AFFORDABLE CERTIFIED CLIMATE FILES – PROCESS USED IN NEW ZEALAND

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ABSTRACT

Not having existing certified Passive House Planning Package (PHPP) climate data is a significant obstacle to the growth of Passive House (PH) design. Certified local PH climate data is needed to confidently design a cost effective PH. Otherwise there is a risk of significant over-design.

To remove this barrier to the uptake of PH design, Passive House Institute New Zealand is sponsoring the development of regional certified climate files for the whole of New Zealand. This paper explains the process used to develop and check these files and discusses the lessons learnt.

The process made use of hourly Typical Meteorological Year (TMY) weather data files produced by New Zealand's National Institute of Water and Atmospheric Research (NIWA). NIWA has defined regional boundaries that group weather stations together and this was the starting point for a proposed regional weather file for PH purposes.

Data was checked for every weather station with at least 30 years worth of historical data, to ensure the variation within a region was within the tolerance established. The checked zones and NIWA TMY files were provided to PHI for a final quality check and calculation of the heating and cooling loads using their DYNBIL hourly simulation code.

This collaborative approach meant that New Zealand climate files were available much faster and at significantly less cost compared to having the Passive House Institute (PHI) in Germany undertake the entire project. This process could be used to produce local certified climate files in other countries.

KEYWORDS:

Climate File; PHPP weather; localised weather files.

1 INTRODUCTION

Several Passive Houses were being planned in New Zealand in early 2012 but little climate data in PHPP format was available. It was also unclear how we could apply what data we did have across a region, and how to check its applicability. This was a difficult situation for PH designers seeking to produce cost effective PH construction that could be certified and added to the challenge of convincing clients to use this new methodology. PHI in Germany was able to develop the necessary files but not in the timeframe needed and funding was not available.

Ideally we wanted PHI certified data with heating/cooling loads covering all of New Zealand with climate zone boundaries that match what local architects and designers are used to. The data would be provided within the PHPP software, available as needed. This would give PH designers the data they needed to design buildings that would perform as required and meet certification criteria—without risk of significant and costly over-specification.

We are progressing toward this ideal situation. All the regional climate files listed as PHI certified in the results table (Table 5-1) will be included in PHPP 9, due for release in April

2015. However, there are still many regions in New Zealand with regional weather files that are not certified and for which heating/cooling loads are not available (although as discussed in this paper files have been checked as regionally applicable). PHINZ is actively seeking funding to certify these remaining regional files for New Zealand.

This paper documents the process used to check the regional applicability of the NIWA TMY hourly climate files for PH certification/design in New Zealand.

2 PASSIVE HOUSE CLIMATE FILES

2.1 What is a Passive House climate file?

A PH climate file is a collection of data that can be used in conjunction with the PHPP software to predict the heating and cooling performance of a building. It has two sections. One part can be measured and/or calculated from temperature and solar radiation data (typically using Meteonorm or similar tools). The second part, consisting of heating and cooling loads data derived from a dynamic hourly simulation model and specifically applicable to Passive Houses, must be done by PHI.

The climate data inputs—monthly averaged data, typically collected over many years—are shown in Figure 1. These can be measured and produced using several tools. I used Meteonorm 7, which could easily combine measured monthly average temperature data from the NIWA Climate Database with New Zealand measured and satellite solar radiation data built into the Meteonorm database to produce a complete PH climate file. This data, once checked by PHI, is sufficient to certify a Passive House using the Space Specific Heating Demand (SSHD) requirement of less than 15kWh/m^2/a.

Bay of Plenty	Latitude:	37.7	Longitude ° East	176.2	Altitude m	4	4	Daily Temperature Swing Summer (K)		8.0	Radiation Data:	kWh/(m²*month)
Ambient Temp	10.4	10.8	12.6	14.3	15.3	18.7	19.5	19.3	18.2	15.8	13.9	10.5
North	15	21	28	37	47	51	47	36	29	23	17	15
East	34	42	61	71	92	85	80	68	67	54	39	32
South	89	92	92	80	64	61	68	73	88	109	93	80
West	35	49	64	79	86	98	103	85	65	60	40	29
Global	59	80	113	145	163	183	190	151	128	102	67	52
Dew Point	7.1	7.1	8.9	10.1	9.9	13.7	14.3	14.7	14.4	11.4	10.6	7.7
Sky Temp	-0.9	-0.1	2.1	4.0	4.7	9.6	10.6	9.5	7.9	4.8	4.0	-1.5

Figure 1: Climate data inputs for a Passive House Climate file.

Figure 2 shows the heating and cooling load data. This is *not* a measured climate parameter. Rather, the heating and cooling load data is produced by PHI using a dynamic hourly building simulation model (DYNBIL) designed specifically to model Passive Houses. In essence, DYNBIL dynamically simulates an example Passive House adjusted to just meet the certification standard on SSHD for the provided hourly climate file (Schnieders, 2003). The heating and cooling load data is produced by looking at the rate of change of heat transfer. This process requires a Typical Meteorological Year (TMY) hourly weather file that has been checked for applicability to the region in which the loads will be used. NIWA had developed TMY hourly files to represent recommended New Zealand regional climates (Liley, Sturman, Shiona & Wratt, 2008), but these had not been checked to confirm they were adequate for PH certification.

Heating Load		Cooling Load
Weather 1	Weather 2	Radiation
Radiation: W/m²		W/m²
7.8	7.9	22.0
15	15	90
40	35	190
75	75	210
35	30	200
50	50	340
0.0	0.0	0.0
		-3.0

Figure 2: The Heating and Cooling Load data is not a measured climate parameter. It is developed from hourly climate data and a dynamic hourly building simulation model (DYNBIL) at PHI.

PH certification is achieved by meeting *either* the SSHD limit of 15 kWh/m^2/a or heating and cooling loads limits of 10 W/m^2. As the foundational economic rationale for passive houses was to remove expensive heating generation and distribution systems in Germany's cold climate by using the ventilation air needed for human health to distribute the needed heat, we can expect this 10 W/m^2 measure to remain. However, I prefer certification to the 15 kWh/m^2/a as the heating and cooling load data is developed using the SSHD certification limit, and the cost/energy savings of PH are measured by the SSHD. To my knowledge, all the Passive Houses designed in New Zealand to meet certification criteria do so by meeting the SSHD target, not the heating and cooling load limits. Also note that the heating and cooling load data produced by Meteonorm 7 is not produced using a building simulation and therefore is not acceptable to PHI for certification.

The combined PH climate file data above is entered into the 'Climate Data' tab in the PHPP Excel file. Functions hidden in the 'Climate Data' tab pre-process the climate data input to adjust for user input site altitude and then calculate the ground temperature to produce the results shown in Figure 3. If heating and cooling load data produced by PHI is not available, this part of the climate file is left blank; the building can still be certified based upon the SSHD (ie 15 kWh/m^2/a or less). Some other way to estimate the heating/cooling loads will need to be found in order to size heating and cooling equipment, but this is a practical consideration and not required for certification.

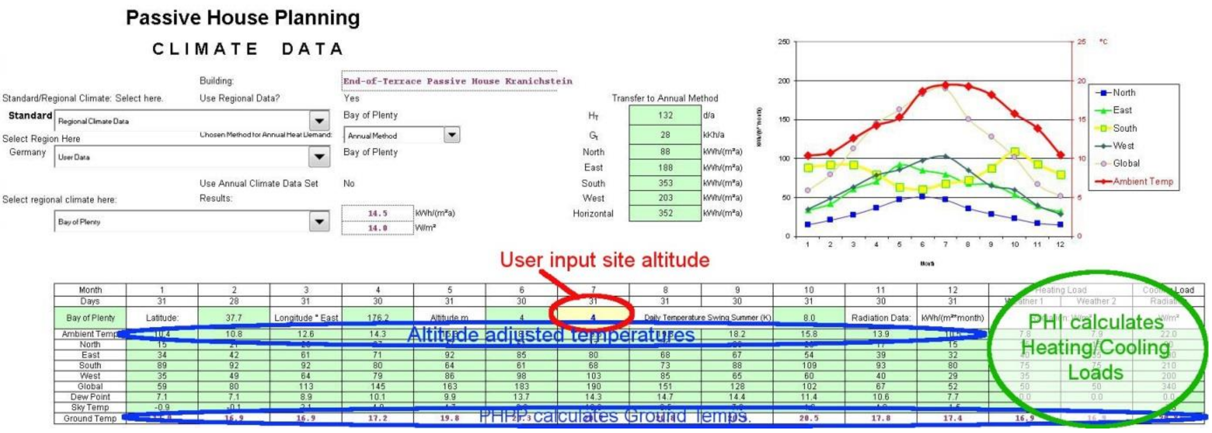

Figure 3: PHPP 'Climate Data' tab. User input site altitude adjusts climate file input to produce altitude adjusted temperatures.

The climate file tab calculates the temperature difference time integral Gt, which is calculated in kKH/a (kilo-Kelvin-Hours per annum). Although this sounds complicated, it is simply the number of hours the climate is below 16˚C, multiplied by a weighting factor and the temperature difference. This is essentially a calibrated heating degree days measure for PH application. Gt is the single most informative number to examine in order to compare various climates impacts on building heat loss. PHPP is a very complex spreadsheet but the core of the tool is the calculation of the building SSHD. SSHD is a function of how the building is designed and constructed and the local climate. For a specific building design/construction, the heat loss from the climate is represented entirely by Gt.

New Zealand climates range from 24 to 68 kKH/a, with even our coldest climate well below the standard Germany Gt of 84 kKH/a. As Equation 1 below shows, the heat loss of a particular building is directly proportional to Gt, so the same building moving from a Gt of 24 to 68 (that is, from Auckland to Queenstown) loses 183% more heat.

Equation 1: Space Specific Heating Demand (SSHD) and its dependence upon Gt

SSHD = Heat Demand / Treated Floor Area

Heat Demand = Heat Loss – Heat Gain

Heat Loss = Surface Conduction + Thermal Bridge + Ventilation

$$Q_T = A \cdot U \cdot f_T \cdot G_t \qquad Q_\Psi = l \cdot \Psi \cdot f_T \cdot G_t \qquad Q_V = n_V \cdot V_V \cdot c \cdot G_t$$

Heat Gain = Solar + Internal Heat Gains

2.2 To what area is a climate file applicable?

Establishing a tolerance band is necessary in order to determine the region that a particular climate file can appropriately span. That is, what degree of variation is acceptable within a region before it is subdivided into multiple regions? It is impossible to exactly predict the climate a building will experience, even if a building site is directly under a long-term weather station. This is due to yearly weather variations, different ways to process measured data and long term climatic shifts.

Yearly weather variations for a single weather station are not small. For several USA sites, comparison of the range of annual energy consumption (i.e. SSHD) due to actual weather over a 30-year period was -11% to +7% (Crawley, 1998).

Different ways to *process* measured weather site data can also impact a building's predicted performance. Before 2009, the only available New Zealand regional climate data was in Test Reference Year (TRY) format, which does not contain measured solar radiation (insolation), only cloud cover (Gates, Liley & Donn, 2011). In 2009, NIWA began generating TMY format hourly weather files and developed 18 climate zones to cover New Zealand. When the same location and building model was run using TRY vs TMY formats, differences of up to 10% in the annual heating demand (equivalent to SSHD) were found! As improvements continue in the processing of measured weather data, TMY files will change, and this will have an impact—although likely much less of an impact than the change from TRY to TMY data.

Finally, long term climatic shifts make it impossible to have climate file that exactly corresponds with the climate at the building site. NIWA state that since 1950, there has been 0.3–0.7°C warming across the Australia/New Zealand region as a whole (NIWA, 2014). The warmer temperatures were readily apparent in processing temperature data during this project. A simple check of the ASHRAE Handbook of Fundamentals (1981 ed.) has

Christchurch 99% winter design temperature at -2.2˚C, while the ASHRAE 2013 edition cites -1.8˚C: an increase of 0.4˚C.

In addition to the climate variation at a specific site, there are also significant changes in weather over even a small distance in New Zealand and the UK (McLeod, Hopfe & Rezgui, 2012). Very local climates can be generated automatically by Meteonorm and other software, but the data was found to be inaccurate for the few sites examined during this project. For example, moving a building site north from Queenstown-Lake weather station, measured data shows a colder ambient temperature trend, but the several computer models examined showed it getting warmer! There are good explorations of computer generation of very large numbers of 'localised' files in the UK (McLeod, Hopfe & Rezgui, 2012) and USA but I am not aware of any studies that compare regional climate files with altitude adjusted temperature, these computer 'localised' files, and *measured* data.

From all this above I conclude it is impossible to provide an exactly correct climate file for any given site. Therefore, discussion with PHI revolved around its prior conclusion that aiming for higher accuracy than a temperature differences of around +/- 1˚C would imply a false sense of accuracy, as yearly weather variations and alternative data processing methodologies can lead to larger discrepancies. PHI's recommendation makes the process of developing regional climate files relatively simple. We use +/-1˚C as the tolerance band, and apply some judgement to those areas where very few homes are likely to be built (eg high mountains), that are slightly outside of this band.

2.3 New Zealand Climate Zones

In 2008 NIWA (Liley, Sturman, Shiona & Wratt, 2008) developed regional climate files for 18 climate zones on the basis of known climate regimes, data availability/quality, and population distribution. These files were developed for software that did not include a correction for altitude, so the zones are smaller than might have been otherwise possible. NIWA created the TMY files by reviewing 30 years of climate data, including measured solar radiation data. The files are created through "selecting, by statistical methods, one Typical Meteorological Month (TMM) for each of the 12 calendar months from a period of years of data and concatenating the 12 months to form a TMY" (Jiang, 2010). As NIWA does not claim the TMY bounds the weather in any sense (ie stations in the zone are within a specified range), it was vital that we checked it was appropriate for regional use for the purpose of PH certification.

Having these climate zones and high quality hourly weather to check rather than starting from a blank slate made the task of producing regional PH climate files easier. Without NIWA's data, TMY file development would have had to occur *after* undertaking the checking process described below, for each of the New Zealand territorial authorities.

Once altitude correction is applied, a few of the NIWA zones are similar enough to combine. The Bay of Plenty or Tauranga weather file was found to be inadequate (per PH standards) to cover the entire Bay of Plenty region but the Rotorua file was adequate for *both* Rotorua and the Bay of Plenty. Also Queenstown is sufficiently representative of Lauder, Dunedin, and Invercargill to recommend consolidation of these into a single zone using the Queenstown-Lakes climate file.

Table 2-1: New Zealand climate zones developed by NIWA (ref). PH notes column added to point out zones that have been combined for PH certification/use.

Zone	PH notes	Station/s	Territorial Local Authorities
NL		Kaitaia	Far North, Whangarei, Kaipara
AK		Auckland	Rodney, North Shore City, Waitakere City, Auckland City, Manukau City, Papakura, Franklin, Thames-Coromandel
HN		Ruakura / Hamilton aero	Hauraki, Waikato, Matamata-Piako, Hamilton City, Waipa, Otorohanga, South Waikato, Waitomo
~~BP~~	Use RR	Tauranga	Western Bay of Plenty, Tauranga, Whakatane, Kawerau, Opotiki
RR		Rotorua	Rotorua
TP		Turangi / Taupo	Taupo, Ruapehu, northern Rangitikei
NP		New Plymouth	New Plymouth, Stratford, South Taranaki, Whanganui
EC		Napier	Gisborne, Wairoa, Hastings, Napier City, Central Hawke's Bay
MW		Paraparaumu	Southern Rangitikei, Manawatu, Palmerston North City, Horowhenua, Kapiti Coast
WI		Masterton	Tararua, Upper Hutt City, Masterton, Carterton, South Wairarapa
WN		Wellington	Porirua City, Hutt City, Wellington City
NM		Nelson	Tasman, Nelson City, Marlborough, Kaikoura
WC		Hokitika	Buller, Grey, Westland
CC		Christchurch	Hurunui, Waimakariri, Christchurch City, Banks Peninsula, Selwyn, Ashburton, Timaru, Waimate
QL		Queenstown	Queenstown-Lakes
~~OC~~	Use QL	Lauder	Mackenzie, western Waitaki, Central Otago
~~DN~~	Use QL	Dunedin / aero	Eastern Waitaki, Dunedin City, Clutha
IN	Use QL	Invercargill	Southland, Gore, Invercargill City

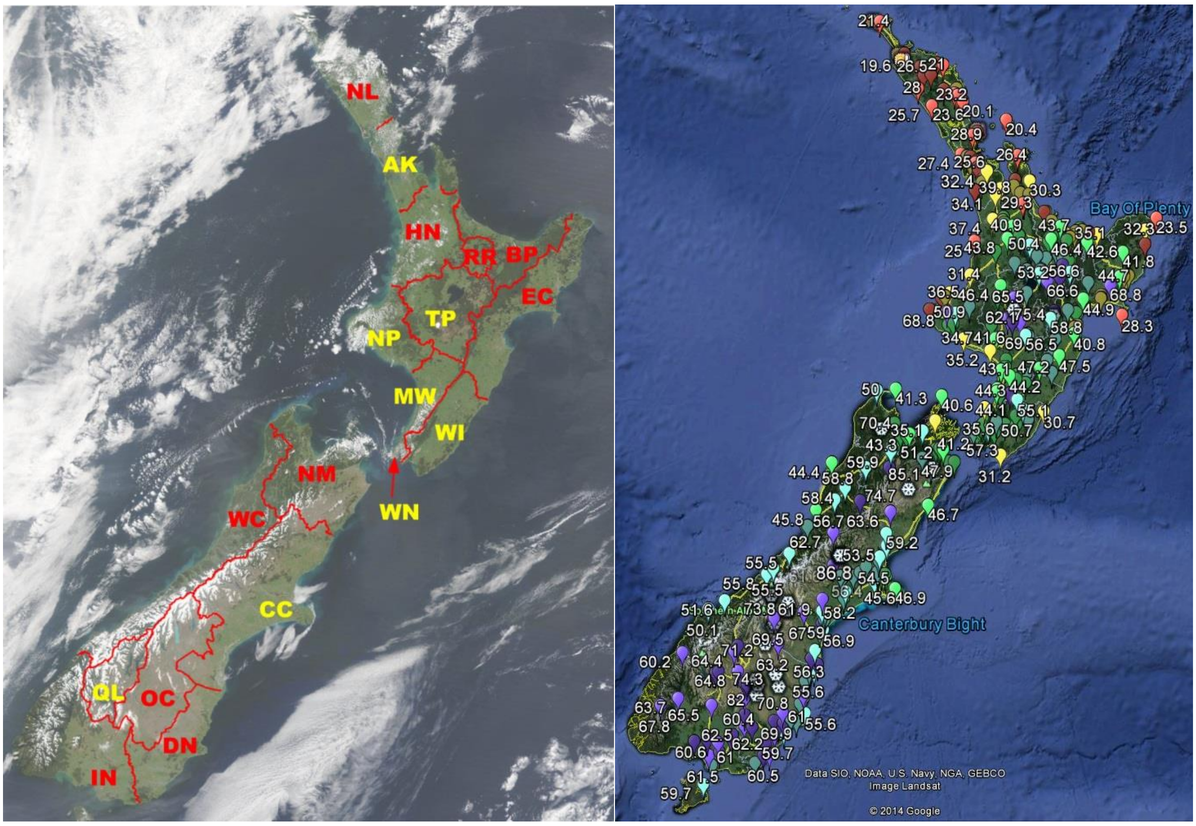

Figure 4: Left Image: New Zealand Climate zones with yellow labels have PHI certified climate data available for PHPP. Right Image: New Zealand Gt data for all weather stations with 30+ years of temperature data.

3 CLIMATE CHECKING PROCESS

In order to check that the proposed regional climate file was appropriate for the region, first the boundary weather stations were identified—those in each region that were most different in terms of Gt from the proposed regional file. Then the boundary sites are compared in terms of altitude adjusted temperature and the most extreme processed into full PHPP climate files so that they can be compared for performance on SSHD using the example PH built into PHPP.

3.1 Check climate region process

A. Calculate Gt for each weather station site from the measured 12 monthly average temperatures. An example of the Bay of Plenty and Rotorua regions with Gt for each site is shown in Figure 5. To calculate Gt, the monthly average temperatures could be entered into PHPP: but the data shown uses a custom spreadsheet with the results output in kml format and displayed using Google Earth. The results table has the Gt for each of the suggested PH climate regions.

B. Use altitude lapse rate (0.6 ˚C per 100 meters) to adjust the temperatures of the weather station sites by changing the altitude to the same as the proposed regional file. Compare the regional site Gt to all the other weather stations adjusted Gt. The sites that are most different are the boundary sites, which need to be compared more closely. The boundary sites for the Bay of Plenty and Rotorua regions are shown in Figure 6.

C. Plot the altitude adjusted temperatures for each weather station boundary site within the zone (example for the Bay of Plenty and Rotorua regions shown in Figure 7) and see if the temperatures are within +/-1 ˚C of the proposed data. Those closest to the limits (or outside the +/-1 ˚C band) need to be processed into PHPP climate files for final checking using PHPP.

D. Adjust the example passive house delivered with PHPP insulation U-values to yield a SSHD of 14.5 kWh/m^2/a with the proposed regional climate data. Then create two modified regional climate files by changing the monthly average temperatures +/-1 ˚C. The resulting SSHD for the example PH built into PHPP for +1 ˚C is the lower bound and -1 ˚C is the upper bound. The adjusted +/-1 ˚C temperatures around the proposed regional file for the Bay of Plenty and Rotorua regions are shown in Figure 7 (dashed lines). This step in the process results in the example house in PHPP having a SSHD of 14.5 kWh/m^2/a. PHPP with the adjusted example PH and using the RR regional file predicts 11 kWh/m^2/a with +1 ˚C monthly temperatures (upper dashed line in Figure 7), and 18.5 kWh/m^2/a with -1 ˚C monthly temperatures (lower dashed line in Figure 7).

E. Calculate PH climate files for each boundary set using the average monthly measured temperature from the NIWA National Climate Database inserted into Metenorm 7. Meteonorm will output a file containing the data as shown in Figure 1 using the internal ground measured and satellite radiation data. Don't forget that the data needs to be inverted for the northern hemisphere before entry into PHPP!

F. Insert each boundary set into the PHPP Climate Data tab (Figure 2). Be certain to enter the regional site altitude into the 'user input site altitude' box (shown in Figure 2): for example, if the boundary site measured weather is 1500m altitude and the regional climate file site is at 10m altitude, enter 10m. PHPP will apply the 0.6˚C per 100m temperature lapse rate, in this case making all of the monthly temperatures 8.9˚C (1490/100*0.6) warmer, allowing comparison. If the boundary set is completely within the SSHD band from step D, the regional file is appropriate.

Figure 5: Rotorua and Bay of Plenty (Tauranga) climate region. Local Gt at weather stations with 30+ years of temperature data.

Figure 6: Rotorua and Bay of Plenty (Tauranga) climate zones - weather stations to be compared.

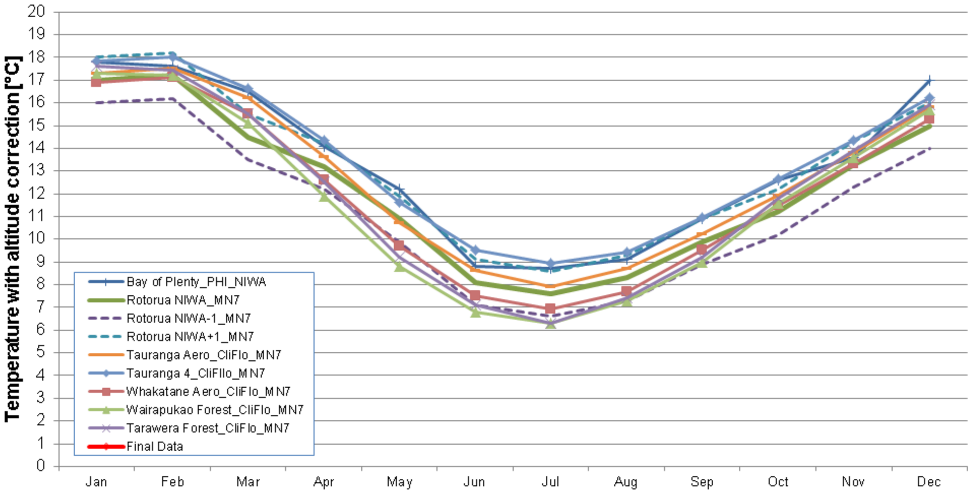

Figure 7: Temperatures corrected for Altitude to match Rotorua 287m - most extreme in zone compared to PHI proposed with +/-1C.

3.2 Generate and check micro-climate

It is possible to generate a local climate file from locally measured temperature data if there are constraints on building design but the design almost achieves PH performance with the regional file. This generally arises when a specific site is believed to be warmer than the rest of the region. If the measured monthly average temperatures are available, these can be combined with Meteonorm radiation data to produce a local climate file. This can be acceptable to PHI for certification based upon SSHD. If necessary, the heating/cooling loads for the surrounding colder climate can be used to size heating and cooling equipment.

4 LESSONS LEARNT

There were several problems encountered during this process of checking regional climate files for PH use. The lessons learnt have been incorporated into the process described above, but are explicitly described below.

The hourly weather file regional applicability (with PH tolerances) should be checked *before* having PHI produce heating and cooling load. This checking process took much more time than originally anticipated.

As several houses were being designed as this project started, several of the NIWA TMY files were sent to PHI and processed into PH climate files (including heating/cooling loads) without checking their regional applicability. Unfortunately, the Bay of Plenty NIWA TMY file was not adequate to cover the entire region for the purpose of PH certification. This file was a good fit for the beach region but, even with altitude correction, did not cover colder sites inland. The Rotorua NIWA TMY file was found to be a better fit for the whole region once corrected for altitude, and applicable to Bay of Plenty *and* Rotorua. If this checking had been done before sending files to PHI, one less TMY file could have been processed. The Bay of Plenty PH climate file is still applicable for locations near the beach (see Fig 8) but the extent of the applicable region was not determined.

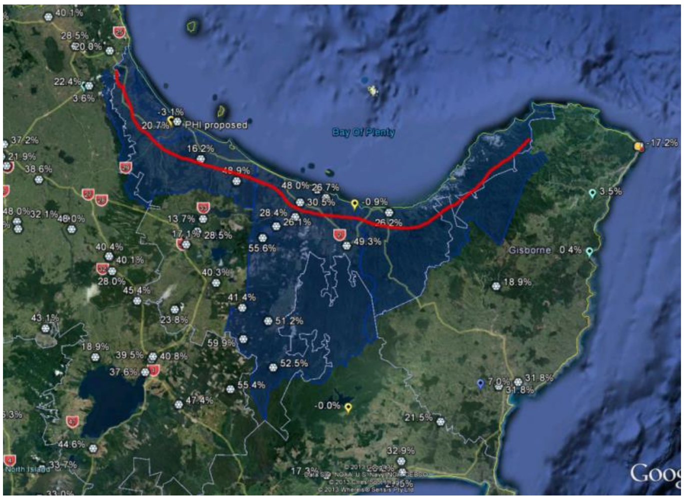

Figure 8: Bay of Plenty weather file only appropriate for warm beachside locations in the Bay of Plenty zone. Red line is notional applicability of BP climate file.

The original plan for this project was to use the batch processing capability in Meteonorm 7 to process *every* 30+ year weather site into a PH climate file. After checking the Meteonorm interpolated data, we decided it was necessary to use measured temperature data, requiring a mostly manual procedure. The process described above was developed to minimise the number of files that needed to be processed with Meteonorm. It would have been much easier to use Meteonorm to generate thousands of highly localised climate files rather than hand checking the measured data and setting up regional files— but in my opinion this would have given inaccurate results.

5 RESULTS

The results of following the above process for each of the climate zones in New Zealand are summarised in the table below. The PHPP formatted placeholder climate files for the non-certified climates are available at www.SustainableEngineering.co.nz/PHClimateNZ. These are offered for research purposes only, as they are uncertified. The PHI certified climate files are available at www.phinz.org.nz/resources/climate-data.

Table 5-1: Results for New Zealand climate zones. SSHD (kWh/m2/a) is Space Specific Heating Demand. Gt (kKH/a) is the time integral temperature difference and is strictly a function of the climate file and building site altitude.

Climate Zone	Gt (kKh/a)	+1˚C SSHD ($kWh/m^2/a$)	-1˚C SSHD ($kWh/m^2/a$)	Notes
NL	19.7			Checked (one site outside of band at higher altitude – acceptable)
AK	24	8.6	20.0	PHI Certified (all sites inside band)
HN	40.5			Checked (West coast beaches are warmer than band similar to AKL but acceptable)
RR (+BP)	49			Checked (few beach sites very slightly warmer than band but rest inside, BP region covered by RR)
TP	55	11.7	18.4	PHI Certified (several mountain top sites are slightly warmer than band - acceptable)
NP	33	10.2	19.6	PHI Certified (single site Omata slightly warmer than band)
EC	36.2			Checked (Havelock N. borderline cold, and Portland Isl. borderline warm - acceptable)
MW	39	10.8	19.2	PHI Certified (all sites inside band)
WI	48	10.9	17.8	PHI Certified (a few beach sites very slightly warmer than band but rest inside)
WN	42	10.9	18.7	PHI Certified (single site Karori mountain is slightly colder than band but as not likely to build many houses there accepted)
NM	45.1			Checked (good representation of zone - Marlborough sounds are warmer more like NP – acceptable)
WC	52.6			Checked (all sites inside band)
CC	56	11.5	18.4	PHI Certified (several mountain and costal Akoroa slightly warmer than band but rest inside)
QL	68.2	11.5	17.7	PHI Certified for QL region only (all sites inside band)
~~OC~~	69.7			Checked (I recommend that we use QL but PHI has NOT confirmed this so do so at your own risk)
~~DN~~	56.1			
~~IN~~	60.7			
Standard Germany	84	12.9	16.4	For reference this is the standard germany climate and +/-˚1 SSHD. The better the insulation the smaller the climate impact on the building performance.

6 CONCLUSION

This process for checking and generating regional climate data files has worked well. Only the generation of the PHI certified heating and cooling load data and final quality review needs to be performed by PHI. The rest of the work can be performed locally. Learning from this experience and following the process developed here would enable more rapid development of climate data for PH certification in other regions. Developing regionalised PH climate files in this way saves time and money.

ACKNOWLEDGEMENTS

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