Retrofitting near to zero energy homes in a Mediterranean climate

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Abstract. The present local built environment has a common thermal comfort problem namely that most dwellings have a great reliance on electricity for environmental control indoors. The main objective of this research work was to offer a practical and cost-effective working solution to this problem. The feasible energy–saving measures that can be retrofitted to an existing dwelling were designed and applied to an existing building; a top third floor flat in Birkirkara, Malta, thus converting it into a thermally comfortable minimum energy home. The indoor climate of the subject flat, its mirror image apartment and the Birkirkara microclimate were monitored for one year and the necessary tools to analyse this data were utilised: a psychrometric chart analysis with Malta's defined thermal comfort zones. Compared to its microclimate and the mirror apartment, the results show that the subject flat managed to keep a constant and very comfortable indoor climate across both the hot and cold seasons. It is only for a small portion (a total of 9 out of 122 days – 7% in summer and 16 out of 121 days – 13% in winter) that the energy–saving retrofit measures did not fall within the thermal comfort zones limits. This case study also shows that the combined energy saving retrofit measures had a payback period of 15 years, which eventually pays off with a surplus of over €700.

1. Introduction

Vitruvius in his classic books, '*De Architectura*', cleverly coined Architecture as resting on three pillars, namely "*Commodity, Firmness and Delight*". This paper essentially deals with Commodity of dwellings in Architecture.

Today's motivation behind building dwellings is to provide a secure shelter, protect ourselves from adverse climatic conditions and to obtain a neutral thermal comfort level. The present local built environment has a common thermal comfort problem as most dwellings lack passive measures and thus have a great reliance on fossil fuels that come at a cost to both the individual and the government. In addition such poor thermal comfort conditions imply health problems, leading to another problem – an escalating national health bill (13.7% related deaths in 2012 up to 16.8% in 2017) [1]. What is certain is that comfort, up to now, has come at a price – high energy consumption because existing buildings are very inefficient energy wise and consume 39% of the national energy load.

All energy and environment stakeholders are very well aware of the 20–20–20 energy targets that all EU countries are bound to achieve by 2020 via the NZEB and relevant legislation [2]. Both EU and local policy follow such legislation via the relevant directives and legal notices – however the latter only focus on new buildings and renewable energy sources. Thus unless policy and legislation look into the possibility of energy retrofitting existing building stock, the EU targets will not be achieved to effectively reduce the evident problem of greenhouse gas emissions [3]. Such a situation, if unchanged, will continue to increase the fossil energy demand problem, increasing CO2 emissions. Thus considering this above scenario, the main objective of this work was to offer a practical working solution to this problem. The idea was to analyse and point out what are the feasible energy–saving measures that can be actually retrofitted to an existing dwelling without affecting the occupant's lifestyle and daily schedule. Such energy–saving retrofit measures must be based on our climatic conditions and existing building fabric to effectively reduce energy consumption.

Some valid information has been analysed both locally and overseas. However, most of these studies remain redundant or limited in dissemination or use. Thus rather than 're-inventing the wheel' and creating another bench study, the idea was intended to analyse these local and foreign studies in detail and utilise their results and suggestions via this hands-on project directly, for Malta. Thermal comfort can be achieved either by adapting to a building's climate or by changing the building's climate to one's comfort. The issue is that people can adapt or be comfortable to a wide range of climates [4]. As a matter of fact various studies quote different comfort temperature ranges and to date, even though an adaptive standard is being mostly considered, the 'ideal' standard comfortable temperature for all simply does not exist [5]. This is because thermal comfort is based on both the physiological aspects and psychological expectations, i.e. what may be ideal for a person might be uncomfortable to another – apart from social and economic constraints [6]. In addition to these factors, the utilisation of a particular building needs also to be taken into account in respect to the requirements of the specific group of people that will be occupying it – e.g. the requirements of a home are different than that of a work place.

In order to rectify this problem, it makes sense to investigate at a more practical level the energy–saving retrofitting solutions suitable for our climate and existing dwellings. The social and economic benefits of such an initiative could be quantified to encourage policy makers to look into them. The first step that needs to be taken before looking into how to design, build or alter a home in any country is to have a detailed look at its climate – in most cases the microclimate is even more important than the former [4], [6]. Once this data is collected and analysed, the relevant passive measures suitable for such a climate can be designed accordingly. If a building has a low thermal mass, adding external insulation, apart from the other benefits, is the key to increasing its thermal mass index. In fact placing thermal mass in between insulation is beneficial. This is indeed a possible solution for many local dwellings as they feature light thermal mass properties. Night time ventilation (when coupled with thermal mass) can be effectively utilised especially in the hot season. However we need to consider pollution and noise issues especially in Malta's urban areas. Dust is also another major issue (construction sites) and apertures must have insect screens. Some foreign case studies confirm that building near to zero energy dwellings that utilise all the prevailing climate conditions to our favour is indeed possible.

The reality is that electricity was considered a social commodity; hence its pricing was originally kept at bay by Government, running Enemalta, the only energy utility in Malta. Passive design solutions were therefore put aside for want for "modern" homes – albeit at a price. Today electricity tariffs were left to float as per international oil markets – often unpredictable. The repercussions we are facing due to this volatility in electricity tariffs are evident. Building *new* energy efficient homes is not going to solve the *old* problem of existing building stock – the solution is therefore to look into retrofitting, deploying energy–saving measures that are cost-effective and adaptive to a Mediterranean climate.

2. Project Methodology

The chosen methodology for this research work was to investigate various options for retrofitting to implement them onto an existing dwelling, thus potentially converting it into a near to zero energy home. An existing building (a top third floor flat in B'Kara), referred to as the subject flat, was used as a test bed for such conversions.

Before applying any energy–saving retrofit changes to an existing building, the said apartment needs to be thoroughly analysed to expose the main areas of heat losses and gains. This can be done by analysing the heat transfer process (HTP) of the building. Such an HTP must be carried out because the outside part of the building shell is strongly thermally influenced by outside air. The HTP can be a very complex analysis, as it involves the combined effect of all three heat transfer methods: convection, conduction and radiation [7]. However it can be safely assumed that buildings reach a steady state of heat transfer – such theory is the basis of all energy performance certification software across all European countries. Such a heat transfer model (HTM) yielded the following results – Figure 1.

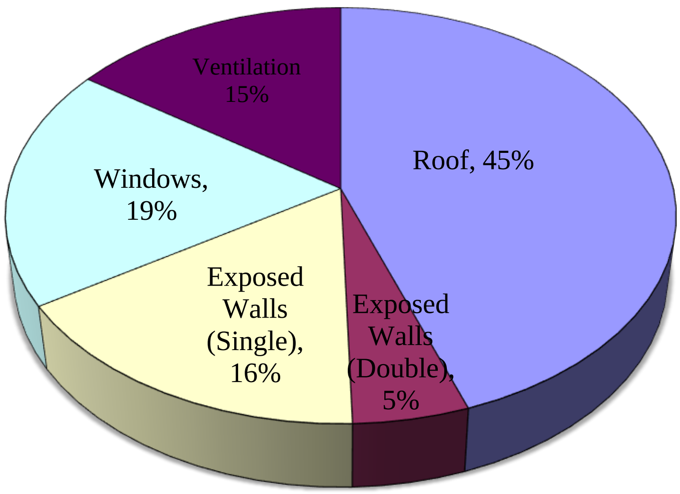

Figure 1: Steady State Heat Transfer Model of the Original Subject Flat

After a cost–effective analysis (based on the available project budget) and site considerations, the following design changes were applied to the HTM – these yielded the respective Heat Transfer Savings (HTS):

1. 75mm of expanded polystyrene (EPS) to the roof – 82% HTS
2. 50mm of rigid polyisocyanurate polyiso foam to the external walls – 74% HTS on double walls and 81% HTS on single walls
3. Existing aluminium apertures replaced with PVC double-glazed and argon-filled windows – 81% HTS
4. All ventilators sealed – 90% HTS

Following the results obtained, Figure 2, the respective energy–saving retrofit measures mentioned above, including adjustable louvers on the south and west apertures were applied to the subject flat.

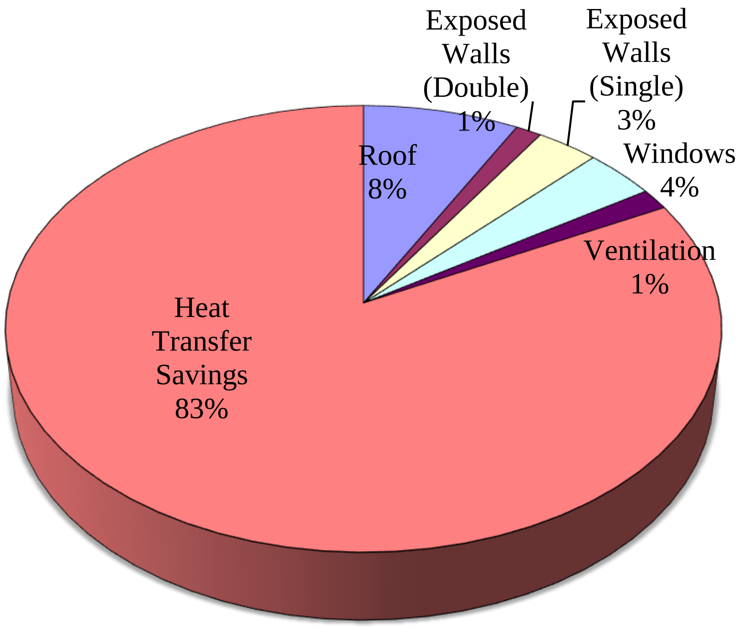

Figure 2: Steady State Heat Transfer Model of the Retrofitted Subject Flat.

As previously described, thermal comfort (TC) is quite an extensive subject and thus requires a quantitative approach to verify if the energy–saving retrofit measures that were applied to the subject flat have managed to contain the indoor climatic conditions inside the standard thermal comfort zone (TCZ). The method of analysis adopted was to utilise the bioclimatic approach via a psychrometric representation [8], [9]. This was applied by first delineating the relevant local TCZ on the psychrometric chart and then superimposing the apartment's indoor climate parameters onto it to verify how many data points plotted were actually contained by such a defined TCZ.

A Microsoft Excel Tool (MET) was programmed with the necessary psychrometric chart parameters and a combination of Szokolay's and Givoni's algorithms for the TCZs were utilised based on the local climate. [10]. It was decided to use the 90% acceptability TCZs throughout the project as it reflects the best thermal comfort conditions needed for our local climate – Figure 3

The pre-requisite to quantify if such energy–saving retrofit measures are effective from a thermal comfort point of view included a detailed analysis of the indoor climatic data, to check whether the temperature (T) and relative humidity (RH) readings fell within the defined TCZs. The hourly mean values of such T and RH readings need to be analysed to sum up the number of hours in the year when each specific value of T and RH occurs. Such data can then be plotted in a psychrometric chart with the number of hours (24 / day across a whole year) at each co-ordinate point [8].

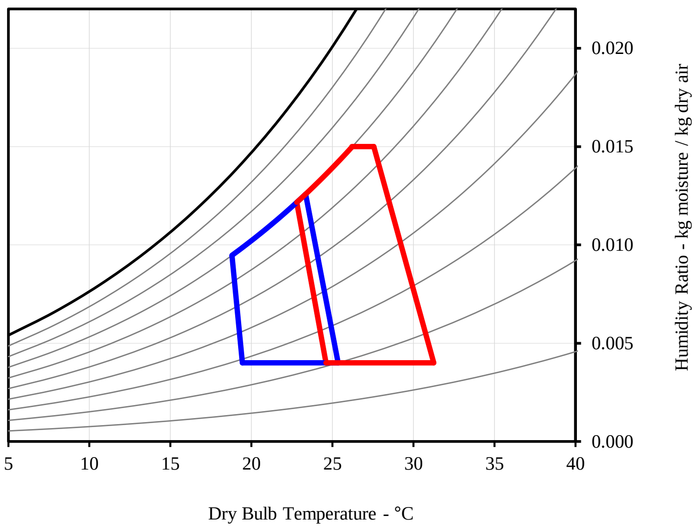

Figure 3: Local Thermal Comfort Zones with 90% Acceptability.

Unfortunately, before the retrofit changes were applied to the subject apartment, the indoor climatic data (for one year) was not recorded. However in order to have a good simultaneous comparison between the retrofitted subject flat and one that is standard, it was decided to also monitor the adjacent apartment (Flat 5) that happened to be a mirror image of the subject flat. As previously stated it was also important to monitor the B'Kara micro climate simultaneously with the subject's apartment readings. Thus T and RH hourly mean readings over a period of one year (June 2013 – May 2014) were recorded by using Lascar EL-USB-2 USB data loggers for both apartments and the B'Kara micro climate. The loggers (2 for each apartment) were placed at a 1.65m height in the living area sleeping area to record a home owner's thermal perspective.

In order to have another form of quantitative comparison and verification of such retrofit measures, the local EPC (energy performance certification) software for dwellings, EPRDM software was used, whereby the subject flat is considered as a single zone dwelling. In addition, the state-of-the-art software DesignBuilder (DB) was also applied since it gave the possibility of introducing adjacent dwellings, which may have some effect on the energy performance of the subject flat. Figure 4 shows the subject flat drawn in DesignBuilder, forming part of a whole block of 6 apartments, with two ground floor shops and adjacent blocks, as shown in Figure 5.

This scenario was created so as to reach as much as possible a close to reality simulation including shading effects and combined thermal masses from the adjacent apartment blocks. In both software, all the relevant building fabric parameters such as U-Values, wall thicknesses and heating / cooling schedules were carefully inputted to obtain a design model as close as possible to reality.

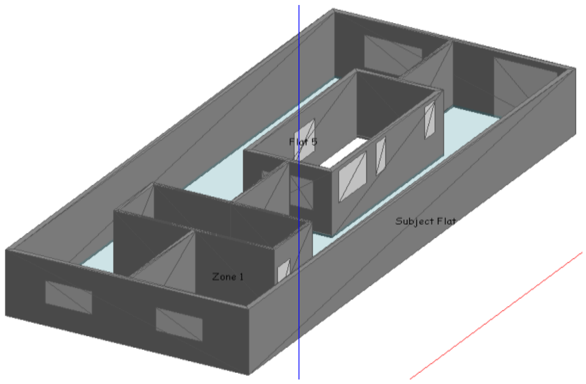

Figure 4: DB 3D view of Subject Flat and Flat 5.

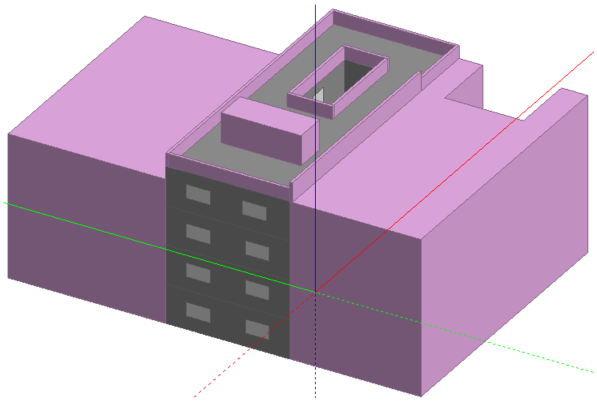

Figure 5: DB 3D view of Apartment Blocks

3. Results and discussion

3.1 Temperature Comparison

Figure 6 is a direct temperature comparison between the subject flat's (Blue) and flat 5's (Red) indoor temperatures, together with the B'Kara microclimate outdoor temperature (Green), following renovations to the subject flat.

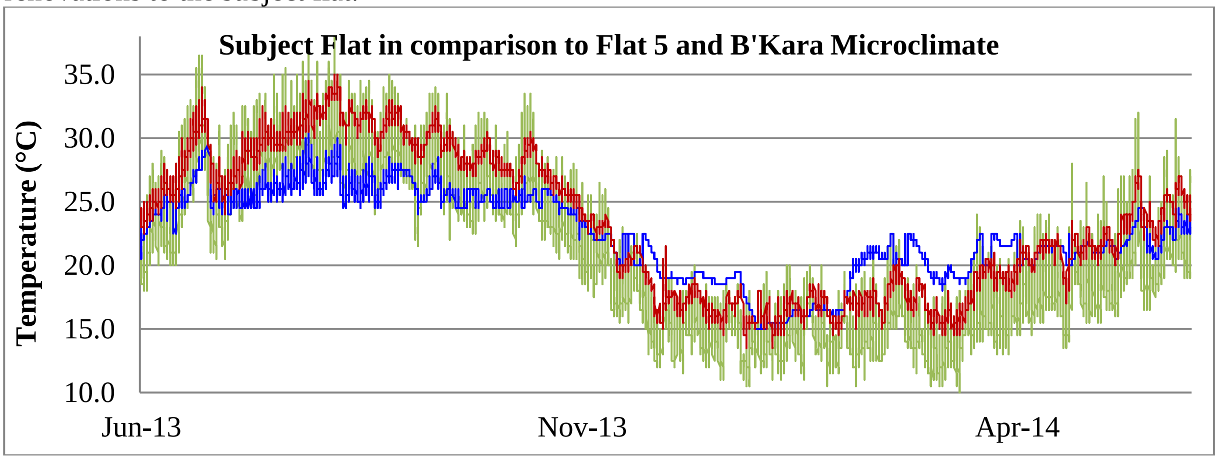

Figure 6: Temperature Comparison between the subject flat, flat 5 and B'Kara microclimate.

The subject flat doesn't make use of air conditioners (ACs), unlike flat 5 that makes extensive use of ACs. In flat 5 the Lascar temperature / humidity sensor was placed in an unoccupied room (spare bedroom) that does not make use of ACs.

Summer analysis: The subject flat was carefully controlled during most of the period July - August 2013 by:

1. Blocking off all sun rays via the adjustable louvers / shutters.
2. Windows were kept closed during most of the day (10:00hrs – 20:00hrs).
3. Night time ventilation was used accordingly to favour the prevailing climatic conditions offered during this period.

The result was that the apartment's inside temperature mirrored the lowest part of the microclimate during this period. On the other hand during the months of June, September and October 2013 the apartment was left unattended (closed up) and as predicated from various studies, it's inside temperature followed the microclimate mean temperature. In addition a fan had to be used for an evaporative cooling effect on the occupant (the author) during the heat wave periods.

Winter Analysis: Once the outside temperatures started falling (November) the subject flat indoor climate was controlled as follows:

1. The adjustable louvers were opened and retracted to allow the incident sun rays build up the internal solar gains.
2. All windows were kept closed at most times. They were only opened occasionally at noon to ventilate the apartment when the outside temperature was prevailing.
3. No form of artificial heating was used.
4. Internal humidity was kept to a minimum.

The results showed that the subject flat managed to keep quite a constant and very comfortable temperature of approximately 18°C throughout the whole cold season – as a matter of fact the occupant noted that unlike other dwellings, the clothing level was kept to a simple long sleeve top and trousers. On the other hand, during the month of January the apartment was left unattended (with closed shutters and louvers). A detailed look at the temperature hourly readings showed that the insulation helped to contain the internal solar gains within the subject flat for an 18-hour period. Once the solar gains were cut off (January), the apartment's temperature started falling towards the microclimate mean temperature.

Figure 6 also shows that flat 5 practically followed the highest temperature section of the B'Kara microclimate and when compared to the subject flat, the inside temperature swings are more frequent. This means that flat 5's thermal mass is very poor, as it did not offer sufficient dampening effect – unlike the subject flat (due to its insulated walls).

The occupants of flat 5 (a middle aged couple) stated that both summer and winter are unbearable without the continuous use of ACs for cooling and gas heating, respectively. Statistical analysis of flat 5 (room without any air-conditioning) showed that the internal temperatures reached up to 33 °C in summer and went down to 13.5 °C in winter. The apartment block featured the standard building practices of the 1950s that lead to a very poor thermal comfort. Apart from some plastering modifications, flat 5 is still in the original state as the subject flat was – both structurally and building fabric wise (230mm globigerina limestone).

The selected energy saving retrofit measures that were applied to the subject flat are very effective with an overall 3 °C (7 °C maximum) temperature difference in extreme hot and cold seasons. This difference comes at a cost; either via using ACs or by investing in such energy saving retrofit measures, thus one would need to analyse the cost effectiveness. However such a preliminary study already showed that if the selected energy saving retrofit measures are correctly installed and the dwelling is controlled well, then it is indeed possible to achieve minimum energy homes in Malta. However if such a retrofitted dwelling is left unoccupied it will simply follow the mean outdoor temperature swing and this will lead to the need of system heating and cooling.

3.2 Psychrometric Chart Analysis

The main scope of collecting the climatic data (T and RH) was to process it in the psychrometric charts to analyse if such energy–saving retrofit measures managed to contain the indoor climate within the TCZ limits. The measured climatic data was processed accordingly and inputted in the MET. The following plots are the results obtained – each black dot represents an average hourly reading of temperature and corresponding humidity ratio, the latter derived from the T, RH and atmospheric pressure (AP).

Figure 7 shows that at most times, the indoor climate is by far out of the TCZs and this means that flat 5 needs a considerable amount of heating and cooling – the latter being the greater load. In addition the humidity in winter is high – this might be due to the fact that the occupants use gas heating and they keep the apartment closed due to cold temperatures. The retrofitted subject flat model was simulated via the DB software with the ISE 2005 weather data. Ideally the DB simulations had to be carried out utilising the B'Kara microclimate weather. Unfortunately this was not possible since apart from the T, RH and AP, further detailed climatic data is necessary, such as: solar incidence (albedo, all direct and diffused components), wind (speed and direction), sky visibility parameters and precipitation. The indoor climate data obtained from the DB simulations was processed via the MET obtaining the respective psychrometric chart – Figure 8.

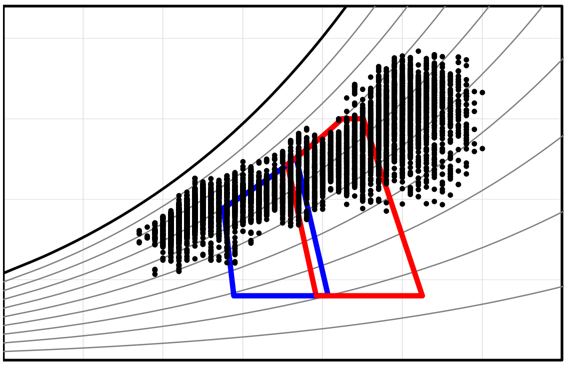

Figure 7: Flat 5 Indoor Climatic Data with 90% TCZs.

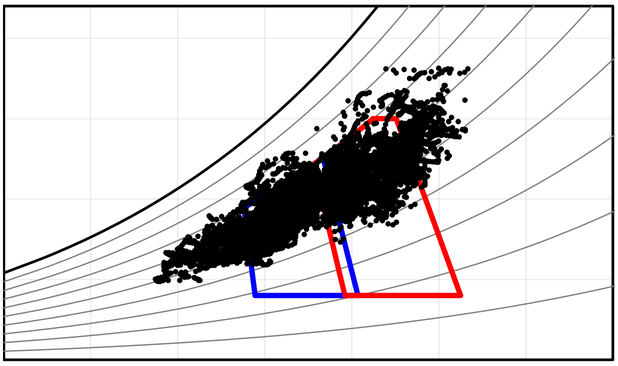

Figure 8: Retrofitted Subject Flat DesginBuilder Indoor Climatic Data with 90% TCZs.

Similarly the actual measured hourly indoor climatic data of the retrofitted subject flat was inputted in the MET and the respective psychrometric chart is shown in Figure 9. Comparing the two plots (Figures 8 and 9), the simulation and actual measured data showed a good correlation, even though they might look different. The differences in the extreme hot and cold periods are due to different humidity levels. This may be due to the fact that the DB software might not manage to accurately calculate the humidity levels – mainly in summer via night time ventilation. In fact the DB software only offers an OFF or ON option for natural ventilation and the air changes per hour (ach) - unlike the detailed heating and cooling schedules that the software can offer.

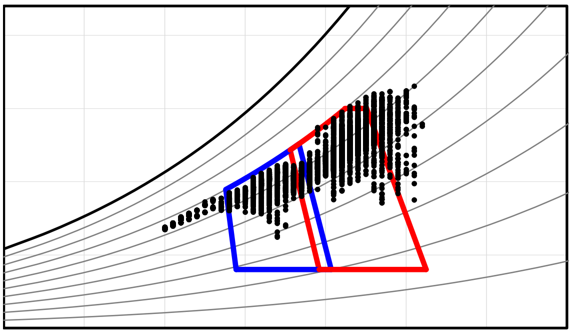

Figure 9: Retrofitted Subject Flat Indoor Climatic Data with 90% TCZs.

This means that it considers natural ventilation throughout the whole hot season. In reality a controlled schedule was used in summer as explained in Section 4.1, since the occupant of the subject flat realised that natural ventilation during the day increases the indoor temperature. In addition the occupant also used the site's prevailing climatic conditions to ventilate the apartment in winter (most often during midday), so as to reduce humidity levels too. All in all, even though the subject apartment actually performed better than the DB simulation, it shows that DB is a potential tool to carry out such climatic simulations as long as all parameters are correctly inputted.

With regards to Figure 9, apart from a few data points that fell out of the TCZs, most of the indoor climate is contained and this means that the energy–saving retrofit measures have successfully served their purpose. Most of the points that fall out of the TCZs are the ones when the subject apartment was intentionally left unattended in winter (no solar and internal gains during the period between December 2013 to January 2014) and in summer (when the apartment was closed up during June, all of September and October 2013). In fact it is only for this small portion (a total of 9 out of 122 days – 7% in summer and 16 out of 121 days – 13% in winter) that the energy–saving retrofit measures failed to satisfy the TCZ limits.

Such psychrometric chart analysis (Figure 9) and the temperature graph (Figure 6) show that energy efficient dwellings are indeed a possibility in our local climate if retrofitted with such measures. However the analysis also showed that if such a dwelling is left unattended or wrongly used, the tendency is that it will follow the mean outdoor temperature, thus the occupants would still have to rely on active measures such as the use of ACs to reach a thermal comfort level – the latter loads won't be as large yet still considerable.

3.3 Software Energy Analysis

Table 1 shows a comparison between the software results and the actual kWh readings over one year. Since no readings are available for the original state of the subject flat, flat No 5's results were used. It stands to reason that actual results for the modified state are not possible and were thus omitted.

Except for the subject flat cooling load, the EPRDM is nowhere close to the actual readings, however on the other hand the DB software and Flat No. 5 readings are close and this means that such a software, if carefully used (as there are many variables to consider), can be employed for relatively good simulations.

Table 1: Software and Actual Energy Analysis.

All Readings : kWh	**EPRDM**	
	Original State	**Retrofitted State**
Space Heating	734	626
Space Cooling	1266	161
Total	**2000**	**787**

All Readings : kWh	**DesignBuilder (DB)**		**Actual**	
	Original State	**Retrofitted State**	**Flat No. 5**	**Subject Flat**
Space Heating	2000	261	1671	0
Space Cooling	2307	1493	2433	164
Total	**4306**	**1754**	**4104**	**164**

Unfortunately neither of the two software managed to get close to the actual results obtained in the retrofitted subject flat. This may be due to the fact that even though the relevant natural ventilation parameters were carefully inputted, such software still relies a lot on system use (as per their defined system standards) rather than work around the adaptive comfort standards. This conclusion was reached since even though the DB temperature and RH readings were close to the actual ones, the DB software still recommended such cooling and heating loads.

3.4 Payback Periods of Energy–Saving Retrofit Measures

The most sought-after FAQ of such energy–saving retrofit 'investments' is "When will they eventually pay off?" The advantage of this project was that the subject flat and flat 5 were identical in size and layout (mirror image). Thus it was decided to utilise the subject flat and flat 5's electricity bills for such a payback calculation exercise. The subject flat electricity bills amounted to an average of 2,439 kWh (€266.41) while Flat 5's were 7,837 kWh (€1,023.88) per year. The cost breakdown was calculated utilising the Enemalta electricity residential tariffs as of April 2014.

The cost of each energy–saving retrofit measure was calculated in detail – Table 2. These costs reflected the actual installed cost as they included all purchased material, hiring of tools and heavy machinery, labour and the corresponding permits that were required. In order to carry out the right financial comparison, the cost of the installed AC units in flat 5 had to be calculated (3 AC Units at €1,012 each => € 3,036) and subtracted from the energy saving retrofit measure costs. This was done by dividing the AC cost in a ratio equivalent to the UA–value percentages (Figure 1) and then subtracting it from the corresponding retrofitted measure as shown in Table 2. Since the air tightness measure's cost is very low, it was decided to shift its ratio to the apertures cost as these are 100% draught-proof. In addition, since the aperture shades cannot be presented as a UA–value, no AC ratio cost was subtracted from the actual retrofit costs.

Table 2: Energy–Saving Retrofit Measures Costing, in Euros.

Retrofit Measure (UA-Value %)	Actual Installed Cost (€)	AC Cost Ratio (€)	Subtracted Cost (€)
Roof Insulation (45%)	2,033.26	1,366.20	667.06
External Insulation (21%)	1,170.00	637.56	532.44
PVC Double Glazing (34%)	3,450.69	1,032.24	2,418.45
Aperture shades	2,276.20	–	2,276.20
Air Tightness and Humidity Control	55.90	–	55.90

It stands to reason that only the cost of the heating and cooling section of flat 5 (4,104kWh) has to be used to calculate the energy–saving retrofit measures paybacks. This part amounts to a cost of €589.49 per year. However for a proper payback period calculation the subject apartment's heating and cooling part (164 kWh – €21.32) has to be subtracted from this amount. Thus this falls to €586.17.

Since the aperture shades cannot be represented in the respective UA-Value ratio, the DB simulation software was used to calculate the difference in the overall cooling load for the solar gains, with and without such shades across the hot period only (May – October). The difference (25%) was converted into the respective cost saving (€144.04) and thus subtracted from €586.17 to reflect the cost savings without the shades: €424.14. This amount was then divided according to the UA–value percentages as shown in Table 3. Rather than working out a simple payback period, a discounted payback period was utilised with a discount rate of 5%, as suggested by various financial institutions [11], [12], [13], [14]. The respective payback periods are shown in Table 3

Table 3: Energy–Saving Retrofit Measures Pay Back Period.

Retrofit Alteration	Subtracted Cost (€)	Yearly Cost Savings (€)	Discounted Payback Period (Years)
Roof Insulation	667.06	190.86 (45%)	3.9
External Insulation	532.44	89.07 (21%)	7.3
PVC Double Glazing	2,418.45	79.93 (19%)	35.9
Aperture shades	2,276.20	147.51 (Solar gains)	17.3
Air tightness and Humidity Control	55.90	63.10 (15%)	0.92

It is evident that the most effective energy saving retrofit measure is the air tightness and humidity control one, followed by the cost effective insulation (roof and external) measures. The last (yet most sought) is the double glazing one. Actually, this exercise shows that such a double glazing measure is not worth investing in. As a matter of fact, locally, there is a misconception that the best form of insulation measure is double glazing. In fact, such a measure comes at a high cost and with a very long payback period as opposed to the other beneficial measures. The shades, with a 17.3 year payback period (quite a long one) are still a more cost effective measure than the double glazing one. Thus it would make more economic sense to perhaps change single glazed windows to draught-proof ones as air tightness is more crucial than actual double glazing and install external shades.

Considering these payback periods, it would make more sense (from an economic point of view) for government to increase subsides on roof insulation and introduce a grant for external wall insulation – rather than the ongoing double glazing scheme. It is important to state that for the right economic analysis, only the discount rate was applied to this payback periods exercise. In reality; even though recently (March 2014) the electricity tariffs were revised downwards, the long-term tendency for energy prices is to rise, given our carbon tax disincentives. Such an outcome would decrease the payback periods and thus make such retrofits even more attractive.

Once the payback periods were calculated and eventually be reached by time, it would be interesting to use the same discount rate method to determine the additional cost savings (revenue) that one can get for the lifetime of the dwelling. Table 4 shows the obtained such cumulative results.

Table 4: Future Income of Energy–Saving Retrofit Measures, following the break-even point. Figures are in Euros.

Retrofit Alteration	5 Years	10 Years	15 Years	20 Years	25 Years
Roof Insulation	159.27	806.72	1,314.01	1,711.49	2,022.93
External Insulation	-146.82	155.83	392.06	577.55	722.89
PVC Double Glazing	-2,027.34	-1,655.20	-1,301.12	-964.23	-643.70
Aperture shades	-1,577.12	-911.98	-279.12	323.03	895.95
Air tightness and Humidity Control	219.54	435.36	604.46	736.95	840.76
Totals	-3,372.47	-1,169.77	730.29	2,384.79	3,838.84

This case study showed that after 15 years the combined energy saving retrofit measures pay off with a surplus of € 730.29. Considering the thermal comfort status achieved and the energy-cost analysis, stating that such energy saving retrofit measures aren't feasible, as most people think, is simply not correct. One has to appreciate that the study did not include any social benefits that may be enjoyed by the application of such retrofitting measures, such as better health and well-being. In fact this project has succeeded to achieve its objectives and its results can be used to aid policy direction and propose incentives regarding 20-20-20 targets for energy efficiency.

4. Conclusion

When considering the temperature distribution across a whole year (Figure 6), the psychrometric representation with the TCZ parameters (Figure 9) and the cost effective analysis carried out (Tables 3 and 4), this case study clearly showed that retrofitting our existing building stock via energy saving measures is indeed an achievable target and the outcome is a winning and positive situation from all aspects – such as:

1. A substantial reduction in energy use – both for the consumer and the national energy grid load.
2. A financial investment worth considering – especially if the payback period is surpassed thus making the investment render a profitable return for the remaining years.
3. A more thermally comfortable lifestyle in our existing dwellings and better well-being.

It is only for this small portion (a total of 9 out of 122 days – 7% in summer and 16 out of 121 days – 13% in winter) that the energy–saving retrofit measures fell outside the TCZ criteria. Such results, if utilised well, can open new business opportunities for an important sector of our economy – the construction industry – which has been on the decline due to the lack of demand and also due to the saturation of new buildings rising within the available land space.

Moreover the restraint on building permits outside development schemes – claimed as 'restricted' – has pushed developers to look inwards within building zones and possibly village cores to demolish and redevelop old houses to build new modern apartments – even if with a limited building height and floor area. These are unfortunately replacing the true houses of character, where most of the inherent physical features lie, including passive design unwittingly incorporated by our forefathers within the building fabric itself. Therefore retrofitting is surely one bold way forward. This not only eliminates the take up of new plots of green land and our finite resources (limestone), but moreover conserves embodied energy from construction as well as exploits the energy saving potential of such in-built features.

Hence retrofitting of existing dwellings into an NZEB home (near zero energy) home could be a potential for resuscitating the building sector. Apart from creating such an opportunity that will help increase our local economy due to new or modified skills and job take up, it will also help in reaching the EU energy efficiency targets.

However, it is of outmost importance that tradesmen need to be educated via adequate courses to improve their skills in retrofitting. In addition all relevant energy efficient products need to be certified and registered with the relevant authorities such as MRA and MCCAA. Quality assurance in the execution of such retrofits is key to it all.

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