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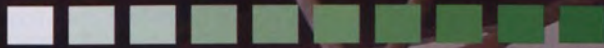
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A review of the Passiv Haus Concept

and an examination of how
this was applied to a
supermarket in Ireland



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Abstract

The aim of this research is to garner a full understanding of low energy construction across a variety of sectors in countries throughout the world, and then investigate how the Passiv Haus concept was applied to a Supermarket in Ireland. In order to carry out this investigation, a case study was performed on the energy efficiency and performance of a Tesco store in Tramore. It was found that its electrical consumption was 24% lower than equivalent stores which were not built to the high specification of the Passiv Haus Standard. As this supermarket is the first of its kind in the world, and with both the SEAI and the European Parliament pushing for this method of construction to be adopted,^[1] this standard will most likely in some shape or form become a new building standard in Ireland. This supermarket offers a unique insight into what can be expected in building design and construction in this sector if it is undertaken.

Key Words:

Passiv Haus; Passive House; Electrical Energy Consumption in Supermarkets.

1 Introduction

In Ireland, the Passiv Haus Standard has become more widely acknowledged in recent years and accepted as a method of reducing energy consumption and the operating costs of a dwelling. However, applying this standard to a commercial building is still in relative infancy. This newer approach to using the Passiv Haus Standard was reviewed in this paper by applying an analysis of the energy consumption of a newly constructed Tesco supermarket in Tramore, Waterford, Ireland.

As this is the first supermarket in the world to be certified by the Passiv Haus Institut (PHI) it is of particular importance to demonstrate whether or not this method of construction shows any real benefits, especially in a commercial sense, as this will be one of the main driving forces behind this movement if it is to be successful.

The main aim of this study was to investigate if there were any cost savings with regards to the operational costs of the Tesco supermarket in Tramore, and if there were any improvements in efficiency in energy consumption in comparison to standard building practices.

Tesco have offsite management systems that remotely obtain all data at the point of use. Given that the store has been in operation since October 2008, there was over a year's worth of data available for this study. Field equipment was also used to independently record data for the research.

2 Governmental influence

On the 8th January 2008 following the work done in the inter-governmental European CEPHEUS research programme, the European Parliament published a document entitled "An Action Plan for Energy Efficiency: Realising the Potential". Within this document, which covered a range of aspects, particular mention was made of the Passiv Haus:

"...29. Calls on the Commission to propose a binding requirement that all new buildings needing to be heated and/or cooled be constructed to passive house or equivalent non-residential standards from 2011, and a requirement to use passive heating and cooling solutions from 2008...^[3]"

3 Technical criteria for Passiv Haus

Specific Space Heating Demand	Max 15 kWh/(m ² a)
Specific Space Heating Load	Max. 10 W/m ²
Pressurisation Test Result n ₅₀	Max. 0.6 h-1
Specific Space Cooling Demand	Max. 15 kWh/(m ² a)
Total Specific Primary Energy Demand	Max. 120 kWh/(m ² a)*

Table 1: Criteria for non-residential buildings for Passiv Haus certification^[2]

*Over runs of this amount is allowable at the discretion of the Passiv Haus Institut

As the case study performed in this research was performed on a non-residential building, it is important to note at this stage the criteria set out by the PHI, for Non-Residential Passive House Buildings (Table 1).

4 Case study: Tesco Tramore, Waterford

A recent study commissioned by the SEAI estimates that the commercial sector could save up to 25% of its energy use through investment in economically viable energy efficiency opportunities.^[4]

In October 2009 Tesco unveiled a new energy efficient supermarket that took on some of the more cutting edge design techniques and technologies that are available today for low energy construction, and to test in a real-world, commercial environment the viability of these technologies. They had sought to create the world's first Passiv Haus supermarket.

A. The supermarket: analysis

1) Physical structure

The structure of the supermarket is broken out into its separate constituents below, and explained in brief detail.^[5]

Roof Panel: The roof was 200 [mm] insulated Kingspan Ks 1150 panel, sitting on timber purlins with insulated pads to achieve the overall U-Value of 0.12w/sqm K

Roof lights: 15 degree pitch triple glazed glass and insulated to the same specification as the roof panels.

Roof penetrations: Fully packed and sealed with insulation to 0.035 thermal conductivity.

Triple Glazing: Curtain wall to design value of 0.8 W/m² K.

Air sealing: Air seal tested by BSRIA. Result was 1.64 M³/h/M² @50Pa. Standard building regulations looks for 10 air changes. 1.64 equates to an air change rate of 0.3.

Floor slab insulated: The floor slab was completely insulated, and most importantly and unusually, right up on the vertical side of the slab also. This was to prevent any cold bridging between the outside and the inside of the building.

Structural Timber Beams: These timber beams are also called Glue Lam Beams, and are selected for their reduction in embedded carbon being introduced into the construction of the building.

Rain water harvesting: The car park areas are cobbled intentionally to allow rain water to be gathered into a rain water harvesting tank.

2) Building services

Though the PHI do not typically dictate what type of building services are used within the construction of a building, the energy

consumption was going to over run the 120 kWh/(m²a) allowable within the criteria. This means that the PHI needed to also approve the Building Services design.

Combined Heat and Power (CHP): CHP on a small scale as is installed in Tesco Tramore can be very beneficial, assuming that a heat load is required all year round.

Tri-Generation: It was also decided to add an absorption chiller, which operates by using heat and a chemical process to create low temperatures, and as such can be used during the summer months to keep the thermal load high and as such keep the CHP running 12 months of the year. This tri-generation plant was not installed during this study.

Hot Water Air Curtains and Heaters: Instead of using electric door curtain and water heaters, the design of the building was to try and incorporate as much of the heat load into the heating system, which was the gas fired CHP.

Chilled Beams (instead of split A/C): Chilled beams were installed in all areas that required cooling: the office areas in particular. Again the reason for using the chilled beams was to make use of the CHP tri-generation facility once it is installed on site.

CO2 Refrigeration: A centralised refrigeration unit was used in the Tesco store for the fridge cabinets. This refrigeration unit operated on CO2 gas. Its efficiency is almost 15% more than that of the typical refrigerant (R404a) that is used, and is substantially more beneficial to the environment.

Intelligent Lighting: A DALI (Digital Addressable Lighting Interface) lighting system is installed within the supermarket. This system enables Tesco to control lighting within the store to take advantage of the large areas of windows by positioning photo cell sensors in the vicinity of these windows. The lighting will dim in these areas when the sun is shining, and thus save on energy.

LED Lighting: All fridges and chilled storage cabinets have LED light installed

Solar PV: Tesco's solar electricity system consists of forty 210 Wp Sanyo HIT modules, giving a total of 8.4 kWp (kilowatt peak).

B. The Supermarket: The Energy Consumption Analysis

The electrical consumption of the building has been broken down into different parts and each section of consumption will be analysed in as much detail as the data allows.

CHP:

The output of the CHP was shown to drop dramatically over the summer months due to there being no requirement for a thermal load (Figure 1).

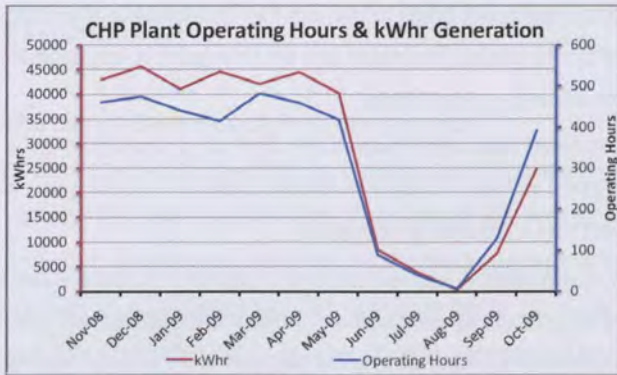


Fig.1: This chart shows the performance of the CHP plant and its generated kWhrs over its operation. The large dip is due to the thermal requirement dictating its usage and as such during spells of warmer weather the unit switched off.

To overcome this lack of usage period, the use of an absorption chiller unit was designed to be installed in the Tesco store. Unfortunately when this research was carried out it was not installed, and as such no results for the performance of such a piece of equipment could be analysed.

Solar PV

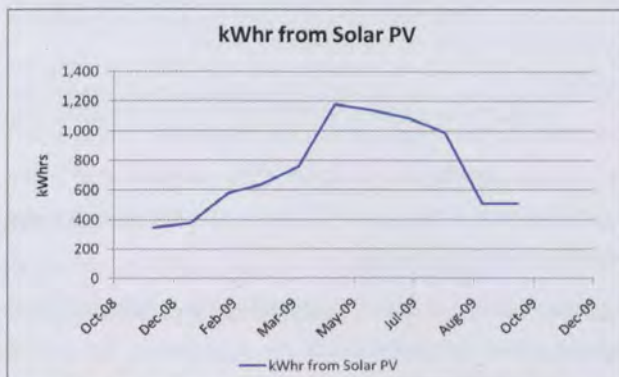


Fig. 2: This chart shows the performance of the Solar PV. This particular installation behaved exactly as it would be expected. However the sudden dip in August is due to an obstruction placed in its way.

It can be seen from Figure 2 that the Solar PV output is at its maximum output from the months of April to August. Conveniently this coincides with the poor output from the CHP at this period, and upon brief inspection one may think that they complement each other very well.

However, the sheer low energy output from this Solar PV array in comparison to the energy consumed is very large. If the maximum cost of electrical units were applied to the cost savings in electrical consumption that this solar array delivered, it would be no more than €1000 over the course of a year.

The large drop off in performance for the month of August is a situation worth investigating. The supplier of this very system to Tesco monitors the data from this installation and noticed the drop off also.

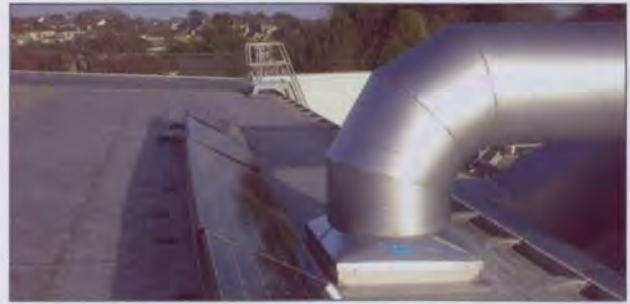


Fig. 3: Picture of the obstruction blocking the Solar PV array

Upon inspection it was seen that a large duct was placed directly in front of the installation (Figure 3). This duct would have had a large effect on the performance of the array due to its proximity and large size blocking sunlight.

CHP, Solar PV and the grid supply:

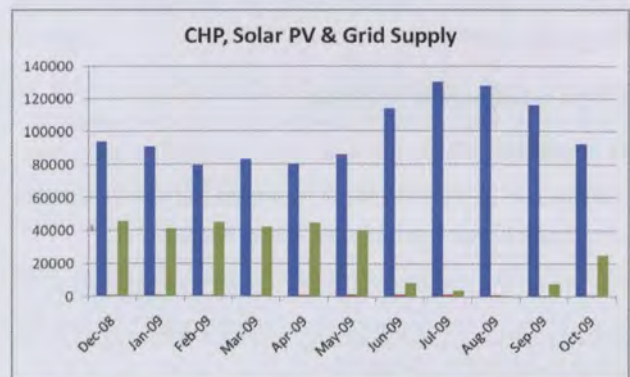


Fig. 4: Chart comparing the performances of the CHP plant, Solar PV and the consumed grid supply. It can be seen that the solar PV barely makes an impact on the overall consumption of a store this size.

Figure 4 shows the clear picture of the output of the different electrical sources over the period of almost one year. This picture shows the general low output of the Solar PV, when it is compared with the other sources, such as that from the CHP and from the grid.

Electrical running costs and comparisons

Bettystown and Letterkenny and the Tesco Tramore installation had their electrical costs and different systems compared in detail (Figure 5). However, Tesco Tramore is the only one of all three with a CHP installation.

Electrical costs are on average 37.73% less expensive than that of the other comparison stores (Figure 6). However, these measurements and costs are taken directly from the bills, and though they show the actual consumption of electricity of the Tesco stores, the results do not take into account the consumption/generation of the CHP plant. When the offset of the CHP are taken into account, the actual energy consumption of the building increases and the energy savings become 24.17%.

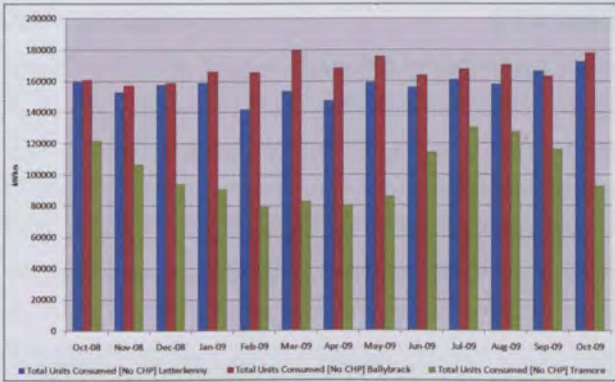


Fig. 5: Comparison of Tesco stores – CHP output has not been added to the overall consumption of Tesco Tramore

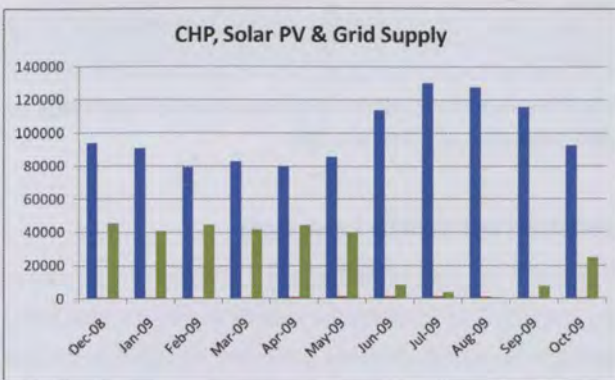


Fig. 6: Percentage less expensive between Tramore and the average costs of the two other Tesco stores

Internal environment



Fig. 7: During the cold October/November 2009 period, the main sales floor area was kept at a constant 20-23°C with the RH rarely going over 50%

Even over the cold October/November 2009 period, the main sales floor area was kept at a constant 20-23°C with the RH rarely going over 50% (Figure 7). The internal environment is within agreeable parameters for any store of this nature. The good control of the internal environment leads to better control over other systems. The low humidity levels prevent condensation from fogging up the fridge cabinets and thus the “de-fogging” heating elements from turning on. This all serves to add to the efficiency of the overall building, especially when so much of the shop floor is taken up with fridge cabinets.

General electrical and lighting readings

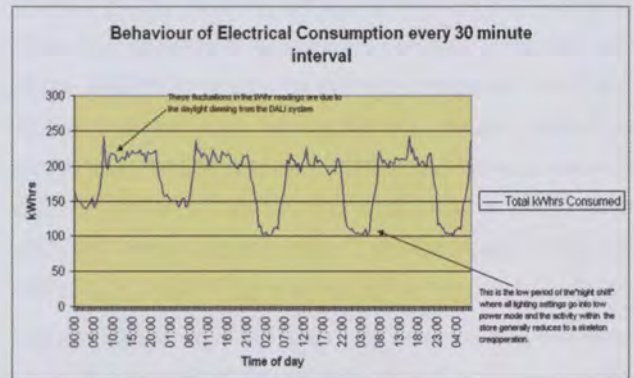


Fig. 8: Behaviour of electrical consumption every 30 minute interval

The source of data that was used to put together the analysis of electrical readings on site, as seen in Figure 8, was from the individual metering in order to help Tesco individually monitor different aspects of the installation. As can be seen the fluctuations during the course of the day are due to electrical requirements of an occupied building moving up and down. This would be due to perhaps ovens being turned on at the bakery and other items, though more importantly in the sense of the electrical efficiency the lighting dimming when it receives daylight to its lighting sensor at the shop floor. The large dips also indicate the night shift operation of the store, and show a very large decrease in activity and the lighting lowering its intensity into night time mode.

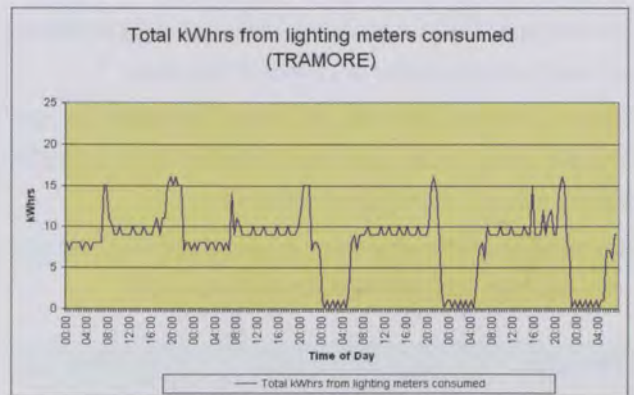


Fig. 9: Total kWhrs from lighting meters (Tramore)

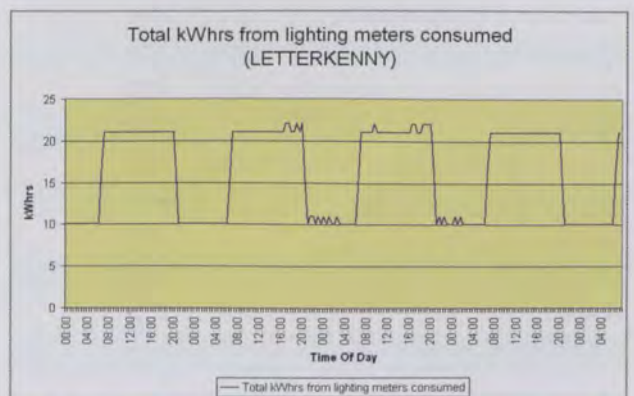


Fig. 10: Total kWhrs from lighting meters (Letterkenny)

The lighting demand from Tesco Tramore (Figure 9) is showing behaviours that is somewhat expected. However, lighting seems to have dropped to zero over the course of three nights. This would need to be investigated to ensure the veracity of this data, as this continually happens throughout the data sample collected. However some behavioural trends can be ascertained. The daylight dimming can be seen to be in operation during the lower troughs during the daylight periods. This time sample is taken during the month of July, where its effects would most likely be most effective.

Letterkenny has also got data for its lighting output (Figure 10). It can be seen that the lighting does not have any peaks or troughs other than those apparent from the night shift. There are small fluctuations, and without being there on the day these recordings happened it would be impossible to say what these are. However, it is important to note that the daylight dimming and any fluctuations in the lighting demand are non-existent in this store.

Tramore's energy profile for the lighting is superior in terms of performance when it comes to energy consumption. The actual level of consumption is also about 25% lower than that of Letterkenny, no doubt due to the high efficient T5 lamps and LED lighting installed throughout the Tesco store.

Comparison of construction cost

The analysis in Table 2 is a breakdown of the cost of the installation and build compared to that of a standard Tesco store.

Due to commercial sensitivity, only limited information is made available, though it does give a good indication for the additional expense that was incurred during this construction.

It is immediately noticeable that every single item on the list was more expensive than that of the standard Tesco store.

Cost Analysis	
<i>This store is based on 2008 prices, on average prices have fallen 20% since construction</i>	
Based on 30,000sq ft retail area store	% of standard item
Timber cladding in lieu of Ranila cladding	389%
Cedar louvre to roof plant in lieu of anodised aluminium	120%
Timber frame front, bulk store steel frame in lieu of steel	274%
Triple glazing	173%
Increased specification wall and roof cladding for insulation	125%
Mechanical	235%
Electrical	114%
Refrigeration	162%
Signage	128%
Roof overhang 1.45 at gables	110%

Table 2: Comparison of construction costs for a Passiv Haus supermarket and a standard format star

Summary

So in summary Tesco Tramore does seem to be leaning towards that of an eco-friendly, highly efficient supermarket. This paper does not claim to be a definitive piece of work on the Passiv Haus application to a supermarket, but was written with the goal in mind to show whether or not the initial indications are promising. With results as can be seen in Table 3 for the energy consumption, the results are very encouraging indeed.

Store Location	Type	Sale Floor Area [m ²]	Electricity Consumption Mains Supply	Electricity Consumption (CPH)	Electricity Consumption Total	Electricity Consumption kWh/m ²
Tesco Tramore	Format 30	2,747.4	1,199,375.17	345,836	1,545,211.17	560
Letterkenny/Ballybrack	Format 30	2683	1947,799.00	0.00 (None installed)	1,947,799.00	726

Table 3: The electrical consumption of the Tesco stores as kilowatt hours per square metre of the sales floor area (SFA)

Limitations and possible future study

It is important to ensure that the point is made that the purpose of this research is to ascertain the viability of this standard being applied in the manner discussed. Some clear limitations to the data is that of using Tesco's own on-site recording equipment and access to energy bills for the research. This meant an over reliance on Tesco themselves, and although they were more than forthcoming with their help and openness with this information. Some data was collected first hand by the researcher and this validated some of Tesco's data.

For this research to be carried out to it's fullest, a wider array of measurement devices would be required. Light meters, humidity sensors and temperature sensors at more than just two locations within the store would be required. A thermal-imaging camera would be extremely useful in order to examine the details of the construction more clearly. However, the cost of this equipment would make it prohibitively difficult to get.

Also, more on site testing methods for verifying the electrical and gas usage would have been desirable.

It is intended by Tesco that this critical evaluation will allow them improve and enhance what is clearly a very promising innovation. This is the first supermarket in the world to attempt a Passiv Haus construction and this research suggests there will be many more in the future.

Acknowledgements

I would like to thank Tesco and Tesco's then Energy Manager Michael McNerney for their help and permission in accessing the data used within this research.

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