A., 2007. Updated world map of the Köppen–Geiger climate classification. *Hydrol. Earth Syst. Sci.,* 11(Hydrol. Earth Syst. Sci. 11: 1633–1644.), p. Hydrol. Earth Syst. Sci. 11: 1633–1644..

Penn, 2008. *"Penn State Green Roof Research: About Green Roofs"..* [Online]
Available at: .http://hortweb.cas.psu.edu/research/greenroofcenter/history.
[Accessed 16 August 2016].

Philippi, P. M., 2002. *INTRODUCTION TO THE GERMAN FLL-GUIDELINE ,* USA: Green Roof Service, LLC .

Progressive materials, 2016. *Average Roofing System Lifespans.* [Online]
Available at: http://www.pmsilicone.com/roofing-system-lifespans/
[Accessed 12 August 2016].

Fioretti, R. 2010. *Green roof energy and water related performance in the Mediterranean climate.* [Online]
Available at: http://www.sciencedirect.com/science/article/pii/S0360132310000806
[Accessed 28 July 2016].

Scharf, B., Pitha, U. & Trimmel, H., 2012. *Thermal performance of green roofs.* Copenhagen, World Green Roof Congress.

Simmons M., 2008. *Green Roofs are not created equal: the hydrological and thermal performance of sis different extensive green roofs and reflective and non-reflective roofs in a sub-tropical climate,* Austin, USA: University of Texas.

Strain, S., 2014. *Trent University's energy conservation and Demand Management Plan,* Ontario: Sustainability Office, Trent University.

T. Carter, A. K., 2008. "Life-cycle cost–benefit analysis of extensive vegetated roof systems".. *Journal of Environmental Management.,* 3(87), p. 350–363..

Taylor, A. F., Kuo, F. 2001. Coping with ADD: The surprising connection to green play settings.. *Environ. J. Behav.*, pp. 54 - 77.

Taylor, A. & Kuo, F., 2009. Children with attention deficits concentrate beter after a walk in the park.. *J. Attention Disorder*.

Times of Malta, 2012.. *Times of Malta,.* [Online]
Available at: http://www.timesofmalta.com/articles/view/20120517/business-comment/Some-home-truths.420146 (online)
[Accessed 3 Feb 2017].

Times of Malta, 2016. *http://www.maltatoday.com.mt/news/national/56609/ (Accessed 6 Feb 2017).* [Online]
Available at: http://www.maltatoday.com.mt/news/national/56609/ (Accessed 6 Feb 2017)
[Accessed 9 January 2017].

LifeMedGreenRoof Project

MEETING ENVIRONMENTAL TARGETS

UNIVERSITY OF MALTA
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