Interreg Europe

European Union | European Regional Development Fund

Interreg Europe
European Union | European Regional Development Fund

Sharing solutions
for better regional policies

ZeroCO_2 Buildings – How Low Can We Go: A Case Study of a Small Hotel in Gozo – Malta

Ing. Damien Gatt & Eur. Ing. Dr. Charles Yousif
damien.gatt@um.edu.mt charles.yousif@um.edu.mt
Institute for Sustainable Energy
University of Malta
Malta

UNIVERSITY OF MALTA
L-Università ta' Malta

ZEROCO2
Interreg Europe

Introduction

- Nowadays energy consumption of buildings in different countries comprises 20-40% of total energy use. In Malta, building sector consumes about 35% of the total energy consumption.

- Hotels are very high energy consumers, with a consumption of between 200-400 kWh/m^2/year.

The hospitality sector, in fact accounts for 2% of the total world's CO_2 emissions.

The tourism industry in Malta

As per 2015 figures, GDP in the Maltese Islands stood at 8,796.5 million Euro

Economic Importance of Tourism in 2015	
Total tourist expenditure (2015*)	EUR 1,643.9 million
Tourist expenditure per capita (2015*)	EUR 918
Employment in accommodation (2014 yearly average)	5,638 full time 3,575 part time
Employment in food and beverage service activities (2014 yearly average)	4,733 full time 6,279 part time

Source: NSO

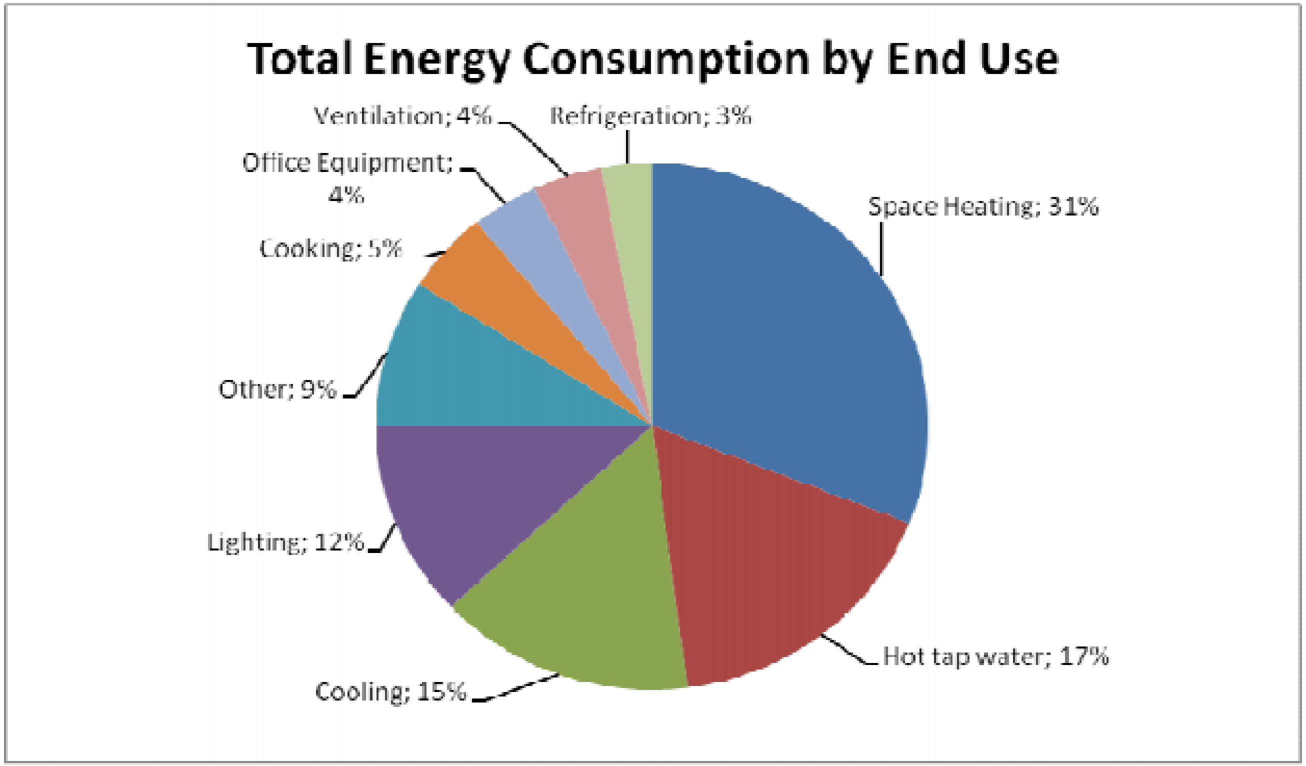
The table shows that tourism contributed to 18.69 % of Malta's GDP in 2015 (which figure is expected to rise in 2016).

The tourism industry is responsible for 50 % of Gozo's GDP.

Tourists spending on accommodation is responsible for a significant if not the major proportion of this GDP.

If hotel owners spend less money on energy consumption, money can be re-invested to improve other hotel services or increase the owner's profitability margin. + Promote sustainable tourism.

HOTELS– General energy consumption by end use (Leonardo Energy – 2008)

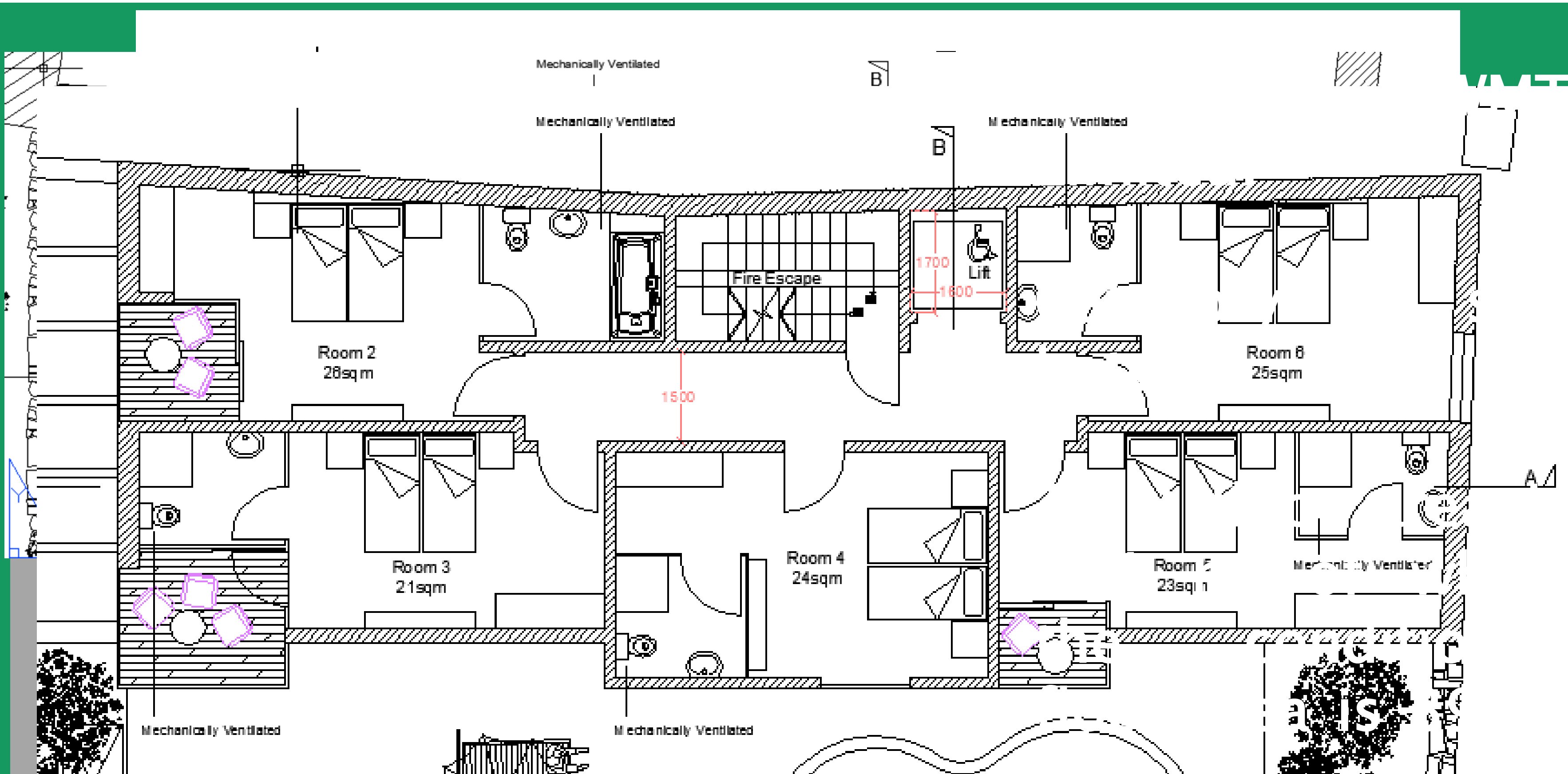


Space heating/ cooling + hot water results in 63 % of the total energy consumption

The Island of Gozo Boutique Hotel

Footprint: 12 m x 20 m
Qala, Gozo

The Island of Gozo Boutique Hotel



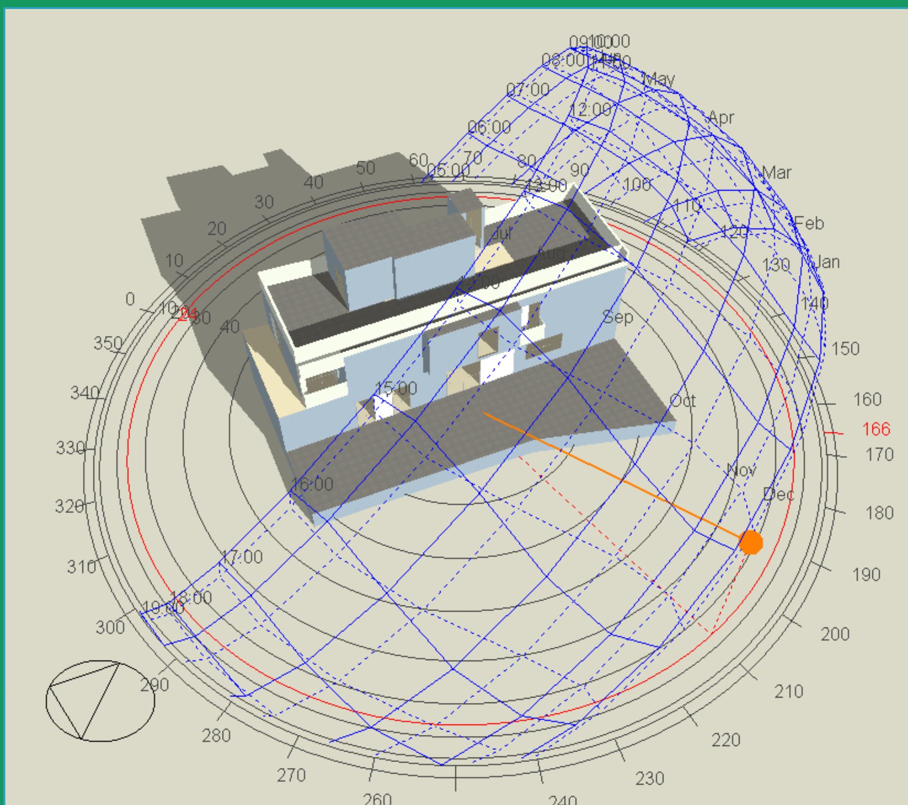
6 bedrooms

EPBD Zero Energy Buildings

- Off-site ZEBS
- On-site ZEBS
  - Net zero site energy
  - Net Zero Source Energy
  - Net Zero Energy Cost
  - Net Zero Energy Emissions

Gozo Hotel Reference Scenario

- Building was modelled with DesignBuilder (EnergyPlus)



Construction and equipment parameters used, as reference case:

- **Roof U-Value:** 0.59 W/m²K
- **External Walls U-value** :1.44 W/m²k
- **Glazing**: 5 mm clear single glazing with aluminium frame.
- **Lighting**: High efficiency fluorescent (equivalent to T5 tubes)- 3.3 W/m²/100 lux
- **Hot water** : Electric storage water heaters
- **Air to Air heat pump**: Seasonal COP in heating: 3.5, Seasonal EER in cooling: 3
- Rooms were taken as naturally ventilated.

Hotel Activity and Comfort Settings

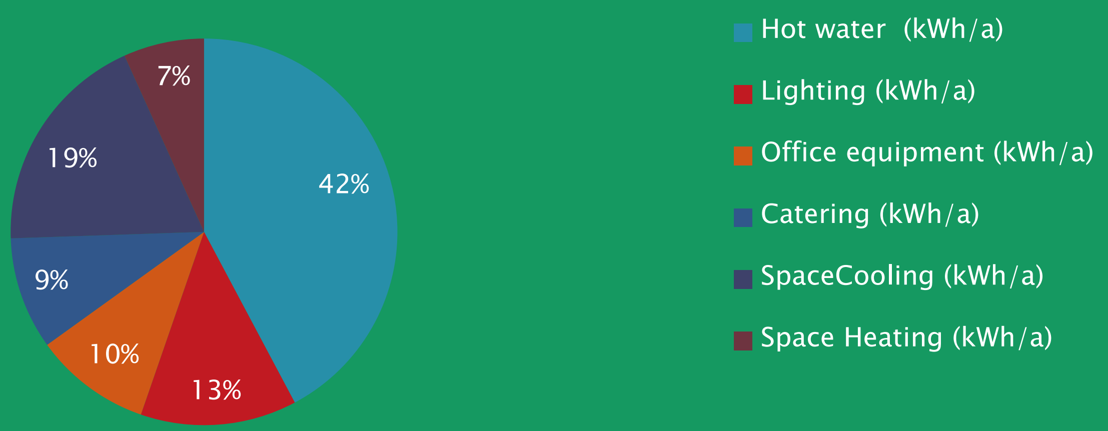
- **Rooms occupancy times and occupational density:** As per UK NCM calculation schedule.

- **Hot water utilisation** : A more conservative approach was taken than that given in the UK NCM calculation schedule. 120 litres/person per day at 65°C (per CIBSE guide A)) = 1400 litres/day was assumed.

- **Temperature set points in Rooms**: Heating set point 20°C, Cooling set point : 25°C.

Gozo Hotel Energy Consumption Pattern as per Reference Scenario

Gozo Hotel Site Energy consumption breakdown (kWh/annum)



- All energy consumption is electricity with a total site energy consumption of approx. 65 MWh/annum corresponding to emissions of 48,000 kg of CO_2 /annum
- **Operational costs due to electricity usage** : Euro 9,750/annum (cost of electricity assumed at euro 15c per kWh)

Effect of improving the roof and wall constructions (from the reference scenario)

Combination of measures	Flat roof construction (U-Value W/m²k)	External wall construction (U-Value W/m²k)	Site energy (kWh/a)	CO_2 emissions (kg/a)	% CO_2 emissions reduction over reference/a
Reference scenario	**0.60**	**1.44**	**65,208.00**	**48,214.80**	**0.00**
1	0.34	0.16	61,791.09	45,688.33	5.24
2	0.34	0.23	61,996.76	45,840.40	4.92
3	0.34	0.43	62,541.67	46,243.31	4.09
4	0.34	1.44	65,109.69	48,142.11	0.15
5	0.60	0.16	62,383.46	46,126.33	4.33
6	0.60	0.23	62,583.38	46,274.15	4.02
7	0.60	0.43	63,114.14	46,666.59	3.21
8	0.15	0.16	61,316.35	45,337.31	5.97
9	0.15	0.23	61,527.13	45,493.16	5.64
10	0.15	0.43	62,084.03	45,904.93	4.79
11	0.15	1.44	64,709.73	47,846.37	0.76
12	0.24	0.16	61,542.39	45,504.44	5.62
13	0.24	0.23	61,749.75	45,657.77	5.30
14	0.24	0.43	62,300.54	46,065.02	4.46
15	0.24	1.44	64,898.98	47,986.30	0.47

Only a maximum of 6% in CO_2 emissions reduction can be achieved by reducing U-values of the roof and walls to a very low level, with high capital costs involved.

This is mainly due to the fact that the climate in Malta is mild unlike Northern Europe.

Effect of improving the roof and wall constructions (from the reference scenario)

- It must be noted however that for the coldest (design) week in winter, upgrading the building to reference scenario 8 from the reference scenario results in 59.5% heat energy savings during that week. For the summer hottest (design) week, upgrading the building to reference scenario 8 will result in 20.8 % cooling energy savings during that week.

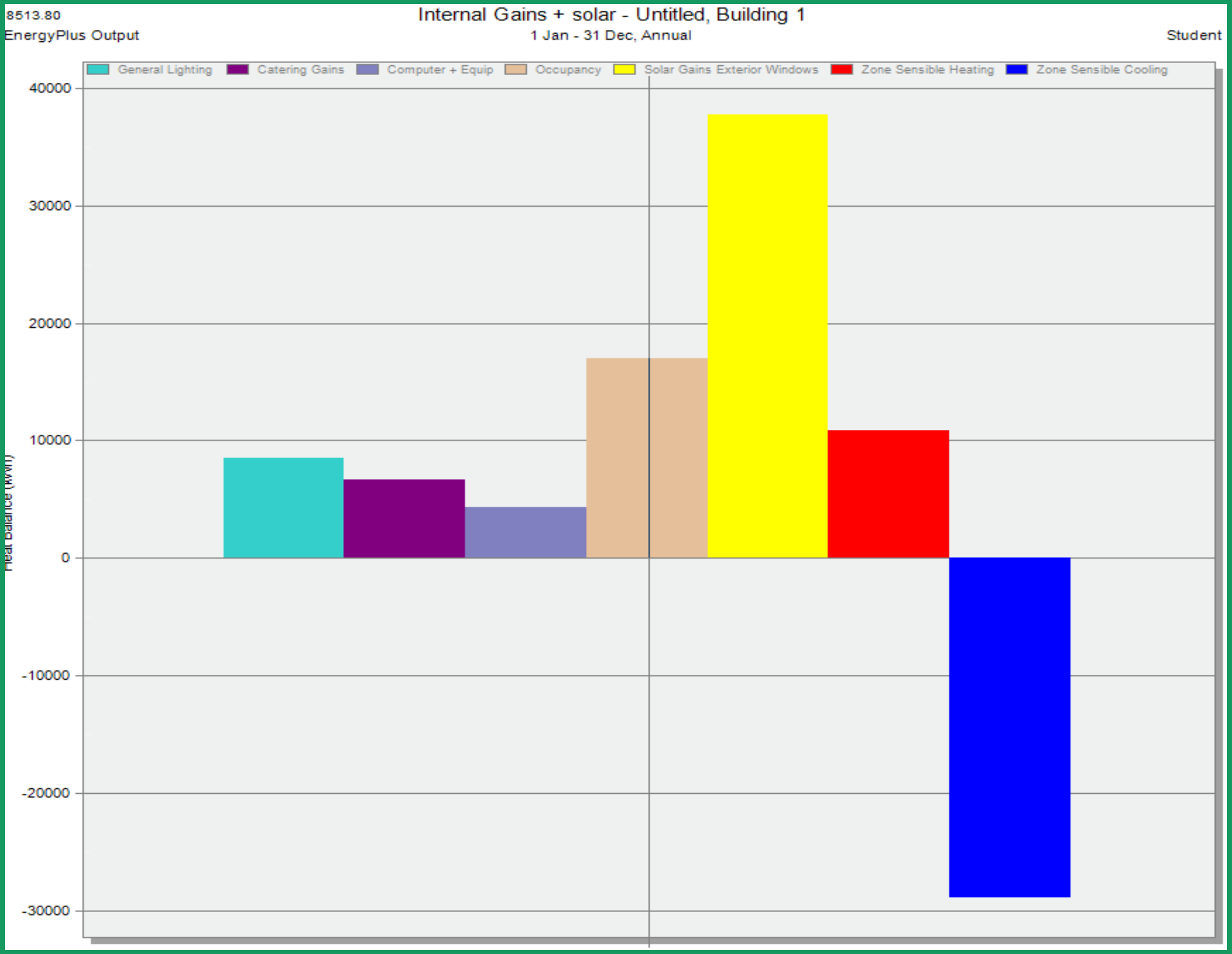
- Furthermore, by upgrading the building to reference scenario 8, one will reduce the heating design sizing load of the heat pump by 30 % and the cooling design sizing load by 19.4 %, which means there is a there is potential reduction in the capital cost of the heat pump equipment when increasing insulation to the walls and roofs.

Effect of improving the windows/ glazing construction (from the reference scenario)

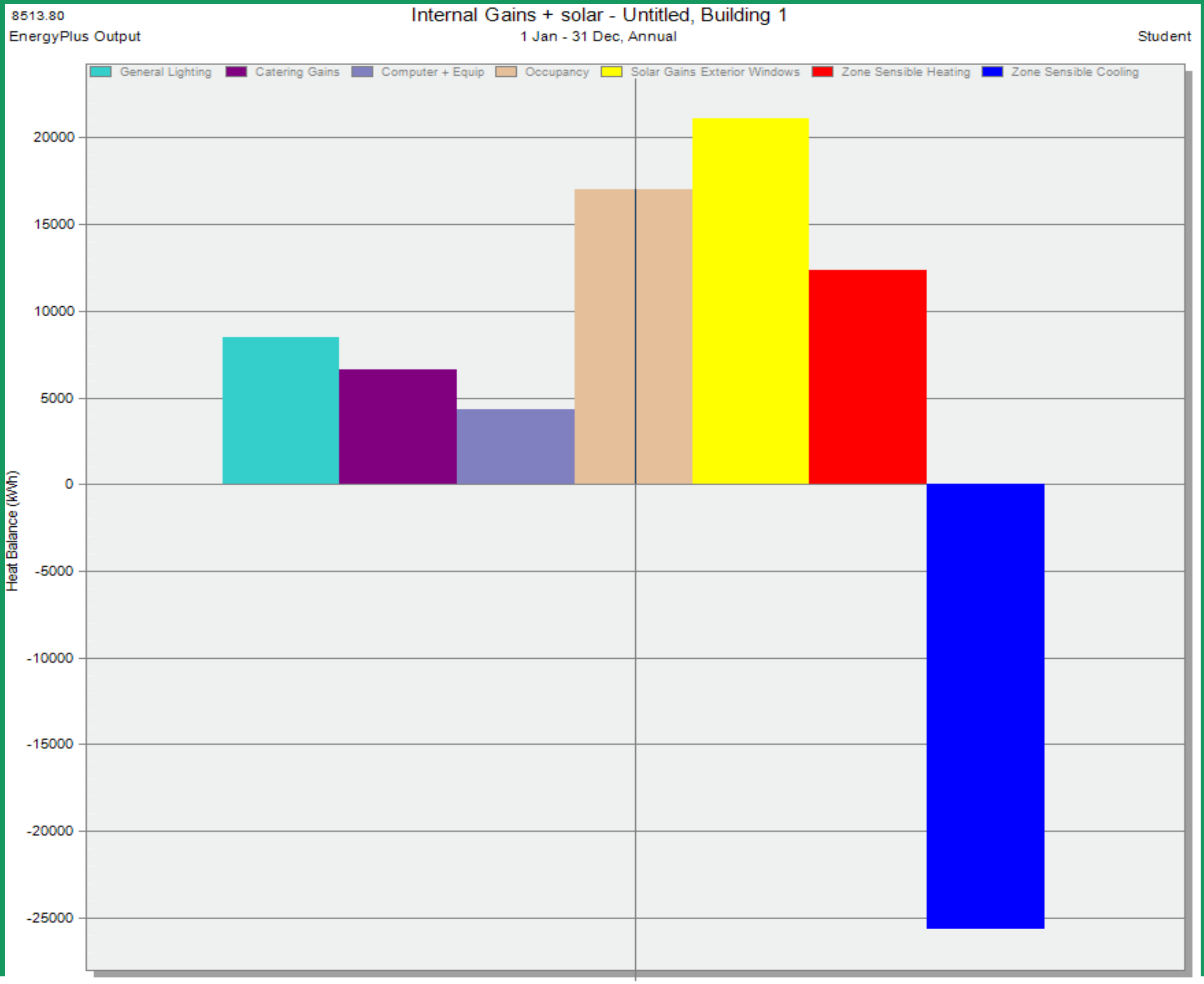
Combination of measures	Window Glazing and Frame template	Site energy (kWh/a)	CO_2 emissions (kg/a)	% CO_2 emissions reduction over reference/a
Reference scenario	Single Clear 5 mm glazing with aluminium frame	65,208.00	48,214.80	0.00
16	Single glazing (Al frame) + solar film (SHGC:0.6, LT:0.45)	64,450.72	47,654.86	1.16
17	Double glazing (wooden Frame)	64,445.89	47,651.29	1.17

Results indicate that it does not make sense in investing in high performance windows, given that the hotel rooms have a small glazing to wall ratio (30%) and that it is only occupied during night time hours and early morning hours.

Heat gains profile (single glazing windows)



Heat gains profile (single glazing windows + film) (VT: 0.45, SHGC :0.6)



10 % reduction in cooling energy over reference scenario, however this saving in cooling energy represents only 1.16 % of the total CO_2 of the Reference scenario total CO_2 emissions

Effect of improving lighting from high efficiency fluorescent to LED

- Efficiency assumed for fluorescent lighting: 3.3 W/m^2–100 lux
- Efficiency assumed for LEDs: 2.5 W/m^2–100 lux

Combination of measures	Lighting Template	Site energy (kWh/a)	CO_2 emissions (kg/a)	% CO_2 emissions reduction over reference/a
Reference scenario	High efficiency fluorescent lighting	65208.00	48860.35	0.00
17	LED	63065.67	46630.76	3.29

3.3 % savings in CO_2 emissions result by simply installing LEDs instead of fluorescent lighting and is therefore worth considering. This given also the added advantages of the increased lifetime of LEDs.

Reducing CO_2 emissions from catering

- Energy consumption assumed for catering (16 W/sq meter as per NCM guidelines).
- To reduce CO_2 emissions from catering, replace electric equipment (generating 0.7394 kg/kWh of CO_2 emissions) with one that operates with gas generating 0.195 kg/kWh of CO_2 emissions).
- Total CO_2 emissions saved: **3,333.4 kg CO_2 emissions/a.**

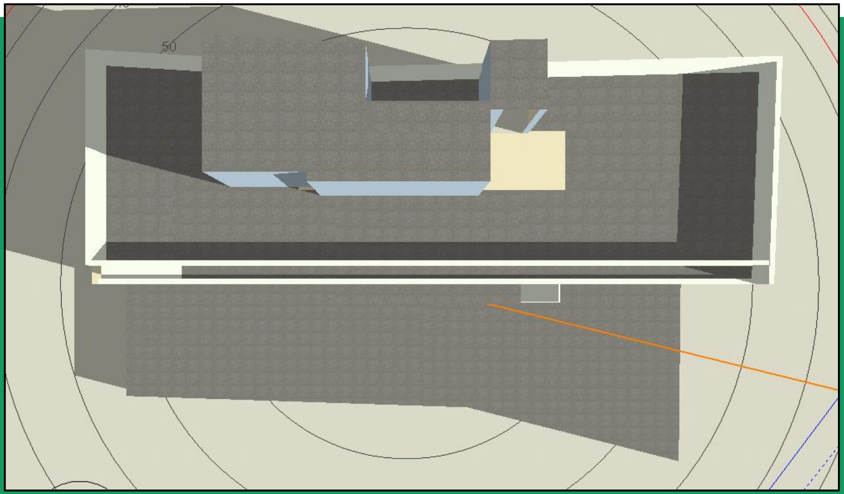
The road to $NZCO_2$ due to energy use for the Gozo hotel

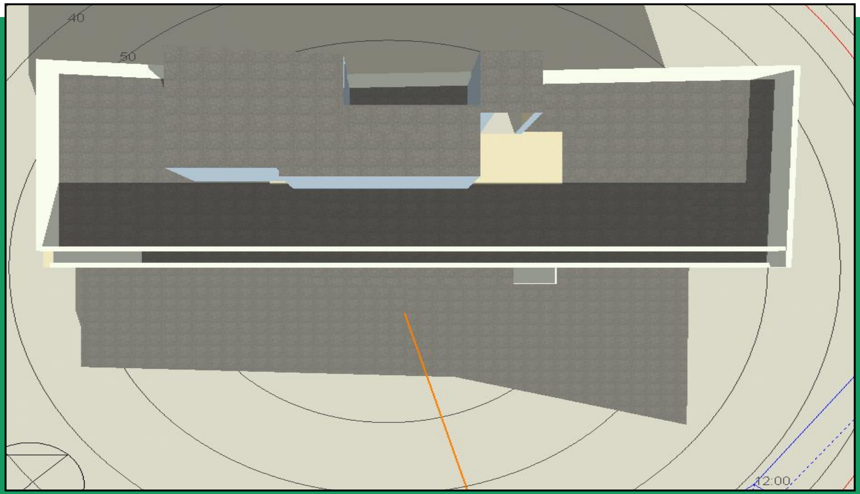
- It was decided that the wall, roof and glazing are left as per reference scenario. Improving the performance of these requires a high capital cost without major improvements in reducing CO_2 emissions.

- Lighting is changed to LED, as fluorescent lighting usually has a short life time in applications such as hotels, where lighting is regularly switched on and off.

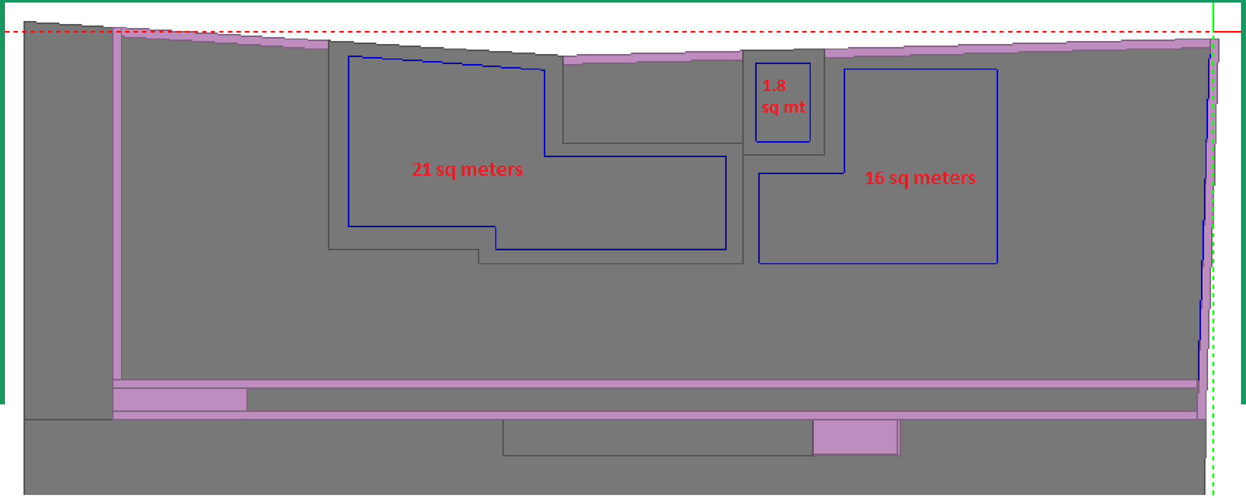
- Catering equipment is changed to one operating on LPG.

Gozo hotel flat roof potential for RES





Roof shading on 21st December at 10:00 (left figure) and at 14:00 (right figure)



Area left available for RES (bordered by blue lines): 38.8 m^2

Reducing CO_2 emissions from the main energy consumer – hot water

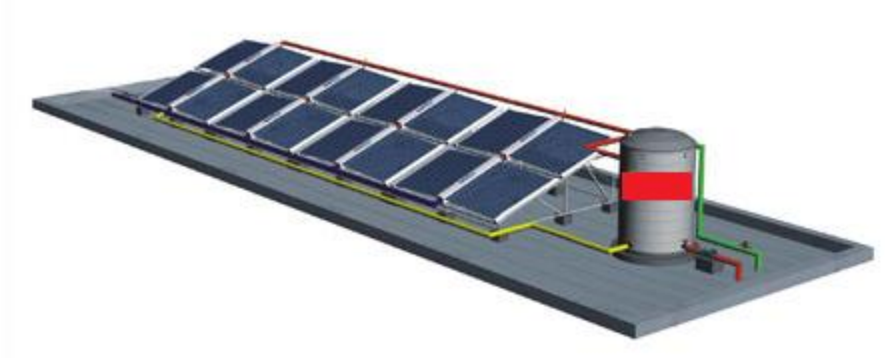
Option 1: Replacing hot water storage heaters with air to water heat pump/s.

- **COP assumed** : 3
- **Advantage**: Air to water heat pumps can be placed in locations within the roof that are not occupied by PVs unlike SWHs which compete for roof space with PVs.
- **Total energy saved from hot water energy consumption** : 18.3 MWh equivalent to 13,555.67 kg of CO_2 emissions.

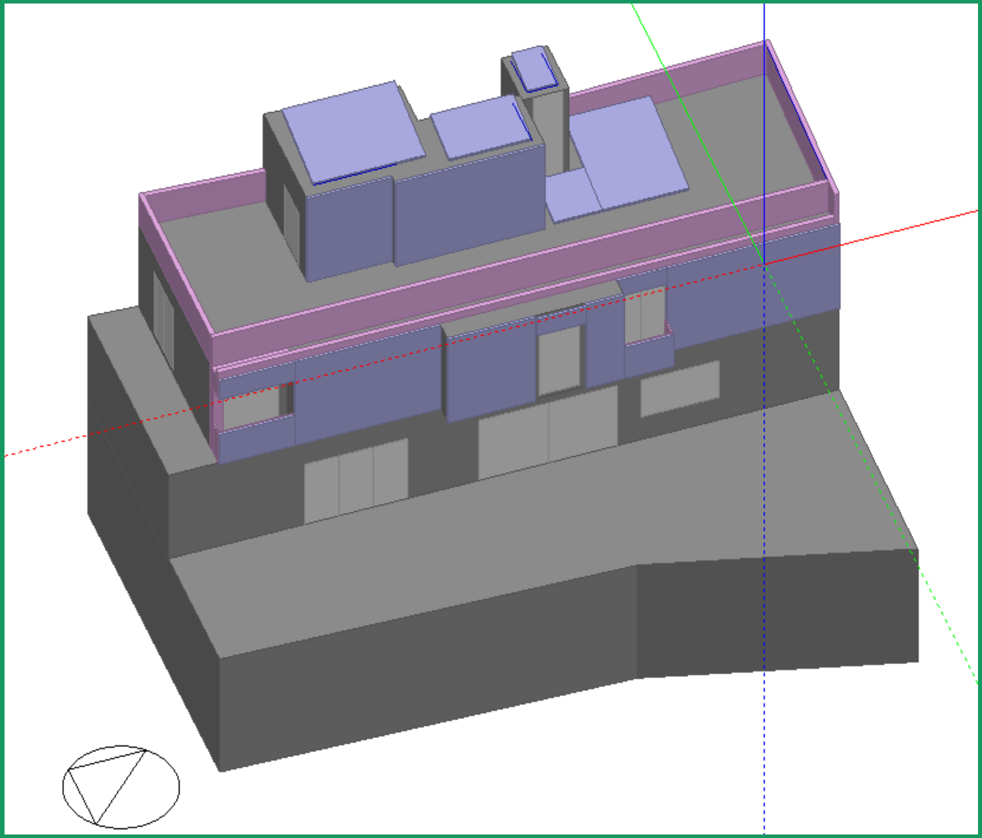
Reducing CO2 emissions from the main energy consumer – hot water

Option 2: Replacing hot water storage heaters with SWH and resistance heaters (as back up). Calorifiers are also required.

- **Optimal annual Solar Fraction (SF) required for Malta**: 0.8
- **Total energy saved from hot water energy consumption** : 22 MWh equivalent to 16,226.8 kg of CO_2 emissions per annum.
- From RetScreen (using a tilt of 45° and a 30 ° azimuth), 36 m^2 of glazed collector area is required to satisfy a SF of 0.8. This means that by installing SWHs there will be no space left to allow for PV generation on the roof top.



Extending the RES potential – Façade Integration



Option A – All RE panels on roof and facade are PVs with a power density of 187.5 W_p/m^2

Option B – Roof RE panels are PVs (power density 187.5 W_p/m^2), SWH on facade is used to satisfy a solar fraction (*SF) of 0.8, rest of facade is used for PVs*

Option C – Roof RE panels are SWH to satisfy a SF of 0.8, PVs (power density of187.5 W_p/m^2) are installed only on the facade

Extending the RES potential – Façade Integration – Option A

RE panels Option A – All RE panels on roof and facade are PVs with a power density of 187.5 W_p/m^2

Roof mounted PV system : Total PV area is 36 m^2 with an azimuth of 30° and 10° inclination . The expected output is is calculated to be 1,500 kWh/kW_p per annum (from RetScreen [17]) for crystalline PVs, which equates to 10,125 kWh or 7,486.43 kg of CO_2 offset per annum.

Facade Building Integrated PVs (BIPVs): Total PV area is 96 m^2 amd azimuth of 30° . Expected output is 900 kWh/kW_p per annum from RetScreen [17]), which equates to 16,200 kWh or 11,978.28 kg of CO_2 offset per annum.

Total CO_2 offset per annum for Option A: 19,464.62 kg

Extending the RES potential – Façade Integration – Option B

<u>RE panels Option B – Roof RE panels are PVs (power density 187.5 Wp/m2), SWH on facade is used to satisfy a solar fraction (SF) of 0.8, rest of facade is used for PVs</u>

Facade: SWHs (70 m^2) on facade generate 22,000 kWh of energy (for hot water) – SF of 0.8 . Space left on facade– 26 m^2 of PV panels at azimuth of 30° have an expected output of 900 kWh/kW_p per annum. The resulting energy generation of PVs equates to 4,387.5 kWh. The total CO_2 emissions per annum offset by RE panels (SWHs and PV panels) integrated on to the facade therefore amounts to 19,510.92 kg.

Roof mounted PV system : Total PV area is 36 m^2 with an azimuth of 30° and 10° inclination . The expected output is is calculated to be 1,500 kWh/kW_p per annum (from RetScreen [17]) for crystalline PVs, which equates to 10,125 kWh or 7,486.43 kg of CO_2 offset per annum.

<u>Total CO_2 offset per annum for Option B: 26,997.35 kg</u>

Extending the RES potential – Façade Integration – Option C

RE panels Option C-Roof RE panels are SWH to satisfy a SF of 0.8, PVs (power density of187.5 Wp/m2) are installed only on the facade

Facade Building Integrated PVs (BIPVs): Total PV area is 96 m^2 with azimuth of 30° . Expected output is 900 kWh/kW_p per annum from RetScreen [17]), which equates to 16,200 kWh or 11,978.28 kg of CO_2 offset per annum.

Roof mounted SWH: To achieve a SF of 0.8, it was estimated from RETScreen using a collector tilt of tilt of 45° and a 30 ° azimuth, that 36 m^2 of glazed collector area is required. This will occupy the whole un shaded roof space. The total CO_2 emissions per annum offset by the 22,000 kWh of (hot water) energy generated is 16,226.80 kg.

Total CO_2 offset per annum for Option B: 28,205.80 kg

The alternative routes to NZCO2 for the Gozo hotel

Scenario No.	Combination of measures to NZCO2 EB	Site energy (kWh)cons. without PVs	Hot water site energy consumption (kWh)	CO_2 emissions (kg) without PVs	Maximum CO_2 emissions offset using by PVs	Resulting CO_2 emissions from building
1	Reference scenario (with LEDs) - No PVs	63,065.67	27,500	46,630.76		46,630.76
2	Reference scenario with LED and electric water storage heaters replaced with air to water heat pump + PVs on facade and roof (Scenario A)	44,732.34	9,166.67	33,075.09	19,464.71	13,610.38
3	Reference scenario with LED and electric storage water heaters replaced with SWH (SF of 0.8) on roof + electric back up+ PVs on facade (Scenario C)	41,065.67	5,500.00	30,363.96	11,978.28	18,358.68
4	Reference scenario with LED , electric water storage heaters replaced with air to water heat pump, LPG catering equipment instead of electrical equipment + PVs on facade and roof (Scenario A)	41,065.67	9,166.67	29,741.69	19,464.71	10,276.98
5	Reference scenario with LED , electric water storage heaters replaced with SWH (SF of 0.8) on roof, + electric back up+ PVs on facade (Scenario C)+ LPG catering equipment instead of electrical equipment	41,065.67	5,500.00	27,030.56	11,978.28	15,052.08
6	Reference scenario with LED, SWH (SF of 0.8) on facade + electric back up+ 26 m^2 of PVs on facade + roof mounted PVs,(Scenario B), LPG catering equipment instead of electrical equipment	41,065.67	5,500.00	27,030.56	10,730.54	19,633.42

Operational cost and payback for scenario 4

Assumption is that all energy generated from PVs is used directly in the building.

The **fuel cost/annum** for scenario 4 is as follows:

- **Electricity cost/a**: 13,899.1 kWh x €0.15/kWh = € 2,084.86/a
- **Gas cost/a** : (6,362.67 kWh /13.6 kWh/kg) = 464 kg @ Euro 1.45/kg = € 672.80

Total savings in fuel costs from reference per annum : € 7,374.99 per annum

O&M costs/ annum from reference scenario:

PVs (assumed 1 % of capital costs) : € 396

Heat Pumps (assumed 2 % of capital costs) : € 480

Total operational cost/annum reduction over reference : € 6,948.99

Total investment cost :

PVs at €1,600/kWp = 24.75 kWp x €1,600 kWp = € 39,600

Air to water Heat Pump/s capital cost (rough estimate) : € 24,000

= € 63, 600

Simple Payback period over reference scenario: 9.15 years

Conclusion

- It has been shown, that one can reduce the operating CO_2 emissions by more than 75% for a small hotel building when compared to a reference scenario.

- Such reductions can be achieved with a reasonable pay back period of approximately nine years if one identifies and studies different combination of EE and RE measures and then carefully chooses the most appropriate measures technologies for his specific scenario.

- Reducing energy consumption from the main energy consumer (hot water) is the key to reducing CO_2 emissions in hotel buildings and therefore RE sources (Heat pumps and/or SWH) for producing hot water should be given priority in terms of policies for hotel buildings.

- This study has shown that air to water heat pumps combined with photovoltaics have a huge potential in reducing the CO_2 emissions for a small hotel in order to achieve $NZCO_2EB$ status. Thus this technology should be further promoted for policy measures.

Conclusion

- The results obtained for scenario 4 do not produce exact zero CO2 emissions from the Gozo hotel building. It must be noted however, that COPs for space heating and cooling heat pumps are improving, and seasonal COPs/EER of 4.5 and 4 are becoming more common. However, performance data specific for Malta is required to verify these COPs for the heat pumps. Other approaches to improve COPs may involve the use of ground source heat pumps, which are currently (2016) being further researched in Malta. In addition, increased generation from PVs may be carried out by using solar optimisers or micro inverters in partially shaded areas of the roof top.

- This means that a zero CO2 hotel building is theoretically possible, if more state of the art technologies are used. The results show however that in order to achieve zero CO2 emissions from small public hotels, RE must also be applied to the facade and not only limited to the roof top.

- Finally, as was also shown in this study choosing equipment that operates with gas instead of electricity can result in a significant reduction in CO2 emissions despite no reduction in site energy.

Discussion

- Is there an investment potential?
- What drivers besides legislation could encourage operators to invest in zero CO_2 technologies?
- How can one reconcile the cost-optimal results as applied in the EPBD to market economic models that do not necessarily follow cost-optimal modalities?
- What timeframe should be implemented to reach zero CO_2 status?

Interreg Europe
European Union | European Regional Development Fund

Sharing solutions for better regional policies

Thanks for your attention

ZeroCO2 Buildings – How Low Can We Go: A Case Study of a Small Hotel in Gozo – Malta

Ing. Damien Gatt & Eur. Ing. Dr. Charles Yousif
damien.gatt@um.edu.mt charles.yousif@um.edu.mt
Institute for Sustainable Energy
University of Malta
Malta

UNIVERSITY OF MALTA
L-Università ta' Malta

ZEROCO2
Interreg Europe