ZeroCO$_2$ Buildings – How Low Can We Go: A Case Study of a Small Hotel in Gozo – Malta

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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/m²/year.

The hospitality sector, in fact accounts for 2% of the total world’s CO₂ emissions.
As per 2015 figures, GDP in the Maltese Islands stood at 8,796.5 million Euro.

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.
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

Owner: WMT Limited
Category: 3 star hotel
Total floor area is 734 m² of which the conditioned floor area is 397.3 m².

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
Building was modelled with DesignBuilder (EnergyPlus) 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 CO₂/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)

<table>
<thead>
<tr>
<th>Combination of measures</th>
<th>Flat roof construction (U-Value W/m²k)</th>
<th>External wall construction (U-Value W/m²k)</th>
<th>Site energy (kWh/a)</th>
<th>CO₂ emissions (kg/a)</th>
<th>% CO₂ emissions reduction over reference/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference scenario</td>
<td>0.60</td>
<td>1.44</td>
<td>65,208.00</td>
<td>48,214.80</td>
<td>0.00</td>
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<tr>
<td>1</td>
<td>0.34</td>
<td>0.16</td>
<td>61,791.09</td>
<td>45,688.33</td>
<td>5.24</td>
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<td>2</td>
<td>0.34</td>
<td>0.23</td>
<td>61,996.76</td>
<td>45,840.40</td>
<td>4.92</td>
</tr>
<tr>
<td>3</td>
<td>0.34</td>
<td>0.43</td>
<td>62,541.67</td>
<td>46,243.31</td>
<td>4.09</td>
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<tr>
<td>4</td>
<td>0.34</td>
<td>1.44</td>
<td>65,109.69</td>
<td>48,142.11</td>
<td>0.15</td>
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<tr>
<td>5</td>
<td>0.60</td>
<td>0.16</td>
<td>62,383.46</td>
<td>46,126.33</td>
<td>4.33</td>
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<tr>
<td>6</td>
<td>0.60</td>
<td>0.23</td>
<td>62,583.38</td>
<td>46,274.15</td>
<td>4.02</td>
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<tr>
<td>7</td>
<td>0.60</td>
<td>0.43</td>
<td>63,114.14</td>
<td>46,666.59</td>
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<tr>
<td>8</td>
<td>0.15</td>
<td>0.16</td>
<td>61,316.35</td>
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<tr>
<td>9</td>
<td>0.15</td>
<td>0.23</td>
<td>61,527.13</td>
<td>45,493.16</td>
<td>5.64</td>
</tr>
<tr>
<td>10</td>
<td>0.15</td>
<td>0.43</td>
<td>62,084.03</td>
<td>45,904.93</td>
<td>4.79</td>
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<tr>
<td>11</td>
<td>0.15</td>
<td>1.44</td>
<td>64,709.73</td>
<td>47,846.37</td>
<td>0.76</td>
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<tr>
<td>12</td>
<td>0.24</td>
<td>0.16</td>
<td>61,542.39</td>
<td>45,504.44</td>
<td>5.62</td>
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<tr>
<td>13</td>
<td>0.24</td>
<td>0.23</td>
<td>61,749.75</td>
<td>45,657.77</td>
<td>5.30</td>
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<tr>
<td>14</td>
<td>0.24</td>
<td>0.43</td>
<td>62,300.54</td>
<td>46,065.02</td>
<td>4.46</td>
</tr>
<tr>
<td>15</td>
<td>0.24</td>
<td>1.44</td>
<td>64,898.98</td>
<td>47,986.30</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Only a maximum of 6% in CO₂ 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 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)

<table>
<thead>
<tr>
<th>Combination of measures</th>
<th>Window Glazing and Frame template</th>
<th>Site energy (kWh/a)</th>
<th>CO₂ emissions (kg/a)</th>
<th>% CO₂ emissions reduction over reference/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference scenario</td>
<td>Single Clear 5 mm glazing with aluminium frame</td>
<td>65,208.00</td>
<td>48,214.80</td>
<td>0.00</td>
</tr>
<tr>
<td>16</td>
<td>Single glazing (Al frame) + solar film (SHGC:0.6, LT:0.45)</td>
<td>64,450.72</td>
<td>47,654.86</td>
<td>1.16</td>
</tr>
<tr>
<td>17</td>
<td>Double glazing (wooden Frame)</td>
<td>64,445.89</td>
<td>47,651.29</td>
<td>1.17</td>
</tr>
</tbody>
</table>

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 CO₂ emissions of the Reference scenario total CO₂ emissions.
## Effect of improving lighting from high efficiency fluorescent to LED

- Efficiency assumed for fluorescent lighting: 3.3 W/m²–100 lux
- Efficiency assumed for LEDs: 2.5 W/m²–100 lux

### Table: Combination of measures

<table>
<thead>
<tr>
<th>Combination of measures</th>
<th>Lighting Template</th>
<th>Site energy (kWh/a)</th>
<th>CO₂ emissions (kg/a)</th>
<th>% CO₂ emissions reduction over reference/a</th>
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</thead>
<tbody>
<tr>
<td>Reference scenario</td>
<td>High efficiency fluorescent lighting</td>
<td>65208.00</td>
<td>48860.35</td>
<td>0.00</td>
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<tr>
<td>17</td>
<td>LED</td>
<td>63065.67</td>
<td>46630.76</td>
<td>3.29</td>
</tr>
</tbody>
</table>

3.3 % savings in CO₂ 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 CO₂ emissions from catering

- Energy consumption assumed for catering (16 W/sq meter as per NCM guidelines).

- To reduce CO₂ emissions from catering, replace electric equipment (generating 0.7394 kg/kWh of CO₂ emissions) with one that operates with gas generating 0.195 kg/kWh of CO₂ emissions).

- Total CO₂ emissions saved: 3,333.4 kg CO₂ 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 m²
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 CO₂ emissions per annum.

- From RetScreen (using a tilt of 45° and a 30° azimuth), 36 m² 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.
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 of 187.5 $W_p/m^2$) are installed only on the facade
**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 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 and 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

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

Facade: SWHs (70 m²) on facade generate 22,000 kWh of energy (for hot water) – SF of 0.8. Space left on facade – 26 m² 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 CO₂ 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 m² with an azimuth of 30° and 10° inclination. The expected output 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 CO₂ offset per annum.

Total CO₂ offset per annum for Option B: 26,997.35 kg
**RE panels Option C**—Roof RE panels are SWH to satisfy a SF of 0.8, PVs (power density of 187.5 Wp/m²) are installed only on the facade.

Facade Building Integrated PVs (BIPVs): Total PV area is 96 m² with azimuth of 30°. Expected output is 900 kWh/kWₚ per annum from RetScreen [17]), which equates to 16,200 kWh or 11,978.28 kg of CO₂ 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 m² of glazed collector area is required. This will occupy the whole unshaded roof space. The total CO₂ emissions per annum offset by the 22,000 kWh of (hot water) energy generated is 16,226.80 kg.

**Total CO₂ offset per annum for Option B:** 28,205.80 kg
## The alternative routes to NZCO2 for the Gozo hotel

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>Combination of measures to NZCO2 EB</th>
<th>Site energy (kWh)cons. without PVs</th>
<th>Hot water site energy consumption (kWh)</th>
<th>CO₂ emissions (kg) without PVs</th>
<th>Maximum CO₂ emissions offset using by PVs</th>
<th>Resulting CO₂ emissions from building</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reference scenario (with LEDs) - No PVs</td>
<td>63,065.67</td>
<td>27,500</td>
<td>46,630.76</td>
<td></td>
<td>46,630.76</td>
</tr>
<tr>
<td>2</td>
<td>Reference scenario with LED and electric water storage heaters replaced with air to water heat pump + PVs on facade and roof (Scenario A)</td>
<td>44,732.34</td>
<td>9,166.67</td>
<td>33,075.09</td>
<td>19,464.71</td>
<td>13,610.38</td>
</tr>
<tr>
<td>3</td>
<td>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)</td>
<td>41,065.67</td>
<td>5,500.00</td>
<td>30,363.96</td>
<td>11,978.28</td>
<td>18,358.68</td>
</tr>
<tr>
<td>4</td>
<td>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)</td>
<td>41,065.67</td>
<td>9,166.67</td>
<td>29,741.69</td>
<td>19,464.71</td>
<td>10,276.98</td>
</tr>
<tr>
<td>5</td>
<td>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</td>
<td>41,065.67</td>
<td>5,500.00</td>
<td>27,030.56</td>
<td>11,978.28</td>
<td>15,052.08</td>
</tr>
<tr>
<td>6</td>
<td>Reference scenario with LED, SWH (SF of 0.8) on facade + electric back up+ 26 m² of PVs on facade + roof mounted PVS,(Scenario B), LPG catering equipment instead of electrical equipment</td>
<td>41,065.67</td>
<td>5,500.00</td>
<td>27,030.56</td>
<td>10,730.54</td>
<td>19,633.42</td>
</tr>
</tbody>
</table>
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/annum**: 13,899.1 kWh x €0.15/kWh = €2,084.86/a
- **Gas cost/annum**: (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
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$_2$EB status. Thus this technology should be further promoted for policy measures.
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 CO₂ 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 CO₂ status?
Thanks for your attention

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