PHIUS Verified Window Performance Data Program

Program Overview

Passive House Institute US (PHIUS) developed the voluntary Verified Window Performance Data Program to make verified performance data for windows, doors, and skylights readily available to passive building practitioners. Manufacturers who have their window component performance data verified by PHIUS are able to better position their products in the marketplace by providing practitioners with the information they need to specify high-performance products in their projects. Manufacturers seeking this verification supply the required product and testing data to PHIUS, from which a custom performance data set is generated.

Verified products achieve the PHIUS product performance data verification mark ® upon completion of the verification process. The verified product performance values are then published to the PHIUS Verified Window Performance Database on the PHIUS website. These verified performance values are also periodically released in database files suitable for import to the WUFI® Passive building simulation modeling tool.

1. Program Overview

The PHIUS Verified Window Performance Data Program is a voluntary program intended to verify the accuracy and appropriateness of the energy performance data for windows and their components needed to accurately model passive building energy balances. For best accuracy in building energy modeling, window performance data (e.g. U-values) are needed at the component level, that is, for the frame and glass separately, so that the performance of the windows can be calculated for the exact sizes and configurations planned in the project. The verification process follows the appropriate window simulation protocols and conditions for high-performance windows, doors, and skylights.

1.1 Window Performance Data Verification Program vs. Building Certification Program

The PHIUS Verified Window Performance Data Program is separate from the **PHIUS+ Passive Building Standard certification program. PHIUS'** building certification program does not require the use of windows, doors, or skylights for which performance data has been verified through the Verified Window Performance Data Program. While the PHIUS building certification program does **not have a "hard requirement" on maximum window U**-value, the window performance does have an impact on interior surface temperatures and thermal comfort. The PHIUS+ Passive Building Standard however does have maximums **the building's peak heating load, and because the windo**w U-value strongly influences peak heat load, the peak load limit indirectly limits the window U-values. However the designer still does have flexibility in meeting the peak load limits by for instance reducing the window area or using a better ventilator instead of increasing the window performance.

It is important to note that the data verification program performs calculations according to set *criteria* in order to produce the recommendation *checkmarks* for which assemblies are recommended for use in which climate zones. That is, the calculation data have the force of *recommendations* as far as building project teams or building certification is concerned, but they have the force of *requirements* as far as window manufacturers are concerned. The products must meet the criteria in order to get recommendation checkmarks for the various climate zones. Since higher performance is required to get recommendations for the colder zones, the data label serves as a selling point for manufacturers looking to position their products in passive building applications.[1] Here are listed the performance criteria by climate zone.

The PHIUS building certification program *does* have a requirement that the window must be good enough to avoid outright condensation, but this is not usually a limiting factor – a window which gets any checkmarks at all under the

[1] Currently, to get any checkmarks at all, the whole-window installed R-value must be at least 4.5 (IP units), and to be recommended for Zone 5 at least R-7. Most types of windows are rated at 1.23 x 1.48 m size.

PHIUS Verified Window Performance Data Program will almost certainly be low-risk for condensation in all climate zones. For reference, a window condensation calculator is linked to here.

PHIUS consultants are trained on how to do basic interior-surface-temperature calculations. If planned window U-values are significantly above those recommended for the climate, but the building overall meets the peak heat load criterion (more likely to happen for larger buildings), it would be appropriate to locate heating devices under the windows. Presently, there are still not many choices for windows better than R-7, and thus recommendable in Zones 6-8, so designers may need to resort to under-window heating to prevent cold air pooling there.[2] [3]

The PHIUS building certification program *does* require that windows are entered into the building energy model in their actual size and configuration (every lite), with the performance of the framing members and the glass broken out separately (as opposed to using whole-window properties at a standard **size). PHIUS' window** data label contains the information needed to model the windows at that level of detail, but if a project team wants to use windows not (yet) rated by PHIUS, there are workarounds to obtain usable data from other (third party) sources and fill in the gaps with conservative assumptions. Reach out to the PHIUS Certification team at certification@passivehouse.us for more information.

1.2 High-Performance Windows: Reliable Information Sources

High-performance windows are an important part of a passive or high-performance building project. Some reliable sources of information about windows include the following:

- Efficient Windows Collaborative (EWC)
    - Focuses on information on how to choose energy-efficient residential windows. A good place to start for DIY home designers and homeowners considering window replacement.

- National Fenestration Rating Council (NFRC)
    - Rates residential and commercial windows, doors, skylights, storefronts, and curtain wall assemblies mainly for energy (thermal) performance.
    - Has a large online database of rated products, with several hundred manufacturers participating in its programs.

- American Architectural Manufacturers Association (AAMA)
    - Rates and certifies windows for resistance to air leakage, water penetration, and wind pressure – particularly relevant in hurricane country.

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[2] Some additional discussion of window comfort and condensation appeared in this November 2015 post on the PHIUS blog.

[3] Note it is possible to design an R-9 window that would meet the recommendations for Zone 8 without using any exotic components, as demonstrated in this hypothetical example.

2. Submit a Window for Data Verification

To submit a product for review under the Verified Window Performance Data Program, please refer to the PHIUS Verified Window Performance Data Program Application & Instructions document available for download on the Submit a Window for Data Verification page on the PHIUS website.

2.1 Data Verification Protocols

Once a product has successfully completed the Verified Window Performance Data Program process, the result is a data label containing all of the thermal performance information for the product. It is important to note that these performance values are based upon calculation results only, and not upon physical testing of the product.

Two options are available when selecting the calculation protocol:

- **Orange Path**: Based on EN standards, this protocol calculates center-of-glass U-value per EN 673, center-of-glass solar gain per EN 410, and frame/spacer performance per EN 10077-2.

- **Blue Path**: This protocol uses calculations by qualified NFRC Simulators, per ISO 15099.

The example data labels below show the information that is included for each calculation protocol: the Orange Path based on EN (European Standards), and the Blue Path based on NFRC standards. The text border at the top of each label notes the corresponding calculation standards. The data label shows detailed data used for energy modeling and provides performance summary information for comparison-shopping. Checkmarks appear on each data label indicating the particular climate zones for which the window is recommended.

To pursue the Blue Path data verification method, contacting a qualified NFRC simulator is the first step. To pursue the Orange Path, please contact Graham Wright, Senior Scientist and Product Program Manager, at graham@passivehouse.us.

2.2 Introducing the New "NFRC Mode" Data Label

As noted in the top border of the example Orange Path data label (based on EN standards) shown below, the PHIUS window rating performance calculations have up until this point been based on the European CEN (European Committee for Standardization) standards: EN 673 (for U-value of the glass), EN 410 (for solar gain of the glass), and EN ISO 10077-2 (for U-value of the frames).

But in North America most windows are calculated to NFRC standards, which are also referenced in building energy code language, including 2012 IECC (2012 International Energy Conservation Code), clause R303.1.3, and ASHRAE 90.1, clause 5.8.2.4. As noted above, there are a number of technical differences between CEN and NFRC standards, such as different standard environmental conditions.

PHIUS now offers a second "mode" of window data verification based on NFRC standards, in addition to the original "CEN mode" verification. An example data label is shown as the Blue Path data label (based on NFRC standards) below. The NFRC mode contains all the same kinds of information as the CEN mode data label, so it can be used the same way for building energy modeling, that is, it supports entering windows at their actual size and configuration.[4] However because of the technical differences in the calculation methods between the two approaches, the numbers should not, strictly speaking, be compared directly to CEN-based data. Therefore, the two kinds of labels are different colors – the CEN-mode label is orange and the NFRC-mode label is blue. Again the calculation standard is noted in the top border – **NFRC's methods are also internationally** recognized and designated ISO 15099.

Calculation based on ISO 10077-2, EN 673, EN 410

Product name: **HH 78mm Tilt & Turn**

PHIUS Passive House Institute US

ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	Whole-window installed U-value W/m2K	Whole-window installed U-value BTU/hr.ft2.F	Center-of-glass properties: Cardinal Cardinal LoE366-Clr-LoE180 No Grids — SHGC	Ucog-Value W/m2K	Ucog-Value BTU/hr.ft2.F
Climate specific recommendations:							
8			0.97	0.17	0.271	0.682	0.120
7			0.95	0.17	0.271	0.647	0.114
6			0.91	0.16	0.271	0.594	0.105
5			0.90	0.16	0.271	0.579	0.102
4			0.89	0.16	0.271	0.560	0.099
Marine North		☑	0.89	0.16	0.271	0.554	0.098
Marine South	☑	☑	0.89	0.16	0.271	0.559	0.098
3	☑	☑	0.89	0.16	0.271	0.556	0.098
2 West	☑	☑	0.90	0.16	0.271	0.569	0.100
2 East	☑	☑	0.90	0.16	0.271	0.569	0.100

HH 78mm Tilt & Turn **Cardinal Endur IG**	FRAME				Psi-spacer		Psi-opaque
	Frame height		U-frame		Ψ		
	mm	in	W/m2K	BTU/hr.ft2.F	W/mK	BTU/hr.ft.F	W/mK
Head	119	4.70	1.09	0.19	0.030	0.018	0.180
Sill	133	5.25	1.10	0.19	0.030	0.018	BTU/hr.ft.F
left jamb	119	4.70	1.09	0.19	0.031	0.018	0.104
right jamb	119	4.70	1.09	0.19	0.031	0.018	Grade C

Valid through March 2018

Figure 1: Orange Path data label, based on EN standards

[4] Up to this point, the use of NFRC data for passive house modeling has been hampered by the fact that the standard NFRC data label reports only whole-window performance at standard sizes.

Calculation based on ISO 15099

Product name: **NFRC casement example**

Center-of-glass properties

Cardinal 4mm med gain LowE,Arg90
No Grids

ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	Whole-window installed U-value W/m2K	Whole-window installed U-value BTU/hr.ft2.F	SHGC	Ucog-Value W/m2K	Ucog-Value BTU/hr.ft2.F
Climate specific recommendations:							
8			1.65	0.29	0.360	1.437	0.253
7			1.59	0.28	0.360	1.365	0.240
6			1.51	0.27	0.360	1.258	0.221
5			1.48	0.26	0.360	1.226	0.216
4			1.44	0.25	0.360	1.176	0.207
Marine North			1.42	0.25	0.360	1.148	0.202
Marine South			1.40	0.25	0.360	1.119	0.197
3			1.41	0.25	0.360	1.134	0.200
2 West			1.39	0.24	0.360	1.100	0.194
2 East			1.39	0.24	0.360	1.100	0.194

NFRC casement example	FRAME				Psi-spacer		Psi-opaque
Cardinal XLedge?	Frame height		U-frame		Ψ		
	mm	in	W/m2K	BTU/hr.ft2.F	W/mK	BTU/hr.ft.F	W/mK
Head	83	3.25	1.80	0.32	0.021	0.012	0.177
Sill	83	3.25	1.80	0.32	0.021	0.012	BTU/hr.ft.F
left jamb	83	3.25	1.72	0.30	0.022	0.013	0.102
right jamb	83	3.25	1.72	0.30	0.022	0.013	Grade C

Valid through April 2018

Figure 2: Blue Path data label, based on NFRC standards

As with the CEN mode labels, an embellishment of the standard methods is made to calculate center-of-glass (COG) properties with outside conditions that vary by climate zone. For window manufacturers, the advantages of the **Orange Path** label are that the CEN calculation procedure inherently produces the desired component level performance data (frame, glass, spacer), and that the data can be compared to performance numbers from any European competitors who also report data based on CEN methods.

The main advantage of the **Blue Path** label is a lower cost of data verification for the manufacturer. Manufacturers who already have, or are pursuing, a NFRC rating can now also have their data verified by PHIUS, allowing them to serve the passive building community for less additional cost than a full recalculation to CEN standards. PHIUS then charges only a listing fee for web publication and inclusion in the WUFI® Passive window database. A second advantage is that the ISO 15099 method for frames is actually more accurate, as recognized in ISO 10077-2.

PHIUS has partnered with NFRC to train their qualified simulators and license them to produce the Blue Path labels as an optional additional service for interested manufacturers. A list of qualified simulators can be found on the [Find a Qualified Blue Path Simulator] page.

The reason that the NFRC calculation mode is possible, from technical standpoint, is that while the standard NFRC label reports only whole-window performance, the calculations performed by NFRC simulators also produce component-level data. The main difference between the CEN and NFRC approaches is the treatment of the extra heat loss at the edge of glass. The CEN approach is to model the window twice; once with a piece of rigid foam in the frame to determine a frame U-value, and once with the actual glazing and spacers. The difference between the two is used to calculate a linear thermal bridge **coefficient "psi-spacer". The NFRC** approach is to model the window once and pick off separate U-values for the frame, the center-of-glass (COG), and an edge-of-glass region 2.5 inches wide.

In a 2012 PHIUS Tech Corner report **entitled "**Calculating Window Performance Parameters for Passive House Energy Modeling,**" the PHIUS Technical Committee** suggested that a conversion could be done in which **the "extra" edge**-of-glass heat loss from an NFRC calculation is converted into an equivalent linear coefficient to get the data into the same format as the CEN results and proposed a corresponding conversion formula.

In a 2014 report **entitled "**NFRC and PHIUS U-factor Calculation Comparison**", Jeff** Baker of WESTLab and NFRC derived a different formula and demonstrated that, if all other things were equal, this edge-conversion procedure in and of itself would introduce very little error.[5] [6] [7] The additional work for an NFRC simulator to produce a Blue Path label thus comprises mainly:

- Running the COG properties through the climate zones.
- Retagging the THERM models for two-lite products to get separate U-values for the two halves of the meeting rail or stile (to support modeling each lite at its actual size in the building energy model).
- Using the workbook that calculates the edge conversion and produces the data label.

The process described above should be significantly less work than a full calculation to CEN standards, produce results equally useful to passive building consultants, and offer the same kind of recognition and exposure for high-performance products.

2.3 A Closer Look at the Data Label

At the **upper right** of each table are listed COG properties, which are climate-dependent. There is confusion in the market stemming from the fact that windows imported from Europe are calculated to European standards with fixed environmental conditions at 0°C (32°F) on the exterior, while domestic windows are calculated to NFRC standards at -18°C (0°F) on the exterior. This protocol

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[5] **Baker's formula properly accounts for the window corners, whereas the** 2012 proposal would have double-counted them.

[6] Note that for NFRC mode the psi-spacer value will likely be generally lower and the U-frame generally higher.

[7] Note that for the whole-window U-value and checkmark criteria application, the window is resized from NFRC standard size to PHIUS standard size.

difference allows European manufacturers to use wider gaps between panes to eke out a bit lower (better) U-value under the milder standard conditions, and thus complaints about unfair comparison with NFRC-rated windows arise.[8]
Top center are the whole-window U-values for a standard size window, correspondingly climate-dependent. The whole-window U-value includes the effect of a nominal installation thermal bridge coefficient of 0.026 W/m.K (0.015 Btu/h.ft.F).

At **top left** the recommendation criteria are applied. If the window meets the recommendation criteria, it receives a green check mark for the zone, south-facing or off-south as appropriate. Note that there are green check marks but no red "X" marks because windows could well be suitable in other zones depending on the details of the building design.

At the **bottom** of the table are the frame / spacer properties. These are calculated at fixed environmental conditions because the frame properties are not as temperature-dependent as the glazing.

At **bottom right the "psi-opaque" value combines the frame and edge**-of-glass heat loss into a single figure of merit. This enables fair comparison of frames of different widths, and comparison of different frame-spacer combinations. These are assigned letter grades as follows:

Psi-opaque (W/mK)	Letter grade
≤0.065	A+
≤0.11	A
≤0.155	B
≤0.2	C
> 0.2	D

Calculating the glass U-value over a range of environmental conditions is intended to bring some clarity to the issue – if wider gaps are used, the performance can be better in moderate climate zones, but drops off in the colder zones where it is most wanted. If narrower gaps are used, performance may not be as good in the mild or moderate zones but holds steadier in the colder conditions. Energy modeling consultants are advised to use the glass properties for the zone where the project is located.

For PHIUS calculations, COG properties are calculated using WINDOW 7 and the International Glazing Database (IGDB) from Lawrence Berkeley National Lab (LBNL).

[8] For more background on the differing protocols between Europe and the US, see RDH (2014) and Ebanks (2014).

PHIUS can provide manufacturers with instructions for calculating the zone-by-zone COG properties per PHIUS protocols to assist with selecting glazing for the window data verification program. Several suggested examples of glazing packages are presented below.

Table of Standard Glazing Sizes

Product type	Model size (width by height) in meters	
Vertical windows	1.23 x 1.48	external frame dimensions
Sliding door	2.4 x 2.5	external frame dimensions
Curtain-wall façade	1.2 x 2.5	unit size
Roof window	1.14 x 1.40	external frame dimensions
Skylight, domelight	1.50 x 1.50	external frame dimensions
Garage overhead door	2.134 x 2.134	external frame dimensions

The **Find and Compare Windows** page of the PHIUS website includes a summary table with the recommendation checkmarks and frame/spacer grades for all rated windows, with corresponding links to the full data labels. PHIUS window data will also be published periodically as a database suitable for import to WUFI® Passive. A hypothetical design for an R-9 window is also listed on the PHIUS site to demonstrate how a window could be designed and constructed to meet PHIUS' performance recommendations for climate Zone 8.

2.4 Additional Window Performance Properties

The following properties and metrics are helpful to keep in mind when evaluating the performance of a window assembly.

Air-tightness is important in passive building construction as well as the windows used in passive buildings. ASTM E283 - 04 (2012) provides a standard test method for air leakage through windows, doors, skylights, and curtain walls. While it is currently optional, manufacturers are encouraged to submit any such air-tightness data they have and those reports are also linked on the summary table.

Anecdotally, windows leak more in the field than in the lab tests. As such, the reported numbers can be used for relative comparison, however it is not advisable to try to use these values **to calculate "air leakage budgets" for building** certification. Also, because ASTM E283 is a short-term test, it may not distinguish very well between more and less durable air-sealing designs.

Energy modeling for building certification also involves entering window installation thermal bridge parameters (**"psi-install"** for short) for each window. The psi-install depends on the window installation detail design. Conservative defaults suffice for most projects, e.g. 0.04-0.05 W/m.K (0.023-0.029 Btu/h.ft.F). However in some cases it may be appropriate to do the 2D finite element calculations to determine psi-install values more precisely.

2.5 Calculating the Psi-Install Value

PHIUS supports consultants in performing psi-install calculations for their project. Manufacturers are asked to choose at least one of the following three options to supply the data to PHIUS necessary to perform the psi-install calculation:

1. Allow PHIUS to publish the THERM models of the frame sections so that the designer can use THERM to do their own calculations. (preferred option)
2. Provide psi-install calculations as an in-house tech-support service.
3. Like Option 2, but the calculation is outsourced to PHIUS.

There is also the option to pre-calculate installation details, however this option has not been popular. As in the building project certification program, this program does not prescribe any particular wall assemblies, but the installation details are reviewed for soundness-of-concept with regard to air-barrier continuity and water control.

For Option 1, zip files containing the THERM models are linked to in the summary table of the **Find and Compare Windows** page.

2.6 Suggested Glazings

In order to generate recommendation checkmarks for both warm and cold zones, both a high-gain option and a low-gain option for the glazing is needed. The following suggested packages are constructed out of the Cardinal Glass catalog.

If verifying the performance values with just <u>two glazings</u>, it is suggested to use two triple-pane systems with Argon fill in 17 mm gaps and 3mm glass layers (43 mm overall thickness):

- High-gain triple: low-e-180#2 / Clear / low-e-180#5
- Low-gain triple: low-e-366#2 / Clear / low-e-180#5

Windows with these glazings can receive checkmarks up to Zone 5, or possibly 6, with a very good frame:

- High-gain: can cover Zone 4C, 4, 5, and 6 south-facing
- Low-gain: can cover Zone 2, 3, 3C south-facing and 2-6 off-south

If a <u>third</u> glazing is included, it is suggested to use a double-pane option for the warm zones, also with Argon fill in 17 mm gaps (23 mm overall thickness):

- Low-gain double: low-e-366#2 / i89#4

For a <u>fourth and fifth glazing</u>, it is suggested to use four-pane options for Zone 7 and 8 with 22% Argon and 66% Krypton in 12 mm gaps:

- High-gain quadruple: low-e-180#2 / Clear / low-e-180#5 / low-e-180#7
- Low-gain quadruple: substitute low-e-272#2 on the first (outer) pane

3. Performance Criteria by Climate Zone

The current climate-by-climate recommendations for window performance are shown below, and indicated on the US climate zone map (per 2009 IECC) on the following page. Climate zone information on a county-by-county basis can be located online at the **DOE's Building Energy Codes Program site**. For more information about IECC fenestration requirements, visit the EWC Performance Codes and Standards page.

Climate-by-Climate Recommendations for Window Performance

ASHRAE/IECC/DOE North American Climate Zone	Overall installed window U-value Btu/h.ft2.F	Center-of-glass U-value Btu/h.ft2.F	SHGC - South	SHGC - North, East, West
8	≤0.11	≤0.10	≥0.50	Any
7	≤0.12	≤0.11	≥0.50	Any
6	≤0.13	≤0.12	≥0.50	Any
5	≤0.14	≤0.13	≥0.50	Any
4	≤0.15	≤0.14	≥0.50	≤0.40
Marine North	≤0.16	≤0.15	≥0.50	≤0.40
Marine South	≤0.22	≤0.20	≤0.50	≤0.30
3	≤0.18	≤0.16	≤0.50	≤0.30
2 West	≤0.18	≤0.16	≤0.30	≤0.30
2 East	≤0.20	≤0.18	≤0.30	≤0.30

In the criteria table and on the data label, the climate zone labels differ slightly from the IECC map as follows:

- 2 East = 2A
- 2 West = 2B
- Marine North = 4C
- Marine South = 3C

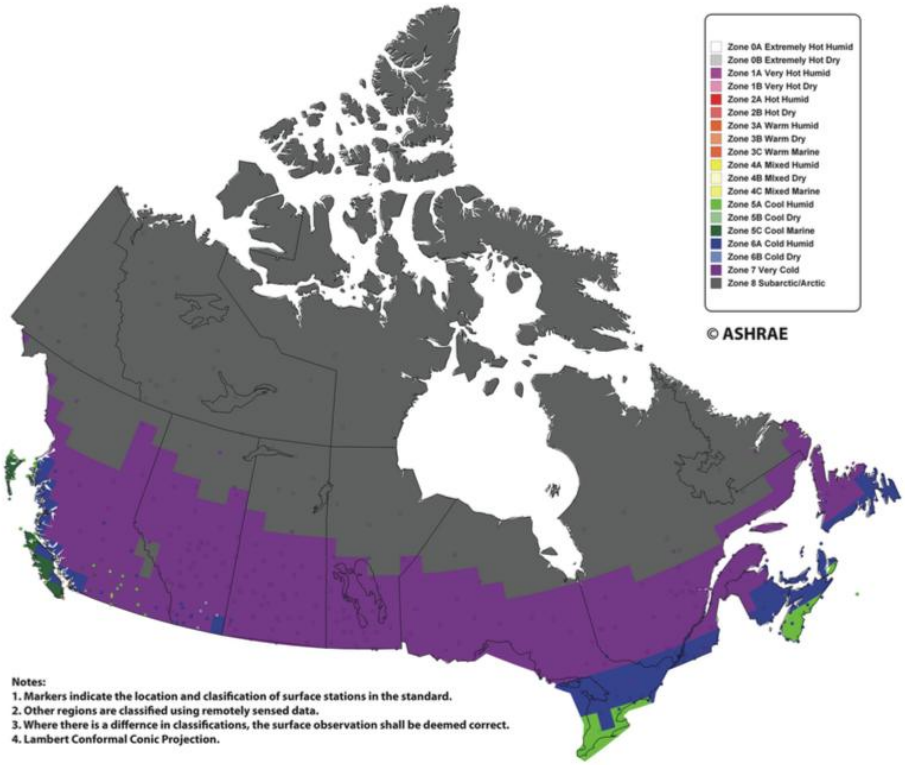

FIGURE C-12 Canada climate zones map.

Figure 3: Canada climate zones map
ASHRAE Standard
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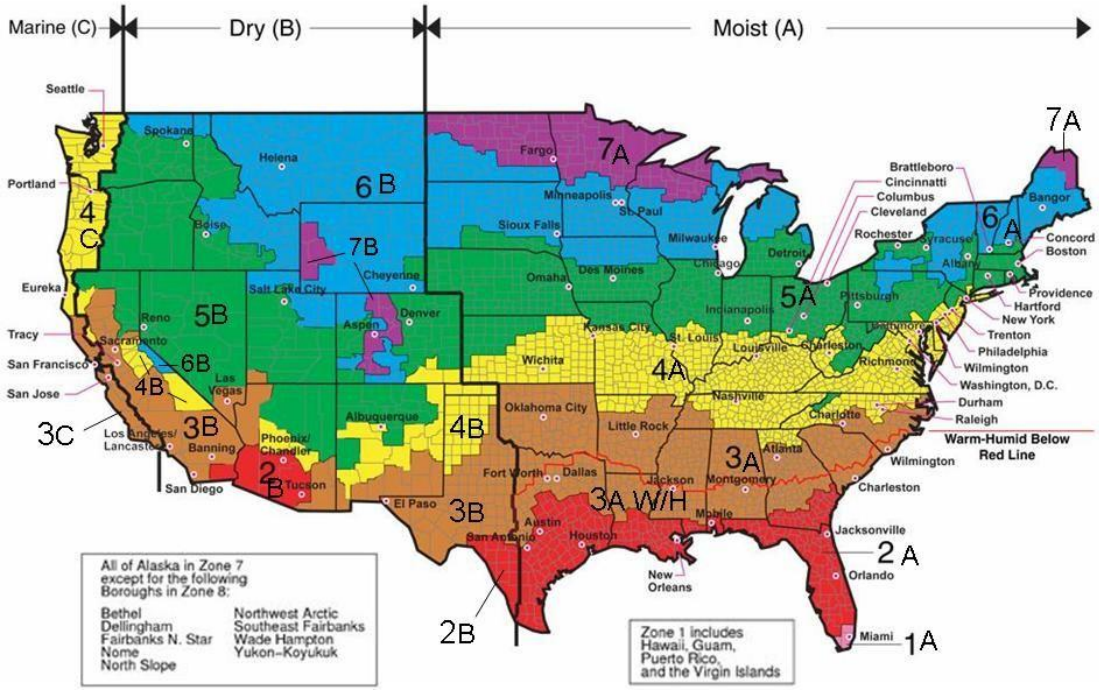

Figure 4: US climate zones map (per 2009 IECC)