SEE THE LIGHT – 2010

“BUILDING A CARBON-FREE FUTURE”,
CROKE PARK,
DUBLIN.

Impact of climate variation in Ireland on the performance of passive and low energy projects

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1. Abstract

This paper addresses the variation in climate within Ireland and highlights the extent to which the variations in Solar Radiation and Ambient Temperature can influence the heating performance of Low energy or Passive House buildings.

It endeavours to identify the principal variation in the climate conditions, the practicality of interpolating data and questions the accuracy of heat energy prediction models when they are calculated based on what could be considered irrelevant climate data. It finds that the agricultural sector have carried out extensive studies in Ireland over recent years with informative results confirming that interpolation of data can be achieved to a high level of accuracy.

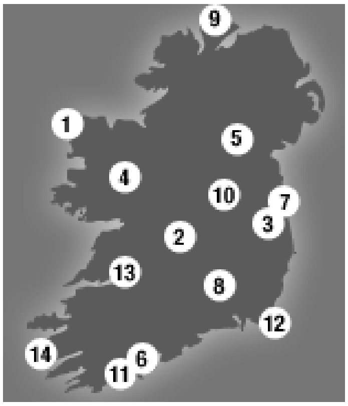
The Heating Energy requirements and Carbon emissions for both a Passive House and Low energy specified variants of the same building are compared.

In an attempt to get some understanding of what the optimum proportion of opaque to glazed wall on a south elevation might be for both Passive and Low Energy buildings, a model is adapted to have between 23% and 54% glazing on the south elevation and the results are reviewed. Simultaneously dynamic simulation is used to compare the performance of a building constructed to meet Passive House certification standards to that with opaque elements having u-values modified so as to meet the requirements of the draft 2010 Building Regulations TGD L in Ireland.

2. Introduction

Climate data for building energy simulation in Ireland is principally available from the Irish synoptic and climatological network which consists of 14 stations maintained by Met Éireann. The radiation and temperature data is fully monitored and the accuracy meets the requirements of the International Geophysical Year 1957. *(K. Black et al).*

1	Belmullet	8	Kilkenny
2	Birr	9	Malin Head
3	Casement	10	Mullingar
4	Claremorris	11	Roche's Point
5	Clones	12	Rosslare
6	Cork Airport	13	Shannon Airport
7	Dublin Airport	14	Valentia



Source: Met Éireann Note:; Clones, Kilkenny and Rosslare were closed in March 2008, Ballyhaise, Carlow and Johstown castle now providing synoptic data in those areas.

Software such as Meteonorm by Meteotest also makes use of satellite data for areas with a low density of weather stations. The data is therefore based on ground measurements and satellite measurements.

There are also a growing number of amateur sites subscribing to the Irish Weather network.

For building energy performance simulation, heating and cooling gains can be estimated by determining the following:

- gains and losses from heat transmission
- gains from solar radiation
- gains and losses from air infiltration
- gains and losses from thermal mass effect
- gains resulting from internal heat gains from appliances and people etc.

The heat losses and gains are then assessed based on specific climate data and the simulations are run accordingly. Mean climate data values over 10 year periods would be recommended.

The accuracy of this climate data is therefore fundamental to the quality of the output. The importance of securing accurate data for the simulation cannot be understated. The variation in climate conditions within a relatively small geographical area cannot be underestimated.

The variety in weather conditions and climate experienced in Ireland is a phenomenon that, although well known to the inhabitants, is too rarely applied to building energy modelling. The climate data based on Dublin Airport has been relied upon for assessing energy performance of buildings to date predominantly in Ireland.

The climate data that interests the building designer in Ireland in particular would be:

- Ambient temperature
- Ground temperature
- Sky temperature
- Solar radiation from each azimuth (North, South, East and West)
- Global radiation
- Linke turbidity
- Cloud cover
- Dew point
- Humidity
- Wind speed and direction

4. Climate Data Research

Dr. Jürgen Schneiders of PHI, in his paper *“Climate data for the determination of Passive House Heat Loads in North West Europe”,* 2006, identified the impact that climate data in a number of European locations had on the energy performance of a typical project and how, using local standard levels of construction, Passive House criteria could be achieved.

He also identified how Passive Houses do not necessarily have their highest heat loads during coldest weather.

This is due to the use they make of available solar radiation, particularly from the south, which, in general, is more available during cold spells, when the sky is clear. In many cases, however, the peak load will be reached during the more moderate but overcast periods. PHPP2007 caters for this variation in weather circumstance by having heat loads calculated for the two separate design periods.

During the final design analysis for a Certified Passive House dwelling in Carrigaline, near Cork, we endeavoured to obtain location-specific climate data to improve our design and achieve a higher level of accuracy with the results. We were concerned that the Birr and Dublin datasets were based on quite different environmental and climatic conditions to the site.

Having commissioned the data, we had anticipated that the climate data from the site should give favourable results, achieving even better energy performance than the Dublin dataset on which the original calculations were based.

The initial results, based on the local climate data, were indicating a disappointing 17.7 kWh/m²a and a heating load of 11.2 W/m². The project, on this basis, would not achieve Passive standard. The data was reviewed and adjustments to elevation, coastal location and albedo (atmospheric reflectance) were taken into account and climate data re-calculated with the following heat energy results:

EN 13790 kW/h(m^2)a	***PHPP2007 kW/h(m^2)a***	***Specific heat load W/m^2***	***Climate data***
9.2	10.4	10.2	Dublin PHPP
15.6	15.2	10.3	Riverside Carrigaline

At 15.2 kW/h (m^2) a AHD, (PH certification limit is ≤ 15 kW/h (m^2) a), the margins for error were considered too close for certification. Thermal bridges, modifications to glass specification and configuration of roof lights were all reviewed and re-calculated. Revisiting the glass specification had a significant impact yielding almost 2 kW/h (m^2) a in AHD yet incurring marginal costs of 1 % off the overall window package. The solar transmittance for glazing was increased from 50 to 55%. Minor adjustments to the configuration of roof lights, window reveal details and HRV efficiencies, all contributed to the overall envelope improvement.

EN 13790 kW/h(m^2)a	***PHPP2007 kW/h(m^2)a***	***Specific heat load W/m^2***	***Climate data***
7.3	8.5	9.7	Dublin PHPP
13.6	13.0	9.9	Riverside Carrigaline

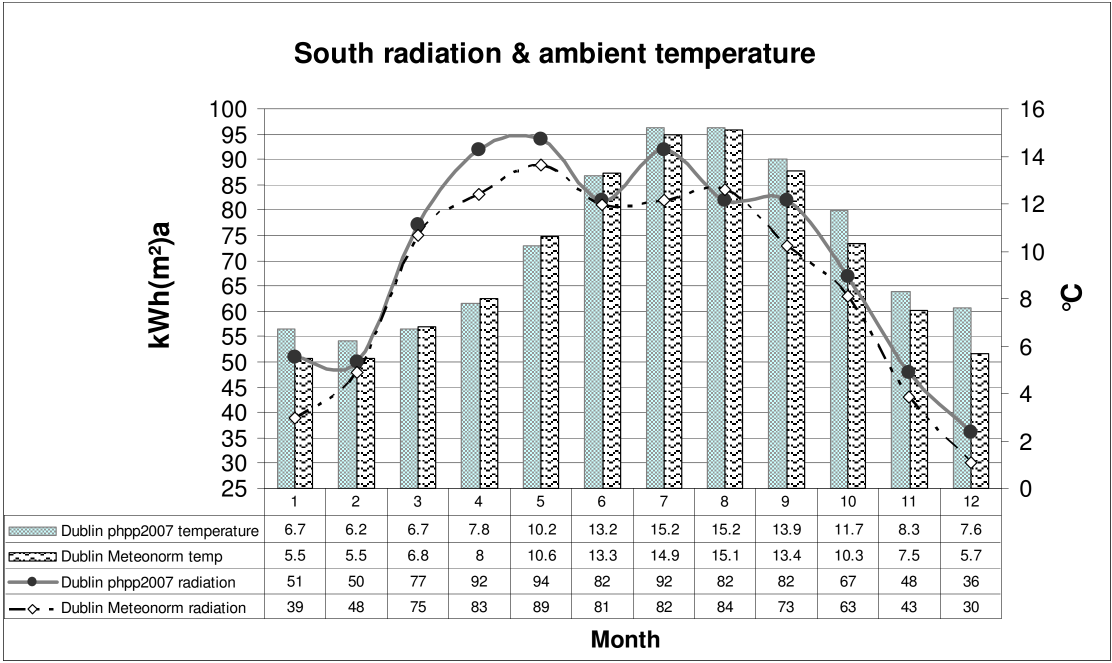
Further investigation into the base climate data revealed that the initial Riverside Carrigaline climate data had been interpolated to output peak rather than mean values over a 10 year period. Though Meteonorm had been used, it was also understood subsequently to be from an earlier release not yet modified to output the specific data format required for use in PHPP2007 and other Building Energy Analysis packages.

As PHPP2007 already makes an allowance for the peaks in calculation output, the use of peak temperature and radiation data as the base climate data was having a negative impact and was subsequently verified to be inappropriate by the PHI. Mean data value only is required for certification. One may have regard to peak data for sizing plant etc., if any concerns exist.

The climate anomaly had a positive side to it. During our interrogation of the Cork climate data, we were kindly afforded the use of some radiation and temperature data collected by a local weather expert some 3 km to our east.

5. The potential of error

In our comparisons, the Dublin data was also put under scrutiny and the radiation and temperature figures identified as being somewhat ambitious during the heating period and indeed at variance to the Met Éireann data for Dublin Airport. This anomaly was subsequently verified and a new dataset has now been generated using Meteonorm (*2010 Dublin*).



	1	2	3	4	5	6	7	8	9	10	11	12
▨ Dublin phpp2007 temperature	6.7	6.2	6.7	7.8	10.2	13.2	15.2	15.2	13.9	11.7	8.3	7.6
▨ Dublin Meteonorm temp	5.5	5.5	6.8	8	10.6	13.3	14.9	15.1	13.4	10.3	7.5	5.7
—●— Dublin phpp2007 radiation	51	50	77	92	94	82	92	82	82	67	48	36
—◇ - Dublin Meteonorm radiation	39	48	75	83	89	81	82	84	73	63	43	30

The PHPP Dublin data had higher temperatures and better radiation during the critical heating period

Achieving an energy balance with misleading data could indeed have a detrimental effect on the energy performance of the finished building. This data is an isolated case. The PHPP 2007 Birr data has been found to be quite consistent with new datasets generated and may be relied upon for use in that region.

EN 13790 kW/h(m^2)a	***PHPP2007 kW/h(m^2)a***	***Specific heat load W/m^2***	***Climate data***
7.9	9.3	9.9	Dublin PHPP2007(obsolete)
14.6	14.2	10.1	Riverside Carrigaline (based on peaks)
11.5	12.6	9.2	Dublin (revised)
9.1	10.1	8	Carrigaline (revised)

The variation in results can be significant if the accuracy of the data is suspect. In this example, Dublin loads for this particular model increased by 34% for AHD yet heating load decreased by 7% - good news for those that already relied upon it as their heating systems should theoretically be capable of dealing with the heating load. In Carrigaline, the heating load decreased by 20% and the AHD by 38%. Again, this could be considered positive news from a plant perspective.

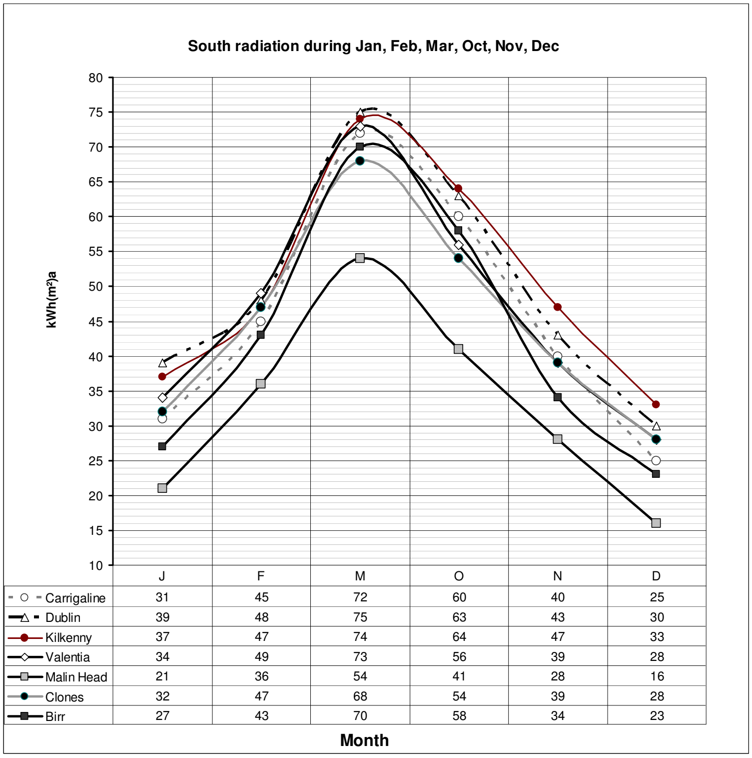
However this level of inaccuracy is unacceptable if a building with a satisfactory energy balance is required or appropriate comfort levels are demanded. Considerable effort is applied to the isolation of cold-bridging, considerable expenditure is demanded by specialised components to reduce energy loads and to improve marginally the overall performances. When calculations are adrift by 30%, resourcing all other efforts to reduce heat energy loads is questionable.

The following graphs give some idea as to the variations in local climatic conditions:

Solar Radiation

Radiation data collection in Ireland is generally based on the 1981-2000 or 1982-2003 period, dependent on station. Some of the weather stations have been upgraded over the years, others have been decommissioned. It is important that a reasonable spread of years (10yrs min.) is used for energy analysis. Regard should also be given to extremes such as those experienced in the winter of 2009 and early 2010.

Though that weather was extremely cold, it was also extremely clear and suited any Passive solar design.



	J	F	M	O	N	D
Carrigaline	31	45	72	60	40	25
Dublin	39	48	75	63	43	30
Kilkenny	37	47	74	64	47	33
Valentia	34	49	73	56	39	28
Malin Head	21	36	54	41	28	16
Clones	32	47	68	54	39	28
Birr	27	43	70	58	34	23

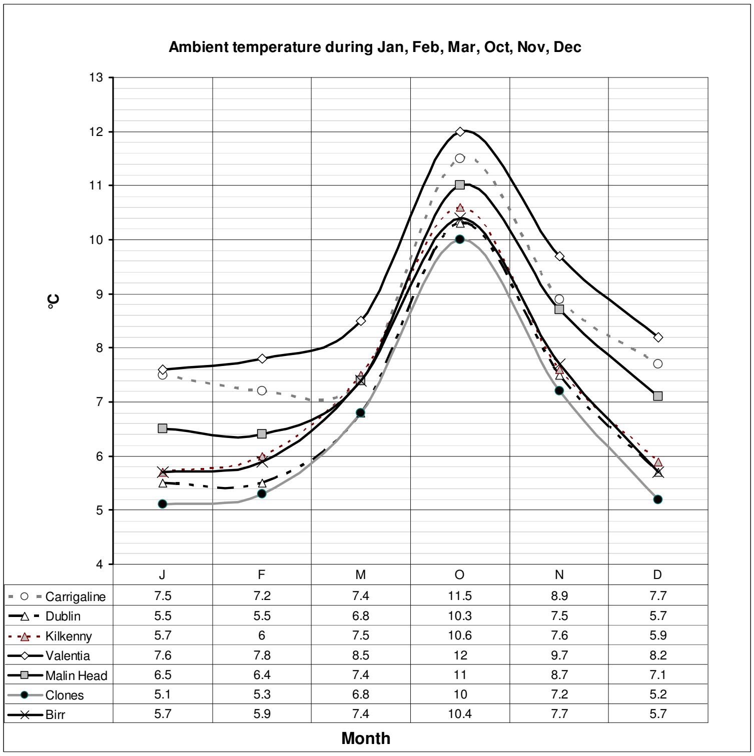
Ambient Temperature

The variation in ambient temperature throughout Ireland is extreme in comparison to that experienced in continental Europe.

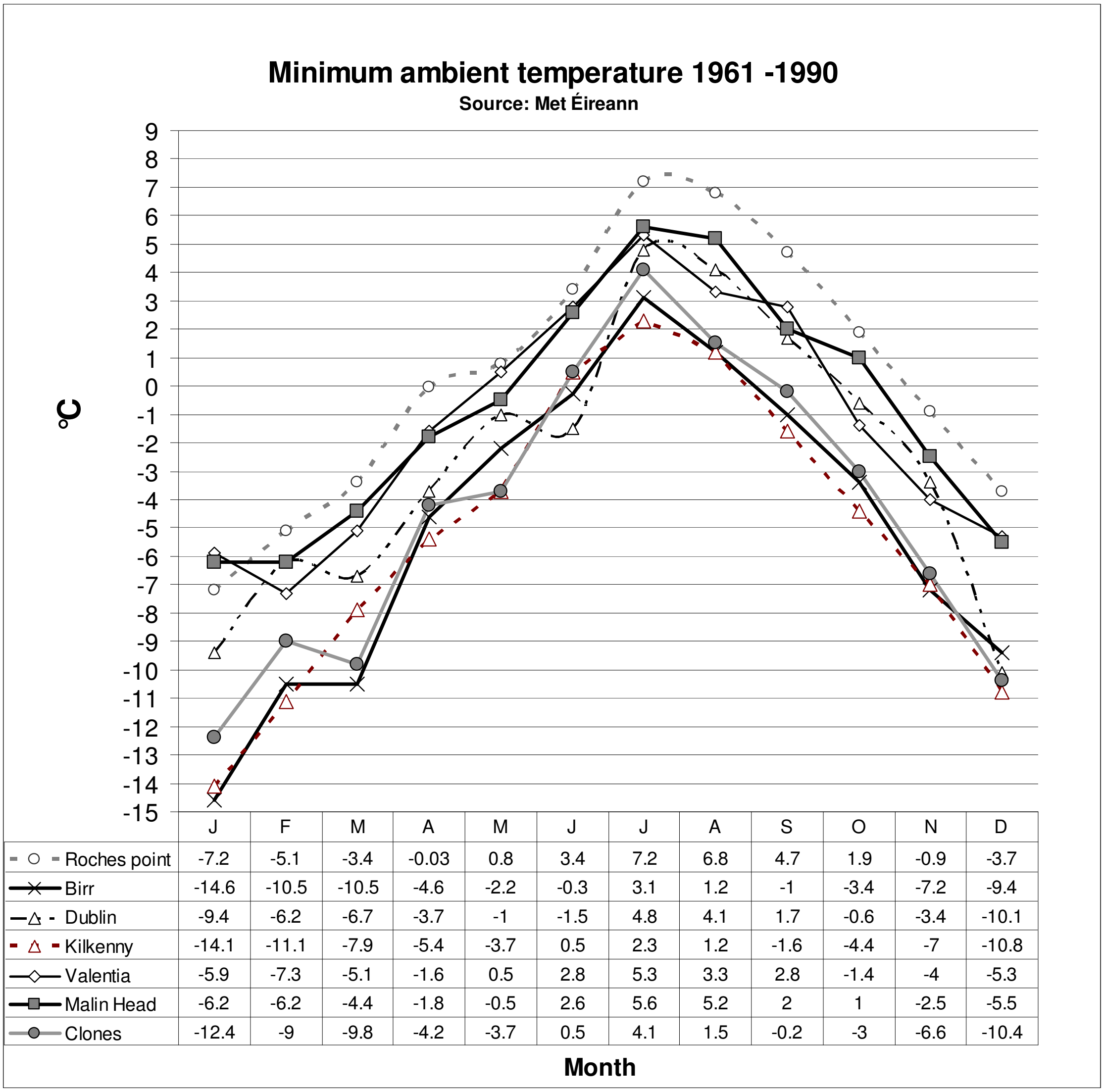
Coastal influences in Ireland maintain a warm airflow and mild ambient temperatures, even in the depths of winter.

Elevation has quite an impact, with every 100m rise in elevation dropping a degree in temperature.

Limited access to solar radiation on the North side of a hill or obstruction can reduce ground and ambient temperatures considerably.



	J	F	M	O	N	D
Carrigaline	7.5	7.2	7.4	11.5	8.9	7.7
Dublin	5.5	5.5	6.8	10.3	7.5	5.7
Kilkenny	5.7	6	7.5	10.6	7.6	5.9
Valentia	7.6	7.8	8.5	12	9.7	8.2
Malin Head	6.5	6.4	7.4	11	8.7	7.1
Clones	5.1	5.3	6.8	10	7.2	5.2
Birr	5.7	5.9	7.4	10.4	7.7	5.7



Minimum ambient temperature 1961 -1990

Source: Met Éireann

	J	F	M	A	M	J	J	A	S	O	N	D
Roches point	-7.2	-5.1	-3.4	-0.03	0.8	3.4	7.2	6.8	4.7	1.9	-0.9	-3.7
Birr	-14.6	-10.5	-10.5	-4.6	-2.2	-0.3	3.1	1.2	-1	-3.4	-7.2	-9.4
Dublin	-9.4	-6.2	-6.7	-3.7	-1	-1.5	4.8	4.1	1.7	-0.6	-3.4	-10.1
Kilkenny	-14.1	-11.1	-7.9	-5.4	-3.7	0.5	2.3	1.2	-1.6	-4.4	-7	-10.8
Valentia	-5.9	-7.3	-5.1	-1.6	0.5	2.8	5.3	3.3	2.8	-1.4	-4	-5.3
Malin Head	-6.2	-6.2	-4.4	-1.8	-0.5	2.6	5.6	5.2	2	1	-2.5	-5.5
Clones	-12.4	-9	-9.8	-4.2	-3.7	0.5	4.1	1.5	-0.2	-3	-6.6	-10.4

The absolute minimum temperatures recorded during the period 1961-1990 were once again prevalent during the extreme conditions experienced during the 2009 / 2010 winter period. The stresses put on conventional buildings during this period were considerable with severe condensation damage, frost damage and, for some, buildings that were incapable of achieving reasonable comfort levels. Frozen ground and frozen pipes were experienced for the first time by many.

Passive solar buildings with excellent thermal envelopes were in their element as solar radiation was plentiful during most of the period in question, providing sufficient heat gains minimising the requirement for backup heating. When the solar radiation levels were low, the insulation levels curtailed the temperatures dropping. HRV units ensured air quality was maintained and heat losses due to air-changes minimised. Subsoil preheating prevented condensation in air systems.

6. A methodology for climate data generation

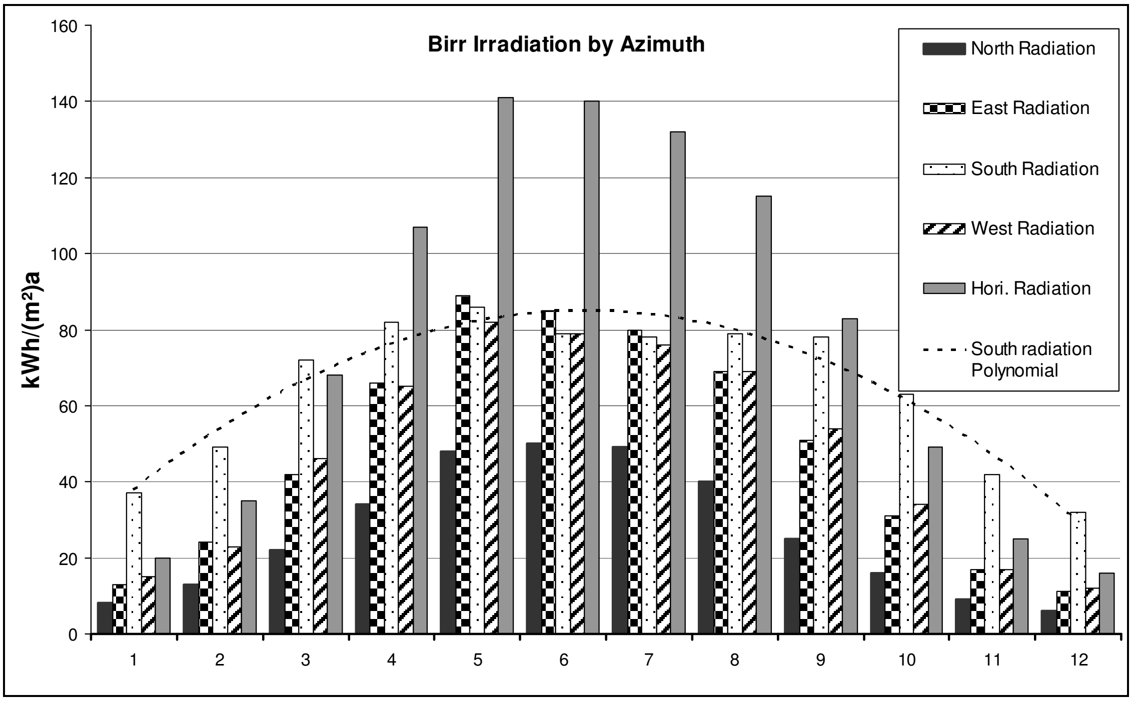
Our simulated climate data experience had called into question the reliability, accuracy or indeed practicality of interpolating weather data in Ireland.

We were encouraged that the use of interpolation and simulation for generating climate data in Ireland had been well researched in recent times. The agricultural sector has put considerable resource into this area to identify the influence of local climate conditions on crop yields.

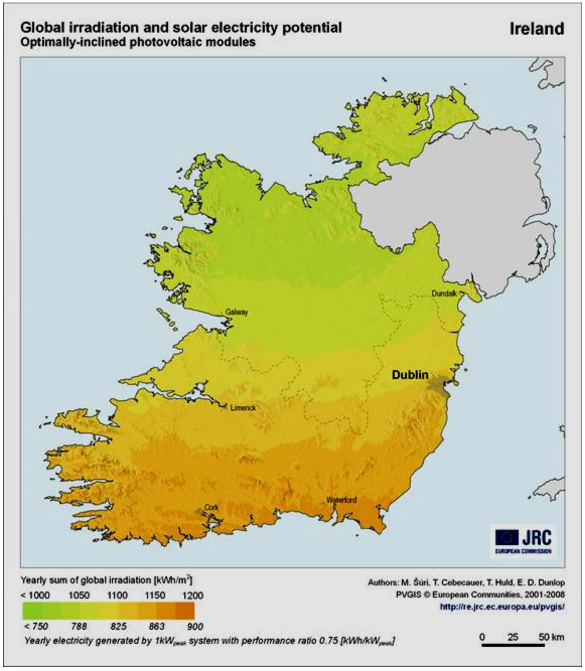
Though monitoring confirms that ambient temperatures have increased in Ireland by 1 degree C over the last 20 years, radiation has not increased. There were trends up to the late 1980's where a phenomenon known as *global dimming* was being monitored. In effect, the amount of available solar radiation was decreasing. This trend has evidently ceased and was attributed to a reduction in pollutants and cloud optical properties *("Long Term Trends in Solar Irradiance in Ireland and their Potential Effects on Gross Primary Productivity": K. Black 2006).*

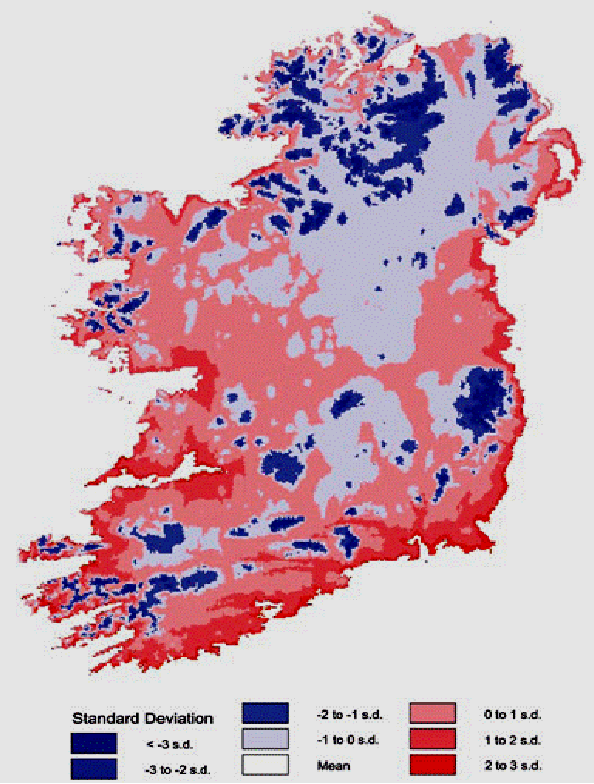
Goodale and Ollinger in 1998, in their paper *"Mapping Monthly Precipitation, Temperature and Solar Radiation for Ireland with Polynomial Regression and a Digital Elevation Model"*, had identified methodologies where accurate simulations and interpolation could be achieved based on location and elevation. A more recent study on "*The Spatial Variation in Degree Days for 1961-1990 Period in Ireland" (by R. Fealy and R.M Fealy 2008)*, confirmed the accuracy of predicted or simulated calculation of degree days when compared to measured data using location and elevation data for interpolating climate data in locations other than the principal stations.

The increase in solar radiation from the south reduces as the heating period finishes. The necessity to provide a robust summer shading strategy becomes obvious when one considers the increase in horizontal radiation during the summer months.



Climate interpolation





This PVGIS Study reflects the pattern of solar radiation intensity in Ireland and the increased availability in the south and southern slopes of elevated areas.
PVGIS © European Communities.

The maps represent yearly sum of global irradiation on horizontal and optimally inclined surface, 10-years average of the period 1981-1990 [kWh/m^2].

The same colour legend also represents potential solar electricity [kWh/kWp] generated by a 1 kWp system per year with photovoltaic modules mounted at an optimum inclination and assuming system performance ratio 0.7.

"Annual accumulated degree days, for the 0°C threshold, converted to standard deviations from the mean".

Source: R. Fealy and R.M. Fealy:

"A marked narrow margin with values of between 2 to 3 standard deviations from above the mean is evident around the Irish coastline, from Wexford to Clare."

Their findings also supported our belief that there is a 1–3km coastal margin in Ireland which is extremely temperate, perhaps as cloud cover accumulates inside this band.

The mapping shows the influence of the North Atlantic Drift, the Gulf Stream, southerly aspect and cloud accumulation patterns are all contributing to the local climate, particularly in the south. The latter research and previous research by Goodall et al, confirmed that simulated radiation and temperature could be generated using the appropriate calculations to interpolate the relevant climate data for particular regions with a high level of accuracy.

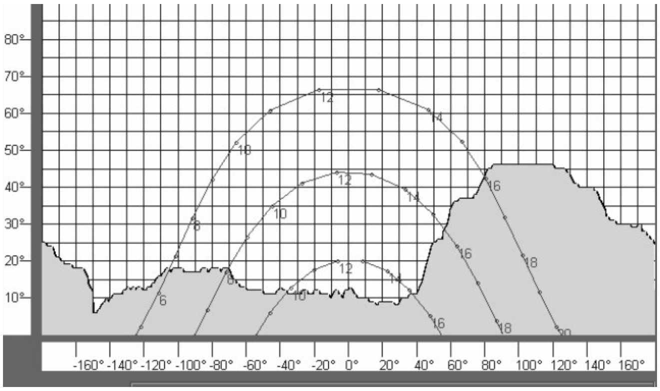
We are now confident that interpolation and simulation can be appropriately applied in Ireland, despite our initial misgivings. Indeed the variation in climate conditions demonstrated highlights the futility of working without accurate site specific climate data.

7. Energy modelling and climate data software:

In order that climate data can be generated to a specific standard, we have proposed a methodology for the production of local climate data using Meteonorm for PHPP2007 use with the Passivhaus Institute and Meteotest, the producers of Meteonorm, to enable the consistently accurate and efficient production of the data to take place.

Despite our confidence in the outputs, we would always recommend that climate data should be verified to be consistent with local data and experience.

We have generated a number of location-specific climate datasets in accordance with defined parameters suitable for use with PHPP2007 based on the periods 1996-2005 for temperature and 1981-2000 for radiation. We initially generated the data near the principal synoptic stations, taking cognisance of the site features, elevation and topography.



The software also integrates mesh surface modelling for the entire Island at a density of 90m x 90m enabling the generation of accurate surface modelling to generate horizon profiles suitable for solar access analysis and calculation at a macro level. Nearby interference with solar access due to building proximity, vegetation, etc., also needs to be accounted for to create the horizon line which will impact on the availability of radiation in particular to the specific location.

There are a number of industry standard energy modelling software packages of varying complexity available to the building designer.

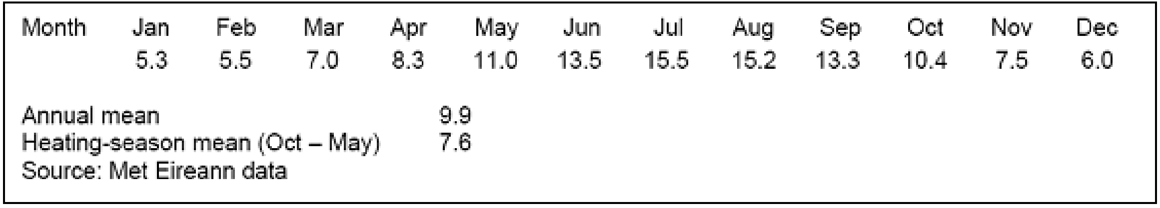
Though they all rely on some form of climate data, some models limit the base data to use Degree day data (temperature), whereas the majority avail of the above mentioned climate conditions in their algorithms. For low energy buildings in this, a comparatively temperate climate, accurate solar radiation data is of particular importance.

PHPP is a Microsoft Excel based programme which was developed since 1985 as a design tool for energy balance modelling and for compliance with Passive House standards. Some 8,000 buildings have been constructed to the Passive House standard in Europe to date and the post-occupation measured results have confirmed the accuracy of the Passive House approach. It is rapidly becoming the industry standard for low energy and comfort standards for buildings.

The present version, PHPP2007, has two climate datasets incorporated within the software for Ireland. These are for Dublin and for Birr and are based on mean data for temperature from the period 1961-1990 and for radiation for the period 1981-1990. However, the software also permits the user to input individual climate datasets in a particular format.
Comfort and the energy balance need to be integrated; PHPP 2007 offers this to the designer.

SEAI have confirmed that the **DEAP III** software used for domestic BER analysis uses Dublin Airport long term mean temperature data, for the period 1962-1991 as its base climate set. DEAP also uses solar radiation data from each azimuth similar to PHPP, but is based on the monthly means of daily solar radiation on un-shaded and horizontal surfaces:

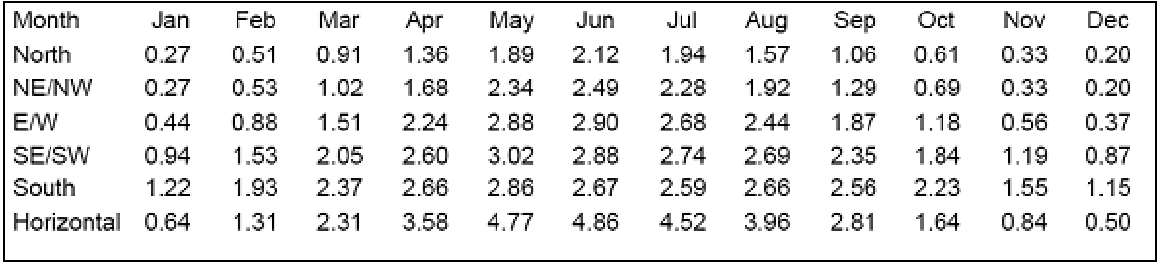
Mean external temperature °C



Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	5.3	5.5	7.0	8.3	11.0	13.5	15.5	15.2	13.3	10.4	7.5	6.0

Annual mean 9.9
Heating-season mean (Oct – May) 7.6
Source: Met Eireann data

Monthly means of daily solar radiation on unshaded vertical and horizontal surfaces [kWh/m² day]



Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North	0.27	0.51	0.91	1.36	1.89	2.12	1.94	1.57	1.06	0.61	0.33	0.20
NE/NW	0.27	0.53	1.02	1.68	2.34	2.49	2.28	1.92	1.29	0.69	0.33	0.20
E/W	0.44	0.88	1.51	2.24	2.88	2.90	2.68	2.44	1.87	1.18	0.56	0.37
SE/SW	0.94	1.53	2.05	2.60	3.02	2.88	2.74	2.69	2.35	1.84	1.19	0.87
South	1.22	1.93	2.37	2.66	2.86	2.67	2.59	2.66	2.56	2.23	1.55	1.15
Horizontal	0.64	1.31	2.31	3.58	4.77	4.86	4.52	3.96	2.81	1.64	0.84	0.50

The **display energy certificate** software for buildings with public access (DES) also from SEAI uses heating degree days set from 15.5°C in a geographic spread of eight different climate stations around Ireland.

IES and the virtual environment suite of toolkits have plug-ins for Revit (Autodesk) / Sketchup (Google), giving effective integrated energy modelling software, though taking advantage of object modelling capability in these design tools is unfortunately limited to Dublin climate data. Interestingly, it appears to be using data from individual years 1989 and 1999, rather than on long term means. Though this approach may address sizing of plant, one must have regard to comfort conditions also.

Energyplus “OpenStudio” by the US Department of Energy also avails of the Sketchup modelling interface for certain inputs and uses seven “TRY” climate datasets for Ireland generated in accordance with the *Climate Design Data 2009 ASHRAE Handbook.*

The use of PHPP can allow the designer to adjust the energy balance of particular components of a building to get the best cost / energy and comfort balance.

Using data from a typical winter, maximum heat loads in the order of 10W/m^2 of living area need to be achieved to reach Passive standards. This level of heating load enables the provision of conventional heating systems to be discarded and adequate heat to be distributed using the air in the HRV system. The specific heat capacity and volume of air being effectively the limiting factor for heat transport.

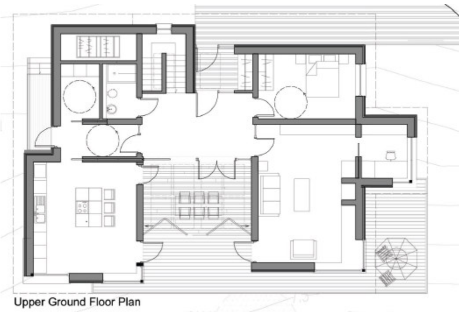
The threshold for Annual Heat Demand to meet Passive standards is ≤15kWh/m²a and the air-tightness 0.6 air-changes per hour @ 50 Pa, nearly 20 times more stringent than the present Building Regulations in a typical dwelling. A heating load of <10W/m² reduces the reliance on conventional heating systems.

8. The model building:

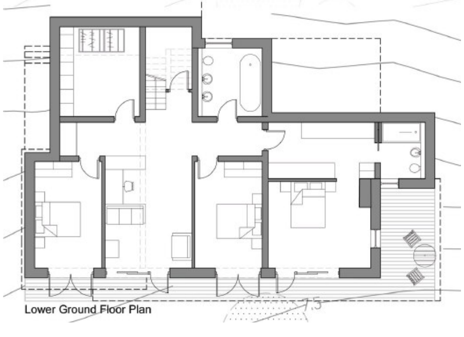
This paper will now address the performance variation of a particular dwelling in different geographical locations when calculated using the various datasets prepared in accordance with the proposed methodology. Though the mean climate data values are relevant for PHPP analysis, regard should also be given to the peak data for heating system sizing. The following chart assesses the variations in heat losses and gains during the principal heating months applicable to Passive housing.

The dwelling considered is a single family house with a treated floor area of 244m^2, is of semi-basement construction, built into a south facing site overlooking the owenabue estuary in Carrigaline, Co. Cork. Living areas are predominantly at the upper level with bedroom and laundry facilities on the lower.

Passive House certification is well advanced.



Upper Ground Floor Plan



Lower Ground Floor Plan

The upper floor envelope is of vapour permeable timber frame construction and the lower floor of ICF (insulated concrete formwork construction). Both elements have rain screen envelopes. Windows are triple glazed throughout and a PH certified MHRV unit is being incorporated with a heating coil powered by a natural gas condensing boiler. We have patented a localised long wave ceramic element infrared heating in the 4-8 µm wavelength to provide the occupants with localised temperature variation capability without unbalancing the air temperatures within the dwelling.

Roof mounted solar collectors provide hot water with a back-up natural gas condensing boiler available should the need arise. The building has a relatively low thermal inertia being semi basement in nature with concrete floors on both levels. The property is provided with a stack clothes drying tower integrated with the heat recovery system.

All opaque elements have u-values better than the 15 W(m^2)K required to meet the Passive House Standard.

The design u-values are:

Element	Designed to Passive Std W/m^2/°k	2010 draft Part L W/m^2/°k
Roof:	0.12	0.16
Upper walls	0.15	0.21
Basement walls	0.12	0.21
Windows	0.8	1.6 * not adjusted

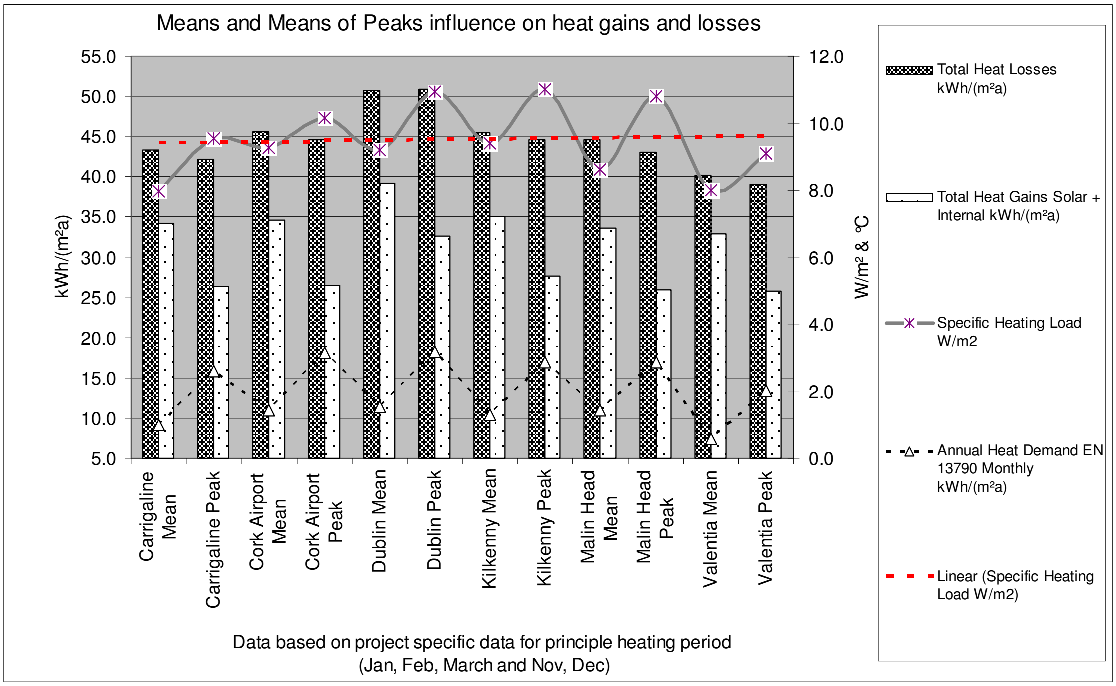
Simulated energy performance was calculated using the climate data generated using Meteonorm 6.1 in accordance with the defined methodology. The energy loads (W/m^2) and

Annual Heat Demand kWh/m^{2}a, were then compared. Elevation was kept at the nearby synoptic station or specific site level.

It became immediately obvious that the energy characteristics of a building constructed in Valentia would be substantially different than one located in Birr.

Also considered during the climate comparison was the impact that the PHPP2007 climate data for Dublin would have in comparison to the new Dublin data. Though the energy load decreased marginally, the Annual Heat Demand increased by 15%. The heat gains are obviously out of sequence, the heat loads also excessive and may be due to comparatively low sky temperatures in the data. Significant improvements in the calculation of sky temperatures have developed in recent years.

As it was clear that the subject dwelling was well within the Passive House criteria of 15kWh/m^{2}a for Annual Heat Demand and below the 10 w/m^2 heating loads, the performance of the dwelling was also considered using the “means of peak” climate data that Meteonorm also creates for PHPP. This data is useful for checking the capacity of plant and heating systems.

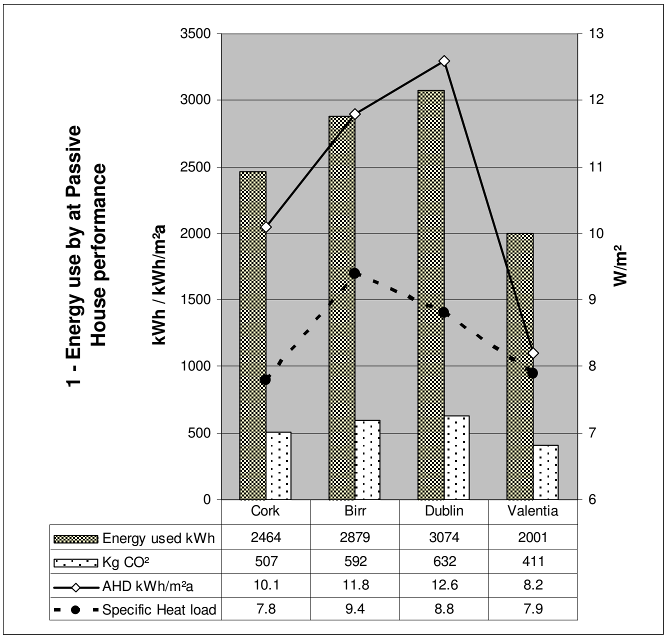


The peak radiation and temperature data are both significantly lower than the mean figures, during the heating period for most of the locations studied.

It is clear that the variation in radiation far exceeds that of temperature. In buildings with thermally efficient opaque elements, the impact of the temperature drop is minimised but the lack of solar radiation has quite an impact on the Annual Heat Demand. The relative importance of access to solar radiation and an ability to harness the gains using glass with high transmittance values is therefore extremely important in the Irish context.

The reduced solar radiation levels have a significant impact on the heat gains and resultant energy use of a building, whereas the excellent thermal efficiencies of the opaque elements minimise any impact the lower ambient temperatures have on heat losses.

9. Comparison between PH and Draft TGD L 2010 performance

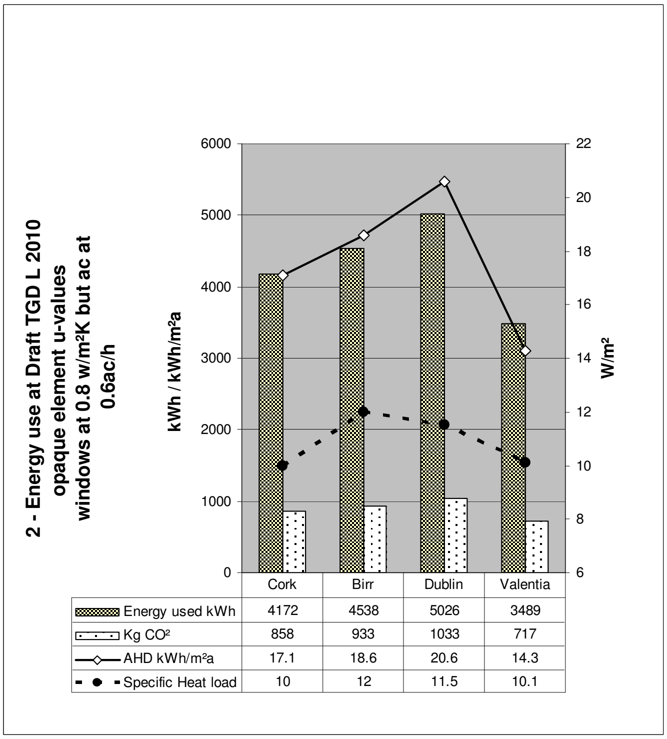


	Cork	Birr	Dublin	Valentia
▨ Energy used kWh	2464	2879	3074	2001
☐ Kg CO^2	507	592	632	411
—◇— AHD kWh/m^{2}a	10.1	11.8	12.6	8.2
- ● - Specific Heat load	7.8	9.4	8.8	7.9

Case 1 PHI Certification level

Case 1 - Retaining the PH energy performance specification, the heating load will reduce the necessity for any conventional heating system to be necessary in any of the locations. The variation in relationship between energy load and heat demand is not always linear, is project specific and is best optimised using experience and dynamic simulation. In general, the lower the heat load the less the Δ T required to deliver heat and comfort levels are improved.

Note: Windows retained at 0.8 W/m^{2}k air-change rates at minimum PHI levels (0.6ac-h) Thermal bridges to PH requirements for both scenarios

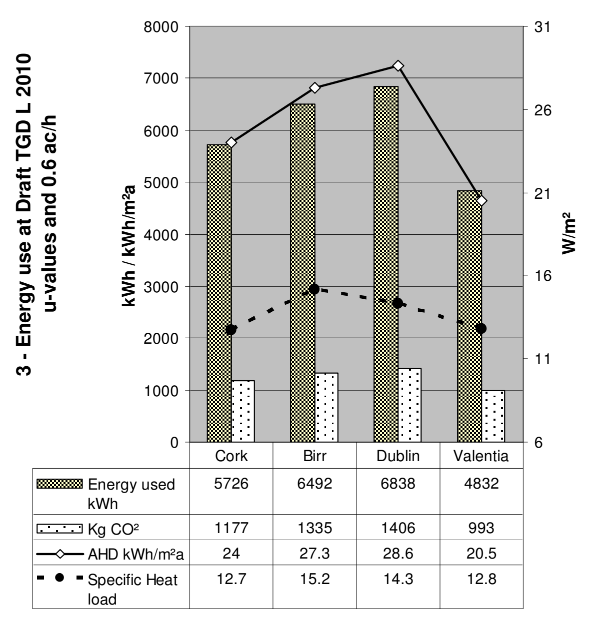


	Cork	Birr	Dublin	Valentia
▨ Energy used kWh	4172	4538	5026	3489
☐ Kg CO^2	858	933	1033	717
—◇— AHD kWh/m^{2}a	17.1	18.6	20.6	14.3
- ● - Specific Heat load	10	12	11.5	10.1

Case 2 TGD opaque elements only adjusted

Case 2 – Applying TGD L 2010 levels for all opaque elements but retaining windows and airtight levels at Passive House levels increases the energy used by some 74% in Valentia and 57% in Birr from Passive House base level.

The additional solar radiation enjoyed in Birr offsetting the thermal envelope losses.

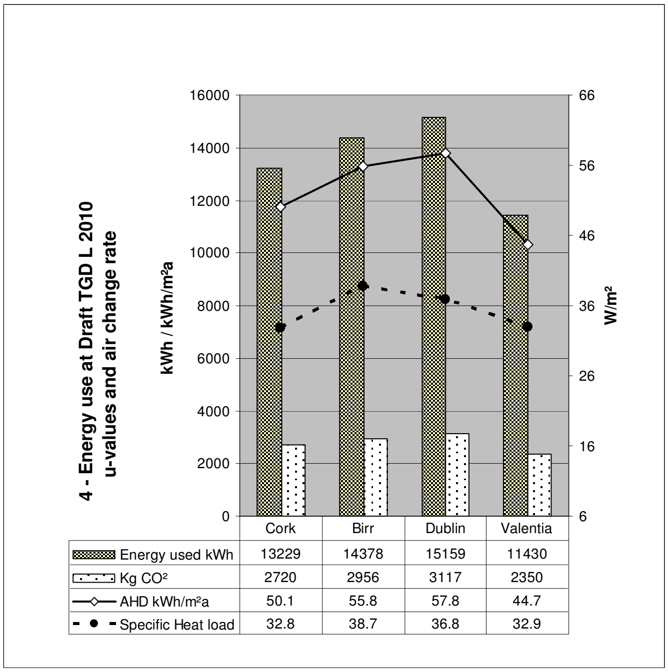


	Cork	Birr	Dublin	Valentia
▨ Energy used kWh	5726	6492	6838	4832
⋯ Kg CO²	1177	1335	1406	993
—◇— AHD kWh/m²a	24	27.3	28.6	20.5
- ● - Specific Heat load	12.7	15.2	14.3	12.8

Case 3 U-values to TGD and 0.6 ach/h (PH level)

Case 3 TGD 2010 Regulations but with air-changes retained at Passive House standards

Energy use in Valentia has increased by 141 % from base levels and 132% for Cork.
When the thermal envelope efficiencies are reduced, the heating loads and CO2 emissions increase. The heating loads are retained at reasonable levels in the more temperate climate areas as the impact of the thermal efficiencies is somewhat reduced. As the building is optimised and energy balanced for the Cork climatic condition, the energy load staying below that of Valentia is not insignificant. During peak climate conditions the increase would be more pronounced.



	Cork	Birr	Dublin	Valentia
▨ Energy used kWh	13229	14378	15159	11430
⋯ Kg CO²	2720	2956	3117	2350
—◇— AHD kWh/m²a	50.1	55.8	57.8	44.7
- ● - Specific Heat load	32.8	38.7	36.8	32.9

Case 4 U-values and air change rate to TGD L, 2010
Equates to 7.29 air changes / h on PH scale

Case 4 TGD L 2010 levels

Finally, with both windows and air-change rates to 7 $m^3/(hm^2)$ adjusted also, the energy requirements begin to increase dramatically and the impact of the climate variations becomes insignificant in the colder areas. Energy use is up some 621% in Valentia, 437% in Cork, 399% in Birr and 393% in Dublin.

The reduction in air-tightness has a very significant increase on energy use.

What is noticeable is the relative equalisation of results between locations as the building performance deteriorates in comparison to the Passive House specification levels.

Thermal envelope impact on heat energy requirements

The performance of the *2010 Draft Building Regulations Part L* proposed elemental u-values were applied to the model. Although the opaque elements are a significant improvement on previous regulations, they have a significant impact on the energy efficiency of a dwelling when compared to the Passive House model. The window u-values at 1.6 W/m^2K are below what we would consider adequate from a comfort perspective or indeed for use in Low Energy Housing.

Although values of 1.2 W/m^2K would have been a better benchmark for a new regulation, we are confident that changes in installation techniques and a better understanding of cold-bridging could potentially improve the u-values from the 1.6 W/m^2K demanded with small modifications to frame construction. This approach will be of benefit particularly in the cooler regions of Ireland.

In the more temperate areas, the relatively poor thermal performance of the windows would not be considered a significant issue as the increased g-factor or radiation transmission factor of the double glazed units will contribute favourably to the overall energy balance.

It is the influence that the frame and spacer performance has on the overall window u-value that is sometimes ignored in this country. Windows are being fitted regularly with u-values based on the glass units alone, with no reference to the frame factor or indeed the quality of the spacers in the hermetically sealed units. The solar transmittance factor is rarely discussed, scrutinised or examined.

The windows, having a u-value of 0.8 W/m^2K and detailing were initially retained for the exercise to ensure that comfort levels could be maintained and to keep the surface temperature of the glass within 4.2°K of adjacent surfaces within the dwelling. The base design had a window area of just over 40m² or 32% of the entire South façade.

Based on the actual performance targets for both opaque elements and windows, etc., the area of windows on the southerly façade was varied in increments of 5m² from 20 to 75 m² to identify any patterns that may arise with respect to energy loads and demand values in the various climate conditions.

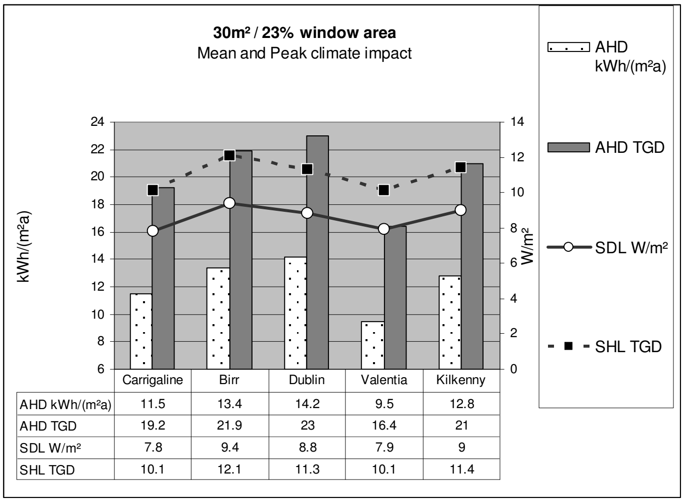
In TGD format at 40m², Valentia came well within the PH AHD criteria and at 10.1 W/m² had an acceptable heating load, although the elemental u-values may impact upon comfort levels in particularly cold periods.

In general, as the area of glazing increases on the south façade, the Annual Heat Demand decreases but the energy loads on the building increases. The severity of the climate and access to radiation has a noticeable impact upon the relationship between the two factors.

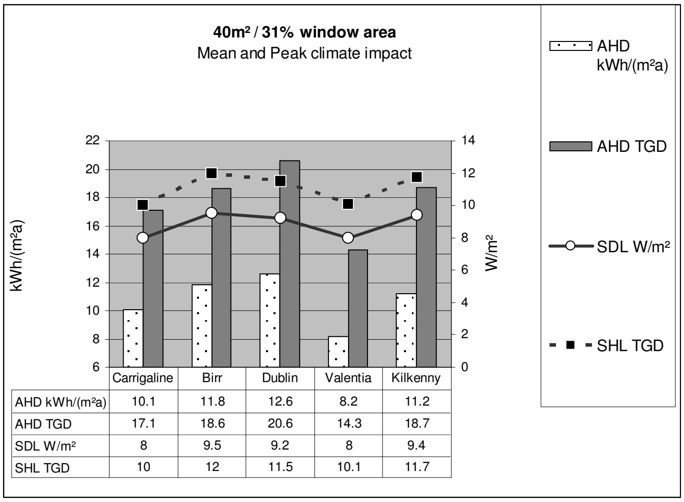
In PH format at 40m², both Valentia and Carrigaline have the same heating loads of c.8 W/m². Carrigaline has an Annual Heating Demand of 10.1kWh/m²a, Valentia only 8.2 kWh/m²a

Both have good solar access, are at similar elevations and are influenced by the large water masses and Gulf Stream influences. Valentia is more influenced by the North Atlantic drift which has average mean temperatures of 7-8°C greater than Global Sea temperatures. In general, sea temperatures are higher than those of the air during the winter but vary by just 5°C over a year. The annual cooling cycle of the sea occurs later than that over land. *(Met Éireann).*

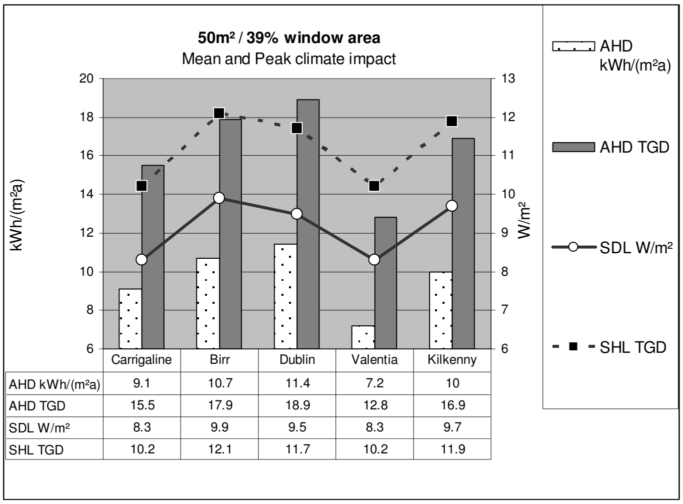
10. Impact on Energy due to variation in window area or % window to south



	Carrigaline	Birr	Dublin	Valentia	Kilkenny
AHD kWh/(m²a)	11.5	13.4	14.2	9.5	12.8
AHD TGD	19.2	21.9	23	16.4	21
SDL W/m²	7.8	9.4	8.8	7.9	9
SHL TGD	10.1	12.1	11.3	10.1	11.4



	Carrigaline	Birr	Dublin	Valentia	Kilkenny
AHD kWh/(m²a)	10.1	11.8	12.6	8.2	11.2
AHD TGD	17.1	18.6	20.6	14.3	18.7
SDL W/m²	8	9.5	9.2	8	9.4
SHL TGD	10	12	11.5	10.1	11.7



	Carrigaline	Birr	Dublin	Valentia	Kilkenny
AHD kWh/(m²a)	9.1	10.7	11.4	7.2	10
AHD TGD	15.5	17.9	18.9	12.8	16.9
SDL W/m²	8.3	9.9	9.5	8.3	9.7
SHL TGD	10.2	12.1	11.7	10.2	11.9

30m² / 23% window area to south

A reduction in the window area reduced heat loads for PH u-values but increased for TGD values, whereas the AHD increased for both models.

40m² / 31% window area to south

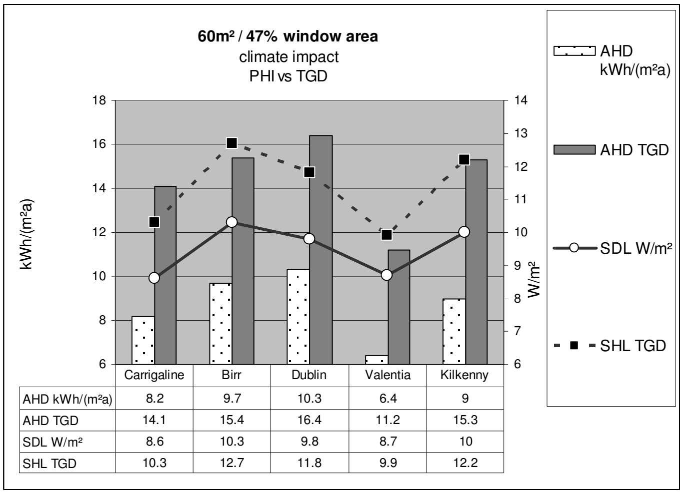
This is the actual design format for the dwelling with c.40m^2 / 31% of south elevation glazed. 80% of all glazing is orientated to the south of this Passive House. Certification could be achieved in all climate areas within Ireland.

The TGD energy requirements broadly match the predicted peak climate response for a PH in this format.

With TGD values, the layout retains favourable heating loads in all areas but with increased AHD (longer heating periods). In Valentia the TGD figures yield an AHD below the 15 kWh/m^{2}a PH criteria.

50m² / 39% window area to south

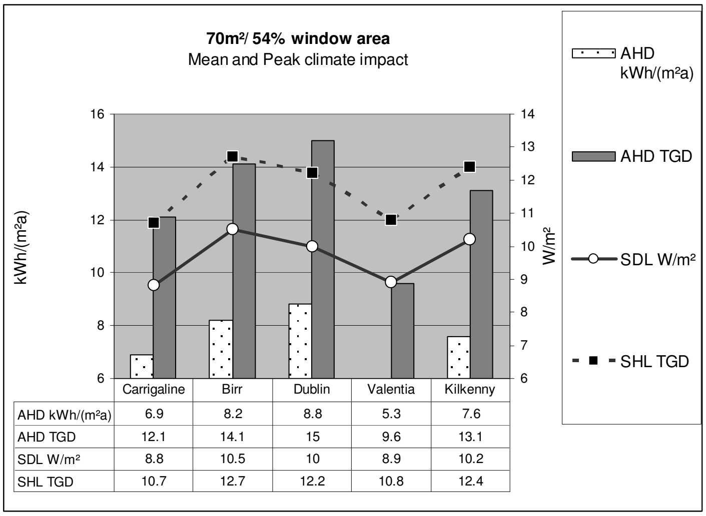
Again certification can be achieved although energy loads are increasing. Valentia and Cork are beginning to meet PH heat demand criteria although heating loads are beginning to rise. This is possibly the optimal arrangement in the milder climate condition.



	Carrigaline	Birr	Dublin	Valentia	Kilkenny
AHD kWh/(m²a)	8.2	9.7	10.3	6.4	9
AHD TGD	14.1	15.4	16.4	11.2	15.3
SDL W/m²	8.6	10.3	9.8	8.7	10
SHL TGD	10.3	12.7	11.8	9.9	12.2

60m² / 47% window area to south

Increasing the glazing to 47% of the South façade further reduces the AHD in all cases with minimal interference to heating loads. Though Cork and Valentia meet PH criteria, Valentia's heat load has actually dropped from the 39% example. Heating loads have increased in other climate areas which would require a supportive heating system.



	Carrigaline	Birr	Dublin	Valentia	Kilkenny
AHD kWh/(m²a)	6.9	8.2	8.8	5.3	7.6
AHD TGD	12.1	14.1	15	9.6	13.1
SDL W/m²	8.8	10.5	10	8.9	10.2
SHL TGD	10.7	12.7	12.2	10.8	12.4

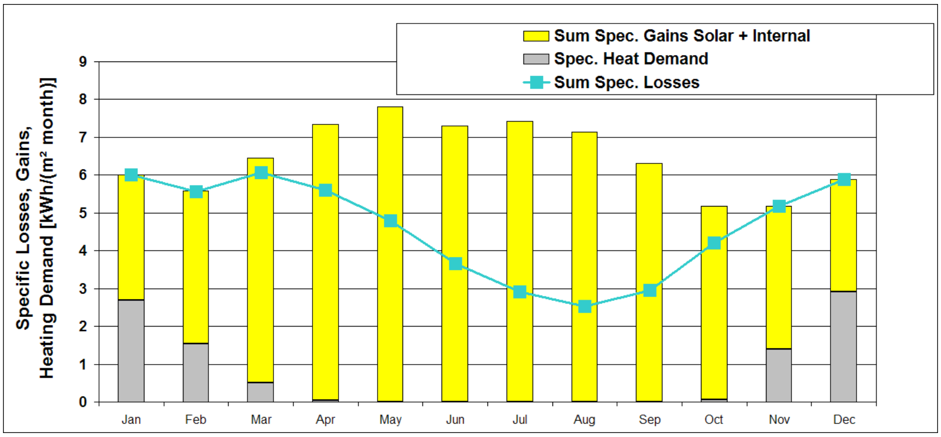
70m² / 54% window area to south

Increasing the glazing to 54% of the South façade further reduces the AHD in all cases with minimal interference to heating loads. Interesting that Birr has not increased heat load for the poorer envelope characteristics. In the more temperate areas with less radiation, the heating load increase is 90% greater for the poorer thermal envelope condition.

The increase in glazing with excellent thermal and solar transmission characteristics significantly reduces Annual Heat Demand but it also generally increases the heating load when the proportion of glazing is outside the optimal energy balance profile. At a certain % of façade the windows can take in more energy than they lose, thereby giving a positive energy balance without increasing heat load.

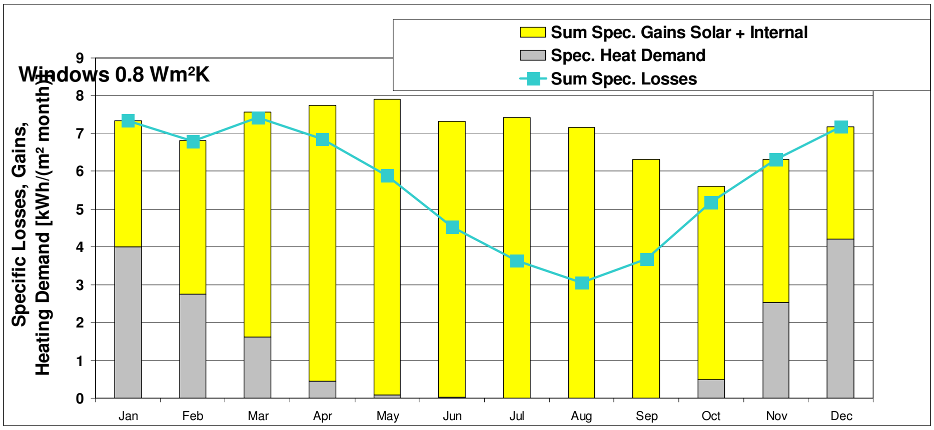
The building in TGD 2010 format has less inertia and becomes more responsive to thermal and solar fluctuations. Overheating during summer months can become an issue and effective solar shading during the summer periods is essential. During extremes in winter temperatures, the glazing areas may become cool and comfort levels deteriorate. For the TGD 2010 levels condensation risk in extremely cold conditions needs to be considered although the risks are significantly less than existed under earlier regulation levels. The following tables represent the heating profiles based on Carrigaline Mean Climate data for the alternative specifications.

Passive house standard

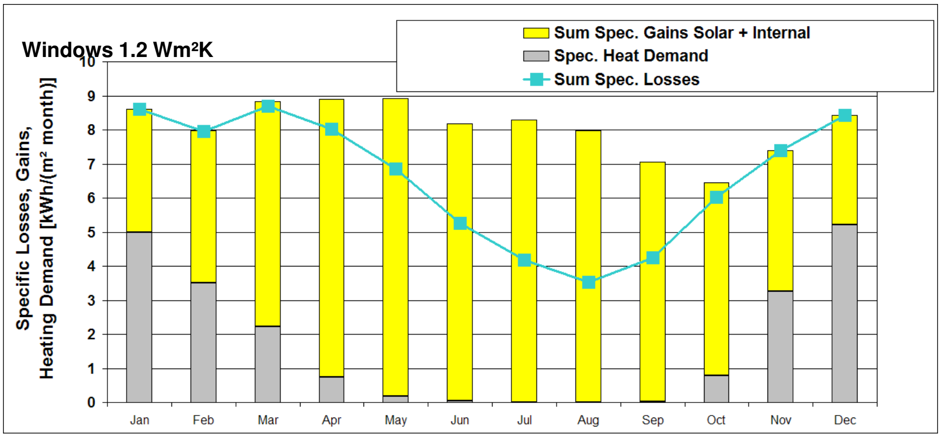


EN 13790 Monthly Method : 2231 kWh/a or 9.1 kWh/(m2a)
PHPP Heating Method, 2497 kWh/a or 10.1 kWh/(m2a)

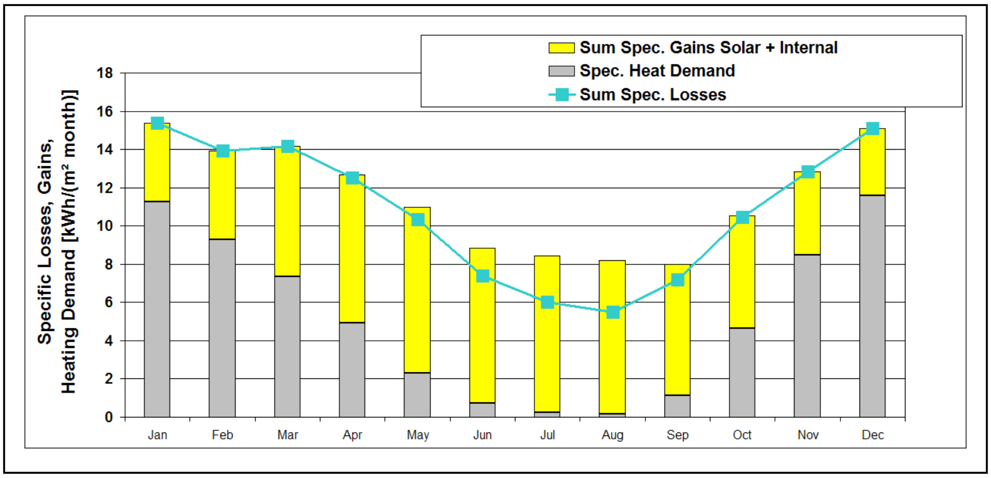
TGD L Draft Building Regulations 2010



EN 13790 Monthly Method : 3944 kWh/a or 16.1 kWh/(m2a)
PHPP Heating Method, 4177 kWh/a or 17.1 kWh/(m2a)



EN 13790 Monthly Method : 5124 kWh/a or 21.0 kWh/(m2a)
PHPP Heating Method, 5305 kWh/a or 21.7 kWh/(m2a)



Heating demand at TGD L, 2010 for all opaque elements and windows and A/C rates

No adjustment made for thermal bridging factor.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - Exterior	10.6	9.5	9.4	8.1	6.4	4.5	3.5	3.3	4.5	7.1	8.9	10.6	86	kKh
Heating Degree Hours - Ground	5.3	4.9	5.4	5.0	4.8	4.3	3.0	2.9	3.8	4.2	4.4	4.9	53	kKh
Losses - Exterior	3381	3011	2979	2586	2034	1442	1111	1040	1419	2270	2815	3381	27470	kWh
Losses - Ground	313	292	322	299	288	256	181	171	229	249	261	294	3155	kWh
Sum Spec. Losses	15.1	13.5	13.5	11.8	9.5	7.0	5.3	5.0	6.7	10.3	12.6	15.0	125.4	kWh/m^2
Solar Gains - North	7	11	19	30	42	43	43	35	22	14	8	5	278	kWh
Solar Gains - East	33	62	108	169	228	218	205	177	131	80	44	28	1483	kWh
Solar Gains - South	514	681	1001	1140	1196	1098	1084	1098	1084	876	584	445	10801	kWh
Solar Gains - West	13	20	40	56	71	68	66	60	47	29	15	10	495	kWh
Solar Gains - Horiz.	23	39	74	112	145	143	135	119	89	54	28	19	979	kWh
Solar Gains - Opaque	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Internal Heat Gains	382	345	382	369	382	369	382	382	369	382	369	382	4494	kWh
Sum Spec. Gains Solar + Internal	4.0	4.7	6.6	7.7	8.4	7.9	7.8	7.7	7.1	5.9	4.3	3.6	75.9	kWh/m^2
Utilisation Factor	100%	100%	99%	98%	91%	80%	66%	63%	84%	99%	100%	100%	88%	
Annual Heat Demand	2722	2147	1688	1053	446	146	37	28	187	1103	2029	2786	14372	kWh
Spec. Heat Demand	**11.1**	**8.8**	**6.9**	**4.3**	**1.8**	**0.6**	**0.2**	**0.1**	**0.8**	**4.5**	**8.3**	**11.4**	**58.8**	kWh/m^2

- END -

11. Conclusion

The generation of climate data in Ireland is of paramount importance if we are to address the energy performance of buildings to an acceptable level of predictability.

Though regional or county wide climate datasets for use in the various regions would be a vast improvement, some direction is required as to the methodology of generation and accuracy levels required regarding horizon patterns and shading. Further research and monitoring is recommended as more low energy, and indeed Passive buildings, are constructed here.

The building with the opaque elements to TGD 2010 levels performed exceptionally well when compared to existing buildings with Annual Heat Demands of 11.2 kWh/ m^2a at a heating load of 9.9 W/m^2 with a fenestration level to the south of 47%. This is an 80% decrease in heat demand from the typical dwelling constructed in recent years. This bodes well for reducing our Carbon footprint and ensures that Low Energy buildings become the norm in the very near future. One may find that in colder regions, high percentages of glazing may be found to be more suitable for uses other than dwellings. As building techniques and quality levels improve, the air leakage levels necessary to reduce heat losses and indeed contain gains will become standard practice and should not incur an overhead. With air-changes / permeability at TGD L requirements of 7 $m^3/(hm^2)$, energy use increases fourfold, when compared to Passive House levels which equate to 0.58 on the TGD L scale for this model. Glass technology is advancing and improvements in solar transmission and thermal performance are anticipated, though it is the former that is of most interest for this country.

The results herein demonstrated are based on a single dwelling model, designed initially using tried and tested Passive solar principles to meet the needs of a family. The building easily hits the mark from an energy perspective with quite a variety of envelope variations without compromising the enjoyment of the dwelling in any way, informed by the correct application of climate data. The perception that a Passive House is restricted to a simple sealed thermally efficient envelope with small window areas is dispelled.

Though with our climate, we can achieve energy performance levels in general with far less effort than those on the Northern European continent, we are far more vulnerable to fluctuations in climate as a result. We would submit that building energy simulations are also carried out using the peak load data at the design stage to ensure that comfort levels can be maintained during an extremely cold period similar to that experienced last winter.

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Note: References to window u-values are overall window u-values, taking account of frame and glazing system characteristics.

PH = Passivhaus Institute Darmstadt.

AHD = Annual Heat Demand PH requires this to be ≤ 15 kWh/(m^2)a.

SHL = Specific Heat load PH requires this to be ≤ 10W/m^2.

Air tightness: 0.6 ac/h @ 50 Pa. In PH this is tested under both positive and negative pressure.

In TGD L 2010 Air permeability is measured as cubic metres per m^2 external surface area / hr limited to 7m3/(hr.m^2) @ 50 pa.
This is approximately 5 times less airtight than the PH requirement.

Thermal Bridges: In TGD L 2010 “Limiting Thermal Bridging acceptable construction details limit the linear thermal bridge permitted at $\psi = 0.08$ W/(mK).
In Passive House detailing this is limited to $\psi = 0.01$ W/(mK).