2015 WSEC Residential Proposals

Number	Submitter	Section	Subject	Form (Short/Long)	Editorial / Policy / Technical	TAG Date / Action	Committee Date / Action
15-E001	Mike Kennedy	R303.1.3	U-value - site built	S	T		
15-E002	Todd Andersen	R402.1.2	SHGC	L	T		
15-E003	Patrick Hayes	R402.1.3	Insulated siding	L (NO$/BTU)	E/T		
15-E004	Gary Nordeen	R402.4.1.2	Air leakage testing - add's	L	E/T		
15-E005	Gary Nordeen	R403.2.2	Duct testing -3rd party	S	E/T		
15-E006	Gary Nordeen	R403.3.1	Duct Insulation	S	E/T		
15-E007	Larry Andrews	R403.4	Hydronic pipe insulation	L	T		
15-E008	Duane Jonlin	R403.5.3	Pipe Insulation	S	E		
15-E009	Bruce Carter	R403.7.1	Electric Resistance heat	L	T		
15-E010	Gary Nordeen	R404.1	Permanently installed fixtures	S	E		
15-E011	Mike Kennedy	R405.5.2	Std Ref Design - hydronic	S	T		
15-E012	Chuck Murray	R406, R405.3	Add'l efficiency measures	L	T		
15-E013	Gary Heikkinen	R406.2	High efficiency HVAC	L	T		
15-E014	Gary Nordeen	R406.2	High efficiency HVAC	S	E/T		
15-E015	Gary Nordeen	R406.2	Duct footnote	S	E/T		
15-E016	Gary Nordeen	R406.2	Envelope Editorial	S	E/T		
15-E017	Jeff Peterson	R406.2	High efficiency HVAC - zonal heating	L	T		
15-E018	Patrick Hayes	R406.2	Point adjustment 1a	L (NO$/BTU)	E/T		
15-E019	Gary Nordeen	R407	ERI Alternative	S	T/P		
15-E020	Gary Nordeen	R502.1.1	Additions	S	E/T		
15-E021	Gary Nordeen	R505.1	Change of use	S	E/T		
15-E022	Gary Nordeen	R601	RS-33	S	E/T		

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Energy Code Proposal Short Form

For editorial **Coordination, Clarifications & Corrections** only,
without substantive energy or cost impacts

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # **R303.1.3 Fenestration product rating**

Brief Description: The code has extensive default U-value tables for doors and skylights and for windows produced by small businesses. However, for owner site built windows the available default u-values are very limited with the best available value of 0.55 – well above code. A typical site built window is non-operable, stopped in glazing unit in a wood frame. Assigning a U-value of 0.55 even if the glazing has a center of glass u-value of 0.3 imposes an unfair burden on home owners with stopped in glazing units – most typically in existing buildings.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

R303.1.3 Fenestration product rating. *U*-factors of fenestration products (windows, doors and skylights) shall be determined in accordance with NFRC 100.

Exception: Where required, garage door U-factors shall be determined in accordance with either NFRC 100 or ANSI/DASMA 105.

U-factors shall be determined by an accredited, independent laboratory, and *labeled* and certified by the manufacturer.

Products lacking such a labeled *U*-factor shall be assigned a default *U*-factor from Table R303.1.3(1), R303.1.3(2) or R303.1.3(4). The solar heat gain coefficient (SHGC) and visible transmittance (VT) of glazed fenestration products (windows, glazed doors and skylights) shall be determined in accordance with NFRC 200 by an accredited, independent laboratory, and labeled and certified by the manufacturer. Products lacking such a labeled SHGC or VT shall be assigned a default SHGC or VT from Table R303.1.3(3).

Exception: Units without NFRC ratings produced by a *small business*, and home owner built non-operable wood frame windows, may be assigned default *U*-factors from Table R303.1.3(5) for vertical fenestration.

Purpose of code change:

Provide a reasonable compliance path for home owners replacing existing stopped in glazing units.

Your name	Mike Kennedy	Email address	codeproposals@energysims.com
Your organization	Mike D Kennedy Inc	Phone number	360-301-0098
Other contact name	Click here to enter text.		

Instructions: For use with Coordination, Clarifications & Corrections **ONLY**. Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280.

Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # ______ **TABLE R402.1.2_ FENESTRATION REQUIREMENTS BY COMPONENT**[a] ___________and **TABLE R405.5.2(1)**

Brief Description: Using the United Kingdom building code energy balance equation for windows and the Canadian government's 2013 review of their window code (as Washington State's has a nearly identical climate environment to both) shows that changing the current solar heat gain coefficient from "No Requirement" for all Washington State climate zones (4marine, 5 and 6) to a minimum value of 0.56 and possibly as high as 0.67 is warranted.

The same conclusion for SHGC holds true when one looks at the European Commission studies for all of Europe including a Danish proposal for windows for the entire continent of Europe. The Nordic Swan Ecolabel (the EnergyStar for the Nordic countries) labeling system, which includes Denmark, will not even allow a window to be labeled without a SHGC of at least 0.48. Denmark is also much closer to Washington State climate wise, far more than Denver, which is what EnergyStar and IECC would group Washington State into for Windows.

The glazing to conditioned floor area should not be 15% but around 30% for West of the Cascades.

See attached *SHGC.WindowflrAreaRatio.supporting info-ver1.1. for WA Windows.docx*

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

TABLE R402.1.2

FENESTRATION U-FACTOR[b]	0.30 EnergyStar indicates higher u factor u =0.32 with higher SHGC ≥ 0.40 for "northern climate" see 7pg of attached *SHGC-version1Energy Balance for Windows For WA – A cool climate.doc*	
SKYLIGHT[b] U-FACTOR	0.50	
GLAZED FENESTRATION SHGC[b, e]	~~NR~~ 0.56 or higher for windows, Skylights NR until further study	

R402.1.5 "For the base building UA calculation, the maximum glazing area is ~~15%~~ 30%-of the floor area."

TABLE R405.5.2(1)

Vertical Fenestration other than Opaque Doors[KB1]	Total area = (a) The proposed glazing area; where proposed glazing area is less than ~~15%~~ 30%of the conditioned floor area. (b) ~~15%~~ 30% of the conditioned floor area; where the proposed glazing area is ~~15%~~ 30% or more of the conditioned floor area.	As proposed
	Orientation: Equally distributed to four cardinal compass orientations (N, E, S & W).	As proposed
	U-factor: From Table R402.1.4	As proposed
	SHGC: From Table R402.1.1 except that for climates with no requirement (NR) SHGC = 0.40 shall be used.	As proposed
	Interior shade fraction: 0.92 - (0.21 × SHGC for the standard reference design) External shading: None (see Department t of Energy Attachment Rating Council work for latest energy saving possibilities.	0.92 - (0.21 × SHGC as proposed) As proposed

The external shading should be flushed out further to say External shades offer significant energy saving.

Purpose of code change: To significantly increase energy savings by windows for existing structures and new structures.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

☒ Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Consistency with state or federal regulations.

☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

☒ Single family/duplex/townhome

☒ Multi-family 1 – 3 stories

☐ Multi-family 4 + stories

☒ Commercial / Retail

☐ Institutional

☐ Industrial

Your name Todd Andersen

Email address todd@matadortech.com

Your organization Bellevue Resident

Phone number 425-449-8889

Other contact name 39T

Instructions: Send this form as an email attachment, along with any other documentation available, to: sbcc@ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

Lowers cost of ownership via energy savings and will have a slight reduction in window costs due to less processing/coating cost for glass with the necessary properties. Not expected to increase costs of windows with a higher SHGC.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$Same to slightly cheaper windows as less processing of the glass is required to keep the naturally high SHRC of glazing glass. /square foot (For residential projects, also provide $39T/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

See attached document called *SHGC.WindowflrAreaRatio.supporting info-ver1.1. for WA Windows.docx*

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

39TKWH/ square foot (or) 39TKBTU/ square foot

(For residential projects, also provide 39TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

See Table 1 of *SHGC.WindowflrAreaRatio.supporting info-ver1.1. for WA Windows.docx* which is on page 24 of 72. These results are from the European Commission in a review of worldwide window energy code requirements. The United Kingdom has a near identical climate in both Degree days and Annual Global Solar radiation as Washington, far more so than the zone the IECC and EnergyStar.gov groups Washington State into. That table 1 shows for windows with a U-factor of 0.343 Btu/h·ft2°F (1.95 W/m2·°K) and a SHGC of 0.67 (window8) would save 41.31 **kWh/m^2/yr** (43.7596-2.4442) over a window with the same u-factor but with a SHGC of 0.46 (window9). For total savings simply multiple this 41.31 value by the amount of square meters of windows replaced annually and summed up over time.

A more insulating window5 with a U-factor of 0.246 Btu/h·ft2°F (1.4 W/m2·°K) and a SHGC of 0.63 would save 9.84 **kWh/year per /m^2** of window (27.36-17.52) over window4 with the same u-factor but with a SHGC of 0.58. This is a more expensive window while saving less energy. Both window 4 and 5 formerly considered "better windows" save less energy than window 8 using the UK energy balance to a net zero energy use window over the entire year.

While not as illuminating on the full energy saving potential as the UK and European Commission Study (also in the attached *SHGC.WindowflrAreaRatio.supporting info-ver1.1. for WA Windows.docx*) the following support the above. Here are calculations of savings from John Carmody and Kerry Haglund in a US Dept. of Energy report "*Measure Guideline: Energy-Efficient Window Performance and Selection*" November 2012. http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_windows.pdf John Carmody also a lead author of *Residential Windows: A Guide to New Technologies and Energy Performance (Third Edition*) 2007, 264 pages. See page 39 of 78 of this Dept of Energy funded report for the table below for Seattle using the RESFEN window modeling program. Oddly while RESFEN (and Windows) is the US standard it is not the model of

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

Table 16. Savings of New Windows in Seattle, Washington

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
11	0.41	0.23	0.49					31	118	$386	$–
15	0.29	0.50	0.57	X	X	X		23	281	$299	$87
16	0.28	0.31	0.52	X	X	X		26	170	$331	$55
17	0.27	0.20	0.46	X	X	X	X	28	111	$352	$34
19	0.19	0.28	0.45	X	X	X	X	25	152	$316	$70

choice in Canada and many of the European countries. See more in attached *SHGC.WindowflrAreaRatio.supporting info-ver1.1. for WA Windows.docx* Window ID 11 is the reference window and far better than the current installed base in Washington residential windows. The most cost effective window is the #15 with a higher U-factor (less insulating) and a higher SHGC. Note the lesser energy savings of the best insulating window #19 with a U-factor of 0.19.

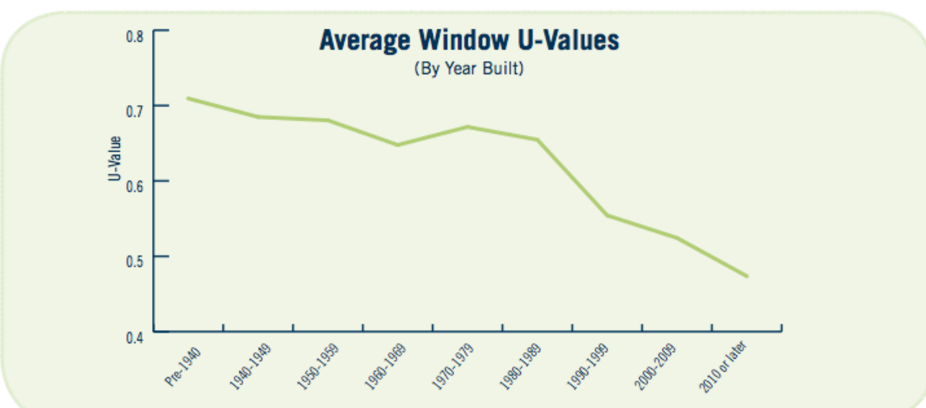
This above table 16 also does a bit of fore shadowing on the future outcome of the unreported war between window and shade makers at the NFRC. This is relevant when considering the 2014 publish report by NEEA on 2011 data and the general lack of consideration of the benefits of high SHGC in Washington State for our very unique climate.
neea.org/2011annualreport/pdf/NEEA_2011_AnnualReport.pdf
The question for those wanting to reduce energy waste is this: is it less expensive and more practical to get existing residential structures with their poor wall/ceiling insulation (13% of WA homes have zero wall insulation) even more energy efficient by today with a major focus on sub 0.3 U-factors or working to zero out summer window heat gains with "Attachments" (Attachments refers to shades internal and external, shutters etc) and further increasing the SHGC for even more winter heating energy savings? UPDATE: the Canadian government in the attached doc may show that summer heat gain from high solar heat gain specified windows may be far less than previously.

neea

WINDOWS

Prior to the 1970s, most houses were built with wood, and later, aluminum, single-pane windows. Building codes and new technologies brought in double-pane, insulated windows, and vinyl and fiberglass frames, significantly dropping window U-values. While many windows in homes built before the 1970s have subsequently been improved, average total U-values have nonetheless dropped significantly since building codes were introduced. The average U-value for homes built prior to the 1940s is 0.71, while windows in houses built since 2010 are averaging about 0.47.

Nearly all windows since the mid-90s are low-e insulated double-panes, with wood/vinyl/fiberglass frames. Some triple-pane windows are also making their way into the market.



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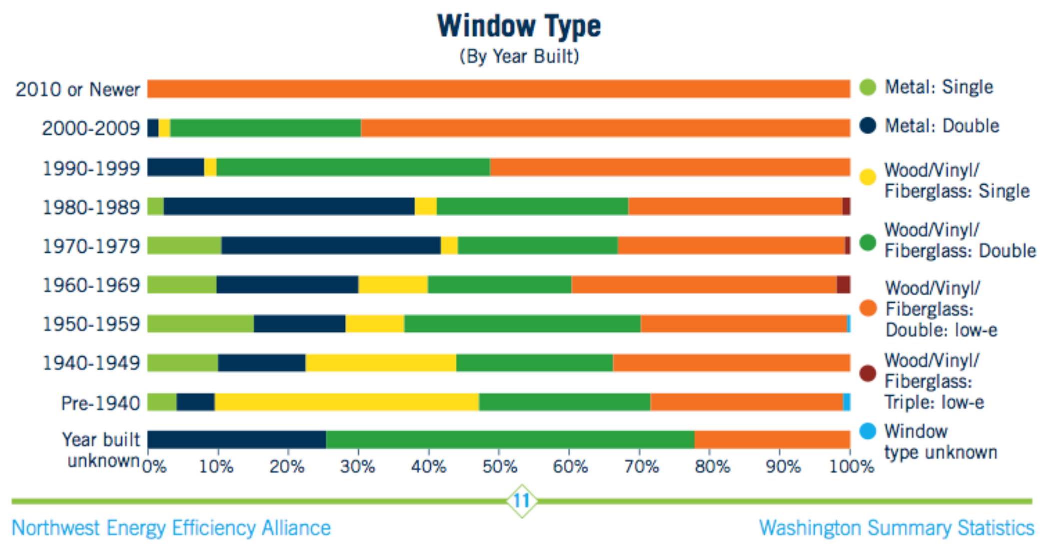
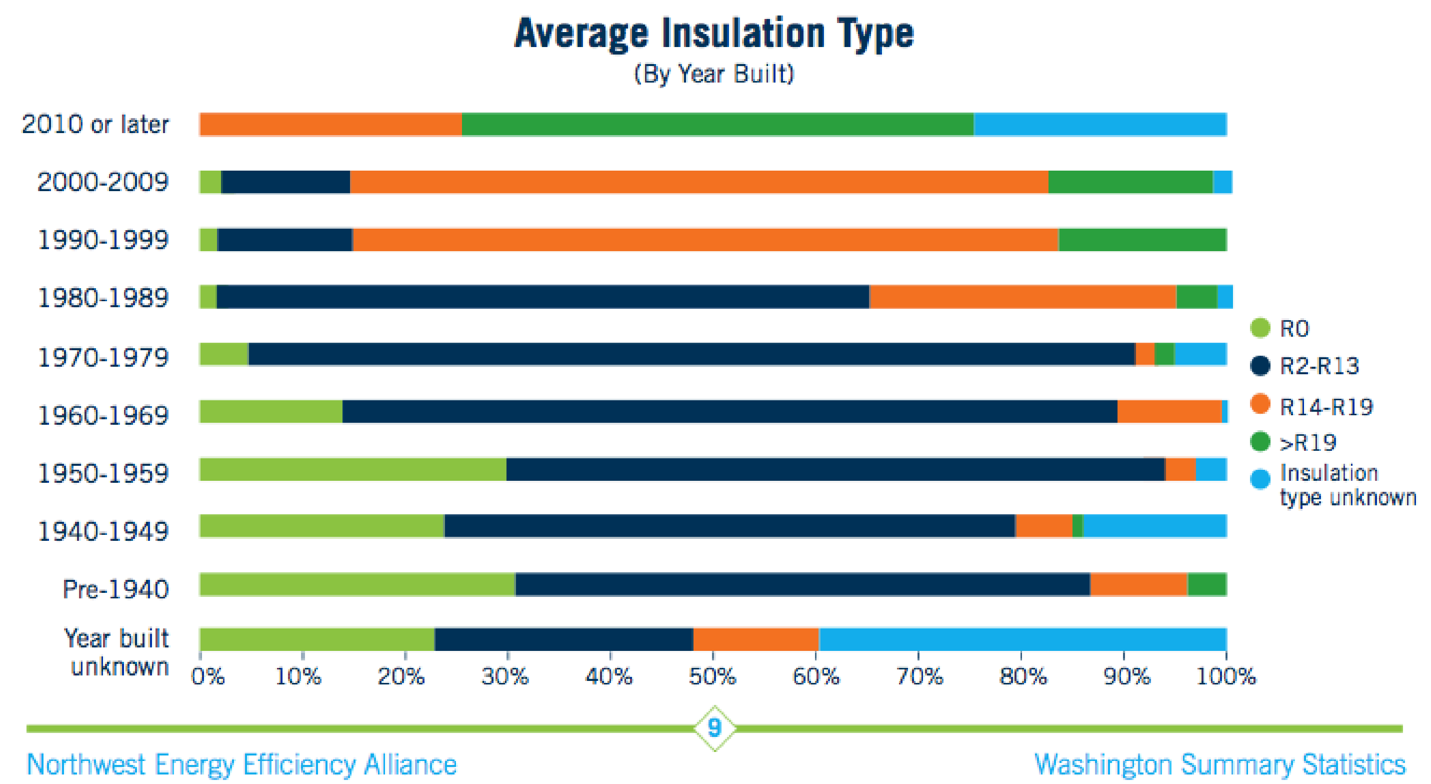


Just the light green alone (see below) of no wall insulation is 13% of all Washington homes! The overall demographics is quite ugly energy wise. Take the mid point of R2-R13 as R7.5 which gives a U of 0.133 and likely leaky in air terms and the case for an even higher minimum SHGC is warranted.



The engineering details of the effect of window shades should have been out a decade ago but vested interests in the National Fenestration Rating Council (NFRC) have prevented this work from being done. In fact, the NFRC has a founding member with a PhD in Physics and a board member who "resigned in disgust" in 2013 who is likely available for questions by the SBCC. And when the Dept of Energy put out the RFP to create the Attachment Energy Ratings Council (AERC), the NFRC proposal lost while having thwarted work in the area for years. And parts of DOE had research agendas that were not optimized for quick and practical solutions.

Hopefully when the newly created Attachment Energy Ratings Council starts to produce **relevant** reports building code authorities can adopt improvements. However this author is not hopeful on this front, at least from US sources.

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Unfortunately some of the first reports out of the Dept of Energy show a shocking lack of operational research knowledge not to mention practical knowledge. The latter can be forgiven, the first is unacceptable. http://energy.gov/sites/prod/files/2013/11/f5/energy_savings_from_windows_attachments.pdf There is not a single scenario that the matrix of the more than 16,000 energy analysis runs that covers the end points of potential energy savings and current waste let alone practical and inexpensive solutions. It is almost if the report's purpose is to keep the status quo of "windows" being the energy savings focus and not inexpensive and properly engineered shades. Or, maybe folks are trying to tee up more funding on dynamic electrochromic windows, $100 million to date that this author is aware of. Hopefully this will not be allowed to derail accurate analysis and competent further improvements to energy building codes related to windows/attachments as the potential of inexpensive and well designed shades are realized. One can see "dynamic glazing " in the draft WA residential code in **R402.3.2** and being striked out for reasons that are unclear to this writer. Might be best to keep it in as the wise energy architect will ask/answer the right questions which would provide progress to all.

As the practical engineering & verified shade usage behavior data comes in one will likely see the required minimum SHGC go even higher than what this author currently recommends of SHGC ≥0.56. And lastly, this author has no financial interest in any window or shading companies of any kind. Last minute update: the Canadian Government code review work says SHGC minimum should be even higher than 0.56.

Here are the simulated potential saving from those expensive dynamic Electrochromic Windows, (which this author would readily buy for lighting control) but they are not the cost effective and practical solution for most residential and many small & medium office situations. Although the below energy savings are "modest" using the report's own word. The statement in the conclusion on page 49 is relevant "As we seen from the discussion in Section 3, the use of high-SHGC EC windows in northern climates appears to have its greatest potential to save overall energy use in small office buildings" Reference to below table= http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-19637.pdf An Exploratory Energy Analysis of Electrochromic Windows in Small and Medium Office Buildings – Simulated Results Using EnergyPlus

Table S.1. Ranges of Percentage Energy Savings for EC Windows

	Lighting, %	Cooling, %	Heating, %	Total Source, %
Small Office				
North	18 to 20 (20 to 22)*	8 to 10 (0 to -3)	0 to -2 (5 to 15)	3 to 4 (4 to 5)
South	15 to 20 (23 to 25)	5 to 10 (0 to 5)	-3 to -7 (5 to 15)	4 to 6 (5 to 7)
Medium Office				
North	9 to 10 (8 to 9)	15 to 17 (0 to 1)	NA**	4 to 5 (2 to 3)
South	10 to 12 (11 to 14)	8 to 10 (2 to 3)	NA	4 to 5 (3 to 4)

Notes:
* Values in parentheses correspond to EC glazings in which the SHGC in its clear state exceeds the requirement in ASHRAE Standard 90.1. The SHGC in the baseline static glazing meets the 90.1 requirements in all cases.
** Heating savings not calculated for medium office because electric and gas heating was used (electricity not broken out by heating versus reheating).

As to savings for a window to floor area ratio of 0.3 see pg 46 of attached doc called SHGC-version1Energy Balance for Windows For WA – A cool climate.doc Per below graph for the equivalent climate as Washington (London) the savings would be 3kWhr/per square meter of window per year. Chuck Murray of WA Dept of Commence informed me that he

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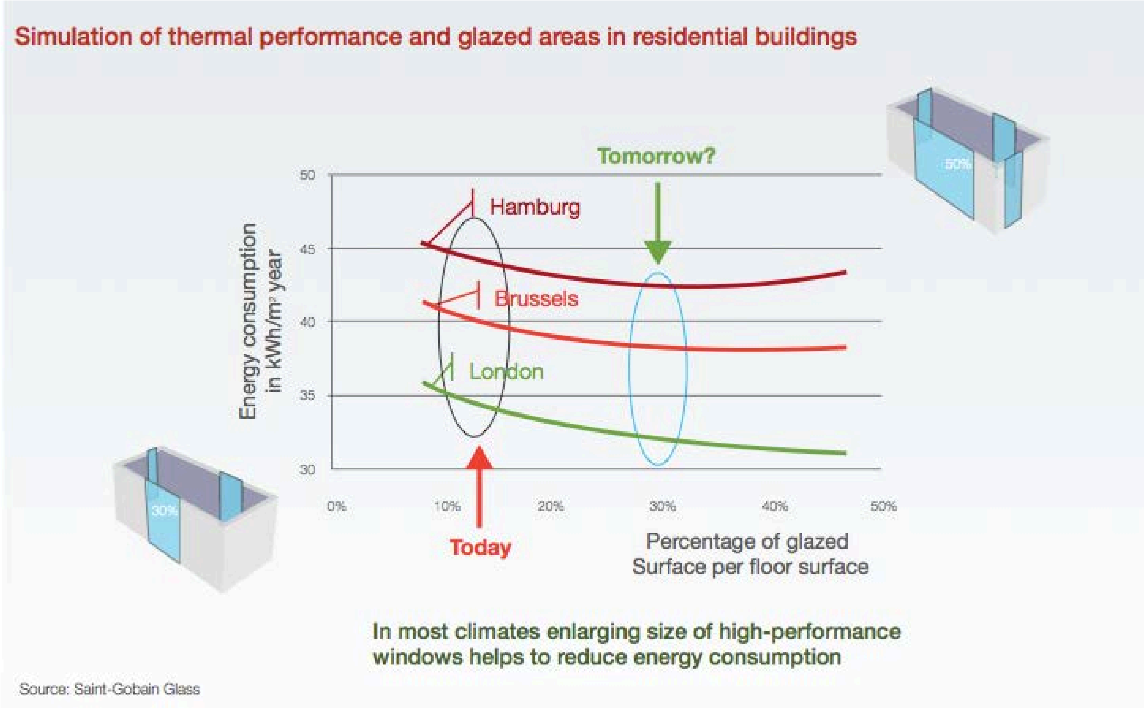
seems to remember that the 0.15 ratio was set from work done in 1990. If so there is little doubt that it is not valid today.



List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

No additional review time or inspection over current.

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

Date: Feb 25th 2015

From: Todd Andersen, resident and home owner, Bellevue WA
To: Washington State Building Code Council
Subject: Validated Engineering Studies and Analysis showing that for Washington State's climate that the State's prescriptive building code for windows should have a minimum required value for Solar Heat Gain Coefficient of 0.56 and separately, a window to floor area of 0.3 not 0.15

This paper uses the UK, European and Canadian window requirements and those governments latest scientific research to show that the current prescriptive Washington State building codes for windows are wasting energy for residential and at least the same for small to mid scale commercial. Given the complexity of the commercial code this author will focus on residential window code. Currently the residential code for windows has no current requirement for Solar Heat Gain Coefficient and sets a maximum of 0.15 for the window to floor area. The evidence will show that a minimum SHGC of 0.56 should required for Washington for both sides of the Cascades, given the up coming required u-value of 0.3.

And even a far from complete literature review supports the maximum window to floor area requirement of 0.15 should be reviewed as current research in Europe and Canada shows that for our climate and improving directional level of energy code requirements overall, it should be 0.3. The author has been told by a State energy official that the 0.15 requirement is based on work done in 1990.

Skip next eight pages to continue the above follow of thought.

A last minute update which could drive the recommended SHGC even higher than the recommended minimum SHGC of 0.56. Or why we should trust the Canadian more than the USA "experts"

Why Vancouver results are highly valid for WA. Vancouver HDD/CDD are 2775/61 Kdeg/day(1990-2014, base18C/64.4F) vs Seattle 2777/87 Kdeg/yr[1] (1948-2012, base 65F/18.3C)

This writer found it odd that many of the window energy saving reports that had good operational research characteristics did not use RESFEN. RESFEN is the USA standard for "fenestration energy performance modeling" per Dept of Energy/NFRC and from the front page of the RESFEN manual "for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings". However, going to the US Dept of Energy's master list of energy models[2] and looking at RESFEN one finds this for Validation/Testing = N/A WOW! Surely that is wrong and there must be much validation with measured results. Odd but I have not found any to date.

Then looking at Windows7, the Lawrence Berkeley National Lab modeling program for fenestration, thermal performance, solar optical characteristics, windows and glazing, one

[1] http://vancouver.weatherstats.ca/charts/cdd-25years.html change cdd to hdd
[2] http://apps1.eere.energy.gov/buildings/tools_directory/alpha_list.cfm

finds for Validation/Testing = N/A WOW again. Surely that too is wrong and there must be much validation with measured results. This writer has not looked at Window7 validation but very odd that Dept of Energy does not point to any. Interestingly LBNL will readily compare results from Window5, 6 and 7 but points to no measured validation studies.[3]

What do the researchers that this writer finds coherent use? More often than not, ESP-r. And here is what the Dept of Energy say about its validation, Validation/Testing = "ESP-r has been extensively validated. See ...."[4] The ESP-r system has been the subject of sustained developments since 1974 and in 2002 converted to the GNU Public License.

Then knowing about the internal fighting at the National Fenestration Rating Council (NFRC) for over a decade, a key question arises. To fully understand that question it might be helpful to understand that this fighting between the window makers and the shade makers went on for over a decade with no productive energy measurement & rating work done on shades, a.k.a attachments. Parts of the Dept of Energy were out in left field; not only on research agendas of their own but apparently absent from bringing order to NFRC, an industry dominated organization. One part of DOE finally settled the fight by setting up the Attachment Energy Rating Council in ~2014. Thus the key question is **Whose model(s) and research are you going to trust?**

The Canadian's have given us a partial answer, or at least the significant limitations of the computer simulation models and who they do not to trust. In the 2013 Canadian government report called "Review of Window Energy Rating Procedure in Canada" This work had 9 funding partners and a massive steering committee. In that report they noted previous Canadian government's (Natural Resources Canada) report that scored ESP-r, which is heavily used in Europe and Asia,[5] the most accurate.[6] ESP-r was better over the US model RESFEN (LBLN/NFRC) and even over the Natural Resources Canada's own model HOT2000. Not surprising, as open source systems so often out preform the "high priests". The below last minute discussion will show that the future will have significant improvement in how windows are optimized for energy efficiency. I am not alone in this view as John Carmody has a similar assessment as stated in the 2012 US Dept of Energy report called *Measure Guideline: Energy-Efficient Window Performance and Selection*. "*However, optimizing window technology and related design decisions is not well understood* "ref=50.

Here is how bad the energy modeling for windows appears to date. The good news however is the Canadian are well on their way excellent result. Right now they are significantly ahead of current "state of the art" in the United States. The Canadian do not trust their HOT2000 model nor the American RESFEN model. As a stop gap measure, they are using DesignBuilder/EnergyPlus until they can finish development on HOT3000 by taking the hourly simulation program ESP-r as the engine for their new HOT3000 program. They are using DesignBuilder as the user interface with EnergyPlus as the engine. EnergyPlus is the Dept of Energy's simulation model geared for very large buildings and thus very wieldy to

[3] http://windows.lbl.gov/software/window/7/w7_docs.htm
[4] http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=39/pagename=alpha_list_sub
[5] http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=39/pagename=alpha_list
[6] 241 pages Jan 2013 www.hpo.bc.ca/files/download/Report/Window-ER-Full-Report.pdf

use/validate for residential but it is heavily validated with measured data from large buildings. EnergyPlus is a newer program that was developed to improve upon the DOE-2 engine.

To get a well-validated and a less wieldy model for residential buildings the Canadian researchers are in the works to build HOT3000 that accurately simulates dynamic effects, including hourly wind, solar radiation and dynamic thermal storage. *"This is supported by research findings from the literature review"*[7] And as we shall see this is a step in the right direct but still not accurate enough as Sandia National Labs/Univ of Wisconsin/ variablegen.org have each shown. The math needs to be done at the minute by minute not even 3 minute by 3 minute.[8] Hour by hour will be off significantly. Making high solar heat gain windows look worse in the winter and the poor accounting for angle of incident reductions making high solar heat gain windows look worse in the summer.

Here is what this means for Seattle see the figure[9] below for the winter problem of not fully accounting for all the solar radiation. The summer modeling error issue related to the angle of incidence reduction factor for solar heat gain will be discussed below this figure 11, in the figure 3.9 below.

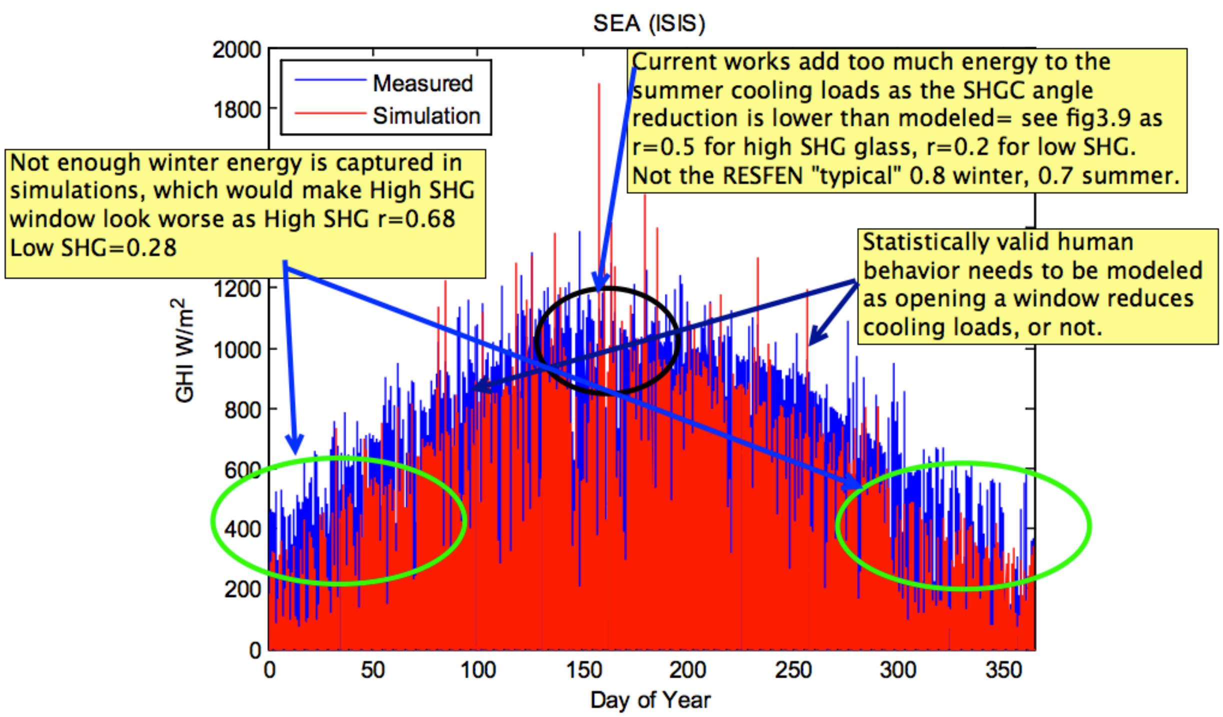


Figure 11. Time Series of Simulated and GHI Irradiance: Seattle, WA

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[7] pg68/241, (Jan 2013)

[8]page17,49,53/133 http://energy.sandia.gov/wp/wp-content/gallery/uploads/2012_Hansen_WWSIS_irradiance_sim_validation_final.pdf. Also see http://wiki.variablegen.org/index.php/Validation_of_Simulated_Irradiance_and_Power and pg6/6 http://sel.me.wisc.edu/publications/conference/asespaper044a1.pdf

[9] pg 27/133, see above Sandia ref

But the Canadians do have their act together validating their whole house energy modeling for low-e and SHGC and validated against measured data for real houses.[10]

The Solar Angle of Incidence Modeling Error

The user manual from the LBNL website for the latest Windows7.3 modeling software is a July 2013 Windows6.3 manuel and since it is only 406 pages so we will use the most recent one from NFRC, a Jan 2014 Window6.3 User manual. (Hmm seems like LBNL work in this area has had its funding cut...) That Jan 2014 manual mentions just one sentence tangentially related to the SHGC angle of incidence "NFRC rated SHGC's are at 0° incidence."[11,] And for the latest RESFEN we have the version "6 Beta – New Based on the 2008 Energy Star modeling assumptions.'[12] Here the manual states what that EnergyStar analysis did "The Energy Star 2008 analysis used the "Typical" option. "This results in a final winter SHGC multiplier of 0.8 and a final summer SHGC multiplier of 0.7." [13] And to see how very wrong this is in any energy use modeling for at least the northern climates lets look at what the Canadians think about that assumption.

Interesting that RESFEN doesn't get the angle of incident calculations right but "NFRC has approved using WINDOW and THERM to model exterior woven shades for vertical and tilted products for U-factor, SHGC and VT." While NFRC can say that, work in Canada and Europe will show it less than useful.

The modeling assumption in the Lawrence Berkeley National Laboratory/NFRC program RESFEN for "typical" becomes less and less valid the further north in terms of latitude one goes. The user has to be knowledgeable enough to plug in their own numbers assuming the model allows and on a minute by minute basis. How many researchers have done so for northern studies? This assumption error for "typical" decreases the farther south you go but is still significant for double pane using a hard coat for the high solar heat gain configuration and a soft coat for the double and triple low solar heat gain configurations, see figure3.9 below. It appears that Canadians missed it their ER formula and thus their review of ER is calling it out. If so the minimum required SHGC for Washington should be even higher as less heat would be collected in the summer

Here are the gory details.[14]

"F_θ is the off-normal angle incidence factor, which reduces the solar heat gain to the space since more solar radiation is reflected off of a window as the angle of incidence increases. CSA A440.3 defines this factor as the value of the SHGC for any off-normal angle of incidence ($SHGC_a$) divided by the SHGC for the normal incidence angle ($SHGC_n$),"

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[10] Summer and winter field monitoring of high and low solar heat gain glazing at a Canadian twin house facility 2008 http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=20378098&article=0&fd=main and Selection of optimum low-e coated glass type for residential 2007 http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=20377223&article=0&fd=main

[11] pg31/420 and pg320/420 http://c.ymcdn.com/sites/nfrccommunity.site-ym.com/resource/resmgr/2014_technical_docs/nfrcsim6.3-january_2014.pdf

[12] http://windows.lbl.gov/software/resfen/resfen.html user manual Dec 2012 93 pageshttp://windows.lbl.gov/software/resfen/6/RESFEN60UserManual.pdf

[13] Pg86/93 of RESFEN USER manual.

[14] Page 29/241 www.hpo.bc.ca/files/download/Report/Window-ER-Full-Report.pdf

$$F_{\theta} = \frac{SHGC_a}{SHGC_n}$$

"The original ER study reports that, since most windows use similar glass, F_{θ} is more a function of latitude and orientation than window type. [wrong also very much a function of material] Fig.3.9 shows a plot of solar heat gain versus solar angle of incidence using optical properties from WINDOW6 for a variety of glazing configurations. The glazing unit configurations used a hard coat for the high solar heat gain configuration and a soft coat for the double and triple low solar heat gain configurations. The incident angle has a significant impact on solar heat gain, and therefore this factor may be important to consider in an ER formula." The Canadian report seems to be saying, woops that was wrong the Energy Rated ER windows correct values for the low and high SGH glass but the value for single pane clear.

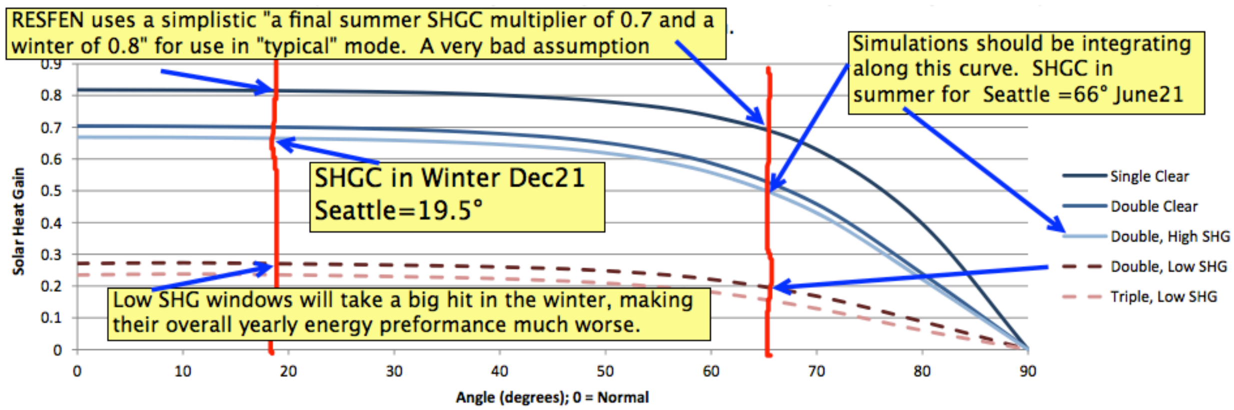


Fig.3.9 Solar heat gain versus angle of incidence for various glazing configurations.

Canadian report authors call the issue out with the comment of "The incident angle has a significant impact on solar heat gain, and therefore this factor may be important to consider in an ER formula " The question then, is how many of the studies using RESFEN use the "typical" setting? For Washington State that would be very wrong. And as the Canadian report shows they do not trust RESFEN enough to try to fix it, and are building a whole new simulation software for residential buildings called HOT3000 as mentioned above

Per the 2013 Canadian report it appears this solar angle of incidence error all fell out from copying ASHRAE winter shading factor. [15]:

"Though not a location dependent variable, it is important to address the solar gain reduction factor, R, as part of this discussion. This factor, set at 0.8, was introduced into the equation to reduce the weight of solar heat gain in the ER equation. A factor of 0.8 was chosen since it is the ASHRAE winter shading factor and is used in the program RESFEN.

RESFEN has different options for solar gain reduction, including none, overhangs, obstructions, blinds, shading, etc. The program also gives an option for "typical" solar gain reduction, which is 0.8 in the winter and 0.7 in the summer. The user manual [for RESFEN] includes the following explanation for the "typical" reduction factor of 0.8:

> "To represent a statistically average solar gain reduction for a generic house, this option includes: interior shades (seasonal SHGC multiplier, summer value = 0.8, winter value = 0.9), 1' overhang, a 67% transmitting same-height obstruction 20' away intended to represent adjacent buildings. To account for other sources of solar heat gain reduction (insect screens,

[15] pg 30/241 www.hpo.bc.ca/files/download/Report/Window-ER-Full-Report.pdf

trees, dirt, building and window self-shading), the SHGC multiplier was further reduced by 0.1. This results in a final winter SHGC multiplier of 0.8 and a final summer SHGC multiplier of 0.7."

In summary, a lot of validation exportation needs to be done.

Until then the best work the Canadian government sees is these results from the DesignBuilder/EnergyPlus modeling, which they and nine other funding partners including Canadian Glass Association and Fenestration Canada and a massive steering committee. That is at least as the best available until they get HOT3000 built and validated. So what are some of the relevant results?

First is this three dimensional plot of u-values and SHGC is show the parametric analysis so rarely really seen, at least in window energy analysis. They also include the info in table form. This Canadian analysis says for a U value of 0.3 (1.7metric) says the higher the solar heat gain coefficient (SHGC), the higher the Energy Rating.[16] Windows with a higher ER use less heating energy. The calculation for the ER is presented in CSA A440.2-09/A440.3-09 Fenestration Energy Performance (Canadian Standards Association, 2009).

Ref pg25/241 "Fig.3.6 shows a table of ER values for a variety of U-value and SHGC combinations. This table allows for quick comparison of U-value, SHGC and ER values. Fig.3.7 and Fig.3.8 shows windows that qualify for ENERGY STAR® on the U-value path and the ER path, respectively. This figure highlights the two paths, and demonstrates the significant impact of the SHGC on the ER path."

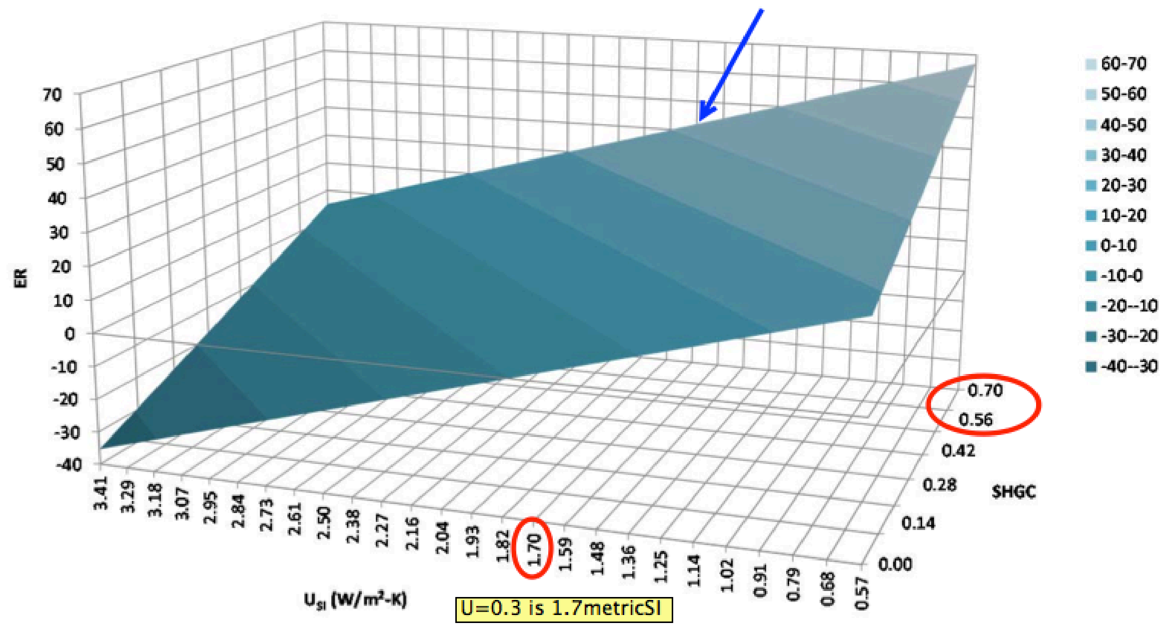


Fig.3.5 ER versus Solar Heat Gain Coefficient and U-value. windows with a higher ER use less heating energy

And to explain the Canadian ER system we have

ref 3/242 "The Energy Rating (ER) is a Canadian energy efficiency metric defined in the CSA A440.2-09 Fenestration Energy Performance standard. The purpose of the ER is to help consumers compare the relative energy efficiency of windows and glazed sliding doors. The ER is a single number rating that evaluates the energy performance under winter heating conditions and takes into account the balance

[16] pg5of 241www.hpo.bc.ca/files/download/Report/Window-ER-Full-Report.pdf

between heat loss through thermal transmittance and air leakage, and solar heat gain through the window or door. The ER was designed mainly for ranking products in a heating dominated climate and for windows and doors installed in low-rise residential buildings."

Ref3/241 "The window energy analysis shows that in general, windows with a higher ER use less heating energy. However, a number of windows were simulated where a slightly higher ER results in higher heating energy consumption under certain conditions. Though the ER does not rank cooling energy appropriately (as expected), cooling energy consumption in houses is very low compared to heating energy in all Canadian locations under worst-case cooling conditions. In general, cooling energy is roughly 10% of overall space conditioning energy, [for Seattle/PugetSound it is 5%] in houses that have mechanical cooling. Therefore, when looking at space conditioning energy consumption alone, heating energy considerations far outweigh cooling. The same trends where a higher ER window generally uses less heating energy were seen for the majority of the geographic locations simulated."

But this Canadian report took it a step further and including in the cooling costs which are expected to be too high as noted in the discussion above. Nevertheless, this simulation work shows that for the Washington State building code we would save more energy calling out a slightly higher u-value (0.35) and a require minimum SHGC of 0.65 and likely have a less expensive window.

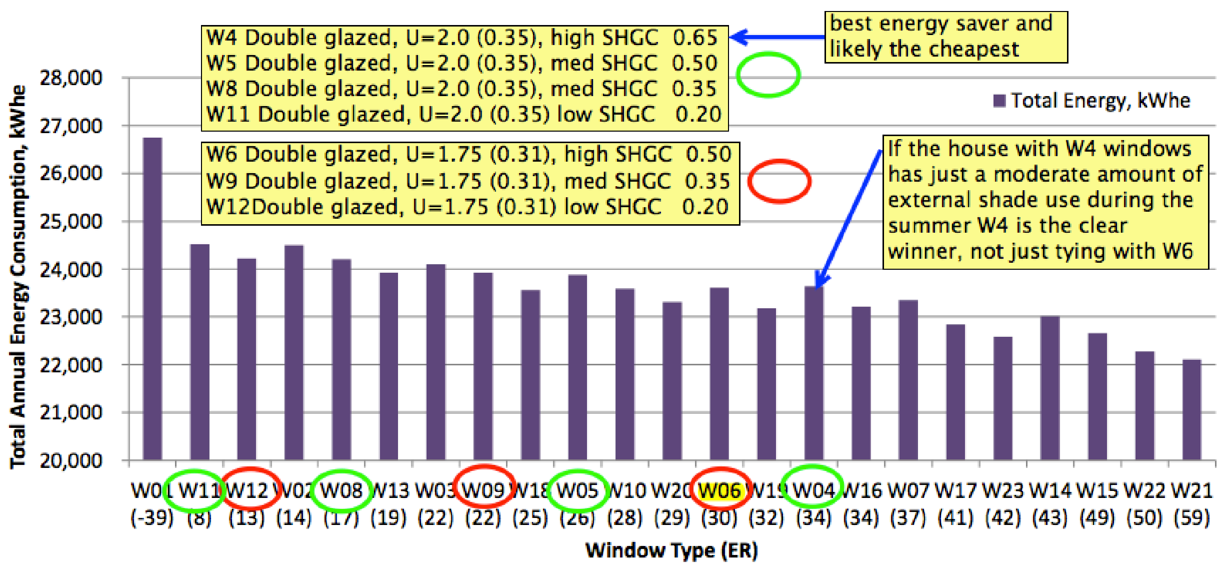


Fig.7.17 Total annual household energy consumption in Vancouver, kWh_e.

Turning to amount of window area, the Canadians appear perfer window to wall ratio (WWR) not window-to-condition floor space ratio. Regardless the below graph is useful as the better the windows get in performance, both solar heat gain and u-value, the more window area a structure should have. The below fig 7.44 is only for annual heating energy consumption.

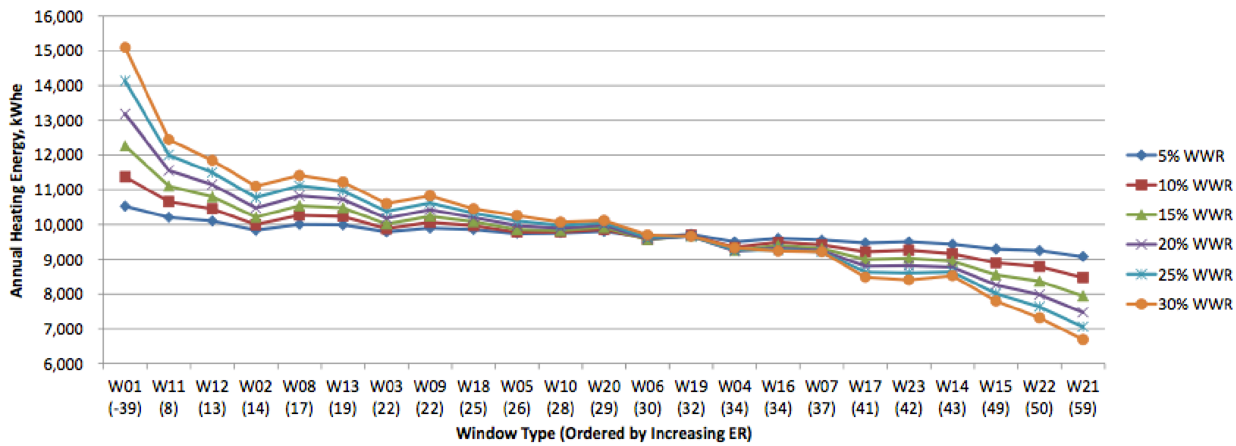


Fig.7.44 Annual heating energy consumption for window to wall ratios in Vancouver, kWh_e.

Below is the total heating and cooling annual consumption. But as stated above there are still significant modeling issues with cooling energy use that need to be dealt with that are also expected to more accurately simulate winter heating further increasing the winter solar gain thus pushing the window to wall ratio higher.

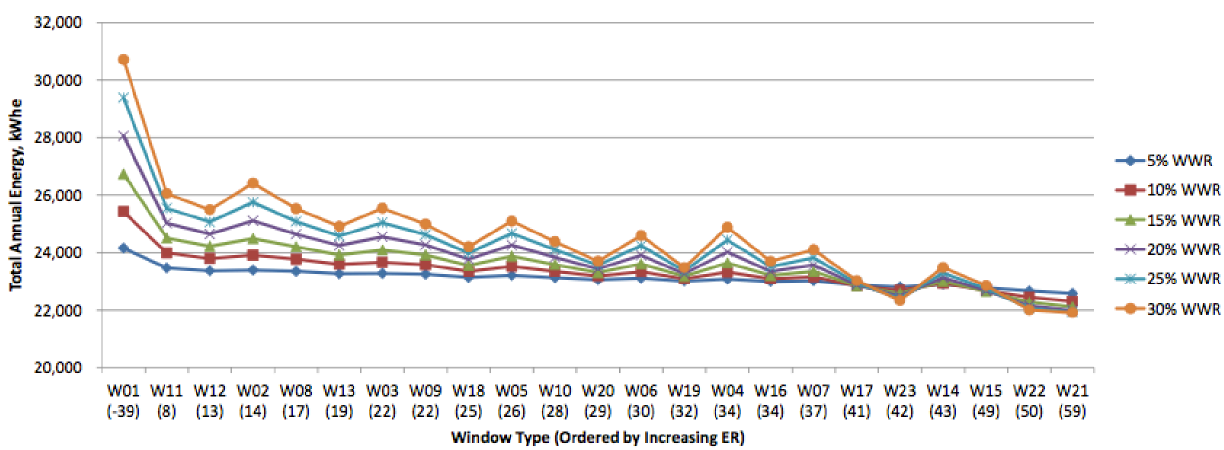


Fig.7.46 Total annual energy consumption for window to wall ratios in Vancouver, kWh_e.

The below figure says that residential building codes for Washington should try push bigger southern windows in the code for further energy savings.

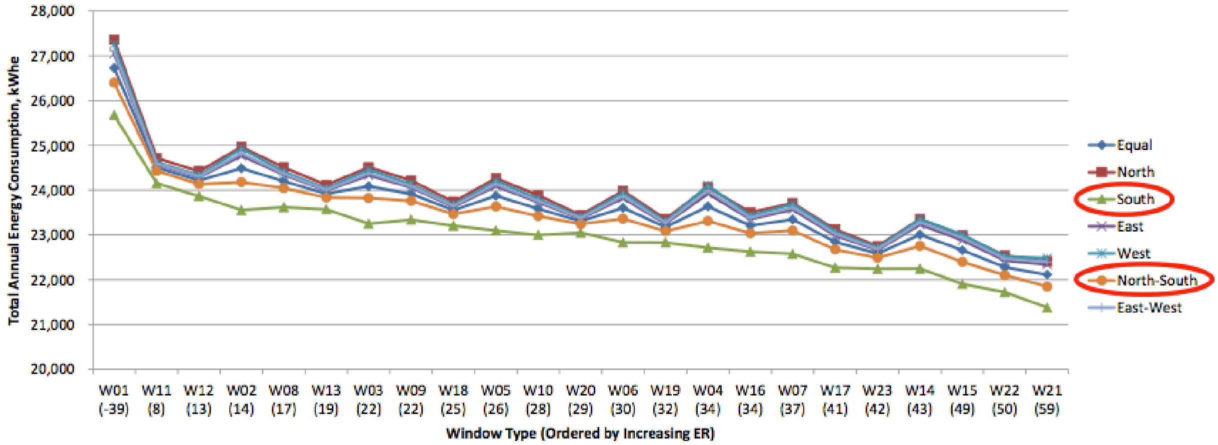


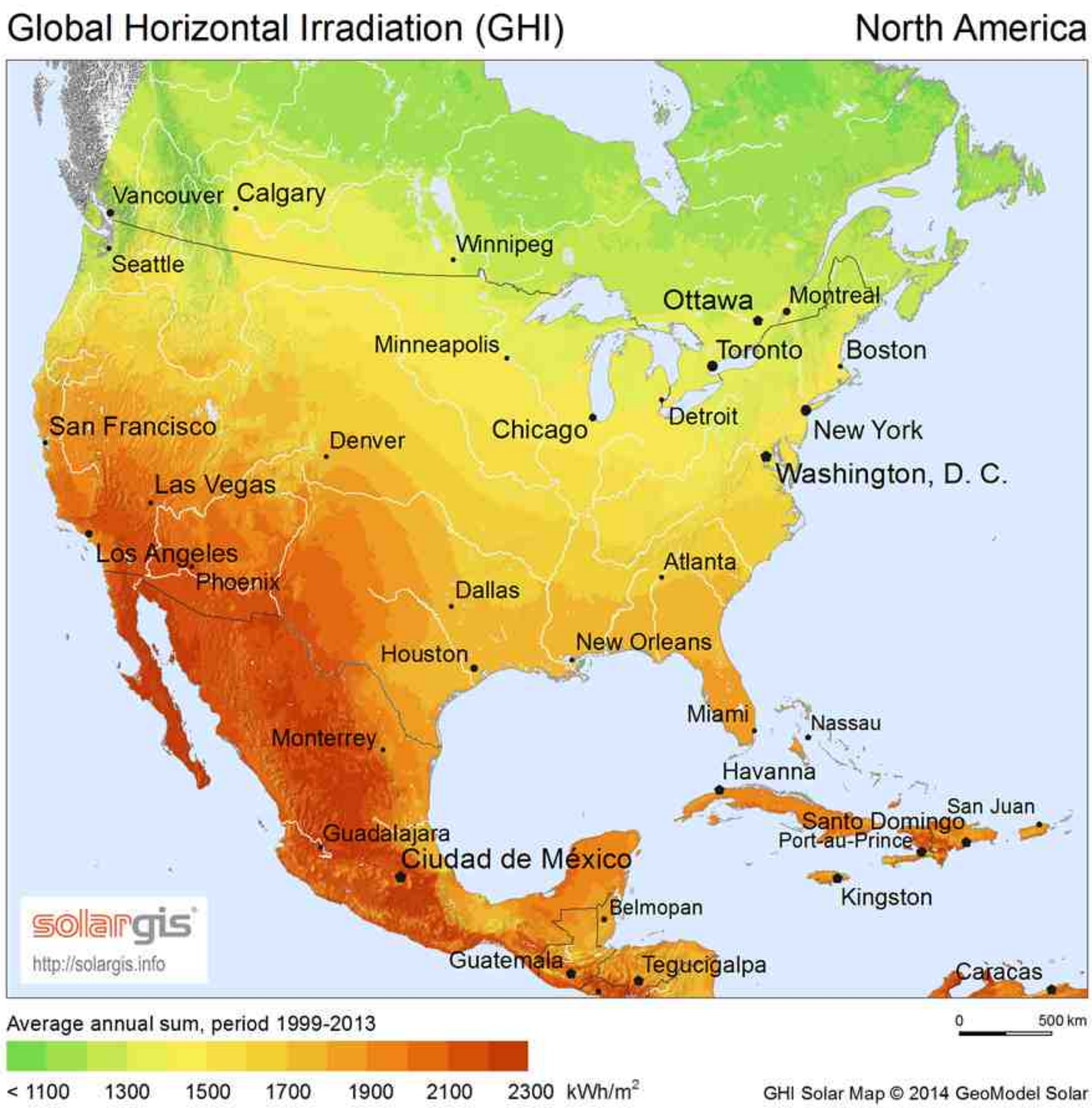
Fig.7.61 Total annual energy consumption for window orientations in Vancouver, kWh_e.

END last minute update

So why do windows differently in Washington? We will provide evidence from the United Kingdom code requirements which is the most relevant given the nearly identical environment to Washington; evidence from Dept. of Energy reports including one from the leading window experts in the US, but also from the leading European glass industry trade group, Canadian researchers as well as basic science[17].

Speaking of basic science, the below picture on global horizontal irradiation says it all, particularly when compared to a map of heating degree days. [18] Why? The key point to notice is that Washington looks significantly different than the rest of the country given the cloudy nature of the Washington State. Given the massive amount of Washington's heating degree days vs the very small amount of cooling degree days (that is when the air

[17] What is rarely used in our society today is science. If you think that is a crazy consider one the most downloaded scientific papers since 2005 "Why Most Published [medical] Research Findings Are False" by NIH researcher John Ioannidis MD, www.ncbi.nlm.nih.gov/pmc/articles/PMC1182327/ After he published that paper the medical centers of Stanford, Harvard and Columbia went all out to recruit him, with Stanford winning. The paper has never been disputed yet nothing has changed.
[18] http://solargis.info/doc/free-solar-radiation-maps-GHI http://en.wikipedia.org/wiki/Insolation



conditioners are on) those that are energy wise will want to collect all the solar energy as possible given Washington is such a cool & cloudy climate. In order to see this we need to see the energy needs from winter to summer. There are standard ways to measure this with the annual heating and cooling degree days. This method, while standard practice, is very crude IF this is the sole criterion and assumes the primary purpose of windows is to NOT loose energy and ignoring the windows ability to collect free solar energy.

However if you consider that windows can also collect needed energy then a building code could be optimized for windows collecting energy relative to the lost performance during summertime requiring air conditioner use. The ideal building code would use an energy balance over the year for the local climate and for the energy "tightness" of a building. Thus we need overall energy demands in heating and cooling over the entire year. The proxy for energy demands is heating and cooling degree days and this is the accepted proxy in both the United States and Europe and will remain so until minute by minute calculation show their value. The Heating degree day (HDD) is a measurement designed to reflect the demand for energy needed to heat a building in a specific location, defined relative to a base temperature. HDD for example is relative to a base temperature, commonly set at 65°F. And lucky for us Europe uses a very similar base of 18C or 64.4F so comparison will be easy.

A 'Heating Degree Day' (HDD) is a proxy for the energy demand needed to heat a home or a business; it is derived from measurements of outside air temperature.[19] Space heating is responsible for a large component of Washington State's and Northern European energy use, so a decrease in the use of heating has the potential to lead to a significant decrease in overall energy use. There are many contributory factors to heating demand, such as the energy performance of the building envelope, the type of heating system available, occupant behavior and energy prices. However, the external temperature is the only component that directly drives the need for heating or cooling. The number of HDD is therefore a proxy for the energy demand for space heating, and hence an indicator for possible changes in overall energy use.

Below are the maps of HHD and CDD for the USA[20] These are the best visual maps from a trusted source and are for 1961 to 1990 data. As degree day data has a high delta year to year we will checking table data for 1948 to 2012 which compares quite well to the maps. The tables give a mean value for SEATAC of 4964 heating degree days and 157 cooling degree days and Spokane airport at 6610/ 427.[21] Thus Seattle has more than 31 times the heating as cooling over an average year and Spokane has 15.5 times more heating. Compare this to Kansas City at 5300/1250=4.24 or Chicago 6500/750=8.6 or Denver =6250/500=12.5.; all getting significantly more solar radiation with Denver getting almost double the solar radiation that Seattle receives.

However, both window rating groups of EnergyStar.gov and International Energy Conservation Code Council put Washington in the same basket as far different locals. This is not wise and there is a massive energy savings possible for Puget Sound and a respectable amount for east of the Cascades. Add in that the current electric grid and natural gas deliver system in the Puget Sound is winter peaking/constrained there are additional savings on top of the energy saving by also needless grid expansion. Both benefits will also further accelerate the adoption of more efficient, sustainable and soon to be cheaper generation of energy systems like of grid storage and multiple distributed generation solutions like wind solar and CHP (co heat and power).

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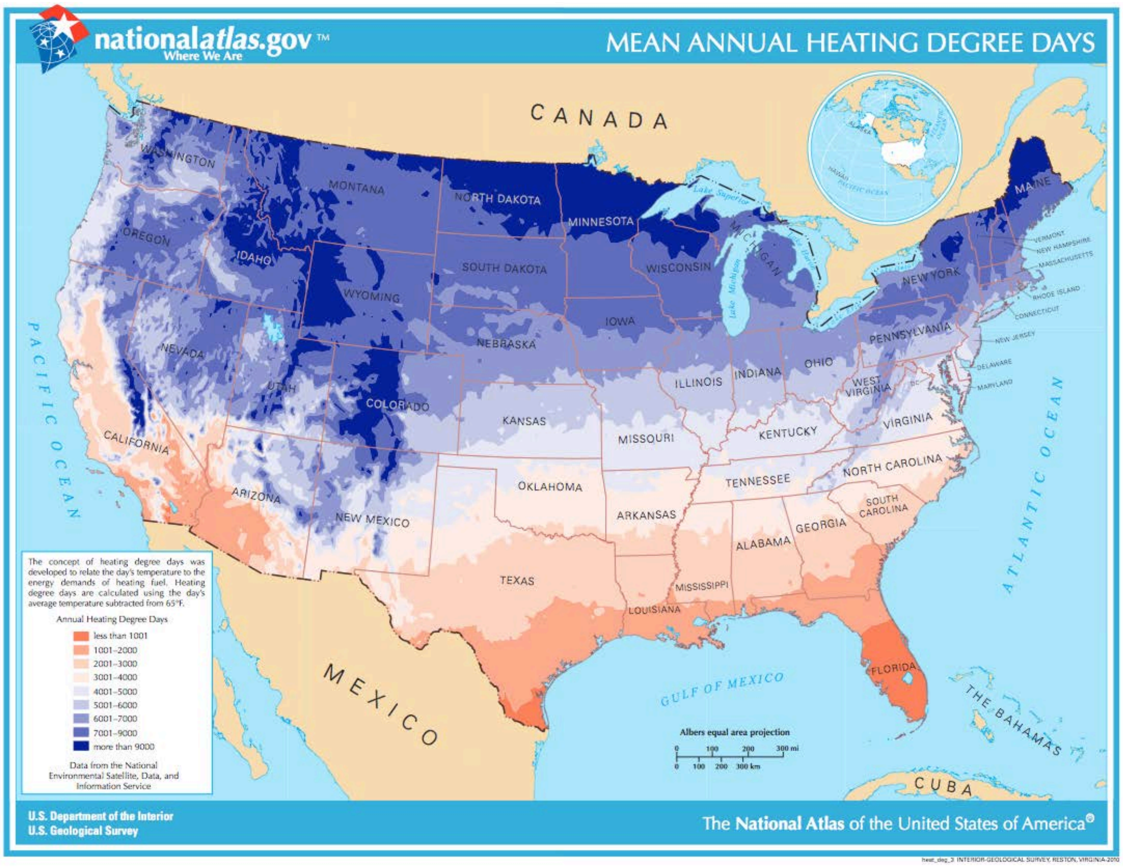
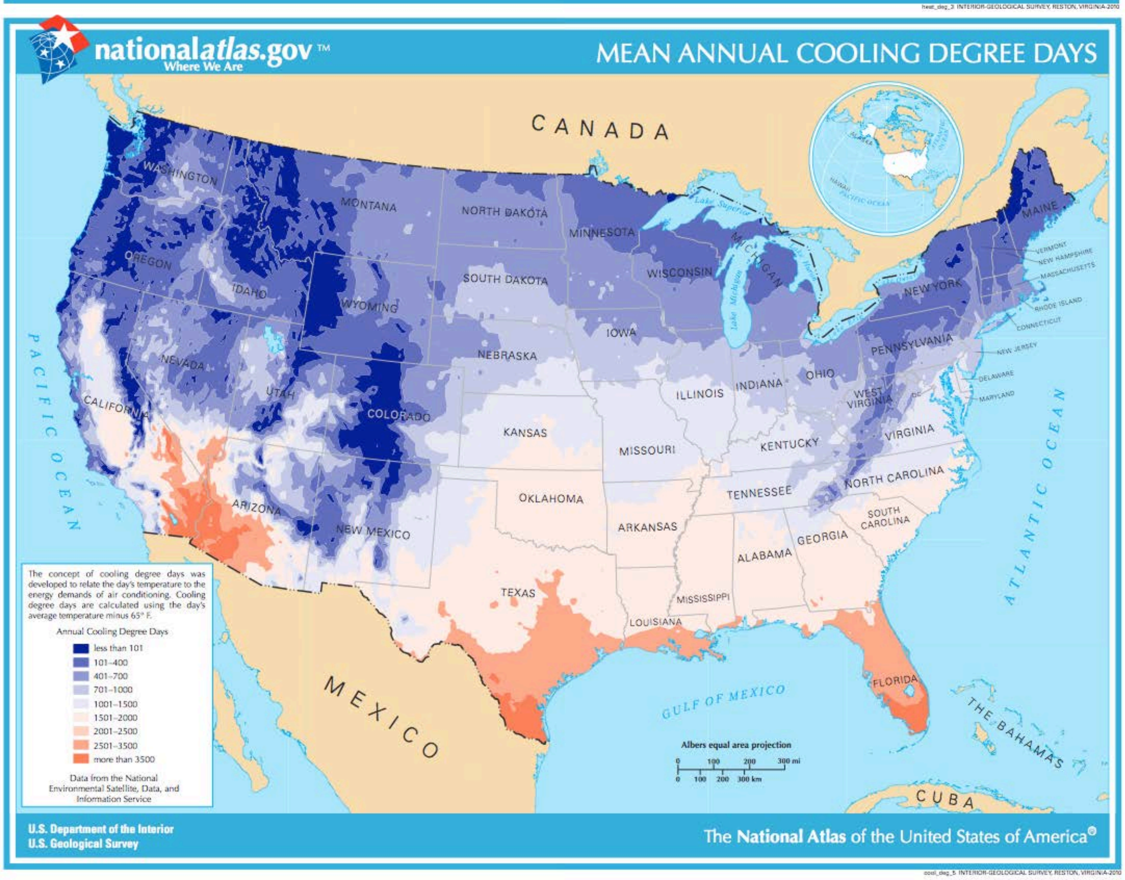
[19] http://www.eea.europa.eu/data-and-maps/indicators/heating-degree-days-1
[20] http://nationalmap.gov/small_scale/printable/climatemap.html from 1961 to 1990
http://nationalmap.gov/small_scale/printable/images/pdf/climate/heat_deg_3.pdf and /cool_deg_6.pdf
[21] www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa7473 need to scroll down to HDD and select


nationalatlas.gov™
Where We Are
MEAN ANNUAL HEATING DEGREE DAYS
CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
CUBA
THE BAHAMAS
WASHINGTON
OREGON
IDAHO
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WISCONSIN
WYOMING
NEVADA
UTAH
COLORADO
NEBRASKA
IOWA
CALIFORNIA
KANSAS
MISSOURI
ILLINOIS
INDIANA
OHIO
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
TENNESSEE
KENTUCKY
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
FLORIDA
PENNSYLVANIA
NEW YORK
MAINE
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
NEW JERSEY
DELAWARE
MARYLAND
Lake Superior
Lake Michigan
MICHIGAN
The concept of heating degree days was developed to relate the day's temperature to the energy demands of heating fuel. Heating degree days are calculated using the day's average temperature subtracted from 65°F.
Annual Heating Degree Days
less than 1001
1001–2000
2001–3000
3001–4000
4001–5000
5001–6000
6001–7000
7001–9000
more than 9000
Data from the National Environmental Satellite, Data, and Information Service
Albers equal area projection
0 100 200 300 mi
0 100 200 300 km
U.S. Department of the Interior
U.S. Geological Survey
The National Atlas of the United States of America®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Where We Are
MEAN ANNUAL COOLING DEGREE DAYS
CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
CUBA
THE BAHAMAS
WASHINGTON
OREGON
IDAHO
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WISCONSIN
WYOMING
NEVADA
UTAH
COLORADO
NEBRASKA
IOWA
CALIFORNIA
KANSAS
MISSOURI
ILLINOIS
INDIANA
OHIO
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GEORGIA
TENNESSEE
KENTUCKY
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
FLORIDA
PENNSYLVANIA
NEW YORK
MAINE
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
NEW JERSEY
DELAWARE
MARYLAND
Lake Superior
Lake Michigan
MICHIGAN
The concept of cooling degree days was developed to relate the day's temperature to the energy demands of air conditioning. Cooling degree days are calculated using the day's average temperature minus 65° F.
Annual Cooling Degree Days
less than 101
101–400
401–700
701–1000
1001–1500
1501–2000
2001–2500
2501–3500
more than 3500
Data from the National Environmental Satellite, Data, and Information Service
Albers equal area projection
0 100 200 300 mi
0 100 200 300 km
U.S. Department of the Interior
U.S. Geological Survey
The National Atlas of the United States of America®

How do EnergyStar.gov and International Energy Code Council (IECC) handle Washington State compared to the above HDD and CDD maps? It is easy to see that the IECC climate map is a fair clone of the heating degree map with and with an exception created for the Puget Sound region. The IECC climate map[22],[23],[24] makes up a special "zone 4 marine" to map their Solar Heating Gain coefficient to the EnergyStar.gov criteria. Well for windows, this does not do a good job of maximizing energy savings for Washington State. IECC's no requirement for SHGC does not make sense at all for Washington as the European countries codes will show.

ENERGY STAR® Qualification Criteria for Residential Windows, Doors, and Skylights

Windows

Climate Zone	U-Factor[1]	SHGC[2]	
Northern	≤ 0.30	Any	Prescriptive
	=0.31	≥ 0.35	Equivalent Energy Performance
	=0.32	≥ 0.40	
North-Central	≤ 0.32	≤ 0.40	
South-Central	≤ 0.35	≤ 0.30	
Southern	≤ 0.60	≤ 0.27	

Doors

Glazing Level	U-Factor[1]	SHGC[2]
Opaque	≤ 0.21	No Rating
≤ ½-Lite	≤ 0.27	≤ 0.30
> ½-Lite	≤ 0.32	≤ 0.30

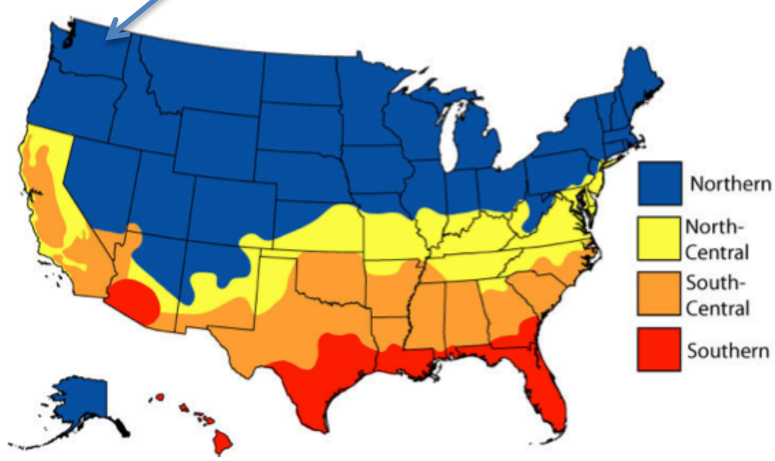
Skylights

Climate Zone	U-Factor[1]	SHGC[2]
Northern	≤ 0.55	Any
North-Central	≤ 0.55	≤ 0.40
South-Central	≤ 0.57	≤ 0.30
Southern	≤ 0.70	≤ 0.30

[1] Btu/h.ft^2.°F
[2] Fraction of incident solar radiation

This part is very flawed for Washington State.

EnergyStar is starting to get this part right.



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[22] https://www.energystar.gov/ia/partners/prod_development/archives/downloads/windows_doors/WindowsDoorsSkylightsProgRequirements7Apr09.pdf same as as download Feb 20 2015 https://www.energystar.gov/sites/default/files/specs//private/Windows,_Doors_and_Skylights_Program_Requirements%20v5_0%20current.pdf

[23] pg28/78 http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_windows.pdf

see footnote22

International Energy Conservation Code
[2012 (First Printing)]
Chapter 4 [RE] - Residential Energy Efficiency
SECTION R303 MATERIALS, SYSTEMS AND EQUIPMENT
R402.1 General (Prescriptive).

R402.1.1 Insulation and fenestration criteria.
R402.1.2
R402.1.3
R402.1.4 Total UA alternative.

Top Previous Section Next Section To view the next subsection please select the Next Section option.

R402.1.1 Insulation and fenestration criteria.
The *building thermal envelope* shall meet the requirements of Table R402.1.1 based on the climate zone specified in Chapter 3.

TABLE R402.1.1 INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

see footnote[24]

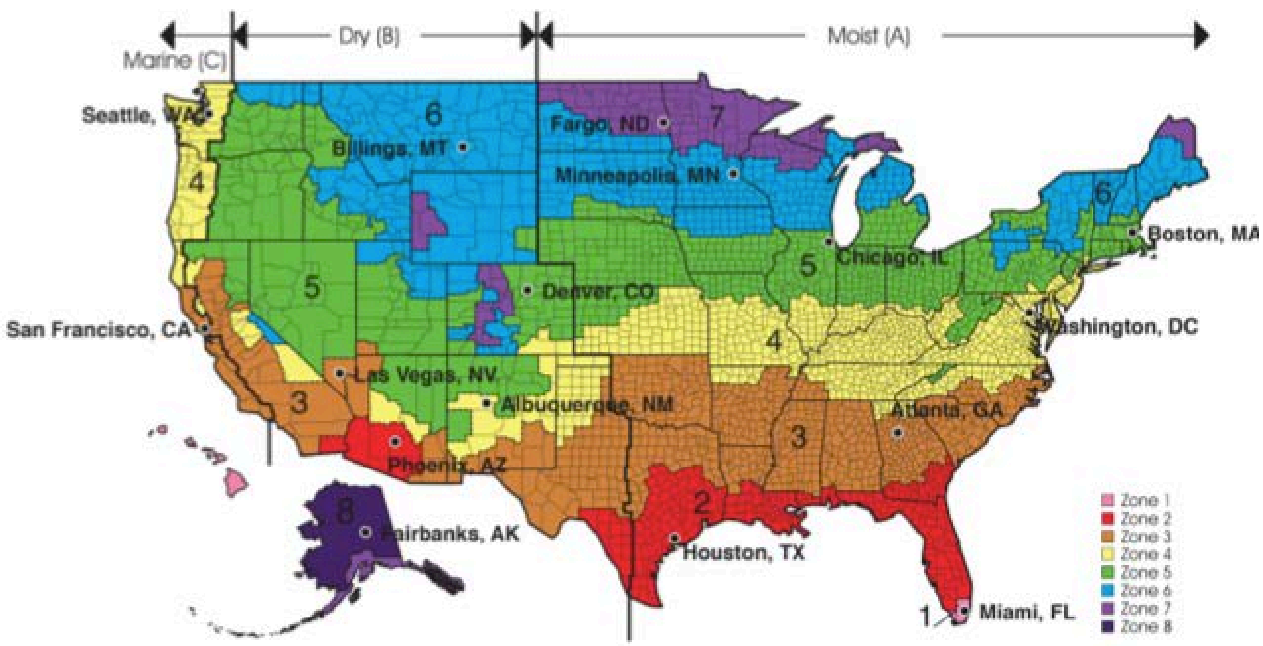


Figure 26. IECC climate zone map with cities used in simulations

see footnote23

24 http://publicecodes.cyberregs.com/icod/iecc/2012/icod_iecc_2012_re4_par005.htm

When one considers the low solar radiation that Washington receives over the year and the amount of heating degree days compared to the cooling degree days it is easy to see that map is not the right one for setting code requirements for windows.

So how does Washington compare to other countries with more advanced window building codes? Below are maps of heating and cooling degree days for Europe.[25]

Seattle is 5000 heating degree°F days which is 2777 Kd/a. Thus look at the color for 3000Kd/a. The Kd/a is Kelvin Days per year and as a reminder, a Kelvin is 1 to 1 proportional to degree Celsius.

Figure 5: European heating degree days map (EUROSTAT method)

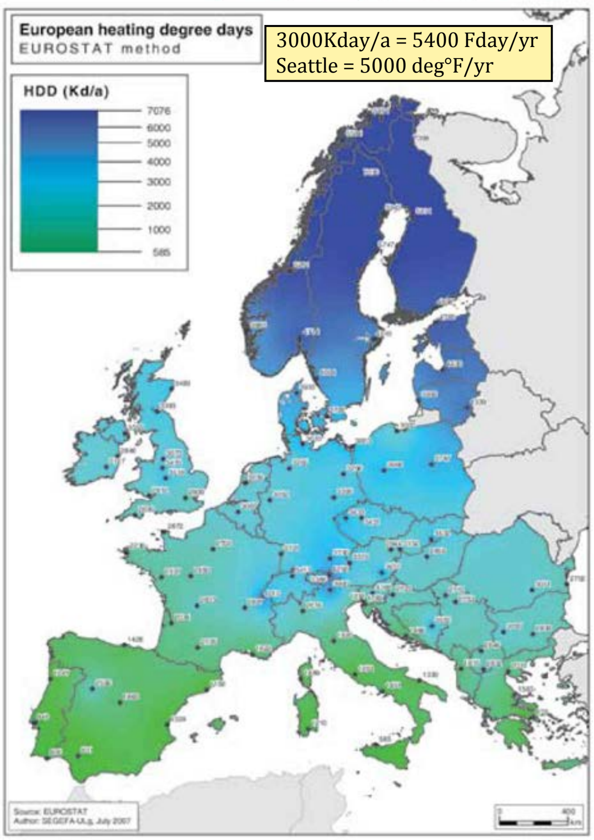
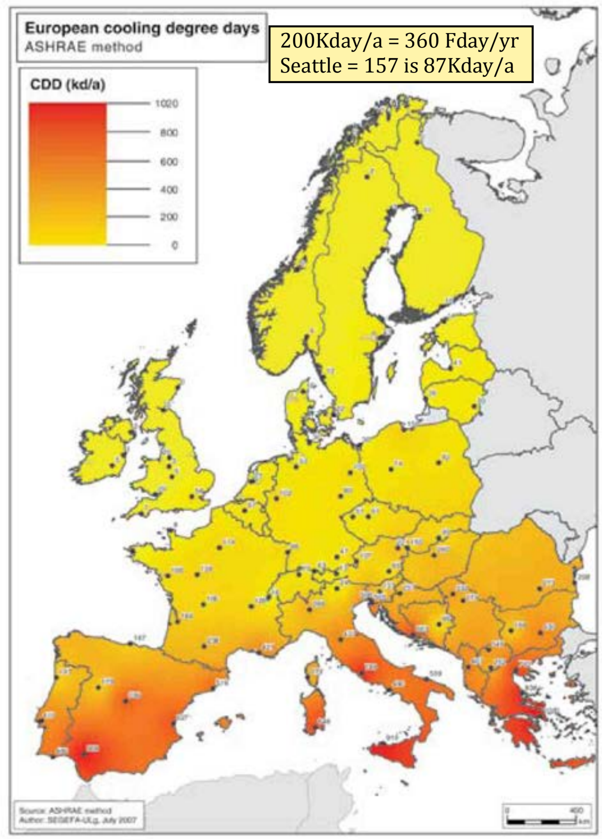


Figure 6: European cooling degree days map (ASHRAE method)



Above European maps are for a base temperature at 64.4F=18C[26] [27]

Given the European use a slightly lower base temp of 64.4F than the USA one of 65F we will select those closest to 5050 instead of 5000.[28] 5050X5/9= 2800. So we need to look for

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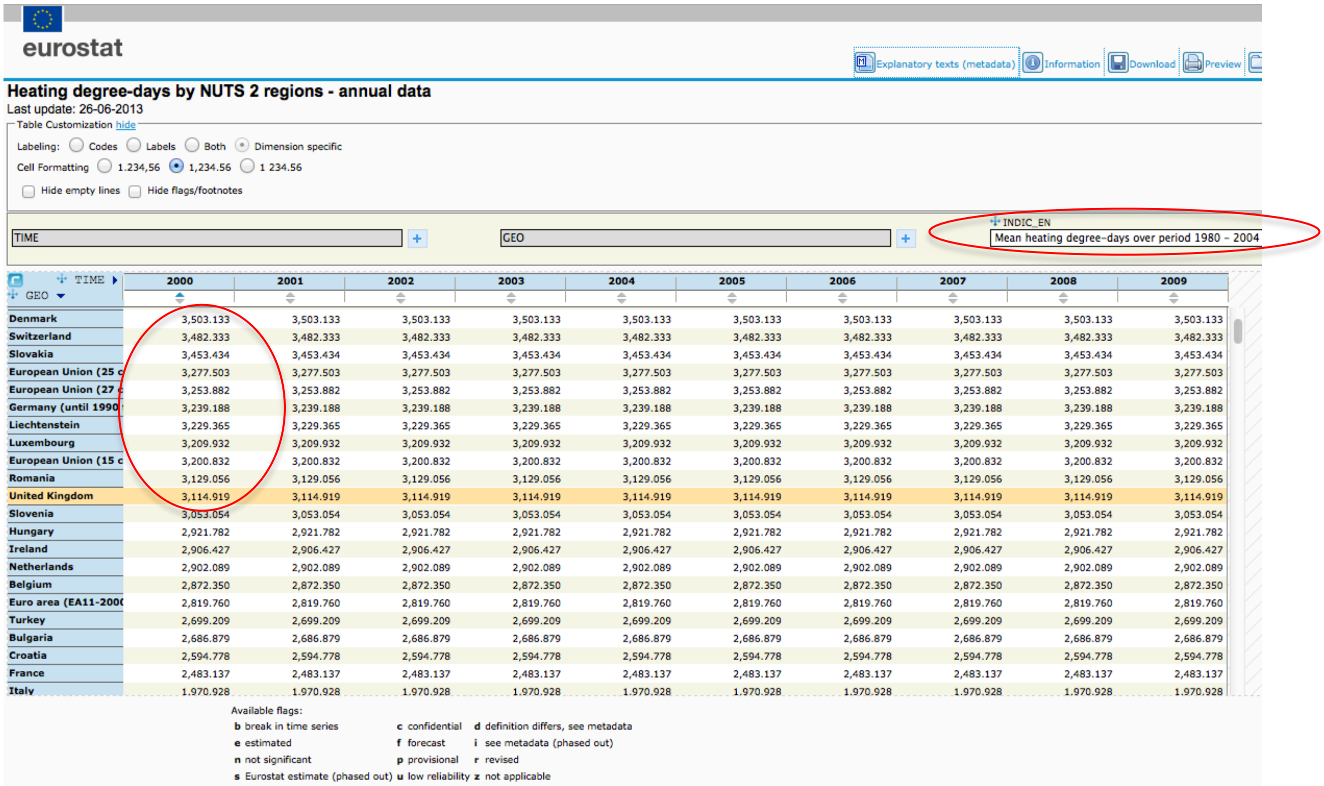
[25] www.eurima.org/reports/u-values-for-better-energy-performance-of-buildings/3-background

[26] www.eea.europa.eu/data-and-maps/indicators/heating-degree-days-1 3000x9/5 = 5,400 Degree-days/yr
To convert °F HDD to °C HDD: °C HDD = (5/9) x (°F HDD) To convert °C HDD to °F HDD: °F HDD = (9/5) x (°C HDD)
Note that, because HDD are relative to a base temperature (as opposed to being relative to zero), it is incorrect to add or subtract 32 when converting degree days from Celsius to Fahrenheit or vice versa. And Kelvin and °C are also directly proportional.

[27] www.eea.europa.eu/data-and-maps/data/external/heating-degree-days-annual-data the links to www.eea.europa.eu/data-and-maps/indicators/heating-degree-days-1 which links to below via "Heating degree-days by NUTS 2 regions - annual data" and *Eurostat calculates HDD as (18 °C - Tm) x d if Tm is lower than or equal to 15 °C (heating threshold) and zero if Tm is greater than 15 °C, where Tm is the mean (Tmin + Tmax / 2) outdoor temperature over a given period of d days.*

2800 Heating degree days in°C The closest to Washington is the UK at 3111 HDD overall and with London at 2855 HDD.


eurostat

Explanatory texts (metadata) Information Download Preview

Heating degree-days by NUTS 2 regions - annual data

Last update: 26-06-2013

Table Customization hide

Labeling: Codes Labels Both Dimension specific

Cell Formatting 1.234,56 1,234.56 1 234.56

Hide empty lines Hide flags/footnotes

TIME GEO INDIC_EN: Mean heating degree-days over period 1980 - 2004

GEO \ TIME	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Denmark	3,503.133	3,503.133	3,503.133	3,503.133	3,503.133	3,503.133	3,503.133	3,503.133	3,503.133	3,503.133
Switzerland	3,482.333	3,482.333	3,482.333	3,482.333	3,482.333	3,482.333	3,482.333	3,482.333	3,482.333	3,482.333
Slovakia	3,453.434	3,453.434	3,453.434	3,453.434	3,453.434	3,453.434	3,453.434	3,453.434	3,453.434	3,453.434
European Union (25 c	3,277.503	3,277.503	3,277.503	3,277.503	3,277.503	3,277.503	3,277.503	3,277.503	3,277.503	3,277.503
European Union (27 c	3,253.882	3,253.882	3,253.882	3,253.882	3,253.882	3,253.882	3,253.882	3,253.882	3,253.882	3,253.882
Germany (until 1990	3,239.188	3,239.188	3,239.188	3,239.188	3,239.188	3,239.188	3,239.188	3,239.188	3,239.188	3,239.188
Liechtenstein	3,229.365	3,229.365	3,229.365	3,229.365	3,229.365	3,229.365	3,229.365	3,229.365	3,229.365	3,229.365
Luxembourg	3,209.932	3,209.932	3,209.932	3,209.932	3,209.932	3,209.932	3,209.932	3,209.932	3,209.932	3,209.932
European Union (15 c	3,200.832	3,200.832	3,200.832	3,200.832	3,200.832	3,200.832	3,200.832	3,200.832	3,200.832	3,200.832
Romania	3,129.056	3,129.056	3,129.056	3,129.056	3,129.056	3,129.056	3,129.056	3,129.056	3,129.056	3,129.056
United Kingdom	3,114.919	3,114.919	3,114.919	3,114.919	3,114.919	3,114.919	3,114.919	3,114.919	3,114.919	3,114.919
Slovenia	3,053.054	3,053.054	3,053.054	3,053.054	3,053.054	3,053.054	3,053.054	3,053.054	3,053.054	3,053.054
Hungary	2,921.782	2,921.782	2,921.782	2,921.782	2,921.782	2,921.782	2,921.782	2,921.782	2,921.782	2,921.782
Ireland	2,906.427	2,906.427	2,906.427	2,906.427	2,906.427	2,906.427	2,906.427	2,906.427	2,906.427	2,906.427
Netherlands	2,902.089	2,902.089	2,902.089	2,902.089	2,902.089	2,902.089	2,902.089	2,902.089	2,902.089	2,902.089
Belgium	2,872.350	2,872.350	2,872.350	2,872.350	2,872.350	2,872.350	2,872.350	2,872.350	2,872.350	2,872.350
Euro area (EA11-200(	2,819.760	2,819.760	2,819.760	2,819.760	2,819.760	2,819.760	2,819.760	2,819.760	2,819.760	2,819.760
Turkey	2,699.209	2,699.209	2,699.209	2,699.209	2,699.209	2,699.209	2,699.209	2,699.209	2,699.209	2,699.209
Bulgaria	2,686.879	2,686.879	2,686.879	2,686.879	2,686.879	2,686.879	2,686.879	2,686.879	2,686.879	2,686.879
Croatia	2,594.778	2,594.778	2,594.778	2,594.778	2,594.778	2,594.778	2,594.778	2,594.778	2,594.778	2,594.778
France	2,483.137	2,483.137	2,483.137	2,483.137	2,483.137	2,483.137	2,483.137	2,483.137	2,483.137	2,483.137
Italy	1,970.928	1,970.928	1,970.928	1,970.928	1,970.928	1,970.928	1,970.928	1,970.928	1,970.928	1,970.928

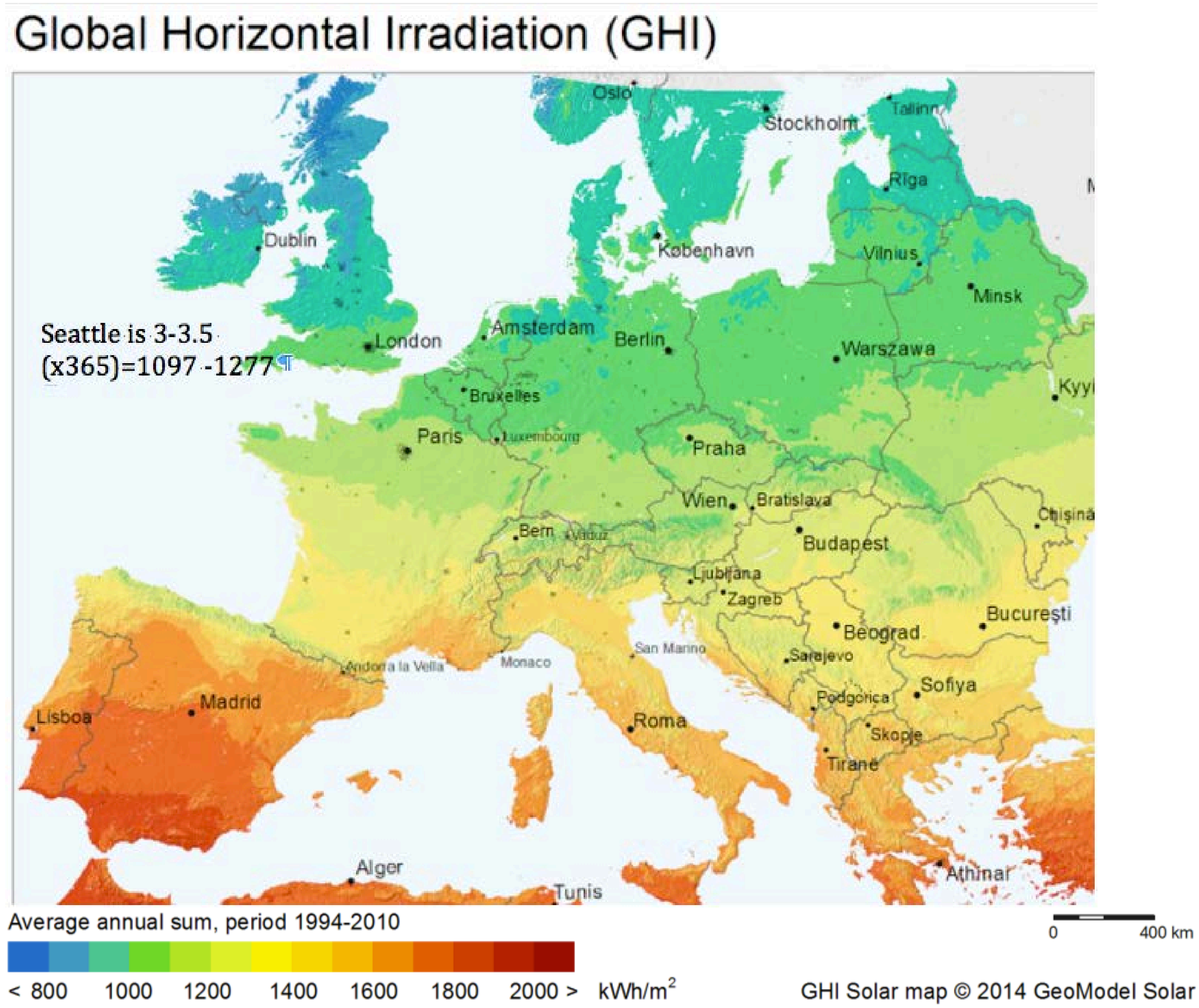
Available flags:
b break in time series; c confidential; d definition differs, see metadata
e estimated; f forecast; i see metadata (phased out)
n not significant; p provisional; r revised
s Eurostat estimate (phased out); u low reliability; z not applicable

Surprisingly they do not give cooling degree data in the tables so we will use the values from the CDD map above and cross check with a Norwegian review of historical Degree days data for Europe.[29] These have HDD/CDD in °C for Copenhagen at 3364/8 Kd/a, London 2855/2 and at Liverpool 3024/5.

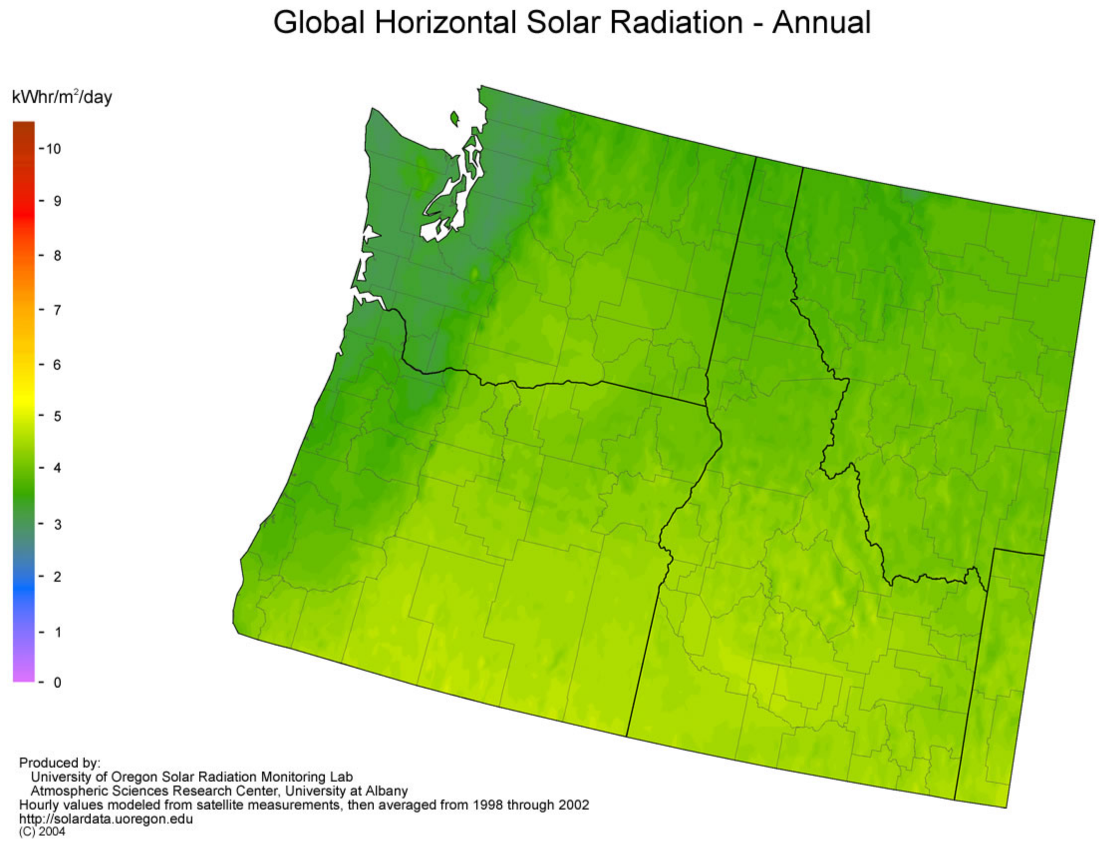
So how does the Washington State and the UK and Denmark look relative to solar radiation relative the cloudiness of each location?

[28] www.eea.europa.eu/data-and-maps/data/external/heating-degree-days-annual-data then this has a link to the page at eurostat is labeled "Dataset URL:" http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_esdgr_a and the choosing mean annual HDD we get the mean HDD from 1980 to 2004.

[29] Pg 34/111 http://met.no/Forskning/Publikasjoner/metno_report/2008/filestore/metno_04-2008.pdf

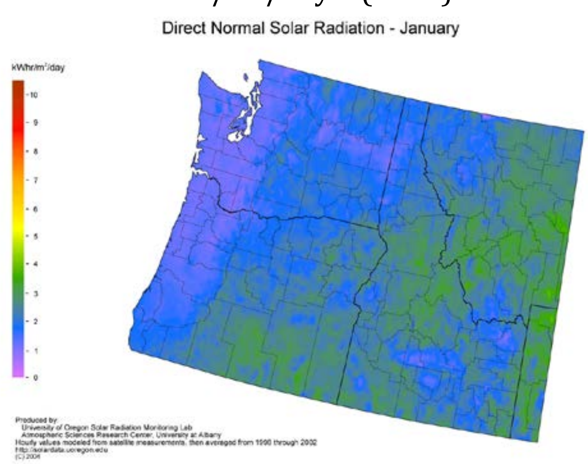


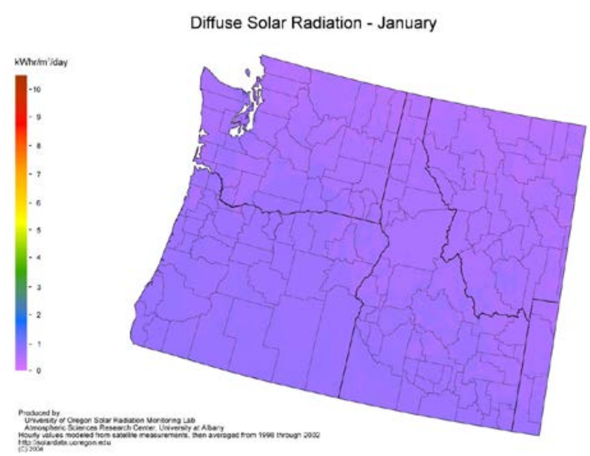
http://solardata.uoregon.edu/NorthwestSolarResourceMaps.html
http://solardata.uoregon.edu/Assets/ayrgl.jpg



ref=[30]

Seattle is 3kWh/m^2/day x (x365)=1097kWh/m^2/year 3.5= 1277





These last two maps are for direct and diffuse radiation for just January. If one adds them together one gets the total solar radiation hitting the ground or GHI for just January. The key thing to note is that during the coldest part of the year, that west of the Cascades, the direct and diffuse energy are almost the same. This means that for northern facing windows one want has high a SHGC as possible to play are very big role in saving energy as

[30] per http://en.openei.org/w/index.php?title=File:NREL-eere-csp-washington.jpg map Seattle is 3-3.5 Kwh/squM x 24/d=72 to 84Kw/day (x365)=

the British Columbia Canada code review hinds at[31]. Note the higher SGHC for northern windows in the below table. See section in on "Sky scattering- Background on Solar radiation …" further below in this paper for detail of the physics.

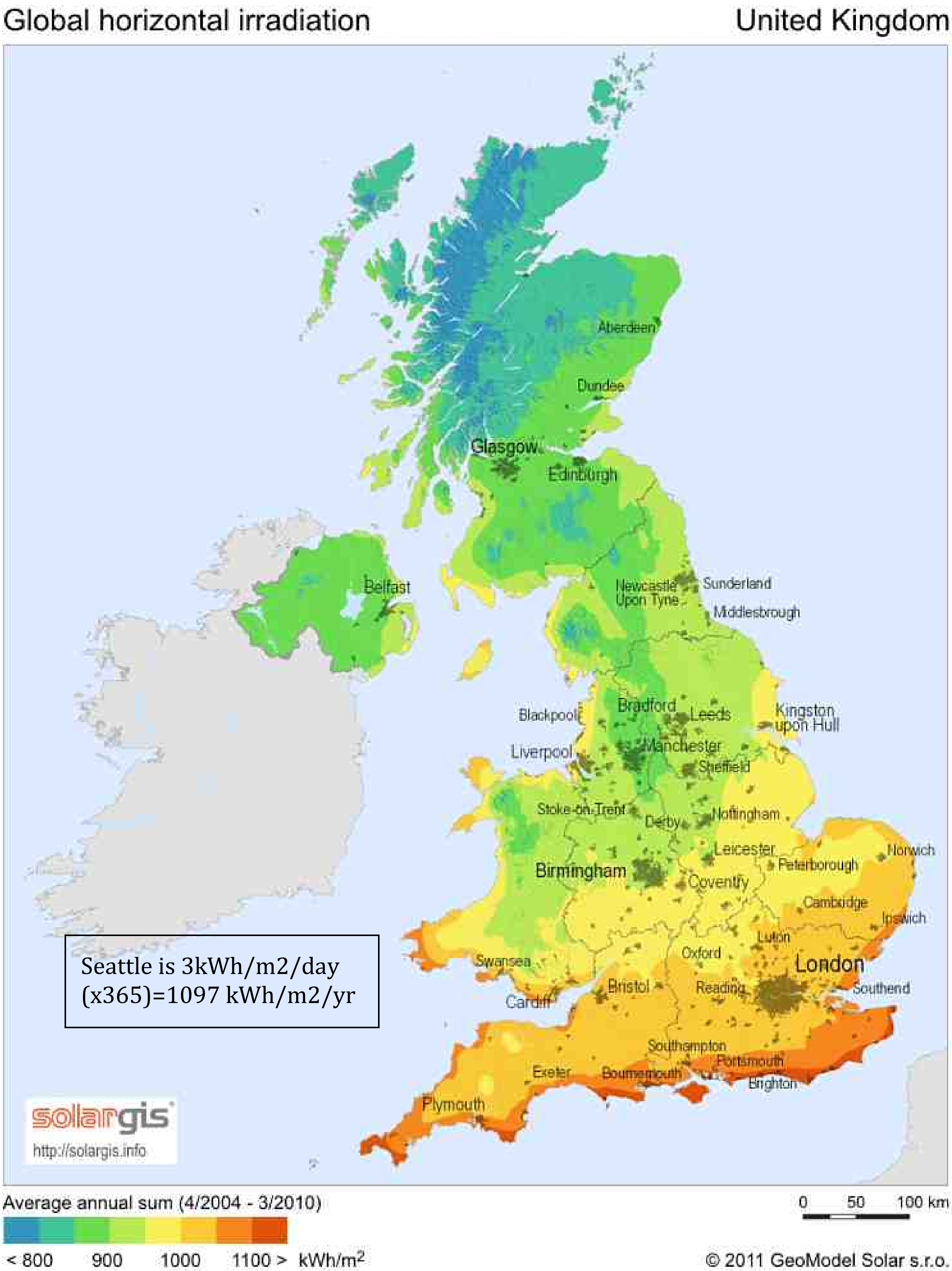
Stantec

BC ENERGY CODE COMPARISON (FINAL REPORT)
Appendix A: Detailed Inputs and Assumptions
October 18, 2012

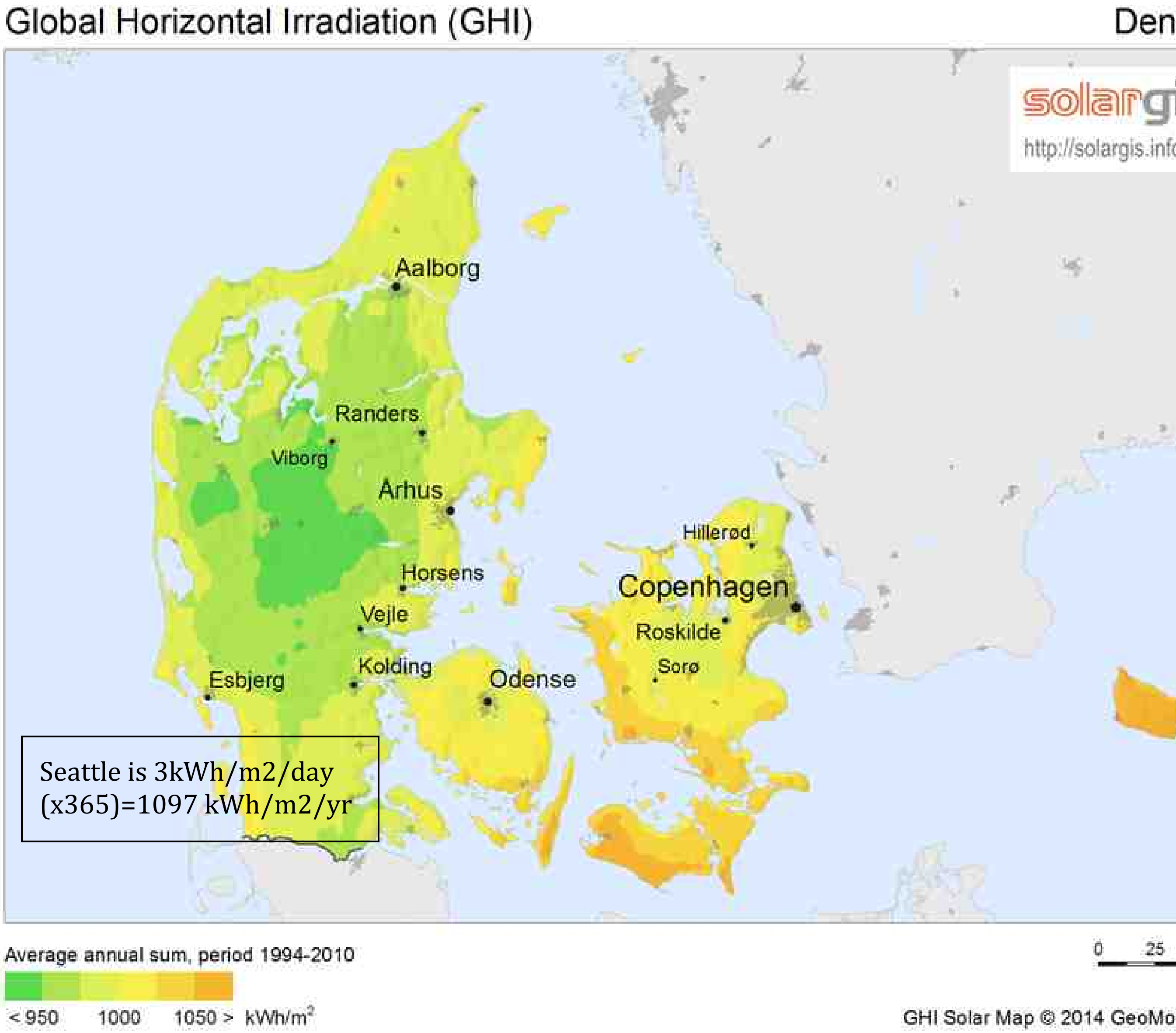
Fenestration			
Vertical Glazing Percentage	**All Climate Zone** **32% was used to maintain consistency with all climate zone and code**		
Vertical Overall Glass U-Value including Frame [h·°F·ft^2/Btu] and Overall Solar Heat Gain Coefficient (Conditioned) note the "crappy" U-value allowed but requiring a high SHGC for the northern windows	**U-values Exceed Code Minimum Requirement, Typical Industry Practice** **Climate Zone 5** **Retail - Fixed Window** U-0.45 $SHGC_{NORTH}$-0.49; $SHGC_{OTHER}$-0.39 **Residential - Operable Window - Vinyl** U-0.30 $SHGC_{NORTH}$-0.49; $SHGC_{OTHER}$-0.39 **Climate Zone 7** **Retail - Fixed Window** U-0.45 $SHGC_{NORTH}$-0.64; $SHGC_{OTHER}$-0.49 **Residential - Operable Window - Vinyl** U-0.30 $SHGC_{NORTH}$-0.64; $SHGC_{OTHER}$-0.49	**Residential U-values Exceed Code Minimum Requirement, Typical Industry Practice** **Climate Zone 5** **Retail** Metal framing (storefront) U-0.45, SHGC-0.40 **Residential** Nonmetal Framing (all other) U-0.30, SHGC-0.40 **Climate Zone 7** **Retail** Metal Framing (storefront) U-0.40, SHGC-0.45 **Residential** Nonmetal Framing (all other) U-0.30, SHGC-40	**Residential U-values Exceed Code Minimum Requirement, Typical Industry Practice** **Climate Zone 4** **Retail** Metal framing (storefront) U-0.423, SHGC-0.40 **Residential** Nonmetal framing U-0.30, SHGC-0.40 **Climate Zone 5** **Retail** Metal framing (storefront) U-0.387, SHGC-0.40 **Residential** Nonmetal framing U-0.30, SHGC-0.40 **Climate Zone 7** **Retail** Metal framing (storefront) U-0.387, SHGC-0.45 **Residential** Nonmetal framing U-0.30, SHGC-0.40

Ok so now back to Europe. Below is an annual summation of the solar radiation for the UK, which on average is very close to Washington particularly when weighting it by population.

[31] www.housing.gov.bc.ca/building/green/energy/Stantec%20-%20Part%203%20Energy%20-%20FINAL-%20rpt01_bc_energy_code_comparison__update_201201022.pdf



Seattle is 3kWh/m2/day (x365)=1097 kWh/m2/yr see ref[32]



In summary , for overall climate we have the following. SEATAC gets 4964 heating degree days and 157 cooling degree days and Spokane airport at 6610/ 427.[33] And solar radiation of GHI=1100 kWh/m2/yr for Washington. Compare this to Denver at 6250 HHD and 500CDD and 1900 kWh/m2/yr solar radiation almost double the twice the radiation that Seattle receives.

Yet EnergyStar and IECC puts Seattle and Denver into the same building code bucket for windows.

---

[32] http://solargis.info/doc/_pics/freemaps/1000px/ghi/SolarGIS-Solar-map-United-Kingdom-en.png
[33] www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa7473 need to scroll down to HDD and select

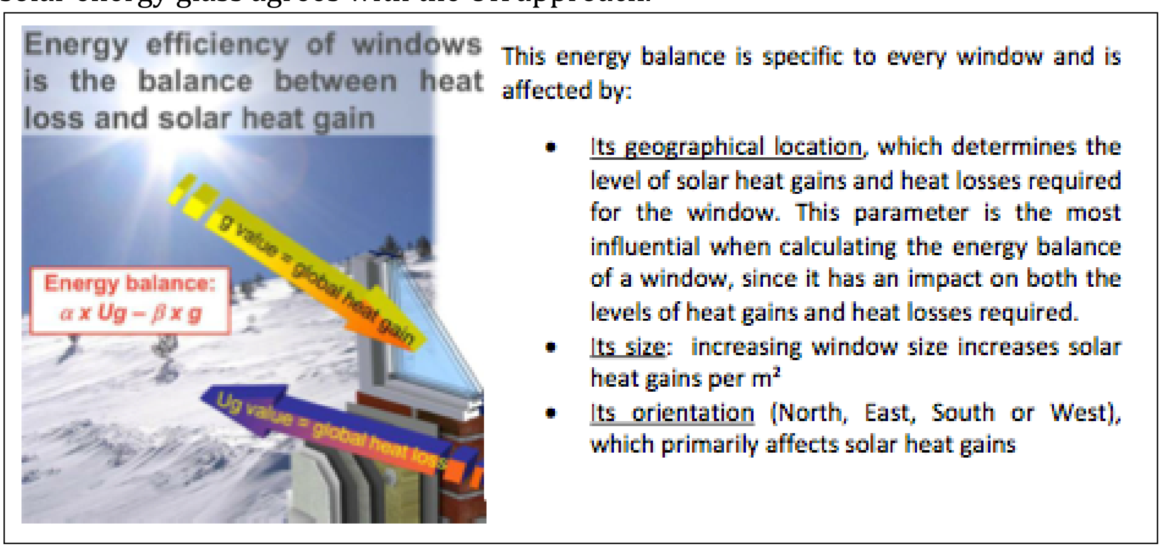
Compare the above to the UK climate of with a solar GHI=950 and an average 5600 HDD°F (3111°C) with London at 5,139 HDD°F (2855°C) and solar GHI=1050 is much closer to Washington's climate than Denver. And Demark has heating degree days for Copenhagen at 6055 HDD°F (3364 °Kday/year) with solar GHI=980. Still a much better climate match to Washington than Denver and the many other locations EnergyStar and IECC lump us into for windows.

Given UK and Denmark are a much better match climate wise than all most all of EnergyStar and IECC's grouping, let us learn what the UK and areas surrounding do for window requirements.

Window codes in UK, Nordic countries and the European Commission work on

Lets look at the UK first where the British Fenestration Rating Council (BFRC) is the lead. Here is a quote from the April 2012 European Commission report reviewing all countries window codes.[34]. *"For windows, most national labels do not calculate an energy balance figure, but instead present standards for the U- and g-value that products must achieve within that country. The BFRC scheme in the UK is the exception (see below)."*

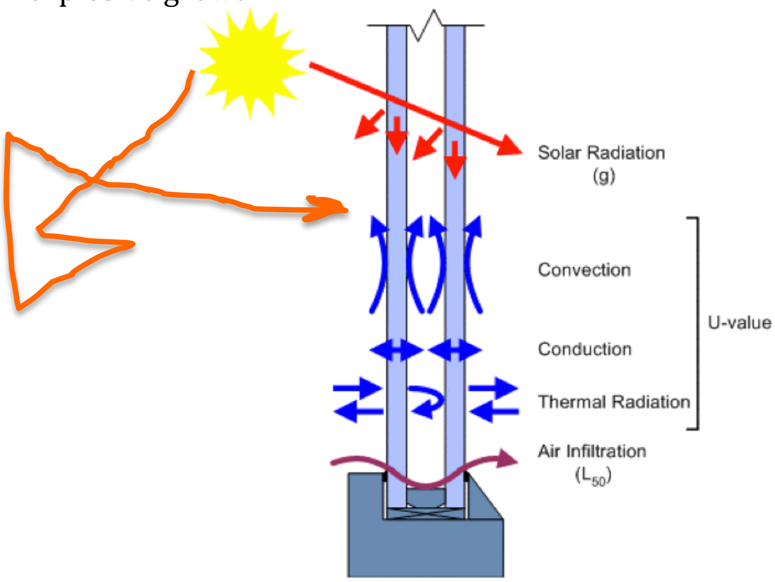
And "Glass For Europe", the main European glazing trade association for building, auto and solar energy glass agrees with the UK approach.[35]



And for those that do not eat and breath this stuff everyday a VERY limited refresher of what is going on with U-factor and solar heat gain. The rough hand drawn oranage line represents what is a major benefit of having a high solar heat gain coefficent (diffuse solar radiation). See section of this doc called **"Sky scattering"** of this document for more

[34] Pg11 & 80/86 Apr 2012 Use link exactly as provided (no www) susproc.jrc.ec.europa.eu/windoors/docs/task 3.pdf
[35] www.glassforeurope.com/images/cont/226_16695_file.pdf

technical detail, much of what was not easyily visualized until the solar panel industry had explosive growth.



ref pg17/43 **Figure 2 The energy flows for a double glazed window.**

For now I will skip the diffuse solar radiation details and get to the results .

The British Fenestration Rating Council (BFRC) rating equation[36] is;

BFRC Rating = 218.6g_{window} - 68.5 x (U_{window} + Effective L_{50})

The BFRC system uses three measures of energy efficiency. These are:

Thermal transmittance (U-value): measuring how well a product prevents heat escaping.
Solar Factor (G-value): This measures how well a product blocks heat caused by sunlight. The Solar Factor is expressed as a number between 0 and 1. A lower Solar Factor means less heat gain.
Air Leakage (L50 value): For good quality windows, air leakage makes little difference to energy performance, for leaky windows, the impact is significant.

The closer the above equation is to zero the higher or better the UK considers the window for its climate.[36]

Table 6 BFRC Rating System

BFRC Rating Scale	BFRC Rating (kWh/m^2/year)
A	0 or greater
B	-10 to < 0
C	-20 to < -10
D	-30 to < -20
E	-50 to < -30
F	-70 to < -50
G	Less than –70

The BFRC rating gives numbers based on the performance of the window in the UK climate. Negative numbers indicate a net energy loss through the window over a year, and positive

36 Pg30/43 June 2010 http://ec.europa.eu/environment/gpp/pdf/windows_GPP_background_report.pdf

numbers indicate a net energy gain over the year (ie the beneficial solar gain is more than the heat lost). Here are the energy saving per meter squared of window for the average UK climate.[34]

Table 1 Energy Performance of a range of windows

Window number	Overall U-value	Glass g-value	BFRC rating ($kWh/m^2/yr$)	
1	0.7	0.51	51.7024	Net energy gain
2	1	0.58	44.9242	
3	1.1	0.6	42.009	
4	1.4	0.58	17.5242	
5	1.4	0.63	27.3612	
6	1.5	0.67	28.3808	
7	1.5	0.46	-12.9346	Net energy loss
8	1.95	0.67	-2.4442	
9	1.95	0.46	-43.7596	
10	2.6	0.78	-25.3278	
11	2.6	0.56	-68.6106	
12	2.5	0.78	-19.1628	
13	4.7	0.87	-151.471	
14	4.7	0.66	-192.787	

Before we look at what the above means for Washington's upcoming u-value of 0.3 Btu/h·ft2°F (1.7 W/m2·°K) let review U values in metric and English units

Here is how those European U-values compare to US code values.[37]

Table 7 Windows and door values awarded the Energy Star Programme certification.

Climate Zone	U-Value*	Equivalent European U-Value***	G-value **
Northern	≤ 0.35	1.99	Any
North/Central	≤ 0.40	2.27	≤ 0.55
South/Central	≤ 0.40	2.27	≤ 0.40
Southern	≤ 0.65	3.69	≤ 0.40

* U-value: The rate of non-solar heat loss or gain through a material or assembly. Expressed here in units of Btu/h·ft2°F.
** G-value is the same as the USA Solar Heat Gain Coefficient SHGC a measure of the fraction of solar radiation admitted through a window. Expressed as a value between 0 and 1 .
*** Multiply American U-value by 5.68 to give European U-value in W/m2·°K.

Note that the European U values are in metric units and American in English units. This table 7 is from a 2010 European Commission report so it had the then current SHGC (G-Values).

Back to Table 1. It shows the benefit of changing to a minimum required SHGC for the Washington State climate. See red circle for window 8 and 9. Note the much higher energy efficiency of -2.44 for window 8 a higher solar heat gain of 0.67 (g-value) verses window 9 with exactly the same U-value but lower g-value.

The real question for Washington is given we are going to a U-value of 0.3 Btu/h·ft2°F (1.7 W/m2/yr) that should our solar heat gain value be? We have to interpolate for a 0.3 or 1.7 metric value. First we have to interpolate between a u-value of 1.5 and 1.95 for a g-value of 0.67 and again between 1.5 and 1.95 for a g-value of 0.46. This yields energy at 14.68 and -13.7 kW/m2/yr respectively. Then we interpolate between those two values to get zero energy balance over the year resulting in a solar heat gain coefficient of 0.561 for the UK

[37] pg32/43 http://ec.europa.eu/environment/gpp/pdf/windows_GPP_background_report.pdf

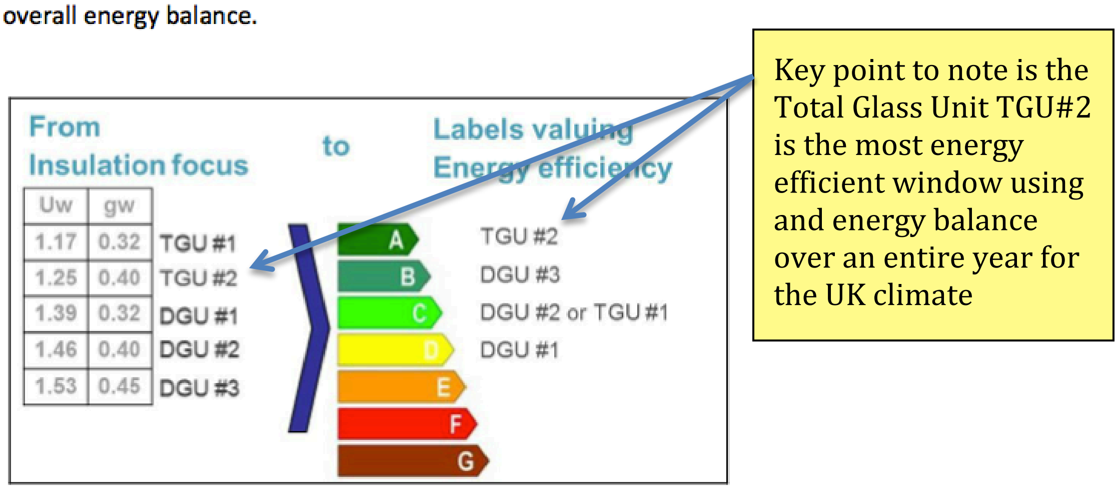
climate, which is nearly identical to Washington State climate. And by climate we mean temperature, level of cloudiness and solar radiation integrated over an entire year(s).

Thus, from the above table, Washington State's residential solar heat gain coefficient should be 0.561 for Washington's best prescriptive U-factor of 0.3 Btu/h·ft2°F (or 1.7 W/m2·°K) and not the current "No Requirement". If the U value is higher than 0.3 Btu/h·ft2°F or leaky existing homes, then the required SHGC should go up.

Moving forward, building codes should be further refined for each major Washington population centers. For temperature HDD can serve as a proxy but given the available data, this should be done on the minute by minute time scale if the data is available as this further improves the accuracy of the "accounting" particularly for the total solar hitting the windows, the GHI. The GHI has been shown to need minute by calculation as not doing so underestimates it level.[38] A location's cloudiness shows up in the GHI, the total solar radiation, so it is very important to get accurate overall energy accounting.

Here is the European glass trade industry association is touting the energy balance method.[39] "Energy balance: the right approach to assess the energy performance of window products"

> The figure below shows the difference in energy ratings of 5 modern glazing solutions for UK residential buildings according to the parameter chosen to assess the energy performance: i.e. insulation or energy balance. It demonstrates that a window performance ranking based on the insulation properties would lead to an incorrect performance assessment: although window TGU#1 offers the best, i.e. the lowest, insulation value (Uw), it is in fact a sub-optimal option in terms of overall energy balance.



Now lets look at Denmark as they were also fairly similar in Heating degree days.

Nordic Swan Ecolabel = EnergyStar for the Nordic countries

"*One of the most comprehensive Ecolabels for windows is the Nordic Swan system.81*(81= Ecolabelling of Windows and Exterior Doors, Criteria document, 12 December 2001 – 30 June 2009, Version 2.4 and http://www.svanen.nu) *This is a voluntary certification system that covers Denmark,*

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[38] Uses data from Seattle in the Integrated Surface Irradiance Study (ISIS) network http://sel.me.wisc.edu/publications/conference/asespaper044a1.pdf also see http://wiki.variablegen.org/index.php/File:Time_Series_of_Simulated_and_GHI_Irradiance_-_Seattle,_WA.png

[39] http://www.glassforeurope.com/images/cont/226_16695_file.pdf

Finland, Iceland, Norway and Sweden. It is designed to provide a guide for fixed and opening windows and window-doors, and exterior doors forming the boundary between free and heated areas."[40] Here is the latest Dec 2014 Nordic Swan Ecolabel

O2 U-value, heat transfer coefficient

To take account of:

- the different energy consumption between wooden windows and windows in non-renewable materials, plus
- the environmental impact of emissions of volatile organic compounds from solvent-based impregnation, the requirement concerning highest permissible U-value for windows, window doors and external doors is as follows:

Requirement concerning highest permissible U-value for windows, window doors and external doors:

Product	**Maximum U-value (W/m²K)**
Wooden windows where wood preservation/impregnation and surface treatment are water-based*. The window may come with or without external cladding**:	
facade window window door roof window	0.9 1.0 1.1
Wooden windows where wood preservation/impregnation and surface treatment are solvent-based (vacuum impregnation). The window may come with or without external cladding*:	
facade window window door roof window	0.8 0.9 1.0

Nordic Ecolabelling 062/4.1 10 December 2014
Background document

Window where the frame and/or casement are partially made from non-renewable material*:	
facade window window door roof window	0.7 0.8 0.9
External door, irrespective of material and any wood preservation:	1.0

** Other wood preservation/impregnation free from solvents is also accepted. One example is impregnation with supercritical carbon dioxide.*

*** see section "Terms and definitions"*

The U-value is determined through calculation or testing of a model/family of windows or external doors, using the methods stated in the product standard EN 14351-1 and conducted by an accredited test laboratory. See also Appendix 1.

For facade windows and roof windows, the U-value is to be measured for the whole window, including frame, for the window size 1.23 m x 1.48 m.

For window doors and exterior doors, the U-value is to be measured for the whole door, including frame, for the door size 1.23m x 2.18 m.

The U-value is to be given to two significant figures in line with ISO 10077. This means stating the U-value to two decimal places if less than 1.0 and to one decimal place if it exceeds 1.0. Rounding is to follow current calculation rules.

✉ The result of testing/measuring the U_W-value and a report on how the measurements were taken.

[40] page 28/43 of http://ec.europa.eu/environment/gpp/pdf/windows_GPP_background_report.pdf

O3 The solar energy transmittance and daylight transmittance of windows
The solar energy transmittance of window glass (g_g-value) must be 0.48 (48%) or higher. At the same time, the solar energy transmittance of window glass (g_W-value) must be 0.34 (34%) or higher. These values are applicable to both facade windows and roof windows.
The daylight transmittance must be 0.63 (63%) or higher.
The window's g_W-value is calculated using the formula:
$g_W = g_g \times (Ag/Aw)$. Where Ag represents the glass area and Aw is the window area.
The g-value and daylight transmittance are to be measured through tests or calculations based on the methods stated in product standard EN 14351-1 and performed by an accredited test laboratory. See also Appendix 1.
For facade and roof windows, the g-value for the window (g_W) is to be stated for the window size 1.23 x 1.48 m.

Ref for below[41]

8.2.4 Denmark - Window Energy Label

The original voluntary energy labelling agreement for windows between the Danish trade organisations and the Danish Energy Authority ended in 2006. In 2010 a new scheme was launched that commits the window industry to energy rate their windows.

The ratings (A-G) are calculated for the window energy balance for a reference window (1.23m x1.48m) based on a Danish reference house. It is aimed primarily at replacement windows. The new scheme is also linked to the Danish Building Regulations, for example a C rated window will fulfil the present requirements for replaced windows.

As part of the scheme the manufacturers are subject to external inspection, and must when requested be able to provide information regarding the energy balance and parameters used to calculate it for their windows.

European Commission -Mainland Europe's Window Efforts

Now turning to what mainland Europe is try to do. There is a Danish proposal[42] chosen by the European Commission to be a center piece for rating all windows in continental Europe. Both sets of work, the European Commission and the Danish proposal which starts with solar radiation totals and heating degree days weather. The Danish report is titled "Proposal for Energy Rating System of windows in EU"[42]. From that they generate a set of energy balance equations for three different proposed climate zones in Europe. The key piece of information is that this report uses a base temperature of 20C (68) degrees hotter what is normal in Europe at 18C and 18.3C for the USA (65F) for heating and cooling degree day. This is very key has it will increase the need for solar radiation and end up with slightly higher minimum required solar heat gain coefficient (g-value). The authors likely set the base temperature at 20C to account for the warm climate in Southern Europe at peoples' expectations do vary by what the local population is used to. In Nordic countries like Finland and Denmark can use 16C as the reference temperatures used as they are comfortable with lower temperatures.

For the Danish proposal I will just screen shot some of the key parts while those that want more detail can down load the full report. Interestingly the source for the HDD was the

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[41] pg 66/107 of pdfhttp://susproc.jrc.ec.europa.eu/windoors/stakeholders.html links to http://susproc.jrc.ec.europa.eu/windoors/docs/Windows%20_Doors_Technical_Report_FINAL_240912_131127.pdf
[42] Solar map on page 9of32 www.byg.dtu.dk/~/media/Institutter/Byg/publikationer/byg_rapporter/byg_r201.ashx

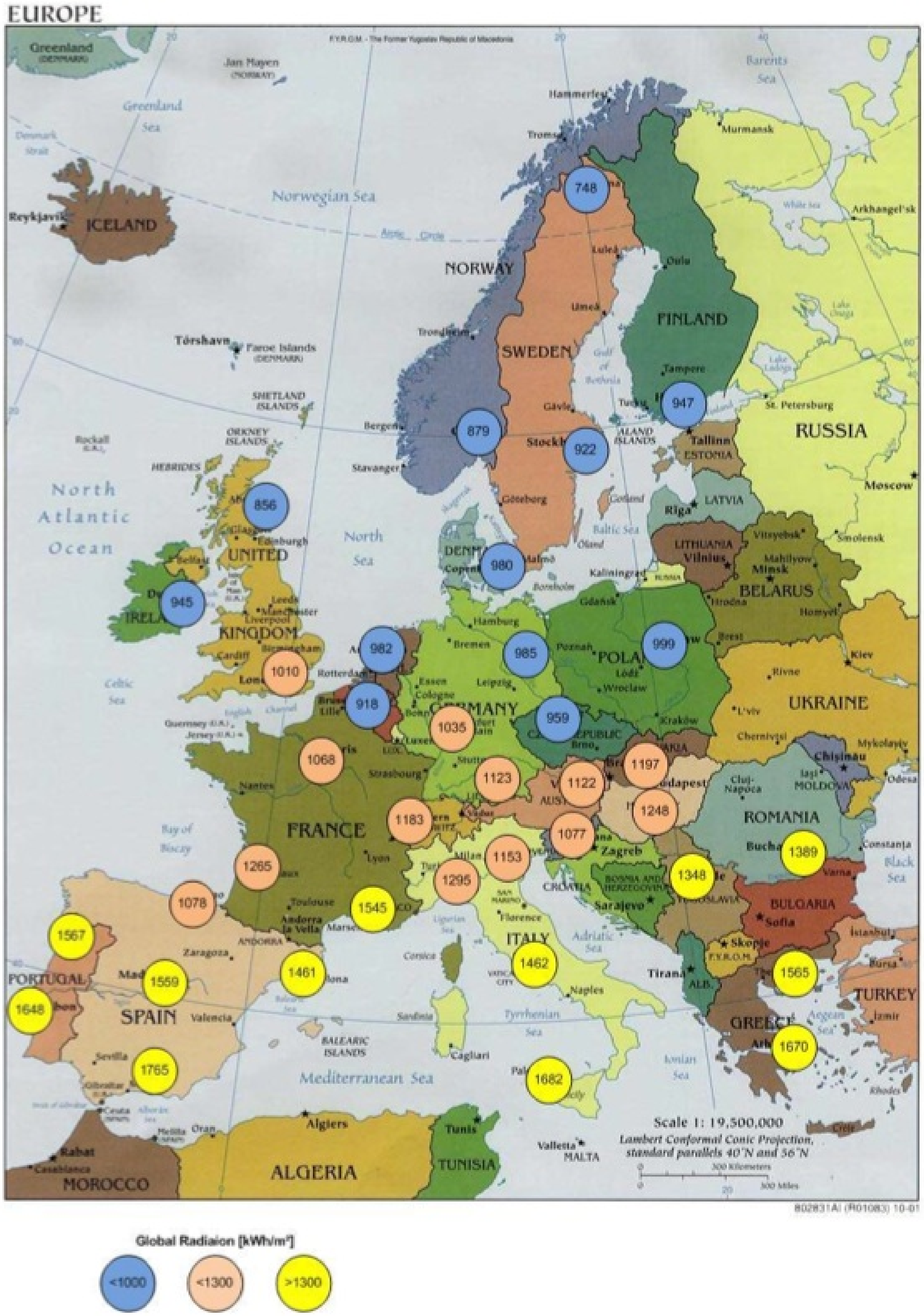

Figure 2 Annual solar radiation on different locations in Europe. (Radiation on horizontal plane)

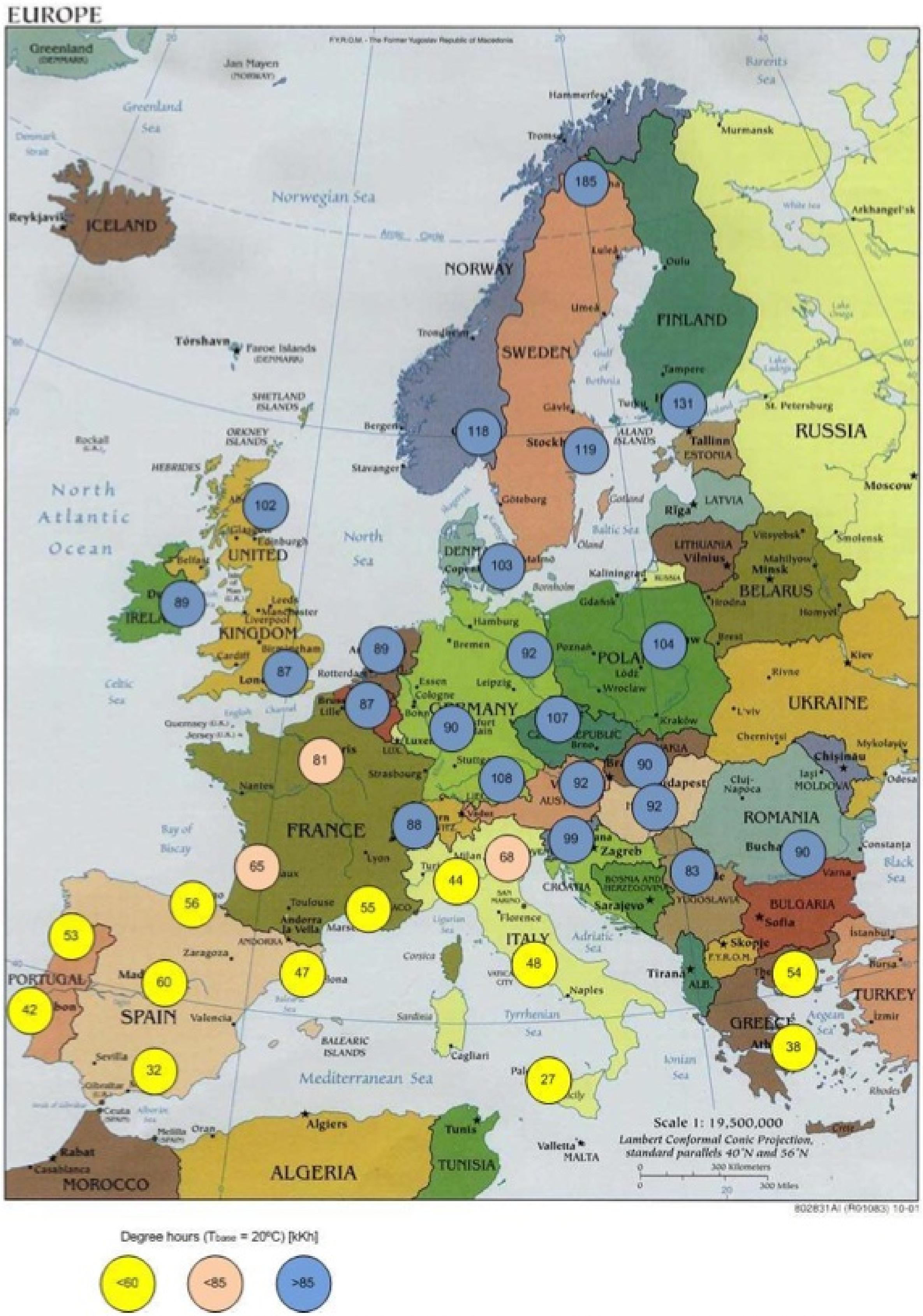

Figure 1 Degree hours on different locations in Europe, based on indoor temperature of 20 °C

US Dept of Energy http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm. These are heating degree hours at 20C in kKH (kiloKelvinHours) which will basis the SHGC to a value higher than appropriate for Washington. They use the above maps to create three climate zones for Europe. These three climate zones are heavily reference in the European Commission efforts on windows without a map. It will be shown here for future reference. [43]

Figure 1 – Suggested climate zones in the EU

[43] page82/86 susproc.jrc.ec.europa.eu/windoors/docs/task 3.pdf This pdf is reference in the 107 EU windows doc on pg 46/107 saw http://www.byg.dtu.dk/upload/institutter/byg/publications/rapporter/byg-r201.pdf after google "byg-r201.pdf" to get

The first reference house (type 1) is a 1½ storey house and the second (type 2) is a single storey house. The ground floor area of the two houses is 96 m and 140 m , respectively.
The total window area of the reference houses is assumed to be 20% of the heated floor area. The distribution of the vertical windows is assumed to be 41 % south, 16.5% west, 16.5% east and 26% north, see Figure 4.

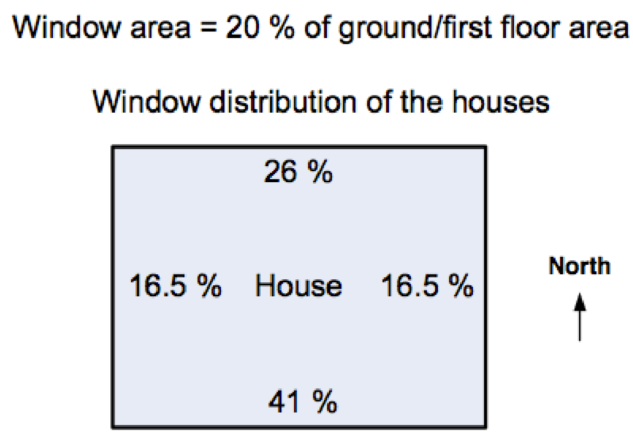

Figure 4 Distribution of the window area in the reference houses regarding the orientations. The total window area is calculated as 20 % of the floor area.

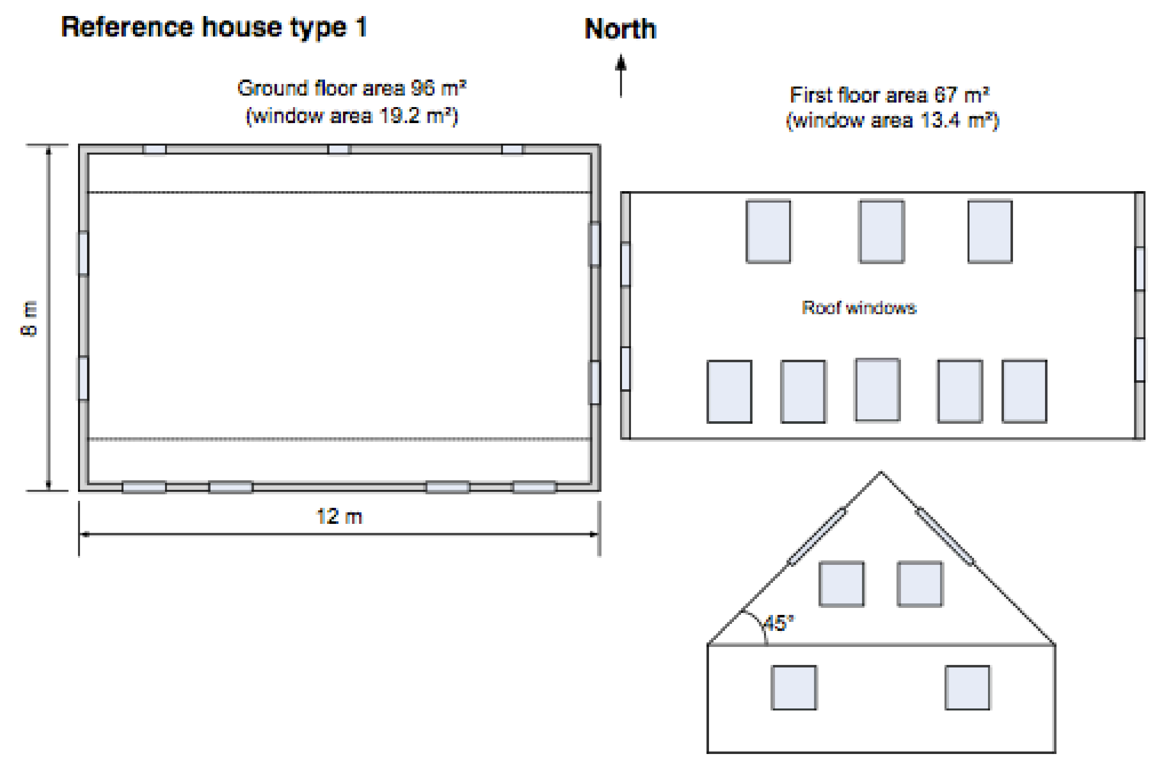

Figure 5 Outline of the reference house type 1 with 45° sloped roof construction

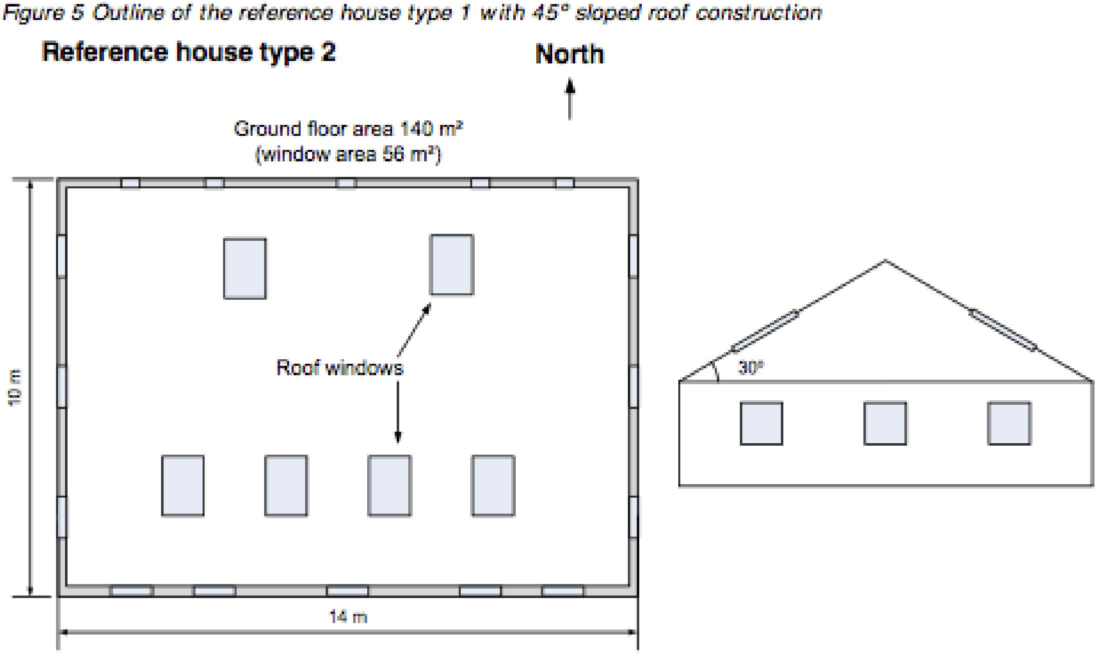

Figure 6 Outline of the reference house type 2 with 30° sloped roof construction

3. THE WINDOW ENERGY PERFORMANCE

The energy performance of the window is calculated as the difference between the transmitted solar energy and the thermal heat loss during the cooling and heating seasons.

$$E_{ref,cooling} = I_{cooling} \cdot F_s \cdot g_w - D_{cooling} \cdot U_w \qquad (8)$$

$$E_{ref,heating} = I_{heating} \cdot F_s \cdot g_w - D_{heating} \cdot U_w \qquad (9)$$

Where,

$E_{ref,\ cooling}$	is the energy performance of the window in the cooling season	[kWh/m]
$E_{ref,\ heating}$	is the energy performance of the window in the heating season	[kWh/m]
$I_{heating}$	is the solar radiation on the window in the heating season	[kWh/m]
$I_{cooling}$	is the unusable solar radiation in the cooling season	[kWh/m]
$D_{cooling}$	is the degree hour in the cooling season	[kKh]
$D_{heating}$	is the degree hour in the heating season	[kKh]
g_w	is the solar energy transmittance of the window (including solar shading)	[-]
F_s	is the shadow factor due to the horizon and build-in (overhang, side fins)	[-]
U_w	is the total heat transfer coefficient of the window	[W/m K]

NOTE: there may be a difference in g_w between heating and cooling mode if the window is adaptive to the season (e.g. movable solar shading devices)

The shadow factor for the horizon and build-in, F_s could be estimated in general to be 0.7 for horizontal windows (European standard EN 832, 1998). For roof windows $F_s = 0.9$ can be used.

4.3 Final proposal

In Table 7 the values of solar radiation and degree hours used in the proposed energy rating system are shown. The values in Table 7 are average values for the two building forms based on the detailed values in Table 6.

Table 7 Solar radiation on vertical and sloped windows and degree hours for the heating and cooling season for the two reference houses used in the three climate zones in Europe. Average values.

	Heating season				Cooling season			
	Solar radiation (kWh/m^2)			Degree hours (kKh)	Solar radiation (kWh/m^2)			Degree hours (kKh)
Location	I_90º	I_45º	I_30º	D	I_90º	I_45º	I_30º	D
Zone 1	212	354	365	89	20	53	64	0
Zone 2	251	444	466	80	36	116	138	1
Zone 3	254	426	437	36	120	425	497	2

For reference the above can be compared with existing national energy labelling schemes for windows.

The Danish Energy Label for vertical windows has a solar radiation of 196 kWh/m and a degree hour of 90 kKh.

The BFRC /7/ label for vertical windows in UK has a solar radiation of 218.6 kWh/m and a degree hour of 68.5 kKh, including the air permeability of the window.

The net energy gain equations

In Table 8 the specific equations of the net energy gain in the heating and cooling season are presented. The table also includes equations for sloped windows of 30° and 45°.

Table 8 Equations for determination of the net energy gain in the heating and cooling season in the three zones for window sloped angles of 90°, 45° and 30°.

Net energy gain [kWh/m²]	Slope angle	Heating	Cooling
Zone 1	90°	$E_{ref,heating} = 212 \cdot g_w - 89 \cdot U_w$	$E_{ref,cooling} = 20 \cdot g_w - 0 \cdot U_w$
	45°	$E_{ref,heating} = 354 \cdot g_w - 89 \cdot U_w$	$E_{ref,cooling} = 53 \cdot g_w - 0 \cdot U_w$
	30°	$E_{ref,heating} = 365 \cdot g_w - 89 \cdot U_w$	$E_{ref,cooling} = 64 \cdot g_w - 0 \cdot U_w$
Zone 2	90°	$E_{ref,heating} = 251 \cdot g_w - 80 \cdot U_w$	$E_{ref,cooling} = 36 \cdot g_w - 1 \cdot U_w$
	45°	$E_{ref,heating} = 444 \cdot g_w - 80 \cdot U_w$	$E_{ref,cooling} = 116 \cdot g_w - 1 \cdot U_w$
	30°	$E_{ref,heating} = 466 \cdot g_w - 80 \cdot U_w$	$E_{ref,cooling} = 138 \cdot g_w - 1 \cdot U_w$
Zone 3	90°	$E_{ref,heating} = 254 \cdot g_w - 36 \cdot U_w$	$E_{ref,cooling} = 120 \cdot g_w - 2 \cdot U_w$
	45°	$E_{ref,heating} = 426 \cdot g_w - 36 \cdot U_w$	$E_{ref,cooling} = 425 \cdot g_w - 2 \cdot U_w$
	30°	$E_{ref,heating} = 437 \cdot g_w - 36 \cdot U_w$	$E_{ref,cooling} = 497 \cdot g_w - 2 \cdot U_w$

Using the above equation, the input data should be

- the U-value calculated according to EN 10077(1-2) or EN 12567 (1-2)
- the U-value of the reference dimension 1230 mm x 1480 mm.
- the U-value for sloped windows must be given for the slope angle
- the g-value for the window, where the g-value for the pane is calculated from EN 610

4. Results

The heating and cooling seasons were calculated for both reference houses in the three climate zones. The three zones are represented by three to four cities each in order to evaluate the climate differences within the zones. The results are shown in Table 6.

Table 6 Calculated solar radiation on vertical and sloped windows and degree hours for the heating and cooling season for the two reference houses used on different locations in Europe.

			Heating season				Cooling season			
			Solar radiation (kWh/m^2)			Degree hours (kKh)	Solar radiation (kWh/m^2)			Degree hours (kKh)
	Location	Ref. House	I_90º	I_45º	I_30º	D	I_90º	I_45º	I_30º	D
Zone 1	**Helsinki**	Type 1	252	420	434	119	16	35	43	0
	Copenhagen	Type 1	203	335	343	88	12	27	34	0
	Frankfurt	Type 1	164	273	281	73	37	105	126	0
	London	Type 1	200	333	342	71	22	63	74	0
Zone 1	**Helsinki**	Type 2	230	382	394	118	14	30	38	0
	Copenhagen	Type 2	227	381	393	90	12	27	34	0
	Frankfurt	Type 2	183	308	317	76	37	104	125	0
	London	Type 2	234	398	413	75	11	32	38	0
Zone 2	**Paris**	Type 1	239	422	443	72	26	78	95	0
	Vienna	Type 1	241	424	445	83	41	130	156	0
	Debrecen	Type 1	235	409	426	83	58	184	219	1
Zone 2	**Paris**	Type 2	265	476	502	75	17	54	65	0
	Vienna	Type 2	269	483	510	85	29	88	106	0
	Debrecen	Type 2	256	449	471	84	48	158	188	1
Zone 3	**Lisbon**	Type 1	283	459	466	33	107	390	458	2
	Rome	Type 1	248	417	430	42	111	388	457	1
	Athens	Type 1	216	366	378	32	161	564	653	4
Zone 3	**Lisbon**	Type 2	302	500	510	34	87	323	379	2
	Rome	Type 2	253	428	442	43	98	340	401	1
	Athens	Type 2	226	383	396	33	157	547	634	4

In order to compare different window solutions, 10 different windows are calculated with the above values. The result is shown in appendix 2.

5. Energy saving potential

The energy saving potential for EU by changing old windows to new improved windows which are found as the best average windows is determined based on the proposed expression (eq. 8 and 9) and the climate data given in Table 7.

The number of old windows in EU, U-values and g-values are assumed as presented in Table 9.

Table 9 Number of windows in EU, assumed U-value and g-value of the old windows /2/ and estimated U-value and g-value of new windows. The window area is estimate as being 15 % of the building area.

Energy saving potential in EU		Number of buildings (mill m²) dwellings	Window area (mill m²) (15 %)	Old windows U-value [W/m²K]	Old windows g-value	New windows U-value [W/m²K]	New windows g-value [-]
North	Before 1975	67	10	3.0	0.58	1.2	0.5
Zone 1	Before 1975, but renovated	266	40				
	1975-1990	102	15	2.0	0.50	1.2	0.5
	1991-2002	86	13	1.6	0.43	1.2	0.5
	2002-2006	43	6				
Baltic	Before 1975	68	10	3.0	0.58	1.2	0.5
Zone 1	Before 1975, but renovated	17	3				
	1975-1990	36	5	2.6	0.50	1.2	0.5
	1991-2002	7	1	2.1	0.50	1.2	0.5
	2002-2006	2	0				
Central Coast	Before 1975	911	137	4.0	0.58	1.2	0.5
Zone 2	Before 1975, but renovated	2125	319				
	1975-1990	840	126	3.5	0.58	1.2	0.5
	1991-2002	633	95	2.0	0.50	1.2	0.5
	2002-2006	187	28				
Central continent	Before 1975	521	78	4.0	0.58	1.2	0.5
Zone 2	Before 1975, but renovated	1216	182				
	1975-1990	480	72	3.5	0.58	1.2	0.5
	1991-2002	362	54	2.0	0.50	1.2	0.5
	2002-2006	107	16				
Poland	Before 1975	189	28	3.5	0.58	1.2	0.5
Zone 2	Before 1975, but renovated	47	7				
	1975-1990	121	18	2.6	0.50	1.2	0.5
	1991-2002	57	9	2.4	0.50	1.2	0.5
	2002-2006	17	3				
Central east	Before 1975	238	36	4.0	0.58	1.2	0.5
Zone 2	Before 1975, but renovated	60	9				
	1975-1990	132	20	3.4	0.58	1.2	0.5
	1991-2002	26	4	3.4	0.58	1.2	0.5
	2002-2006	8	1				
South	Before 1975	599	90	4.2	0.58	1.2	0.5
Zone 3	Before 1975, but renovated	599	90				
	1975-1990	748	112	4.2	0.58	1.2	0.5
	1991-2002	506	76	3.5	0.58	1.2	0.5
	2002-2006	102	15				

Calculating the difference in the net energy gain (both the cooling and heating seasons) shows an energy saving potential of 134,749 GWh per year. See appendix A for the savings in the different zones of EU.

10. Appendix 2 – Evaluation of 10 different windows

An evaluation of 10 different windows and their classification has been calculated in order to study their energy performance in different climates and in order to evaluate the classification.

The technical values are estimated for different panes which are available on the market.

Windows with U-values of 0.8 W/m K are estimated to be triple glazed windows with special gas fillings (Krypton) that are not available as standard solutions for all windows produced in Europe, however they are included in the evaluation to show the performance.

Windows with U-values of 1.0 W/m K are estimated to be triple glazed windows with standard gas fillings (Argon) and low e coatings.

Windows with U-values of 1.2 W/m K and above are estimated to be double glazed windows with standard gas filling (Argon), with low e coatings and with different energy performances of sash and frame.

The glazed area of the windows is estimated to be 80% of the total window area.

Table 10 Technical values for the windows evaluated

Type	U_w [W/m K] vertical window (90°)	U_w [W/m K] roof window (45°)	U_w [W/m K] roof window (30°)	g-value for the pane	g-value for the window
1	0.8	0.95	1.0	0.30	0.24
2	0.8	0.95	1.0	0.40	0.32
3	1.0	1.15	1.2	0.40	0.32
4	1.0	1.15	1.2	0.50	0.40
5	1.2	1.4	1.5	0.50	0.40
6	1.2	1.4	1.5	0.60	0.48
7	1.4	1.6	1.7	0.50	0.40
8	1.4	1.6	1.7	0.60	0.48
9	1.6	1.8	1.9	0.50	0.40
10	1.6	1.8	1.9	0.60	0.48

Table 11 shows the energy performance of the different windows in the heating season for the different locations in Europe. And in the reference document tables 12 & 13 show for skylight at 45 and 30 degree angles which I did not cut and paste. The calculations are based on the numbers from table 6.

The above energy balance equations use a base temperature of 20·°C to slant human expectations to warm and hot climates. Normal base heating degree days for Europe are 18°C (64.4°F) and 65°F degree for the USA

Given Washington's U-factor limit of 0.3 Btu/h·ft2°F =1.7 W/m2·°K
Window type 10 is the best code optimatization for SHGC (g-value)
we can hope for given the U-factor limit of 0.3

Table 11 Vertical windows

Window type	1	2	3	4	5	6	7	8	9	10
U-value - 90 degrees	0.8	0.8	1	1	1.2	1.2	1.4	1.4	1.6	1.6
g-value for the window	0.24	0.32	0.32	0.40	0.40	0.48	0.40	0.48	0.40	0.48
Location/Energy balance [kWh/m²]										
Helsinki	-35	-15	-38	-18	-42	-22	-66	-46	-90	-69
Copenhagen	-21	-5	-23	-6	-24	-8	-41	-25	-59	-43
Frankfurt	-19	-6	-20	-7	-22	-9	-36	-23	-51	-38
London	-8	8	-7	9	-5	11	-19	-3	-33	-17
Helsinki	-39	-21	-44	-26	-49	-31	-73	-54	-96	-78
Copenhagen	-18	0	-18	1	-18	1	-36	-17	-54	-36
Frankfurt	-17	-2	-17	-3	-18	-3	-33	-18	-48	-33
London	-4	15	0	19	4	23	-11	8	-26	-7
Paris	0	19	4	23	9	28	-6	14	-20	-1
Vienna	-9	10	-6	13	-4	16	-20	-1	-37	-18
Debrecen	-10	9	-7	11	-5	14	-22	-3	-38	-19
Paris	4	25	10	31	16	38	1	23	-13	8
Vienna	-4	18	1	22	5	27	-12	10	-29	-8
Debrecen	-6	15	-2	18	1	22	-16	5	-32	-12
Lisbon	42	64	58	80	74	96	67	90	60	83
Rome	26	46	37	57	49	69	41	60	32	52
Athens	26	43	37	54	48	65	41	58	35	52
Lisbon	45	70	63	87	80	104	73	98	67	91
Rome	27	47	39	59	50	71	42	62	33	54
Athens	28	46	39	57	51	69	44	62	37	55

Green	Best performing product
Cyan	2. best performing product
Yellow	3. best performing product
Light orange	4. best performing product
Red	~~Worth~~ performing product

Worst

See ref[44] for the above several pages of screen shots. Looking at table 11 we see that for Washington's building code with a u value of 0.3 Btu/h·ft2°F (1.7 W/m2/yr) then we should have a SHGC above 0.48. However they use a base HHD of 20C for the base temperature which would require more heating then we in Washington are using at 18.3C. And given the SGHCs push higher the higher the u-value is it is hard to say exactly where if the two deltas cancel each other out. Thus this author cannot state where the actual number would land. But given even poor use of interior or exterior shades one quickly determines that a high

[44] www.byg.dtu.dk/~/media/Institutter/Byg/publikationer/byg_rapporter/byg_r201.ashx

SHGC of 0.56 or higher is what is ideal for Washington. I reference this report by the US Dept of Energy which reference human behavior with shades "The deployment schedule for window attachments was developed from the results of a behavioral study, funded jointly by DOE and the Window Attachment Industry (DRI 2013)"[45] However as I mentioned in the code change form this report shows a shocking lack of operational research knowledge not to mention practical knowledge. The latter can be forgiven, the first is unacceptable. There is not a single scenario that the matrix of the more than 16,000 energy analysis runs that covers the end points of potential energy savings let alone practical and inexpensive solutions. The only thing that can be learned is that shades do have benefit which for our climate push the optimal SHGC higher.

How back to the European Commission pending proposal.[46]

Table 29: Energy balance equations for calculating improvement potential

Zone	Heating Season	Cooling Season
Zone 1 (North)	Eref,heating = 212*gw-89*Uw	Eref,cooling – 20*gw-0*Uw
Zone 2 (Central)	Eref,heating = 251*gw-80*Uw	Eref,cooling – 36*gw-1*Uw
Zone 3 (South)	Eref,heating = 254*gw-36*Uw	Eref,cooling – 120*gw-2*Uw

Notes:
Eref,heating: energy performance of the window in the heating season
Eref,cooling: energy performance of the window in the cooling season
gw: solar energy transmittance of the window
Uw: total heat transfer coefficient of the window

Table 30: U and g values for baseline

Zone	U value	G value
Zone 1 (North)	2.19	0.69
Zone 2 (Central)	2.93	0.75
Zone 3 (South)	3.85	0.80

ref[47] = **Figure 1 – Suggested climate zones in the EU**

[45] pg 28/106 http://energy.gov/sites/prod/files/2013/11/f5/energy_savings_from_windows_attachments.pdf at http://energy.gov/eere/buildings/downloads/energy-savings-window-attachments
[46] pg47/107 Sept 2012 http://susproc.jrc.ec.europa.eu/windoors/docs/Windows%20_Doors_Technical_Report_FINAL_240912_131127.pdf

Table 34: Potential Energy Savings for Scenarios

Zone	Scenario	U value (window)	g value (window)	Total savings (GWh) compared to baseline
Zone 1	Baseline	2.19	0.69	N/A
	Scenario 1 (Typical)	1.0	0.46	71422
	Scenario 2 (Typical)	1.4	0.46	30453
	Scenario 3 (Best)	0.90	0.34	55149
Zone 2	Baseline	2.93	0.75	N/A
	Scenario 1 (Typical)	1.65	0.45	20630
	Scenario 2 (Best)	0.90	0.34	40988
Zone 3	Baseline	3.85	0.80	N/A
	Scenario 1 (Typical)	3.5	0.56	(-10669)
	Scenario 2 (Best)	1.95	0.37	3697

ref[48] =

This is an apples to oranges comparisons of u-value and g-value so no specific information to be gained other than this would say Washington SHGC would much higher than 0.46 and less than 0.69 for a Washington prescriptive u-value of 0.3 Btu/h·ft2°F (1.7 W/m2/yr).

US Window Expert John Carmody and the European glass Trade Association "Glass For Europe"

For further evidence for at least a SHGC =0.56 for new construction (and for leaky existing structures even higher) see the November 2012 report fund by the US Dept of Energy called *Measure Guideline: Energy-Efficient Window Performance and Selection*. It is by John Carmody one of the leading technical experts on windows in the USA with Kerry Haglund who use to work for John before he retired. She is now the Executive Director of the Efficient Windows Collaborative and a returning board member of National Fenestration Rating Council.49 A quote from the executive summary of that report

"*Up-to-date information about window products, attributes, and performance is needed in the Building America Program to reach the higher levels of overall energy efficiency that are targeted. Over the last 20 years, window technology and building codes have advanced to the point where low-e windows are commonplace and often required. However, optimizing window technology and related design decisions is not well understood.*[50]

I wonder if the author really meant to say 'not well understood by IECC/US EnergyStar window building code personnel'.

Another quote "*Solar heat gain can provide free heat in the winter but can also lead to overheating in the summer. The best balance of solar heat gain with an appropriate SHGC depends on climate, orientation, shading conditions, and other factors..*"

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[47] Pg82/86 susproc.jrc.ec.europa.eu/windoors/docs/task 3.pdf
[48] pg49/107
http://susproc.jrc.ec.europa.eu/windoors/docs/Windows%20_Doors_Technical_Report_FINAL_240912_131127.pdf
[49] www.efficientwindows.org
[50] http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_windows.pdf

Below is a table for Seattle from that report using the Resfen[51] window modeling program

Table 16. Savings of New Windows in Seattle, Washington

ID	U	SHGC	VT	2009 IECC	2012 IECC	2010 ENERGY STAR	2014 ENERGY STAR	Heat (MBtu)	Cool (kWh)	Total Cost	Annual Savings
11	0.41	0.23	0.49					31	118	$386	$–
15	0.29	0.50	0.57	X	X	X		23	281	$299	$87
16	0.28	0.31	0.52	X	X	X		26	170	$331	$55
17	0.27	0.20	0.46	X	X	X	X	28	111	$352	$34
19	0.19	0.28	0.45	X	X	X	X	25	152	$316	$70

ref=50 118kWh=0.406Mbtu 100kWh=0.341MBTU
Given window ID 15 outperforms window ID 19 even though window 19 has 52% better insulation. 52%=(5.25-3.44)/ 3.44. A lot can be learned from just this apples to oranges comparisons of U-values and SHGCs.

What is the biggest driver? The UK and the Canadian results would say only the proper balance between SHGC and U-value as Window15's SHGC value of 0.5 verses Window 19's lower 0.19 u-value. To say for sure we need the components of an energy balance being broken out, that is heat gain and loss from the u value as summed over an entire year and the same for the SHGC. But the above table is the 2nd best display set of parameters this writer has seen to date. That said having the energy gain (heating) and energy lost (cooling) from a range of U-value and the SHGC is more valuable engineering information and thus thus needed for selecting and appropriate window for Seattle verses Spokane. Not sure if anyone (knowledgeable) believes the latest versions of Resfen or Window[52] can breakout the energy balance but if is so they need to be run to do so. And validated against measured results. Luckily the Canadians are leading the way so Washington will be able to move forward.

Window 15 still saves $87 dollars a year over the baseline with just two thirds of the U-value of ID 19 and is likely cheaper to buy. What is the cost saving for Window 15 with the same u value and external rollers shades under actual usage demographics. How much less winter heating is used for ID15 at the same U-value? And how far does the cooling cost drop with actual measured shade use data with effective solar shades?

I will leave out of the discussion (for now) the fact that a simple external shade with the ability the ability to block solar heat gain can almost completely eliminate the cooling costs related to windows for Seattle residential homes. Surprisingly and unfortunately the consumer cannot buy a decent exterior shade off the shelf, even though the materials to so cheaply are readily available. This author was forced to purchase a $80 8ftx8ft shade at Lowes and replace the material with $10 worth of white "aluminized" fabric sold by numerous "Home Depots for Cannabis Growers" here in Puget Sound. This allows an entire 3000 square foot home with 70% window to floor area ratio (for southern & western rooms) to be cooled with just a single 12kBTU air conditioner for the 2 weeks/year it needs to be ran.

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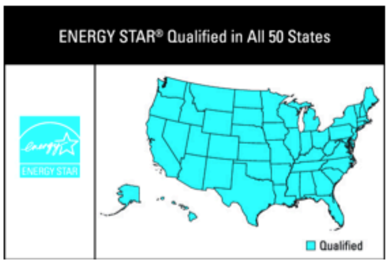
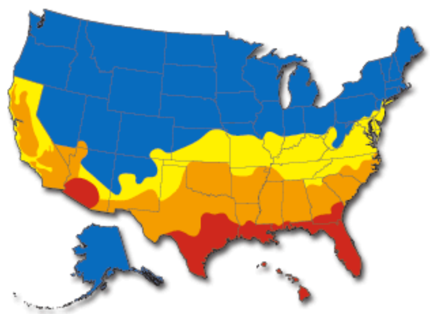
[51] http://windows.lbl.gov/software/resfen/resfen.html
[52] http://windows.lbl.gov/software/window/window.html

The above table 12 work is the latest technical work this author has seen from John Carmody, date November 2012, and might put the results at the Efficient Windows Collaborative somewhat out of date. (If not the Canadian work does) Nevertheless Washington should build on top that work or learn from what has been done there.

John wrote most of the content at the Efficient Windows Collaborative so what does he say for our climate?[53] "Look for a high SHGC window 0.35-0.60" for a u-value of 0.25. That is different from EnergyStar and different from what John published in table 12 above. What

products, use the **NFRC label** or the **NFRC Certified Products Directory**.





Most Efficient 2015
ENERGY STAR www.energystar.gov

ENERGY STAR in Canada

Information and data on this web site follow the U.S. ENERGY STAR criteria. Canada is an international partner in the ENERGY STAR program. The criteria for fenestration in Canada is different than in the United States. For information on products in Canada, see **Natural Resourses Canada.**

Northern Zone Required Properties (mostly heating)			
U-factor	**Solar Heat Gain Coefficient (SHGC)**	**Visible Transmittance (VT)**	**Air Leakage (AL)**
Windows: U≤0.30 Windows: U=0.31 Windows: U=0.32 Skylights: U≤0.55 *EWC Recommendation:* For superior energy performance, use windows with a U-factor of 0.25 or less. If passive solar strategies are to be used, there may be a trade-off with a high SHGC value. If this is the case, make sure proper passive design strategies are implemented (thermal mass, proper shading) to prevent overheating during the summer seasons.	Windows: SHGC=No Requirement Windows: SHGC≥0.35 Windows: SHGC≥0.40 Skylights: SHGC=No Requirement *EWC Recommendation:* If air conditioning is not a concern, look for a high SHGC (0.35-0.60) so that winter solar heat gains can offset a portion of the heating energy need. If cooling is a significant concern and no shading is available, select windows with a SHGC less than 0.35. Select skylights with a SHGC of 0.40 or less.	Windows: VT=No Requirement Skylights: VT=No Requirement *EWC Recommendation:* Select windows with a higher VT to maximize daylight and view.	Windows: AL≤0.30 Skylights: AL≤0.30 *EWC Recommendation:* Select windows with an AL of 0.30 or less.

is correct? I will repeat what John said in his November 2012 Dept of Energy report *However, optimizing window technology and related design decisions is not well understood.*[54]

What does the John Carmody's Efficient Window Collaborative (EWC) say about SHGC for mid and high rise residential buildings a July 2011 report?[55]

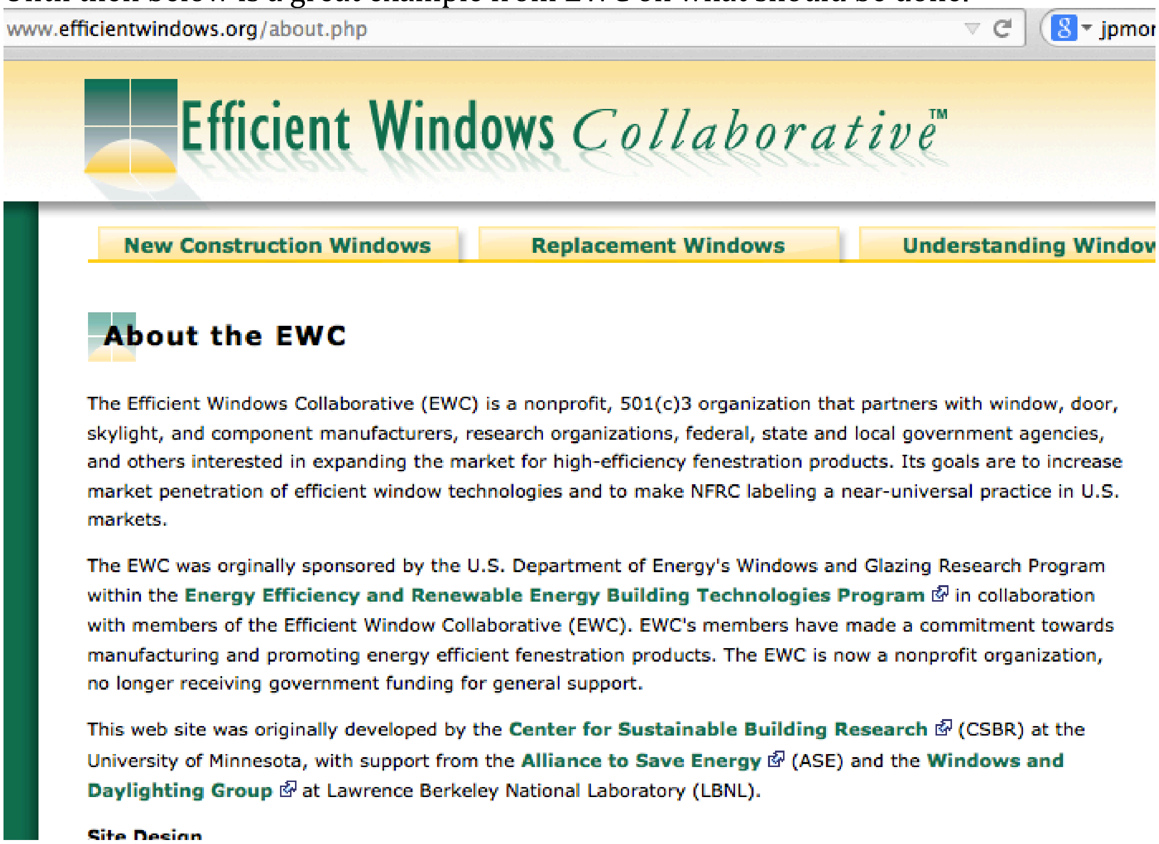
SHGC recommendations
Northern Zone: SHGC ≤0.40
Central and Southern Zones: Specify SHGC ≤0.25

(I say "Carmody's" as he wrote most of or approved the site's content)[56]

[53] www.efficientwindows.org/energystar.php
[54] http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_windows.pdf
[55] from http://energycodesocean.org/resource/windows-mid-and-high-rise-residential-buildings got http://efficient-windows.org/MidHighRiseResidential.pdf
[56] http://www.efficientwindows.org/about.php

The EWC website shows what state building code should strive for a window selection guide which gives results for specific cities for U-value and SHGC for existing and new construction for orientation, number of floors, shading. Extremely unfortunate the Dept. of Energy stopped funding that site a few years ago and instead has been funding research to the tune of +$100 million on dynamic windows. See comments in the SBCC form submitted by Todd Andersen on this topic. Time to get Washington State Senate and House representative to help DOE focus on a coherent research goals at a small faction of the money spent on dynamic windows.

Until then below is a great example from EWC on what should be done.


www.efficientwindows.org/about.php

Efficient Windows Collaborative™

New Construction Windows | Replacement Windows | Understanding Window

About the EWC

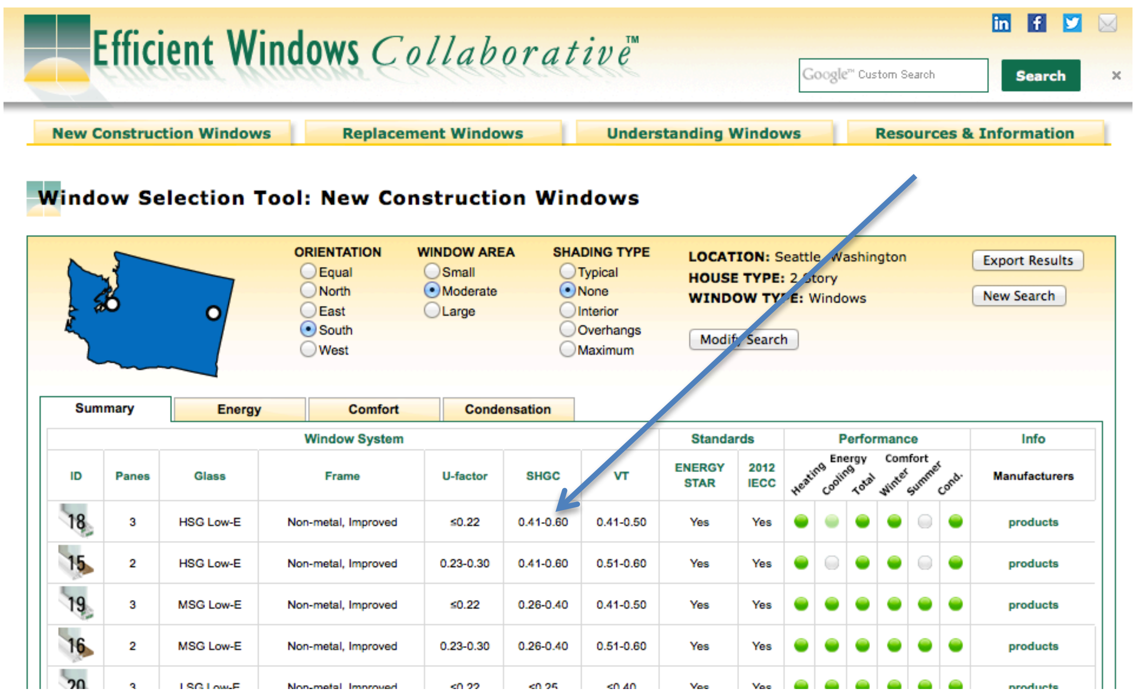
The Efficient Windows Collaborative (EWC) is a nonprofit, 501(c)3 organization that partners with window, door, skylight, and component manufacturers, research organizations, federal, state and local government agencies, and others interested in expanding the market for high-efficiency fenestration products. Its goals are to increase market penetration of efficient window technologies and to make NFRC labeling a near-universal practice in U.S. markets.

The EWC was orginally sponsored by the U.S. Department of Energy's Windows and Glazing Research Program within the **Energy Efficiency and Renewable Energy Building Technologies Program** in collaboration with members of the Efficient Window Collaborative (EWC). EWC's members have made a commitment towards manufacturing and promoting energy efficient fenestration products. The EWC is now a nonprofit organization, no longer receiving government funding for general support.

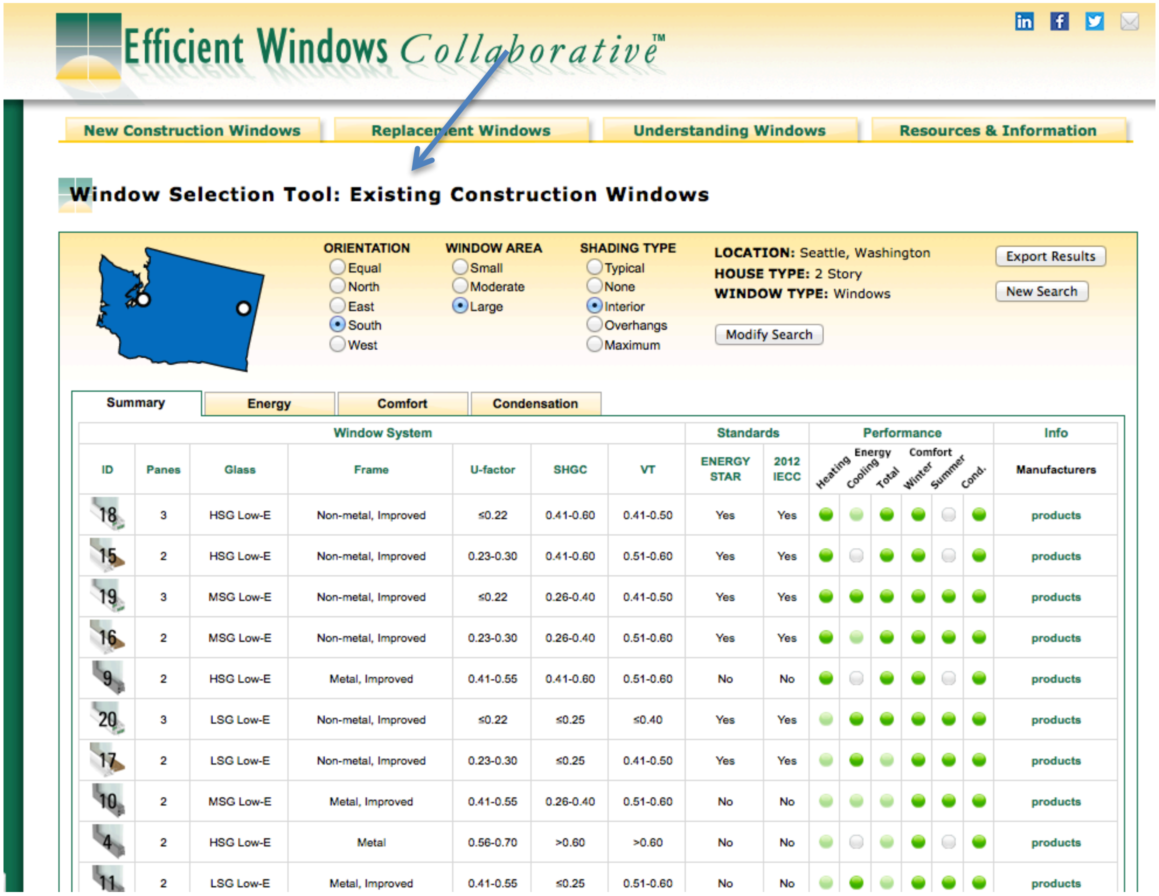
This web site was originally developed by the **Center for Sustainable Building Research** (CSBR) at the University of Minnesota, with support from the **Alliance to Save Energy** (ASE) and the **Windows and Daylighting Group** at Lawrence Berkeley National Laboratory (LBNL).

The EWC has a great window selection tool which Washington State sould validate and include as a source for optimazed building code reqquirements.

Efficient Windows Collaborative™
Search
New Construction Windows
Replacement Windows
Understanding Windows
Resources & Information
Window Selection Tool: New Construction Windows
SELECT ORIENTATION:
Equal
North
East
South
West
SELECT WINDOW AREA:
Small (10%)
Moderate (15%)
Large (20%)
SELECT SHADING TYPE:
Typical
None
Interior
Overhangs
Maximum
Location: Seattle, Washington
House Type: 2 Story
Window Type: Windows
ENERGY STAR Zones | IECC Zones
Energy Costs
Natural Gas: $1.102/therm
Electricity: $0.088/kWh
Additional Tools & Information:
Washington Fact Sheet
State Code Information
Selection Guidance Fact Sheet
«Previous
Next»

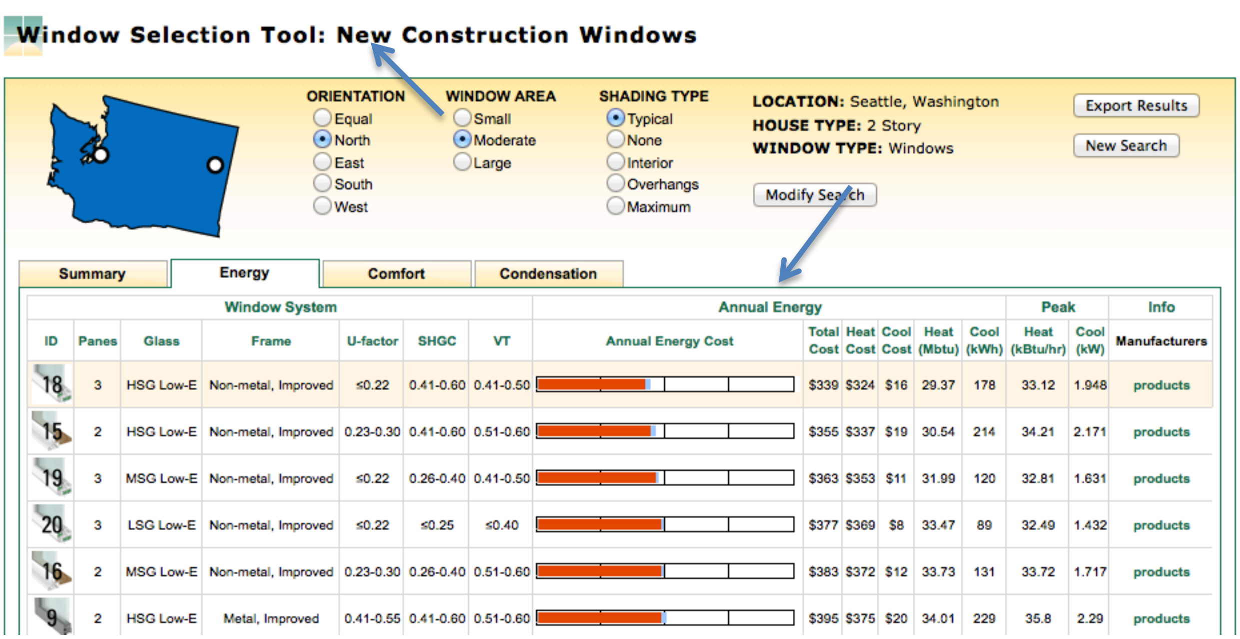


Efficient Windows Collaborative™
Google™ Custom Search
Search
New Construction Windows
Replacement Windows
Understanding Windows
Resources & Information
Window Selection Tool: New Construction Windows
ORIENTATION
Equal
North
East
South
West
WINDOW AREA
Small
Moderate
Large
SHADING TYPE
Typical
None
Interior
Overhangs
Maximum
LOCATION: Seattle, Washington
HOUSE TYPE: 2 Story
WINDOW TYPE: Windows
Modify Search
Export Results
New Search
Summary
Energy
Comfort
Condensation
Window System
Standards
Performance
Info
ID
Panes
Glass
Frame
U-factor
SHGC
VT
ENERGY STAR
2012 IECC
Energy
Heating
Cooling
Total
Comfort
Winter
Summer
Cond.
Manufacturers
18 3 HSG Low-E Non-metal, Improved ≤0.22 0.41-0.60 0.41-0.50 Yes Yes products
15 2 HSG Low-E Non-metal, Improved 0.23-0.30 0.41-0.60 0.51-0.60 Yes Yes products
19 3 MSG Low-E Non-metal, Improved ≤0.22 0.26-0.40 0.41-0.50 Yes Yes products
16 2 MSG Low-E Non-metal, Improved 0.23-0.30 0.26-0.40 0.51-0.60 Yes Yes products

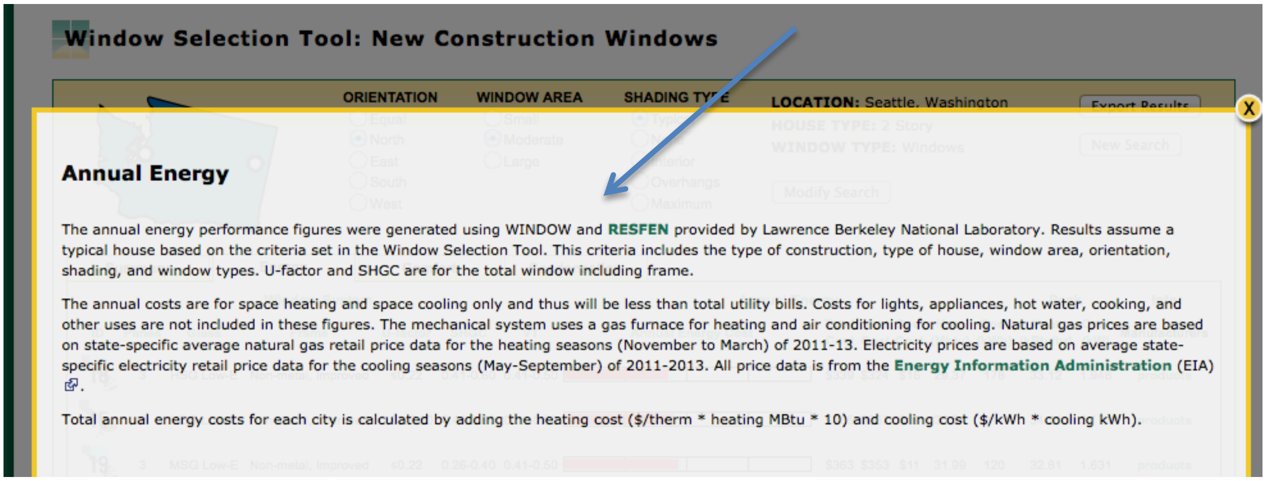


Window System							Standards		Info
ID	Panes	Glass	Frame	U-factor	SHGC	VT	ENERGY STAR	2012 IECC	Manufacturers
18	3	HSG Low-E	Non-metal, Improved	≤0.22	0.41-0.60	0.41-0.50	Yes	Yes	products
15	2	HSG Low-E	Non-metal, Improved	0.23-0.30	0.41-0.60	0.51-0.60	Yes	Yes	products
19	3	MSG Low-E	Non-metal, Improved	≤0.22	0.26-0.40	0.41-0.50	Yes	Yes	products
16	2	MSG Low-E	Non-metal, Improved	0.23-0.30	0.26-0.40	0.51-0.60	Yes	Yes	products
9	2	HSG Low-E	Metal, Improved	0.41-0.55	0.41-0.60	0.51-0.60	No	No	products
20	3	LSG Low-E	Non-metal, Improved	≤0.22	≤0.25	≤0.40	Yes	Yes	products
17	2	LSG Low-E	Non-metal, Improved	0.23-0.30	≤0.25	0.41-0.50	Yes	Yes	products
10	2	MSG Low-E	Metal, Improved	0.41-0.55	0.26-0.40	0.51-0.60	No	No	products
4	2	HSG Low-E	Metal	0.56-0.70	>0.60	>0.60	No	No	products
11	2	LSG Low-E	Metal, Improved	0.41-0.55	≤0.25	0.51-0.60	No	No	products

And a calculation of energy savings



Window System							Annual Energy						Peak		Info
ID	Panes	Glass	Frame	U-factor	SHGC	VT	Annual Energy Cost	Total Cost	Heat Cost	Cool Cost	Heat (Mbtu)	Cool (kWh)	Heat (kBtu/hr)	Cool (kW)	Manufacturers
18	3	HSG Low-E	Non-metal, Improved	≤0.22	0.41-0.60	0.41-0.50		$339	$324	$16	29.37	178	33.12	1.948	products
15	2	HSG Low-E	Non-metal, Improved	0.23-0.30	0.41-0.60	0.51-0.60		$355	$337	$19	30.54	214	34.21	2.171	products
19	3	MSG Low-E	Non-metal, Improved	≤0.22	0.26-0.40	0.41-0.50		$363	$353	$11	31.99	120	32.81	1.631	products
20	3	LSG Low-E	Non-metal, Improved	≤0.22	≤0.25	≤0.40		$377	$369	$8	33.47	89	32.49	1.432	products
16	2	MSG Low-E	Non-metal, Improved	0.23-0.30	0.26-0.40	0.51-0.60		$383	$372	$12	33.73	131	33.72	1.717	products
9	2	HSG Low-E	Metal, Improved	0.41-0.55	0.41-0.60	0.51-0.60		$395	$375	$20	34.01	229	35.8	2.29	products



As the Cana

Views of the European glass trade association - Glass for Europe

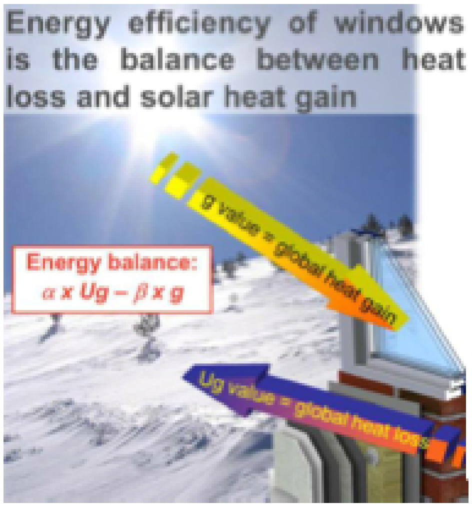
Lets see what European trade association for Europe's manufacturers of flat glass says for a high solar gain requirement? Glass for Europe has four members: AGC Glass Europe, NSG Group, Saint-Gobain Glass and Sisecam/Trakya Cam and works in association with Guardian. [57] They are the major glass makers for a variety of end products such as windows and facades for buildings, windscreens for automotive, solar panels, furniture, electronics, etc. They control more than 80% of Europe glass market which tells me to be vigilant. Nevertheless, They appear to be approaching the problem correctly with approaching the problem of measuring the energy efficiency of windows with an the energy balance equation. That is what is the annual energy consumption balance for the geographic location, size and orientation where new windows are going in.

> "**This is where the concept of energy balance of windows comes in**. Indeed, the energy performance of a window is determined by its energy balance. The energy balance of a window is the difference between heat losses (measured by way of the U-value) and solar heat gains (measured by way of the g-value)." [58]

Here is a figure from the referenced paper.

[57] pg 55of68 , The Smart Use of Glass in Sustainable Buildings 2013. www.glassforeurope.com/images/cont/165_90167_file.pdf

[58] http://www.glassforeurope.com/images/cont/226_16695_file.pdf this is linked inside document from http://www.glassforeurope.com/images/cont/166_92511_file.pdf which was on www.glassforeurope.com/en/statements/energy-efficiency.php listed first as "An integrated policy approach to sustainable buildings"

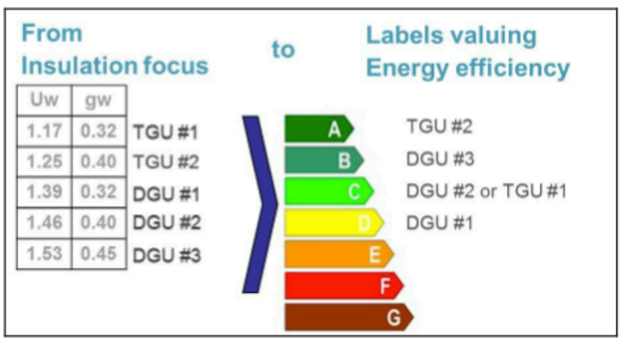


This energy balance is specific to every window and is affected by:

- Its geographical location, which determines the level of solar heat gains and heat losses required for the window. This parameter is the most influential when calculating the energy balance of a window, since it has an impact on both the levels of heat gains and heat losses required.
- Its size: increasing window size increases solar heat gains per m²
- Its orientation (North, East, South or West), which primarily affects solar heat gains

And other screen shot from that paper below.

The figure below shows the difference in energy ratings of 5 modern glazing solutions for UK residential buildings according to the parameter chosen to assess the energy performance: i.e. insulation or energy balance. It demonstrates that a window performance ranking based on the insulation properties would lead to an incorrect performance assessment: although window TGU#1 offers the best, i.e. the lowest, insulation value (Uw), it is in fact a sub-optimal option in terms of overall energy balance.



ref58

Key parameters for an EU energy labelling scheme for windows[59]

✓ The energy performance of a window should take into account the energy balance between heat gain (expressed by the g-value) and heat loss (expressed by the u-value), and should be calculated according to whether the building in which it is to be used is heated only or also air- conditioned.

✓ Europe will need to be divided into several zones to reflect the variety of climatic conditions.

✓ The scope of the scheme should be limited to the residential replacement market only.

✓ Additional parameters such as summer comfort and light transmittance should also be indicated.

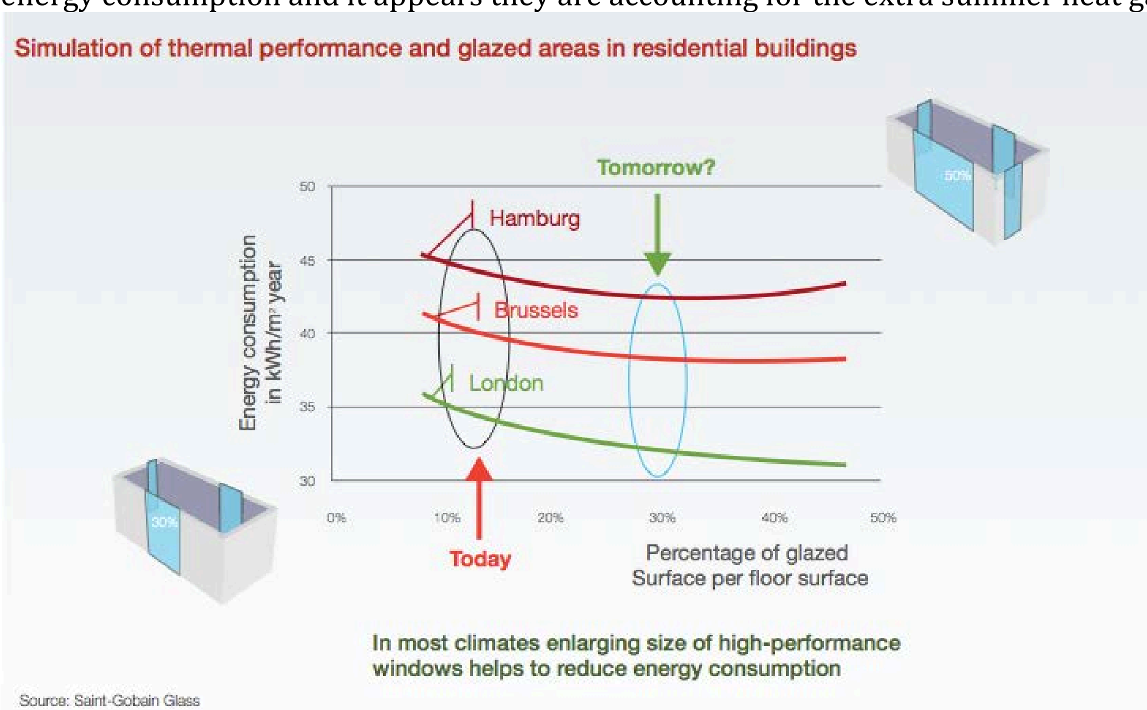
It would appear the UK, Danish and the European Trade Assication for glass are on exactly the same track as to how to specify the energy preformance of a wondow. However it is very interesting to note that glass trade assication prefers to keep such a scheme "limited to the residential replacement market only."

[59] www.glassforeurope.com/images/cont/38_57247_file.pdf found from www.glassforeurope.com/en/statements/energy-efficiency.php see 4th in list

Is a 15% maxiumum window area per floor area the optimal Energy performance code for Washington State?

In the below simulation for three northern cities with roughly the same GHI as Seattle we see that increasing the amount of window area per floor area improves energy performance[60] For London that energy improvement goes from the current 10% to somewhere above 45%. Quite surprising. If true then the Washington State building code prescriptive at a maximum at 15% could be wrong.

Given the massive growth in Puget Sound area it seems a critical point to address immediately. (See Canadian results) For Hamburg and Brussels the current 15% (like WA building code's current upper requirement for residential) would improve until around 30%. There is no specific reference to a specific solar heat gain number and the paper just talks to the solar gain being a positive attribute. If so, there would be a minimum required SHGC number for building codes in cool/cloudy/cold climates. The paper plots the annual energy consumption and it appears they are accounting for the extra summer heat gain



as increased window area would bring as at some point of increasing window area one expects the energy comsumption to go back up. Being a industry policy paper directed to the European governing bodies one would think this analysis would be solid but best to see if independent organizations reach the same conclusions.

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60 Ibid, pg 5of68 www.glassforeurope.com/images/cont/165_90167_file.pdf

What does a Canadian study say?[61] (This is not part of the massive Canadian work noted above as a last minute find)

The below is a very crude modeling showing results for saving energy in the winter but not sure how accurate the modeling is in accounting for all the parameters, particularly convection flows and use shading attachments and normal house venting in the summer. This writer would not trust the results without other verification just based on the how the model would handle the convection flows around a window. Nevertheless the study is instructive as to what to do and not to do for future work for the Washington building code.

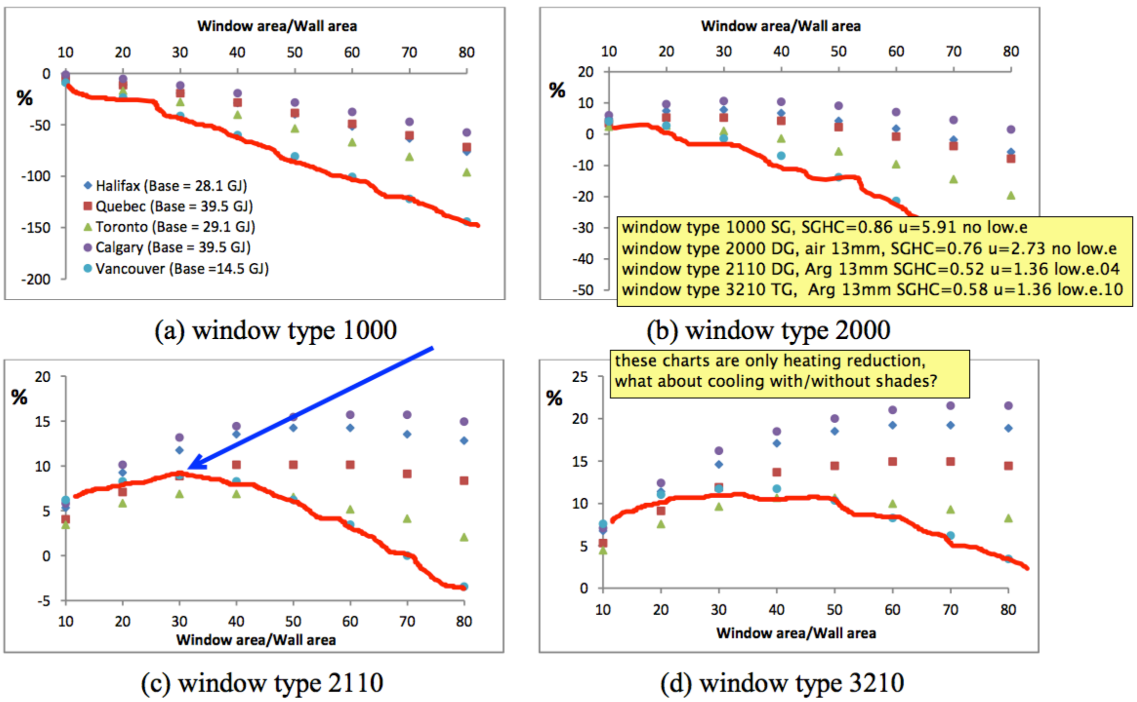

Figure 7. Decrease in annual heating energy requirement (%) due to window enlargement compared to the base case house that has no windows

For Vancouver this report would let us for window type 2110, a double pane window with a SHGC=0.52 and a very low u-value compared to American standards of 1.36 (metric units); the optimal window to floor area peaks at 30%. See blue arrow. Same for a triple pane, window type 3210. But this is for heating only.

Looking at total savings in the figure 8 below for windows with energy performance much better than the new Washington code of u-value at 0.3 (1.7 metric) this highly idealized model shows no energy improvement as all the winter heating saving are wasted on air conditioning in the summer. The report used the Canadian Hybrid Residential End-use Energy and Emission model (CHREM) model and the modeled using the building energy simulation program, ESP-r "a comprehensive building modeling tool based on the finite

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[61] pg13of 14 www.solarbuildings.ca/documents/Effect_of_window_modifications_on_household_energy_requirement_for_heating_and_cooling_in_Canada.pdf

volume" program. ESP-r only ran unshaded windows and no measured shading attachments behavior. Thus the results with unshaded windows and no normal window vending are expected. This work shows increased total energy use for Vancouver for the quality of U-value and SHGC studies and the idealized house. While I would not trust the CHREM part as they modeled many items very crudely. For example I doubt they correctly accounted for all the convection flows around the windows as can be seen in the "figure 2" below.

What is most interesting is that the author chose CHREM.

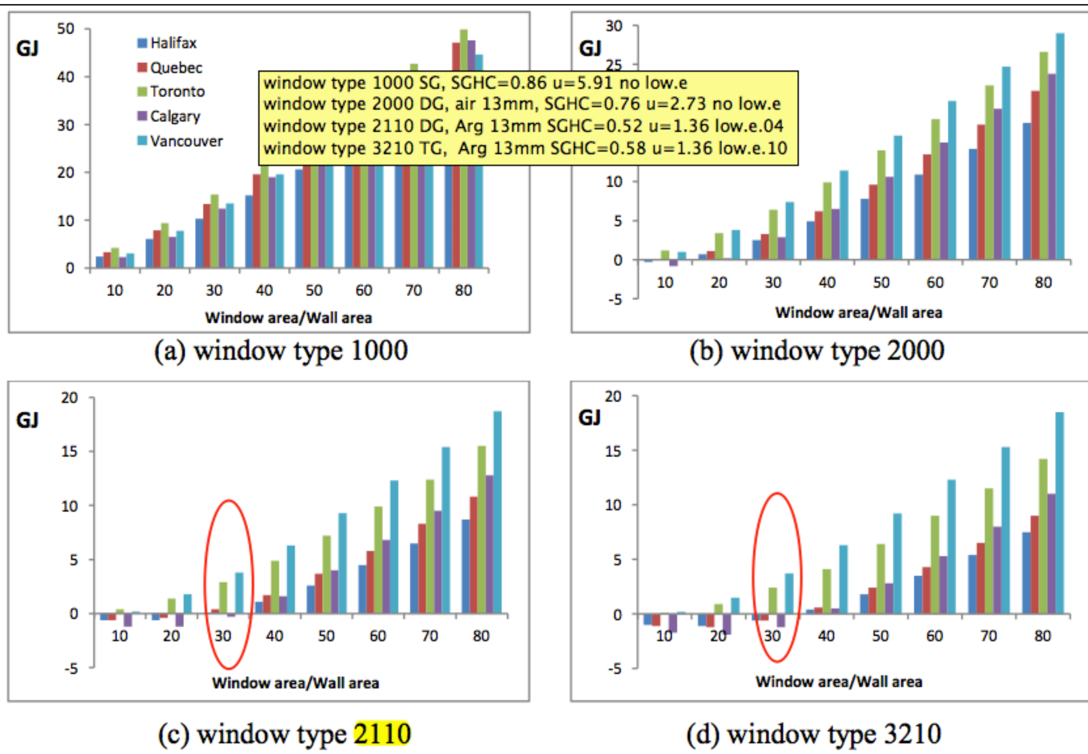


Figure 8. Effect of window enlargement: annual increase in space energy requirement (GJ) (i.e. difference between the increase in cooling energy requirement and the decrease in heating energy requirement) due to window enlargement

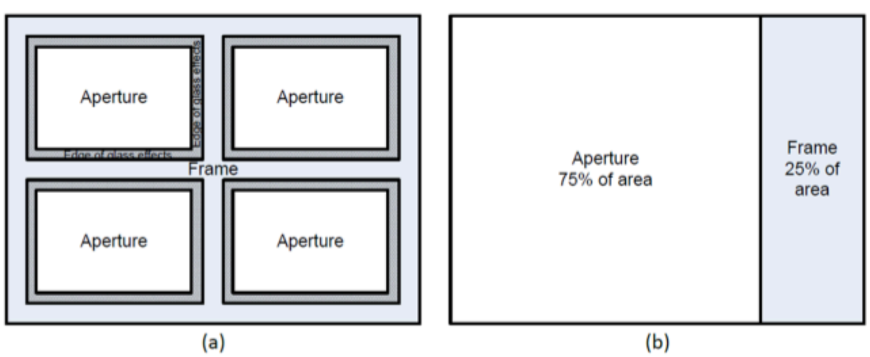


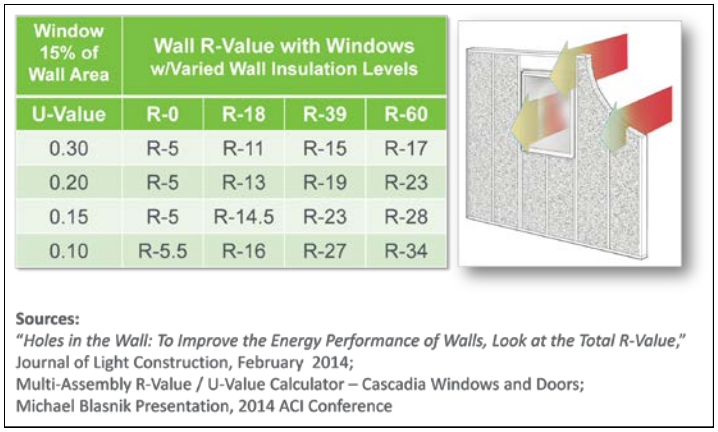
Figure 2. Window aperture and frame relationships for (a) the realistic layout showing the aperture, frame, and "edge of glass effects", and (b) the CHREM modeling representation (Swan, 2010)

This work does not support the Glass For Europe when looking at results for Vancouver. Who is right? The massive Canadian government work way above says the Glass for Europe work is.

It is significant to note that The Northwest Energy Efficiency Alliance NEEA.org only measured heat loss in their otherwise excellent 2011 detailed energy survey of Pacific Northwest homes. Surprisingly missing is heat gain and state-by-state details of window area to floor area demographic in the final reoprt. (might be buried in a database) It did have the overall window area for the four states at 12.5% of conditioned floor area. Focusing on U-value frame type is important and critical but only half or less of the story. Not trading off low-e and SHGC is a huge mistake is causing a lot of energy to be wasted. Understandable given how complex the nature of doing the window energy balance is. Had I not worked on military systems looking at other "windows" in the infrared and visable area for aircraft signature reduction, then even my masters in photonics would not have given me the tools to handle the two way nature (gain & loss) of the energy balance. Without the real world experince that is rarely found outside the conventional US Defense Laboratories (and only because the conventational side has, unfornatately, been validated so often in the real world) I could see myself writing the below article and have the common (and wrong) belief is that windows are just hole energy holes and not energy sources.

http://energycodesocean.org/resource/it%E2%80%99s-window-stupid%E2%80%A6

It's the Window Stupid…
Author: Sam Rashkin
Publication Date: Tuesday, November 4, 2014
A note from Sam Rashkin:
Article from DOE Zero Energy Ready Home Program Update 11/4/2014
I have personally delivered over 25 zero energy ready home (ZERH) training classes across the country. Consistently, one of the biggest "ah-hah" moments in the four-hour course is the huge impact windows have on overall wall assembly performance. Even with just a 15% window-to-floor-area ratio, windows represent a giant thermal hole that disproportionately upsets all the good work you do on the insulated wall assemblies. Who knew? Below is a table I developed that compares the overall R-Value of the entire wall assembly with various cavity insulation levels. Assuming approximately an R-3 window (e.g., U-value = 0.30) representing 15% of the wall area, we can invest substantial cost to increase the wall cavity insulation from R-18 to R-39 with only a marginal increase in the overall wall assembly R-value (e.g., R-11 vs. R-15). In other words, we've more than doubled the wall insulation at substantial cost and only realized about a 33% improvement in overall wall assembly R-value due to the impact of much lower R-value windows. With these same assumptions, we can increase the R-18 insulated wall over 300% to R-60 and only get a 50% improvement in overall wall assembly R-value (e.g., R-11 vs. R-17). Now look at the power of high-R windows. We get nearly the same overall wall assembly R-value with an R-10 window (e.g., U-value = 0.10) and R-18 insulated wall as an R-3 window and R-60 insulated wall (e.g., R-16 vs. R-17). Yes, windows are a really big deal! There is a desperate need for reasonably priced, high-R windows.



Window 15% of Wall Area	Wall R-Value with Windows w/Varied Wall Insulation Levels			
U-Value	R-0	R-18	R-39	R-60
0.30	R-5	R-11	R-15	R-17
0.20	R-5	R-13	R-19	R-23
0.15	R-5	R-14.5	R-23	R-28
0.10	R-5.5	R-16	R-27	R-34

Sources:
"Holes in the Wall: To Improve the Energy Performance of Walls, Look at the Total R-Value," Journal of Light Construction, February 2014;
Multi-Assembly R-Value / U-Value Calculator – Cascadia Windows and Doors;
Michael Blasnik Presentation, 2014 ACI Conference

While accurate in his energy loss description the is no accounting for the energy gain a window can provide.

Sky Scattering - A Background on Solar radiation and the Unusual Properties of Diffuse or scattered energy in Cloudy Environments.   And needed technical info on glass types.

The key point is notice Washington looks significantly than the rest of the country given the cloudy nature of the Washington State, see map page 1. What is this GHI thing? Global Horizontal Radiation is the amount of total solar energy that makes it to the ground[62] Also called Global Horizontal Irradiance or total solar radiation; is the sum of Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), and ground-reflected radiation. Because ground reflected radiation is usually insignificant compared to direct and diffuse (think solar radiation bouncing around the air), for most practical purposes global radiation is said to be the sum of direct and diffuse radiation only. A little more than 1 percent of the sun's energy is at the shorter wavelengths (UV and X-solar radiation) and the rest comes to us at wavelengths in the visible spectrum, about 45 percent.[63] Most of the energy is in the non-visible infrared region at 54 percent. This is important as many of the "accountings" of solar radiation will just cover UV, visible and <u>near</u> infrared skipping the longer or far infrared wavelengths for gain but somehow magically remember to handle it for loss. http://en.wikipedia.org/wiki/Air_mass_%28solar_energy%29
Even the ATSM G-173 standard measures solar intensity over the band 280 to 4000 nm, but leaves out 4 microns (4000 nm) and above[64] While this might be relevant for other applications, like photo-voltaic systems, they are not for building code determinations for windows.

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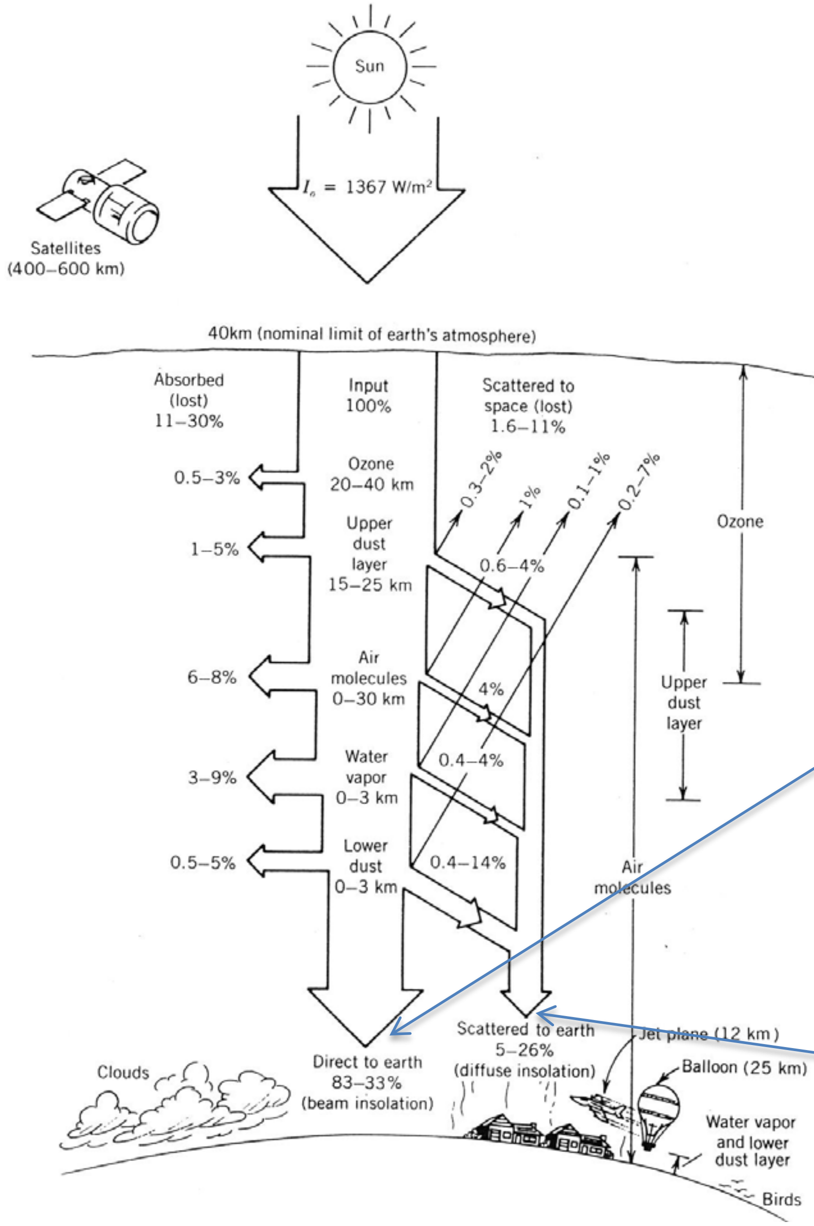
[62] http://rredc.nrel.gov/solar/glossary/gloss_g.html
[63] www.powerfromthesun.net/Book/chapter02/chapter02.html
[64] http://en.wikipedia.org/wiki/Air_mass_%28solar_energy%29   ref 16 of that wiki page =The ASTM G-173 standard measures solar intensity over the band 280 to 4000 nm, but leaves out 4 microns (4000 nm) and above

Why? Because a lot of that energy does not come in directly from the sun shining on them. Surprisingly, a significant portion of that energy comes from the energy bouncing around the atmosphere and not straight line from the sun. Thus in window north facing windows collect a lot more energy than one would naturally expect.



In the winter this direct energy is what comes through the southern windows directly. The lower 33% is too generous for cloudy climates and can be dominated by diffuse energy, as we shall show climates similar to Puget Sound where the direct solar in winter is 10% and diffuse is 90%
This diffuse energy comes in windows from all directions: North, East, West and South.

ref=[70]

An "incoming" energy map or GHI map comes from integrating thousands of subsets of local climates and climate driven energy demand over an entire year and plotting to get GHI. This is what venture capitalists and banks use to fund solar energy projects. For Seattle (SEATAC) clouds and pollution increase scattering and needs to be integrated over the local energy demand drivers temperatures, wind driven like the weather charts farther below detail.

Also key is xxx Need to the below curves for the various types of glass and frequency dependency of angle of incidence (if any). Below is for an example for the atmosphere only.

http://www.ssec.wisc.edu/library/coursefiles/03_abs_emiss_ref.pdf

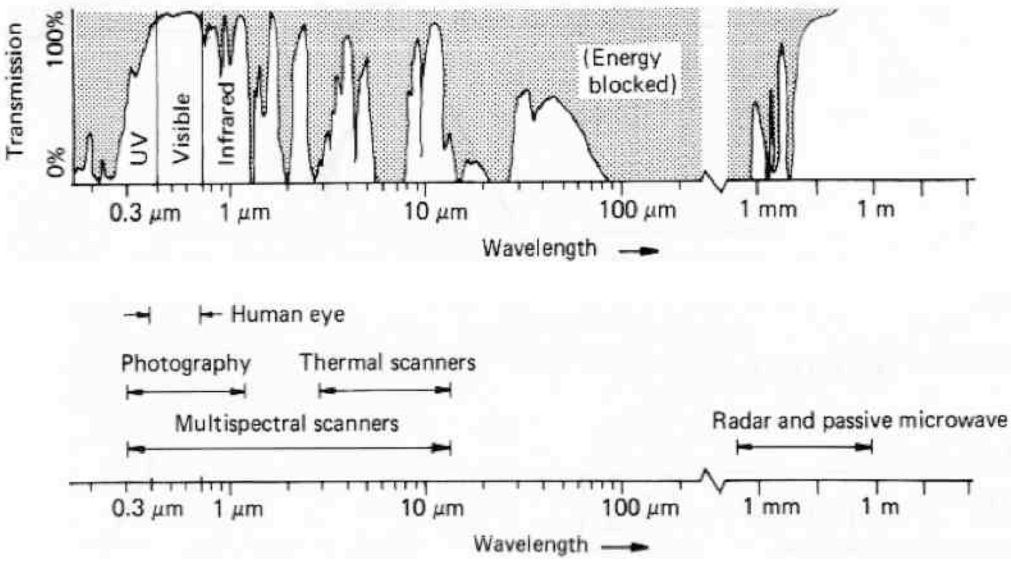


Figure 3.8b: Atmospheric transmission characteristics and the associated remote sensing technologies.

Figure 3.8b Atmospheric transmission characteristics and the associated remote sensing technologies

Need higher fidelity curves than below and out to 20 microns. Note the below figure have the decimal point missing between the digits as this chart is 0.3-2.3 microns. It is incorrectly labeled as 3-23 microns. This author believes, with the data to date, that clear glass is the most energy efficent way way to go, and has done so for his home with true solar blocking external shade. And with cheap semi automated external shades how much better does the energy saving get at night in the winter?

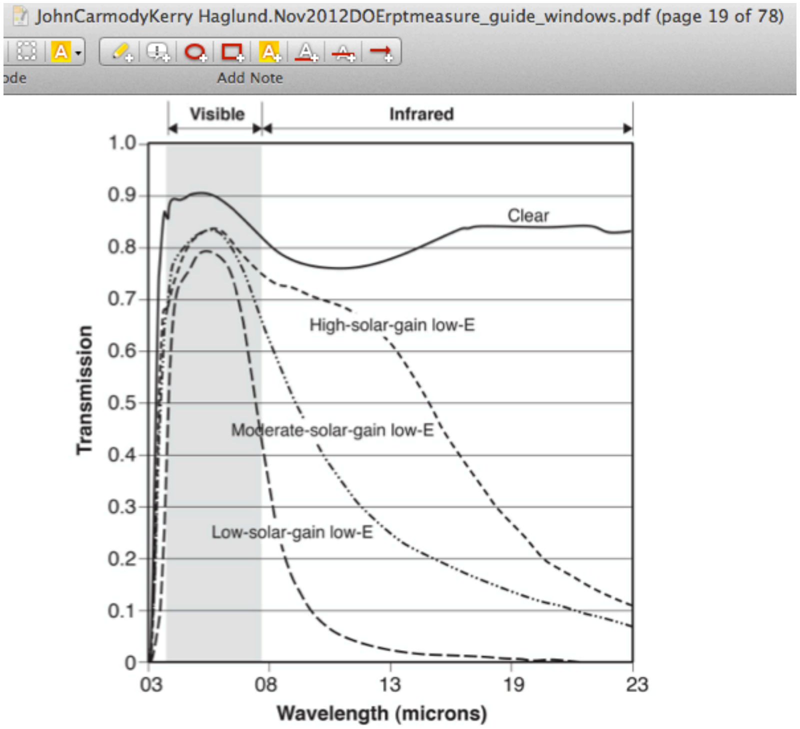
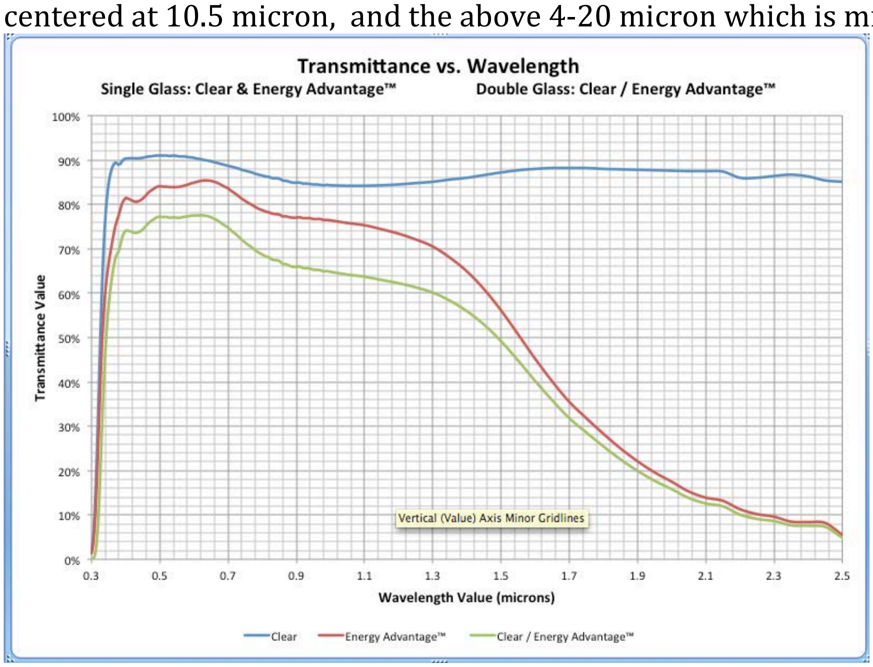
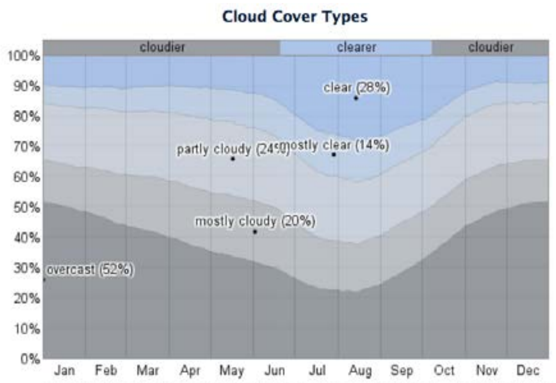


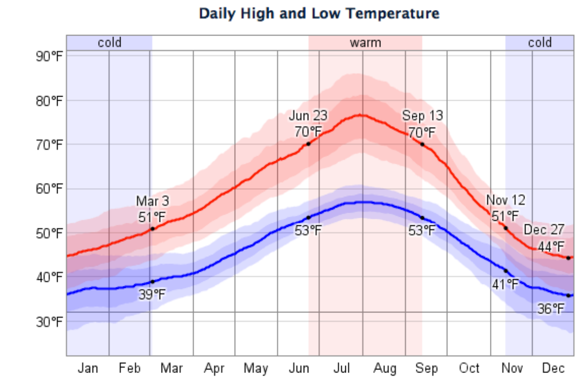
Figure 9. Spectral transmittance curves for glazings with low-e coatings

here is what Pilkington Glass has. But again the "action" for black body raditation at 70F is centered at 10.5 micron, and the above 4-20 micron which is missing.



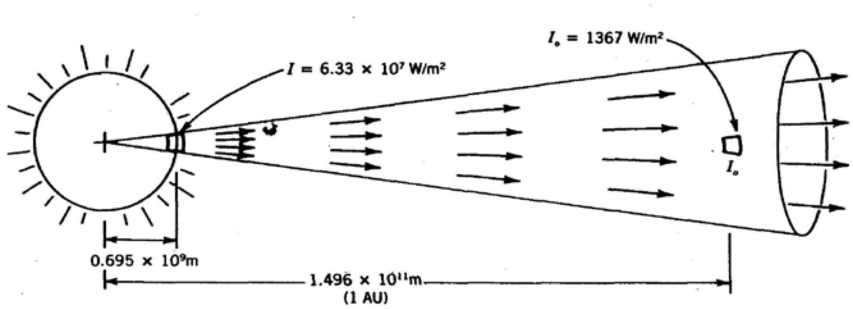


The fraction of time spent in each of the five sky cover categories. From top (most blue) to bottom (most gray), the categories are clear, mostly clear, partly cloudy, mostly cloudy, and overcast. Pink indicates missing data. Outside of the United States clear skies are often reported ambiguously, leading them to be lumped in with the missing data.

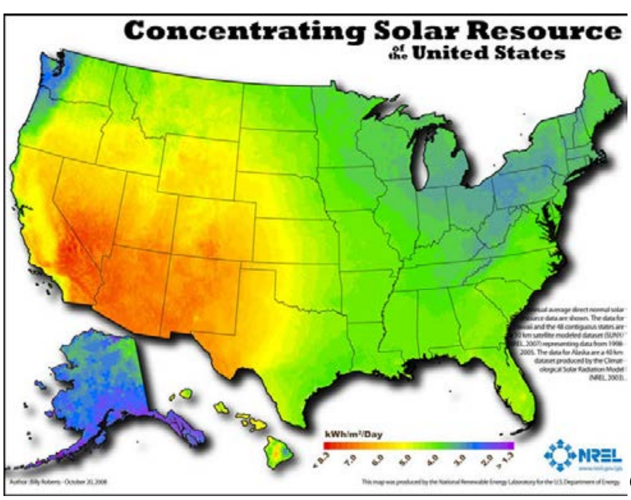


The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

Take thousands of these local annual temperature and cloud cover densities and integrate with the overall solar energy hitting the earth of 1367 W/square meter as depicted in this figure.



The divergence of energy from the sun to the earth.[65]



66

Let compare the above maps of just direct normal solar energy or Direct Normal Irradiance (DNI) mentioned above to the final total solar energy hitting the ground (straight line DNI + diffuse DHI) or the GHI.[67] Subtract the left map DNI from the right map GHI and you get the

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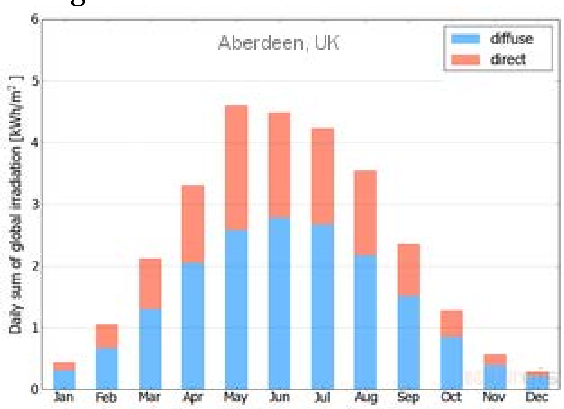
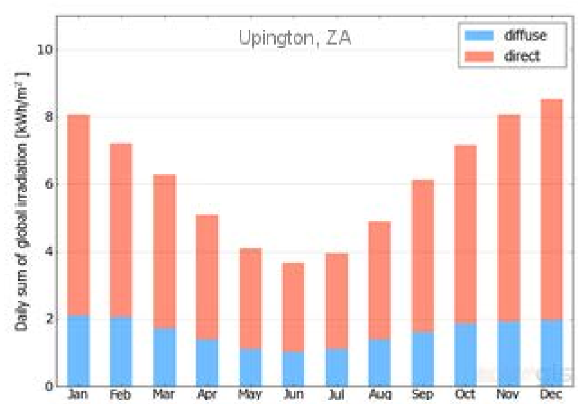
65 www.powerfromthesun.net/Book/chapter02/chapter02.html 2.1.1 The Solar Constant
66 www.nrel.gov/gis/mapsearch/ http://en.openei.org/w/index.php?title=File:NREL-map-csp-national-lo-res.jpg
67 http://solargis.info/doc/solar-and-pv-data#GHI

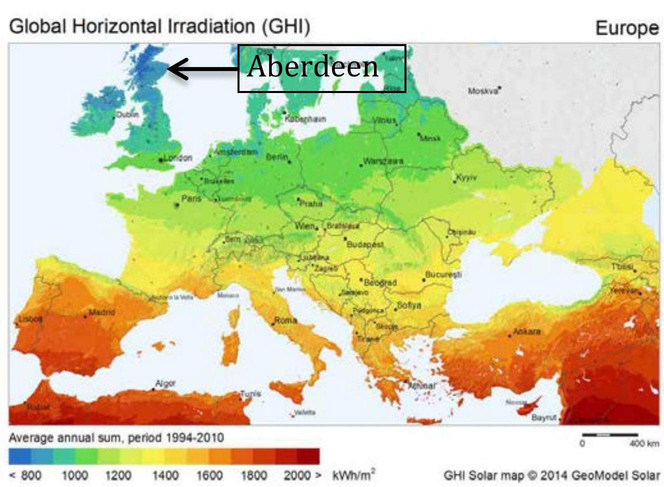
amount bouncing around the atmosphere and then hitting the ground. Thus a lot more energy hits the north side of your house than you might expect.

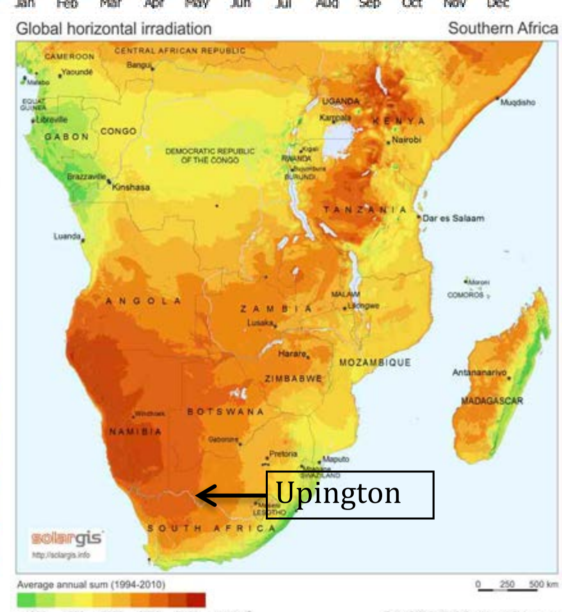
Consider the ratio of direct and indirect/diffuse energy. or Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI). DNI is the amount of direct solar radiation from the straight line from the sun. Diffuse or DHI is defined the radiation component that strikes a point from the sky, excluding circumsolar radiation (which is a disc around the sun 5 to 7 time bigger in diameter the actual visible diameter.[68] In the absence of atmosphere, there should be almost no DHI. High DHI values are produced by an unclear atmosphere (pollution and/or dust) or reflections from clouds. What is going on is very complex as the scattering figure two gages above details.[69]

Lets take a look at real numbers of direct and diffuse radiation over and entire year for a area which is cloudy roughly 85% of the time Aberdeen Scotland and a much hotter and much more cloud free area, Upington South Africa which is cloudy only 25% of the time. See the figures below for both locations. [70]









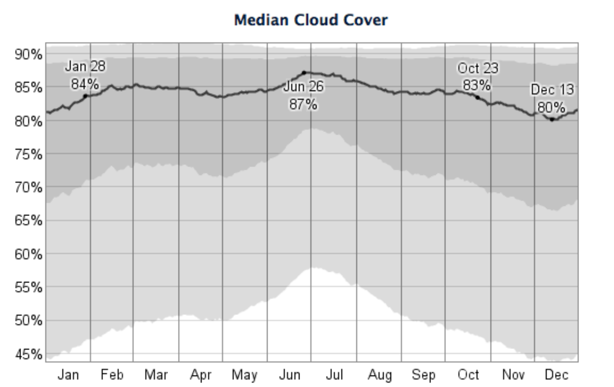
[68] http://rredc.nrel.gov/solar/glossary/gloss_d.html#directnormalirradiance
[69] www.powerfromthesun.net/Book/chapter02/chapter02.html
[70] http://solargis.info/doc/solar-and-pv-data#GHI http://solargis.info/doc/free-solar-radiation-maps-GHI http://solargis.info/doc/_pics/freemaps/1000px/ghi/SolarGIS-Solar-map-Europe-en. png

The ratio between DHI and DIF can be variable in time and spatial context. It plays an important role when comparing various technology options i.e. cSi vs aSi, concentrating solar power (CSP) vs Concentrating Photovoltaic (CPV), etc. And as we shall see, the diffuse energy is also very important for setting building codes for windows. The below figure shows that in a heavily cloudy location of Aberdeen Scotland, the energy hitting Northern windows is from the blue bars below which sums to the 60% percent portion of all the annual energy, which delivers much more energy to “shaded” northern windows. In the winter up to 90% of the energy hitting windows is diffuse making its solar heat gain coefficient very important and making windows clear or transparent for those frequencies bands with the highest SHGC the most energy conservation choice. Having a “no requirement” for SHGC is an unwise building code and not scientifically or economically defendable for our Washington State climate .

Missing graph of Solar heat gain for buildings

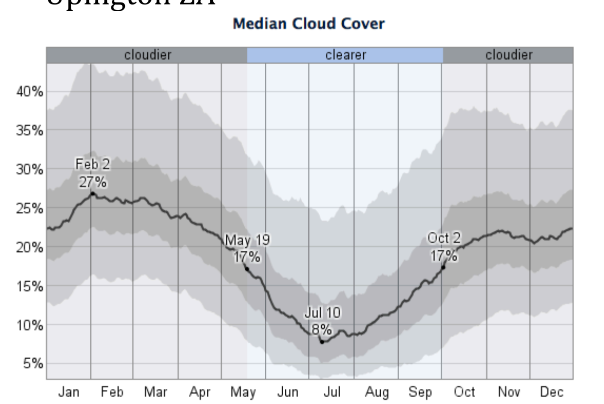
https://weatherspark.com/averages/28750/Aberdeen-Scotland-United-Kingdom

Aberdeen UK



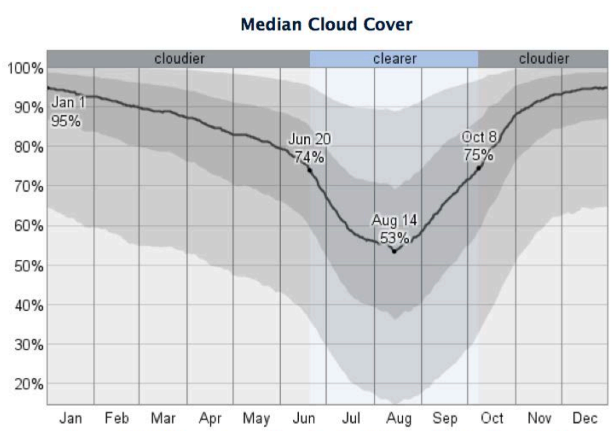
The median daily cloud cover (black line) with percentile bands (inner band from 40th to 60th percentile, outer band from 25th to 75th percentile).

Upington ZA

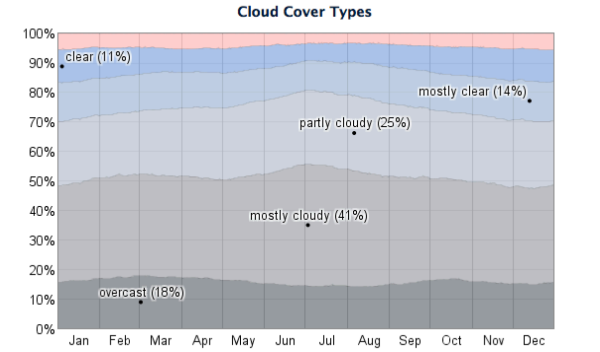


The median daily cloud cover (black line) with percentile bands (inner band from 40th to 60th percentile, outer band from 25th to 75th percentile).

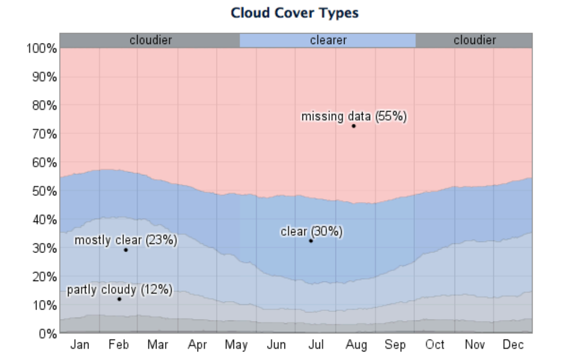
SeaTac



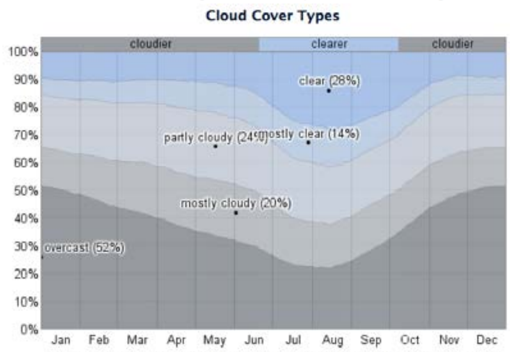
The median daily cloud cover (black line) with percentile bands (inner band from 40th to 60th percentile, outer band from 25th to 75th percentile).



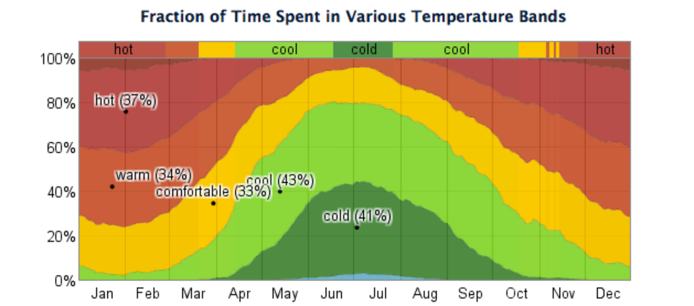
The fraction of time spent in each of the five sky cover categories. From top (most blue) to bottom (most gray), the categories are clear, mostly clear, partly cloudy, mostly cloudy, and overcast. Pink indicates missing data. Outside of the United States clear skies are often reported ambiguously, leading them to be lumped in with the missing data.



The fraction of time spent in each of the five sky cover categories. From top (most blue) to bottom (most gray), the categories are clear, mostly clear, partly cloudy, mostly cloudy, and overcast. Pink indicates missing data. Outside of the United States clear skies are often reported ambiguously, leading them to be lumped in with the missing data.



The fraction of time spent in each of the five sky cover categories. From top (most blue) to bottom (most gray), the categories are clear, mostly clear, partly cloudy, mostly cloudy, and overcast. Pink indicates missing data. Outside of the United States clear skies are often reported ambiguously, leading them to be lumped in with the missing data.



The average fraction of time spent in various temperature bands: frigid (below 15°F), freezing (15°F to 32°F), cold (32°F to 50°F), cool (50°F to 65°F), comfortable (65°F to 75°F), warm (75°F to 85°F), hot (85°F to 100°F) and sweltering (above 100°F).

SEATAC

Upington South Africa

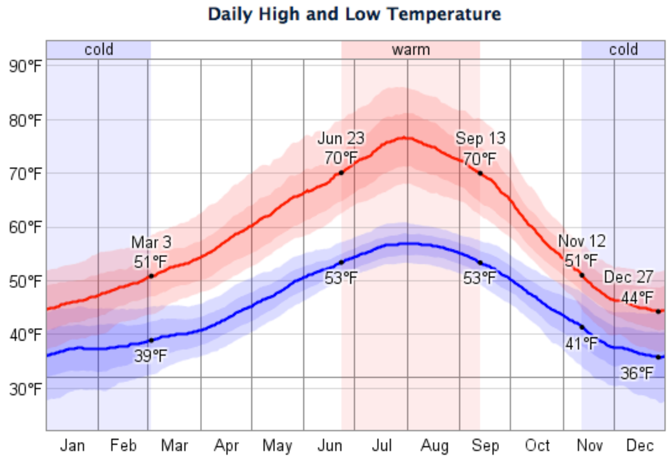
https://weatherspark.com/averages/29735/Seattle-Washington-United-States

This report describes the typical weather at the Seattle-Tacoma International Airport (Seattle, Washington, United States) weather station over the course of an average year. It is based on the historical records from 1974 to 2012. Earlier records are either unavailable or unreliable.

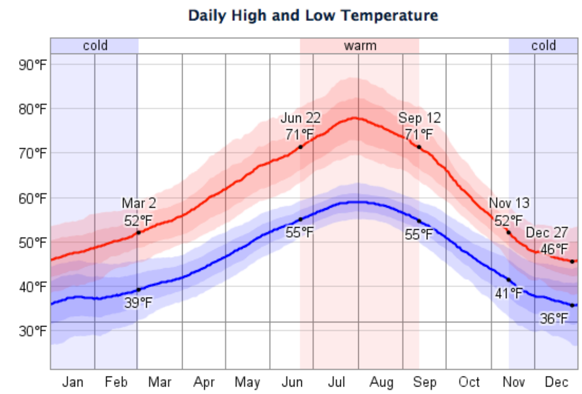
Seattle, Washington has a mediterranean climate with dry warm summers and mild winters. The area within 25 miles of this station is covered by forests (61%), built-up areas (17%), oceans and seas (17%), and croplands (4%).

SEATAC

Boeing Field

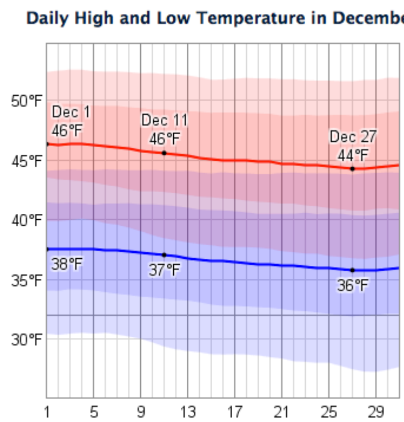


The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

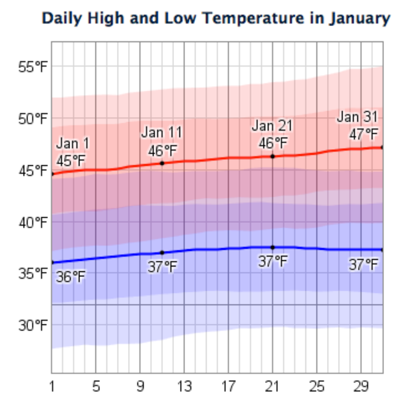


The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

and average monthly for Dec and Jan SEATAC



The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

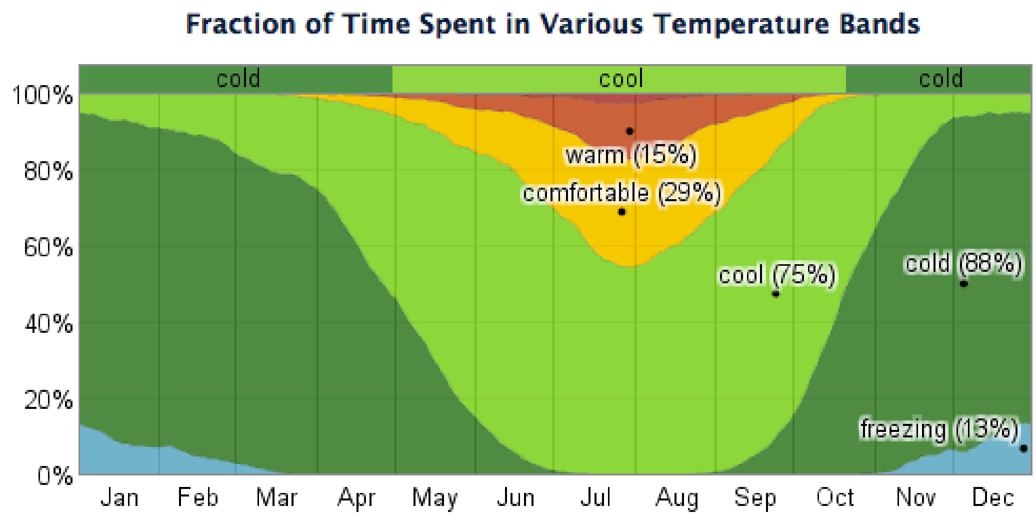


The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

Going forward with SEATAC info

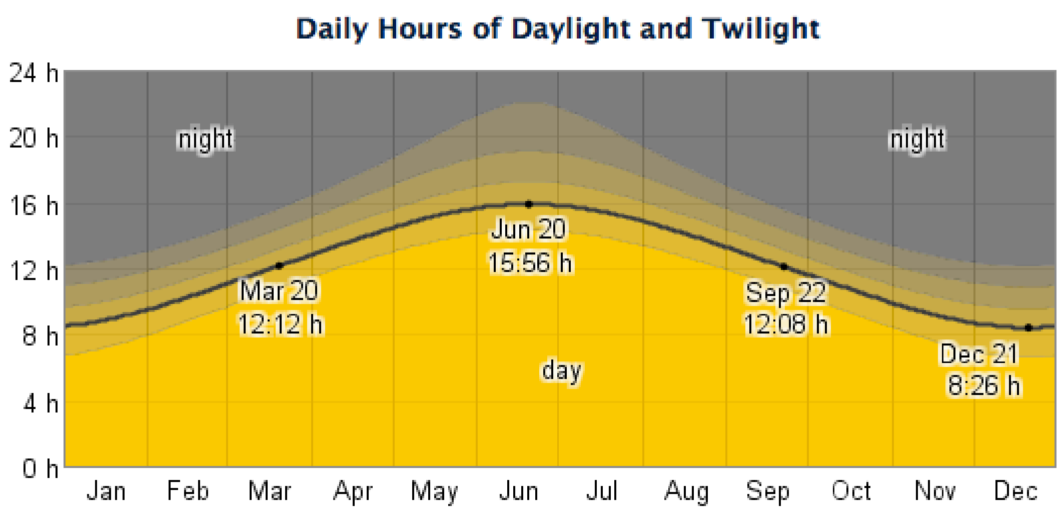
The warm season lasts from June 23 to September 13 with an average daily high temperature above 70°F. The hottest day of the year is July 30, with an average high of 77°F and low of 57°F.

The cold season lasts from November 12 to March 3 with an average daily high temperature below 51°F. The coldest day of the year is December 27, with an average low of 36°F and high of 44°F.



The average fraction of time spent in various temperature bands: frigid (below 15°F), freezing (15°F to 32°F), cold (32°F to 50°F), cool (50°F to 65°F), comfortable (65°F to 75°F), warm (75°F to 85°F), hot (85°F to 100°F) and sweltering (above 100°F).

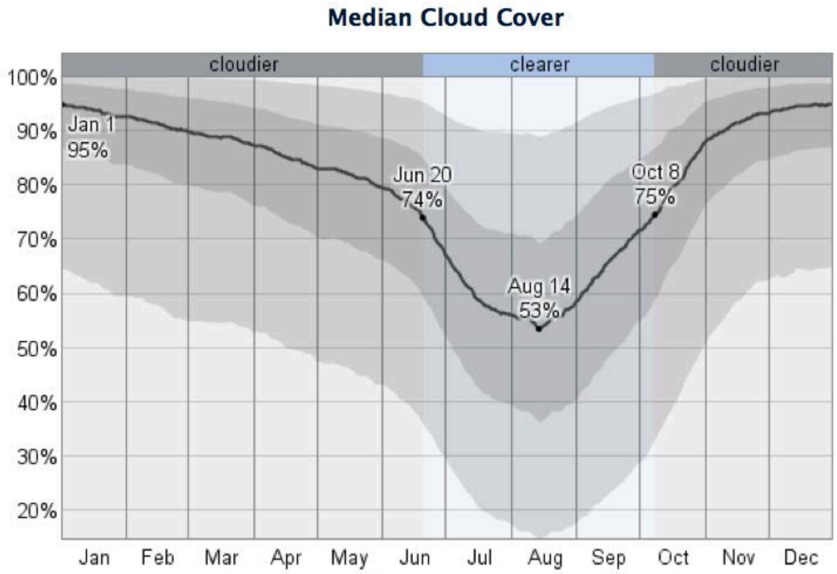
SEATAC info – above & below



The number of hours during which the Sun is visible (black line), with various degrees of daylight, twilight, and night, indicated by the color bands. From bottom (most yellow) to top (most gray): full daylight, solar twilight (Sun is visible but less than 6° from the horizon), civil twilight (Sun is not visible but is less than 6° below the horizon), nautical twilight (Sun is between 6° and 12° below the horizon), astronomical twilight (Sun is between 12° and 18° below the horizon), and full night.

The length of the day varies significantly over the course of the year. The shortest day is December 21 with 8:26 hours of daylight; the longest day is June 20 with 15:56 hours of daylight
The earliest sunrise is at 5:11am on June 13 and the latest sunset is at 9:11pm on June 28. The latest sunrise is at 7:57am on November 3 and the earliest sunset is at 4:18pm on December 12.

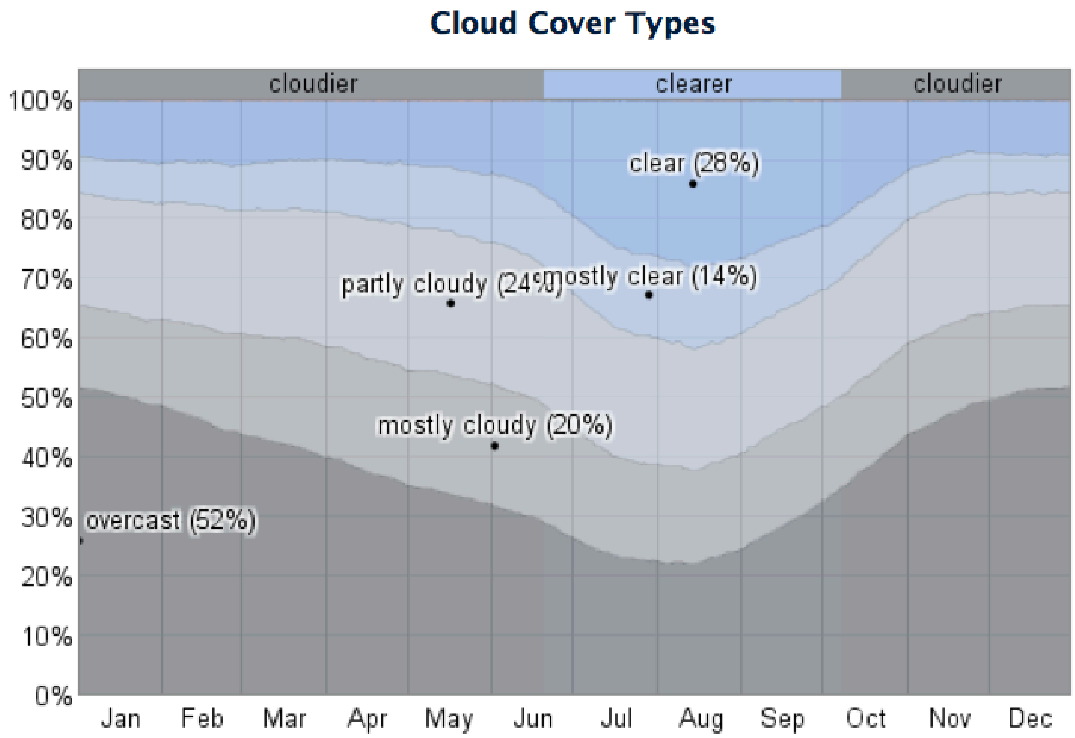
Daylight savings time (DST) is observed in this location during 2012, starting in the spring on March 11 and ending in the fall on November 4.



The median daily cloud cover (black line) with percentile bands (inner band from 40th to 60th percentile, outer band from 25th to 75th percentile).

SEATAC info – above & below

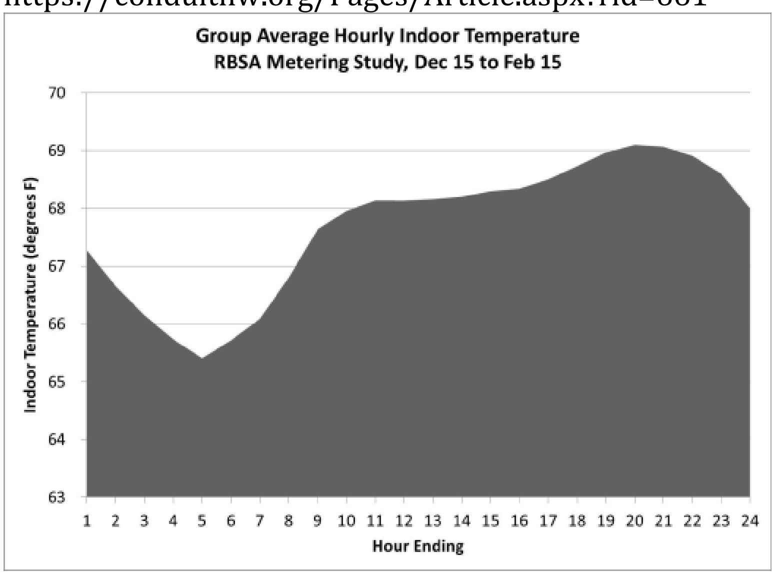
The median cloud cover ranges from 53% (partly cloudy) to 95% (mostly cloudy). The sky is cloudiest on January 1 and clearest on August 14. The clearer part of the year begins around June 20. The cloudier part of the year begins around October 8.
On August 14, the clearest day of the year, the sky is clear, mostly clear, or partly cloudy 62% of the time, and overcast or mostly cloudy 38% of the time.
On January 1, the cloudiest day of the year, the sky is overcast, mostly cloudy, or partly cloudy 85% of the time, and clear or mostly clear 15% of the time.



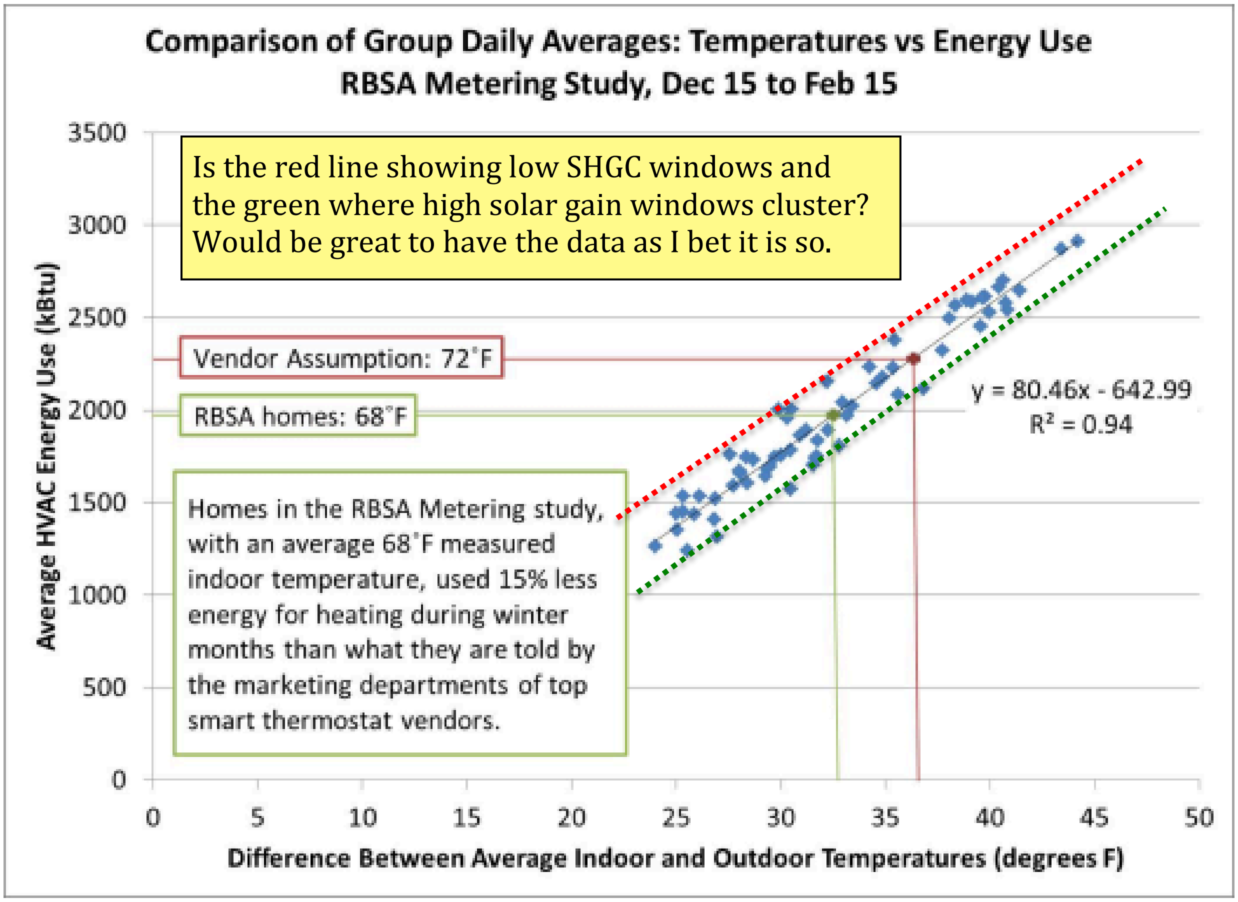
The fraction of time spent in each of the five sky cover categories. From top (most blue) to bottom (most gray), the categories are clear, mostly clear, partly cloudy, mostly cloudy, and overcast. Pink indicates missing data. Outside of the United States clear skies are often reported ambiguously, leading them to be lumped in with the missing data.

SEATAC info – above

Here is NEEA.org data for residential temperature for the winter.
https://conduitnw.org/Pages/Article.aspx?rid=661



And another chart from NEEA.org data, that id the SHGC of the windows was available along with the leakiness of the house might shed further light on the best prescriptive SHGC.

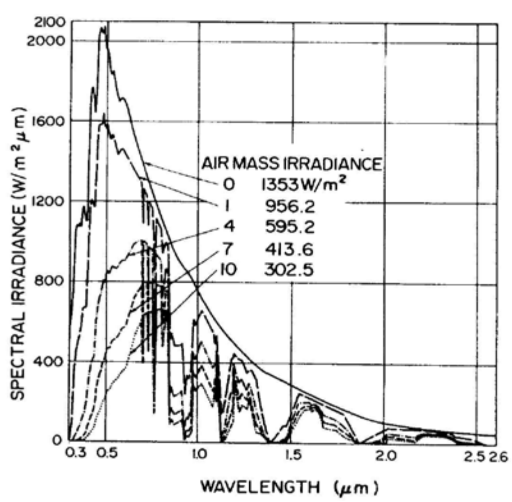


Random items / Issues with THERM 6.3 / WINDOW 6.3 Simulation program

http://en.wikipedia.org/wiki/Air_mass_%28solar_energy%29

Solar intensity vs zenith angle z and airmass coefficient AM

z	AM	range due to pollution[12]	formula (I.1)	ASTM G-173[11]
degree		W/m²	W/m²	W/m²
-	0	1367[15]	1353	1347.9[16]
0°	1	840 .. 1130 = 990 ± 15%	1040	
23°	1.09	800 .. 1110 = 960 ± 16%[17]	1020	
30°	1.15	780 .. 1100 = 940 ± 17%	1010	
45°	1.41	710 .. 1060 = 880 ± 20%[17]	950	
48.2°	1.5	680 .. 1050 = 870 ± 21%[17]	930	1000.4[18]
60°	2	560 .. 970 = 770 ± 27%	840	
70°	2.9	430 .. 880 = 650 ± 34%[17]	710	
75°	3.8	330 .. 800 = 560 ± 41%[17]	620	
80°	5.6	200 .. 660 = 430 ± 53%	470	
85°	10	85 .. 480 = 280 ± 70%	270	
90°	38		20	



16= The ASTM G-173 standard measures solar intensity over the band 280 to 4000 nm

18=The ASTM G-173 standard measures solar intensity under "rural aerosol loading" i.e. clean air conditions - thus the standard value fits closely to the maximum of the expected range.

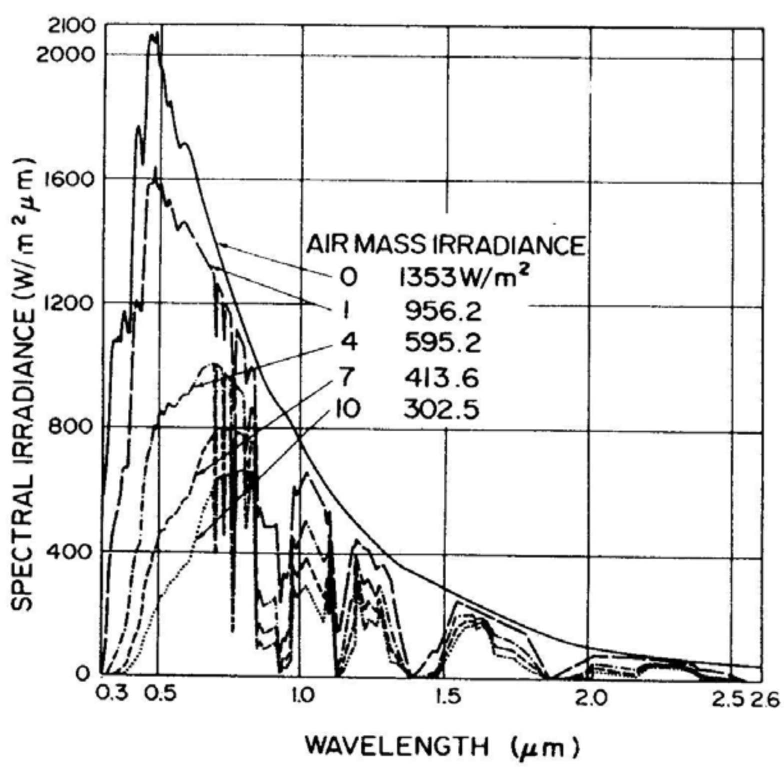
http://www.newport.com/Introduction-to-Solar-Radiation/411919/1033/content.aspx

Table 1 Power Densities of Published Standards

Solar Condition	Standard	Power Density (Wm^{-2})		
		Total	250 - 2500 nm	250 - 1100 nm
	WMO Spectrum	1367		
AM 0	ASTM E 490	1353	1302.6	1006.9
AM 1	CIE Publication 85, Table 2		969.7	779.4
AM 1.5 D	ASTM E 891	768.3	756.5	584.7
AM 1.5 G	ASTM E 892	963.8	951.5	768.6
AM 1.5 G	CEI/IEC* 904-3	1000	987.2	797.5

* Integration by modified trapezoidal technique
CEI = Commission Electrotechnique Internationale
IEC = International Electrotechnical Commission

http://www.powerfromthesun.net/Book/chapter02/chapter02.html



The author finds this NFRC graph troubling and two fronts. The first is just the simple magnitude error of the 75F blackbody. But the more important is the all the energy in the near infrared, mid infrared and long infrared which is not accounted for at least in high level over view form.

Issues with THERM 6.3 / WINDOW 6.3 Simulation program

THERM6.3/WINDOW6.3 NFRC Simulation Manual January 2014 2-11

2.6 Improved Glazing Products 2. FENESTRATION PRODUCTS

the 75F peak is centered correct but too large in magnitude by 1 million fold

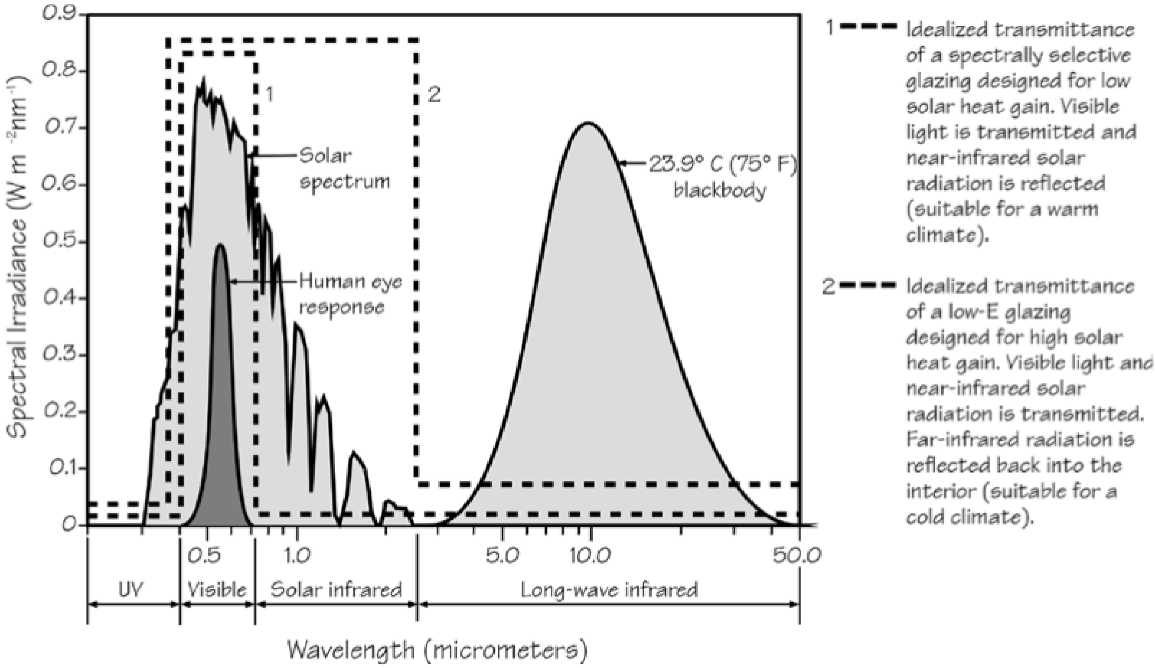
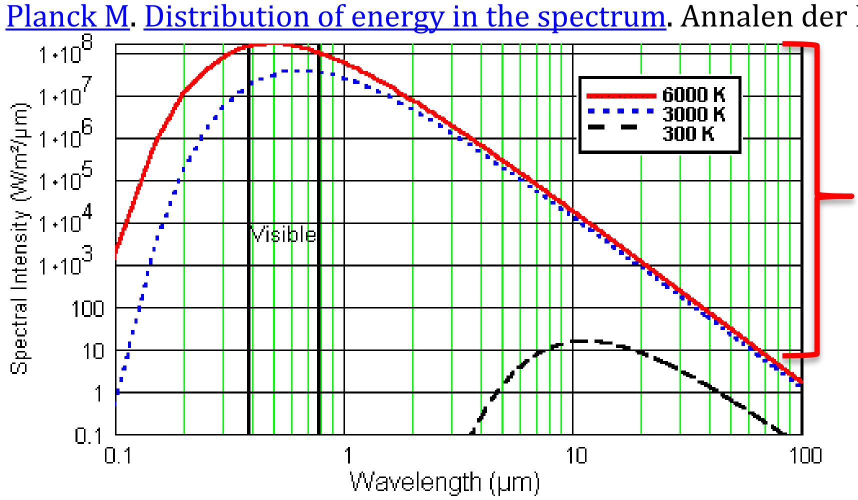


Figure 2-3. Ideal spectral transmittance for glazings in different climates. (Source: "Sensitivity of Fenestration Solar Gain to Source Spectrum and Angle of Incidence." ASHRAE Transactions 10, R. McCluney, June 1996).

http://pveducation.org/pvcdrom/properties-of-sunlight/blackbody-radiation

Planck M. Distribution of energy in the spectrum. Annalen der Physik. 1901 ;4:553-563.



A one million fold magnitude error in representing. Hopefully that is the only error. But given how hard it is to find validation against measured results this reviewer is left wanting

Below is the original graph from Ross McCluney 1996 work which he sent to this author. Notice it is properly labeled. And the red represents a crude representation of the proper magnitude for blackbody at 75F

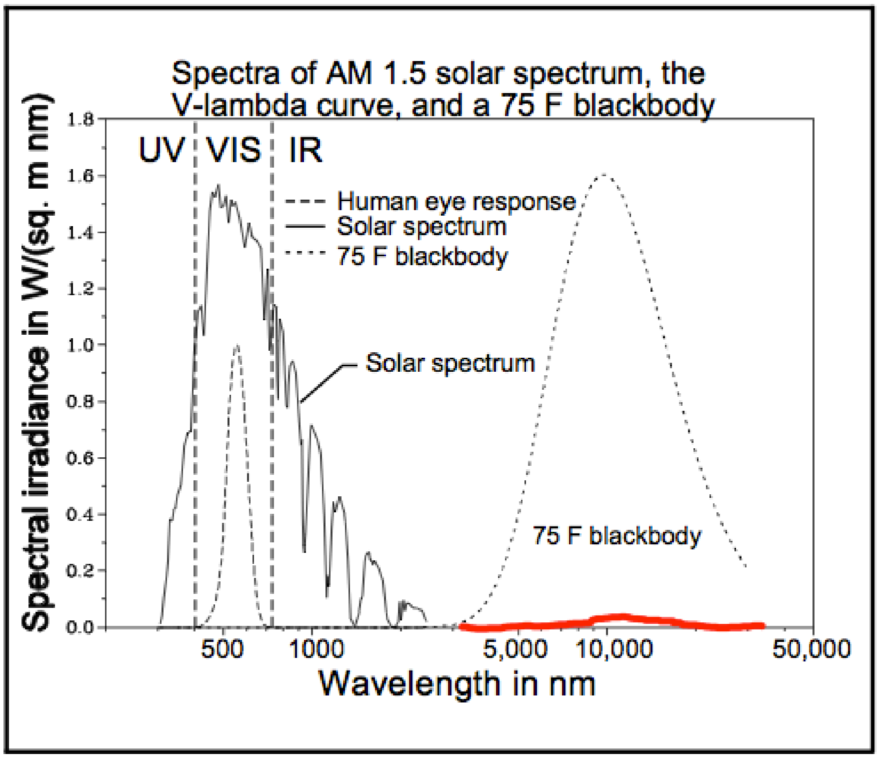
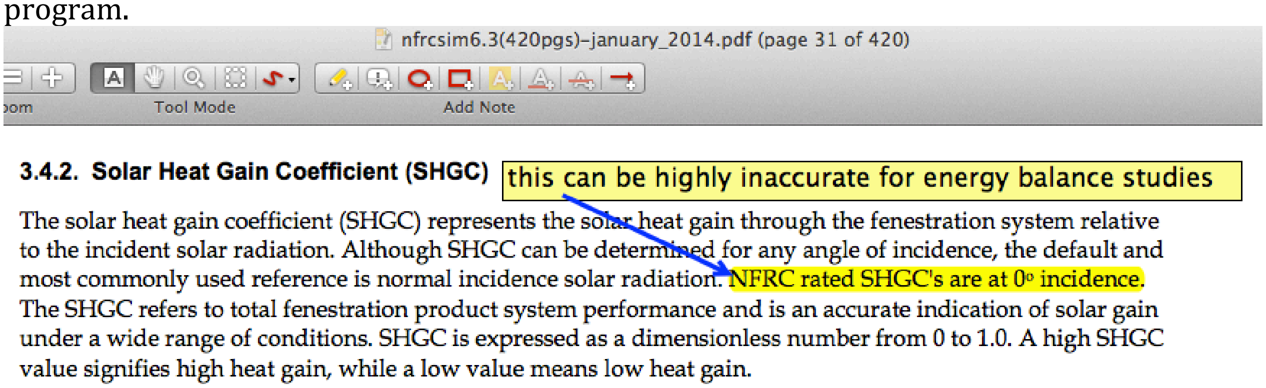


Figure 7. Spectral distributions of solar radiation, the human eye response, and a room temperature blackbody. Human eye response and blackbody curves have been scaled vertically for comparison purposes.

And from NFRC's January 2014 user manual for THERM 6.3 / WINDOW 6.3 Simulation program.



3.4.2. Solar Heat Gain Coefficient (SHGC)

The solar heat gain coefficient (SHGC) represents the solar heat gain through the fenestration system relative to the incident solar radiation. Although SHGC can be determined for any angle of incidence, the default and most commonly used reference is normal incidence solar radiation. NFRC rated SHGC's are at 0° incidence. The SHGC refers to total fenestration product system performance and is an accurate indication of solar gain under a wide range of conditions. SHGC is expressed as a dimensionless number from 0 to 1.0. A high SHGC value signifies high heat gain, while a low value means low heat gain.

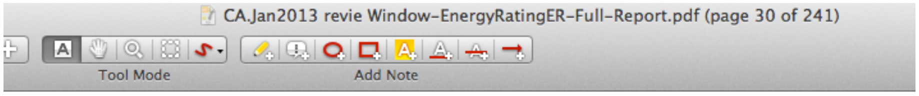


Table 3.2 Solar angle of incidence at south elevation, noon (0 = Normal).

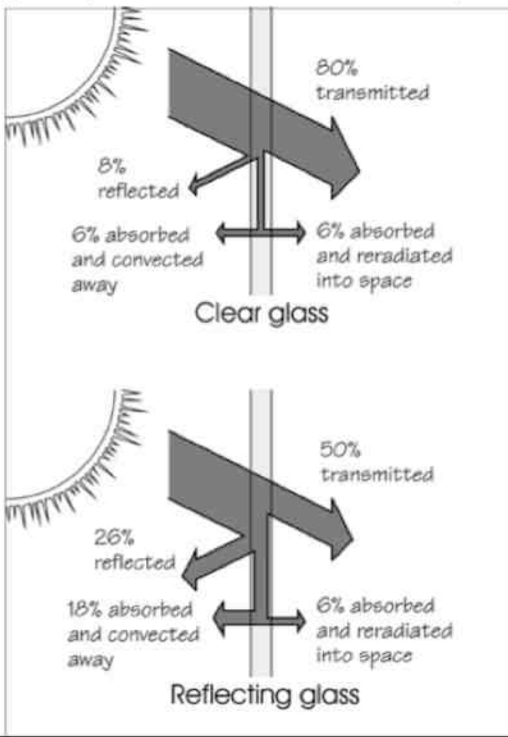
	June 21	December 21
Toronto	69.8°	23.1°
Vancouver	64.3°	17.7°
Edmonton	60.9°	15.2°
Yellowknife	52.1°	9.3°

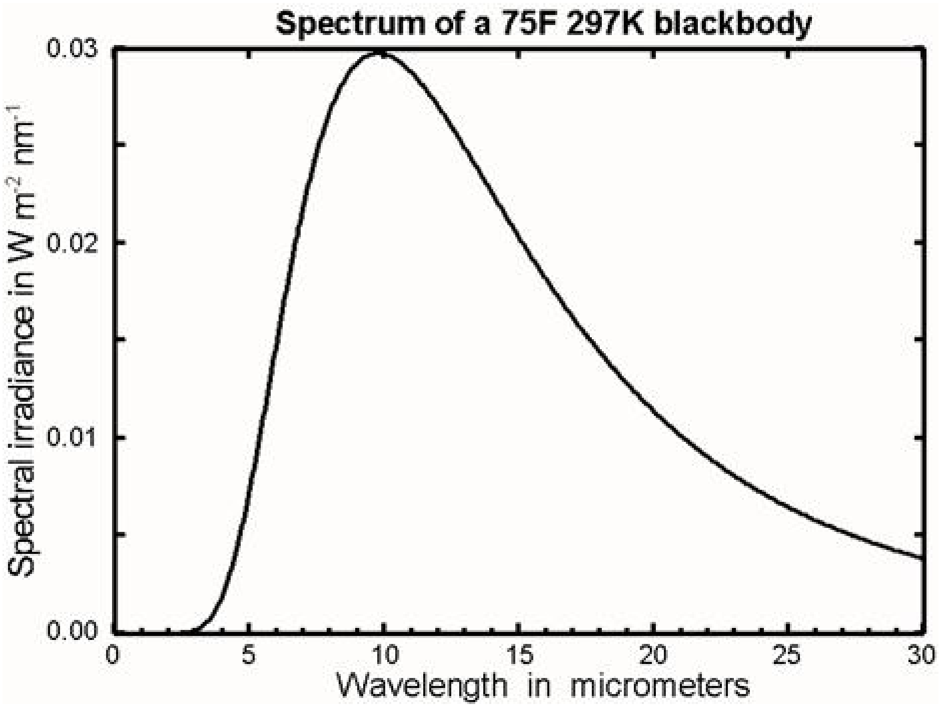
proof =

3.7 Solar Properties of Glazing Materials 3. FENESTRATION HEAT TRANSFER BASICS

If far-infrared heat loss is an important heat loss, then why is it never detailed?

On the other hand, a product optimized for collecting solar heat gain in winter should transmit the maximum amount of visible light as well as the heat from the near-infrared wavelengths in the solar spectrum, while blocking the lower-energy radiant heat in the far-infrared range that is an important heat loss component. These are the strategies of spectrally selective and low-emittance coatings, described later in the chapter.





The second edition of my textbook *Introduction to Radiometry and Photometry* was published November 2014 by Artech House out of Massachusetts.

The figure on the left below is my Fig. 3.1 in that book.Â Below that is my Fig. 3.4. and below that is Fig. 3.6.

27C is 80.6F, not far from 75F. The ratio of 1000 W/sq for solar radiation to 460 W/sqm for 80 F blackbody is 2 to 1, if I did it correctly.

To convert this ratio to 75F we have to convert 75 to Kelvin degrees: 24C + 273C = 297K. The 4th power of this is 7.78 x 109 and when multiplied by Ïƒ = 5.67032 x 10-8 we have 52.156 W/sqm. This ratio is 19 to 1.
Toddswork=5777 K $(5777)^4$ x5.67x10^{-8} = 63.1MW/sqm
Toddswork=80F= 299.8 K $(299.8)^4$ x5.67x10^{-8} = 458Watt/sqm
Toddswork=75F= 297.039K $(297.04)^4$ x5.67x10^{-8} = 441Watt/sqm
Toddswork=70F= 294.11K $(294.11)^4$ x5.67032 x 10-8. =424 Watts/sqm
Toddswork=68F= 293.15 K $(293.15)^4$ x5.67032 x 10-8. =418.7 Watts/sqm
Toddswork=65F= 291.483 $(291.483)^4$ x5.67032 x 10-8. =409 Watts/sqm

Toddswork= 36F= 275.372K and $(275.3)^4$ =5,473,632,256 x 5.67032 x 10-8. = 326
Toddswork= 30F= 272.0K and $(272)^4$ =5,473,632,256 x 5.67032 x 10-8. = 310
Toddswork@75F (441Watt/sqm- 310W/sqm)=131W/sqm
Toddswork@70F (424 Watts/sqm -310W/sqm)=111W/sqm
Toddswork@75F (441Watt/sqm- 326W/sqm)=115W/sqm
Toddswork@70F (424 Watts/sqm -326W/sqm)=98W/sqm
Toddswork@68F (418.7Watt/sqm- 326W/sqm)=92.7W/sqm
Toddswork@65F (409 Watts/sqm -326W/sqm)=83W/sqm

Toddswork= 30F. = 310 W/sqm

Toddswork=75F= 441Watt/sqm
Toddswork=70F= 424 Watts/sqm
Toddswork= 30F= 310
Toddswork@75F (441Watt/sqm- 310W/sqm)=131W/sqm
Toddswork@70F (424 Watts/sqm -310W/sqm)=111W/sqm
Toddswork= 30F. = 310 W/sqm
http://www.pilkington.com/en-gb/uk/architects/glass-information/energycontrolthermalsolarproperties/window-energy-ratings

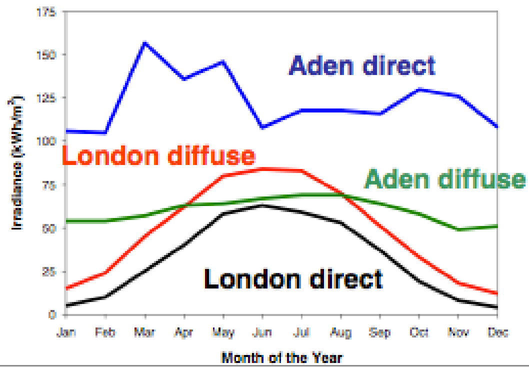
In October 2010 Building Regulation Part L was amended again with changes to the qualifying criteria. New and replacement windows either have to be rated C or higher. At the same time the Energy Saving Trust raised the criterion for EER to band B or higher.

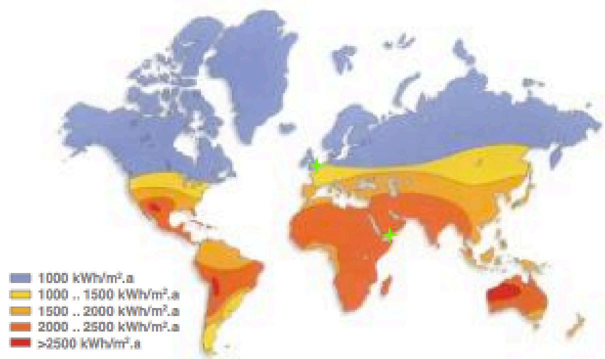
'End of the road' for U-values

For too long, in the context of energy conservation, glazing has been regarded by specifiers and legislators as the weak point in the building envelope. No matter how low window U-values become, they will never approach those of the walls that can always be made more insulating by being thicker. That is why the response of house-builders to successive Building Regulations changes based purely on tighter U-values has been to reduce window size. Clearly, reductions in window size are as unattractive for consumers as they are for architects and the window industry in general.

Solar resource

Solar photovoltaic – resource characteristics





Direct and diffuse

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STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: X Commercial Provisions X Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R402.1.3

Brief Description: Adding Language, for correct R-Values.

Proposed code change text:

R402.1.3 *R*-value computation. Insulation material used in layers, such as framing cavity insulation ~~and insulating sheathing~~or continuous insulation , shall be summed to compute the corresponding component *R*-value. The manufacturer's settled *R*-value shall be used for blown insulation. Computed *R*-values shall not include an *R*-value for other building materials or air films. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table R402.1.2, the manufacturer~~'s labeled R-value shall be reduced by R-0.6. .~~ must supply an ICC Report, that the R-Factor has been Certified, or use R5 per in. for Extruded polystyrene, and R 6.5 per in. for polyisocyanurate rigid insulation.

Your amendment must meet one of the following criteria. Select at least one:

Addresses a critical life/safety need.

X Consistency with state or federal regulations.

X Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

Addresses a unique character of the state.

X Corrects errors and omissions.

Check the building types that would be impacted by your code change:

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

X Single family/duplex/townhome	Multi-family 4 + stories	Institutional
X Multi-family 1 – 3 stories	Commercial / Retail	Industrial

Your name	Patrick C. Hayes	Email address	patrickchayes1@msn.com
Your organization	Energy Consultant	Phone number	206.819.7684
Other contact name	Click here to enter text.		

Instructions: Send this form as an email attachment, along with any other documentation available, to: sbcc@ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$Click here to enter text./square foot (For residential projects, also provide $Click here to enter text./ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

Click here to enter text.KWH/ square foot (or) Click here to enter text.KBTU/ square foot

(For residential projects, also provide Click here to enter text.KWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R402.4.1.2

Brief Description: This proposal exempts small additions from air leakage testing requirements and allows the

flexibility to test both the addition and the existing house to demonstrate compliance.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use <u>underline</u> for new text and ~~strikeout~~ for text to be deleted.)

R402.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding 5 air changes per hour. Testing shall be conducted in accordance with ASTM E779 or ASTM E1827 and reported at a pressure of 0.2 inches w.g. (50 Pascals). Where required by the code official, testing shall be conducted by an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the code official. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope. Once visual inspection has confirmed sealing (see Table R402.4.1.1), operable windows and doors manufactured by small business shall be permitted to be sealed off at the frame prior to the test.

During testing:

1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures;

2. Dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures;

3. Interior doors, if installed at the time of the test, shall be open, access hatches to conditioned crawl spaces and conditioned attics shall be open;

4. Exterior openings for continuous ventilation systems and heat recovery ventilators shall be closed and sealed;

5. Heating and cooling systems, if installed at the time of the test, shall be turned off; and

Supply and return registers, if installed at the time of the test, shall be fully open.

<u>Exceptions:</u>

<u>1. Additions less than 500 square feet of conditioned floor area.</u>

2. Additions tested with the existing home having a combined maximum air leakage rate of 7 air changes per hour. To qualify for this exception, the date of construction of the existing house must be prior to the 2009 Washington State Energy Code.

Purpose of code change:

This amendment allows small additions to be constructed without have to do an air leakage test. This can be difficult to do for additions with an open wall to the existing building. This also allows both the addition and the existing house be tested together as long as they meet an air leakage rate of up to 7 ACH50.

Your amendment must meet one of the following criteria. Select at least one:

- ☐ Addresses a critical life/safety need.
- ☒ Addresses a specific state policy or statute. (Note that energy conservation is a state policy)
- ☐ Consistency with state or federal regulations.
- ☐ Addresses a unique character of the state.
- ☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

- ☒ Single family/duplex/townhome
- ☐ Multi-family 1 – 3 stories
- ☐ Multi-family 4 + stories
- ☐ Commercial / Retail
- ☐ Institutional
- ☐ Industrial

Your name	Gary Nordeen	Email address	nordeeng@energy.wsu.edu
Your organization	WSU Energy Program	Phone number	(360) 956-2040
Other contact name	Chuck Murray		

Instructions: Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

This proposal will eliminate the cost of an air leakage test if the addition is less than 500 square feet in area. Also, the time needed to isolate the addition from the existing house is eliminated saving both labor and material costs. If the existing house and addition are tested together, there is no cost for isolating the addition from the existing house. Sealing the existing house and addition to meet the 7 ACH requirements will result in more energy savings than if the addition met the air leakage requirements alone.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

Cost savings from exemption:

$38T/square foot (For residential projects, also provide <u>$319/ dwelling unit</u>)

Show calculations here, and list sources for costs/savings, or attach backup data pages

Labor rate* (King County) X 3 hours = $69.00

Air Leakage test = $150.00

Materials = $100.00

<u>Total cost savings = $319.00</u>

*Info from L&I. Does not include any benefits.

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

Annual cost savings from reducing air leakage to 7 ACH50*

Reduce air leakage from 10 ACH50 to 7 ACH50 = $67.00/ year

Reduce air leakage from 15 ACH50 to 7 ACH50 = $174.00/ year

Reduce air leakage from 20 ACH50 to 7 ACH50 = $288.00/ year

* REM/rate Version 14.5.1 PNW

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

There is no additional plan review or inspection time associated with this proposal.

STATE OF WASHINGTON

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2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R403.2.2

Brief Description: This proposal provides some flexibility when installing mechanical equipment and ducts inside the conditioned space. In many cases it is difficult to get all ductwork inside the conditioned space. For example, a short duct run may be necessary in an attic space to connect a return grill to the furnace. This run is typically less than 10 feet in length. The third party language allows the Building Official to require a third party to conduct the test if they think it is necessary. This language is identical to language for air leakage testing. Some jurisdictions have expressed concern about the validity of the tests and this change allows them to have the test done by an independent third party.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

R403.3.3 Duct testing (Mandatory). Ducts shall be leak tested in accordance with WSU RS-33, using the maximum duct leakage rates specified. Where required by the code official, testing shall be conducted by an approved third party.

Exception: The total leakage or leakage to outdoors test is not required for ducts and air handlers located entirely within the building thermal envelope. A maximum of 10 linear feet of return ducts and 5 linear feet of supply ducts are allowed to be located outside of the building thermal envelope. Ducts located in crawl spaces do not qualify for this exception.

A written report of the results shall be signed by the party conducting the test and provided to the code official.

Purpose of code change:

This amendment allows some flexibility for builders and HVAC installers to obtain the credit for High Efficiency HVAC Distribution System. In addition, duct testing would not be required. This proposal also authorizes the code official to require third party testing if they feel the necessity to do so.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

☐ Consistency with state or federal regulations.

☒ Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

☒ Single family/duplex/townhome	☐ Multi-family 4 + stories	☐ Institutional
☒ Multi-family 1 – 3 stories	☐ Commercial / Retail	☐ Industrial

Your name	Gary Nordeen	Email address	nordeeng@energy.wsu.edu
Your organization	WSU Energy Program	Phone number	(360) 956-2040
Other contact name	38T		

Instructions: Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

This proposal has two parts. If the code official requires that the ducts be tested by a third party the cost for the test might be higher than if it is done by the technician working for the HVAC contractor. If the proposed exemption is used, it would eliminate the cost of the duct test and reduce construction costs.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$38T/square foot (For residential projects, also provide $$200.00/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

The average cost of a duct test is $200.00 per dwelling unit.

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

38TKWH/ square foot (or) 38TKBTU/ square foot

(For residential projects, also provide 38TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

38T

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

Enforcement and plan review time is not impacted by this proposal.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Energy Code Proposal Short Form

For editorial **Coordination, Clarifications & Corrections** only,
without substantive energy or cost impacts

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R403.3.1

Brief Description: Add language back into the energy code that was deleted when changing formats.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

R403.3.1 Insulation (Prescriptive). Ducts outside the building thermal envelope shall be insulated to a minimum of R-8. Ducts within a concrete slab or in the ground shall be insulated to R-5 with insulation designed to be used below grade. ((~~Supply and return ducts in attics shall be insulated to a minimum or R-8 where 3-inch diameter and greater and R-6 where less than 3 inch diameter. Supply and return ducts located in other portions of the building shall be insulated to a minimum of R-6 where 3-inch diameter and greater and R-4.2 where less than 3-inch diameter~~.))

Exception: Ducts or portions thereof located completely inside the *building thermal envelope*. Ducts located in crawl spaces do not qualify for this exception.

Purpose of code change:

Specifically cite the R-value of insulation required for ducts installed below grade or passing through, or contained within concrete slabs.

Your name Gary Nordeen

Email address nordeeng@energy.wsu.edu

Your organization WSU Energy Program

Phone number (360) 956-2040

Other contact name 39T

Instructions: For use with Coordination, Clarifications & Corrections **ONLY**. Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280.

Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.

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2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions X☐ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R403.4

Brief Description: Add to exception as below

Reduce pipe insulation to ½" thickness for piping for 2" and less.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

Purpose of code change: Exception1. Where Hydronic piping for the building heating cooling system with total run length of 200' measured from boiler/ chiller supply and return length on the longest run not to include the measurement of convertors/ radiant piping used as the convertor in the measurement, ½" pipe insulation is allowed with a temperature range of 46 Degrees to 180 degrees with piping sizes from 2" and less. Piping must be within the building thermal envelope, piping in crawl spaces do not qualify. Piping within both crawl space and building piping inside the building thermal envelope only the piping not inside the crawl space that meets the other requirements could use the ½ thick insulation in areas other then the crawls space.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

☐ Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Consistency with state or federal regulations.

X☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

X☐ Single family/duplex/townhome X☐ Multi-family 4 + stories X☐ Institutional

X☐ Multi-family 1 – 3 stories X☐ Commercial / Retail X☐ Industrial

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

Your name	Edwin L. Andres II	Email address	larryandrewsmechanicalinc@gmail.com
Your organization	Andrews Mechanical, Inc.		
Other contact name	Click here to enter text.	Phone number	509-435-7830

<u>Instructions</u>: Send this form as an email attachment, along with any other documentation available, to: sbcc@ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **<u>Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.</u>**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

Less cost and the cost that is used has benefit for the owner but is not a wasteful as it is now. Sometimes just adding more insulation is not saving any energy that it was intend to. Also owner won't have to add extra cost for the building to make room for the extra insulation with this change.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$1.0/square foot (For residential projects, also provide $1.0/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

Show calculations here, and list sources for costs/savings, or attach backup data pages
5/8" X1/2" pipe insulation .40 cent per foot

5/8"x1" pipe insulation .82 cent per foot

Note in many areas it is lot harder to install 1" insulation then ½"so the labor cost could as high as double

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

0.KWH/ square foot (or) 0.KBTU/ square foot

(For residential projects, also provide 0.KWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

None

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application: None

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

ANDREWS MECHANICAL, INC.

2727 North Madelia Unit 8 (Shop & ship to address)
1503 East Wabash (Mailing address)
Spokane, Washington 99207
Office (509) 489-3860
Fax (509) 489-6140

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Andrews Mechanical, Inc.

February 12, 2015

Let's look at how efficient a hot water delivery system is with respect to energy loss with ½" fiberglass pipe insulation in a 200 foot run. This would be 100' run out to the convector and back to the boiler. The reason I picked ¾" is because it is one of the most used run out size piping in use today.

1. ¾" pipe with 180 degree supply water and 200' of pipe with ½" insulation. Let's look on our provided chart, it shows 18 BTU's drop per foot of pipe. Multiply 18 BTU's by 200' this is 3600 BTU's. The ¾" pipe is carrying 40,000 BTU's of heat in the pipe. One must remember that this loss out of the insulation is still going into the building.
2. What is the % of loss for the 200' with the ¾" pipe? 3600/40000 **= 91% heat transfer** The temperature drop due to insulation losses is 1-3/4 degree drop in temperature for the 200' of piping.
3. Now let's look at 6" duct with R3 insulation wrap around this metal duct. We will say that the room temperature return air temperature is 70 degrees and the air out of the furnace is 120 degrees. Using some known laws, BTUH=CFM x TD(D.B.)x 1.08 a common amount of air in a 6 " duct is 100 CFM which give us 5400= 100CFM x 50 degrees x 1.08 if we plug the numbers in to the law above. When we use the 3E Plus software, we find that in that 100' of duct we lose 14.3 degrees of temperature in the duct with R3 insulation around it. So how many BTU's did we lose in that 100'. BTU's = 100CFM x 50-14.3 x 1.08 = 3855 BTU's note this true only, if you did not lose any air due to duct leakage. But let's say you didn't lose air, this is a dream, I know. So let's look how efficient this system is. BTU's going out the register 3855/5400 **= 71% heat transfer** Note this **20 % less than** the hot water system running at 180 degrees. If you look at temperatures around 140 for hot water with ½" fiberglass insulation on the pipe it has over **95% heat transfer** with just over a one degree drop in 200' and **more than 25% efficiency** than an air system. So I ask you, why would you want any more insulation than ½" when it's clear this is about the most efficient thing going, by far. Remember this loss is still inside the insulated envelope. If you were to look at the H.P. it took to move the BTU's around in a ducted air system the hot water system it would even be more ridiculously efficient than a ducted air system. This is a real energy loss in an air system the H.P. it takes to move the air around.
4. Why put more cost into a system that is so efficient to begin with? Please give us a break.
5. See data sheet from 3E on duct loss to support data in #3.
6. I hope this may shed some light why I'm willing to fight for this so much.
7. Radiant and hydronic systems are more expensive to install, but are much more efficient than air systems.

Larry Andrews

	Comparison of Table C403.2.8 to know BTU's of loss and surface temp					
	Information from 3E plus software from the insulation provider					
	Owens Corning SSL-II Fiberglas Pipe Insulation					
	BTU's losses per foot of pipe					
Iron pipe Size	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
Bare pipe steel @ 104 °F fluid inside	**12.5 BTU's**	**15 BTU'S**	**18 1/4 BTU's**	**22 1/2 BTU's**	**25 1/2 BTU's**	**31 BTU's**
Surface temperature	**104 °F**	**104 °F**	**104 °F**	**104 °F**	**104 °F**	**104 °F**
Iron pipe Size	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
1/2" Fiberglass pipe Insul. @ 140°F FI	9 BTU's	10.5 BTU's	12 BTU's	15 BTU's	17 BTU's	19 BTU's
Surface temperature	86°F	86°F	87°F	88°F	89°F	89°F
Iron pipe Size	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
1" Fiberglass pipe Insul. @ 140°F FI	6 BTU's	8 BTU's	8 BTU's	10 BTU's	11 BTU's	12 BTU's
Surface temperature	81°F	82°F	82°F	83°F	83°F	83°F
Iron pipe Size	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
1/2" Fiberglass pipe Insul. @ 180°F FI	16 BTU's	18 BTU's	21 BTU's	26 BTU's	29 BTU's	32 BTU's
Surface temperature	93°F	93°F	94°F	96°F	97°F	97°F
Iron pipe Size	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
1" Fiberglass pipe Insul. @ 180°F FI	11 BTU's	13 BTU's	14 BTU's	18 BTU's	18 BTU's	21 BTU's
Surface temperature	84°F	86°F	86°F	87°F	87°F	87°F
	R=1/C=L/K		**K/L=C**			

Mechanical Insulation Design Guide - Design Objectives

by the National Mechanical Insulation Committee (NMIC)

Last updated: 06-19-2014

Temperature Drop Calculator for Air Ducts

Calculates the Temperature Change of Air Flowing in a Duct
Reference: 2009 ASHRAE HoF, Chapter 4, Equation 48, (pg 4.21)

This calculator estimates the temperature drop (or rise) of air flowing in a duct.

Input Information

1. Entering air temperature, °F	120
2. Ambient temperature, °F	75
3. Flow rate of air, cfm	100
4. Length of run, ft	100
5. Outside perimeter of duct, in	19
6. R-value of duct insulation, ft	3

Results

Temperature Drop, (°F)	14.3
Leaving Air Temperature (°F)	105.7

the positive closure. Application may be at ambient temperatures from 25°F (-4°C) to 110°F (43°C).

Fiberglas™ "No-Wrap" Pipe Insulation is designed for field-jacketing. The pipe covering is secured by wires or bands, and vapor sealed where required.

Outdoor applications must be protected from weather. If painting is required, use only water based latex paint.

Standards, Codes Compliance

- ASTM C547, Mineral Fiber Pipe Insulation, Type I to 850°F (454°C)
- ASTM C1136, Flexible Low Permeance Vapor Retarders for Thermal Insulation: Types I-IV
- ASTM C795, Thermal Insulation for Use in Contact with Austenitic Stainless Steel[4]
- MIL-I-22344D, Insulation, Pipe, Thermal, Fibrous Glass
- Nuclear Regulatory Commission Guide 1.36, Non-Metallic Thermal Insulation[4]
- Doesn't contain the fire retardant decabrominated diphenyl ether (decaBDE)
- MIL-I-24244C (Ships) Insulation Material with Special Corrosion, Chloride, and Fluoride Requirements[4]
- U.S. Coast Guard Approval No. 164.109, Noncombustible Materials (no-wrap)
- CAN/CGSB-51.9 – Type 1,

4. Preproduction qualification testing complete and on file. Chemical analysis of each production lot required for total conformance.

Availability

Fiberglas™ Pipe Insulations are available in thicknesses and for pipe sizes as follows[1]:

Insulation Thickness		Nominal Pipe Size	
in.	(mm)	in.	(mm)
½	(13)	½ - 2 ½	(15 - 65)
1	(25)	½ - 33	(15 - 825)
1 ½	(38)	½ - 33	(15 - 825)
2	(51)	½ - 33	(15 - 825)
2 ½	(64)	½ - 32	(15 - 800)
3	(76)	½ - 31	(15 - 775)
3 ½	(89)	½ - 30	(15 - 750)
4	(102)	½ - 29	(15 - 725)
4 ½	(114)	½ - 28	(15 - 700)
5	(127)	½ - 27	(15 - 675)
5 ½	(140)	6 - 26	(150 - 650)
6	(152)	6 - 25	(150 - 625)

1. Please refer to product packaging and data guide for load factors, standard products, minimum order quantity and carton sizes. Contact your customer service representative for product leadtime.

Physical Property Data

Property	Test Method	Value
Density (size dependent)	ASTM C302	3.5 to 5.5 pcf
Operating Temperature Range[2]	ASTM C411	0°F to 850°F (-18°C to 454°C)
Jacket Temperature Limitation	ASTM C1136	-20°F to 150°F (-29°C to 66°C)
Jacket Permeance	ASTM E96, Proc.A	0.02 perm
Burst Strength, min	ASTM D774/D774M	55 psi
Composite Surface Burning Characteristics[3]	UL 723, ASTM E84 or CAN/ULC-S102	Flame spread 25 Smoke Developed 50

2. Limited to single layer applications above 650°F (343°C), but not greater than 6" (152mm) thickness.
3. The surface burning characteristics of these products have been determined in accordance with UL 723, ASTM E84 or CAN/ULC-S102. These standards should be used to measure and describe the properties of materials, products or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use. Values are reported to the nearest 5 rating.

Thermal Conductivity

Mean Temperature °F	k Btu•in/hr•ft²•°F	Mean Temperature °C	λ W/m•°C
50	0.22	10	0.032
75	0.23	25	0.034
100	0.24	50	0.037
150	0.27	100	0.043
200	0.29	125	0.047
250	0.32	150	0.051
300	0.35	175	0.056
350	0.39	200	0.062
400	0.43	225	0.068
450	0.48	250	0.075
500	0.54	275	0.082

Apparent thermal conductivity values determined in accordance with ASTM practice C1045 with data obtained by ASTM Test Method C335. Values are nominal, subject to normal testing and manufacturing tolerances.

Fiberglas™
Pipe Insulation

Product Data Sheet

Personnel Protection Table

Thickness Required for Surface Temperatures ≤ 140 °F, inches (mm)[6,7]

Nominal Pipe Size		System Operating Temperatures °F (°C)											
in.	(mm)	200°F	(93°C)	300°F	(149°C)	400°F	(204°C)	500°F	(260°C)	600°F	(316°C)	800°F	(427°C)
0.5	(15)	0.5	(15)	0.5	(15)	0.5	(15)	1.0	(25)	1.0	(25)	1.5	(38)
0.75	(20)	0.5	(15)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	2.0	(51)
1	(25)	0.5	(15)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	2.0	(51)
1.25	(32)	0.5	(15)	0.5	(15)	1.0	(25)	1.0	(25)	1.5	(38)	2.0	(51)
1.5	(40)	0.5	(15)	0.5	(15)	1.0	(25)	1.0	(25)	1.5	(38)	2.0	(51)
2	(50)	0.5	(15)	0.5	(15)	1.0	(25)	1.0	(25)	1.5	(38)	2.0	(51)
2.5	(65)	0.5	(15)	0.5	(15)	1.0	(25)	1.0	(25)	1.5	(38)	2.0	(51)
3	(80)	0.5	(15)	0.5	(15)	1.0	(25)	1.0	(25)	1.5	(38)	2.5	(64)
4	(100)	0.5	(15)	0.5	(15)	1.0	(25)	1.0	(25)	1.5	(38)	2.5	(64)
5	(125)	0.5	(15)	0.5	(15)	1.0	(25)	1.0	(25)	1.5	(38)	2.5	(64)
6	(150)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	1.5	(38)	2.5	(64)
7	(175)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	1.5	(38)	2.5	(64)
8	(200)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	1.5	(38)	2.5	(64)
9	(225)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	1.5	(38)	2.5	(64)
10	(250)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	1.5	(38)	2.5	(64)
12	(300)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	1.5	(38)	3.0	(76)
14	(350)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	2.0	(51)	3.0	(76)
16	(400)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	2.0	(51)	3.0	(76)
18	(450)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	2.0	(51)	3.0	(76)
20	(500)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	2.0	(51)	3.0	(76)
24	(600)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	2.0	(51)	3.0	(76)
30	(750)	0.5	(15)	0.5	(15)	1.0	(25)	1.5	(38)	2.0	(51)	3.0	(76)

6. Calculations estimated using NAIMA 3E Plus Version 4.0 Software. Fixed Design Conditions: Steel horizontal piping, 80°F (27°C) average ambient temperature, 0 mph wind speed and outer surface jacket emittance of 0.9. For alternate design conditions, contact your Owens Corning representative.
7. Thermal conductivity values used in these calculations are subject to normal manufacturing tolerances.

Thickness to Prevent Surface Condensation

Owens Corning™ ASJ Jacket for up to 16" NPS (400mm DN), in. (mm)[8,9]

Ambient Temperature °F (°C)	Relative Humidity	System Operating Temperatures 35°F (2°C)	45°F (7°C)	55°F (13°C)
110 (43)	70%	1 (25)	1 (25)	1 (25)
	80%	1½ (38)	1½ (38)	1½ (38)
	90%	3½ (89)	3½ (89)	3 (76)
100 (38)	70%	1 (25)	1 (25)	1 (25)
	80%	1½ (38)	1½ (38)	1 (25)
	90%	3½ (89)	3 (76)	2½ (64)
90 (32)	70%	1 (25)	1 (25)	1 (25)
	80%	1½ (38)	1 (25)	1 (25)
	90%	3½ (89)	3 (76)	2½ (64)
80 (27)	80%	1½ (38)	1 (25)	1 (25)
	90%	3 (76)	2½ (64)	2 (51)
70 (21)	80%	1 (25)	1 (25)	1 (25)
	90%	2½ (64)	2 (51)	1 (25)

8. Calculations estimated using NAIMA 3E Plus version 4.0 software. Fixed design conditions: Steel Horizontal Piping, 16" NPS, 0 mph wind speed, Outer Surface Jacket Emittance of 0.9.
9. Thermal conductivity values used in these calculations are subject to normal manufacturing tolerances.

Class 2[5]

- New York City MEA No. 344-83, 408-07-M
- NFPA 90A

5. Standard Obsolete, replaced by ASTM C547.

OWENS CORNING ®

Fiberglas™ Pipe Insulation

Product Data Sheet

Certifications and Sustainable Features of Fiberglas™ Pipe Insulation

- Certified by SCS Global Services to contain a minimum of 53% recycled glass content, 31% pre-consumer and 22% post-consumer.
- Certified to meet indoor air quality standards under the stringent GREENGUARD Certification Program, and the GREENGUARD Gold Certification.*

Environmental and Sustainability

Owens Corning is a worldwide leader in building material systems, insulation and composite solutions, delivering a broad range of high-quality products and services. Owens Corning is committed to driving sustainability by delivering solutions, transforming markets and enhancing lives. More information can be found at http://sustainability.owenscorning.com.

GREENGUARD

*No-Wrap Pipe Insulation is not yet GREENGUARD® Certified.

GREENGUARD GOLD

*No-Wrap Pipe Insulation is not GREENGUARD® Gold Certified.

CERTIFIED RECYCLED CONTENT™ SCS GLOBAL SERVICES

AVERAGE 53% RECYCLED CONTENT
31% PRE-CONSUMER
22% POST-CONSUMER

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SCS Global Services provides independent verification of recycled content in building materials and verifies recycled content claims made by manufacturers. For more information, visit www.SCSglobalservices.com

GREENGUARD Certified products are certified to GREENGUARD standards for low chemical emissions into indoor air during product usage. For more information, visit ul.com/gg.

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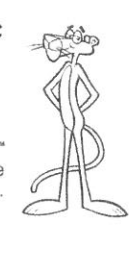
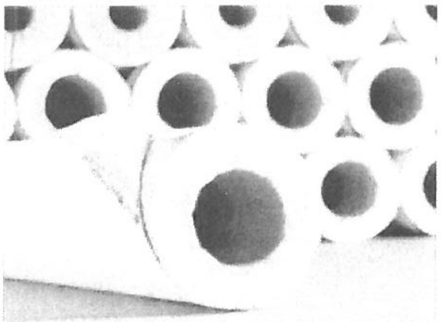


Pub. No. 20547-L. Printed in U.S.A. December 2014.

Submittal Sheet

Fiberglas® Pipe Insulation



- SSL II® All-Service Jacket (ASJ), Self-Sealing Lap
- SSL® I ASJ
- No-Wrap

Description

Owens Corning Fiberglas® pipe insulations are molded of heavy density resin bonded inorganic glass fibers. These one-piece, 36" (914mm) long, hinged sections are opened, placed over the pipe, closed and secured by means specific to the type as described below.

Fiberglas SSL II® Pipe Insulation is jacketed with a smooth, reinforced, wrinkle-resistant all-service (ASJ) vapor retarder jacket. Factory applied DOUBLESURE† double pressure sensitive adhesive closure provides positive mechanical and vapor sealing of the longitudinal jacket seam. Two-part butt strip seals complete the positive closure. Available in the most popular sizes.

In larger sizes *Fiberglas* Pipe Insulation is furnished with SSL® I, a single adhesive lap seal.

Fiberglas "No-Wrap" Pipe Insulation is also available without a jacket. It is intended for field installation of jacketing appropriate to the vapor control, damage or corrosion resistance requirements of the application.

Uses

Insulation of hot, cold, concealed and exposed piping operating at temperatures from 0°F (-18°C) to 850°F (454°C) in commercial buildings, industrial facilities and process or power plants.

†DOUBLESURE is a registered trademark of Morgan Adhesives Company.

Features/Benefits

SSL II Positive Closure System

Effective long-term vapor sealing of both longitudinal and butt joints. With double-adhesive lap seal, plus two-part butt strip seal, positive closure is fast, neat and foolproof. No need for staples and mastic, promoting unexcelled jobsite productivity.

Jacket and Lap Shipped Adhered

Short pieces of insulation can be cut without jacket loss; it won't come apart in handling. No "dog-ears" in or out of the carton. Dust and moisture can't reach the seal. Butt strips come in sealed bags inside the carton, staying clean until the moment of use.

Excellent Thermal Performance

Fiberglas Pipe Insulation's low thermal conductivity contributes to lower operating costs of heating and cooling equipment.

Meets Model Code Fire Ratings

Flame spread rating of 25 or less, and smoke developed rating of 50 or less, usually means that *Fiberglas* Pipe Insulation will be granted immediate building code approval.

Availability

Fiberglas Pipe Insulations are available in thicknesses and for pipe sizes as follows:

Insulation Thickness, in.	(mm)	Nominal Pipe Sizes, NPS, in. (DN, mm) SSL II Pipe Insulation		SSL I Pipe Insulation*		No-Wrap Pipe Insulation**	
½	(13)	½-6	(15-150)			½-6	(15-150)
1	(25)	½-15	(15-375)	16-33	(400-825)	½-33	(15-825)
1½	(38)	½-14	(15-350)	15-33	(375-825)	½-33	(15-825)
2	(51)	½-12	(15-300)	14-33	(350-825)	½-33	(15-825)
2½	(64)	2-11	(50-275)	12-26	(300-650)	½-32	(15-800)
3	(76)	3-10	(75-250)	11-26, 30	(275-650, 750)	½-31	(15-900)
3½	(89)	4½-9	(115-225)	10-18, 20-22, 24	(250-450, 500-550, 600)	½-30	(15-750)
4	(102)	4½-8	(115-200)	9-21, 24, 25	(225-525, 600, 625)	½-29	(15-725)
4½	(114)	6-7	(150-175)	8-10, 12, 14, 16, 18, 20, 24	(200-250, 300, 350, 400, 450, 500, 600)	½-28	(15-700)
5	(127)	6	(150)	7-14, 16-24	(175-350, 400-600)	½-27	(15-675)
5½	(140)					6-26	(150-650)
6	(152)					6-25	(150-625)

* SSL I all made-to-order except 14" x 2" (350mm x 51mm) and 16" x 1", 11/2" and 2" (400mm x 25mm, 38mm and 51mm).
** Consult Product Guide available upon request for standard and made-to-order sizes.

Specification Compliance

- ASTM C 547, Mineral Fiber Pre-Formed Pipe Insulation, Type I to 850°F (454°C)
- ASTM C 1136, Flexible Low Permeance Vapor Retarders for Thermal Insulation: Types I and II
- ASTM C 795, Thermal Insulation for Use Over Austenitic Stainless Steel*
- Mil. Spec. MIL-I-22344D, Insulation, Pipe, Thermal, Fibrous Glass
- Mil. Spec. MIL-I-24244C (SH), Insulation Materials, Special Requirements, Type XVIh*
- Nuclear Regulatory Commission Guide 1.36, Non-Metallic Thermal Insulation*
- U.S. Coast Guard Approval No. 164.009, Noncombustible Materials (no-wrap)
- New York City MEA No. 344-83
- CAN/CGSB-51.9 – Type 1, Class 2
- NFPA 90A

* Preproduction qualification testing complete and on file. Chemical analysis of each production lot required for total conformance.

Fiberglas® Pipe Insulation

Physical Property Data

Property	Test Method	Value	
Operating temperature range	ASTM C 411	0 to 850°F* (-18°C to 454°C)*	
Jacket temperature limitation	ASTM C 1136	-20°F to 150°F (-29°C to 66°C)	
Jacket permeance	ASTM E 96, Proc.A	0.02 perm	
Puncture resistance	ASTM D 781	50 units	
Composite surface burning characteristics	UL 723** or CAN/ULC-S102-M**	Flame spread Smoke developed	25** 50

*Limited to single layer applications above 650°F (343°C), but not greater than 6" (152mm) thickness.
**The surface burning characteristics of these products have been determined in accordance with UL 723 or CAN/ULC-S102-M. These standards should be used to measure and describe the properties of materials, products or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use. Values are reported to the nearest 5 rating.

Thermal Performance, ASTM C 680

Insulation NPS x Thk. in.	(DN x Thk. mm)	300 (149) HL	300 (149) ST	500 (280) HL	500 (280) ST	700 (371) HL	700 (371) ST
		Pipe Operating Temperature, F (C)					
2 x ½	(50 x 13)	77 (74)	128 (53)				
4 x 1	(100 x 25)	78 (75)	109 (43)				
8 x 1	(200 x 25)	140 (135)	112 (44)				
12 x 1	(300 x 25)	199 (191)	113 (45)				
2 x 1½	(50 x 38)			88 (85)	116 (47)		
4 x 1½	(100 x 38)			142 (137)	123 (51)		
8 x 1½	(200 x 38)			242 (233)	128 (53)		
12 x 1½	(300 x 38)			330 (317)	129 (54)		
2 x 2	(50 x 51)					139 (134)	127 (53)
4 x 2½	(100 x 64)					188 (181)	125 (52)
8 x 2½	(200 x 64)					295 (284)	129 (54)
12 x 3	(300 x 76)					359 (345)	125 (52)

Heat Loss (HL), Btu/hr•ft (W/m); Surface Temperature (ST), °F (°C).
Design Conditions: Horizontal piping, 80°F (27°C) average ambient temperature, 0 mph wind speed, ASJ jacket.
For similar information using other assumptions, contact your Owens Corning Representative.

Thickness to Prevent Surface Condensation

Owens Corning ASJ Jacket for up to 16" NPS (400mm DN)(1), in. (mm)

Ambient Temperature, °F	(°C)	Relative Humidity(2)	35°F (2°C)		45°F (7°C)		55°F (13°C)	
			System Operating Temperatures					
110	(43)	50%-70%	1	(25)	1	(25)	1	(25)
		80%	1½	(38)	1½	(38)	1	(25)
		90%	3½	(89)	3	(76)	2½	(64)
100	(38)	50%-70%	1	(25)	1	(25)	1	(25)
		80%	1½	(38)	1½	(38)	1	(25)
		90%	3	(76)	3	(76)	2½	(64)
90	(32)	50%-70%	1	(25)	1	(25)	1	(25)
		80%	1½	(38)	1	(25)	1	(25)
		90%	3	(76)	2½	(64)	2	(51)
80	(27)	50%-80%	1	(25)	1	(25)	1	(25)
		90%	2½	(64)	2	(51)	1½	(38)
70	(21)	50%-80%	1	(25)	1	(25)	1	(25)
		90%	1½	(38)	1½	(38)	1	(25)

(1) For NPS (DN) greater than 16" (400mm), please contact your local Owens Corning Representative.
(2) If humidity exceeds 90%, some condensation is to be expected; therefore, a coating of a mastic or PVC jacket overwrap is recommended as repeated or continual wetting of the ASJ jacket will degrade its vapor retarder performance.

OWENS CORNING

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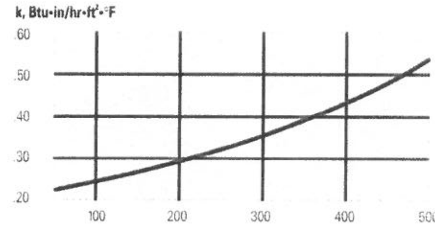
Thermal Conductivity



Apparent thermal conductivity curve determined in accordance with ASTM Practice C 1045 with data obtained by ASTM Test Method C 177. Values are nominal, subject to normal testing and manufacturing tolerances.

Mean Temp. °F	k Btu•in/hr•ft²•°F	Mean Temp. C	λ W/m•°C
50	0.22	10	0.032
75	0.23	25	0.034
100	0.24	50	0.037
150	0.27	100	0.043
200	0.29	125	0.047
250	0.32	150	0.051
300	0.35	175	0.056
350	0.39	200	0.062
400	0.43	225	0.068
450	0.48	250	0.075
500	0.54	275	0.082

Application Recommendations

The hinged sections of *Fiberglas* Pipe Insulation are opened, placed over the pipe, carefully aligned, and sealed or jacketed as required by the form of the insulation and the application.

Fiberglas SSL II Pipe Insulation is shipped with the jacket and longitudinal lap closed, the two adhesives separated by a release strip. The insulation is opened by pulling the release strip from between the two adhesive strips. The insulation is placed on the pipe, carefully aligned, and the two adhesives rubbed firmly together to close and seal. The two part butt strip seal completes the positive closure. Application may be at ambient temperatures from 25°F (-4°C) to 110°F (43°C).

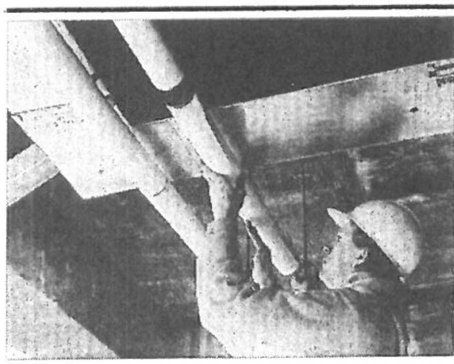
Fiberglas "No-Wrap" Pipe Insulation is designed for field-jacketing with pipe covering secured by wires or bands, vapor sealed where required.

Outdoor applications must be protected from weather. If painting is required, use only water base latex paint.

SUBMITTAL SHEET

OWENS/CORNING FIBERGLAS

Owens-Corning Fiberglas SSL-II® Pipe Insulation with Doublesure* Closure System



Uses

Fiberglas SSL-II pipe insulation is recommended for use on all hot, cold, concealed, and exposed piping operating at temperatures from 0 to 850F in commercial and institutional buildings, industrial facilities, and process or power plants.

Description

Owens-Corning Fiberglas SSL-II® Pipe Insulation is jacketed with reinforced all service vapor retarder jacketing. The jacketing has a factory-applied double pressure-sensitive adhesive system which provides positive closure and vapor sealing of the longitudinal joint, at ambient temperatures ranging from 25F to 110F. Joints between insulation sections are sealed with butt strips which also have a two-component adhesive system. This Doublesure* jacket closure system provides an extremely effective vapor seal, protecting the insulation against entry of moisture. It can also significantly improve installation productivity by eliminating in most cases the need for staples, mastics and bands.

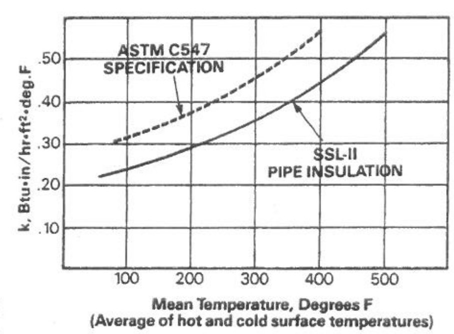
Physical Properties

Property	Test Method	Specification
Pipe operating temperature range	ASTM C 411	0 to 850F (1)
Jacket surface temperature limitation		-20F to +150F
Jacket permeance	ASTM E 96	0.02 perm
Puncture resistance	ASTM D 781	50 units
Composite surface burning characteristics	UL 723*	Flame spread 25* Smoke developed 50

(1) Limited to single layer applications above 650F, but not greater than 6" thickness.

*The surface burning characteristics of these products have been determined in accordance with UL 723. This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of these tests may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use. Values are reported to the nearest 5 rating.

Thermal Conductivity, k (ASTM C 335)



Specification Compliance

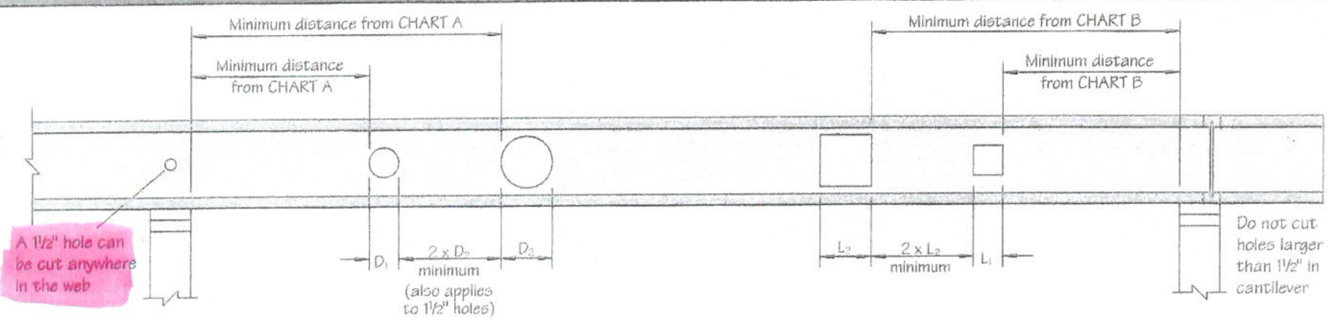
Fiberglas SSL-II pipe insulation complies with the property requirements of the following specifications:

**Preproduction qualification testing complete and on file. Chemical analysis of each production lot required for total conformance.

Availability

Fiberglas SSL-II pipe insulation is available in thicknesses from 1/2" to 5" for application to nominal pipe sizes from 1/2" up, as listed on the reverse side of this submittal sheet.

*Trademark registered Morgan Adhesives Co.



HOW TO USE THESE CHARTS

1. Determine the hole shape (round, square or rectangular) and select the appropriate chart – A or B.
2. Under HOLE SIZE, locate the column which meets or exceeds the size of hole you require.
3. Use the first two columns to identify the TJI® joist series and depth being used in your floor or roof system.
4. Scan right across the row until you intersect the column which contains the hole size you selected.
   The value shown is the **required minimum distance** from edge of the hole to the the inside face of the nearest support.

CHART A – ROUND HOLES

MINIMUM DISTANCE FROM INSIDE FACE OF ANY SUPPORT TO NEAREST EDGE OF HOLE

DEPTH	TJI®/Pro™	ROUND HOLE SIZE													
		2"	3"	4"	5"	6"	6¼"	7"	8"	8⅝"	9"	10"	10¾"	12"	12¾"
9½"	150	1'-0"	1'-6"	3'-0"	4'-6"	7'-0"	7'-6"								
	250	1'-0"	2'-6"	4'-0"	5'-6"	7'-6"	8'-0"								
11⅞"	150	1'-0"	1'-0"	1'-0"	1'-0"	3'-0"	3'-6"	5'-0"	7'-0"	8'-6"					
	250	1'-0"	1'-0"	2'-0"	3'-0"	4'-6"	5'-0"	6'-0"	8'-0"	9'-0"					
	350	1'-0"	2'-0"	3'-0"	4'-6"	5'-6"	6'-0"	7'-0"	9'-0"	10'-0"					
	550	1'-0"	1'-6"	3'-0"	4'-6"	6'-0"	6'-6"	7'-6"	9'-6"	10'-6"					
14"	250	1'-0"	1'-0"	1'-0"	1'-0"	1'-6"	2'-0"	3'-0"	5'-0"	6'-0"	6'-6"	8'-6"	10'-0"		
	350	1'-0"	1'-0"	1'-0"	1'-6"	3'-0"	3'-6"	4'-6"	6'-0"	7'-0"	8'-0"	9'-6"	11'-0"		
	550	1'-0"	1'-0"	1'-0"	2'-6"	4'-0"	4'-6"	6'-0"	7'-6"	8'-6"	9'-0"	11'-0"	12'-0"		
16"	250	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-6"	2'-6"	3'-0"	5'-0"	6'-6"	9'-0"	11'-0"
	350	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-6"	3'-0"	4'-6"	5'-0"	6'-6"	8'-0"	10'-6"	12'-0"
	550	1'-0"	1'-0"	1'-0"	1'-0"	1'-6"	2'-0"	3'-6"	5'-0"	6'-0"	7'-0"	8'-6"	10'-0"	12'-0"	13'-6"

CHART B – SQUARE OR RECTANGULAR HOLES

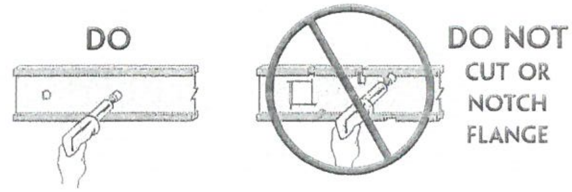
MINIMUM DISTANCE FROM INSIDE FACE OF ANY SUPPORT TO NEAREST EDGE OF HOLE

DEPTH	TJI®/Pro™	SQUARE OR RECTANGULAR HOLE SIZE													
		2"	3"	4"	5"	6"	6¼"	7"	8"	8⅝"	9"	10"	10¾"	12"	12¾"
9½"	150	1'-0"	2'-0"	4'-0"	6'-0"										
	250	1'-0"	2'-6"	4'-0"	6'-6"										
11⅞"	150	1'-0"	1'-0"	1'-6"	4'-0"	7'-0"	7'-6"	8'-0"	9'-0"						
	250	1'-0"	1'-6"	3'-0"	5'-0"	8'-0"	8'-0"	8'-6"	9'-0"						
	350	1'-0"	2'-0"	4'-0"	5'-6"	8'-6"	8'-6"	9'-0"	9'-6"						
	550	3'-0"	4'-0"	5'-6"	7'-0"	9'-6"	9'-6"	10'-0"	10'-0"	10'-6"					
14"	250	1'-0"	1'-0"	1'-6"	3'-6"	5'-6"	6'-6"	8'-0"	10'-0"	10'-6"	11'-0"	11'-6"	12'-6"		
	350	1'-0"	1'-0"	2'-0"	4'-6"	6'-6"	7'-0"	9'-0"	10'-6"	11'-0"	11'-6"	12'-0"	12'-6"		
	550	1'-0"	3'-0"	5'-0"	6'-6"	8'-6"	9'-0"	10'-0"	11'-6"	12'-0"	12'-0"	12'-6"	13'-0"		
16"	250	1'-0"	1'-0"	1'-0"	1'-0"	4'-0"	4'-6"	6'-6"	9'-0"	11'-0"	11'-6"	12'-0"	13'-0"	14'-0"	15'-0"
	350	1'-0"	1'-0"	1'-0"	2'-6"	5'-0"	5'-6"	7'-0"	10'-0"	12'-0"	12'-0"	12'-6"	13'-6"	14'-6"	15'-6"
	550	1'-0"	1'-6"	3'-0"	5'-0"	7'-0"	7'-6"	9'-6"	11'-6"	13'-0"	13'-6"	14'-0"	14'-6"	15'-0"	16'-0"

Rectangular holes based on measurement of longest side.

GENERAL NOTES

- If more than one hole is cut into the web, the distance between the edges of the holes must be at least 2x the length of the largest hole.
- Holes may be located vertically anywhere within the web. Leave ⅛" of web minimum at top and bottom of hole.
- TJI® joists are manufactured with 1½" perforated knockouts in the web at approximately 12" on-center along the length of the joist.
- Distances in the charts above are based on uniformly loaded joists using the maximum loads shown for any of the tables listed within this brochure. For other load conditions or hole configurations not included in these charts, refer to our TJ-Beam™ software or contact your Trus Joist MacMillan representative.
- For simple span (5 foot minimum) uniformly loaded joists meeting the requirements of this brochure, one maximum size round hole may be located at the center of the joist span provided no other holes occur in the joist. DO NOT cut into joist flanges when cutting out web.



FULL WEB DEPTH RECTANGULAR HOLES ARE ALSO POSSIBLE. CONTACT YOUR TRUS JOIST MACMILLAN REPRESENTATIVE FOR ASSISTANCE.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Energy Code Proposal Short Form

For editorial **Coordination, Clarifications & Corrections** only,
without substantive energy or cost impacts

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # **R403.5.3 Hot water pipe insulation**

Brief Description: Clarifies that pipe insulation can be discontinuous where it passes through or close to framing members and other elements.

Proposed code change text:

R403.5.3 Hot water pipe insulation (Prescriptive). Insulation for hot water pipe shall have a minimum thermal resistance (*R*-value) of R-3.

> **Exception.** Pipe insulation is permitted to be discontinuous where it passes through studs, joists or other structural members and where the insulated pipes pass other piping, conduit or vents, provided the insulation is installed tight to each obstruction.

Purpose of code change:

Clarification to make the 2015 energy code more clearly reflect 2013 and 2014 SBCC interpretations, particularly Interpretation 13-15.

Your name	Duane Jonlin	Email address	Duane.jonlin@seattle.gov
Your organization	City of Seattle DPD	Phone number	206-228-8195
Other contact name	(none)		

<u>Instructions</u>: For use with <u>Coordination, Clarifications & Corrections</u> **ONLY**. Send this form as an email attachment, along with any other documentation available, to: sbcc@ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280.

<u>Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.</u>

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions X Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # 403.7.1

Brief Description: **Electric resistance zone heated units (Mandatory).**

Proposed code change text:
All detached one and two family dwellings and multiple single-family dwellings (townhouses) up to three stories in height above grade plane using electric zonal heating as the primary heat source shall install an inverter-driven ductless mini-split heat pump in the main living area. Building permit drawings shall specify the heating equipment type and location of the heating system.

Purpose of code change:

- To lock in energy savings in compliance with the governors energy efficiency goal of 70-percent reduction in building energy usage from the base 2006 WSEC by 2030.
- This code change significantly reduces homeowners monthly, annual and life-cycle net cost of home ownership by taking advantage of lost opportunity economic savings
- Later retrofit of this efficiency measure will result in higher homeowner and societal costs.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

X Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Consistency with state or federal regulations.

☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

X Single family/duplex/townhome

☐ Multi-family 1 – 3 stories

☐ Multi-family 4 + stories

☐ Commercial / Retail

☐ Institutional

☐ Industrial

Your name Bruce Carter

Your organization Tacoma Public Utilities

Email address bcarter@cityoftacoma.org

Phone number 253-502-8304

Other contact name Click here to enter text.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

<u>Instructions</u>: Send this form as an email attachment, along with any other documentation available, to: sbcc@ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **<u>Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.</u>**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

The homeowner expected life-cycle savings benefit in 2015 real dollars is $5,501 for a ductless heat pump in the common living area and electric resistance zonal heating in the other conditioned spaces when compared to an all-electric resistance zonal heated home.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

Based on a 1280 square foot single family dwelling, the incremental first cost increase of a hybrid ductless heat pump-electric resistance home is $1825 per dwelling, or $1.43 per square foot.

Show calculations here, and list sources for costs/savings, or attach backup data pages

See A Case Study of Residential new Construction ductless Heat-Pump Performance and Cost Effectiveness study included with this proposal.

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

Annual estimated energy savings of a 1280 square foot single family dwelling is 2,806 kWh, or 2.19 kWh per square foot.

(For residential projects, also provide KWH/KBTU / dwelling unit). The annual energy savings of a 1280 square foot dwelling is 2,806 kWh per year or 9,574.5 KBTU.

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

See A Case Study of Residential new Construction ductless Heat-Pump Performance and Cost Effectiveness study included with this proposal.

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

No additional plan review time is required for this proposal.

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

A Case Study of Residential New Construction Ductless Heat-Pump Performance and Cost Effectiveness

Washington State University Energy Program
Building Technologies Program
February 13, 2015

NOTICE

A Case Study of Residential New Construction Ductless Heat-Pump Performance and Cost Effectiveness

Prepared for:

Tacoma Power

WSU

Prepared by:

Michael Lubliner and Rick Kunkle

Washington State University Energy Program

905 Plum St. SE

Olympia, WA 98504

And

Bruce Carter, Rich Arneson, and Jeremy Stewart

Tacoma Power Planning Research, and Evaluation Team

3628, South 35th St

Tacoma, WA 98407

Prepared under Contract No. 4600009196

February 14, 2015

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Contents

List of Figures

List of Tables

Definitions

BE Opt	Building Energy Optimization
BPA	Bonneville Power Administration
BTU/h	British thermal units per hour
CDD	Cooling Degree Days
CI	confidence interval
COP	coefficient of performance
CT	current transducer
DD	degree days
DH	degree hours
DHP	ductless heat pump
DHW	domestic hot water
DOE	Department of Energy
EIA	Energy Information Administration
EB	error bound
EPA	Environmental Protection Agency
ER	electric resistance
ER Heat	Electric Resistance Heating
HDD	heating degree days
HFH	Habitat for Humanity
HSPF	heating seasonal performance factor
HVAC	heating, ventilation, and air conditioning
kWh	kilowatt hours

kWh/yr	kilowatt hours per year
kWh/sqft	kilowatt hours per square feet
LVRM	Living Room
MEL	miscellaneous electric load
N	number of observations
NIST	National Institute of Standards and Technology
NWPCC	Northwest Power and Conservation Council
NCDC	National Climatic Data Center
NWS	National Weather Service
OFM	Office of Financial Management
PNW	Pacific Northwest
R2	coefficient of determination
RASS	Residential Appliance Saturation Survey
RAC	room air conditioning
RBSA	Residential Building Stock Assessment
RMS	root mean squared
RTF	Regional Technical Forum
SD	standard deviation of the population
SBCC	State Building Code Council
SEER	Seasonal Energy Efficiency Ratio
TMY	Typical Meteorological Year
TPU	Tacoma Public Utilities
VLT	vapor line temperature
WSEC	Washington State Energy Code
WSU	Washington State University

Executive Summary

Tacoma Power and the Washington State University (WSU) Energy Program implemented a research project on high-performance ductless heat pump in an affordable new construction housing community: The Woods at Golden Given. The primary research goals of this project are to assess the performance, cost, benefit, and homeowner acceptance of a hybrid Ductless Heat Pump (DHP) – Electric Resistance (ER) heating system in single family residential dwellings. The results of this study indicate that the hybrid DHP-ER heating system provides cost-effective energy savings in new residential construction.

The Woods is a Tacoma/Pierce County Habitat for Humanity (HFH) community that, when completed, will have 30 single-family ENERGY STAR Homes® Northwest (ESHNW)-certified homes located in the marine climate of Tacoma/Pierce County, Washington. This research report presents preliminary results from field testing, monitoring, modeling and economic analysis of hybrid ductless heat pump heating systems in seven homes built and occupied from 2013 through 2015. The final report, expected to be completed in May 2015, will include additional energy use data for the study homes and updated performance, cost benefit analysis and occupant survey results.

In a hybrid DHP-ER system home, a DHP is located in the main living area, and electric resistance zonal heaters are located in the remaining conditioned zones. Current standard practice is to use an all-electric resistance zonal heating system. The DHP can provide space heating at a substantially higher level of energy efficiency than ER, while providing the opportunity to have air conditioning.

To compare two heating systems, both electric resistance and DHP heating systems were installed in the common living area of each home. Each week, an electronic time-clock switched between the electric resistance and DHP systems in the common living area. The schedule of the switch between ER and DHP was different for each home. The electric resistance heating in other rooms was available for use by the participants throughout the period. Data loggers collected hourly energy use and temperature data for each home.

This research effort is funded over 2013-2015 by Tacoma Public Utilities (TPU), the Bonneville Power Administration (BPA), Snohomish County PUD, and Cowlitz County PUD.

This preliminary research report presents:

- Cost data from HFH and other sources related to the hybrid DHP-ER heating system and an all-electric resistance heating system.
- A comparison of the space heat energy consumption of a hybrid DHP-ER heating system and a traditional all-electric resistance zonal heating system installed in the same home. This comparison is made by implementing a series of weekly “switch-back” tests when in the all-electric resistance zonal mode and when in hybrid DHP-ER mode to compare space heating energy use, temperature, and relative humidity (RH).
- A life cycle economic analysis of Hybrid DHP-ER heating systems was compared to an all-electric resistance zonal heating systems in these high-performance homes from a homeowner’s perspective.
- Customer acceptance of a hybrid DHP-ER heating system compared to an all-electric resistance zonal heating system.

Key Research Questions Answered

Below are the key research questions posed and answers found in this study:

1. **What are the average annual electricity and bill savings of a hybrid DHP-ER heating system when compared to the alternative all electrical resistance system in this study of HFH homeowners in a Pacific Northwest (PNW) climate?**

   The case study weather normalized annual energy savings from the hybrid DHP-ER system were 2,806 kWh. Using a 2016 weighted average Washington state residential electric rate of $0.0853/kWh, average annual bill savings is $239. Site-specific savings ranged from a low of 2,019 kWh to just over 4,289 kWh.

2. **What are the estimated total and incremental installed costs of hybrid DHP/electric zonal heating systems in new construction single family residential homes?**

   The average hybrid DHP-ER heating system cost to a new home buyer is $2,146. Average cost for an all-electric resistance heating system is $321 resulting in an incremental cost of $1,825 per home.

3. **What is the average expected life-cycle impact of a DHP-ER heating system when compared to an all-electric resistance heating system?**

   On average these homes are expected to have a 2015 present value gain of $5,154 with a hybrid DHP-ER heating system when compared to an All-ER heating system.

4. **Are participants at least as comfortable with DHP systems as with zonal electric systems, and what occupant behavior parameters may impact energy savings and/or thermal comfort?**

   Early survey results suggest that homeowners in this study see the DHP as a superior alternative to standard electrical resistance heating in their common living areas due to better heating performance cooling functionality, the freedom it offers for furniture placement and the reduced effort required to avoid fire hazard.

1 Introduction and Background

Research conducted in the PNW suggests that retrofitting older, ER zone-heated homes with a DHP single fan coil unit ("head") in the main living area is cost effective and may reduce energy use on average about 33%. (Ecotope 2013, 2014) However, no studies had been conducted of the effectiveness of hybrid DHP-ER in very efficient new construction homes. This study aims to help fill that void. It takes an innovative approach to measuring household energy savings on two alternative heating systems (a hybrid DHP-ER heating system and an all electrical resistance system) by switching homes from one system to the other on a weekly basis and comparing energy use by the same household under the two different systems.

PNW builders of housing communities where natural gas is unavailable often use all-electric resistance heating and no air conditioning. New energy codes reduce space-heating energy use, so it is often difficult to justify the high first cost of a ducted heat pump, natural gas, or propane HVAC systems.

This report describes results from preliminary analyses of heating energy usage data and heating system cost data for a small set of new construction ENERGY STAR ® homes located in the Tacoma Power service territory. The homes analyzed in this study were built and occupied during the 2013-2015 period. Two heating systems were installed in the common living area of each home. Each week, an electronic programmable time-clock switched between a standard all-electric resistance heated home and a hybrid ductless heat pump-electric resistance heated home (hybrid DHP-ER heating system). Homeowners were instructed to "just be comfortable" and to operate each of these heating systems to meet that goal. A secondary benefit of the DHP system is builder-installed air conditioning. This is unusual luxury for HFH and other affordable housing stakeholders, who tend to build small homes with limited HVAC budgets.

Data loggers were installed at each site to monitor energy use and indoor temperatures. Data on consumption related to whole-house, ER space heat, DHP, water heater (DHW), on DHP vapor line temperature (VLT) and on indoor temperatures in three rooms in the house were recorded as hourly averages. The data logging methodology employed on this study has been widely used and accepted in the PNW to test the performance of DHP systems in situ. A survey is currently under way to gauge homeowner acceptance of the DHP.

Logged data were analyzed to determine the costs and benefit economics for homeowners of installing a DHP instead of electric resistance zonal heating in the main living area in a new, all-electric, high-performance, affordable housing in the PNW marine climate.

The results of this case study suggest that hybrid DHP-ER heating systems achieve significant energy savings over all electrical resistance heating system in new construction homes and are cost-effective. These findings are consistent with those from other DHP/Hybrid energy savings analysis research on existing single family home retrofits. Findings from this case study add to the body of research showing the promise of hybrid DHP-ER heating systems. However, it is important to keep in mind that generalizing performance from a small sample is problematic, as the sample may not represent the broader population of interest.

1.1 Project Goals and Objectives

This preliminary research report presents:

- Cost data from HFH and other sources related to the hybrid DHP-ER heating system and an all-electric resistance heating system.

- A comparison of the space heat energy consumption of a hybrid DHP-ER heating system and a traditional all-electric resistance zonal heating system installed in the same home. This comparison is made by implementing a series of weekly “switch-back tests” to compare space heating energy use, temperature, and relative humidity (RH) in all-electric resistance zonal mode with and hybrid DHP-ER mode. The timing of the “switch” between heating systems was unique to each home.

- A life cycle economic analysis of Hybrid DHP-ER heating systems compared to an all-electric resistance zonal heating systems in these high-performance homes from the perspective of home buyers.

- Preliminary participant survey results about homeowner preferences for the Hybrid DHP-ER heating system versus the all-electrical resistance zonal heating system. .

1.2 Washington State Energy Efficiency Code Goals

This research is being conducted to help support continued progress to meet State of Washington 2030 Challenge goals signed by Governor Gregoire. The goal of the 2030 Challenge is to establish residential energy codes that result in 70% lower energy use when compared to homes built under the 2006 WSEC. In 2009 the Washington state legislature passed E2SSB 5854 which codified this goal as part of RCW19.27A.160.

This study suggests that using high-efficiency DHPs in what would otherwise be all-electric resistance heated homes will contribute significantly to achieving this goal. Experience among Northwest conservation experts indicates that the best time to implement home-based energy efficient technology such as DHPs is during initial design and construction. At this stage, these technologies are both less costly and easier to integrate naturally into the design of the home.

1.3 Popularity of Electric Resistance Heating in Western Washington

Each year, hundreds of new single family dwellings with electrical resistance zonal heating are built in Washington State. PNW builders in areas where natural gas is unavailable often install all-electric resistance heating. It is the lowest first cost heating system available and remains a popular construction option in part because of the very low electricity rates in Washington State.

Tacoma Power reviewed customer account records and County Assessor data to quantify home heating system type, square footage and built year. Of the 112,000 single-family homes in the service territory, about 50,000 (47%) have electric resistance space heating systems. Just over 16,500 (nearly 15%) are electric resistance zonal heated homes. Across Washington State, nearly 39% of single family dwellings use some type of electric heat as its primary heating system (RBSA). Of these, about 14 percent are electric resistance zonal heated.

1.4 About the Project Site

Tacoma/Pierce County HFH is building 30 owner-occupied, single-family homes in the TPU service area between 2013 and 2016. The community, called “The Woods at Golden Given,” includes six different models of cottage-style dwellings ranging in size from 895 to 2,200 square feet. Habitat elected to forego the expense of bringing natural gas to the site. The homes will be heated using zonal electric heating in bedrooms. For this study, both a DHP and an electric resistance heater were installed in the main living area. At the end of the study, the homeowner will select one of these common area heating systems to keep. The duplicative heater, either the DHP or the electric resistance heater will be removed at the end of the study. There is no supplemental heat in the form of wood or gas heaters in these homes. As of January of 2015, 12 of the 30 homes have been built and occupied.

To maintain homeowner privacy, homeowner names, home addresses or lot numbers are not used in this study. Instead, a list of specific tree names have been assigned to each home, e.g. Western White Pine (Pine), Western Larch (Larch), Douglas Fir (Fir), Western Hemlock (Hemlock), and Red Alder (Alder), etc.

1.5 Ductless Heat Pump Description

The ductless mini-split heat pump (DHP) is a refrigerant based heating and cooling system that delivers heated or cooled air through one or more fan-coil units mounted in specific zones within the building. Thousands of electric zonal heated single family dwellings throughout the Pacific Northwest have successfully been retrofit with DHPs. Studies have found this technology to be reliable and cost effective and to provide energy saving over electric resistance heaters in existing construction.

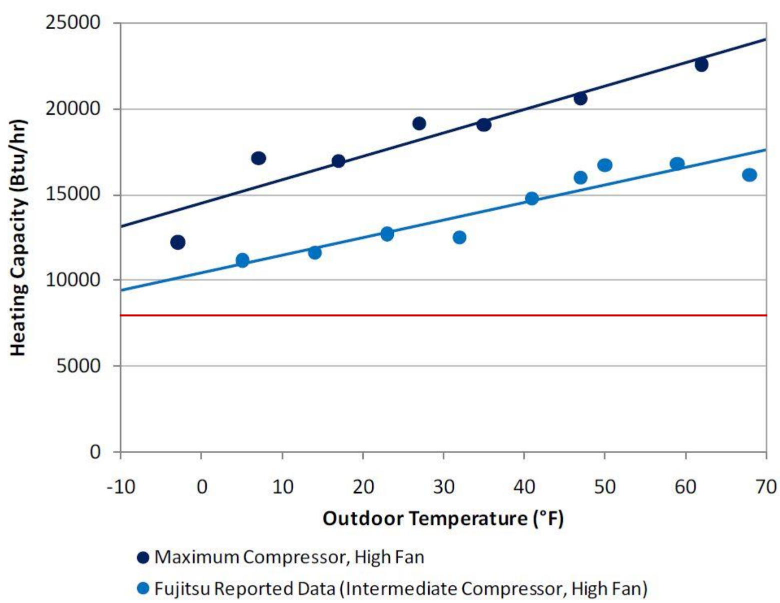
1.6 Previous DHP Performance

DHPs perform well over a wide range of temperatures and have been found to operate much better than their larger ducted heat pump "cousins". The National Renewable Energy Laboratory (NREL) and Ecotope conducted an independent lab study in 2012 of two typical DHP models: the Fujitisu 12RLS and the Mitsubishi FE12NA.

The Fujitisu unit tested by NREL is an older version of the Fujitsu 12RLS installed for this study. In general, the study concluded that manufacturer performance specifications aligned with independent testing results. The performance results outlined below support the assertion that DHPs are capable of supplying adequate heat to a home well below Washington State design temperature requirements.

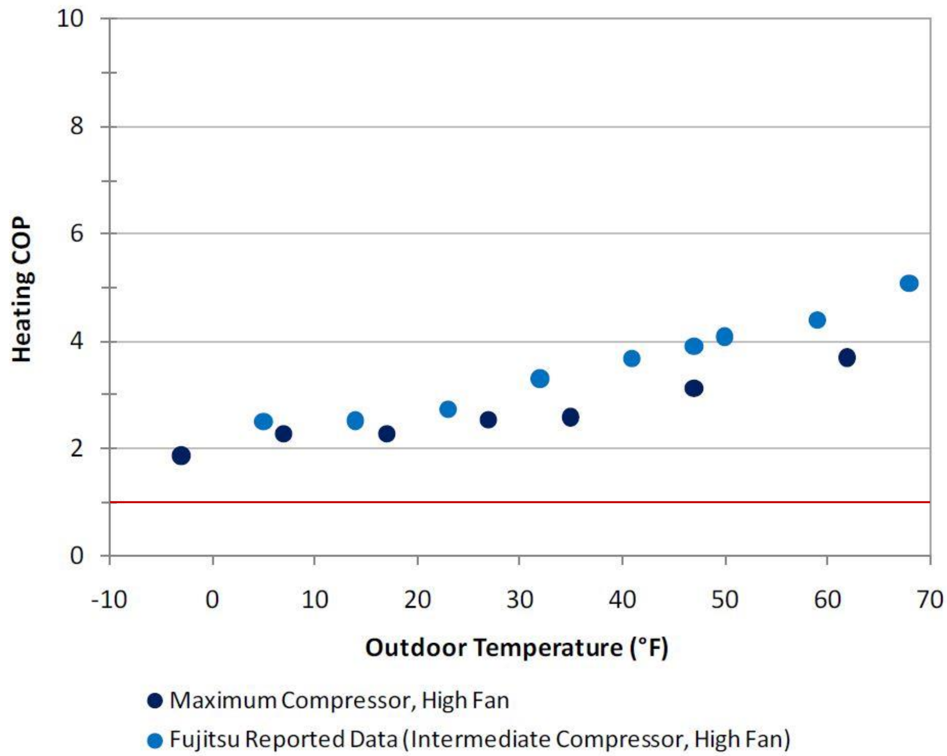
NREL conducted BTU output performance testing over a wide range of outside temperatures and operating modes. Figure 1 presents BTU bench testing of the Fujitisu unit at intermediate (manufacturers data) and maximum (NREL data) compressor speeds. This unit is able to supply more than 10,000 BTU per hour at intermediate compressor speeds even at 0 F and was able to supply more than 12,000 BTU per hour at maximum compressor speed. By comparison, for the Habitat homes studied, the two 1.25 kW (four foot long) baseboards installed in the common living area can provide a maximum of 8,530 BTU per hour (red line superimposed on Figure 1).

Figure 1. Fujitsu 12RLS Heating Capacity Compared to Manufacturer reported data (70 F return temperature) NREL



NREL also performed Coefficient of Performance (COP) performance testing over a wide range of outside temperatures and operating modes. Figure 2 presents DHP COP bench testing of the Fujitsu unit at intermediate (manufacturer data) and maximum (NREL data) compressor speeds. This unit was nearly twice as efficient as ER at intermediate compressor speeds even at 0 F and was nearly twice as efficient at maximum compressor speed. By comparison, electric resistance zonal heating is 100% efficient at all outdoor temperatures and so ER COP would be a flat 1.0 at all outdoor temperatures (red line superimposed on Figure 2).

Figure 2. Fujitsu 12RLS Heating COP Compared to Manufacturer reported data (70 F return temperature) NREL



1.7 Residential Air Conditioning in Washington State

Ductless heat pumps offer homeowners the additional benefit of cooling. While this is typically perceived favorably by homeowners, it would increase energy use in homes that would otherwise have all electrical resistance heating and no air conditioning system. This is taken into account in this study.

While this study assumes that homes on the alternative all electrical resistance heating systems would not have had air conditioning, market assessments clearly indicate that many households do, in fact, have air conditioning systems. The RBSA found that approximately 24% of all single family homes surveyed had some form of cooling equipment in Washington state’s cooling zone 1 (Western Washington) and 72% in cooling zone 2 (Eastern Washington).

Tacoma Power's most recent Residential and Appliance Saturation Survey (RASS) in 2011 found that nearly 34% of single family homes have some form of cooling system. A majority of these were portable or window type air conditioners.

1.8 The Study Team and Project Co-Funders

This study was made possible by the interest and collaboration of many organizations and the homeowner participants.

The Tacoma/Pierce County Habitat for Humanity: Maureen Fife CEO, Gomer Roseman Director of Site Development and Construction, Guy Nielsen construction site manager, and Carolyn Benbow Family Services Coordinator. The Habitat for Humanity homeowner participants, who allowed the installation of study instrumentation in their homes, agreed to weekly switching of the heating system in their common living area, and participated in study related surveys. Gomer Roseman for providing cost data for the ER heating systems, DHP system, and DHP installation preparation.

Tacoma Public Utilities/Tacoma Power: Rich Arneson, Bruce Carter, Cathy Carruthers, Jeremy Stewart, Rachel Clark, Molly Ortiz, and Ying Tang provided project planning, project management, documentation, technical services, and statistical/analytical services.

Washington State University Energy Extension: Michael Lubliner, Luke Howard, David Hales, and Rick Kunkle provided onsite commissioning of data logger systems, monitoring, data management, documentation, and analysis. Research and technical support to the project was also provided to WSU by the US Department Energy as a member of the Building America Partnership for Improved Residential Construction (BA-PIRC).

Bates Technical College: Dave Leenhouts instructor, and students of the 2013, 2014, and 2015 electrician classes provided electrical wiring design and installation of the electronic time-clock switching system that controlled the living room space heating and installation of the data loggers devices on the 120/240 volt circuits. Leenhouts also provided cost estimates of wiring time and miscellaneous material for typical living room electric resistance zonal heating and for the ductless heat pumps.

This project was co-funded by three Washington State electric utilities; Tacoma Power, Snohomish County PUD, and Cowlitz County PUD along with funding and data logger equipment loans from the Bonneville Power Administration.

2 Site Characteristics

2.1 House Envelope Efficiency

The Woods at Golden Given community is constructed on a site located in Pierce County Washington. Surface run off is minimized through the use of pervious hard surface for drives and sidewalks throughout the development. A series of rain gardens catch runoff from roofs and surrounding yards. The southern portion of the site has been declared a “solar zone” and the planned community center located there will incorporate both photovoltaic and solar thermal technologies for generating electricity and hot water for use in the building.

HFH chose to build the homes at the Woods at Golden Givens in compliance with the Northwest ENERGY STAR Compliance Option 10 (NWESH), exceeding current standards required by the Washington State Energy Code (WSEC). While attic insulation is consistent with the WA code, slab and wall insulation both exceed current code requirements. The entire under slab is insulated to R-10 and the exterior 2x6, R21 walls are constructed with one inch of XPS foam sheathing giving them a thermal value of R26. The homes are built tighter than required by code as well; 4.0 air changes per hour at 50 Pascals (4 ACH50). The WSEC requires building tightness of 5 ACH50. Whole-house ventilation is required in all new homes in Washington. Rather than the minimum exhaust only ventilation as required by state code, NWESH requires a ducted heat recovery ventilation (HRV) system be installed and commissioned in these homes.

Appendix A provides a breakdown of the home energy features for the first four homes monitored. The Woods incorporates all of the requirements for certification under ENERGY STAR Northwest Version 3.0. BEopt modeling indicates that these designs achieve the goal of the BA program to reduce home energy use by 30% to 50% (compared to 2009 energy codes for new homes), and roughly 15% over current WSEC.

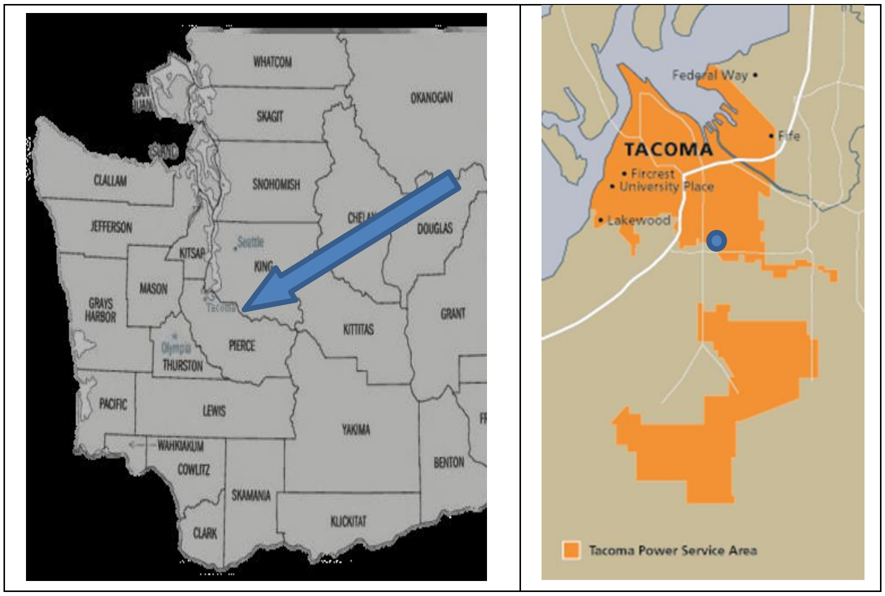
2.2 Study House Size Representativeness of Housing Stock

Over the last twenty years in the Tacoma Power service territory, new constructed single family zone-heated homes averaged 1,462 sqft, while the average size home with other heating systems for the same period was 2,000 sqft. The average home size in this study is 1,280 sqft, just 180 sqft smaller than the average zone-heated home in the Tacoma Power service territory.

2.3 Geographic location

Project sites are located in Pierce County, Washington State. Pierce County is in the Western Washington area known as South Sound.

Figure 3. Washington State and South Sound and Project Site



2.4 Occupant Characteristics

All homes are occupied as primary residences. The number of bedrooms in each home is dependent on the number of occupants. Habitat's model design ensures that each child in the household has their own bedroom. In practice, children in some homes share bedrooms, with the "additional" room(s) used as play rooms, offices, etc.

A participant survey is under way, and seven of the twelve families living in their new homes have been surveyed to date. Occupants of the homes in this study consist of one or two parents and their children, with the total number of occupants ranging from 3 to 11. Of the households interviewed so far, six of seven have children under the age of 12, three of seven have adolescents aged 13 to 17 and two of seven have children 18 or older living at home.

There is some variation in home occupancy during the daytime. Three reported having regular times of the day when the homes were unoccupied during the week, while four reported that their houses were virtually always occupied.

3 Hybrid Heating Systems

For this study, all homes are heated with DHPs as well as ER baseboard heaters and fan-assisted wall heaters. Each of the four homes that were audited has a single air handler (head), 1-ton DHP with an HSPF of 12.0/SEER 25. The DHP's interior unit (head) is installed in the main living area of each home in addition to 2,500 watts of installed baseboard heater. These homes have the same DHP model installed. This equipment is pictured in Figure 4.

Figure 4. DHP: Outdoor, Indoor units and remote thermostat in living room

Each bedroom in these homes is directly heated with one 750W fan-assisted ER wall heater located in the exterior wall below a window. All zones are controlled by independent manual thermostats. This equipment is picture in Figure 5 along with a data logger adjacent to the thermostat.

Figure 5. Electric Resistance, fan and baseboard types and hard wired thermostat in living room w/T/RH data logger

The DHP's interior unit (head) is installed in the main living area of each home in addition to 2,500 watts of installed baseboard heater. Each bedroom in these homes is directly heated with one 750W fan-assisted ER wall heater located in the exterior wall below a window. All zones are controlled by independent manual thermostats.

4 Field Monitoring

For this study, Washington State University Energy Extension (WSU) staff placed data logger systems and Bates Technical College student electricians (overseen by their instructor) installed wiring, CTs, time-clocks, and contactors.

WSU developed a field installation guide in the early stages of field installation. Site technicians were required to fill out a detailed site protocol, including types of sensors and individual sensor serial numbers (because these are the primary identifiers of sensors after data returns from the data logging vendor).

As of this report, twelve homes are occupied and monitored with data logger systems. This report analyzes data of seven homes. The remaining five homes have wiring or occupant behavior challenges that have rendered the data unusable at this time. These five homes were excluded from this preliminary analysis. The study team will work to include as many of these homes as possible in the final report.

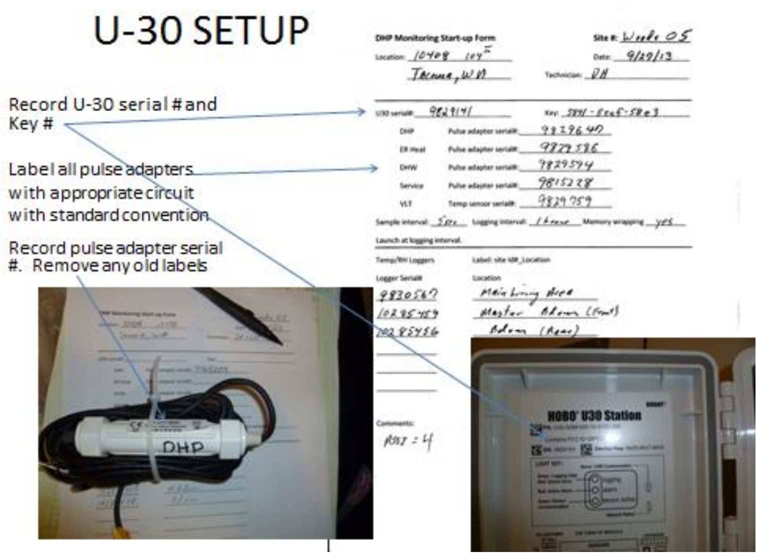
End-use metering using a HOBO U30 data logger included hourly measurement of whole house energy use, ER and DHP energy use in the common living area, ER energy use other conditioned rooms in the home, domestic water heater energy use, and the vapor line temperature at the DHP. Temperature and relative humidity were also logged for the common living area and two bedrooms using standalone HOBO data loggers.

The data logger vendor "web services" enabled electronic data delivery from the data warehouse to Tacoma Power computers.

4.1 Objective of the field metering

A documented process was used to configure and manage data logging equipment. HOBO U30 data loggers measured energy use of key electric circuits to quantify space heating energy use within study homes. It also quantifies cooling energy use.

Figure 6. Data Logger Commissioning

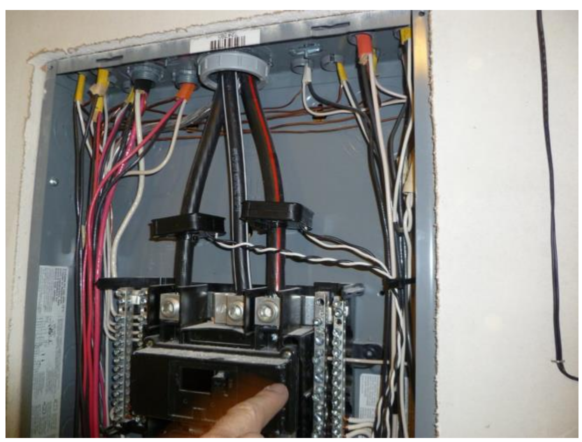


4.2 Metering Specifications

4.2.1 ***Service Panel***

A 100 amp Current Transducer (CT) was installed by electricians at each 120 volt leg of the main service panel to collect data on all end-uses of the home and as part of a check for the .

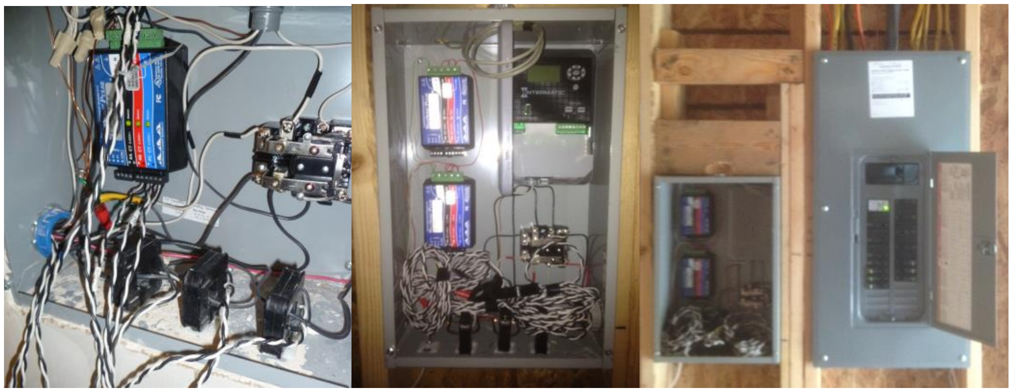
Figure 7. Service Panel CTs to Measure All Electric Load



4.2.2 ***Living Room DHP/Electric Resistance Heat***

A 50 amp CT was installed by electricians at each 120 volt leg serving the common living area. A contactor for the DHP and the common area ER-zonal was switched each week with an electronic time clock.

Figure 8. Panel Containing Time Clock-Contactors-CTs for Switch-Back and Monitoring



4.2.3 *Other Room Electric Resistance Heat*

All other electric resistance zonal heating was not controlled with the time clock-contactor system. However CTs were installed by the electrician to separately measure energy use of this circuit.

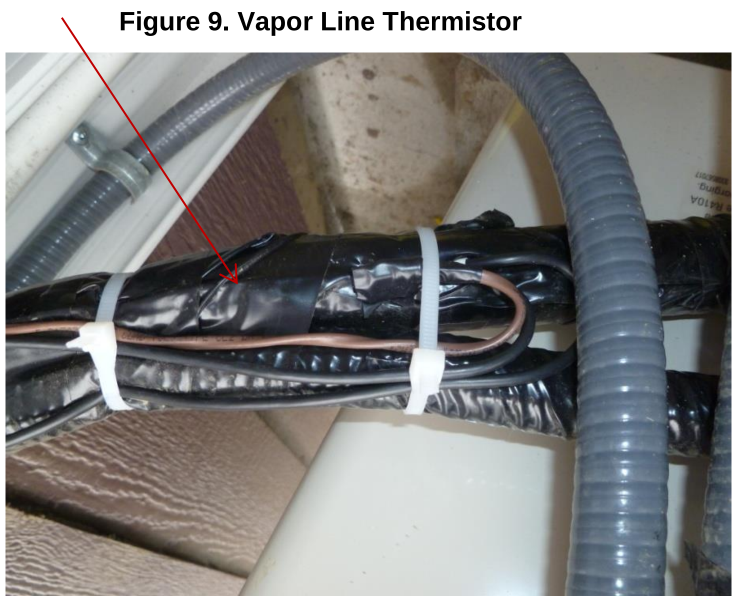
4.2.4 *Domestic Water Heater*

One CT was installed by the electrician (shown in figure X above) on one 120 volt leg of the domestic water heater (DWH). This CT was scaled at twice the value to account for energy use of the two 120 volt legs that serve the DWH.

4.2.5 *Vapor Line Thermistor*

At each home, a Vapor Line Thermistor (VLT) was placed and tapped directly on the small refrigerant line, wrapped with insulation and zip tied in place. The VLT data provides information on the DHP operation.

Figure 9. Vapor Line Thermistor



4.2.6 ***Indoor temperature/Relative Humidity***

At each home, a temperature/relative humidity data logger was placed in the common living area and in two of the bedrooms and logged at hourly intervals. For each room, the data logger was placed adjacent to the thermostats which control the electric resistance zonal heating.

Figure 10. Indoor Temperature/Relative Humidity Data Logger at Zonal Thermostat

5 Data Collection and Assembly

5.1 Energy Use Data Collection Time Frame

Analysis looked at total kWh used by two channels responsible for heating; a 240 volt circuit for living room heat (switched between DHP and Resistance) and a 240 volt circuit for electric resistance in other parts of the home.

Data collection for each house was dependent on Habitat for Humanity's dwelling construction and occupancy schedule. Length of time in this study ranged from 2 months to 15 months. Individual home details may be found in Appendix B.

The analyses use data from move-in date through January 20, 2015. The median number of data-days per site for the entire sample was 256 days, with the longest (Pine) being 381 days and the shortest (Alder) being 63 days. Data through January 20, 2015 were downloaded directly from HOBOLink and compiled into a master file for analysis.

5.2 Error Checking and Energy Use Data Quality Control

The data logger vendor "web services" enabled electronic data delivery from the data warehouse to Tacoma Power computers. Data were reviewed after field installations and scaling of the data channels was verified and corrected if necessary. Once downloaded, data were subjected to range and sum checks. These checks ensured that data used in the analysis were logically accurate (total household energy use is never smaller than use from a single channel). Additionally, significant time was invested to ensure switching schedules were accurate by verifying site consumption and temperature data.

5.3 Incremental First Cost Data

Two approaches were used to estimate heating system costs for the All-electric resistance zonal heated home and the hybrid DHP-ER heating system home; based on data provided by staff associated with the construction project, and by a MEANS/supplier estimation .

In the first method, the total costs and mark-up data were provided by HFH, the winning DHP bidder and the Bates Technical College electrician for the DHP and electric resistance heating systems. Based on these data, the team determined the average hybrid DHP-ER heating system cost to a home buyer is $2,146, the average all-electric resistance heating system cost is $321, and resulting incremental cost is $1,825 per home. This cost estimate included labor, materials, equipment, mark-ups, and tax. Cost details are included in Appendix C.

In the second method, cost estimations based on standard HVAC/General Contractor estimation practices using MEANs and industry provided cost assumptions were compiled and applied to the study home characteristics.

These approaches generally agreed with each other; $2,146 based on Habitat construction data, and $2,298 for MEAN estimation using prevailing wages and typical HVAC and GC mark-ups. Given the results, the remaining cost analysis starts with the Habitat provided cost data

Based on these cost assessments an incremental value of $1,825 and other incremental cost scenarios were used for the Life Cycle Cost Analysis (LCCA) and summarized in Section 8. It is important to note that the costs identified in this study are substantially lower than the cost of retrofitting DHP into existing homes. It is also important to note that in there is no HVAC sub-contractor involved in all-electric resistance homes, since most of the work is done by the electrician and GC laborers.

Table 1. Summary of Common Living Area Incremental First Costs

Cost Category	Electric Resistance Home	Hybrid Home	Net Incremental Costs
Materials	$31	$23	-$8
Heating Systems	$152	$1702	$1550
Wiring Labor	$85	$63	-$22
Adders	$54	$358	$304
Total	$321	$2146	$1825

6 Methodology for Measuring Energy Savings

One of the challenges in establishing an estimate of savings estimate for a given technology is coming up with an accurate counter-factual (a measure of what would have happened in the absence of that technology). While sometimes necessary, it is not ideal to compare household energy consumption in one household with one technology to another household with the alternative technology, because every household behaves differently. This study takes an innovative approach to solving the counter-factual problem by comparing energy use by the same household under two different systems. Because houses are switched between one system and another on a weekly basis, each on a different schedule, household energy use is observed at a variety of different temperatures under both the hybrid DHP-ER system and the all electrical resistance system.

6.1 Statistical Tools

Two statistical tools are used to estimate energy saving using daily consumption and temperature values. First, a multivariable regression is used to establish the existence of a strong, statistically significant relationship between energy use and the heating system in place (hybrid DHP-ER vs all-electric resistance) while controlling for a number of other factors (outside temperature, number of bedrooms, day of the week, and number of occupants).

Next, a set of two polynomial regressions are used to predict energy consumption separately for houses in all-electric resistance mode and for the same houses in hybrid DHP-ER mode. Using these polynomial regressions, total energy use is predicted for each system using temperatures in a weather-normalized year. The savings from hybrid DHP-ER mode is estimated by taking the difference between total predicted energy use in hybrid DHP-ER mode and total predicted energy use in all-electric resistance mode.

These statistical analyses are conducted for the heating season only, focusing on the September-June period. These months are when the vast majority of space conditioning energy is used for heating in Western Washington.

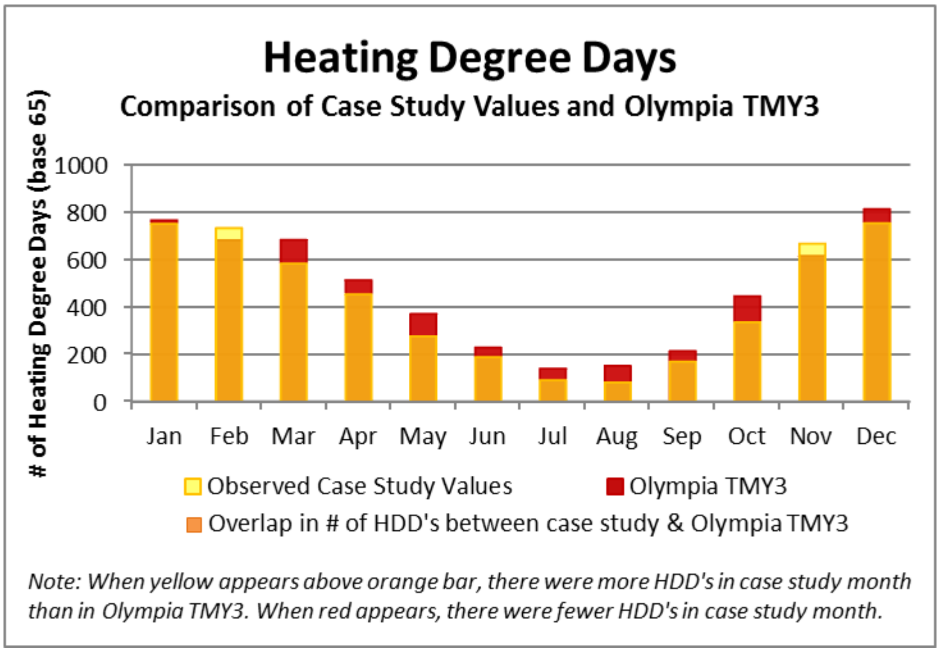
During the heating season, we have a strong counter-factual for energy consumption using the alternative to the hybrid DHP-ER system (standard all-electric resistance heating). However, Tacoma Power honored occupant requests that the weekly switching between systems be suspended during the summer to allow cooling on all days. The study was thus suspended from July 11 through September 14, 2014, and data from this period were removed from the statistical analyses. Cooling from DHPs is accounted for separately (see discussion below).

6.2 Weather Normalization

Savings estimates from the polynomial were normalized to Olympia TMY3, since the study period was warmer and longer than a normal heating season. Discussion of why Olympia TMY3 was used may be found in Appendix E.

Figure 11 presents a bar graph comparing the number of monthly heating degree days observed during the study to those for Olympia TMY3. Yellow represents case study values, red represents TMY3, and orange represents overlap between the case study period and Olympia TMY3. The preponderance of red at the top of most bars indicates that the study period tended to have fewer heating degree days in most months than a "normal" year would have. Over the course of the heating season, the study year had 8% fewer heating degree days than a "normal" year.

Figure 11. Comparison of Heating Degree Days in Study Period vs. "Normal" Weather Year



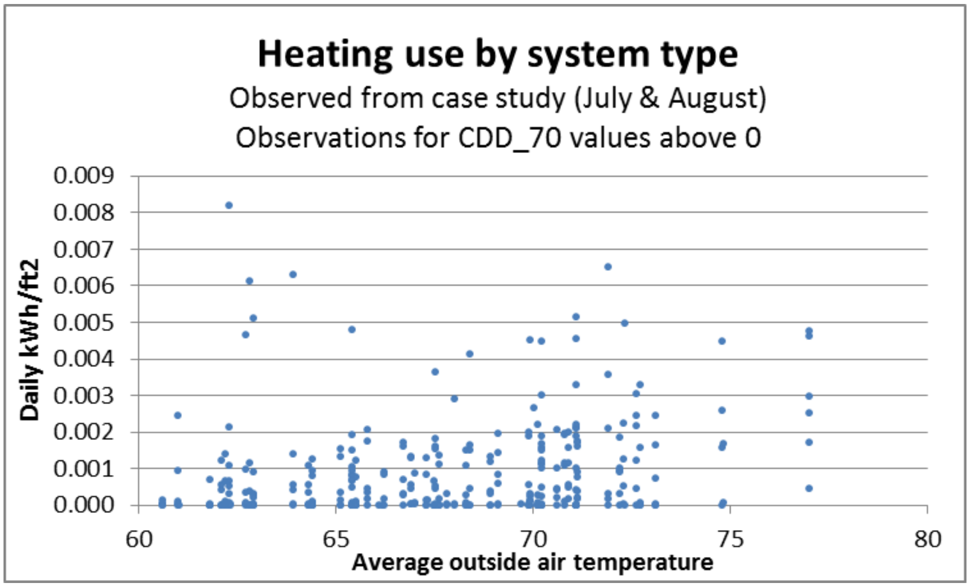
6.3 Accounting for Cooling use with DHPs

Unlike all-electric resistance heating systems, DHPs can function as both a heating and cooling system. While this can improve household comfort, the potential for increased energy consumption in hot weather must be addressed.

In order to determine the most conservative annual energy savings from DHPs, the heating season energy savings were reduced by "cooling season" energy consumption between July 1st and August 31st, which contains the large majority of cooling degree days.

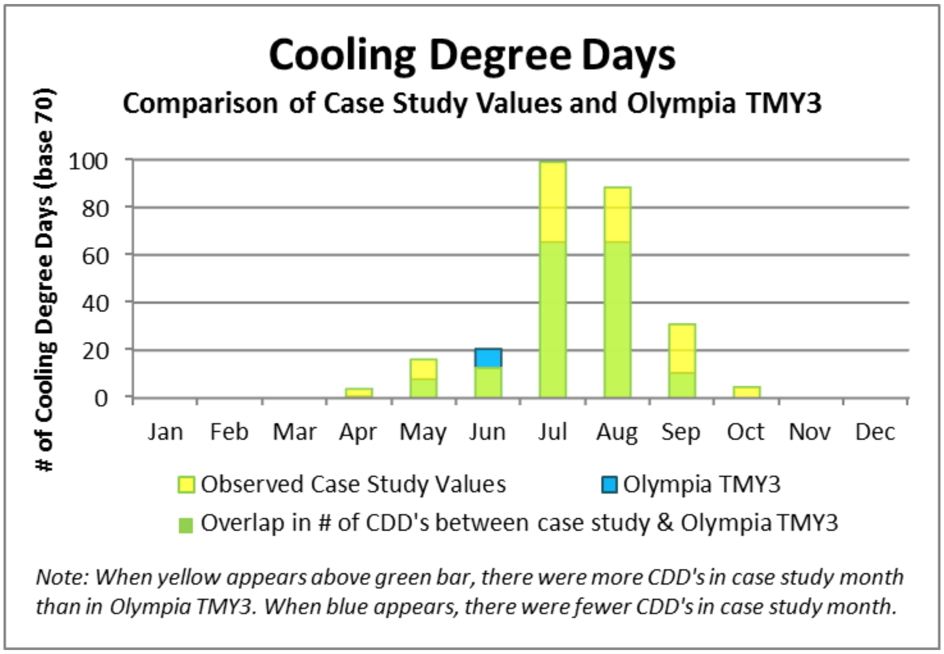
Analyses of data in the cooling season did not show a relationship between outside air temperature and cooling energy use. Figure 12 illustrates that while energy was used during warm periods there was no statistical correlation between outside air temperature and energy usage. Because no statistical relationship existed, cooling energy consumption was estimated using average observed consumption in lieu of a regression to estimate cooling load.

Figure 12. Distribution of TMY3 Temperatures



This method of adjusting estimated energy savings to account for cooling yields a conservative estimate of energy savings from DHPs for two reasons: First, we are not accounting for any displacement of inefficient room air conditioners which are used in approximately 25% of home in Western Washington. Second, our estimates for summer energy consumption are from a warmer-than-normal summer. Figure 13 compares the number of monthly cooling degree days (base 70) observed during the study to those for Olympia TMY3. Yellow represents case study values, blue represents Olympia TMY3, and green represents overlap between the case study period and Olympia TMY3. The preponderance of yellow at the top of bars in all months except June indicates that the study period tended to have more cooling degree days than a "normal" year would have. Overall, the study year had 43% more cooling degree days than a normal year. Thus, estimates of DHP energy use for cooling likely over-estimates the amount of energy used by a DHP in a normal summer.

Figure 13. Comparison of Colling Degree Days in Study Period vs "Normal" Weather Year



7 Energy Use Analysis

7.1 Energy Use Analysis

Figures 14 through 16 below illustrate the energy use savings observed during the study period. Figure 14 presents observed energy use for houses in ER-only mode over all temperatures observed during the study period; Figure 15 presents observed energy use for houses in DHP-hybrid mode; and Figure 16 presents predicted energy use at a given temperature with each heating system.

Figures 14 and 15 demonstrate a visibly strong quadratic relationship between consumption and outside air temperature for both systems, with differences in the shape of the curve describing the relationship across the two systems. In Figure 10, the two systems are compared side-by-side. The gap between the line for hybrid DHP-ER heating and all-electric resistance shows the estimated difference in energy use between the two systems.

Figure 14. Energy Use in All ER Mode

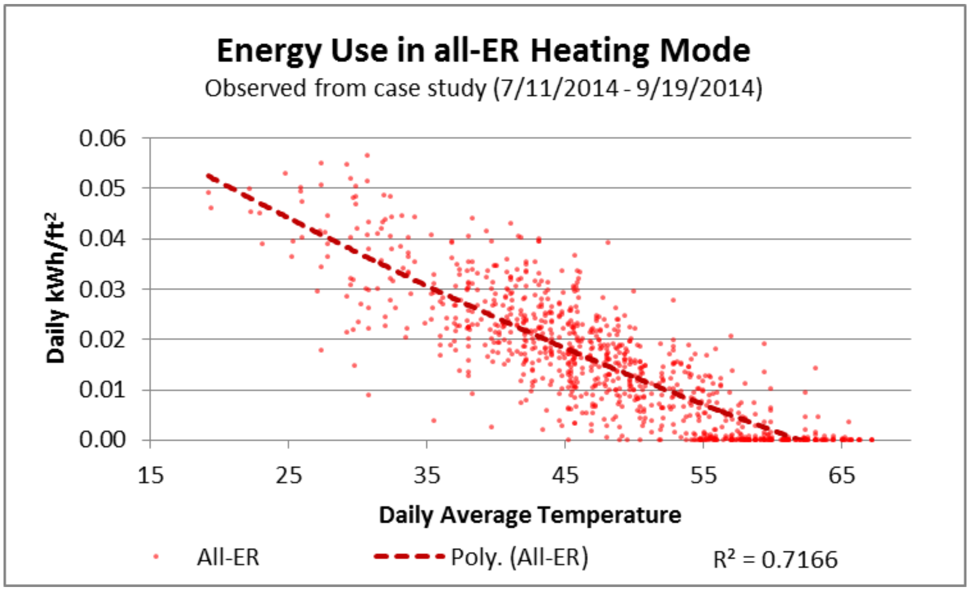


Figure 15. Energy Use Hybrid DHP-ER Mode

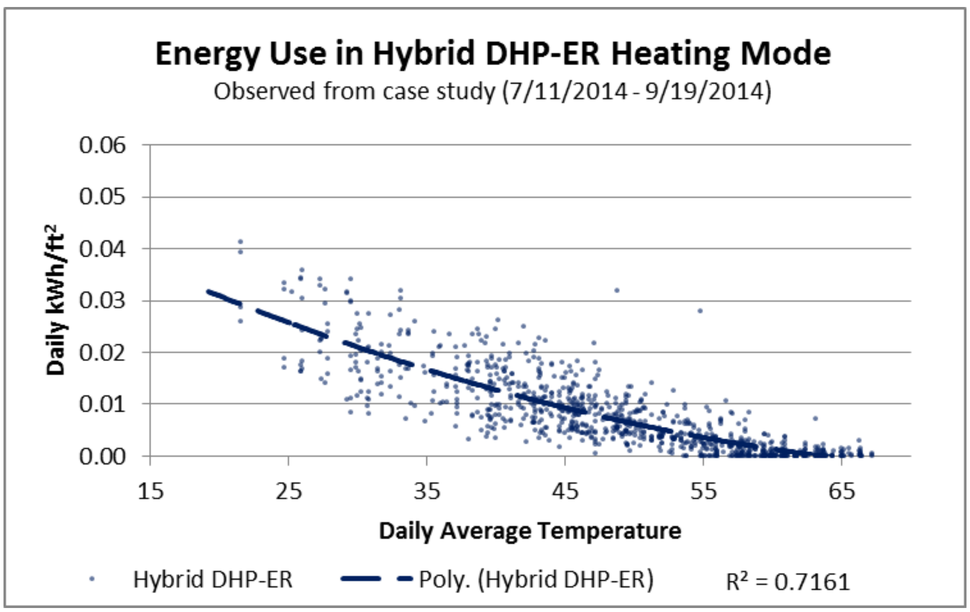
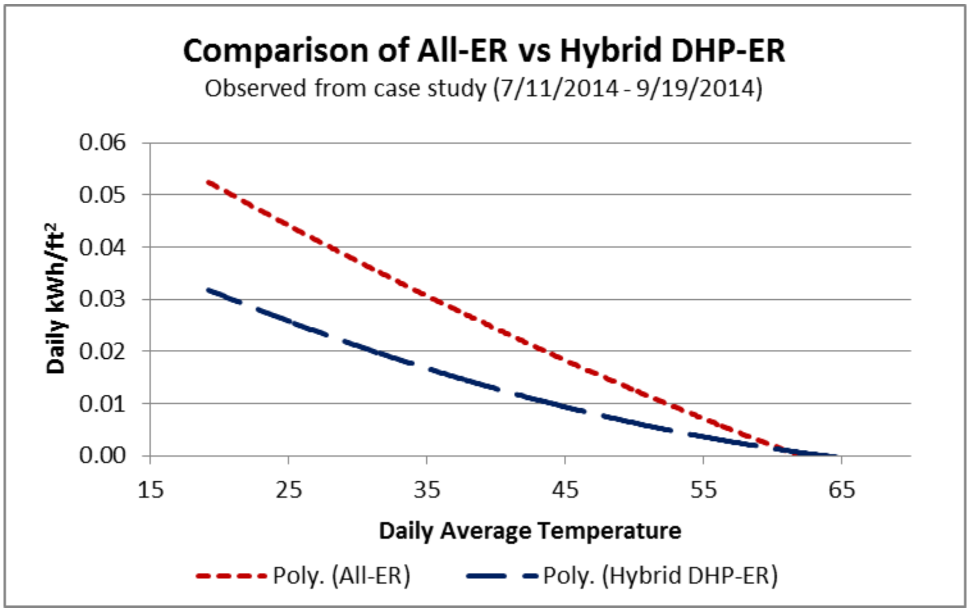


Figure 16. Energy Comparison of energy Use in All-electric resistance vs. Hybrid DHP-ER Systems



7.2 Results of Multivariable Regression

A multivariable regression (represented in the equation below) is conducted to first verify that the type of HVAC system (ER-only or DHP-hybrid) has a statistically measurable impact on heating energy usage. Observations that vary at the household level are represented by the sub-script h in the equation below, and observations that vary at the daily level are represented by subscript t. Observations that vary at both the household and daily levels have the subscript ht. The coefficient β_1 measures the average difference in daily energy use per square foot between the ER-only system and the DHP-hybrid system during the study period. The regression controls for outside temperature, number of bedrooms, number of occupants, and month of the year (with a separate dummy variable for each month).

$$kWh/ft^2_{ht} = \alpha + \beta_1 SystemType_{ht} + \beta_2 OutsideAirTemp_t + \beta_3 OutsideAirTemp_t^2 + \beta_4 Occupants_h + \beta_5 Bedrooms_h + \sum_m \beta_m Month_t^m + \varepsilon_{ht}$$

Analyses are conducted using daily temperature rather than heating degree days (HDD) because temperature is more accessible to a variety of readers. For this study period, temperature and HDD65 are functionally, since the study period, which excludes the cooling season, contained no cases of zero-valued heating degree days with base 65 (HDD65). A squared temperature term was included in all regressions because the relationship between energy use and temperature is nonlinear.

The regression shows a strong, statically significant relationship between energy use and the choice of heating system. All things being equal (month, outside air temperature), the hybrid DHP-ER heating system realized a daily savings of 0.0069 kWh/ft2 during the study period. The point estimate on β1 is robust to a number of variations in the control variables included in the regression. Detailed regression output may be found in Appendix F.

7.3 Predicted Energy Savings

In order to estimate predicted annual energy savings, two separate polynomial regressions predicting energy use as a function of air temperature were performed; one for the resistance heating system and one for the hybrid heating system. Both regressions are described the equation below:

$$kWh/ft^2{}_{ht} = \mu + \gamma_1 OutsideAirTemp_t + \gamma_2 OutsideAirTemp_t^2 + \varepsilon_{ht}$$

Consumption has a strong relationship to outside air temperature for both systems. The coefficient estimates on temperature and temperature squared (γ_1 and γ_2) from each regression are used to predict annual heating electricity use for the two systems for actual and typical temperature (weather) conditions using Olympia TMY. Hybrid system savings is the difference in the annual estimates between the two systems in a “normal” weather year.

The formulas generated from the coefficient estimates are described by equations the two equations in the table below:

Table 2. Formulas used to Predict Energy Use for Each Heating System

System Type	R2 Value	Formula
Resistance	0.717	$kWh/ft^2 = 0.08281736 - 0.00169144 * OutsideAirTemp + 0.00000571 * OutsideAirTemp^2$
Hybrid	0.716	$kWh/ft^2 = 0.05568347 - 0.00140654 * OutsideAirTemp + 0.00000835 * OutsideAirTemp^2$

In order to determine the most conservative annual energy savings from DHPs, the heating season energy savings were reduced by “cooling season” energy consumption between July 1st and August 31st, which contains the large majority of cooling degree days.

Cooling estimates are calculated based on DHP electricity use during hourly periods where outdoor temperature was equal to or above 70 F. It is assumed that electricity use at these warmer temperatures was for cooling. This analysis also accounts for cooling-induced heating by including DHP electricity use for temperatures below 70 F; it is assumed this heating would not have occurred if indoor temperatures were not cooled during the day. Results of this analysis show an average cooling energy use for the DHP of 53 kWh, yielding an average daily cooling energy use value of 0.04 kWh per square foot on cooling degree days. Since no statistical relationship between cooling kWh usage and outside air temperature was found, a constant 0.04 kWh per square foot was added to DHP energy use in July and August. Adjusting energy savings from the DHP-hybrid system downward in this way yields a conservative estimate of energy savings, as it does not account for any displacement of inefficient room air conditioners or for the fact that use of DHPs for cooling during the study's summer period, which had approximately 43% more cooling degree days than a normal summer, was likely higher than cooling use in a normal summer.

Applying the formulas above to outside temperatures observed in Olympia TMY3 and deducting expected cooling energy usage yields an expected savings of 2.19 kWh per ft2, which is equivalent to 2,806 kWh in a 1,280 ft2 home, the average size of home observed in this study.

Table 3. Summary of Expected Savings

	Heating Energy Savings (kWh)	Cooling energy Adjustment (kwH)	Net Annual Energy Savings (kWh)
Savings/ft2	2.23	-0.04	2.19
Savings in 1,280 ft2 Home	2,859	-53	2,806

8 Economics

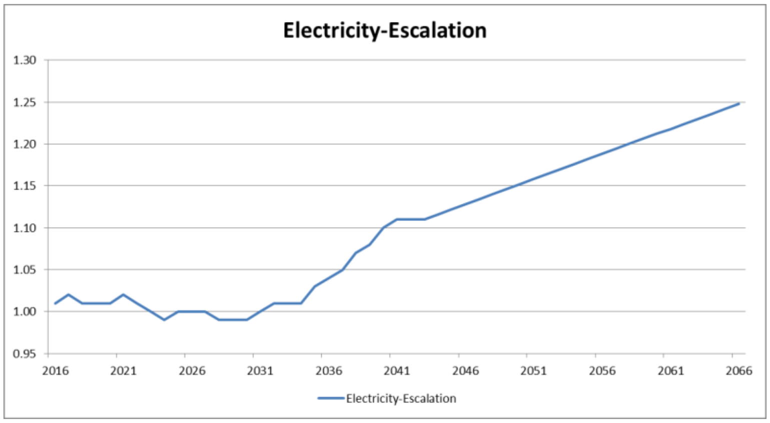
8.1 Economic Analysis Tool and Assumptions

The Washington State Office of Financial Management (OFM) Life Cycle Cost Analysis Tool version 2014-D was used to determine the economics of a hybrid DHP-ER heating system compared to an all-electric resistance heating system. Modeled costs include installed initial heating system cost to home buyer, financing cost, maintenance cost, operating cost (electricity use), periodic heating system replacement costs based on measure life, and a state required estimate of CO_2 societal cost. Monetized values are reported in net present value (NPV) terms over a 51 year life cycle per the OFM methodology. Both the baseline measure and the alternative measure have shorter lifetimes, which result in scheduled equipment replacement over the 51 year lifecycle.

Retail rate projections (figure 17) are based on National Institute of Standards and Technology (NIST) forecasts and assumptions per the OFM methodology.

NIST assumes residential real retail rates will remain relatively flat through 2035, and increase by 25% by the year 2066.

Figure 17. NIST Retail Rate Price Escalation Forecast



8.2 Data and Assumptions Used in Analysis

Installed initial heating system costs for the ER heating systems and the DHPs were collected from documents and interviews with HFH staff, the Bates Technical College project electrician and reviews of the individual house plans. The living room installed ER heating system cost to the home buyer for (2) four foot 1.25 kW baseboards plus wall mount zonal thermostat was estimated to be $321.00 and assumed to last 30 years. The living room installed DHP heating system cost to the home buyer for a one-ton inverter-driven ductless mini-split heat pump system was estimated to be $2,146.00 and assumed to last 18 years. Details on equipment installations costs are available in Appendix C.

Financing costs were modeled with the OFM assumptions which include a 20 percent down payment, a nominal interest rate of 4.54 percent, and general inflation of 2.87 percent. Scenarios were run with 15 and 30 year mortgage terms and incremental cost scenarios from the study average to the breakeven cost.

No maintenance costs were assumed for the electric resistance zonal heating system. In general, DHPs are designed to be relatively maintenance free. This analysis assumed that periodic cleaning of a re-useable filter would be completed by the homeowner and was not included as a cost. However this analysis assumed an $11 per year allocation toward maintenance (nearly $200 during the course of the measure life) for a professional check-up/cleaning of the unit.

Operating costs are a function of annual electric energy use measured in kWhs and a Washington State weighted average residential retail rate per kWh. The Energy Information Administration Forms (EIA 861 4A and 4D and EIA 861S) document Washington State 2012 residential retail rates. From this data, a weighted average rate of $0.0853/kWh was determined and used in the analysis. As described in chapter 7 above, the weather normalized energy use of a electric resistance zonal heating system is estimated to be 6,027 kWh. The weather normalized energy use of a hybrid DHP-ER heating system is estimated to be 3,221 kWh.

8.3 Economic Analysis Findings

Economic results include the present value of construction, financing, maintenance, utilities, and periodic equipment replacement. Results are summarized in Table 4. Results are based on the analysis tool and assumptions described sections 8.1 and 8.2. The baseline all-electric resistance zonal heated home life cycle NPV cost is approximately $22,757, while the hybrid DHP-ER heating system life cycle NPV cost is $17,603. The home owner NPV benefit of a hybrid DHP-ER heating system is estimated to be a $5,154. Details on the annualized costs are available in Appendix D.

Table 4. Summary of Life Cycle Cost Analysis

Alternative	Baseline All-ER Zonal System	Alternative Hybrid DHP-ER System
1st Construction Costs	$318	$2,127
PV of Capital Costs	$503	$5,236
PV of maintenance Costs	$-	$473
PV of Utility Costs	$22,254	$11,893
Total Life Cycle Cost (LCC)	$22,757	$17,603
Net Present Savings (NPS)	N/A	$5,154

Using the methodology and assumptions described in Sections 8.1 and 8.2, a sensitivity analysis was run by changing DHP cost assumptions ranging from $2,146 to the LCCA break-even point, and mortgage terms of 30 and 15 years. These results indicate that from the home owner perspective, the hybrid DHP-ER Heating system remains a cost effective over a wide range of installed costs. Given the retrofit market can typically install a DHP for $3,500 (Tacoma Power program), most of these higher cost DHP scenarios may be unlikely.

Table 5. Sensitivity Analysis of Home Owner Impacts

Incremental Cost	Mortgage Term	Incremental Down Payment	Life Cycle NPV	Average Annual Net Reduction of Costs During Financed Period
$1,825	30	$429	$5,154	$207
$2,679	30	$600	$3,070	$99
$3,179	30	$700	$1,850	$72
$3,679	30	$800	$630	$45
$3,937 BE*	30	$852	$0	$31
$1,825	15	$429	$5,206	$148
$2,679	15	$600	$3,146	$103
$3,179	15	$700	$1,941	$77
$3,679	15	$800	$735	$51
$3,984 BE*	15	$861	$0	$35

*Break Even incremental cost

The SBCC is also required to determine an economic societal value to reduced CO_2 emissions as a result of reduced electricity use. The OFM analysis tool also estimates the CO_2 emission impacts and monetizes these impacts for the life cycle period. The results of the CO_2 analysis are summarized in Table 6 below.

Carbon externality costs were estimated using assumptions provided in the OFM economic analysis tool. The site emission factor electricity CO2e (g/mmBTU) is 40,182.2, or 1.37E04 tons/unit per kWh. These assumptions are from eGRID 9th edition Version 1.0 Year 2010, and WA State CO2e Total Output Emission Rate. However, actual emissions will vary considerably depending on what utility serves the home. Tacoma's emission factor is extremely low given that hydro generation dominates our resource portfolio.

Table 6. Summary of Societal Cost of Carbon

Alternative	Baseline All-ER Zonal System	Alternative Hybrid DHP-ER System
Tons of CO_2 e over Study Period	42	22
Present Social Cost of Carbon (SCC)	$3,275	$1,750
Total LCC with SCC	$26,032	$19,353
NPS with SCC	N/A	$6,678

9 Customer Acceptance of the hybrid DHP-ER Heating System

The homeowner survey conducted as part of this study suggests that homeowners see ductless heat pumps as a superior alternative to standard electric resistance baseboard heating in their common living areas. Of the seven homeowners in the study who have been surveyed to date, all but one had already decided that they would choose to keep the DHP instead of the baseboards. The one homeowner who did not already know which system they would choose preferred the DHP in terms of performance but wanted to see verification from the study that it does indeed save on energy costs before making a decision.

While all homeowners rated the DHP at least as well as baseboards in their common living areas in terms of heating performance and most owners (5/7) rated the DHP better, heating performance was only one of several reasons that homeowners preferred the DHP to their baseboards. Nearly half of the homeowners (3/7) viewed the DHP's cooling function as a key advantage of the system. Two out of seven said that the baseboards limited furniture placement. The DHP thus effectively increased their usable living space. Nearly half of homeowners (3/7) also mentioned concern over fire hazards from electric baseboards. Two of these homeowners had to raise their curtains on electric resistance weeks, and one expressed concern that their children would leave toys on or near the baseboards. Early survey evidence from this homeowner survey suggests that DHP's are not only well accepted but also desired by homeowners and can be marketed to new home buyers as a desirable step up from standard electric resistance heating systems.

10 Conclusions

1) With an average present value homeowner expected life-cycle savings of $5,501 when compared to an all-ER heating system, the DHP hybrid heating system is a cost effective alternative to all-ER heating systems. This is true even when considering additional DHP M&O and replacement costs over the life of a home.

2) The average annual electricity savings of a hybrid DHP-ER heating system for HFH homeowners was 2,806 kWh. Using a 2016 weighted average Washington state residential electric rate of $0.0853/kWh, average annual bill savings is $239.

3) When installed at the time of design and construction, the incremental cost of hybrid DHP/electric zonal heating systems to a buyer of a new construction single family residential home is $1,825 per home, substantially lower than the cost of retrofit installations.

4) In general, HFH homeowner participants preferred the DHP hybrid heating system over electrical resistance heating units in their common living areas.

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Appendices

Appendix A

Measure	2 Story 5 Bedroom 6 People	2 Story 3 Bedroom 4 People	1 Story 2 Bedroom 2 People	2 Story 4 Bedroom 4 People
Slab insulation	R-15 (3" XPS)			
Wall insulation	R-21 + R-5 XPS c.i. (24" o.c.)			
Windows	Area weighted U-Factor = 0.29			
Ceiling	R~49 with minimum of R-21 at exterior wall edges			
Space heating	Main Living Room Area: 1-ton single head DHP; HSPF = 11.3, SEER = 25, Fujitsu RLS2 and (2-1250W) 2,500W electric baseboard for flip flop test Bedrooms: 750W of fan-assisted electric resistance wall heaters used in each bedroom w/individual zone controlled thermostats 250W heat lamps in bathrooms on switch (occupant switch not included)			
Thermostat set	BEOPT Modeling – Set to 71°F (no setback) heating, 76F cooling w/natural ventilation in summer			
Water heating	0.91 EF 50 gallon electric storage type in mechanical "buffer" space			
Lighting	100% high-efficacy lamps + a 250W heat lamp in bathrooms			
Dishwasher	Energy Star – Whirlpool DU810SWPQ4 - 290 KWH/YR			
Refrigerator	Energy Star – Whirlpool W8TXEWFYQ01 18 ft3, EF = 21.9 TOP fREEZER – 348 kWh/yr			
Clothes washer	Energy Star – Whirlpool WFW70HEBW0			
Ventilation	Fantech FLEX100H Sensible recovery efficiency at 0.3" = 64%			
Measured envelope leakage	3.29 ACH_{50}	4.65 to 4.32 ACH_{50}	3.15 ACH_{50}	3.96 ACH_{50}
Solar Orientation and shading	South Adjacent home	South Adjacent home	South Adjacent Home	East None

Appendix B

PINE

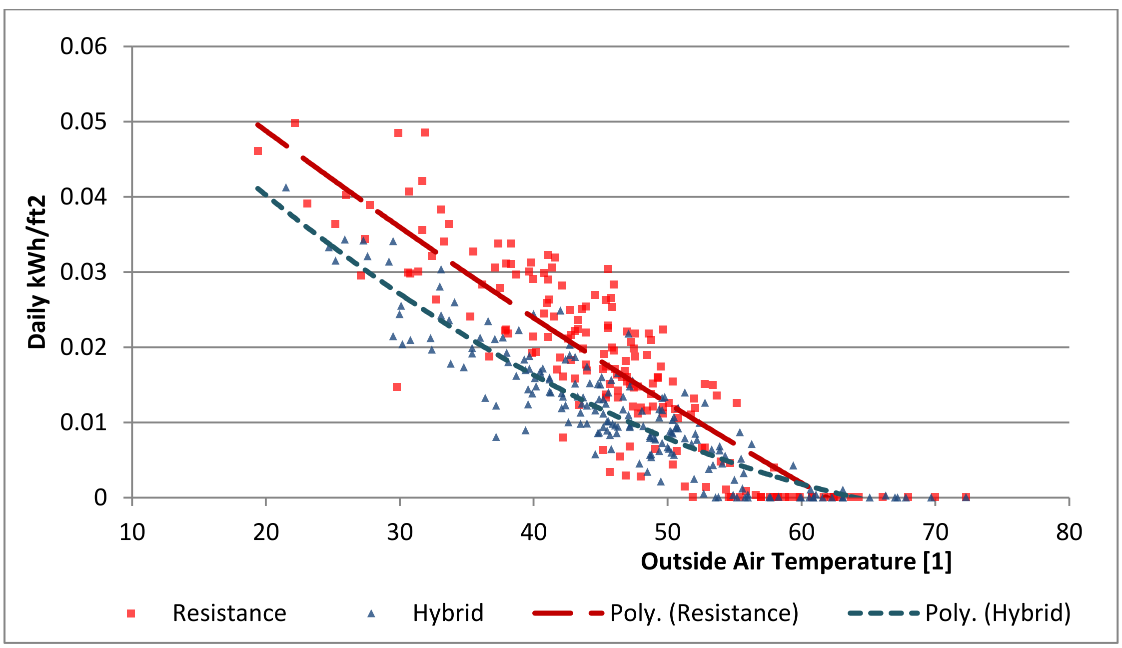
Estimated Weather Normalized Annual Results [2]

Mode	Heating Season Energy (kWh/ft2)	Cooling Season Energy (kWh/ft2)	Total (kWh/ft2)
All ER Zonal	4.671 kWh/ft2	0.000 kWh/ft2	4.671 kWh/ft2
Hybrid DHP-ER	3.183 kWh/ft2	0.037 kWh/ft2	3.220 kWh/ft2
Difference	32% savings		31% savings
Weather Normalized Heating Savings:		2070 kWh/yr	
Total Est. Cooling Usage:		51 kWh/yr	
Net Annual Savings:		**2019 kWh/yr**	

Observed Case Study Conditions (Excludes 07/11/2014 – 09/19/2014)

Data Timeframe	Mode	#Observations	Outside Air Temp [1] (Low/Average/high)	R Values
9/28/2013 to 1/20/2013	All-ER Zonal	178	19/45/72	0.774
	Hybrid	192	22/46/72	0.835

Regression of observed energy use based on outside temperature [1]



[1] Outside temperature data based on McChord Air Force Base (5.6 miles from study site)
[2] Results normalized to Olympia TMY3

FIR

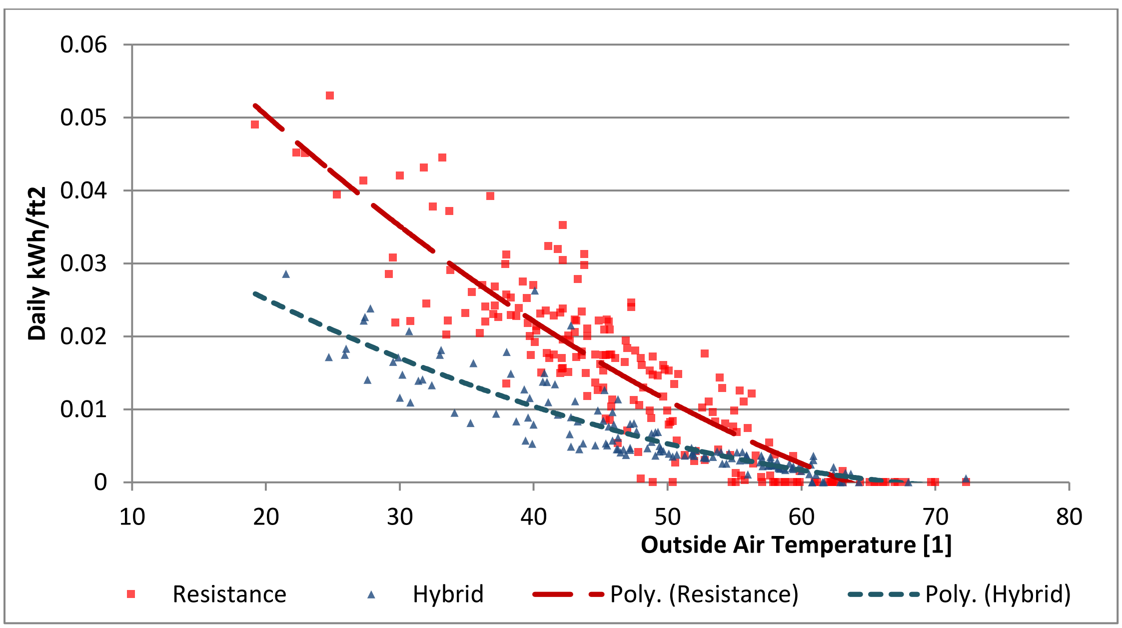
Estimated Weather Normalized Annual Results [2]

Mode	Heating Season Energy (kWh/ft2)	Cooling Season Energy (kWh/ft2)	Total (kWh/ft2)
All ER Zonal	4.319 kWh/ft^2	0 kWh/ft^2	4.319 kWh/ft^2
Hybrid DHP-ER	2.087 kWh/ft^2	0.086 kWh/ft^2	2.173 kWh/ft^2
Difference	48% savings		50% savings
Weather Normalized Heating Savings:		2,938 kWh/yr	
Total Est. Cooling Usage:		113 kWh/yr	
Net Annual Savings:		**2,825 kWh/yr**	

Observed Case Study Conditions (Excludes 07/11/2014 – 09/19/2014)

Data Timeframe	Mode	#Observations	Outside Air Temp [1] (Low/Average/high)	R Values
11/27/2013 to 1/20/2015	All-ER Zonal	202	19 / 47 / 72	0.798
	Hybrid	146	22 / 48 / 72	0.784

Regression of observed energy use based on outside temperature [1]



[1] Outside temperature data based on McChord Air Force Base (5.6 miles from study site)
[2] Results normalized to Olympia TMY3

CEDAR

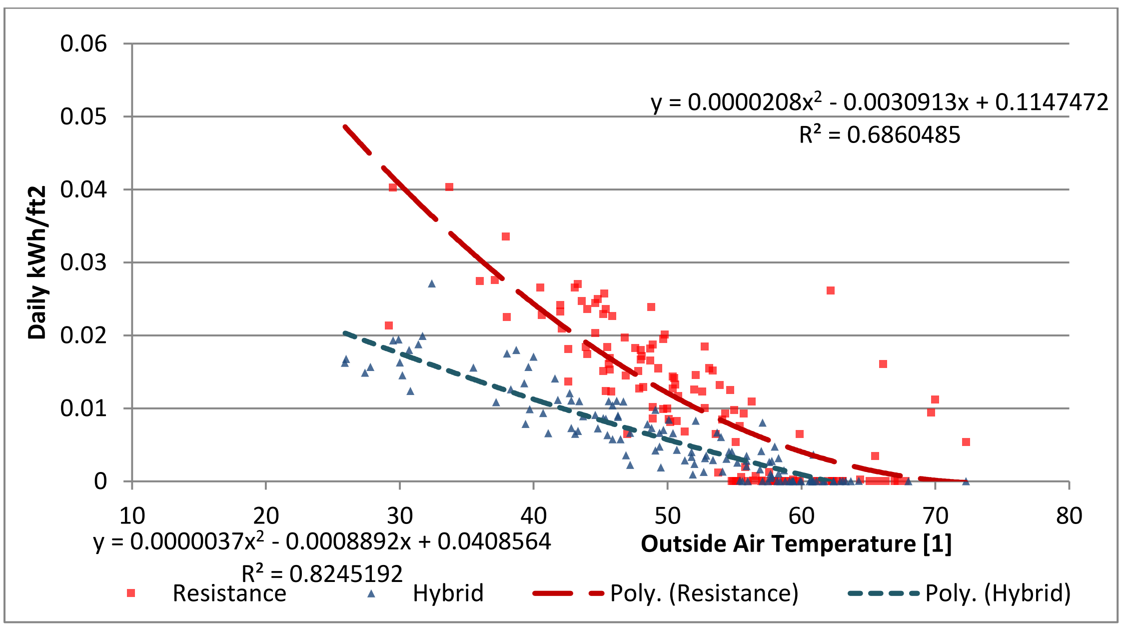
Estimated Weather Normalized Annual Results [2]

Mode	Heating Season Energy (kWh/ft2)	Cooling Season Energy (kWh/ft2)	Total (kWh/ft2)
All ER Zonal	4.869 kWh/ft^2	0 kWh/ft^2	4.869 kWh/ft^2
Hybrid DHP-ER	2.160 kWh/ft^2	0.024 kWh/ft^2	2.184 kWh/ft^2
Difference	56% savings		55% savings
Weather Normalized Heating Savings:		3,433 kWh/yr	
Total Est. Cooling Usage:		30 kWh/yr	
Net Annual Savings:		**3,403 kWh/yr**	

Observed Case Study Conditions (Excludes 07/11/2014 – 09/19/2014)

Data Timeframe	Mode	#Observations	Outside Air Temp [1] (Low/Average/high)	R Values
3/3/2014 to 1/20/2015	All-ER Zonal	128	29 / 52 / 72	0.686
	Hybrid	125	26 / 49 / 72	0.825

Regression of observed energy use based on outside temperature [1]



[1] Outside temperature data based on McChord Air Force Base (5.6 miles from study site)
[2] Results normalized to Olympia TMY3

LARCH

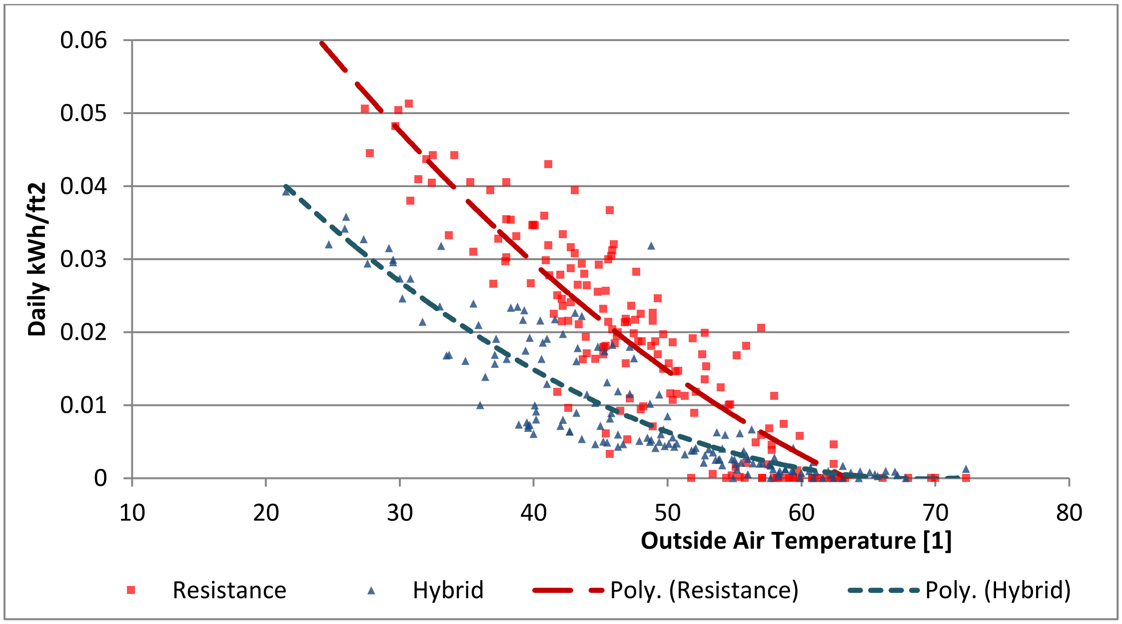
Estimated Weather Normalized Annual Results [2]

Mode	Heating Season Energy (kWh/ft2)	Cooling Season Energy (kWh/ft2)	Total (kWh/ft2)
All ER Zonal	5.707 kWh/ft^2	0 kWh/ft^2	5.707 kWh/ft^2
Hybrid DHP-ER	2.790 kWh/ft^2	0.015 kWh/ft^2	2.806 kWh/ft^2
Difference	51% savings		50% savings
Weather Normalized Heating Savings:		3,692 kWh/yr	
Total Est. Cooling Usage:		19 kWh/yr	
Net Annual Savings:		**3,673 kWh/yr**	

Observed Case Study Conditions (Excludes 07/11/2014 – 09/19/2014)

Data Timeframe	Mode	#Observations	Outside Air Temp [1] (Low/Average/high)	R Values
12/14/2013 to 1/20/2015	All-ER Zonal	168	27 / 48 / 72	0.811
	Hybrid	163	22 / 48 / 72	0.791

Regression of observed energy use based on outside temperature [1]



[1] Outside temperature data based on McChord Air Force Base (5.6 miles from study site)
[2] Results normalized to Olympia TMY3

HEMLOCK

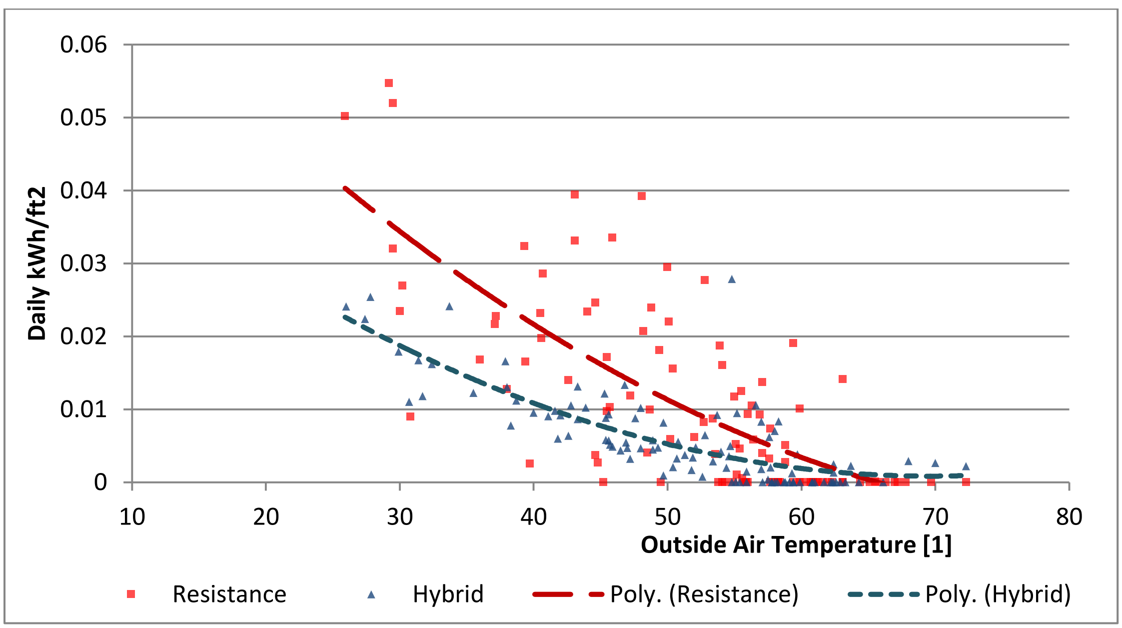
Estimated Weather Normalized Annual Results [2]

Mode	Heating Season Energy (kWh/ft2)	Cooling Season Energy (kWh/ft2)	Total (kWh/ft2)
All ER Zonal	4.324 kWh/ft^2	0 kWh/ft^2	4.324 kWh/ft^2
Hybrid DHP-ER	2.145 kWh/ft^2	0.067 kWh/ft^2	2.212 kWh/ft^2
Difference	50% savings		49% savings
Weather Normalized Heating Savings:		2,760 kWh/yr	
Total Est. Cooling Usage:		85 kWh/yr	
Net Annual Savings:		**2,675 kWh/yr**	

Observed Case Study Conditions (Excludes 07/11/2014 – 09/19/2014)

Data Timeframe	Mode	#Observations	Outside Air Temp [1] (Low/Average/high)	R Values
4/16/2014 to 1/20/2015	All-ER Zonal	104	26 / 52 / 72	0.552
	Hybrid	105	26 / 51 / 72	0.644

Regression of observed energy use based on outside temperature [1]



[1] Outside temperature data based on McChord Air Force Base (5.6 miles from study site)
[2] Results normalized to Olympia TMY3

OAK

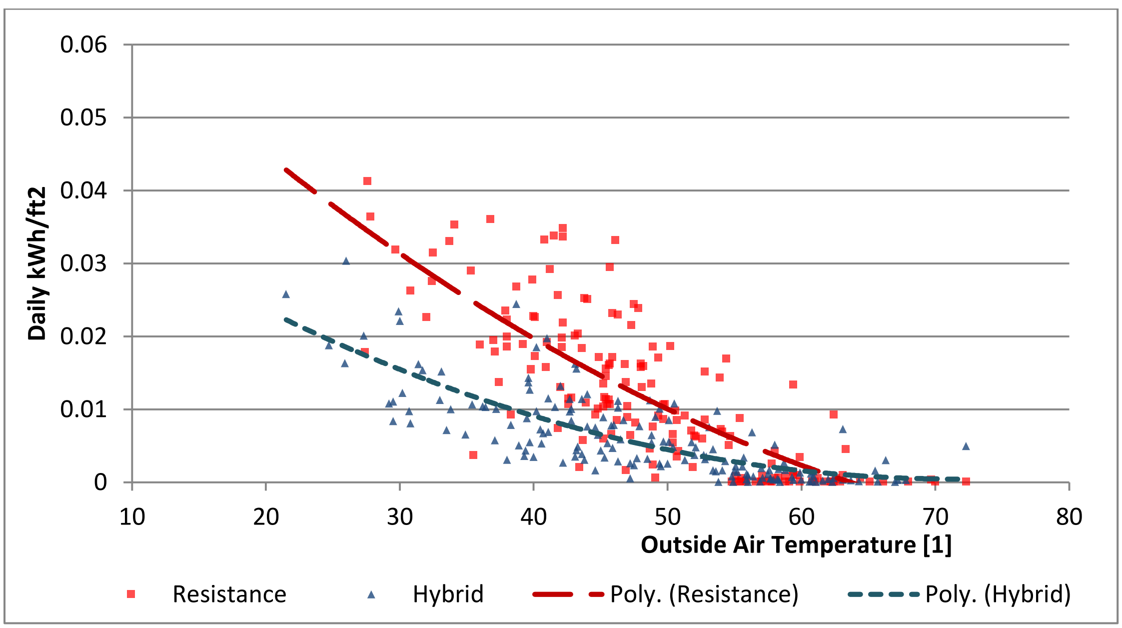
Estimated Weather Normalized Annual Results [2]

Mode	Heating Season Energy (kWh/ft2)	Cooling Season Energy (kWh/ft2)	Total (kWh/ft2)
All ER Zonal	3.901 kWh/ft^2	0 kWh/ft^2	3.901 kWh/ft^2
Hybrid DHP-ER	1.848 kWh/ft^2	0.025 kWh/ft^2	1.873 kWh/ft^2
Difference	53% savings		52% savings
Weather Normalized Heating Savings:		2,326 kWh/yr	
Total Est. Cooling Usage:		28 kWh/yr	
Net Annual Savings:		**2,298 kWh/yr**	

Observed Case Study Conditions (Excludes 07/11/2014 – 09/19/2014)

Data Timeframe	Mode	#Observations	Outside Air Temp [1] (Low/Average/high)	R Values
12/13/2013 to 1/20/2015	All-ER Zonal	168	27 / 48 / 72	0.623
	Hybrid	164	22 / 48 / 72	0.613

Regression of observed energy use based on outside temperature [1]



[1] Outside temperature data based on McChord Air Force Base (5.6 miles from study site)
[2] Results normalized to Olympia TMY3

ALDER [3]

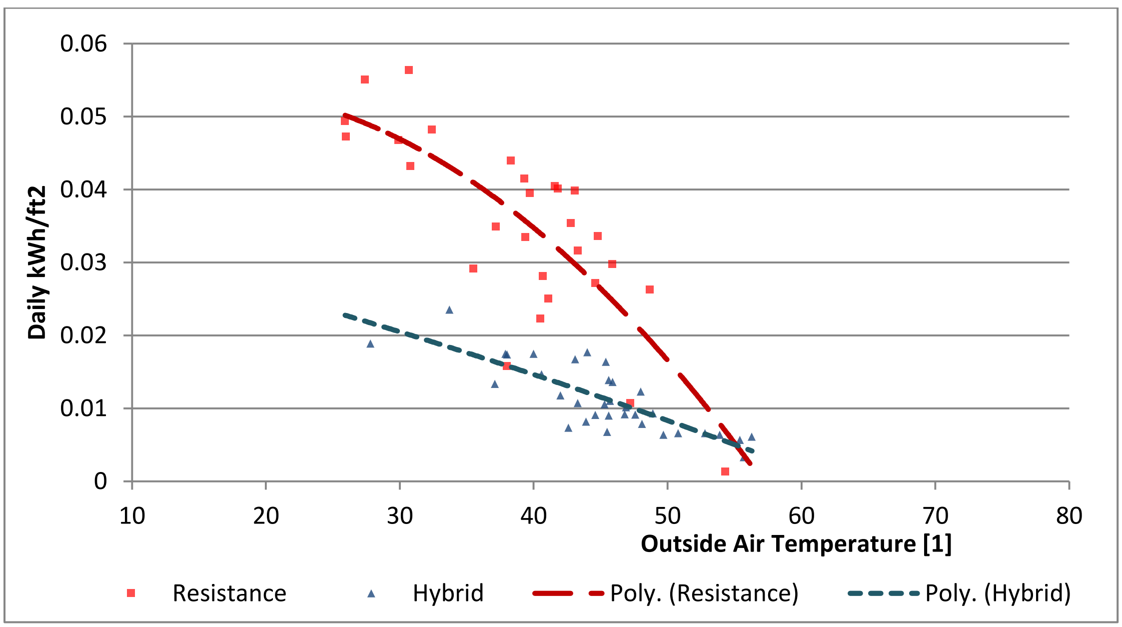
Estimated Weather Normalized Annual Results [2]

Mode	Heating Season Energy (kWh/ft2)	Cooling Season Energy (kWh/ft2)	Total (kWh/ft2)
All ER Zonal	6.197 kWh/ft^2	N/A [4]	6.197 kWh/ft^2
Hybrid DHP-ER	2.938 kWh/ft^2	N/A [4]	2.938 kWh/ft^2
Difference	53% savings		53% savings
Weather Normalized Heating Savings:		4,289 kWh/yr	
Total Est. Cooling Usage:			
Net Annual Savings:		**4,289 kWh/yr**	

Observed Case Study Conditions (Excludes 07/11/2014 – 09/19/2014)

Data Timeframe	Mode	#Observations	Outside Air Temp [1] (Low/Average/high)	R Values
11/20/2014 to 1/20/2015	All-ER Zonal	28	26 / 38 / 54	0.619
	Hybrid	34	28 / 44 / 56	0.656

Regression of observed energy use based on outside temperature [1]



[1] Outside temperature data based on McChord Air Force Base (5.6 miles from study site)
[2] Results normalized to Olympia TMY3
[3] ALDER was occupied in November 2014 and has few observations
[4] Not included in calculations as no cooling loads were observed

Appendix C

NEW CONSTRUCTION INSTALLATION COST ESTIMATION

ELECTRIC RESISTANCE SYSTEM HOMES

House	1 or 2	Bedroom	House	Lineal Feet								220V Wire Materials ER Run $			ER Heaters $		ER Total Material $			220V Wire Labor hrs			Labor $			Total ER GC Installed Cost			Total ER GC Installed Price		
ID	Sto	Coun	ft2	LI	BR	BR	BR	BR	BR	Tot	w/o L	Total	w/o L	LR onl	LR	BR	Tota	w/o L	LR on	Tota	w/o l	LR	Total	w/o L	LR onl	Total	w/o LR	LR	Total	w/o LR	LR
Pine	2	5	1391	140	46	44	57	30	22	339	199	$ 102	$ 60	$ 42	$ 152	$ 657	$ 910	$ 716	$ 194	2.8	1.7	1.2	$ 283	$ 166	$ 117	$ 1,192	$ 882	$ 310	$ 1,431	$ 1,058	$ 373
Larch	2	3	1267	104	42	27	56			229	125	$ 69	$ 38	$ 31	$ 152	$ 394	$ 614	$ 431	$ 183	1.9	1.0	0.9	$ 191	$ 104	$ 87	$ 805	$ 536	$ 270	$ 966	$ 643	$ 324
Fir	2	4	1316	80	76	51	22			229	149	$ 69	$ 45	$ 24	$ 152	$ 525	$ 746	$ 570	$ 176	1.9	1.2	0.7	$ 191	$ 124	$ 67	$ 936	$ 694	$ 242	$ 1,124	$ 833	$ 291
Hemlock	2	3	1267	104	42	27	56			229	125	$ 69	$ 38	$ 31	$ 152	$ 394	$ 614	$ 431	$ 183	1.9	1.0	0.9	$ 191	$ 104	$ 87	$ 805	$ 536	$ 270	$ 966	$ 643	$ 324
Alder	2	4	1316	80	76	51	22			229	149	$ 69	$ 45	$ 24	$ 152	$ 525	$ 746	$ 570	$ 176	1.9	1.2	0.7	$ 191	$ 124	$ 67	$ 936	$ 694	$ 242	$ 1,124	$ 833	$ 291
Oak	1	3	1133	118	32	13	48			210	92	$ 63	$ 28	$ 35	$ 152	$ 394	$ 609	$ 422	$ 187	1.7	0.8	1.0	$ 175	$ 77	$ 98	$ 783	$ 498	$ 285	$ 940	$ 598	$ 342
Cedar	2	3	1267	104	42	27	56			229	125	$ 69	$ 38	$ 31	$ 152	$ 394	$ 614	$ 431	$ 183	1.9	1.0	0.9	$ 191	$ 104	$ 87	$ 805	$ 536	$ 270	$ 966	$ 643	$ 324
Spruce	1	3	1133	88	32	13	48			180	92	$ 54	$ 28	$ 26	$ 152	$ 394	$ 600	$ 422	$ 178	1.5	0.8	0.7	$ 150	$ 77	$ 73	$ 749	$ 498	$ 251	$ 899	$ 598	$ 302
Average	1.8	3.5	1261	102	48	32	46	30	22	234	132	$ 70	$ 40	$ 31	$ 152	$ 460	$ 682	$ 499	$ 182	2.0	1.1	0.9	$ 195	$ 110	$ 85	$ 877	$ 609	$ 268	$ 1,052	$ 731	$ 321
Max	2	5	1391	140	76	51	57	30	22	339	199	$ 102	$ 60	$ 42	$ 152	$ 657	$ 910	$ 716	$ 194	2.8	1.7	1.2	$ 283	$ 166	$ 117	$ 1,192	$ 882	$ 310	$ 1,431	$ 1,058	$ 373
Min	1	3	1133	80	32	13	22	30	22	180	92	$ 54	$ 28	$ 24	$ 152	$ 394	$ 600	$ 422	$ 176	1.5	0.8	0.7	$ 150	$ 77	$ 67	$ 749	$ 498	$ 242	$ 899	$ 598	$ 291

HYBRID HEATING SYSTEM HOMES

House	1 or 2	Bedroom	House	Lineal Feet								220V Wire Materials Hybrid Run			Hybrid Heaters $		Hybrid Total Material $			220V Wire Labor hrs			Labor $			Total Hybrid GC Installed Cost			Total ER GC Installed Price		
ID	Story	Count	ft2	LR	BR1	BR2	BR3	BR4	BR5	Total	w/o LR	Total	w/o LR	LR only	LR	BR	Total	w/o LR	LR only	Total	w/o LR	LR	Total	w/o LR	LR only	Total	w/o LR	LR	Total	w/o LR	LR
Pine	2	5	1391	110	46	44	57	30	22	309	199	$ 93	$ 60	$ 33	$ 1,702	$ 657	$ 2,451	$ 716	$ 1,735	2.6	1.7	0.9	$ 258	$ 166	$ 92	$ 2,709	$ 882	$ 1,827	$ 3,250	$ 1,058	$ 2,192
Larch	2	3	1267	74	42	27	56			199	125	$ 60	$ 38	$ 22	$ 1,702	$ 394	$ 2,156	$ 431	$ 1,724	1.7	1.0	0.6	$ 166	$ 104	$ 62	$ 2,321	$ 536	$ 1,786	$ 2,786	$ 643	$ 2,143
Fir	2	4	1316	50	76	51	22			199	149	$ 60	$ 45	$ 15	$ 1,702	$ 525	$ 2,287	$ 570	$ 1,717	1.7	1.2	0.4	$ 166	$ 124	$ 42	$ 2,453	$ 694	$ 1,759	$ 2,943	$ 833	$ 2,110
Hemlock	2	3	1267	74	42	27	56			199	125	$ 60	$ 38	$ 22	$ 1,702	$ 394	$ 2,156	$ 431	$ 1,724	1.7	1.0	0.6	$ 166	$ 104	$ 62	$ 2,321	$ 536	$ 1,786	$ 2,786	$ 643	$ 2,143
Alder	2	4	1316	50	76	51	22			199	149	$ 60	$ 45	$ 15	$ 1,702	$ 525	$ 2,287	$ 570	$ 1,717	1.7	1.2	0.4	$ 166	$ 124	$ 42	$ 2,453	$ 694	$ 1,759	$ 2,943	$ 833	$ 2,110
Oak	1	3	1133	88	32	13	48			180	92	$ 54	$ 28	$ 26	$ 1,702	$ 394	$ 2,150	$ 422	$ 1,728	1.5	0.8	0.7	$ 150	$ 77	$ 73	$ 2,300	$ 498	$ 1,802	$ 2,760	$ 598	$ 2,162
Cedar	2	3	1267	74	42	27	56			199	125	$ 60	$ 38	$ 22	$ 1,702	$ 394	$ 2,156	$ 431	$ 1,724	1.7	1.0	0.6	$ 166	$ 104	$ 62	$ 2,321	$ 536	$ 1,786	$ 2,786	$ 643	$ 2,143
Spruce	1	3	1133	88	32	13	48			180	92	$ 54	$ 28	$ 26	$ 1,702	$ 394	$ 2,150	$ 422	$ 1,728	1.5	0.8	0.7	$ 150	$ 77	$ 73	$ 2,300	$ 498	$ 1,802	$ 2,760	$ 598	$ 2,162
Average	1.8	3.5	1261	76	48	32	46	30	22	208	132	$ 62	$ 40	$ 23	$ 1,702	$ 460	$ 2,224	$ 499	$ 1,725	1.7	1.1	0.6	$ 173	$ 110	$ 63	$ 2,397	$ 609	$ 1,788	$ 2,877	$ 731	$ 2,146
Max	2	5	1391	110	76	51	57	30	22	309	199	$ 93	$ 60	$ 33	$ 1,702	$ 657	$ 2,451	$ 716	$ 1,735	2.6	1.7	0.9	$ 258	$ 166	$ 92	$ 2,709	$ 882	$ 1,827	$ 3,250	$ 1,058	$ 2,192
Min	1	3	1133	50	32	13	22	30	22	180	92	$ 54	$ 28	$ 15	$ 1,702	$ 394	$ 2,150	$ 422	$ 1,717	1.5	0.8	0.4	$ 150	$ 77	$ 42	$ 2,300	$ 498	$ 1,759	$ 2,760	$ 598	$ 2,110
															$ 1,550	**$ -**	**$ 1,542**	**$ -**	**$ 1,542**	**$ (0)**	**$ -**	**$ (0)**	**$ (22)**	**$ -**	**$ (22)**	**$ 1,521**	**$ -**	**$ 1,521**	**$ 1,825**	**$ -**	**$ 1,825**

Notes
1. Cells highlighted in orange are data entry cells
x. GC General Contractor
2. LR Living Room
3. BR Bed Room 1,2,3,4,5
4. ER Electric Resistance
5. LF Lineal Foot
6. Living room electric resisitance heaters are two, 4' 1.25 kW baseboad heaters controlled by zonal thermostat. Living room wire and wire labor cost reflect the longer runs for the two separate heaters.
7. Bedroom electric resistance heaters are one, cadet type heater with wall mounted thermostat per bedroom. An additional 30 feet labor cost is assumed to install line voltage thermostats for ER zonal heaters.

Calculations
8. 220V Wire Materials for ER Run $: Lineal Feet X Materials Cost per LF
9. ER Heaters $: Living Room Heater Cost + (Bedroom Count X Bedroom Cadet ER Heater Cost

Bates-HFH Cost Data	
Labor rate/hour	$ 100
Labor hrs (30 sec/LF)	30
Materials ($0.30/LF)	$ 0.30
DHP site prep and installation @ 2 hours	$ 100
DHP Convenience Outlet and connection to outdoor unit	$ 25
Bedroom Cadet ER Heater Cost w/wall mount stat	$ 131
Living Room Baseboard ER Heaters Cost w/wall mount stat	$ 152
1-Head DHP Cost (includes commissioning and tax)	$ 1,577

Builder Market Assumptions	
Percent Assumed General Contractor Mark-Ups	20%

Average Estimated Hybrid vs ER Heating System GC Incremental Cost	$ 1,521
Average Estimated Hybrid vs ER Heating System Incremental Home Owner Cost	$ 1,825

Appendix D

Scenario 1: 30-Year Mortgage Term at Study Actual Costs

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenanc	Utilities	Financing	**Total**	Baseline	Capital	Maintenanc	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 2,146	$ -	$ -	$ (1,717)	$ 429	$ 429	$ 365	$ 365
2017	$ -	$ -	$ 524	$ 15	$ 539	$ 603	$ -	$ 11	$ 280	$ 98	$ 390	$ 819	$ (149)	$ 216
2018	$ -	$ -	$ 519	$ 14	$ 534	$ 1,137	$ -	$ 11	$ 277	$ 96	$ 384	$ 1,203	$ (149)	$ 66
2019	$ -	$ -	$ 519	$ 14	$ 533	$ 1,670	$ -	$ 11	$ 277	$ 93	$ 382	$ 1,585	$ (152)	$ (85)
2020	$ -	$ -	$ 519	$ 13	$ 533	$ 2,203	$ -	$ 11	$ 277	$ 90	$ 379	$ 1,964	$ (154)	$ (239)
2021	$ -	$ -	$ 524	$ 13	$ 537	$ 2,740	$ -	$ 11	$ 280	$ 88	$ 379	$ 2,343	$ (158)	$ (397)
2022	$ -	$ -	$ 519	$ 13	$ 532	$ 3,272	$ -	$ 12	$ 277	$ 85	$ 374	$ 2,717	$ (158)	$ (555)
2023	$ -	$ -	$ 514	$ 12	$ 526	$ 3,799	$ -	$ 12	$ 275	$ 83	$ 369	$ 3,086	$ (157)	$ (712)
2024	$ -	$ -	$ 509	$ 12	$ 521	$ 4,320	$ -	$ 12	$ 272	$ 80	$ 364	$ 3,451	$ (157)	$ (869)
2025	$ -	$ -	$ 514	$ 12	$ 526	$ 4,845	$ -	$ 12	$ 275	$ 78	$ 365	$ 3,815	$ (161)	$ (1,030)
2026	$ -	$ -	$ 514	$ 11	$ 525	$ 5,371	$ -	$ 12	$ 275	$ 76	$ 363	$ 4,178	$ (163)	$ (1,193)
2027	$ -	$ -	$ 514	$ 11	$ 525	$ 5,896	$ -	$ 12	$ 275	$ 74	$ 360	$ 4,538	$ (165)	$ (1,358)
2028	$ -	$ -	$ 509	$ 11	$ 520	$ 6,416	$ -	$ 12	$ 272	$ 71	$ 356	$ 4,894	$ (164)	$ (1,522)
2029	$ -	$ -	$ 509	$ 10	$ 519	$ 6,935	$ -	$ 12	$ 272	$ 69	$ 354	$ 5,248	$ (166)	$ (1,687)
2030	$ -	$ -	$ 509	$ 10	$ 519	$ 7,454	$ -	$ 13	$ 272	$ 67	$ 352	$ 5,600	$ (167)	$ (1,854)
2031	$ -	$ -	$ 514	$ 10	$ 524	$ 7,978	$ -	$ 13	$ 275	$ 65	$ 353	$ 5,953	$ (171)	$ (2,025)
2032	$ -	$ -	$ 519	$ 10	$ 529	$ 8,507	$ -	$ 13	$ 277	$ 64	$ 354	$ 6,306	$ (175)	$ (2,200)
2033	$ -	$ -	$ 519	$ 9	$ 528	$ 9,035	$ -	$ 13	$ 277	$ 62	$ 352	$ 6,659	$ (176)	$ (2,377)
2034	$ -	$ -	$ 519	$ 9	$ 528	$ 9,563	$ 2,146	$ 13	$ 277	$ 60	$ 2,497	$ 9,155	$ 1,968	$ (408)
2035	$ -	$ -	$ 530	$ 9	$ 538	$ 10,102	$ -	$ 11	$ 283	$ 58	$ 352	$ 9,507	$ (186)	$ (594)
2036	$ -	$ -	$ 535	$ 8	$ 543	$ 10,645	$ -	$ 11	$ 286	$ 57	$ 353	$ 9,861	$ (190)	$ (784)
2037	$ -	$ -	$ 540	$ 8	$ 548	$ 11,193	$ -	$ 11	$ 288	$ 55	$ 355	$ 10,215	$ (193)	$ (977)
2038	$ -	$ -	$ 550	$ 8	$ 558	$ 11,751	$ -	$ 11	$ 294	$ 53	$ 359	$ 10,574	$ (199)	$ (1,177)
2039	$ -	$ -	$ 555	$ 8	$ 563	$ 12,314	$ -	$ 11	$ 297	$ 52	$ 360	$ 10,934	$ (203)	$ (1,380)
2040	$ -	$ -	$ 566	$ 8	$ 573	$ 12,887	$ -	$ 12	$ 302	$ 50	$ 364	$ 11,298	$ (209)	$ (1,589)
2041	$ -	$ -	$ 571	$ 7	$ 578	$ 13,465	$ -	$ 12	$ 305	$ 49	$ 366	$ 11,664	$ (212)	$ (1,801)
2042	$ -	$ -	$ 571	$ 7	$ 578	$ 14,043	$ -	$ 12	$ 305	$ 47	$ 364	$ 12,028	$ (213)	$ (2,014)
2043	$ -	$ -	$ 571	$ 7	$ 578	$ 14,620	$ -	$ 12	$ 305	$ 46	$ 363	$ 12,391	$ (215)	$ (2,229)
2044	$ -	$ -	$ 574	$ 7	$ 580	$ 15,201	$ -	$ 12	$ 307	$ 45	$ 363	$ 12,755	$ (217)	$ (2,446)
2045	$ -	$ -	$ 577	$ 7	$ 583	$ 15,784	$ -	$ 12	$ 308	$ 44	$ 364	$ 13,119	$ (219)	$ (2,665)
2046	$ 321	$ -	$ 580	$ 6	$ 907	$ 16,691	$ -	$ 12	$ 310	$ 42	$ 364	$ 13,483	$ (543)	$ (3,208)
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,274	$ -	$ 12	$ 312	$ -	$ 324	$ 13,807	$ (259)	$ (3,467)
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,860	$ -	$ 13	$ 313	$ -	$ 326	$ 14,133	$ (260)	$ (3,728)
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,449	$ -	$ 13	$ 315	$ -	$ 328	$ 14,460	$ (262)	$ (3,989)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,042	$ -	$ 13	$ 317	$ -	$ 329	$ 14,789	$ (263)	$ (4,252)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,637	$ -	$ 13	$ 318	$ -	$ 331	$ 15,121	$ (264)	$ (4,516)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,235	$ 2,146	$ 13	$ 320	$ -	$ 2,479	$ 17,599	$ 1,880	$ (2,636)
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,837	$ -	$ 11	$ 321	$ -	$ 332	$ 17,932	$ (269)	$ (2,905)
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,441	$ -	$ 11	$ 323	$ -	$ 334	$ 18,266	$ (270)	$ (3,175)
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,049	$ -	$ 11	$ 325	$ -	$ 336	$ 18,602	$ (272)	$ (3,447)
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,660	$ -	$ 11	$ 326	$ -	$ 338	$ 18,940	$ (273)	$ (3,720)
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,274	$ -	$ 11	$ 328	$ -	$ 339	$ 19,279	$ (274)	$ (3,994)
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,891	$ -	$ 12	$ 330	$ -	$ 341	$ 19,621	$ (276)	$ (4,270)
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,511	$ -	$ 12	$ 331	$ -	$ 343	$ 19,964	$ (277)	$ (4,547)
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,134	$ -	$ 12	$ 333	$ -	$ 345	$ 20,308	$ (278)	$ (4,825)
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,760	$ -	$ 12	$ 335	$ -	$ 347	$ 20,655	$ (280)	$ (5,105)
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,389	$ -	$ 12	$ 336	$ -	$ 348	$ 21,003	$ (281)	$ (5,386)
2063	$ -	$ -	$ 632	$ -	$ 632	$ 27,022	$ -	$ 12	$ 338	$ -	$ 350	$ 21,353	$ (282)	$ (5,668)
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,657	$ -	$ 12	$ 340	$ -	$ 352	$ 21,705	$ (284)	$ (5,952)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,295	$ -	$ 12	$ 341	$ -	$ 354	$ 22,059	$ (285)	$ (6,237)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,830	$ (477)	$ 13	$ 343	$ -	$ (121)	$ 21,937	$ (656)	$ (6,893)

Scenario 2: 30-Year Mortgage Term at $3000 DHP Cost

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenanc	Utilities	Financing	**Total**	Baseline	Capital	Maintenanc	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 3,000	$ -	$ -	$ (2,400)	$ 600	$ 600	$ 536	$ 536
2017	$ -	$ -	$ 524	$ 15	$ 539	$ 603	$ -	$ 11	$ 280	$ 138	$ 429	$ 1,029	$ (110)	$ 426
2018	$ -	$ -	$ 519	$ 14	$ 534	$ 1,137	$ -	$ 11	$ 277	$ 134	$ 422	$ 1,451	$ (111)	$ 314
2019	$ -	$ -	$ 519	$ 14	$ 533	$ 1,670	$ -	$ 11	$ 277	$ 130	$ 419	$ 1,870	$ (115)	$ 200
2020	$ -	$ -	$ 519	$ 13	$ 533	$ 2,203	$ -	$ 11	$ 277	$ 126	$ 415	$ 2,285	$ (118)	$ 82
2021	$ -	$ -	$ 524	$ 13	$ 537	$ 2,740	$ -	$ 11	$ 280	$ 123	$ 414	$ 2,699	$ (123)	$ (41)
2022	$ -	$ -	$ 519	$ 13	$ 532	$ 3,272	$ -	$ 12	$ 277	$ 119	$ 408	$ 3,107	$ (124)	$ (165)
2023	$ -	$ -	$ 514	$ 12	$ 526	$ 3,799	$ -	$ 12	$ 275	$ 116	$ 402	$ 3,509	$ (124)	$ (290)
2024	$ -	$ -	$ 509	$ 12	$ 521	$ 4,320	$ -	$ 12	$ 272	$ 112	$ 396	$ 3,905	$ (125)	$ (415)
2025	$ -	$ -	$ 514	$ 12	$ 526	$ 4,845	$ -	$ 12	$ 275	$ 109	$ 396	$ 4,301	$ (130)	$ (545)
2026	$ -	$ -	$ 514	$ 11	$ 525	$ 5,371	$ -	$ 12	$ 275	$ 106	$ 393	$ 4,693	$ (133)	$ (677)
2027	$ -	$ -	$ 514	$ 11	$ 525	$ 5,896	$ -	$ 12	$ 275	$ 103	$ 390	$ 5,083	$ (135)	$ (813)
2028	$ -	$ -	$ 509	$ 11	$ 520	$ 6,416	$ -	$ 12	$ 272	$ 100	$ 384	$ 5,467	$ (135)	$ (948)
2029	$ -	$ -	$ 509	$ 10	$ 519	$ 6,935	$ -	$ 12	$ 272	$ 97	$ 381	$ 5,849	$ (138)	$ (1,086)
2030	$ -	$ -	$ 509	$ 10	$ 519	$ 7,454	$ -	$ 13	$ 272	$ 94	$ 379	$ 6,228	$ (140)	$ (1,226)
2031	$ -	$ -	$ 514	$ 10	$ 524	$ 7,978	$ -	$ 13	$ 275	$ 92	$ 379	$ 6,606	$ (145)	$ (1,371)
2032	$ -	$ -	$ 519	$ 10	$ 529	$ 8,507	$ -	$ 13	$ 277	$ 89	$ 379	$ 6,986	$ (150)	$ (1,521)
2033	$ -	$ -	$ 519	$ 9	$ 528	$ 9,035	$ -	$ 13	$ 277	$ 86	$ 377	$ 7,362	$ (152)	$ (1,673)
2034	$ -	$ -	$ 519	$ 9	$ 528	$ 9,563	$ 3,000	$ 13	$ 277	$ 84	$ 3,374	$ 10,737	$ 2,846	$ 1,173
2035	$ -	$ -	$ 530	$ 9	$ 538	$ 10,102	$ -	$ 11	$ 283	$ 81	$ 375	$ 11,112	$ (163)	$ 1,011
2036	$ -	$ -	$ 535	$ 8	$ 543	$ 10,645	$ -	$ 11	$ 286	$ 79	$ 376	$ 11,488	$ (167)	$ 843
2037	$ -	$ -	$ 540	$ 8	$ 548	$ 11,193	$ -	$ 11	$ 288	$ 77	$ 377	$ 11,865	$ (171)	$ 672
2038	$ -	$ -	$ 550	$ 8	$ 558	$ 11,751	$ -	$ 11	$ 294	$ 75	$ 380	$ 12,245	$ (178)	$ 494
2039	$ -	$ -	$ 555	$ 8	$ 563	$ 12,314	$ -	$ 11	$ 297	$ 72	$ 381	$ 12,625	$ (182)	$ 311
2040	$ -	$ -	$ 566	$ 8	$ 573	$ 12,887	$ -	$ 12	$ 302	$ 70	$ 384	$ 13,009	$ (189)	$ 123
2041	$ -	$ -	$ 571	$ 7	$ 578	$ 13,465	$ -	$ 12	$ 305	$ 68	$ 385	$ 13,394	$ (193)	$ (70)
2042	$ -	$ -	$ 571	$ 7	$ 578	$ 14,043	$ -	$ 12	$ 305	$ 66	$ 383	$ 13,778	$ (195)	$ (265)
2043	$ -	$ -	$ 571	$ 7	$ 578	$ 14,620	$ -	$ 12	$ 305	$ 64	$ 381	$ 14,159	$ (196)	$ (461)
2044	$ -	$ -	$ 574	$ 7	$ 580	$ 15,201	$ -	$ 12	$ 307	$ 63	$ 381	$ 14,540	$ (199)	$ (660)
2045	$ -	$ -	$ 577	$ 7	$ 583	$ 15,784	$ -	$ 12	$ 308	$ 61	$ 381	$ 14,922	$ (202)	$ (862)
2046	$ 321	$ -	$ 580	$ 6	$ 907	$ 16,691	$ -	$ 12	$ 310	$ 59	$ 381	$ 15,303	$ (526)	$ (1,388)
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,274	$ -	$ 12	$ 312	$ -	$ 324	$ 15,627	$ (259)	$ (1,647)
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,860	$ -	$ 13	$ 313	$ -	$ 326	$ 15,953	$ (260)	$ (1,908)
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,449	$ -	$ 13	$ 315	$ -	$ 328	$ 16,280	$ (262)	$ (2,169)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,042	$ -	$ 13	$ 317	$ -	$ 329	$ 16,609	$ (263)	$ (2,432)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,637	$ -	$ 13	$ 318	$ -	$ 331	$ 16,940	$ (264)	$ (2,697)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,235	$ 3,000	$ 13	$ 320	$ -	$ 3,333	$ 20,273	$ 2,734	$ 38
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,837	$ -	$ 11	$ 321	$ -	$ 332	$ 20,606	$ (269)	$ (231)
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,441	$ -	$ 11	$ 323	$ -	$ 334	$ 20,940	$ (270)	$ (502)
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,049	$ -	$ 11	$ 325	$ -	$ 336	$ 21,276	$ (272)	$ (773)
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,660	$ -	$ 11	$ 326	$ -	$ 338	$ 21,614	$ (273)	$ (1,046)
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,274	$ -	$ 11	$ 328	$ -	$ 339	$ 21,953	$ (274)	$ (1,321)
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,891	$ -	$ 12	$ 330	$ -	$ 341	$ 22,294	$ (276)	$ (1,596)
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,511	$ -	$ 12	$ 331	$ -	$ 343	$ 22,637	$ (277)	$ (1,873)
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,134	$ -	$ 12	$ 333	$ -	$ 345	$ 22,982	$ (278)	$ (2,152)
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,760	$ -	$ 12	$ 335	$ -	$ 347	$ 23,329	$ (280)	$ (2,431)
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,389	$ -	$ 12	$ 336	$ -	$ 348	$ 23,677	$ (281)	$ (2,712)
2063	$ -	$ -	$ 632	$ -	$ 632	$ 27,022	$ -	$ 12	$ 338	$ -	$ 350	$ 24,027	$ (282)	$ (2,994)
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,657	$ -	$ 12	$ 340	$ -	$ 352	$ 24,379	$ (284)	$ (3,278)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,295	$ -	$ 12	$ 341	$ -	$ 354	$ 24,733	$ (285)	$ (3,563)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,830	$ (667)	$ 13	$ 343	$ -	$ (311)	$ 24,421	$ (846)	$ (4,409)

Scenario 3: 30-Year Mortgage Term at $3500 DHP Cost

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenanc	Utilities	Financing	Total	Baseline	Capital	Maintenanc	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 3,500	$ -	$ -	$ (2,800)	$ 700	$ 700	$ 636	$ 636
2017	$ -	$ -	$ 524	$ 15	$ 539	$ 603	$ -	$ 11	$ 280	$ 161	$ 452	$ 1,152	$ (87)	$ 549
2018	$ -	$ -	$ 519	$ 14	$ 534	$ 1,137	$ -	$ 11	$ 277	$ 156	$ 445	$ 1,596	$ (89)	$ 460
2019	$ -	$ -	$ 519	$ 14	$ 533	$ 1,670	$ -	$ 11	$ 277	$ 152	$ 440	$ 2,037	$ (93)	$ 367
2020	$ -	$ -	$ 519	$ 13	$ 533	$ 2,203	$ -	$ 11	$ 277	$ 147	$ 436	$ 2,473	$ (97)	$ 270
2021	$ -	$ -	$ 524	$ 13	$ 537	$ 2,740	$ -	$ 11	$ 280	$ 143	$ 435	$ 2,907	$ (103)	$ 167
2022	$ -	$ -	$ 519	$ 13	$ 532	$ 3,272	$ -	$ 12	$ 277	$ 139	$ 428	$ 3,335	$ (104)	$ 63
2023	$ -	$ -	$ 514	$ 12	$ 526	$ 3,799	$ -	$ 12	$ 275	$ 135	$ 421	$ 3,756	$ (105)	$ (42)
2024	$ -	$ -	$ 509	$ 12	$ 521	$ 4,320	$ -	$ 12	$ 272	$ 131	$ 415	$ 4,171	$ (106)	$ (148)
2025	$ -	$ -	$ 514	$ 12	$ 526	$ 4,845	$ -	$ 12	$ 275	$ 127	$ 414	$ 4,585	$ (112)	$ (260)
2026	$ -	$ -	$ 514	$ 11	$ 525	$ 5,371	$ -	$ 12	$ 275	$ 124	$ 410	$ 4,995	$ (115)	$ (375)
2027	$ -	$ -	$ 514	$ 11	$ 525	$ 5,896	$ -	$ 12	$ 275	$ 120	$ 407	$ 5,402	$ (118)	$ (494)
2028	$ -	$ -	$ 509	$ 11	$ 520	$ 6,416	$ -	$ 12	$ 272	$ 117	$ 401	$ 5,803	$ (119)	$ (612)
2029	$ -	$ -	$ 509	$ 10	$ 519	$ 6,935	$ -	$ 12	$ 272	$ 113	$ 398	$ 6,201	$ (122)	$ (734)
2030	$ -	$ -	$ 509	$ 10	$ 519	$ 7,454	$ -	$ 13	$ 272	$ 110	$ 394	$ 6,595	$ (125)	$ (859)
2031	$ -	$ -	$ 514	$ 10	$ 524	$ 7,978	$ -	$ 13	$ 275	$ 107	$ 394	$ 6,989	$ (130)	$ (989)
2032	$ -	$ -	$ 519	$ 10	$ 529	$ 8,507	$ -	$ 13	$ 277	$ 104	$ 394	$ 7,383	$ (135)	$ (1,123)
2033	$ -	$ -	$ 519	$ 9	$ 528	$ 9,035	$ -	$ 13	$ 277	$ 101	$ 391	$ 7,774	$ (137)	$ (1,261)
2034	$ -	$ -	$ 519	$ 9	$ 528	$ 9,563	$ 3,500	$ 13	$ 277	$ 98	$ 3,888	$ 11,663	$ 3,360	$ 2,099
2035	$ -	$ -	$ 530	$ 9	$ 538	$ 10,102	$ -	$ 11	$ 283	$ 95	$ 389	$ 12,052	$ (149)	$ 1,950
2036	$ -	$ -	$ 535	$ 8	$ 543	$ 10,645	$ -	$ 11	$ 286	$ 92	$ 389	$ 12,441	$ (154)	$ 1,796
2037	$ -	$ -	$ 540	$ 8	$ 548	$ 11,193	$ -	$ 11	$ 288	$ 90	$ 389	$ 12,830	$ (159)	$ 1,638
2038	$ -	$ -	$ 550	$ 8	$ 558	$ 11,751	$ -	$ 11	$ 294	$ 87	$ 392	$ 13,223	$ (166)	$ 1,472
2039	$ -	$ -	$ 555	$ 8	$ 563	$ 12,314	$ -	$ 11	$ 297	$ 85	$ 393	$ 13,615	$ (170)	$ 1,302
2040	$ -	$ -	$ 566	$ 8	$ 573	$ 12,887	$ -	$ 12	$ 302	$ 82	$ 396	$ 14,011	$ (177)	$ 1,124
2041	$ -	$ -	$ 571	$ 7	$ 578	$ 13,465	$ -	$ 12	$ 305	$ 80	$ 396	$ 14,408	$ (182)	$ 943
2042	$ -	$ -	$ 571	$ 7	$ 578	$ 14,043	$ -	$ 12	$ 305	$ 77	$ 394	$ 14,802	$ (184)	$ 759
2043	$ -	$ -	$ 571	$ 7	$ 578	$ 14,620	$ -	$ 12	$ 305	$ 75	$ 392	$ 15,194	$ (185)	$ 574
2044	$ -	$ -	$ 574	$ 7	$ 580	$ 15,201	$ -	$ 12	$ 307	$ 73	$ 392	$ 15,586	$ (189)	$ 385
2045	$ -	$ -	$ 577	$ 7	$ 583	$ 15,784	$ -	$ 12	$ 308	$ 71	$ 391	$ 15,977	$ (192)	$ 193
2046	$ 321	$ -	$ 580	$ 6	$ 907	$ 16,691	$ -	$ 12	$ 310	$ 69	$ 391	$ 16,368	$ (516)	$ (323)
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,274	$ -	$ 12	$ 312	$ -	$ 324	$ 16,692	$ (259)	$ (582)
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,860	$ -	$ 13	$ 313	$ -	$ 326	$ 17,018	$ (260)	$ (842)
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,449	$ -	$ 13	$ 315	$ -	$ 328	$ 17,346	$ (262)	$ (1,104)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,042	$ -	$ 13	$ 317	$ -	$ 329	$ 17,675	$ (263)	$ (1,367)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,637	$ -	$ 13	$ 318	$ -	$ 331	$ 18,006	$ (264)	$ (1,631)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,235	$ 3,500	$ 13	$ 320	$ -	$ 3,833	$ 21,839	$ 3,234	$ 1,603
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,837	$ -	$ 11	$ 321	$ -	$ 332	$ 22,171	$ (269)	$ 1,334
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,441	$ -	$ 11	$ 323	$ -	$ 334	$ 22,505	$ (270)	$ 1,064
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,049	$ -	$ 11	$ 325	$ -	$ 336	$ 22,841	$ (272)	$ 792
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,660	$ -	$ 11	$ 326	$ -	$ 338	$ 23,179	$ (273)	$ 519
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,274	$ -	$ 11	$ 328	$ -	$ 339	$ 23,519	$ (274)	$ 245
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,891	$ -	$ 12	$ 330	$ -	$ 341	$ 23,860	$ (276)	$ (31)
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,511	$ -	$ 12	$ 331	$ -	$ 343	$ 24,203	$ (277)	$ (308)
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,134	$ -	$ 12	$ 333	$ -	$ 345	$ 24,548	$ (278)	$ (586)
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,760	$ -	$ 12	$ 335	$ -	$ 347	$ 24,894	$ (280)	$ (866)
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,389	$ -	$ 12	$ 336	$ -	$ 348	$ 25,243	$ (281)	$ (1,147)
2063	$ -	$ -	$ 632	$ -	$ 632	$ 27,022	$ -	$ 12	$ 338	$ -	$ 350	$ 25,593	$ (282)	$ (1,429)
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,657	$ -	$ 12	$ 340	$ -	$ 352	$ 25,945	$ (284)	$ (1,712)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,295	$ -	$ 12	$ 341	$ -	$ 354	$ 26,298	$ (285)	$ (1,997)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,830	$ (778)	$ 13	$ 343	$ -	$ (422)	$ 25,876	$ (957)	$ (2,954)

Scenario 4: 30-Year Mortgage Term at $4000 DHP Cost

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenanc	Utilities	Financing	**Total**	Baseline	Capital	Maintenanc	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 4,000	$ -	$ -	$ (3,200)	$ 800	$ 800	$ 736	$ 736
2017	$ -	$ -	$ 524	$ 15	$ 539	$ 603	$ -	$ 11	$ 280	$ 184	$ 475	$ 1,275	$ (64)	$ 671
2018	$ -	$ -	$ 519	$ 14	$ 534	$ 1,137	$ -	$ 11	$ 277	$ 178	$ 467	$ 1,742	$ (67)	$ 605
2019	$ -	$ -	$ 519	$ 14	$ 533	$ 1,670	$ -	$ 11	$ 277	$ 173	$ 462	$ 2,204	$ (71)	$ 534
2020	$ -	$ -	$ 519	$ 13	$ 533	$ 2,203	$ -	$ 11	$ 277	$ 168	$ 457	$ 2,661	$ (76)	$ 458
2021	$ -	$ -	$ 524	$ 13	$ 537	$ 2,740	$ -	$ 11	$ 280	$ 163	$ 455	$ 3,116	$ (82)	$ 375
2022	$ -	$ -	$ 519	$ 13	$ 532	$ 3,272	$ -	$ 12	$ 277	$ 159	$ 448	$ 3,563	$ (84)	$ 291
2023	$ -	$ -	$ 514	$ 12	$ 526	$ 3,799	$ -	$ 12	$ 275	$ 154	$ 441	$ 4,004	$ (86)	$ 205
2024	$ -	$ -	$ 509	$ 12	$ 521	$ 4,320	$ -	$ 12	$ 272	$ 150	$ 433	$ 4,437	$ (88)	$ 118
2025	$ -	$ -	$ 514	$ 12	$ 526	$ 4,845	$ -	$ 12	$ 275	$ 145	$ 432	$ 4,869	$ (94)	$ 24
2026	$ -	$ -	$ 514	$ 11	$ 525	$ 5,371	$ -	$ 12	$ 275	$ 141	$ 428	$ 5,297	$ (97)	$ (73)
2027	$ -	$ -	$ 514	$ 11	$ 525	$ 5,896	$ -	$ 12	$ 275	$ 137	$ 424	$ 5,721	$ (101)	$ (175)
2028	$ -	$ -	$ 509	$ 11	$ 520	$ 6,416	$ -	$ 12	$ 272	$ 133	$ 417	$ 6,139	$ (102)	$ (277)
2029	$ -	$ -	$ 509	$ 10	$ 519	$ 6,935	$ -	$ 12	$ 272	$ 129	$ 414	$ 6,553	$ (106)	$ (382)
2030	$ -	$ -	$ 509	$ 10	$ 519	$ 7,454	$ -	$ 13	$ 272	$ 126	$ 410	$ 6,963	$ (109)	$ (491)
2031	$ -	$ -	$ 514	$ 10	$ 524	$ 7,978	$ -	$ 13	$ 275	$ 122	$ 409	$ 7,372	$ (114)	$ (606)
2032	$ -	$ -	$ 519	$ 10	$ 529	$ 8,507	$ -	$ 13	$ 277	$ 119	$ 409	$ 7,781	$ (120)	$ (726)
2033	$ -	$ -	$ 519	$ 9	$ 528	$ 9,035	$ -	$ 13	$ 277	$ 115	$ 406	$ 8,186	$ (123)	$ (849)
2034	$ -	$ -	$ 519	$ 9	$ 528	$ 9,563	$ 4,000	$ 13	$ 277	$ 112	$ 4,402	$ 12,589	$ 3,874	$ 3,025
2035	$ -	$ -	$ 530	$ 9	$ 538	$ 10,102	$ -	$ 11	$ 283	$ 109	$ 403	$ 12,991	$ (136)	$ 2,890
2036	$ -	$ -	$ 535	$ 8	$ 543	$ 10,645	$ -	$ 11	$ 286	$ 105	$ 402	$ 13,394	$ (141)	$ 2,749
2037	$ -	$ -	$ 540	$ 8	$ 548	$ 11,193	$ -	$ 11	$ 288	$ 102	$ 402	$ 13,796	$ (146)	$ 2,603
2038	$ -	$ -	$ 550	$ 8	$ 558	$ 11,751	$ -	$ 11	$ 294	$ 99	$ 405	$ 14,201	$ (153)	$ 2,450
2039	$ -	$ -	$ 555	$ 8	$ 563	$ 12,314	$ -	$ 11	$ 297	$ 97	$ 405	$ 14,605	$ (158)	$ 2,292
2040	$ -	$ -	$ 566	$ 8	$ 573	$ 12,887	$ -	$ 12	$ 302	$ 94	$ 408	$ 15,013	$ (165)	$ 2,126
2041	$ -	$ -	$ 571	$ 7	$ 578	$ 13,465	$ -	$ 12	$ 305	$ 91	$ 408	$ 15,421	$ (170)	$ 1,956
2042	$ -	$ -	$ 571	$ 7	$ 578	$ 14,043	$ -	$ 12	$ 305	$ 89	$ 405	$ 15,826	$ (172)	$ 1,784
2043	$ -	$ -	$ 571	$ 7	$ 578	$ 14,620	$ -	$ 12	$ 305	$ 86	$ 403	$ 16,229	$ (175)	$ 1,609
2044	$ -	$ -	$ 574	$ 7	$ 580	$ 15,201	$ -	$ 12	$ 307	$ 84	$ 402	$ 16,631	$ (178)	$ 1,431
2045	$ -	$ -	$ 577	$ 7	$ 583	$ 15,784	$ -	$ 12	$ 308	$ 81	$ 402	$ 17,033	$ (182)	$ 1,249
2046	$ 321	$ -	$ 580	$ 6	$ 907	$ 16,691	$ -	$ 12	$ 310	$ 79	$ 401	$ 17,434	$ (506)	$ 743
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,274	$ -	$ 12	$ 312	$ -	$ 324	$ 17,758	$ (259)	$ 484
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,860	$ -	$ 13	$ 313	$ -	$ 326	$ 18,084	$ (260)	$ 223
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,449	$ -	$ 13	$ 315	$ -	$ 328	$ 18,411	$ (262)	$ (38)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,042	$ -	$ 13	$ 317	$ -	$ 329	$ 18,740	$ (263)	$ (301)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,637	$ -	$ 13	$ 318	$ -	$ 331	$ 19,071	$ (264)	$ (566)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,235	$ 4,000	$ 13	$ 320	$ -	$ 4,333	$ 23,404	$ 3,734	$ 3,169
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,837	$ -	$ 11	$ 321	$ -	$ 332	$ 23,737	$ (269)	$ 2,900
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,441	$ -	$ 11	$ 323	$ -	$ 334	$ 24,071	$ (270)	$ 2,629
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,049	$ -	$ 11	$ 325	$ -	$ 336	$ 24,407	$ (272)	$ 2,358
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,660	$ -	$ 11	$ 326	$ -	$ 338	$ 24,745	$ (273)	$ 2,085
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,274	$ -	$ 11	$ 328	$ -	$ 339	$ 25,084	$ (274)	$ 1,810
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,891	$ -	$ 12	$ 330	$ -	$ 341	$ 25,425	$ (276)	$ 1,535
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,511	$ -	$ 12	$ 331	$ -	$ 343	$ 25,768	$ (277)	$ 1,258
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,134	$ -	$ 12	$ 333	$ -	$ 345	$ 26,113	$ (278)	$ 979
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,760	$ -	$ 12	$ 335	$ -	$ 347	$ 26,460	$ (280)	$ 700
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,389	$ -	$ 12	$ 336	$ -	$ 348	$ 26,808	$ (281)	$ 419
2063	$ -	$ -	$ 632	$ -	$ 632	$ 27,022	$ -	$ 12	$ 338	$ -	$ 350	$ 27,158	$ (282)	$ 137
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,657	$ -	$ 12	$ 340	$ -	$ 352	$ 27,510	$ (284)	$ (147)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,295	$ -	$ 12	$ 341	$ -	$ 354	$ 27,864	$ (285)	$ (432)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,830	$ (889)	$ 13	$ 343	$ -	$ (533)	$ 27,330	$ (1,068)	$ (1,500)

Scenario 5: 30-Year Mortgage Term at DHP Break Even Cost

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenanc	Utilities	Financing	**Total**	Baseline	Capital	Maintenanc	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 2,146	$ -	$ -	$ (1,717)	$ 429	$ 429	$ 365	$ 365
2017	$ -	$ -	$ 524	$ 15	$ 539	$ 603	$ -	$ 11	$ 280	$ 98	$ 390	$ 819	$ (149)	$ 216
2018	$ -	$ -	$ 519	$ 14	$ 534	$ 1,137	$ -	$ 11	$ 277	$ 96	$ 384	$ 1,203	$ (149)	$ 66
2019	$ -	$ -	$ 519	$ 14	$ 533	$ 1,670	$ -	$ 11	$ 277	$ 93	$ 382	$ 1,585	$ (152)	$ (85)
2020	$ -	$ -	$ 519	$ 13	$ 533	$ 2,203	$ -	$ 11	$ 277	$ 90	$ 379	$ 1,964	$ (154)	$ (239)
2021	$ -	$ -	$ 524	$ 13	$ 537	$ 2,740	$ -	$ 11	$ 280	$ 88	$ 379	$ 2,343	$ (158)	$ (397)
2022	$ -	$ -	$ 519	$ 13	$ 532	$ 3,272	$ -	$ 12	$ 277	$ 85	$ 374	$ 2,717	$ (158)	$ (555)
2023	$ -	$ -	$ 514	$ 12	$ 526	$ 3,799	$ -	$ 12	$ 275	$ 83	$ 369	$ 3,086	$ (157)	$ (712)
2024	$ -	$ -	$ 509	$ 12	$ 521	$ 4,320	$ -	$ 12	$ 272	$ 80	$ 364	$ 3,451	$ (157)	$ (869)
2025	$ -	$ -	$ 514	$ 12	$ 526	$ 4,845	$ -	$ 12	$ 275	$ 78	$ 365	$ 3,815	$ (161)	$ (1,030)
2026	$ -	$ -	$ 514	$ 11	$ 525	$ 5,371	$ -	$ 12	$ 275	$ 76	$ 363	$ 4,178	$ (163)	$ (1,193)
2027	$ -	$ -	$ 514	$ 11	$ 525	$ 5,896	$ -	$ 12	$ 275	$ 74	$ 360	$ 4,538	$ (165)	$ (1,358)
2028	$ -	$ -	$ 509	$ 11	$ 520	$ 6,416	$ -	$ 12	$ 272	$ 71	$ 356	$ 4,894	$ (164)	$ (1,522)
2029	$ -	$ -	$ 509	$ 10	$ 519	$ 6,935	$ -	$ 12	$ 272	$ 69	$ 354	$ 5,248	$ (166)	$ (1,687)
2030	$ -	$ -	$ 509	$ 10	$ 519	$ 7,454	$ -	$ 13	$ 272	$ 67	$ 352	$ 5,600	$ (167)	$ (1,854)
2031	$ -	$ -	$ 514	$ 10	$ 524	$ 7,978	$ -	$ 13	$ 275	$ 65	$ 353	$ 5,953	$ (171)	$ (2,025)
2032	$ -	$ -	$ 519	$ 10	$ 529	$ 8,507	$ -	$ 13	$ 277	$ 64	$ 354	$ 6,306	$ (175)	$ (2,200)
2033	$ -	$ -	$ 519	$ 9	$ 528	$ 9,035	$ -	$ 13	$ 277	$ 62	$ 352	$ 6,659	$ (176)	$ (2,377)
2034	$ -	$ -	$ 519	$ 9	$ 528	$ 9,563	$ 2,146	$ 13	$ 277	$ 60	$ 2,497	$ 9,155	$ 1,968	$ (408)
2035	$ -	$ -	$ 530	$ 9	$ 538	$ 10,102	$ -	$ 11	$ 283	$ 58	$ 352	$ 9,507	$ (186)	$ (594)
2036	$ -	$ -	$ 535	$ 8	$ 543	$ 10,645	$ -	$ 11	$ 286	$ 57	$ 353	$ 9,861	$ (190)	$ (784)
2037	$ -	$ -	$ 540	$ 8	$ 548	$ 11,193	$ -	$ 11	$ 288	$ 55	$ 355	$ 10,215	$ (193)	$ (977)
2038	$ -	$ -	$ 550	$ 8	$ 558	$ 11,751	$ -	$ 11	$ 294	$ 53	$ 359	$ 10,574	$ (199)	$ (1,177)
2039	$ -	$ -	$ 555	$ 8	$ 563	$ 12,314	$ -	$ 11	$ 297	$ 52	$ 360	$ 10,934	$ (203)	$ (1,380)
2040	$ -	$ -	$ 566	$ 8	$ 573	$ 12,887	$ -	$ 12	$ 302	$ 50	$ 364	$ 11,298	$ (209)	$ (1,589)
2041	$ -	$ -	$ 571	$ 7	$ 578	$ 13,465	$ -	$ 12	$ 305	$ 49	$ 366	$ 11,664	$ (212)	$ (1,801)
2042	$ -	$ -	$ 571	$ 7	$ 578	$ 14,043	$ -	$ 12	$ 305	$ 47	$ 364	$ 12,028	$ (213)	$ (2,014)
2043	$ -	$ -	$ 571	$ 7	$ 578	$ 14,620	$ -	$ 12	$ 305	$ 46	$ 363	$ 12,391	$ (215)	$ (2,229)
2044	$ -	$ -	$ 574	$ 7	$ 580	$ 15,201	$ -	$ 12	$ 307	$ 45	$ 363	$ 12,755	$ (217)	$ (2,446)
2045	$ -	$ -	$ 577	$ 7	$ 583	$ 15,784	$ -	$ 12	$ 308	$ 44	$ 364	$ 13,119	$ (219)	$ (2,665)
2046	$ 321	$ -	$ 580	$ 6	$ 907	$ 16,691	$ -	$ 12	$ 310	$ 42	$ 364	$ 13,483	$ (543)	$ (3,208)
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,274	$ -	$ 12	$ 312	$ -	$ 324	$ 13,807	$ (259)	$ (3,467)
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,860	$ -	$ 13	$ 313	$ -	$ 326	$ 14,133	$ (260)	$ (3,728)
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,449	$ -	$ 13	$ 315	$ -	$ 328	$ 14,460	$ (262)	$ (3,989)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,042	$ -	$ 13	$ 317	$ -	$ 329	$ 14,789	$ (263)	$ (4,252)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,637	$ -	$ 13	$ 318	$ -	$ 331	$ 15,121	$ (264)	$ (4,516)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,235	$ 2,146	$ 13	$ 320	$ -	$ 2,479	$ 17,599	$ 1,880	$ (2,636)
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,837	$ -	$ 11	$ 321	$ -	$ 332	$ 17,932	$ (269)	$ (2,905)
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,441	$ -	$ 11	$ 323	$ -	$ 334	$ 18,266	$ (270)	$ (3,175)
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,049	$ -	$ 11	$ 325	$ -	$ 336	$ 18,602	$ (272)	$ (3,447)
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,660	$ -	$ 11	$ 326	$ -	$ 338	$ 18,940	$ (273)	$ (3,720)
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,274	$ -	$ 11	$ 328	$ -	$ 339	$ 19,279	$ (274)	$ (3,994)
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,891	$ -	$ 12	$ 330	$ -	$ 341	$ 19,621	$ (276)	$ (4,270)
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,511	$ -	$ 12	$ 331	$ -	$ 343	$ 19,964	$ (277)	$ (4,547)
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,134	$ -	$ 12	$ 333	$ -	$ 345	$ 20,308	$ (278)	$ (4,825)
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,760	$ -	$ 12	$ 335	$ -	$ 347	$ 20,655	$ (280)	$ (5,105)
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,389	$ -	$ 12	$ 336	$ -	$ 348	$ 21,003	$ (281)	$ (5,386)
2063	$ -	$ -	$ 632	$ -	$ 632	$ 27,022	$ -	$ 12	$ 338	$ -	$ 350	$ 21,353	$ (282)	$ (5,668)
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,657	$ -	$ 12	$ 340	$ -	$ 352	$ 21,705	$ (284)	$ (5,952)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,295	$ -	$ 12	$ 341	$ -	$ 354	$ 22,059	$ (285)	$ (6,237)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,830	$ (477)	$ 13	$ 343	$ -	$ (121)	$ 21,937	$ (656)	$ (6,893)

Scenario 6: 15-Year Mortgage Term at Study Costs

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenanc	Utilities	Financing	Total	Baseline	Capital	Maintenanc	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 2,146	$ -	$ -	$ (1,717)	$ 429	$ 429	$ 365	$ 365
2017	$ -	$ -	$ 524	$ 22	$ 547	$ 611	$ -	$ 11	$ 280	$ 149	$ 440	$ 869	$ (107)	$ 258
2018	$ -	$ -	$ 519	$ 22	$ 541	$ 1,152	$ -	$ 11	$ 277	$ 144	$ 433	$ 1,302	$ (108)	$ 151
2019	$ -	$ -	$ 519	$ 21	$ 540	$ 1,692	$ -	$ 11	$ 277	$ 140	$ 429	$ 1,731	$ (111)	$ 39
2020	$ -	$ -	$ 519	$ 20	$ 540	$ 2,232	$ -	$ 11	$ 277	$ 136	$ 425	$ 2,156	$ (115)	$ (75)
2021	$ -	$ -	$ 524	$ 20	$ 544	$ 2,776	$ -	$ 11	$ 280	$ 132	$ 424	$ 2,580	$ (120)	$ (195)
2022	$ -	$ -	$ 519	$ 19	$ 538	$ 3,314	$ -	$ 12	$ 277	$ 129	$ 418	$ 2,998	$ (121)	$ (316)
2023	$ -	$ -	$ 514	$ 19	$ 533	$ 3,847	$ -	$ 12	$ 275	$ 125	$ 411	$ 3,409	$ (122)	$ (438)
2024	$ -	$ -	$ 509	$ 18	$ 527	$ 4,374	$ -	$ 12	$ 272	$ 121	$ 405	$ 3,814	$ (122)	$ (560)
2025	$ -	$ -	$ 514	$ 18	$ 532	$ 4,906	$ -	$ 12	$ 275	$ 118	$ 404	$ 4,219	$ (127)	$ (687)
2026	$ -	$ -	$ 514	$ 17	$ 531	$ 5,437	$ -	$ 12	$ 275	$ 114	$ 401	$ 4,620	$ (130)	$ (817)
2027	$ -	$ -	$ 514	$ 17	$ 531	$ 5,968	$ -	$ 12	$ 275	$ 111	$ 398	$ 5,018	$ (133)	$ (950)
2028	$ -	$ -	$ 509	$ 16	$ 525	$ 6,493	$ -	$ 12	$ 272	$ 108	$ 392	$ 5,410	$ (133)	$ (1,083)
2029	$ -	$ -	$ 509	$ 16	$ 525	$ 7,017	$ -	$ 12	$ 272	$ 105	$ 389	$ 5,799	$ (135)	$ (1,218)
2030	$ -	$ -	$ 509	$ 15	$ 524	$ 7,542	$ -	$ 13	$ 272	$ 102	$ 386	$ 6,185	$ (138)	$ (1,356)
2031	$ -	$ -	$ 514	$ 15	$ 529	$ 8,071	$ -	$ 13	$ 275	$ 99	$ 386	$ 6,572	$ (143)	$ (1,499)
2032	$ -	$ -	$ 519	$ -	$ 519	$ 8,590	$ -	$ 13	$ 277	$ -	$ 290	$ 6,862	$ (229)	$ (1,728)
2033	$ -	$ -	$ 519	$ -	$ 519	$ 9,109	$ -	$ 13	$ 277	$ -	$ 290	$ 7,152	$ (229)	$ (1,957)
2034	$ -	$ -	$ 519	$ -	$ 519	$ 9,628	$ 2,146	$ 13	$ 277	$ -	$ 2,437	$ 9,589	$ 1,917	$ (39)
2035	$ -	$ -	$ 530	$ -	$ 530	$ 10,158	$ -	$ 11	$ 283	$ -	$ 294	$ 9,883	$ (236)	$ (275)
2036	$ -	$ -	$ 535	$ -	$ 535	$ 10,692	$ -	$ 11	$ 286	$ -	$ 297	$ 10,180	$ (238)	$ (513)
2037	$ -	$ -	$ 540	$ -	$ 540	$ 11,232	$ -	$ 11	$ 288	$ -	$ 300	$ 10,479	$ (240)	$ (753)
2038	$ -	$ -	$ 550	$ -	$ 550	$ 11,782	$ -	$ 11	$ 294	$ -	$ 305	$ 10,785	$ (245)	$ (998)
2039	$ -	$ -	$ 555	$ -	$ 555	$ 12,338	$ -	$ 11	$ 297	$ -	$ 308	$ 11,093	$ (247)	$ (1,245)
2040	$ -	$ -	$ 566	$ -	$ 566	$ 12,903	$ -	$ 12	$ 302	$ -	$ 314	$ 11,407	$ (252)	$ (1,496)
2041	$ -	$ -	$ 571	$ -	$ 571	$ 13,474	$ -	$ 12	$ 305	$ -	$ 317	$ 11,723	$ (254)	$ (1,750)
2042	$ -	$ -	$ 571	$ -	$ 571	$ 14,044	$ -	$ 12	$ 305	$ -	$ 317	$ 12,040	$ (254)	$ (2,004)
2043	$ -	$ -	$ 571	$ -	$ 571	$ 14,615	$ -	$ 12	$ 305	$ -	$ 317	$ 12,357	$ (254)	$ (2,258)
2044	$ -	$ -	$ 574	$ -	$ 574	$ 15,189	$ -	$ 12	$ 307	$ -	$ 319	$ 12,676	$ (255)	$ (2,513)
2045	$ -	$ -	$ 577	$ -	$ 577	$ 15,766	$ -	$ 12	$ 308	$ -	$ 320	$ 12,996	$ (256)	$ (2,770)
2046	$ 321	$ -	$ 580	$ -	$ 901	$ 16,667	$ -	$ 12	$ 310	$ -	$ 322	$ 13,318	$ (579)	$ (3,348)
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,250	$ -	$ 12	$ 312	$ -	$ 324	$ 13,642	$ (259)	$ (3,607)
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,836	$ -	$ 13	$ 313	$ -	$ 326	$ 13,968	$ (260)	$ (3,868)
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,425	$ -	$ 13	$ 315	$ -	$ 328	$ 14,295	$ (262)	$ (4,129)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,017	$ -	$ 13	$ 317	$ -	$ 329	$ 14,625	$ (263)	$ (4,392)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,612	$ -	$ 13	$ 318	$ -	$ 331	$ 14,956	$ (264)	$ (4,656)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,211	$ 2,146	$ 13	$ 320	$ -	$ 2,479	$ 17,435	$ 1,880	$ (2,776)
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,812	$ -	$ 11	$ 321	$ -	$ 332	$ 17,767	$ (269)	$ (3,045)
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,417	$ -	$ 11	$ 323	$ -	$ 334	$ 18,101	$ (270)	$ (3,315)
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,025	$ -	$ 11	$ 325	$ -	$ 336	$ 18,437	$ (272)	$ (3,587)
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,635	$ -	$ 11	$ 326	$ -	$ 338	$ 18,775	$ (273)	$ (3,860)
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,249	$ -	$ 11	$ 328	$ -	$ 339	$ 19,115	$ (274)	$ (4,135)
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,866	$ -	$ 12	$ 330	$ -	$ 341	$ 19,456	$ (276)	$ (4,410)
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,486	$ -	$ 12	$ 331	$ -	$ 343	$ 19,799	$ (277)	$ (4,687)
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,109	$ -	$ 12	$ 333	$ -	$ 345	$ 20,144	$ (278)	$ (4,965)
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,735	$ -	$ 12	$ 335	$ -	$ 347	$ 20,490	$ (280)	$ (5,245)
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,365	$ -	$ 12	$ 336	$ -	$ 348	$ 20,839	$ (281)	$ (5,526)
2063	$ -	$ -	$ 632	$ -	$ 632	$ 26,997	$ -	$ 12	$ 338	$ -	$ 350	$ 21,189	$ (282)	$ (5,808)
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,632	$ -	$ 12	$ 340	$ -	$ 352	$ 21,540	$ (284)	$ (6,092)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,271	$ -	$ 12	$ 341	$ -	$ 354	$ 21,894	$ (285)	$ (6,377)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,805	$ (477)	$ 13	$ 343	$ -	$ (121)	$ 21,773	$ (656)	$ (7,033)

Scenario 7: 15-Year Mortgage Term at $3000 DHP Cost

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenance	Utilities	Financing	Total	Baseline	Capital	Maintenance	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 2,146	$ -	$ -	$ (1,717)	$ 429	$ 429	$ 365	$ 365
2017	$ -	$ -	$ 524	$ 22	$ 547	$ 611	$ -	$ 11	$ 280	$ 149	$ 440	$ 869	$ (107)	$ 258
2018	$ -	$ -	$ 519	$ 22	$ 541	$ 1,152	$ -	$ 11	$ 277	$ 144	$ 433	$ 1,302	$ (108)	$ 151
2019	$ -	$ -	$ 519	$ 21	$ 540	$ 1,692	$ -	$ 11	$ 277	$ 140	$ 429	$ 1,731	$ (111)	$ 39
2020	$ -	$ -	$ 519	$ 20	$ 540	$ 2,232	$ -	$ 11	$ 277	$ 136	$ 425	$ 2,156	$ (115)	$ (75)
2021	$ -	$ -	$ 524	$ 20	$ 544	$ 2,776	$ -	$ 11	$ 280	$ 132	$ 424	$ 2,580	$ (120)	$ (195)
2022	$ -	$ -	$ 519	$ 19	$ 538	$ 3,314	$ -	$ 12	$ 277	$ 129	$ 418	$ 2,998	$ (121)	$ (316)
2023	$ -	$ -	$ 514	$ 19	$ 533	$ 3,847	$ -	$ 12	$ 275	$ 125	$ 411	$ 3,409	$ (122)	$ (438)
2024	$ -	$ -	$ 509	$ 18	$ 527	$ 4,374	$ -	$ 12	$ 272	$ 121	$ 405	$ 3,814	$ (122)	$ (560)
2025	$ -	$ -	$ 514	$ 18	$ 532	$ 4,906	$ -	$ 12	$ 275	$ 118	$ 404	$ 4,219	$ (127)	$ (687)
2026	$ -	$ -	$ 514	$ 17	$ 531	$ 5,437	$ -	$ 12	$ 275	$ 114	$ 401	$ 4,620	$ (130)	$ (817)
2027	$ -	$ -	$ 514	$ 17	$ 531	$ 5,968	$ -	$ 12	$ 275	$ 111	$ 398	$ 5,018	$ (133)	$ (950)
2028	$ -	$ -	$ 509	$ 16	$ 525	$ 6,493	$ -	$ 12	$ 272	$ 108	$ 392	$ 5,410	$ (133)	$ (1,083)
2029	$ -	$ -	$ 509	$ 16	$ 525	$ 7,017	$ -	$ 12	$ 272	$ 105	$ 389	$ 5,799	$ (135)	$ (1,218)
2030	$ -	$ -	$ 509	$ 15	$ 524	$ 7,542	$ -	$ 13	$ 272	$ 102	$ 386	$ 6,185	$ (138)	$ (1,356)
2031	$ -	$ -	$ 514	$ 15	$ 529	$ 8,071	$ -	$ 13	$ 275	$ 99	$ 386	$ 6,572	$ (143)	$ (1,499)
2032	$ -	$ -	$ 519	$ -	$ 519	$ 8,590	$ -	$ 13	$ 277	$ -	$ 290	$ 6,862	$ (229)	$ (1,728)
2033	$ -	$ -	$ 519	$ -	$ 519	$ 9,109	$ -	$ 13	$ 277	$ -	$ 290	$ 7,152	$ (229)	$ (1,957)
2034	$ -	$ -	$ 519	$ -	$ 519	$ 9,628	$ 2,146	$ 13	$ 277	$ -	$ 2,437	$ 9,589	$ 1,917	$ (39)
2035	$ -	$ -	$ 530	$ -	$ 530	$ 10,158	$ -	$ 11	$ 283	$ -	$ 294	$ 9,883	$ (236)	$ (275)
2036	$ -	$ -	$ 535	$ -	$ 535	$ 10,692	$ -	$ 11	$ 286	$ -	$ 297	$ 10,180	$ (238)	$ (513)
2037	$ -	$ -	$ 540	$ -	$ 540	$ 11,232	$ -	$ 11	$ 288	$ -	$ 300	$ 10,479	$ (240)	$ (753)
2038	$ -	$ -	$ 550	$ -	$ 550	$ 11,782	$ -	$ 11	$ 294	$ -	$ 305	$ 10,785	$ (245)	$ (998)
2039	$ -	$ -	$ 555	$ -	$ 555	$ 12,338	$ -	$ 11	$ 297	$ -	$ 308	$ 11,093	$ (247)	$ (1,245)
2040	$ -	$ -	$ 566	$ -	$ 566	$ 12,903	$ -	$ 12	$ 302	$ -	$ 314	$ 11,407	$ (252)	$ (1,496)
2041	$ -	$ -	$ 571	$ -	$ 571	$ 13,474	$ -	$ 12	$ 305	$ -	$ 317	$ 11,723	$ (254)	$ (1,750)
2042	$ -	$ -	$ 571	$ -	$ 571	$ 14,044	$ -	$ 12	$ 305	$ -	$ 317	$ 12,040	$ (254)	$ (2,004)
2043	$ -	$ -	$ 571	$ -	$ 571	$ 14,615	$ -	$ 12	$ 305	$ -	$ 317	$ 12,357	$ (254)	$ (2,258)
2044	$ -	$ -	$ 574	$ -	$ 574	$ 15,189	$ -	$ 12	$ 307	$ -	$ 319	$ 12,676	$ (255)	$ (2,513)
2045	$ -	$ -	$ 577	$ -	$ 577	$ 15,766	$ -	$ 12	$ 308	$ -	$ 320	$ 12,996	$ (256)	$ (2,770)
2046	$ 321	$ -	$ 580	$ -	$ 901	$ 16,667	$ -	$ 12	$ 310	$ -	$ 322	$ 13,318	$ (579)	$ (3,348)
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,250	$ -	$ 12	$ 312	$ -	$ 324	$ 13,642	$ (259)	$ (3,607)
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,836	$ -	$ 13	$ 313	$ -	$ 326	$ 13,968	$ (260)	$ (3,868)
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,425	$ -	$ 13	$ 315	$ -	$ 328	$ 14,295	$ (262)	$ (4,129)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,017	$ -	$ 13	$ 317	$ -	$ 329	$ 14,625	$ (263)	$ (4,392)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,612	$ -	$ 13	$ 318	$ -	$ 331	$ 14,956	$ (264)	$ (4,656)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,211	$ 2,146	$ 13	$ 320	$ -	$ 2,479	$ 17,435	$ 1,880	$ (2,776)
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,812	$ -	$ 11	$ 321	$ -	$ 332	$ 17,767	$ (269)	$ (3,045)
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,417	$ -	$ 11	$ 323	$ -	$ 334	$ 18,101	$ (270)	$ (3,315)
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,025	$ -	$ 11	$ 325	$ -	$ 336	$ 18,437	$ (272)	$ (3,587)
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,635	$ -	$ 11	$ 326	$ -	$ 338	$ 18,775	$ (273)	$ (3,860)
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,249	$ -	$ 11	$ 328	$ -	$ 339	$ 19,115	$ (274)	$ (4,135)
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,866	$ -	$ 12	$ 330	$ -	$ 341	$ 19,456	$ (276)	$ (4,410)
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,486	$ -	$ 12	$ 331	$ -	$ 343	$ 19,799	$ (277)	$ (4,687)
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,109	$ -	$ 12	$ 333	$ -	$ 345	$ 20,144	$ (278)	$ (4,965)
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,735	$ -	$ 12	$ 335	$ -	$ 347	$ 20,490	$ (280)	$ (5,245)
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,365	$ -	$ 12	$ 336	$ -	$ 348	$ 20,839	$ (281)	$ (5,526)
2063	$ -	$ -	$ 632	$ -	$ 632	$ 26,997	$ -	$ 12	$ 338	$ -	$ 350	$ 21,189	$ (282)	$ (5,808)
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,632	$ -	$ 12	$ 340	$ -	$ 352	$ 21,540	$ (284)	$ (6,092)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,271	$ -	$ 12	$ 341	$ -	$ 354	$ 21,894	$ (285)	$ (6,377)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,805	$ (477)	$ 13	$ 343	$ -	$ (121)	$ 21,773	$ (656)	$ (7,033)

Scenario 8: 15-Year Mortgage Term at $3500 DHP Cost

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenance	Utilities	Financing	**Total**	Baseline	Capital	Maintenance	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 2,146	$ -	$ -	$ (1,717)	$ 429	$ 429	$ 365	$ 365
2017	$ -	$ -	$ 524	$ 22	$ 547	$ 611	$ -	$ 11	$ 280	$ 149	$ 440	$ 869	$ (107)	$ 258
2018	$ -	$ -	$ 519	$ 22	$ 541	$ 1,152	$ -	$ 11	$ 277	$ 144	$ 433	$ 1,302	$ (108)	$ 151
2019	$ -	$ -	$ 519	$ 21	$ 540	$ 1,692	$ -	$ 11	$ 277	$ 140	$ 429	$ 1,731	$ (111)	$ 39
2020	$ -	$ -	$ 519	$ 20	$ 540	$ 2,232	$ -	$ 11	$ 277	$ 136	$ 425	$ 2,156	$ (115)	$ (75)
2021	$ -	$ -	$ 524	$ 20	$ 544	$ 2,776	$ -	$ 11	$ 280	$ 132	$ 424	$ 2,580	$ (120)	$ (195)
2022	$ -	$ -	$ 519	$ 19	$ 538	$ 3,314	$ -	$ 12	$ 277	$ 129	$ 418	$ 2,998	$ (121)	$ (316)
2023	$ -	$ -	$ 514	$ 19	$ 533	$ 3,847	$ -	$ 12	$ 275	$ 125	$ 411	$ 3,409	$ (122)	$ (438)
2024	$ -	$ -	$ 509	$ 18	$ 527	$ 4,374	$ -	$ 12	$ 272	$ 121	$ 405	$ 3,814	$ (122)	$ (560)
2025	$ -	$ -	$ 514	$ 18	$ 532	$ 4,906	$ -	$ 12	$ 275	$ 118	$ 404	$ 4,219	$ (127)	$ (687)
2026	$ -	$ -	$ 514	$ 17	$ 531	$ 5,437	$ -	$ 12	$ 275	$ 114	$ 401	$ 4,620	$ (130)	$ (817)
2027	$ -	$ -	$ 514	$ 17	$ 531	$ 5,968	$ -	$ 12	$ 275	$ 111	$ 398	$ 5,018	$ (133)	$ (950)
2028	$ -	$ -	$ 509	$ 16	$ 525	$ 6,493	$ -	$ 12	$ 272	$ 108	$ 392	$ 5,410	$ (133)	$ (1,083)
2029	$ -	$ -	$ 509	$ 16	$ 525	$ 7,017	$ -	$ 12	$ 272	$ 105	$ 389	$ 5,799	$ (135)	$ (1,218)
2030	$ -	$ -	$ 509	$ 15	$ 524	$ 7,542	$ -	$ 13	$ 272	$ 102	$ 386	$ 6,185	$ (138)	$ (1,356)
2031	$ -	$ -	$ 514	$ 15	$ 529	$ 8,071	$ -	$ 13	$ 275	$ 99	$ 386	$ 6,572	$ (143)	$ (1,499)
2032	$ -	$ -	$ 519	$ -	$ 519	$ 8,590	$ -	$ 13	$ 277	$ -	$ 290	$ 6,862	$ (229)	$ (1,728)
2033	$ -	$ -	$ 519	$ -	$ 519	$ 9,109	$ -	$ 13	$ 277	$ -	$ 290	$ 7,152	$ (229)	$ (1,957)
2034	$ -	$ -	$ 519	$ -	$ 519	$ 9,628	$ 2,146	$ 13	$ 277	$ -	$ 2,437	$ 9,589	$ 1,917	$ (39)
2035	$ -	$ -	$ 530	$ -	$ 530	$ 10,158	$ -	$ 11	$ 283	$ -	$ 294	$ 9,883	$ (236)	$ (275)
2036	$ -	$ -	$ 535	$ -	$ 535	$ 10,692	$ -	$ 11	$ 286	$ -	$ 297	$ 10,180	$ (238)	$ (513)
2037	$ -	$ -	$ 540	$ -	$ 540	$ 11,232	$ -	$ 11	$ 288	$ -	$ 300	$ 10,479	$ (240)	$ (753)
2038	$ -	$ -	$ 550	$ -	$ 550	$ 11,782	$ -	$ 11	$ 294	$ -	$ 305	$ 10,785	$ (245)	$ (998)
2039	$ -	$ -	$ 555	$ -	$ 555	$ 12,338	$ -	$ 11	$ 297	$ -	$ 308	$ 11,093	$ (247)	$ (1,245)
2040	$ -	$ -	$ 566	$ -	$ 566	$ 12,903	$ -	$ 12	$ 302	$ -	$ 314	$ 11,407	$ (252)	$ (1,496)
2041	$ -	$ -	$ 571	$ -	$ 571	$ 13,474	$ -	$ 12	$ 305	$ -	$ 317	$ 11,723	$ (254)	$ (1,750)
2042	$ -	$ -	$ 571	$ -	$ 571	$ 14,044	$ -	$ 12	$ 305	$ -	$ 317	$ 12,040	$ (254)	$ (2,004)
2043	$ -	$ -	$ 571	$ -	$ 571	$ 14,615	$ -	$ 12	$ 305	$ -	$ 317	$ 12,357	$ (254)	$ (2,258)
2044	$ -	$ -	$ 574	$ -	$ 574	$ 15,189	$ -	$ 12	$ 307	$ -	$ 319	$ 12,676	$ (255)	$ (2,513)
2045	$ -	$ -	$ 577	$ -	$ 577	$ 15,766	$ -	$ 12	$ 308	$ -	$ 320	$ 12,996	$ (256)	$ (2,770)
2046	$ 321	$ -	$ 580	$ -	$ 901	$ 16,667	$ -	$ 12	$ 310	$ -	$ 322	$ 13,318	$ (579)	$ (3,348)
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,250	$ -	$ 12	$ 312	$ -	$ 324	$ 13,642	$ (259)	$ (3,607)
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,836	$ -	$ 13	$ 313	$ -	$ 326	$ 13,968	$ (260)	$ (3,868)
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,425	$ -	$ 13	$ 315	$ -	$ 328	$ 14,295	$ (262)	$ (4,129)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,017	$ -	$ 13	$ 317	$ -	$ 329	$ 14,625	$ (263)	$ (4,392)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,612	$ -	$ 13	$ 318	$ -	$ 331	$ 14,956	$ (264)	$ (4,656)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,211	$ 2,146	$ 13	$ 320	$ -	$ 2,479	$ 17,435	$ 1,880	$ (2,776)
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,812	$ -	$ 11	$ 321	$ -	$ 332	$ 17,767	$ (269)	$ (3,045)
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,417	$ -	$ 11	$ 323	$ -	$ 334	$ 18,101	$ (270)	$ (3,315)
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,025	$ -	$ 11	$ 325	$ -	$ 336	$ 18,437	$ (272)	$ (3,587)
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,635	$ -	$ 11	$ 326	$ -	$ 338	$ 18,775	$ (273)	$ (3,860)
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,249	$ -	$ 11	$ 328	$ -	$ 339	$ 19,115	$ (274)	$ (4,135)
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,866	$ -	$ 12	$ 330	$ -	$ 341	$ 19,456	$ (276)	$ (4,410)
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,486	$ -	$ 12	$ 331	$ -	$ 343	$ 19,799	$ (277)	$ (4,687)
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,109	$ -	$ 12	$ 333	$ -	$ 345	$ 20,144	$ (278)	$ (4,965)
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,735	$ -	$ 12	$ 335	$ -	$ 347	$ 20,490	$ (280)	$ (5,245)
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,365	$ -	$ 12	$ 336	$ -	$ 348	$ 20,839	$ (281)	$ (5,526)
2063	$ -	$ -	$ 632	$ -	$ 632	$ 26,997	$ -	$ 12	$ 338	$ -	$ 350	$ 21,189	$ (282)	$ (5,808)
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,632	$ -	$ 12	$ 340	$ -	$ 352	$ 21,540	$ (284)	$ (6,092)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,271	$ -	$ 12	$ 341	$ -	$ 354	$ 21,894	$ (285)	$ (6,377)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,805	$ (477)	$ 13	$ 343	$ -	$ (121)	$ 21,773	$ (656)	$ (7,033)

Scenario 9: 15-Year Mortgage Term at $4000 DHP Cost

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenanc	Utilities	Financing	Total	Baseline	Capital	Maintenanc	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 2,146	$ -	$ -	$ (1,717)	$ 429	$ 429	$ 365	$ 365
2017	$ -	$ -	$ 524	$ 22	$ 547	$ 611	$ -	$ 11	$ 280	$ 149	$ 440	$ 869	$ (107)	$ 258
2018	$ -	$ -	$ 519	$ 22	$ 541	$ 1,152	$ -	$ 11	$ 277	$ 144	$ 433	$ 1,302	$ (108)	$ 151
2019	$ -	$ -	$ 519	$ 21	$ 540	$ 1,692	$ -	$ 11	$ 277	$ 140	$ 429	$ 1,731	$ (111)	$ 39
2020	$ -	$ -	$ 519	$ 20	$ 540	$ 2,232	$ -	$ 11	$ 277	$ 136	$ 425	$ 2,156	$ (115)	$ (75)
2021	$ -	$ -	$ 524	$ 20	$ 544	$ 2,776	$ -	$ 11	$ 280	$ 132	$ 424	$ 2,580	$ (120)	$ (195)
2022	$ -	$ -	$ 519	$ 19	$ 538	$ 3,314	$ -	$ 12	$ 277	$ 129	$ 418	$ 2,998	$ (121)	$ (316)
2023	$ -	$ -	$ 514	$ 19	$ 533	$ 3,847	$ -	$ 12	$ 275	$ 125	$ 411	$ 3,409	$ (122)	$ (438)
2024	$ -	$ -	$ 509	$ 18	$ 527	$ 4,374	$ -	$ 12	$ 272	$ 121	$ 405	$ 3,814	$ (122)	$ (560)
2025	$ -	$ -	$ 514	$ 18	$ 532	$ 4,906	$ -	$ 12	$ 275	$ 118	$ 404	$ 4,219	$ (127)	$ (687)
2026	$ -	$ -	$ 514	$ 17	$ 531	$ 5,437	$ -	$ 12	$ 275	$ 114	$ 401	$ 4,620	$ (130)	$ (817)
2027	$ -	$ -	$ 514	$ 17	$ 531	$ 5,968	$ -	$ 12	$ 275	$ 111	$ 398	$ 5,018	$ (133)	$ (950)
2028	$ -	$ -	$ 509	$ 16	$ 525	$ 6,493	$ -	$ 12	$ 272	$ 108	$ 392	$ 5,410	$ (133)	$ (1,083)
2029	$ -	$ -	$ 509	$ 16	$ 525	$ 7,017	$ -	$ 12	$ 272	$ 105	$ 389	$ 5,799	$ (135)	$ (1,218)
2030	$ -	$ -	$ 509	$ 15	$ 524	$ 7,542	$ -	$ 13	$ 272	$ 102	$ 386	$ 6,185	$ (138)	$ (1,356)
2031	$ -	$ -	$ 514	$ 15	$ 529	$ 8,071	$ -	$ 13	$ 275	$ 99	$ 386	$ 6,572	$ (143)	$ (1,499)
2032	$ -	$ -	$ 519	$ -	$ 519	$ 8,590	$ -	$ 13	$ 277	$ -	$ 290	$ 6,862	$ (229)	$ (1,728)
2033	$ -	$ -	$ 519	$ -	$ 519	$ 9,109	$ -	$ 13	$ 277	$ -	$ 290	$ 7,152	$ (229)	$ (1,957)
2034	$ -	$ -	$ 519	$ -	$ 519	$ 9,628	$ 2,146	$ 13	$ 277	$ -	$ 2,437	$ 9,589	$ 1,917	$ (39)
2035	$ -	$ -	$ 530	$ -	$ 530	$ 10,158	$ -	$ 11	$ 283	$ -	$ 294	$ 9,883	$ (236)	$ (275)
2036	$ -	$ -	$ 535	$ -	$ 535	$ 10,692	$ -	$ 11	$ 286	$ -	$ 297	$ 10,180	$ (238)	$ (513)
2037	$ -	$ -	$ 540	$ -	$ 540	$ 11,232	$ -	$ 11	$ 288	$ -	$ 300	$ 10,479	$ (240)	$ (753)
2038	$ -	$ -	$ 550	$ -	$ 550	$ 11,782	$ -	$ 11	$ 294	$ -	$ 305	$ 10,785	$ (245)	$ (998)
2039	$ -	$ -	$ 555	$ -	$ 555	$ 12,338	$ -	$ 11	$ 297	$ -	$ 308	$ 11,093	$ (247)	$ (1,245)
2040	$ -	$ -	$ 566	$ -	$ 566	$ 12,903	$ -	$ 12	$ 302	$ -	$ 314	$ 11,407	$ (252)	$ (1,496)
2041	$ -	$ -	$ 571	$ -	$ 571	$ 13,474	$ -	$ 12	$ 305	$ -	$ 317	$ 11,723	$ (254)	$ (1,750)
2042	$ -	$ -	$ 571	$ -	$ 571	$ 14,044	$ -	$ 12	$ 305	$ -	$ 317	$ 12,040	$ (254)	$ (2,004)
2043	$ -	$ -	$ 571	$ -	$ 571	$ 14,615	$ -	$ 12	$ 305	$ -	$ 317	$ 12,357	$ (254)	$ (2,258)
2044	$ -	$ -	$ 574	$ -	$ 574	$ 15,189	$ -	$ 12	$ 307	$ -	$ 319	$ 12,676	$ (255)	$ (2,513)
2045	$ -	$ -	$ 577	$ -	$ 577	$ 15,766	$ -	$ 12	$ 308	$ -	$ 320	$ 12,996	$ (256)	$ (2,770)
2046	$ 321	$ -	$ 580	$ -	$ 901	$ 16,667	$ -	$ 12	$ 310	$ -	$ 322	$ 13,318	$ (579)	$ (3,348)
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,250	$ -	$ 12	$ 312	$ -	$ 324	$ 13,642	$ (259)	$ (3,607)
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,836	$ -	$ 13	$ 313	$ -	$ 326	$ 13,968	$ (260)	$ (3,868)
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,425	$ -	$ 13	$ 315	$ -	$ 328	$ 14,295	$ (262)	$ (4,129)
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,017	$ -	$ 13	$ 317	$ -	$ 329	$ 14,625	$ (263)	$ (4,392)
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,612	$ -	$ 13	$ 318	$ -	$ 331	$ 14,956	$ (264)	$ (4,656)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,211	$ 2,146	$ 13	$ 320	$ -	$ 2,479	$ 17,435	$ 1,880	$ (2,776)
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,812	$ -	$ 11	$ 321	$ -	$ 332	$ 17,767	$ (269)	$ (3,045)
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,417	$ -	$ 11	$ 323	$ -	$ 334	$ 18,101	$ (270)	$ (3,315)
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,025	$ -	$ 11	$ 325	$ -	$ 336	$ 18,437	$ (272)	$ (3,587)
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,635	$ -	$ 11	$ 326	$ -	$ 338	$ 18,775	$ (273)	$ (3,860)
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,249	$ -	$ 11	$ 328	$ -	$ 339	$ 19,115	$ (274)	$ (4,135)
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,866	$ -	$ 12	$ 330	$ -	$ 341	$ 19,456	$ (276)	$ (4,410)
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,486	$ -	$ 12	$ 331	$ -	$ 343	$ 19,799	$ (277)	$ (4,687)
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,109	$ -	$ 12	$ 333	$ -	$ 345	$ 20,144	$ (278)	$ (4,965)
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,735	$ -	$ 12	$ 335	$ -	$ 347	$ 20,490	$ (280)	$ (5,245)
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,365	$ -	$ 12	$ 336	$ -	$ 348	$ 20,839	$ (281)	$ (5,526)
2063	$ -	$ -	$ 632	$ -	$ 632	$ 26,997	$ -	$ 12	$ 338	$ -	$ 350	$ 21,189	$ (282)	$ (5,808)
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,632	$ -	$ 12	$ 340	$ -	$ 352	$ 21,540	$ (284)	$ (6,092)
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,271	$ -	$ 12	$ 341	$ -	$ 354	$ 21,894	$ (285)	$ (6,377)
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,805	$ (477)	$ 13	$ 343	$ -	$ (121)	$ 21,773	$ (656)	$ (7,033)

Scenario 10: 15-Year Mortgage Term at Break Even Cost

	Baseline Expenditure Report					Cumulative Expenditures	Alternative 1 Expenditure Report					Cumulative Expenditures	Expenditures over Baseline	Expenditures over Baseline
Year	Capital	Maintenance	Utilities	Financing	Total	Baseline	Capital	Maintenance	Utilities	Financing	Total	Alt. 1	Annual	Cumulative
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ 321	$ -	$ -	$ (257)	$ 64	$ 64	$ 4,305	$ -	$ -	$ (3,444)	$ 861	$ 861	$ 797	$ 797
2017	$ -	$ -	$ 524	$ 22	$ 547	$ 611	$ -	$ 11	$ 280	$ 298	$ 590	$ 1,450	$ 43	$ 840
2018	$ -	$ -	$ 519	$ 22	$ 541	$ 1,152	$ -	$ 11	$ 277	$ 290	$ 578	$ 2,029	$ 37	$ 877
2019	$ -	$ -	$ 519	$ 21	$ 540	$ 1,692	$ -	$ 11	$ 277	$ 281	$ 570	$ 2,599	$ 30	$ 907
2020	$ -	$ -	$ 519	$ 20	$ 540	$ 2,232	$ -	$ 11	$ 277	$ 273	$ 562	$ 3,161	$ 23	$ 930
2021	$ -	$ -	$ 524	$ 20	$ 544	$ 2,776	$ -	$ 11	$ 280	$ 265	$ 557	$ 3,718	$ 13	$ 943
2022	$ -	$ -	$ 519	$ 19	$ 538	$ 3,314	$ -	$ 12	$ 277	$ 258	$ 547	$ 4,265	$ 8	$ 951
2023	$ -	$ -	$ 514	$ 19	$ 533	$ 3,847	$ -	$ 12	$ 275	$ 250	$ 537	$ 4,802	$ 4	$ 955
2024	$ -	$ -	$ 509	$ 18	$ 527	$ 4,374	$ -	$ 12	$ 272	$ 243	$ 527	$ 5,329	$ (0)	$ 955
2025	$ -	$ -	$ 514	$ 18	$ 532	$ 4,906	$ -	$ 12	$ 275	$ 236	$ 523	$ 5,852	$ (9)	$ 946
2026	$ -	$ -	$ 514	$ 17	$ 531	$ 5,437	$ -	$ 12	$ 275	$ 229	$ 516	$ 6,368	$ (15)	$ 931
2027	$ -	$ -	$ 514	$ 17	$ 531	$ 5,968	$ -	$ 12	$ 275	$ 223	$ 510	$ 6,878	$ (21)	$ 910
2028	$ -	$ -	$ 509	$ 16	$ 525	$ 6,493	$ -	$ 12	$ 272	$ 216	$ 501	$ 7,378	$ (24)	$ 886
2029	$ -	$ -	$ 509	$ 16	$ 525	$ 7,017	$ -	$ 12	$ 272	$ 210	$ 495	$ 7,873	$ (30)	$ 856
2030	$ -	$ -	$ 509	$ 15	$ 524	$ 7,542	$ -	$ 13	$ 272	$ 204	$ 489	$ 8,362	$ (36)	$ 820
2031	$ -	$ -	$ 514	$ 15	$ 529	$ 8,071	$ -	$ 13	$ 275	$ 198	$ 486	$ 8,847	$ (43)	$ 777
2032	$ -	$ -	$ 519	$ -	$ 519	$ 8,590	$ -	$ 13	$ 277	$ -	$ 290	$ 9,138	$ (229)	$ 548
2033	$ -	$ -	$ 519	$ -	$ 519	$ 9,109	$ -	$ 13	$ 277	$ -	$ 290	$ 9,428	$ (229)	$ 319
2034	$ -	$ -	$ 519	$ -	$ 519	$ 9,628	$ 4,305	$ 13	$ 277	$ -	$ 4,595	$ 14,023	$ 4,076	$ 4,395
2035	$ -	$ -	$ 530	$ -	$ 530	$ 10,158	$ -	$ 11	$ 283	$ -	$ 294	$ 14,317	$ (236)	$ 4,160
2036	$ -	$ -	$ 535	$ -	$ 535	$ 10,692	$ -	$ 11	$ 286	$ -	$ 297	$ 14,614	$ (238)	$ 3,922
2037	$ -	$ -	$ 540	$ -	$ 540	$ 11,232	$ -	$ 11	$ 288	$ -	$ 300	$ 14,914	$ (240)	$ 3,682
2038	$ -	$ -	$ 550	$ -	$ 550	$ 11,782	$ -	$ 11	$ 294	$ -	$ 305	$ 15,219	$ (245)	$ 3,437
2039	$ -	$ -	$ 555	$ -	$ 555	$ 12,338	$ -	$ 11	$ 297	$ -	$ 308	$ 15,527	$ (247)	$ 3,190
2040	$ -	$ -	$ 566	$ -	$ 566	$ 12,903	$ -	$ 12	$ 302	$ -	$ 314	$ 15,841	$ (252)	$ 2,938
2041	$ -	$ -	$ 571	$ -	$ 571	$ 13,474	$ -	$ 12	$ 305	$ -	$ 317	$ 16,158	$ (254)	$ 2,684
2042	$ -	$ -	$ 571	$ -	$ 571	$ 14,044	$ -	$ 12	$ 305	$ -	$ 317	$ 16,475	$ (254)	$ 2,430
2043	$ -	$ -	$ 571	$ -	$ 571	$ 14,615	$ -	$ 12	$ 305	$ -	$ 317	$ 16,791	$ (254)	$ 2,176
2044	$ -	$ -	$ 574	$ -	$ 574	$ 15,189	$ -	$ 12	$ 307	$ -	$ 319	$ 17,110	$ (255)	$ 1,921
2045	$ -	$ -	$ 577	$ -	$ 577	$ 15,766	$ -	$ 12	$ 308	$ -	$ 320	$ 17,431	$ (256)	$ 1,665
2046	$ 321	$ -	$ 580	$ -	$ 901	$ 16,667	$ -	$ 12	$ 310	$ -	$ 322	$ 17,753	$ (579)	$ 1,086
2047	$ -	$ -	$ 583	$ -	$ 583	$ 17,250	$ -	$ 12	$ 312	$ -	$ 324	$ 18,077	$ (259)	$ 827
2048	$ -	$ -	$ 586	$ -	$ 586	$ 17,836	$ -	$ 13	$ 313	$ -	$ 326	$ 18,402	$ (260)	$ 567
2049	$ -	$ -	$ 589	$ -	$ 589	$ 18,425	$ -	$ 13	$ 315	$ -	$ 328	$ 18,730	$ (262)	$ 305
2050	$ -	$ -	$ 592	$ -	$ 592	$ 19,017	$ -	$ 13	$ 317	$ -	$ 329	$ 19,059	$ (263)	$ 42
2051	$ -	$ -	$ 595	$ -	$ 595	$ 19,612	$ -	$ 13	$ 318	$ -	$ 331	$ 19,390	$ (264)	$ (222)
2052	$ -	$ -	$ 598	$ -	$ 598	$ 20,211	$ 4,305	$ 13	$ 320	$ -	$ 4,638	$ 24,028	$ 4,039	$ 3,817
2053	$ -	$ -	$ 602	$ -	$ 602	$ 20,812	$ -	$ 11	$ 321	$ -	$ 332	$ 24,360	$ (269)	$ 3,548
2054	$ -	$ -	$ 605	$ -	$ 605	$ 21,417	$ -	$ 11	$ 323	$ -	$ 334	$ 24,695	$ (270)	$ 3,278
2055	$ -	$ -	$ 608	$ -	$ 608	$ 22,025	$ -	$ 11	$ 325	$ -	$ 336	$ 25,030	$ (272)	$ 3,006
2056	$ -	$ -	$ 611	$ -	$ 611	$ 22,635	$ -	$ 11	$ 326	$ -	$ 338	$ 25,368	$ (273)	$ 2,733
2057	$ -	$ -	$ 614	$ -	$ 614	$ 23,249	$ -	$ 11	$ 328	$ -	$ 339	$ 25,708	$ (274)	$ 2,459
2058	$ -	$ -	$ 617	$ -	$ 617	$ 23,866	$ -	$ 12	$ 330	$ -	$ 341	$ 26,049	$ (276)	$ 2,183
2059	$ -	$ -	$ 620	$ -	$ 620	$ 24,486	$ -	$ 12	$ 331	$ -	$ 343	$ 26,392	$ (277)	$ 1,906
2060	$ -	$ -	$ 623	$ -	$ 623	$ 25,109	$ -	$ 12	$ 333	$ -	$ 345	$ 26,737	$ (278)	$ 1,628
2061	$ -	$ -	$ 626	$ -	$ 626	$ 25,735	$ -	$ 12	$ 335	$ -	$ 347	$ 27,083	$ (280)	$ 1,348
2062	$ -	$ -	$ 629	$ -	$ 629	$ 26,365	$ -	$ 12	$ 336	$ -	$ 348	$ 27,432	$ (281)	$ 1,067
2063	$ -	$ -	$ 632	$ -	$ 632	$ 26,997	$ -	$ 12	$ 338	$ -	$ 350	$ 27,782	$ (282)	$ 785
2064	$ -	$ -	$ 635	$ -	$ 635	$ 27,632	$ -	$ 12	$ 340	$ -	$ 352	$ 28,134	$ (284)	$ 501
2065	$ -	$ -	$ 639	$ -	$ 639	$ 28,271	$ -	$ 12	$ 341	$ -	$ 354	$ 28,487	$ (285)	$ 216
2066	$ (107)	$ -	$ 642	$ -	$ 535	$ 28,805	$ (957)	$ 13	$ 343	$ -	$ (601)	$ 27,886	$ (1,136)	$ (919)

Appendix E

TMY3 (Typical-Month-Year version 3) was chosen to weather normalize heating system performance. TMY3 uses the most "typical" month from historical weather data to represent a specific month within the model; e.g. January 1976 represents a typical January, February 2006 represents a typical February, and so on.

TMY3 was chosen because it's widely used to normalize heating and cooling calculations and available in an hourly format. Hourly data is necessary to calculate heating degree days (HDD) and cooling degree days (CDD) using the preferred "integration method [1]".

TMY3 does not lend itself to normalization based on weighted population. Because locations use weather from various years, normalization removes extreme hot and cold occurrences; e.g. Olympia TMY3 uses January 2001 to represent typical January, Bellingham uses January 1976 to represent typical January, and so on. Because cold and hot snaps do not occur within the same year these temperatures are removed when normalized; e.g. most TMY3's have several days colder than 32*F, but the daily weighted average has no days below 35*F.

Table X*! below shows temperatures for various TMY3's in Western Washington. Note the weighted average temperature contains significantly fewer extreme cold or hot observations.

	Bellingham *F	Hoquium *F	Kelso *F	McChord *F	Olympia *F	Sea-Tac *F	Snohomish *F	Toledo-Winlock *F	Whidbey *F	Daily Weighted Average *F	Average of TMY3's
Minimum	25	24	28	23	28	29	35	25	31	35	29
25th Percentile	42	45	45	41	42	45	44	40	44	44	43
Median	49	50	52	50	50	52	49	49	50	50	50
75th Percentile	58	57	61	58	59	60	57	57	56	59	58
Maximum	70	70	73	79	76	74	73	78	65	70	73
Days under 32*f	11	4	5	27	13	5	0	36	2	0	11
HDD_65	5,915	5,342	5,042	5,894	5,621	4,950	5,349	6,231	5,633	5,160	5,492
Same (= to TMY3 average; +/- 2 days under F*32 to TMY3 average; closest HDD_65 of TMY3 average)											
Close (+/- 1*F of TMY3 average; +/- 10 days under F*38; +/- 200 HDD_65 of TMY3 average)											

Olympia TMY3 was chosen to weather normalize system performance. TMY3 values for weather stations in Western Washington were considered for normalization. Each weather station was compared against daily averages across weather stations using basic statistics. Olympia TMY3 was found to be the most similar to the average weather station because it was close to the average across the most categories (minimum temperature, 25th percentile temperature, median, etc.)

[1] The integration method calculates HDD based on hourly weather data and returns a more accurate result. See http://www.degreedays.net/calculation and http://www.degreedays.net/introduction for details.

Appendix F

Regression Output (regressions performed in R)

lm(formula = HVAC_kWh_FT2 ~ HVAC_System_Type + McChord_Temp_Daily +
McChord_Temp_DailySQ + Occupants + Num_BdRm + Jan + Feb +
Mar + Apr + Jun + Jul + Sep + Oct + Nov + Dec, data = Dataset)

Residuals:

Min	1Q	Median	3Q	Max
-0.0223283	-0.0039083	-0.0000588	0.0033016	0.0287907

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	6.566e-02	2.889e-03	22.725	< 2e-16 ***
HVAC_System_Type	-6.891e-03	2.735e-04	-25.198	< 2e-16 ***
McChord_Temp_Daily	-1.791e-03	1.282e-04	-13.974	< 2e-16 ***
McChord_Temp_DailySQ	1.221e-05	1.454e-06	8.396	< 2e-16 ***
Occupants	1.081e-03	1.942e-04	5.565	2.99e-08 ***
Num_BdRm	-3.968e-04	2.632e-04	-1.508	0.1318
Jan	6.535e-03	7.458e-04	8.762	< 2e-16 ***
Feb	5.700e-03	8.697e-04	6.554	7.21e-11 ***
Mar	3.711e-03	7.644e-04	4.855	1.30e-06 ***
Apr	1.017e-03	7.043e-04	1.444	0.1489
Jun	-2.982e-04	6.742e-04	-0.442	0.6583
Jul	7.583e-04	1.100e-03	0.689	0.4909
Sep	-1.649e-03	8.613e-04	-1.914	0.0557 .
Oct	8.116e-04	6.253e-04	1.298	0.1945
Nov	4.139e-03	7.186e-04	5.760	9.78e-09 ***
Dec	6.024e-03	7.208e-04	8.357	< 2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.005946 on 1895 degrees of freedom
Multiple R-squared: **0.714**, Adjusted R-squared: 0.7118
F-statistic: 315.4 on 15 and 1895 DF, p-value: < 2.2e-16

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Energy Code Proposal Short Form

For editorial **Coordination, Clarifications & Corrections** only,
without substantive energy or cost impacts

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R404.1

Brief Description: This proposal corrects language regarding "lamps" and "fixtures" for residential lighting.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

> R404.1 Lighting equipment (Mandatory). Not less than 75 percent of ~~permanently installed~~ lamps in permanently installed lighting fixtures shall be high-efficacy lamps.

Purpose of code change:

The language in the code is incorrect. There are no permanently installed lamps but there are permanently installed lighting fixtures.

Your name	Gary Nordeen	Email address	nordeeng@energy.wsu.edu
Your organization	WSU Energy Program	Phone number	(360) 956-2040
Other contact name	38T		

Instructions: For use with Coordination, Clarifications & Corrections **ONLY**. Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280.

March 2, 2015

<u>Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.</u>

2015 Washington State Energy Code Development

Energy Code Proposal Short Form

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Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # **Table R4.5.5.2**

Brief Description: WSEC 2012 Section R405 does not specify a baseline distribution system type and simply states the proposed system will be modeled as tested or according to the default table R405.5.2(2). The new integrated draft specifies a distribution factor of 0.88 in the base case - equivalent to the default value for ducted systems entirely in the heated space. This now allows system trade-offs to be made. This is a concern because the hydronic system values are unrealistic. The default factors, 1.00 for locations in the heated space and 0.95 for those outside, give interior hydronic systems 14% and exterior systems 8% more credit than a ducted system with ducts in the interior space. My experience with hydronic systems is they are not particularly efficient and are often very inefficient with control issues and lots of parasitic losses. In Port Townsend there are lots of systems with tubing attached to the bottom side of a wood floor with batts below. Depending upon whether this is considered exterior or interior it would result in an 8% or 14% advantage to the interior system. Heated slabs would get a 14% advantage. Hydronic system efficiency numbers are not well established and allowing a competitive advantage based upon them is not good policy. Proposed here is to adjust the hydronic numbers so they are equivalent to ducts in the heated space.
An additional concern is how duct testing is used to establish distribution efficiency. I would delete all references to testing or provide a reference or method to standardize estimated system efficiency.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

TABLE R405.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Thermal distribution systems	Duct insulation: From Section R403.3.3 A thermal distribution system efficiency (DSE) of 0.88 shall be applied to both the heating and cooling system efficiencies for all ducted systems other than tested duct systems. For tested duct systems, the leakage rate shall be 4 cfm (113.3 L/min) per 100 ft2 (9.29 m2) of conditioned floor area at a pressure differential of 0.1 inches w.g. (25 Pa). A thermal distribution system efficiency (DSE) of 1.0 shall be applied to both the heating and cooling system efficiencies for all hydronic systems.	As tested or as specified in Table R405.5.2(2) if not tested. Duct insulation shall be as proposed.

Comment [KB1]: RE 167; approved AM

TABLE R405.5.2(2)
DEFAULT DISTRIBUTION SYSTEM EFFICIENCIES FOR PROPOSED DESIGNS[a]

DISTRIBUTION SYSTEM CONFIGURATION AND CONDITION	FORCED AIR SYSTEMS	HYDRONIC SYSTEMS[b]
Distribution system components located in unconditioned space	-	0.95
Untested distribution systems entirely located in conditioned space[c]	0.88	1
"Ductless" systems[d]	1	-

For SI: 1 cubic foot per minute = 0.47 L/s, 1 square foot = 0.093m^2, 1 pound per square inch = 6895 Pa, 1 inch water gauge = 1250 Pa.

a. Default values given by this table are for untested distribution systems, which must still meet minimum requirements for duct system insulation.
b. Hydronic systems shall mean those systems that distribute heating and cooling energy directly to individual spaces using liquids pumped through closed-loop piping and that do not depend on ducted, forced airflow to maintain space temperatures.
c. Entire system in conditioned space shall mean that no component of the distribution system, including the air-handler unit, is located outside of the conditioned space.
d. Ductless systems shall be allowed to have forced airflow across a coil but shall not have any ducted airflow external to the manufacturer's air-handler enclosure.

Purpose of code change:

Provide a reasonable compliance path for home owners replacing existing stopped in glazing units.

Your name Mike Kennedy Email address mikekennedy@energysims.com

Your organization Mike D Kennedy Inc Phone number 360-301-0098

Other contact name Click here to enter text.

Instructions: For use with Coordination, Clarifications & Corrections **ONLY**. Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280.

Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # **R405.3,R406**

Brief Description: **This proposal updates section R406 and requires additional energy efficiency credits**

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

R405.3 Performance-based compliance. Compliance based on simulated energy performance requires that a proposed residence (*proposed design*) be shown to have an annual energy consumption based on site energy expressed in Btu and Btu per square foot of *conditioned floor area* as follows:

1., For structures serving Group R-3 or R-4 occupancies less than 1,500 square feet of conditioned floor area, the annual energy consumption shall be less than or equal to ~~97~~ 80 percent of the annual energy consumption of the *standard reference design*.

2. For structures serving Group R-3 or R-4 occupancies 1,500 to 5,000 square feet of conditioned floor area, the annual energy consumption shall be no more than ~~89~~ 72 percent of the *standard reference design*.

3. For structures serving Group R-3 or R-4 occupancies over 5,000 square feet of conditioned floor area, the annual energy consumption shall be no more than ~~83~~66 percent of the *standard reference design*.
4. For structures serving Group R-2 occupancies, the annual energy consumption shall be less than or equal to ~~97~~ 85 percent of the annual energy consumption of the *standard reference design*.

SECTION R406
ADDITIONAL ENERGY EFFICIENCY REQUIREMENTS

R406.1 Scope. This section establishes options for additional criteria to be met by residential buildings ~~for one- and two-family dwellings and townhouses,~~ as defined in ~~Section R101.2 of~~ the *International Residential Code* to demonstrate compliance with this code.

R406.2 Additional energy efficiency requirements (Mandatory). Each dwelling unit ~~in one- and two-family dwellings and townhouses,~~ as defined in ~~Section 101.2 of~~ the *International Residential Code* shall comply with sufficient options from Table R406.2 so as to achieve the following minimum number of credits:

1. Small Dwelling Unit serving Group R-3 or R-4 occupancies: ~~0.5 points~~ 2.5 credits
   Dwelling units less than 1500 square feet in conditioned floor area with less than 300 square feet of fenestration area. Additions to existing building that are less than 750 square feet of heated floor area.
2. Medium Dwelling Unit serving Group R-3 or R-4 occupancies: ~~1.5 points~~ 3.5 credits
   All dwelling units that are not included in #1 or #3.
3. Large Dwelling Unit serving Group R-3 or R-4 occupancies: ~~2.5 points~~ 4.5 credits
   Dwelling units exceeding 5000 square feet of conditioned floor area.
4. Dwelling units serving R-2 occupancies.. 2.5 credits

5. Additions greater than 500 square feet..... 0.5 credits

The drawings included with the building permit application shall identify which options have been selected and the point value of each option, regardless of whether separate mechanical, plumbing, electrical, or other permits are utilized for the project.

TABLE 406.2
ENERGY CREDITS

OPTION	DESCRIPTION	CREDIT(S)
1a	EFFICIENT BUILDING ENVELOPE 1a: Prescriptive compliance is based on Table R402.1.2 with the following modifications: Fenestration U .= 0.28 Floor R-38 Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 5%.	0.5
1b	EFFICIENT BUILDING ENVELOPE 1b: Prescriptive compliance is based on Table R402.1.2 with the following modifications: Fenestration U .= 0.25 Wall R-21 plus R-4 Floor R-38 Basement wall R-21 int plus R-5 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 15%.	1.0
1c	EFFICIENT BUILDING ENVELOPE 1c: Prescriptive compliance is based on Table R402.1.2 with the following modifications: Fenestration U .= 0.22 Ceiling and single-rafter or joist-vaulted R-49 advanced Wood frame wall R-21 int plus R-12 ci Floor R-38 Basement wall R-21 int plus R-12 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 30%.	2.0
1d	EFFICIENT BUILDING ENVELOPE 1d: Prescriptive compliance is based on Table R402.1.2 with the following modifications: Fenestration U .= 0.24	0.5
2a	AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION 2a: Compliance based on R402.4.1.2: Reduce the tested air leakage to ~~4.0~~ 3.0 air changes per hour maximum **and** All whole house ventilation requirements as determined by Section M1507.3 of the *International Residential Code* shall be met with a high efficiency fan (maximum 0.35 watts/cfm), not interlocked with the furnace fan. Ventilation systems using a furnace including an ECM motor are allowed, provided that they are controlled to operate at low speed in ventilation only mode. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the maximum tested building air leakage and shall show the qualified ventilation system.	0.5
2b	AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION 2b: Compliance based on Section R402.4.1.2: Reduce the tested air leakage to 2.0 air changes per hour maximum **and** All whole house ventilation requirements as determined by Section M1507.3 of the *International Residential Code* shall be met with a heat recovery ventilation system with minimum sensible heat recovery efficiency of 0.70. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the maximum tested building air leakage and shall show the heat recovery ventilation system.	1.0

2c	AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION 2c: Compliance based on Section R402.4.1.2: Reduce the tested air leakage to 1.5 air changes per hour maximum **and** All whole house ventilation requirements as determined by Section M1507.3 of the *International Residential Code* shall be met with a heat recovery ventilation system with minimum sensible heat recovery efficiency of 0.85. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the maximum tested building air leakage and shall show the heat recovery ventilation system.	1.5
3a[a]	HIGH EFFICIENCY HVAC EQUIPMENT 3a: Gas, propane or oil-fired furnace with minimum AFUE of 94~~5~~%, or gas, propane or oil-fired boiler with minimum AFUE of 92% To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and the minimum equipment efficiency.	~~0.5~~ 1.0
3b[a]	HIGH EFFICIENCY HVAC EQUIPMENT 3b: Air-source heat pump with minimum HSPF of ~~8.~~5 9 To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and the minimum equipment efficiency.	1.0
3c[a]	HIGH EFFICIENCY HVAC EQUIPMENT 3c: Closed-loop ground source heat pump; with a minimum COP of 3.3 **or** Open loop water source heat pump with a maximum pumping hydraulic head of 150 feet and minimum COP of 3.6 To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and the minimum equipment efficiency.	~~2.0~~ 1.5
3d[a]	HIGH EFFICIENCY HVAC EQUIPMENT 3d: DUCTLESS SPLIT SYSTEM HEAT PUMPS, ZONAL CONTROL: In homes where the primary space heating system is zonal electric heating, a ductless heat pump system shall be installed and provide heating to ~~at least one~~ the largest zone of the housing unit. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and the minimum equipment efficiency.	~~1.0~~ 1.5
4	HIGH EFFICIENCY HVAC DISTRIBUTION SYSTEM:[a] All heating and cooling system components installed inside the conditioned space. This includes all equipment and distribution system components such as forced air ducts, hydronic piping, hydronic floor heating loop, convectors and radiators. All combustion equipment shall be direct vent or sealed combustion. For forced air ducts: A maximum of 10 linear feet of return ducts and 5 linear feet of supply ducts may be located outside the conditioned space. All metallic ducts located outside the conditioned space must have both transverse and longitudinal joints sealed with mastic. If flex ducts are used, they cannot contain splices. Flex duct connections must be made with nylon straps and installed using a plastic strapping tensioning tool. Ducts located outside the conditioned space must be insulated to a minimum of R-8. Locating system components in conditioned crawl spaces is not permitted under this option. Electric resistance heat and ductless heat pumps is not permitted under this option. Direct combustion heating equipment with AFUE less than 80% is not permitted under this option. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and shall show the location of the heating and cooling equipment and all the ductwork.	~~1.0~~ 0.5
5a	EFFICIENT WATER HEATING 5a: ~~Water heating system shall include one of the following:~~ ~~Gas, propane or oil water heater with a minimum EF of 0.62~~ ~~**or**~~ ~~Electric water heater with a minimum EF of 0.93.~~ ~~**and for both cases**~~ All showerhead and kitchen sink faucets installed in the house shall be rated at 1.75 GPM or less. All other lavatory faucets shall be rated at 1.0 GPM or less.[b] To qualify to claim this credit, the building permit drawings shall ~~specify the option being selected and shall specify the water heater equipment type and the minimum equipment efficiency~~ specify the maximum flow rates for all showerheads, kitchen sink faucets, and other lavatory faucets.	0.5

5b	EFFICIENT WATER HEATING 5b: Water heating system shall include one of the following: Gas, propane or oil water heater with a minimum EF of ~~0.82~~ 0.74 ~~**or**~~ ~~Electric heat pump water heater with a minimum EF of 2.0~~ 1.9 ~~and meeting the standards of NEEA's Northern Climate Specifications for Heat Pump Water Heaters~~ ~~**or**~~ ~~Solar water heating supplementing a minimum standard water heater. Solar water heating will provide a rated minimum savings of 85 therms or 2000 kWh based on the Solar Rating and Certification Corporation (SRCC) Annual Performance of OG-300 Certified Solar Water Heating Systems~~ **or** Water heater heated by ground source heat pump meeting the requirements of Option 3c. For R-2 occupancy a central heat pump water heater with an EF greater than 2.0 that would supply DHW to all the units through a central water loop insulated with R-8 minimum pipe insulation throughout the building. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the water heater equipment type and the minimum equipment efficiency and, for solar water heating systems, the calculation of the minimum energy savings.	~~1.5~~ 1.0
5c	EFFICIENT WATER HEATING 5c: Water heating system shall include one of the following: Gas, propane or oil water heater with a minimum EF of 0.91 **or** Solar water heating supplementing a minimum standard water heater. Solar water heating will provide a rated minimum savings of 85 therms or 2000 kWh based on the Solar Rating and Certification Corporation (SRCC) Annual Performance of OG-300 Certified Solar Water Heating Systems **or** Electric heat pump water heater with a minimum EF of 2.0 and meeting the standards of NEEA's Northern Climate Specifications for Heat Pump Water Heaters To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the water heater equipment type and the minimum equipment efficiency and, for solar water heating systems, the calculation of the minimum energy savings.	1.5
5d	EFFICIENT WATER HEATING 5d: A drain water heat recovery units(s) shall be installed, which captures waste water heat from all the showers, and has a minimum efficiency of 40% if installed for equal flow or a minimum efficiency of 52% if installed for unequal flow. Such units shall be rated in accordance with the CSA B55.1 standard and be so labeled. To qualify to claim this credit, the building permit drawings shall include a plumbing diagram that specifies the drain water heat recovery units and the plumbing layout needed to install it and labels or other documentation shall be provided that demonstrates that the unit complies with the standard.	0.5
6	RENEWABLE ELECTRIC ENERGY: For each 1200 kWh of electrical generation per housing unit provided annually by on-site wind or solar equipment a 0.5 credit shall be allowed, up to 3 credits. Generation shall be calculated as follows: For solar electric systems, the design shall be demonstrated to meet this requirement using the National Renewable Energy Laboratory calculator PVWATTs. Documentation noting solar access shall be included on the plans. For wind generation projects designs shall document annual power generation based on the following factors: The wind turbine power curve; average annual wind speed at the site; frequency distribution of the wind speed at the site and height of the tower. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall show the photovoltaic or wind turbine equipment type, provide documentation of solar and wind access, and include a calculation of the minimum annual energy power production.	0.5

~~**a. Interior Duct Placement.** Ducts included as Option 4 of Table R406.2 shall be placed wholly within the heated envelope of the housing unit. The placement shall be inspected and certified to receive the credits associated with this option.~~

~~**Exception:** Ducts complying with this section may have up to 5% of the total linear feet of ducts located in the exterior cavities or buffer spaces of the dwelling. If this exception is used the ducts will be tested to the following standards:~~

~~Post-construction test: Leakage to outdoors shall be less than or equal to 1 CFM per 100 ft^2 of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the entire system, including the manufacturer's air handler enclosure. All register boots shall be taped or otherwise sealed during the test.~~

a. Projects may only include credit from one space heating option, 3a, 3b, 3c or 3d. When a housing unit has two pieces of equipment,(ie two furnaces) both must meet the standard to receive the credit.

b. Plumbing Fixtures Flow Ratings. Low flow plumbing fixtures (water closets and urinals) and fittings (faucets and showerheads) shall comply with the following requirements:

- Residential bathroom lavatory sink faucets: Maximum flow rate - 3.8 L/min (1.0 gal/min) when tested in accordance with ASME A112.18.1/CSA B125.1.
- Residential kitchen faucets: Maximum flow rate - 6.6 L/min (1.75 gal/min) when tested in accordance with ASME A112.18.1/CSA B125.1.
- Residential showerheads: Maximum flow rate - 6.6 L/min (1.75 gal/min) when tested in accordance with ASME A112.18.1/CSA B125.1.

Purpose of code change:

Incremental Improvements in Energy Efficiency consistent with RCW 19.27a.160.

Change in Scope: Because this code covers multi-family construction and additions as well as single family homes, we have added these applications to Section 406. We do not anticipate other code changes that would improve the efficiency of these applications.

Changes to Table R-406 To provide some context for the code changes to section 406, this section provides some background on the process that went in to developing this solution.

Consider clarifications and implementation changes. To provide clear enforceable code language, several editorial changes have been included. We have also included a code change to option 4 to make it easier to implement. This follows a common practice applied by some production builders.

Add New Efficiency Options: To continue to provide a diverse set of options for implementation, several new options have been added. Option 1d provides credit for triple pane glazing. Option 5d provides credit for a drain water heat recovery system. Option 5c provides credits for condensing water heaters.

Consider the Impact of Federal Standards: Changes to federal equipment standards have two impacts. First, federal equipment is mandatory in all cases, resulting in implementation of these upgrades in the base code. Second, the federal standards impact in incremental improvement of any efficiency upgrades provided in table R406.

> 3a, anticipated federal standards for gas and propane furnaces were rescinded. The base case is lower, and as a result the incremental improvement for this equipment is better. The credit for this measure is changed from .5 to 1.
>
> 3b, new federal standards for heat pumps has changed from 7.8 HSPF to 8.2 HSPF. To adjust for this change, the HAPF required gaining this credit changes from HSPF 8 to HSPF 9.
>
> 5, Federal standards for water heating equipment were adopted and will be implemented in April 2015. This brings up the baseline for all equipment. This requires the elimination of some equipment options and changes in the incremental credits provided for the remaining options.

Calculate Building Energy Use for the base code and section 406 options: The base code changes made in 2012 and by the 2015 IECC additions are first assessed to determine the base energy use of the prototype buildings. This ultimately impacts the credit provided by section 406 options. For example, the changes to duct leakage in 2012 improve the base case efficiency and impact the incremental value of other measures including whole building air leakage credits and ducts indoors credits. Based on this work, the value of each credit is reassess and if needed, reassigned.

Asses the number of credits required to achieve the objectives of RCW 19.27a.160. This proposal is designed to meet the high level goal included in the SBCC 2012 WASHINGTON STATE ENERGY CODE LEGISLATIVE REPORT. This is 64% of the energy use of a home constructed to the 2006 state energy code. This work is reflected in the credits required to comply with code in **Section R406.2.**

Adjust the targets for systems analysis approach, section 405.3. The last step is to assess the performance based approach. New this cycle is am additional adjustment to the target to compensate for the flexibility of the systems approach. The targets for single family homes have been reduced an additional 5 percent. This is a consideration that has been applied to commercial buildings since 2003.

Your amendment must meet one of the following criteria. Select at least one:

- [ ] Addresses a critical life/safety need.
- [X] Addresses a specific state policy or statute. (Note that energy conservation is a state policy)
- [X] Consistency with state or federal regulations.
- [ ] Addresses a unique character of the state.
- [ ] Corrects errors and omissions.

Check the building types that would be impacted by your code change:

- [X] Single family/duplex/townhome
- [X] Multi-family 1 – 3 stories
- [ ] Multi-family 4 + stories
- [ ] Commercial / Retail
- [ ] Institutional
- [ ] Industrial

Your name Chuck Murray

Your organization WA State Dept. of Commerce

Email address chuck.murray@commerce.wa.gov

Phone number 360 725-3113

Other contact name

Instructions: Send this form as an email attachment, along with any other documentation available, to: sbcc@ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

First cost and energy savings
First cost and energy savings estimates have been developed using an estimating procedure used by the Northwest Power and Conservation Council (NPCC). This method uses 4 prototype homes and one multi-family building to assess regional energy impacts. This includes a 1344 sf rambler, a 2200 square foot rambler, a 2866 sf home with half basement and a 5000 sf home with a full basement. For each building both cost and energy savings are estimated for each prototype and each measure.

First Cost: The first cost included in tables XX and XX were developed using multiple sources of information.

NPCC, the Regional Technical Forum (RTF), http://rtf.nwcouncil.org/ This is a federally mandated multi-state compact that develops the efficiency resources for the region's electric utilities.

Navigant is a business consulting firm which provides resource planning for both gas and electric utilities, including gas utilities in Washington State. http://www.navigant.com/industries/energy/

CEE is the Consortium for Energy Efficiency. CEE is the US and Canadian consortium of gas and electric efficiency program administrators. http://www.cee1.org/

This study also uses cost information provided to the SBCC by Ecotope.

Cost are considered for 4 single family and 1 multi-family prototype. The cost of each option is included in **Table XX**

Energy Savings Estimates
The energy savings estimates below have been developed using 4 single family and one multi-family prototype. For each prototype, fuel type, and option, a combination of simulations were run. This results in some **XXXX thousands** of energy simulations.

The resulting savings in table XX provides a weighted average savings for all 4 prototypes. The weighting results on an estimate for approximately 2181 sf.

Table 1. Total Measure Costs by Single Family Prototype, Savings All Climates, All Systems

Option	Description	Points	Costs					Weighted Avarage Savings (2181 SF)		
			Total	Prototypes				kwh/yr	therms/yr	kWh/yr
			($/meas)	1344	2200	2688	5000			(equiv)
1a	Envelope #1	0.5	852	887	563	1543	2347	52	31	962
1b	Envelope #2	1	3570	4649	2487	5036	8912	116	67	2076
1c	Envelope #3	2	6606	8032	4590	8033	13776	203	108	3381
1d	Envelope #4 (window)	0.5	1582	1980	900	1800	4500	49	30	932
2a	Infiltration/vent #1	0.5	496	476	322	564	1960	381	-9	104
2b	Infiltration/vent #2	1	2119	2088	1626	2352	4300	-29	23	657
2c	Infiltration/vent #3	1.5	4210	3186	2647	3493	5950	134	50	1592
3a	HVAC-gas furnace	1	235	230	230	230	460	0	53	1564
3b	HVAC- Heat pump	1	1224	1200	1200	1200	2400	230	0	230
3c	HVAC- GSHP	1.5	11034	10900	10900	10900	17600	-	-	-
3d	HVAC- DHP (zonal)	1.5	2856	2800	2800	2800	5600	2662	0	2662
4a	Interior Ducts	0.5	300	300	300	0	0	36	12	394
5a	DHW- Low Flow	0.5	33	25	50	50	75	52	13	442
5b	DHW- Efficient Gas	1	608	600	600	600	1000	0	27	802
5c (elect)	DHW- HPWH	1.5	1020	1010	1010	1010	1515	1524	0	1524
5c (gas)	DHW- High Efficient Gas	1.5	1200	1200	1200	1200	1200	0	40	1172
5d	DHW- DWHR	0.5	408	400	400	400	800	70	18	597

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

Table 2. Total Measure Costs and Savings, All Climates, Multifamily Units, Electric Zonal

Option	Description	Points	Costs ($/meas)	Savings kWh/yr
1a	Envelope #1	0.5	192	337
1b	Envelope #2	1	1666	727
1c	Envelope #3	2	2121	1183
1d	Envelope #4 (window)	0.5	275	326
2a	Infiltration/vent #1	0.5	296	73
2b	Infiltration/vent #2	1	864	299
2c	Infiltration/vent #3	1.5		
3a	HVAC-gas furnace	1		
3b	HVAC- Heat pump	1		
3c	HVAC- GSHP	1.5		
3d	HVAC- DHP (zonal)	1.5	2200	1211
4a	Interior Ducts	0.5		
5a	DHW- Low Flow	0.5	17	288
5b	DHW- Efficient Gas	1		
5b (elect)	DHW- HPWH	1	714	950
5c (gas)	DHW- High Efficient Gas	1.5		
5d	DHW- DWHR	0.5	204	388

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

Table 3. Measures cost estimates ($/component area, SF or housing unit)

Component	Measure	Size	Cost ($/unit)	Source
Windows				
	U-.32 to U-.28		$0.80/sf	NPCC Standard workbook
	U-.32 to U-.25		$4.50/sf	NPCC Standard workbook
	U-.32 to U-.22		$6.60/sf	NPCC Standard workbook
Walls				
	add R-5 foam		$1.00/sf	RTF RESnew.xls
	add R-12 foam		$1.40/sf	RTF RESnew.xls
Ceilings				
	Adv. Frame (R-49)		$0.90/sf	NPCC Standard workbook
Floor				
	R30-R38		$0.30/sf	NPCC Standard workbook
Slab				
	R-10 Cont.		$0.91/sf	
Basement Wall				
	R-4		$0.70/sf	
	R-12		$1.10/sf	
Infiltration/Ventilation				
	Air Sealing		$0.18/sf	RTF workbook RESWXsf.xls
	Fan		$50	Ecotope, WSEC 2012
	ATAHE (ἠ>.5)		$800	Ecotope, WSEC 2013
	ATAHE (ἠ>.8)		$2.00/sf	Ecotope, WSEC 2014
HVAC				
	Furnace (>.92 AFUE)		$230	Navigant, 2011
	HP (HSPF 9.0+)		$1,200	RTF workbook RESHPSF.xls
	GSHP	2 tons	$10,900	RTF workbook RESGSHP.xls
		3 tons	$12,600	RTF workbook RESGSHP.xls
		5 tons	$17,600	RTF workbook RESGSHP.xls
	DHP		$2,800	Ecotope, WSEC 2012
DHW				
	Low flow		$25	RESShowerheads.xls
	GAS dhw (ef>.74)		$600	CEE,2010
	GAS dhw (ef>.90)		$1,200	CEE,2010
	HPWH		$1,010	RTF ResHPWH.xls
	HPWH (R-2 Central)		$714	BPA, 2011 ET3 RCC report
	DWHR		$400	RTF RESDHWDrainWaste.xls

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$**See Table 3 for square foot Cost** (For residential projects, also provide $See Tables 1 and 2 for per unit cost.)

Show calculations here, and list sources for costs/savings, or attach backup data pages

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

See tables 1 and 2 for KWH/ square foot (or) KBTU/ square foot

(For residential projects, also provide Click here to enter text.KWH/KBTU / dwelling unit)

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application: **This process is consistent with the current code. We do not anticipate additional enforcement cost.**

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # **Table 406.2 Energy Credits**

Brief Description: **Update the efficiency and credits available for options 3a and 3b to reflect new Federal standards and to reflect equivalency in credits between gas/oil/propane furnaces and heat pumps.**

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

TABLE 406.2
ENERGY CREDITS

OPTION	DESCRIPTION	CREDIT(S)
1a	EFFICIENT BUILDING ENVELOPE 1a: Prescriptive compliance is based on Table R402.1.2 with the following modifications: Fenestration U .= 0.28 Floor R-38 Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 5%.	0.5
1b	EFFICIENT BUILDING ENVELOPE 1b: Prescriptive compliance is based on Table R402.1.2 with the following modifications: Fenestration U .= 0.25 Wall R-21 plus R-4 Floor R-38 Basement wall R-21 int plus R-5 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 15%.	1.0
1c	EFFICIENT BUILDING ENVELOPE 1c: Prescriptive compliance is based on Table R402.1.2 with the following modifications: Fenestration U .= 0.22 Ceiling and single-rafter or joist-vaulted R-49 advanced Wood frame wall R-21 int plus R-12 ci Floor R-38 Basement wall R-21 int plus R-12 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 30%.	2.0

2a	AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION 2a: Compliance based on R402.4.1.2: Reduce the tested air leakage to 4.0 air changes per hour maximum **and** All whole house ventilation requirements as determined by Section M1507.3 of the *International Residential Code* shall be met with a high efficiency fan (maximum 0.35 watts/cfm), not interlocked with the furnace fan. Ventilation systems using a furnace including an ECM motor are allowed, provided that they are controlled to operate at low speed in ventilation only mode. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the maximum tested building air leakage and shall show the qualified ventilation system.	0.5
2b	AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION 2b: Compliance based on Section R402.4.1.2: Reduce the tested air leakage to 2.0 air changes per hour maximum **and** All whole house ventilation requirements as determined by Section M1507.3 of the *International Residential Code* shall be met with a heat recovery ventilation system with minimum sensible heat recovery efficiency of 0.70. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the maximum tested building air leakage and shall show the heat recovery ventilation system.	1.0
2c	AIR LEAKAGE CONTROL AND EFFICIENT VENTILATION 2c: Compliance based on Section R402.4.1.2: Reduce the tested air leakage to 1.5 air changes per hour maximum **and** All whole house ventilation requirements as determined by Section M1507.3 of the *International Residential Code* shall be met with a heat recovery ventilation system with minimum sensible heat recovery efficiency of 0.85. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the maximum tested building air leakage and shall show the heat recovery ventilation system.	1.5
3a	HIGH EFFICIENCY HVAC EQUIPMENT 3a: Gas, propane or oil-fired furnace with minimum AFUE of 95%, or gas, propane or oil-fired boiler with minimum AFUE of 92% To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and the minimum equipment efficiency.	~~0.5~~ 1.0
3b	HIGH EFFICIENCY HVAC EQUIPMENT 3b: Air-source heat pump with minimum HSPF of ~~8.5~~ 8.7 To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and the minimum equipment efficiency.	1.0
3c	HIGH EFFICIENCY HVAC EQUIPMENT 3c: Closed-loop ground source heat pump; with a minimum COP of 3.3 **or** Open loop water source heat pump with a maximum pumping hydraulic head of 150 feet and minimum COP of 3.6 To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and the minimum equipment efficiency.	2.0
3d	HIGH EFFICIENCY HVAC EQUIPMENT 3d: DUCTLESS SPLIT SYSTEM HEAT PUMPS, ZONAL CONTROL: In homes where the primary space heating system is zonal electric heating, a ductless heat pump system shall be installed and provide heating to at least one zone of the housing unit. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and the minimum equipment efficiency.	1.0

4	HIGH EFFICIENCY HVAC DISTRIBUTION SYSTEM:[a] All heating and cooling system components installed inside the conditioned space. All combustion equipment shall be direct vent or sealed combustion. Locating system components in conditioned crawl spaces is not permitted under this option. Electric resistance heat is not permitted under this option. Direct combustion heating equipment with AFUE less than 80% is not permitted under this option. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and shall show the location of the heating and cooling equipment and all the ductwork.	1.0
5a	EFFICIENT WATER HEATING 5a: Water heating system shall include one of the following: Gas, propane or oil water heater with a minimum EF of 0.62 **or** Electric water heater with a minimum EF of 0.93. **and for both cases** All showerhead and kitchen sink faucets installed in the house shall be rated at 1.75 GPM or less. All other lavatory faucets shall be rated at 1.0 GPM or less.[b] To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the water heater equipment type and the minimum equipment efficiency and shall specify the maximum flow rates for all showerheads, kitchen sink faucets, and other lavatory faucets.	0.5
5b	EFFICIENT WATER HEATING 5b: Water heating system shall include one of the following: Gas, propane or oil water heater with a minimum EF of 0.82 **or** Solar water heating supplementing a minimum standard water heater. Solar water heating will provide a rated minimum savings of 85 therms or 2000 kWh based on the Solar Rating and Certification Corporation (SRCC) Annual Performance of OG-300 Certified Solar Water Heating Systems **or** Electric heat pump water heater with a minimum EF of 2.0 and meeting the standards of NEEA's Northern Climate Specifications for Heat Pump Water Heaters **or** Water heater heated by ground source heat pump meeting the requirements of Option 3c. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the water heater equipment type and the minimum equipment efficiency and, for solar water heating systems, the calculation of the minimum energy savings.	1.5
6	RENEWABLE ELECTRIC ENERGY: For each 1200 kWh of electrical generation provided annually by on-site wind or solar equipment a 0.5 credit shall be allowed, up to 3 credits. Generation shall be calculated as follows: For solar electric systems, the design shall be demonstrated to meet this requirement using the National Renewable Energy Laboratory calculator PVWATTs. Documentation noting solar access shall be included on the plans. For wind generation projects designs shall document annual power generation based on the following factors: The wind turbine power curve; average annual wind speed at the site; frequency distribution of the wind speed at the site and height of the tower. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall show the photovoltaic or wind turbine equipment type, provide documentation of solar and wind access, and include a calculation of the minimum annual energy power production.	0.5

Purpose of code change: **The Federal standard for residential gas and fuel oil furnaces and boilers is 80% AFUE. However, condensing equipment with 90% AFUE and higher is widely available and has become "standard practice" at least in the new construction market. On June 27, 2011, amended Federal standards were issued for residential central air conditioners and heat pumps. As a result, central air conditioning heat pumps manufactured on or after January 1, 2015 will have Heating Seasonal Performance Factors not less than 8.2. Using 90% AFUE and 8.2 HSPF as the baseline cases, this recommendation is to provide a credit of 1.0 for both a 95% AFUE furnace and an 8.7 HSPF heat pump. These efficiency are both approximately 6% better than the proposed baselines and should be treated as equivalent.**

Your amendment must meet one of the following criteria. Select at least one:

- [ ] Addresses a critical life/safety need.
- [ ] Consistency with state or federal regulations.
- [ ] Addresses a specific state policy or statute. (Note that energy conservation is a state policy)
- [x] Addresses a unique character of the state.
- [ ] Corrects errors and omissions.

Check the building types that would be impacted by your code change:

- [x] Single family/duplex/townhome
- [ ] Multi-family 4 + stories
- [ ] Institutional
- [ ] Multi-family 1 – 3 stories
- [ ] Commercial / Retail
- [ ] Industrial

Your name Gary Heikkinen, PE

Email address gary.heikkinen@nwnatural.com

Your organization NW Natural

Phone number 503-721-2471

Other contact name 38T

Instructions: Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

Improved efficiencies will lead to additional energy savings and reduced energy bills for customers.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$38T/square foot (For residential projects, also provide $38T/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

This proposal does not change the required efficiency of a furnace, so does not incrementally impact construction cost for furnaces. The efficiency for the heat pump option is simply updating the required HSPF based on a new federal standard minimum efficiency. I do not believe there will be an incremental impact on construction cost for this option either.

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

38TKWH/ square foot (or) 38TKBTU/ square foot

(For residential projects, also provide 38TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

Using a heating energy requirement of 50,000,000 annual Btu would result in savings of $30/year for both the 8.7 HSPF heat pump and the 95% AFUE furnace. The calculating used the following electricity and natural gas prices.

EIA Average Retail Residential Electricity price for Nov. 2014 was $.0866/kwh
EIA Average Retail Residential Natural Gas price for Nov. 2014 was $10.42/1000 cu. ft. or approximately $1.01/therm.

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application: **No additional plan review or inspection time anticipated.**

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R406.2

Brief Description: This proposal adds three changes to the current language for Option 4 in R406.2. The first change is adding hydronic type heating components to the option and the second adds a limited amount of ducts to be outside the conditioned space and still qualify for the credit. The final change is deletion of footnote a as it is replaced by the proposed language.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

4	HIGH EFFICIENCY HVAC DISTRIBUTION SYSTEM:[a] All heating and cooling system components installed inside the conditioned space. This includes all equipment and distribution system components such as forced air ducts, hydronic piping, hydronic floor heating loop, convectors and radiators. All combustion equipment shall be direct vent or sealed combustion. For forced air ducts: A maximum of 10 linear feet of return ducts and 5 linear feet of supply ducts may be located outside the conditioned space. All metallic ducts located outside the conditioned space must have both transverse and longitudinal joints sealed with mastic. If flex ducts are used, they cannot contain splices. Flex duct connections must be made with nylon straps and installed using a plastic strapping tensioning tool. Ducts located outside the conditioned space must be insulated to a minimum of R-8. Locating system components in conditioned crawl spaces is not permitted under this option. Electric resistance heat is not permitted under this option. Direct combustion heating equipment with AFUE less than 80% is not permitted under this option. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and shall show the location of the heating and cooling equipment and all the ductwork.	1.0

Purpose of code change:

This proposal provides some flexibility when installing mechanical equipment and ducts inside the conditioned space. In many cases it is difficult to get all ductwork inside the conditioned space. For example, a short duct run may be necessary in an attic space to connect a return grill to the furnace. This run is typically less than 10 feet in length. This amendment allows installation flexibility for builders and HVAC installers to obtain the credit for High Efficiency HVAC Distribution System. In addition, duct testing would not be required. The allowance of a small amount of ductwork in an unconditioned space will broaden the use of this option increasing energy savings throughout the state. Adding this language would make the allowance in footnote “a” unnecessary which, to my knowledge, is not used.

Your amendment must meet one of the following criteria. Select at least one:

- ☐ Addresses a critical life/safety need.
- ☒ Addresses a specific state policy or statute. (Note that energy conservation is a state policy)
- ☐ Consistency with state or federal regulations.
- ☐ Addresses a unique character of the state.
- ☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

- ☒ Single family/duplex/townhome
- ☒ Multi-family 1 – 3 stories
- ☐ Multi-family 4 + stories
- ☐ Commercial / Retail
- ☐ Institutional
- ☐ Industrial

Your name Gary Nordeen

Your organization WSU Energy Program

Other contact name 38T

Email address nordeeng@energy.wsu.edu

Phone number (360) 956-2040

Instructions: Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

This proposal adds the allowance to claim 1 credit for hydronic heating systems with all components inside the conditioned space. Without this allowance, an additional credit must be chosen and installed to meet the WSEC requirements.

This change also allows a small percentage of ductwork to be located outside of the conditioned space while still qualifying for the credit and does not have to have a duct leakage test.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$38T/square foot (For residential projects, also provide $38T/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

38T

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

38TKWH/ square foot (or) 38TKBTU/ square foot

(For residential projects, also provide 38TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

38T

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

There is no additional time for plan review or inspection time associated with this proposal.

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STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R406.2 footnote a

Brief Description: This proposal eliminates 406.2 footnote a as the amount of ductwork allowed to be located outside the conditioned space is addressed in the proposed code change to 406.2 (4)

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

Purpose of code change:

~~a. Interior Duct Placement. Ducts included as Option 4 of Table R406.2 shall be placed wholly within the heated envelope of the housing unit. The placement shall be inspected and certified to receive the credits associated with this option.~~
~~Exception: Ducts complying with this section may have up to 5% of the total linear feet of ducts located in the exterior cavities or buffer spaces of the dwelling. If this exception is used the ducts will be tested to the following standards: Post-construction test: Leakage to outdoors shall be less than or equal to 1 CFM per 100 ft2 of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the entire system, including the manufacturer's air handler enclosure. All register boots shall be taped or otherwise sealed during the test.~~
~~B~~a.. Plumbing Fixtures Flow Ratings. Low flow plumbing fixtures (water closets and urinals) and fittings (faucets and showerheads) shall comply with the following requirements:
1. Residential bathroom lavatory sink faucets: Maximum flow rate - 3.8 L/min (1.0 gal/min) when tested in accordance with ASME A112.18.1/CSA B125.1.
2. Residential kitchen faucets: Maximum flow rate - 6.6 L/min (1.75 gal/min) when tested in accordance with ASME A112.18.1/CSA B125.1.
3. Residential showerheads: Maximum flow rate - 6.6 L/min (1.75 gal/min) when tested in accordance with ASME A112.18.1/CSA B125.1.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

☒ Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Consistency with state or federal regulations.

☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

☒ Single family/duplex/townhome ☒ Multi-family 1 – 3 stories ☐ Multi-family 4 + stories

☐ Commercial / Retail ☐ Institutional ☐ Industrial

Your name	Gary Nordeen	Email address	nordeeng@energy.wsu.edu
Your organization	WSU Energy Program	Phone number	(360) 956-2040
Other contact name	38T		

Instructions: Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

This proposal is coupled with the proposal to R406.2 allowing a small amount of ductwork to be outside the conditioned space and still be eligible to claim the credit.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$38T/square foot (For residential projects, also provide $200.00/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

This proposal would not require a duct leakage test if the criteria is met. A duct leakage test is about $200.00 per dwelling unit.

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

38TKWH/ square foot (or) 38TKBTU/ square foot

(For residential projects, also provide 38TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

38T

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

Giving contractors a specific length of ductwork allowed outside the conditioned space rather than calculating a percentage of ductwork will lessen plan review and inspection time.

Estimated time savings is 2 hours (plan review and inspection combined)

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Energy Code Proposal Short Form

For editorial **<u>Coordination, Clarifications & Corrections</u>** only, without substantive energy or cost impacts

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # Table 406.2

Brief Description: This proposal clarifies that the fenestration U-factor cited is for vertical fenestration and not skylights.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use <u>underline</u> for new text and ~~strikeout~~ for text to be deleted.)

TABLE 406.2
ENERGY CREDITS

OPTION	DESCRIPTION	CREDIT(S)
1a	EFFICIENT BUILDING ENVELOPE 1a: Prescriptive compliance is based on Table R402.1.2 with the following modifications: <u>Vertical</u> Fenestration U .= 0.28 Floor R-38 Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 5%.	0.5
1b	EFFICIENT BUILDING ENVELOPE 1b: Prescriptive compliance is based on Table R402.1.2 with the following modifications: <u>Vertical</u> Fenestration U .= 0.25 Wall R-21 plus R-4 Floor R-38 Basement wall R-21 int plus R-5 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 15%.	1.0
1c	EFFICIENT BUILDING ENVELOPE 1c: Prescriptive compliance is based on Table R402.1.2 with the following modifications: <u>Vertical</u> Fenestration U .= 0.22 Ceiling and single-rafter or joist-vaulted R-49 advanced Wood frame wall R-21 int plus R-12 ci Floor R-38 Basement wall R-21 int plus R-12 ci Slab on grade R-10 perimeter and under entire slab Below grade slab R-10 perimeter and under entire slab **or** Compliance based on Section R402.1.4: Reduce the Total UA by 30%.	2.0

Purpose of code change:

This proposal clarifies the intent of the code by citing the word “vertical”. The U-factors in Options 1a, 1b, and 1c are intended for vertical windows not skylights.

Your name	Gary Nordeen	Email address	nordeeng@energy.wsu.edu
Your organization	WSU Energy Program	Phone number	(360) 956-2040
Other contact name	38T		

Instructions: For use with Coordination, Clarifications & Corrections **ONLY**. Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280.

Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.

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Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # ____Table 406.2 ENERGY CREDITS______________

Brief Description: HIGH EFFICIENCY HVAC DISTRIBUTION SYSTEM: 4b

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

HIGH EFFICIENCY HVAC DISTRIBUTION SYSTEM: 4b

In centrally distributed, ducted HVAC systems, provide a minimum of 2 HVAC distribution *zones*, with a minimum of 1 zone per conditioned *story*, and a minimum of one zone for each 1,500 square feet of conditioned space. Bypass ducts that deliver supply air to the return system shall not be used. Each zone must be controlled by a central programmable thermostat that can control the conditioning equipment and maintain preset temperatures for varying time periods in each zone independent of the other. To qualify to claim this credit, the building permit drawings shall specify the option being selected and shall specify the heating equipment type and number of zones.

Credits (1)

~~(DEBIT~~

Purpose of code change

As growth restrictions limit available land in this state, an ever increasing number of 3-story homes are being constructed. These homes, when constructed in accordance with Washington State requirements for furnace sizing and without bypass ducts, would have a substantial efficiency benefit from zonal temperature control. Option 4b provides an alternative to other systems that may not be feasible because of cost or design, and can easily integrate into other options available for credit.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

☒ Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Consistency with state or federal regulations.

☒ Addresses a unique character of the state.

☐ Corrects errors and omissions.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

Check the building types that would be impacted by your code change:

☒ Single family/duplex/townhome	☐ Multi-family 4 + stories	☐ Institutional
☒ Multi-family 1 – 3 stories	☐ Commercial / Retail	☐ Industrial

Your name	Jeff Peterson	Email address	Jeff@mncustom.com
Your organization	Click here to enter text.	Phone number	425.829.6039
Other contact name	Click here to enter text.		

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Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

Zoning improves comfort and reduces overheating and overcooling homes with 3 stories of conditioned space. If constructed without a bypass duct, zoning increases efficiency of these systems significantly. On larger homes, which may normally be zoned, elimination of the bypass duct will increase efficiency.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$450 + an additional $200/1500 SF per dwelling unit) when selected, variable on configuration.

Show calculations here, and list sources for costs/savings, or attach backup data pages

($90/damper + $60/ducting & RA Grill)x2 + 3 hours of additional labor at $50/hour.

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

See attached report, Residential Zoned Ducted HVAC Systems, addressing various savings based on configuration.

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

See attached report, Residential Zoned Ducted HVAC Systems, addressing various savings based on configuration.

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

Plan approval – checklist item – nominal.

Verification of bypass damper elimination and number of dampers in system during HVAC field inspection – 5-minutes.

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

STATE OF WASHINGTON

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2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: X Commercial Provisions X Residential Provisions
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Code Section # Table R 406.2 Extra Measures

Brief Description: Option 1b, edit to make it consistent with 1a.

Mathematically matching the net Differences between 1a at .5 points and 5% under the code to 1b at 1.0 points and 15% under the code is not consistent.

Proposed code change text:

Proposed Option #1. Leave it as is at 1.0 points but lower the threshold to 10% under the code. This would allow this to be used, and would save more Energy.

Proposed Option #2. Leave the Text as is, but give 2.0 points if you can Achieve 15% under the code.

Even though you have the carrot out there of getting 2.0 points, this option would not be utilized very much as getting 15% under our current code is very difficult on any building single family to high rises, if not impossible or costly impossible. Option #1, would get it in use and save energy as it is achievable.

Your amendment must meet one of the following criteria. Select at least one:

Addresses a critical life/safety need.

X Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

X Consistency with state or federal regulations.   X Corrects errors and omissions.

X Addresses a unique character of the state.

Check the building types that would be impacted by your code change:

X Single family/duplex/townhome	Multi-family 4 + stories	Institutional
X Multi-family 1 – 3 stories	Commercial / Retail	Industrial

Your name	Patrick C. Hayes	Email address	patrickchayes1@msn.com
Your organization	Energy Consultant	Phone number	206.819.7684

Other contact name Click here to enter text.

<u>Instructions</u>: Send this form as an email attachment, along with any other documentation available, to: sbcc@ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **<u>Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.</u>**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$Click here to enter text./square foot (For residential projects, also provide $Click here to enter text./ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

Click here to enter text.KWH/ square foot (or) Click here to enter text.KBTU/ square foot

(For residential projects, also provide Click here to enter text.KWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

2015 Washington State Energy Code Development

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Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R407

Brief Description: This proposal eliminates Section R407 in its entirety.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

~~**SECTION R407**~~
~~**ENERGY RATING INDEX COMPLIANCE ALTERNATIVE**~~

~~**R407.1 Scope.** This section establishes criteria for compliance using an Energy Rating Index (ERI) analysis.~~

~~**R407.2 Mandatory requirements.** Compliance with this section requires that the mandatory provisions identified in Section R401 through R404 labeled as "Mandatory" and Section R403.5.3 be met. The building thermal envelope shall be greater than or equal to levels of efficiency and Solar Heat Gain Coefficient in Table 402.1.1 or 402.1.3 of the 2009 *International Energy Conservation Code*.~~

~~**Exception:** Supply and return ducts not completely inside the building thermal envelope shall be insulated to a minimum of R-6.~~

~~**R407.3 Energy Rating Index.** The Energy Rating Index (ERI) shall be a numerical integer value that is based on a linear scale constructed such that the *ERI reference design* has an Index value of 100 and a *residential building* that uses no net purchased energy has an Index value of 0. Each integer value on the scale shall represent a one percent (1%) change in the total energy use of the rated design relative to the total energy use of the *ERI reference design*. The ERI shall consider all energy used in the *residential building*.~~

~~**R407.3.1 ERI reference design.** The *ERI reference design* shall be configured such that is it meets the minimum requirements of the 2006 *International Energy Conservation Code* prescriptive requirements.~~

~~The proposed *residential building* shall be shown to have an annual total normalized modified loads that are less than or equal to the annual total loads of the *ERI reference design*.~~

~~**R407.4 ERI based compliance.** Compliance based on an ERI analysis requires that the *rated design* be shown to have an ERI less than or equal to the appropriate value listed in Table R407.4, when compared to the *ERI reference design*.~~

~~**TABLE R407.4**~~
~~**MAXIMUM ENERGY RATING INDEX**~~

~~Climate Zone~~	~~Energy Rating Index~~
~~4~~	~~54~~
~~5~~	~~55~~

~~**R407.5 Verification by approved agency.** Verification of compliance with Section R407 shall be completed by an *approved* third party.~~

~~**R407.6 Documentation.** Documentation of the software used to determine the energy rating index and the parameters for the residential building shall be in accordance with Sections R407.6.1 through R407.6.3.~~

~~**R407.6.1 Compliance software tools.** Documentation verifying that the methods and accuracy of the compliance software tools conform to the provisions of this section shall be provided to the *code official*.~~

R407.6.2 Compliance report. Compliance software tools shall generate a report that documents that the energy rating index of the *rated design* complies with Sections R407.3 and R407.4. The compliance documentation shall include the following information:

1. Address or other identification of the residential building.
2. An inspection checklist documenting the building component characteristics of the *rated design*. The inspection checklist shall show results for both the *ERI reference design* and the *rated design*, and shall document all inputs entered by the user necessary to reproduce the results.
3. Name of individual completing the compliance report.
4. Name and version of the compliance software tool.

Exception: Multiple orientations. When an otherwise identical building model is offered in multiple orientations, compliance for any orientation shall be permitted by documenting that the building meets the performance requirements in each of the four cardinal (north, east, south and west) orientations.

R407.6.3 Additional documentation. The *code official* shall be permitted to require the following documents:

1. Documentation of the building component characteristics of the *ERI reference design.*
2. A certification signed by the builder providing the building component characteristics of the *rated design.*
3. Documentation of the actual values used in the software calculations for the *rated design.*

R407.7 Calculation software tools. Calculation software, where used, shall be in accordance with Sections R407.7.1through R407.7.3.

R407.7.1 Minimum capabilities. Calculation procedures used to comply with this section shall be software tools capable of calculating the energy rating index as described in Section R407.3, and shall include the following capabilities:

1. Computer generation of the *ERI reference design* using only the input for the *rated design.* The calculation procedure shall not allow the user to directly modify the building component characteristics of the *ERI reference design.*
2. Calculation of whole-building, as a single *zone,* sizing for the heating and cooling equipment in the *ERI reference design* residence in accordance with Section R403.7.
3. Calculations that account for the effects of indoor and outdoor temperatures and part-load ratios on the performance of heating, ventilating and air-conditioning equipment based on climate and equipment sizing.
4. Printed *code official* inspection checklist listing each of the *rated design* component characteristics determined by the analysis to provide compliance, along with their respective performance ratings.

R407.7.2 Specific approval. Performance analysis tools meeting the applicable sections of Section R407 shall be *approved.* Tools are permitted to be *approved* based on meeting a specified threshold for a jurisdiction. The *code official* shall approve tools for a specified application or limited scope.

R407.7.3 Input values. When calculations require input values not specified by Sections R402, R403, R404 and R405, those input values shall be taken from an *approved* source.

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Purpose of code change: This proposal eliminates Section R407 because of a number of concerns including: No minimum qualifications for the modeler, no cited quality assurance method, adds an additional compliance path (that would make 5) which adds confusion, no training in place for teaching code enforcement personnel about how the model works and what has to be inspected in the field, and the use of appliances to achieve code compliance.

Your amendment must meet one of the following criteria. Select at least one:

- ☐ Addresses a critical life/safety need.
- ☒ Addresses a specific state policy or statute. (Note that energy conservation is a state policy)
- ☐ Consistency with state or federal regulations.
- ☐ Addresses a unique character of the state.
- ☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

- ☒ Single family/duplex/townhome
- ☒ Multi-family 1 – 3 stories
- ☐ Multi-family 4 + stories
- ☐ Commercial / Retail
- ☐ Institutional
- ☐ Industrial

Your name Gary Nordeen

Email address nordeeng@energy.wsu.edu

Your organization WSU Energy Program

Phone number (360) 956-2040

Other contact name 39T

Instructions: Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

There are no positive or negative economic impacts associated with this proposal.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$39T/square foot (For residential projects, also provide $39T/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

39TKWH/ square foot (or) 39TKBTU/ square foot

(For residential projects, also provide 39TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

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2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R502

Brief Description: Allow trading off a deficiency in an addition by compensating for it by upgrading an element of the existing structure.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

SECTION R502
ADDITIONS

R502.1 General. Additions to an existing building, building system or portion thereof shall conform to the provisions of this code as those provisions relate to new construction without requiring the unaltered portion of the existing building or building system to comply with this code. Additions shall not create an unsafe or hazardous condition or overload existing building systems. An addition shall be deemed to comply with this code where the addition alone complies, where the existing building and addition comply with this code as a single building, or where the building with the addition uses no more energy than the existing building. Additions shall be in accordance with Section R502.1.1 or R502.1.2.

R502.1.1 Additions. An addition shall be deemed to comply with this code if the addition alone complies, if the existing building and addition comply as a single building, or if the building with the addition uses no more energy than the existing building. Additions shall be in accordance with Section 406.4.1.1 or Section 406.4.1.2.

Exception: Additions which do not fully comply with the requirements of this Code and which have a floor area which is less than seven hundred fifty square feet shall be approved provided that improvements are made to the existing occupancy to compensate for any deficiencies in the new addition. Compliance shall be demonstrated by UA Alternative calculations. Target UA shall be the addition meeting minimum code requirements. Proposed UA shall be the proposed addition plus the existing home with proposed upgrades. The proposed UA must be equal to or less than the target UA.

Purpose of code change: This code change would allow flexibility to builders to compensate for an energy deficient aspect of the addition if it is compensated for in the existing house. This results in no overall energy efficiency loss to the structure.

Your amendment must meet one of the following criteria. Select at least one:

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

☐ Addresses a critical life/safety need.

☒ Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Consistency with state or federal regulations.

☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

☒ Single family/duplex/townhome

☒ Multi-family 1 – 3 stories

☐ Multi-family 4 + stories

☐ Commercial / Retail

☐ Institutional

☐ Industrial

Your name	Gary Nordeen	Email address	nordeeng@energy.wsu.edu
Your organization	WSU Energy Program	Phone number	(360) 956-2040
Other contact name	39T		

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Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

There are no positive or negative economic impacts from this proposal.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$39T/square foot (For residential projects, also provide $39T/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

39TKWH/ square foot (or) 39TKBTU/ square foot

(For residential projects, also provide 39TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application: Additional ½ hour plan review and inspection time required.

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # R502

Brief Description: Allow trading off an energy deficeincy in a space undergoing a change of use by compensating for it by upgrading an element of the existing structure.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

SECTION R505
CHANGE OF OCCUPANCY OR USE

R505.1 ~~R101.4.4~~ Change in occupancy or use. Any space not within the scope of Section R101.2 which is converted to space that is within the scope of Section R101.2 shall be brought into full compliance with this code.

Exception: Spaces undergoing a change of use which do not fully comply with the requirements of this Code and which have a floor area which is less than seven hundred fifty square feet shall be approved provided that improvements are made to the existing occupancy to compensate for any deficiencies in the altered space. Compliance shall be demonstrated by UA Alternative calculations. Target UA shall be the altered space meeting minimum code requirements. Proposed UA shall be the proposed altered space plus the existing home with proposed upgrades. The proposed UA must be equal to or less than the target UA.

Purpose of code change: This code change would allow flexibility to builders to compensate for an energy deficient aspect of the addition if it is compensated for in the existing house. This results in no overall energy efficiency loss to the structure.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

☒ Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Consistency with state or federal regulations.

☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

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☒ Single family/duplex/townhome ☐ Multi-family 4 + stories ☐ Institutional

☒ Multi-family 1 – 3 stories ☐ Commercial / Retail ☐ Industrial

Your name	Gary Nordeen	Email address	nordeeng@energy.wsu.edu
Your organization	WSU Energy Program	Phone number	(360) 956-2040
Other contact name	39T		

Instructions: Send this form as an email attachment, along with any other documentation available, to: www.sbcc.ga.wa.gov. For further information, call the State Building Code Council at 360-407-9280. **Deadline for all 2015 code change proposals is March 1, 2015 at 11:59 PM.**

Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

There are no positive or negative economic impacts from this proposal.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$39T/square foot (For residential projects, also provide $39T/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

39TKWH/ square foot (or) 39TKBTU/ square foot

(For residential projects, also provide 39TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application: Additional ½ hour plan review and inspection time required.

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

STATE OF WASHINGTON

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2015 Washington State Energy Code Development

Standard Energy Code Proposal Form

Code being amended: ☐ Commercial Provisions ☒ Residential Provisions
(A MS Word version of the code is linked to the name)

Code Section # ~~R403.3.3~~ Chapter 6

Brief Description: This proposal aligns Reference Standard 33 with other code change proposals and makes some minor editorial changes.

Proposed code change text: (Copy the existing text from the Integrated Draft, linked above, and then use underline for new text and ~~strikeout~~ for text to be deleted.)

WSU

Washington State University Energy Extension Program
905 Plum Street SE, Bldg 3
PO Box 43165
Olympia, WA 98506-3166

Standard reference number	Title	Referenced in code section number
WSU RS 33	Duct Testing Standard for New and Existing Construction Publication No. ~~WSUEEP12~~WSUEEP15-016..	~~R403.2.2~~R403.3.3

For reference and review:

Duct Testing Standard (RS-33)

For New and Existing Construction

New Construction

Based on the protocol for "Total Leakage Testing," or "Leakage Testing to Outdoors" duct leakage in new construction shall not exceed 0.04 CFM_{25} x floor area (in square feet) served by the system for leakage to outdoors or for total leakage when tested post construction. When testing at rough-in, targets should not exceed 0.04 CFM_{25} x floor area (in square feet) for total leakage or 0.03 CFM_{25} x floor area (in square feet) if the air handler is not installed.

Exception:

1. The total leakage or leakage to outdoors test is not required for ducts and air handlers located ~~entirely~~ within the building thermal envelope. Ducts located in vented or conditioned crawl spaces do not qualify for this exception.
2. A maximum of 10 linear feet of return ducts and 5 linear feet of supply ducts are allowed to be located outside of the building thermal envelope.

Existing Construction

When a space-conditioning system is altered by the installation or replacement of space-conditioning equipment (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, cooling or heating coil, or the furnace heat exchanger), the duct system that is connected to the new or replacement space-conditioning equipment shall be tested. The test results shall be provided to the building official and the homeowner.

Exception 1: Duct systems that are documented to have been previously sealed as confirmed through field verification and diagnostic testing in accordance with procedures in RS-33.

Exception 2: Ducts with less than 40 linear feet in unconditioned spaces.

Exception 3: Existing duct systems constructed, insulated or sealed with asbestos.

Exception 4: Additions of less than 750 square feet of conditioned floor area.

In addition, the following requirements must be met:

1. All testing must be done by a qualified technician. The minimum qualification requirement is documented attendance at a duct testing training course approved by the building official. The following existing training programs are recognized as equivalent to this requirement:
   a. Northwest ENERGY STAR Homes Program, Performance Testing training for new construction.
   b. Performance Tested Comfort Systems (PTCS) training for existing homes and new construction.
2. Where required by the code official, testing shall be conducted by an approved third party.
3. Duct systems must be designed, sized, and installed using recognized industry standards and International Residential Code (IRC) requirements, so that calculated heating and/or cooling loads are delivered to each zone.

Total Duct Leakage Test

Testing Procedure Application:
This test is appropriate in new construction when ducts are to be tested at the rough-in stage before the house envelope is intact and can also be done post construction. The test measures the total collected leaks in the system at an induced pressure of 25 Pascals (PA). Compared to the leakage to exterior test, the total leakage test is simpler, but does not discriminate between leakage to inside and outside the heated space; as such, this test is not recommended for homes with complete house envelopes and HVAC systems. In such cases, the leakage to outside test is recommended.

Standard:
1) For certification, the measured duct leakage must not exceed ***0.04 CFM_{25} x floor area*** (in square feet) served by the system at rough-in **when the air handler is installed.**

2) The measured duct leakage at rough-in must not exceed ***0.03 CFM_{25} x floor area*** (in square feet) served by the system **when the air handler is <u>not</u> installed.**

3) If testing post construction, the total leakage must not exceed ***0.04 CFM_{25} x floor area*** (in square feet) served by the system.

***Example* -** For a 2240 $Ft.^2$ home:

- Total leakage target 2240 X .04 = 90 CFM
- Leakage to exterior target 2240 X .04 = 90 CFM

Tools and Equipment:

- Duct testing device
- Manometer
- Tape and paper or duct mask to seal registers

Setup:

- Ensure air handler does not operate during test.
- Remove air filters from the air handler.
- Open all duct dampers (Note setting and return after testing).
- Attach the duct testing device to the air handler cabinet (preferred location), **or**:
  - o Attach the duct testing device to the return register closest to the air handler.
- Place the duct pressure tap in the supply register closest to the air handler, **or**
  - o Place the duct tap in the supply plenum.
- Seal all the duct system supply and return registers with tape, paper, or mask.
- If the duct testing equipment is not located outside of conditioned space, open an exterior door or window to insure all spaces exterior to the ducts are at outside pressure.
- Install a flow ring which you think best matches the needed capacity of the fan and will provide a duct system pressure of over 25 Pa (see duct testing equipment manual).

Test:

1. With the duct testing device, **pressurize** the ducts to **+25 Pascals with respect to (WRT) outside** (see Figure 1).

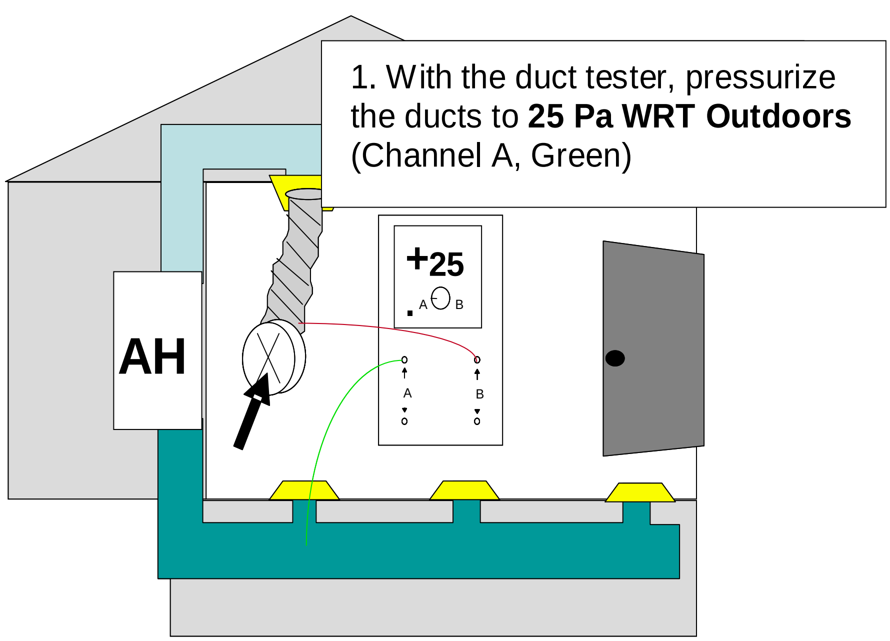


Figure 1: Pressurizing the duct system

2. Determine the duct leakage (with simple manometers, the fan pressure (Pa) is converted to CFM_{25} using a flow table. Many digital manometers sold with duct testing equipment can automatically perform this conversion, and display CFM_{25} directly.) Consult your duct testing equipment manual (see Figure 2).

- **Note**: You may need to adjust the ring size of the duct testing device (see duct testing equipment manual).

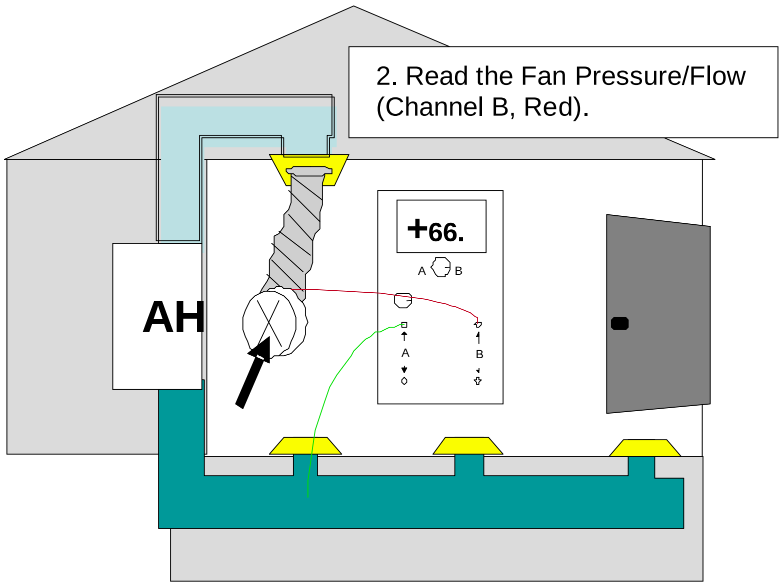


Figure 2: Determining duct leakage

Duct Leakage Testing to Outdoors ~~the Exterior Test~~

Testing Procedure Application:
In new construction, doors and windows must be installed and the building envelope capable of maintaining +25 Pascals WRT outside pressure with the operation of a blower door. By pressurizing the interior of the home with a blower door while using a duct testing device, duct leakage to the interior is eliminated from the measurement. The test is designed to measure the CFM_{25} value for leakage in the duct system to outside of the conditioned space.

Standard: The measured duct leakage must not exceed ***0.04 CFM_{25} x floor area*** (in square feet) served by the system.

Tools and Equipment:

- Blower Door
- Duct testing device.
- Manometer (a second manometer is helpful, but not required)
- Tape and paper or duct mask to seal registers.

Setup:
Example 1. Duct testing device is hooked up at ***largest return register***. The duct testing equipment is ***inside the pressurized zone*** of the house when the blower door is turned on.

- Prepare house for a standard blower door test.
- Set up **blower door** and set to pressurize the house.
- Set up the **duct testing device** as in a total leakage test except ***all exterior doors and windows must be closed.***

Test:

1. Using the **blower door**, pressurize the interior to **+25 PA WRT outdoors** (see Figure 3).

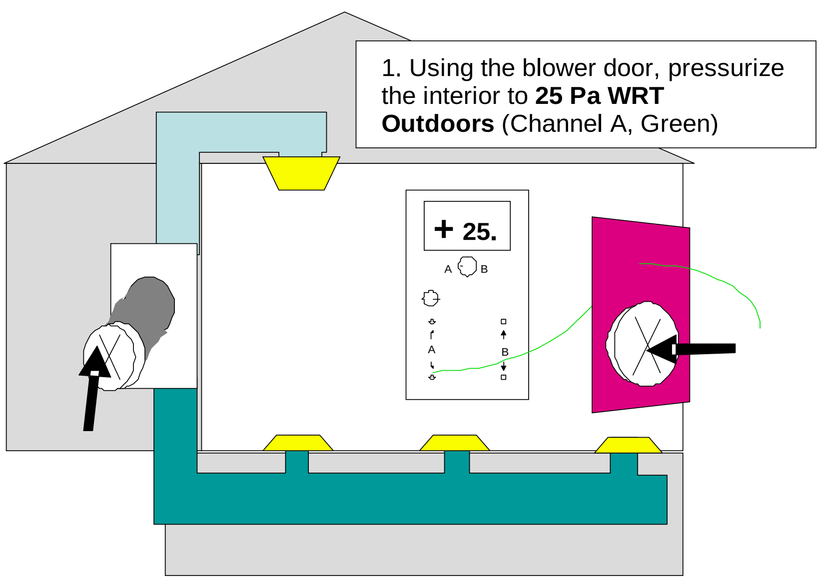
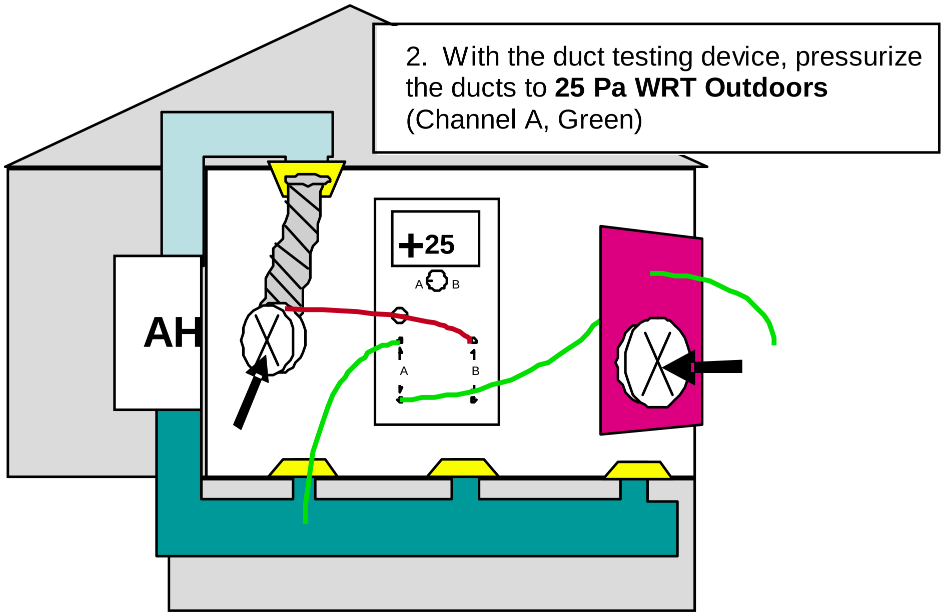


Figure 3: Pressurizing interior to +25 PA WRT outdoors.

2. With the duct testing device, pressurize the ducts to **+ 25 PA WRT outdoors, or**
    - o With the duct testing device, pressurize the ducts to **0 PA WRT interior** (see Figure 4).



or

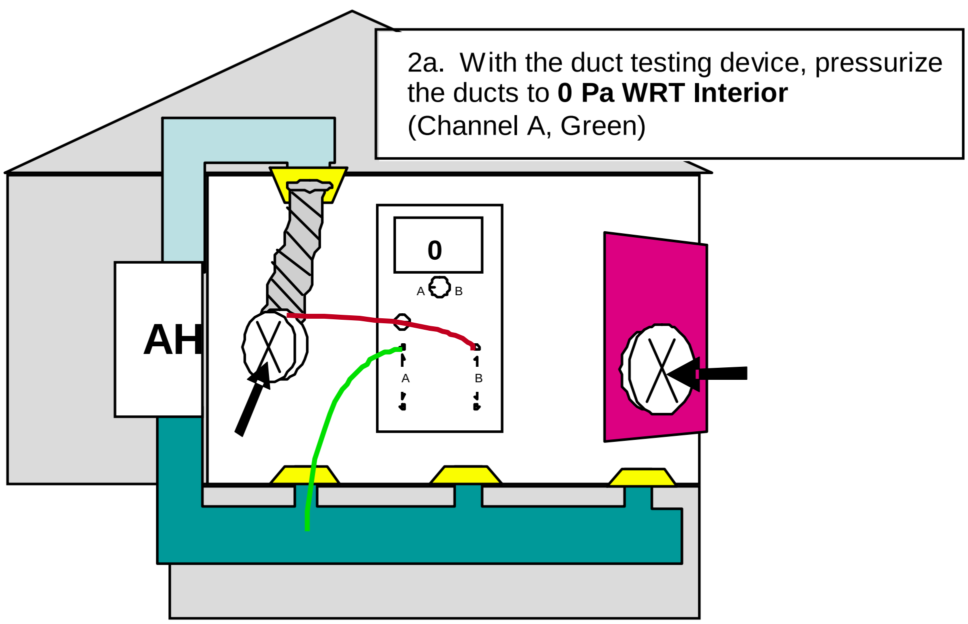


Figure 4: Pressurizing ducts to +25 PA WRT outdoors, or 0 PA WRT Indoors. (Duct testing device hooked up to largest return duct, inside the pressurized zone of the house).

3. Check the blower door reading to assure it is still at +25PA.
4. Determine the duct leakage (with simple manometers, the fan pressure (Pa) is converted to CFM25 using a flow table. Many digital manometers sold with duct testing equipment can automatically perform this conversion, and display CFM25 directly.) Consult your duct testing equipment manual (see Figure 5).
   - **Note**: You may need to adjust the ring size of the duct testing device (see duct testing equipment manual).

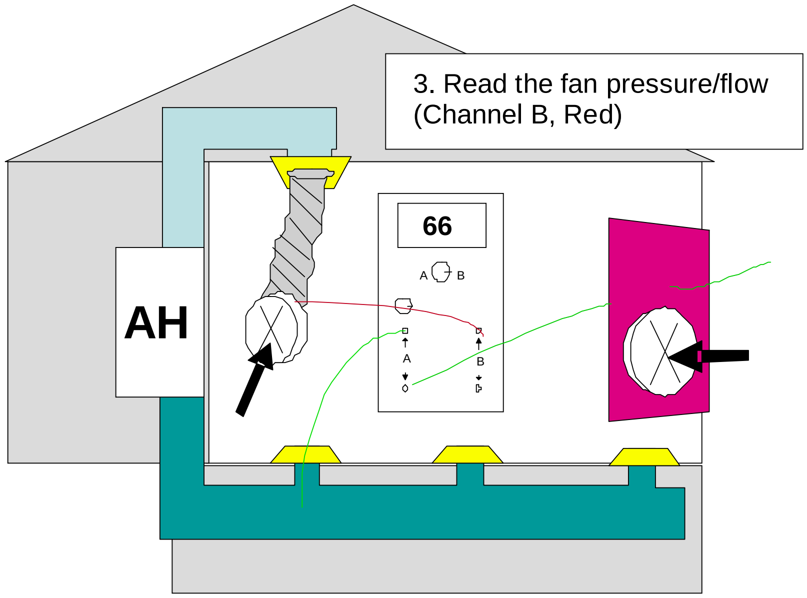


Figure 5: Determining duct leakage.

Example 2. Duct testing device is hooked up at ***air handler***. Depending on the location of the air handler, the duct testing device may be either *inside or outside* the pressurized zone of the house. (Air handler is "Outside" in Figures 6, 7, 8). Follow the same steps as in Example 1.

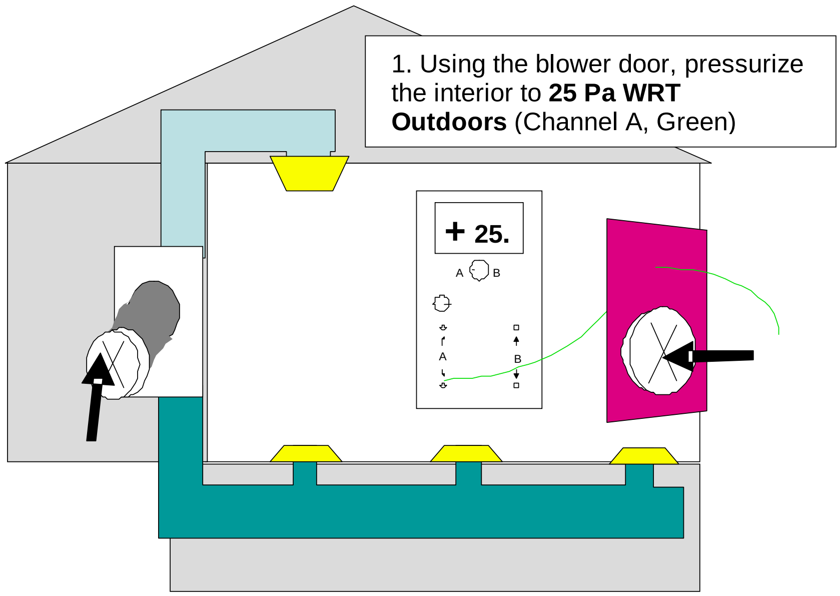


Figure 6: Pressurizing interior to +25 PA WRT outdoors

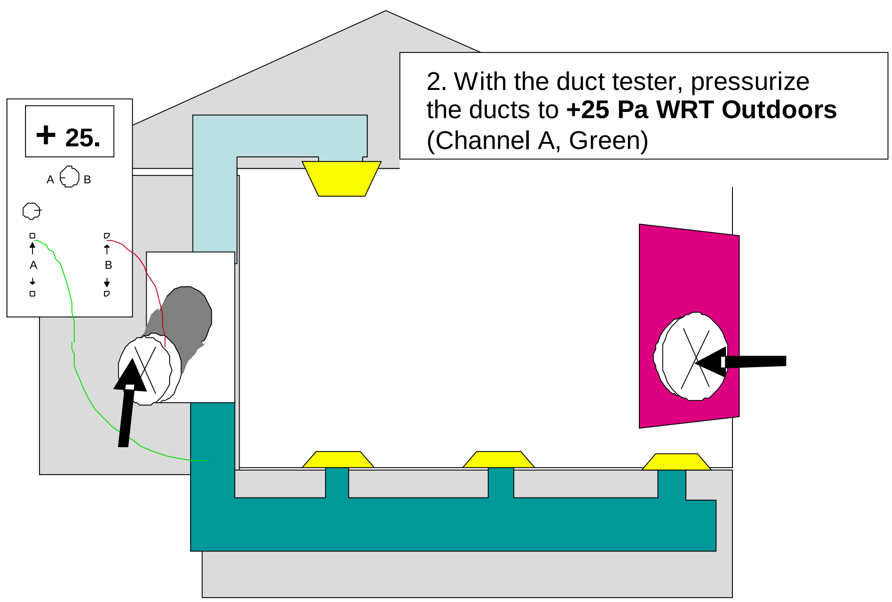


Figure 7: Pressurizing ducts to +25 PA WRT outdoors (duct testing device located outside the pressurized zone of the house).

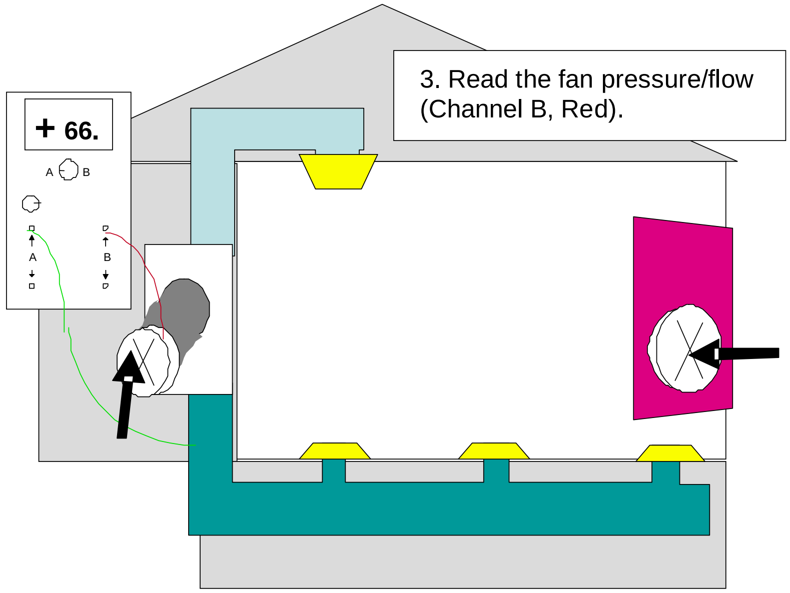


Figure 8: Determining duct leakage

Note: When the duct testing device is ***outside*** of the pressurized zone of the house, it is no longer necessary to run a pressure tube from the reference pressure tap on channel A to the outside when determining the duct pressure WRT to outside as it was in Example 1.

Purpose of code change:

This code change proposal provides necessary changes to align RS-33 with other code change proposals.

Your amendment must meet one of the following criteria. Select at least one:

☐ Addresses a critical life/safety need.

☒ Consistency with state or federal regulations.

☐ Addresses a specific state policy or statute.
(Note that energy conservation is a state policy)

☐ Addresses a unique character of the state.

☐ Corrects errors and omissions.

Check the building types that would be impacted by your code change:

☒ Single family/duplex/townhome

☐ Multi-family 4 + stories

☐ Institutional

☒ Multi-family 1 – 3 stories

☐ Commercial / Retail

☐ Industrial

Your name Gary Nordeen

Email address nordeeng@energy.wsu.edu

Your organization WSU Energy Program

Phone number (360) 956-2040

Other contact name 38T

STATE OF WASHINGTON

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Economic Impact Data Sheet

Briefly summarize your proposal's primary economic impacts and benefits to building owners, tenants and businesses.

There are no positive or negative economic impacts related to this proposed change to the reference standard.

Provide your best estimate of the construction cost (or cost savings) of your code change proposal?

$38T/square foot (For residential projects, also provide $38T/ dwelling unit)

Show calculations here, and list sources for costs/savings, or attach backup data pages

38T

Provide your best estimate of the annual energy savings (or additional energy use) for your code change proposal?

38TKWH/ square foot (or) 38TKBTU/ square foot

(For residential projects, also provide 38TKWH/KBTU / dwelling unit)

Show calculations here, and list sources for energy savings estimates, or attach backup data pages

38T

List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

There is no additional plan review or inspection time associated with this proposal.