# Energy Performance Certification

## Is the software currently used in Malta suitable for the energy assessment of its historic buildings?

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***Abstract –*** The aim of this study is to assess whether the official Maltese software used for Energy Performance Certifications for Non-Dwellings, Simplified Building Energy Model (SBEM), is suitable for the assessment of historic buildings. The study takes into consideration two Maltese historic non-dwellings, Auberge de France, Birgu and Casa Rocca Piccola, Valletta, which were modelled using quasi-steady-state software (SBEM) and dynamic software (DesignBuilder®). Results from the two models were compared between themselves and with actual energy consumption. These comparisons indicated that SBEM over-estimates the energy usage in historic buildings. Results obtained from dynamic simulation approached the actual consumption closer, although discrepancies were noted. It is recommended that historic buildings are assessed using a proposed hybrid software which allows for the dynamic nature of the building's thermal performance whilst having partially fixed datasets to improve reproducibility. When possible this should be substantiated by the Operational Rating of the historic building.

***Keywords –*** Energy Performance Certification (EPC); energy performance of historic buildings; dynamic simulation; Simplified Building Energy Model (SBEM); asset vs operational rating

### 1. INTRODUCTION

#### 1.1 ENERGY PERFORMANCE CERTIFICATION

The Energy Performance of Buildings Directive (EPBD) aims to improve the overall energy performance of buildings. One of its main targets is to establish an energy audit and certification system for buildings, known as Energy Performance Certificates (EPCs) [1].

EPCs assess the energy performance of buildings and rate them on a scale depending on their Asset Rating. When calculating energy performance, the pre-established National Calculation Methodology (NCM) is adopted [1] to ensure comparability and reproducibility. In most European Member States, the calculation methodology has taken the form of a software package [2], which may be classified into three types [3]:

- Steady-state models, which assume steady conditions;
- Quasi-steady-state (QSS) models, which assume a constant average temperature for the calculation period. Utilization factors are used to account for thermal storage;

- Dynamic models, which take into consideration sub-hourly time steps to reflect the continually changing conditions within the building. These yield results that are more accurate but they are more complex, time-consuming and costly to run.

### 1.2 LIMITATIONS OF ENERGY PERFORMANCE CERTIFICATIONS

One of the main limitations of EPCs relates to the discrepancy between the estimated performance of a building and its actual performance [4]. This discrepancy is attributed to a number of factors including the type of software used. Studies have shown that different types of software yield different results and they attribute this discrepancy to the algorithms which are inherent to the calculation methodology employed [5].

### 1.3 ENERGY PERFORMANCE OF HISTORIC BUILDINGS

Historic buildings were originally designed to exploit passive design measures to provide internal comfort conditions [6]. The heavy reliance on passive systems would suggest that historic buildings perform favourably in terms of energy demand. Studies [7, 8] indicate that historic buildings out-perform expectations and in some cases they also out-perform recent buildings. Notwithstanding this, there is a general perception that historic buildings are energy inefficient. This makes them undesirable and may also lead to unnecessary retrofit measures which may cause irreparable damage to the historic fabric of the building [6]. These misconceptions may be partly attributed to inaccurate EPCs.

### 1.4 ENERGY PERFORMANCE CERTIFICATIONS IN HISTORIC BUILDINGS

Surveys carried out indicate that EPCs for historic buildings have a high Standard Assessment Procedure (SAP) rating [8], suggesting that historic buildings are energy inefficient and that their high operational energy levels reduce the benefits achieved by saving on embodied energy. Studies [7, 10] indicate that EPCs grossly over-estimate energy consumption of historic buildings, in some cases by as much as 40 % more than the actual energy consumption. This discrepancy may be attributed to the fact that the software used to calculate EPCs does not take into consideration the complex dynamic performance of historic buildings, ultimately leading to erroneous results.

## 2. CASE STUDY IN MALTA

### 2.1 GEOGRAPHICAL LOCATION AND CLIMATE

This study is based in Malta, a small archipelago in the Mediterranean Sea, located to the south of Sicily. The Köppen-Geiger climate classification categorizes the Maltese climate as Csa, a temperate climate with long, hot summers and mild, wet winters [11].

## 2.2 MALTESE ARCHITECTURE

### 2.2.1 Construction Materials and Methodologies

Lower Globigerina Limestone (LGL) was used for the construction of walls and of roofs due to the fact that historically it was the only naturally occurring construction material. LGL has a high total porosity (32–41 %) [12], a density of 1700 kg/m$^3$ and a thermal conductivity of 1.1 W/mK [13]. However, given its high total porosity and the effect that moisture content may have on thermal conductivity, the latter value may fluctuate.

In historic buildings up until the end of the 19$^{th}$ Century, external walls generally consisted of a massive, two leaf construction. The central cavity was either filled with un-compacted masonry chippings and soil (cavity > 100 mm) or else left empty (cavity < 100 mm). Internal walls consisted in single leaf construction with an average thickness of 300 mm. Roofs consisted in LGL slabs supported by masonry arches or timber beams. The exposed roof had a final waterproofing layer, which consisted in a compacted mixture of crushed pottery, lime and water [14].

### 2.2.2 Bio-Climatic Features

Due to the long hot summers, a greater emphasis was given to cooling. Up until the 17$^{th}$ Century, buildings had a more introverted nature and had minimal openings on the external façades in order to minimize external heat gains. On the other hand, later buildings had larger openings on their façades and these were shielded by the introduction of external timber louvres that provided shade yet still allowed ventilation [14].

The use of massive construction coupled with natural ventilation was considered an optimal way to maintain thermal comfort. To this effect, one main feature which remained in use throughout the various historical periods was the central courtyard that would provide cross ventilation and shading to the habitable rooms by means of loggias. Other commonly found bioclimatic features include high ceilings and later on the use of ventilation stacks.

## 2.3 ENERGY PERFORMANCE CERTIFICATIONS IN MALTA

For official EPC assessment purposes, buildings in Malta are categorized into dwellings and non-dwellings, each requiring a different software. Non-dwellings, which are assessed in this study, require the Simplified Building Energy Model (SBEM) which is a QSS model.

# 3. AIMS

The aim of this study is to determine whether the officially recognized software currently used by registered assessors in Malta to carry out EPCs for Non-Dwellings (SBEM) is suitable for the assessment of historic buildings and whether it is adequately representing their energy usage in specific cases.

A secondary aim is to assess different simulation model typologies (steady-state/ QSS and dynamic state) in order to evaluate their suitability when compared with actual energy consumption readings.

## 4. METHODOLOGY

### 4.1 CASE STUDIES

This study focussed on two local non-dwellings (Figure 1), namely:

- *Auberge de France* in *Birgu*, which dates back to 1533 and is currently being used as a local council (offices);
- *Casa Rocca Piccola* in *Valletta*, which dates back to 1580 and houses a privately owned museum at the upper levels and a restaurant at ground and basement level.

These were chosen because their original construction is mostly intact and because they each still operate as an individual interconnected unit.


Figure 1. (a) Location of Case Studies (b) Auberge de France (c) Casa Rocca Piccola.
Source: (a) Google Earth (b,c) Author.

### 4.2 RATIONALE

In order to determine their official EPC rating, the two case studies were assessed using SBEM, the only local official software available to calculate EPCs. To assess whether discrepancies arise between results obtained from dynamic and QSS models, the case studies were also modelled using dynamic simulation software, *DesignBuilder*®, a graphical user interface for the dynamic simulation engine *EnergyPlus*®.

The results obtained from both simulations were compared with the actual metered energy consumption in order to ascertain which type of simulation results approach closer to the actual consumption.

### 4.3 CREATING THE MODELS

#### 4.3.1 Ensuring Comparability and Reproducibility

In order to ensure that an optimal comparison was achieved, it was essential that the two models were as similar as possible. Hence, input parameters were kept constant between the two software packages. Data forming part of SBEM's lockable library was replicated in the *DesignBuilder*® data input.

#### 4.3.2 Geometry and Zoning

Detailed survey drawings of the two buildings were consulted to determine the overall areas, dimensions and the size and location of each aperture. Zoning and dimensions were taken in accordance with SBEM guidelines [15] and were replicated in the *DesignBuilder*® model.

#### 4.3.3 Weather Data

SBEM makes use of a locked weather database with standard weather data. As the pre-set weather data in *DesignBuilder*® does not include the hourly data required to run simulations using the *EnergyPlus*® interface, a new weather dataset, including hourly data, was produced using *Meteonorm*®. This was compared with statistical weather data for the Maltese islands [11] in order to ensure its accuracy.

#### 4.3.4 Building Fabric

Both buildings had been constructed similarly using traditional Maltese materials and construction techniques. Walls and roofs both consist of LGL elements. Details of the building elements are given in Figures 2 and 3.

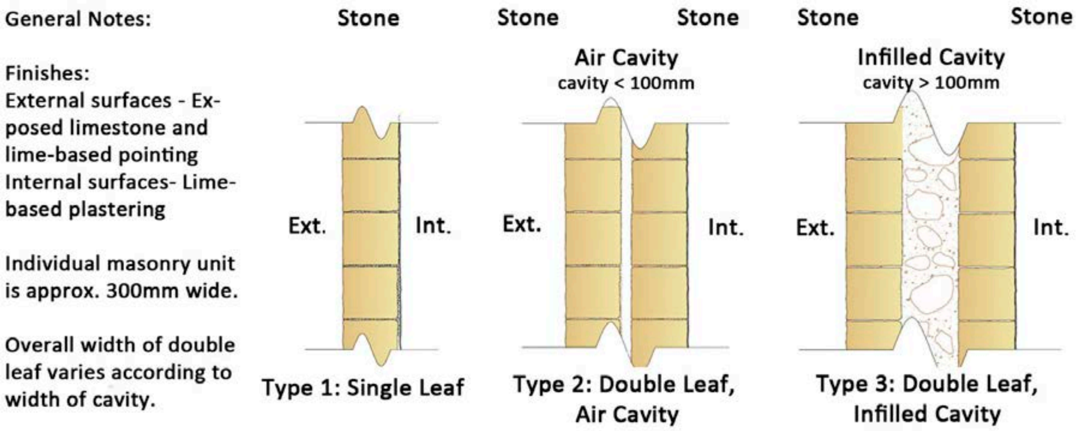


Figure 2. Typical wall types found in case studies. Source: Author.

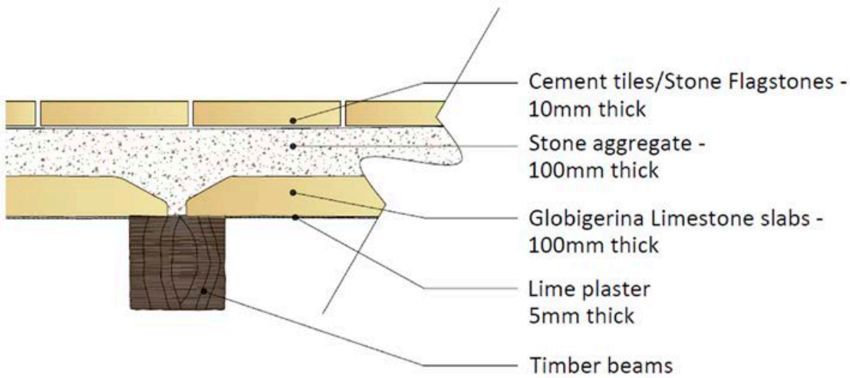


Figure 3. Typical intermediate ceiling. (For top roofs the cement tile layer would be substituted by a 10 mm crushed pottery mix; a 4 mm bituminous layer was added in more recent times.) Source: Author.

Apertures in both case studies consist of timber elements with single glazing. The default value found in SBEM was used for both models as this was thought to be more representative of local timber windows.

#### 4.3.5 Services

Lighting and Heating Ventilation and Air-Conditioning (HVAC) installed in the two case studies were noted and included in the two models. Technical literature for the installed services was consulted when possible. However when this was missing, default SBEM values were used for both models, as these were thought to be more representative of typical local services.

### 4.4 CHANGES IN OCCUPANCY AND USAGE

Schedules for occupancy, lighting and HVAC are part of the lockable library in SBEM and are based on CIBSE guidelines [16]. To enable comparison of SBEM results with those obtained from the dynamic model, these were kept constant even in the dynamic model. In order to assess whether dynamic models are more suited to evaluate energy consumption in historic buildings, another dynamic simulation was run, this time using actual timeframes and occupancy rates to reflect the actual usage of the building. This second simulation (Dynamic Model Modified, DMM) was carried out only for the *Auberge de France* because it functions as an office and therefore has a more regular usage pattern.

### 4.5 COMPARISON WITH ACTUAL CONSUMPTION

Results obtained from the two simulations were compared with actual consumption in order to determine which simulation yielded the more accurate results. This comparison was carried out for *Auberge de France*. The electricity bills provided for *Casa Rocca Piccola* were incomplete. Therefore for the purpose of this paper, only the comparison for the former case study will be presented.

Table 1. Energy Consumption

| **Model Type** | **Energy Consumption (kWh p.a.)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | Room Electricity | Lighting | Heating | Cooling | Domestic Hot Water | Auxilliary | Total |
| ***Auberge de France*** | | | | | | | |
| SBEM | n/a | 30,096.7 | 3446.2 | 3330.4 | 3062.5 | 0.0 | 39,935.8 |
| DesignBuilder® | 12,604.7 | 13,884.5 | 633.3 | 2354.8 | 864.9 | n/a | 30,342.2a |
| DMM | 8239.1 | 13,608.4 | 380.1 | 1771.9 | 864.9 | n/a | 24,864.4a |
| ***Casa Rocca Piccola*** | | | | | | | |
| SBEM | n/a | 88,973.5 | 32,055.7 | 14,600.3 | 18,456.6 | 2521.4 | 156,579.6 |
| DesignBuilder® | 22,854.3 | 35,385.4 | 18,927.5 | 14,840.1 | 254.9 | n/a | 92,262.2a |

[a] *DesignBuilder® models include room electricity whereas SBEM models do not.*

Table 2. EPC Asset Rating

| Case Study | $kgCO_2/m^2$ p.a. | | | EPC Band | | |
|---|---|---|---|---|---|---|
| | SBEM | DesignBuilder® | DMM | SBEM | DesignBuilder® | DMM |
| Auberge de France | 199.4 | 118.2 | 96.7 | D | C | B |
| Casa Rocca Piccola | 145.4 | 72.1 | n/a | C | B | n/a |

## 5. RESULTS

By comparing the results obtained, it is clear that QSS results indicate a significantly higher energy usage than those obtained from the dynamic models. Both the default QSS and dynamic simulations indicate a higher energy consumption than the results obtained by the DMM. Table 1 gives a complete comparison of the results obtained from all the simulations.

The results obtained from the official EPC software SBEM are more than twice the actual consumption for Auberge de France. The results from the default dynamic simulation are still quite high, whereas DMM results approach the actual consumption (Table 3).

Table 3. Simulation Results vs Actual Consumption

| Actual Consumption: 16,160 kWh p.a. | | |
|---|---|---|
| **Model** | **Calculated Results (kWh p.a.)** | **Difference Factor** |
| SBEM | 39,935.8 | x 2.5 |
| DesignBuilder® | 30,342.2 | x 1.9 |
| DMM | 24,864.4 | x 1.5 |

## 6. CONCLUSIONS

### 6.1 SOFTWARE SHORTCOMINGS

It is clear that different simulation models yield different results. QSS models clearly over-estimate energy consumption, possibly due to a number of inherent flaws, including:

- their simplistic nature, which does not consider the dynamic behaviour of buildings;
- the exclusion of an ability to recognise the contribution of passive systems, which inevitably leads to incorrect certifications, especially when considering that historic buildings rely heavily on such passive systems.

Some shortcomings were observed in both software packages. The use of default values and standard data invariably leads to incorrect results. Historic buildings are by their very nature very diverse from each other and so the use of standard or default data may not be appropriate.

Another shortcoming is the fact that neither software package accounts for the actual condition of the building. This is well documented to have a considerable bearing on the thermal performance of a building. *DesignBuilder*® allows for a crack template to mimic air infiltration from unkept walls. However, the quantification of this condition is very subjective and should be measured using air-tightness values.

Furthermore, neither software package considers the moisture content and the permeability of the building materials. This is a very important factor in historic buildings as the dynamic behaviour of moisture not only affects the insulation properties of the masonry wall but also affects the radiant temperature of the surfaces. This ultimately affects thermal comfort within the building impinging directly on the amount of energy consumed for heating and cooling.

**6.2 RECOMMENDATIONS**

From the results obtained it is evident that the official EPC software SBEM is not an ideal method to carry out energy audits or issue EPCs for historic buildings as it grossly over-estimates energy usage, potentially leading to devastating results in terms of decision making that affects the conservation of historic built fabric. The use of dynamic models is better suited to assess historic buildings, although further similar studies should be carried out to ascertain the behaviour of dynamic models vis-à-vis actual energy usage.

However, it is clear that in order to routinely carry out such detailed, dynamic models would be a very arduous task. The inclusion of so many different variables might well increase the risk of human error and reduce the potential for reproducibility, which is a key element set out in the EPBD.

To make up for these limitations, a compromise between the two types of software would be ideal. The model should be based on dynamic calculations but should have a controlled data-set for certain parameters. This would be especially viable for places such as Malta, in which a single building material has been so widely used historically in the construction of its buildings. Due to the variation in building fabric, the material properties should still be input manually, and hygrothermal simulation may also be included. The latter should be used with caution as moisture content fluctuates over time and even between one area of the wall and another. Occupancy and schedules could possibly be catered for by means of drop-down menus to include multiple standard options to better reflect current conditions. One may opt to model the building using Adaptive Comfort Standards rather than Predicted Mean Vote Standards, especially in view of the heavy reliance of historic buildings on passive design measures.

If, however, actual energy consumption readings are available, the energy audit should also take note of this and use the Operational Rating. This should substantiate the Asset Rating in order to obtain a more holistic representation of the energy efficiency of the building.

## 7. REFERENCES


[1] Directive 2010/31/EU of the European Parliament and of the Council of the 19th May 2010 on the Energy Performance of Buildings.

[2] International Energy Agency. (2010, November). Energy Performance Certification of Buildings: A policy tool to improve energy efficiency. [Online]. Available: https://www.iea.org/publications/freepublications/publication/buildings_certification.pdf [20th January 2018].

[3] B.D. Hunn, Fundamentals of Building Energy Dynamics. Cambridge USA: MIT Press Ltd., 1996, p. 226.

[4] P. de Wilde and R. Jones. (2014, April). "The building energy performance gap: up close and personal". Session 9, Paper 2, CIBSE ASHRAE Technical Symposium, Dublin, Ireland, 3–4 April 2014. [Online]. Available: http://www.cibse.org/knowledge/cibse-technical-symposium–2014/the-building-energy-performance-gap-up-close-and-p [Accessed 10th December 2015].

[5] V. Ingram, P.F.G. Banfill and C.J. Kennedy. "Towards an objective assessment of energy efficiency in heritage buildings". Proceedings of the World Renewable Energy Congress 2011, 57 ed., Vol. 8, 2011, pp. 2018–2025.

[6] M. Suhr and R. Hunt, R. Old House Eco Handbook: A Practical Guide to Retrofitting for Energy-Efficiency & Sustainability. London: Francis Lincoln Publisher, 2013, p. 10.

[7] J. Wallsgrove. (2008, March). "The justice estate's energy use". Context. [Online]. Issue 103, pp. 19–20. Available: http://ihbc.org.uk/context_archive/103/wallsgrove/page.htmlbake [20th January 2016].

[8] P. Baker. 2011. (2008, October). Historic Scotland Technical Paper 10: U-values and traditional buildings In situ measurements and their comparisons to calculated values. [Online]. Available: http://www.historic-scotland.gov.uk/hstp102011-u-values-and-traditional-buildings.pdf [Accessed 11th August 2015).

[9] Department for Communities and Local Government. (2009, September). English House Condition Survey ECHS, 2007. [Online]. Available: http://doc.ukdataservice.ac.uk/doc/6449/mrdoc/pdf/6449ehcs_annual_report_2007.pdf [Accessed 11th December 2017].

[10] Historic England. 2014, May. Energy Efficiency and Historic Buildings: Energy Performance Certificates. [Online]. Available: https://content.historicengland.org.uk/images-books/publications/eehb-energy-performance-certificates/heag015-eehb-epcs.pdf/ [20th July 2015].

[11] C. Galdies. (2011). The Climate of Malta: statistics, trends and analysis 1951–2010. [Online]. Available at: https://nso.gov.mt/en/publicatons/Publications_by_Unit/Documents/B3_Environment_Energy_Transport_Agriculture_Statistics/The_Climate_of_Malta.pdf [15th September 2015].

[12] J. Cassar. "Comparing visual and geochemical classification of limestone types: the Maltese Globigerina Limestone". Proceedings of the 10th International Congress on Deterioration and Conservation of Stone Vol II, Stockholm, 2004, pp. 569–577.

[13] Building Regulations Office (BRO). Technical Document F Part 1. Floriana, Malta: Ministry for Resources and Rural Affairs, 2015, p. 29.
[14] V. Buhagiar. "The Refurbishment of Historic Buildings for Re-Use: An Energy Efficient and Heritage Sensitive Approach. Generic Guidelines with Application for Malta". PhD. thesis, Cardiff University, Wales, UK, 1999.
[15] Building Regulations Office (BRO). Course for Energy Performance of Buildings Non-Dwellings in Malta: Course Notes. Floriana, Malta: Ministry for Resources and Rural Affairs (unpublished), 2012.
[16] Department for Communities and Local Government. (2015, November). SBEM: A Technical Manual for SBEM. [Online]. Available: http://www.uk-ncm.org.uk/filelibrary/SBEM-Technical-Manual_v5.2.g_20Nov15.pdf [20th February 2016].