National Fenestration Rating Council Incorporated

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Guidelines to Estimate the Effects of Fenestration on Heating and Cooling Energy Consumption in Single Family Residences

PREPARED BY:
National Fenestration Rating Council
6305 Ivy Lane, Suite 140
Greenbelt, MD 20770
Voice: (301) 589-1776
Fax: (301) 589-3884
Email: info@nfrc.org
Website: www.nfrc.org

FOREWORD

NFRC has developed standards to determine the energy related physical properties of fenestration products. Three of these properties, the U-factor, the Solar Heat Gain Coefficient (SHGC), and the Air Leakage (AL) rate, are directly related to energy loss or gain through the fenestration product as a result of temperature differences, direct solar radiation, and air pressure differences, respectively. In combination, these three fenestration properties can be used in building energy analysis software to more accurately estimate the effects of fenestration on heating and cooling energy consumption and peak energy impacts resulting from use of a specific product.

The guidelines presented in this document are intended to permit an estimate of the effects of fenestration on heating and cooling energy consumption in single-family residential buildings in the United States by using an NFRC-approved building energy simulation tool. Future versions of these guidelines may expand the scope to include multi-family buildings and manufactured housing.

This document does not mandate a certain approach. Rather it prescribes guidelines that represent the NFRC's best recommendations as to how to estimate fenestration annual energy performance, balancing accuracy and simplicity.

These guidelines make use of building energy software to model a hypothetical specific home under a set of user-specific assumptions. NFRC is also currently developing a procedure to estimate the effects of fenestration on energy use in a generic reference house with a general set of assumptions that represent a broad average of lifestyles. In all cases, the combination of simplifying assumptions used in this procedure will not give results exactly consistent with a particular home. Also, other factors such as year-to-year variations in weather and differences between the assumed and actual housing characteristics will impact actual energy consumption and the role that fenestration products play in the building performance.

Users should be cautioned that estimated energy consumption is only one of many parameters that should be considered in selecting a fenestration product. For example, this estimated energy consumption analysis does not factor in issues such as comfort, durability, visible light transmission and condensation.

Questions on the use of this procedure should be addressed to:

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1. PURPOSE

To provide a guideline for how to estimate the effects of fenestration (such as windows, doors, and skylights) on heating and cooling energy consumption and peak energy impacts resulting from use of a specific product.

2. SCOPE

This guideline is applicable to single-family residences in the U.S.

This guideline does not address multifamily housing, manufactured housing, or nonresidential buildings.

3. REFERENCED DOCUMENTS

NFRC 100-2004	Procedure for Determining Fenestration Product U-Factors
NFRC 200-2004	Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence
NFRC 400-2004	Procedure for Determining Fenestration Product Air Leakage
AAMA/WDMA/CSA 101/I.S.2/A440 – 08	NAFS - North American Fenestration Standard / Specification for windows, doors, and unit skylights

4. PREREQUISITES

Fenestration heating and cooling energy consumption can only be accurately determined when the total product U-factor, Solar Heat Gain Coefficient, and Air Leakage rate are known. These properties are determined in accordance with NFRC 100, 200, and 400, respectively. The Air Leakage rate may also be determined in accordance with AAMA/WDMA/CSA 101/I.S.2/A440.

If an Air Leakage rate determined in accordance with NFRC 400 or AAMA/WDMA/CSA 101/I.S.2/A440 is not available, a default value of 3.0 $L/s \bullet m^2$ (0.6 cfm/ft^2) for existing fenestration and 1.5 $L/s \bullet m^2$ (0.3 cfm/ft^2) for new fenestration shall be assumed for the purposes of determining the effects of fenestration on heating and cooling energy consumption.

5. TYPES OF HOUSES

This procedure may be used to estimate the effects of fenestration on heating and cooling energy consumption for a single specific client and/or house.

For a Specific House, where the user desires to estimate the effects of fenestration on heating and cooling energy consumption for a specific home or situation, the user shall input the primary parameters that influence fenestration annual energy use (see Table 1, Table 2, and Section 7.3). Secondary parameters which do not vary significantly from house to house and/or which do not influence the relative performance of fenestration products are fixed (see Table 1).

6. CHOOSING A REPRESENTATIVE CLIMATE

Fenestration heating and cooling energy consumption is a function of climate specifics. Weather data used with the software (see Section 8) is available for many cities in the U.S. Choose a city which best represents the local conditions.

Weather data used with the software (see Section 8) should be Typical Meteorological Year (TMY2) weather tapes from the National Renewable Energy Laboratory, which includes average weather data compiled from 30+ years of historical weather data. (National Renewable Energy Laboratory, 1995.) Weather data for other locations may also be available in TMY2 format.

7. USER DEFINED AND FIXED PARAMETERS

The following parameters shall either be fixed or shall be defined by the user.

7.1 Fixed Parameters

Fixed parameters are listed in Table 1 and Table 2.

7.2 Specific House – User Defined Parameters

7.2.1 Climate

Define a climate in accordance with Section 6.

7.2.2 Floor area

Define the floor area to the nearest 10 m^2 (100 ft^2).

7.2.3 Construction Type

Choose between the options in Table 1 for New or Existing home, Frame or Masonry construction, and 1-story, 2-story, or 1½-story split level. The New home choice is intended to represent homes that are

insulated in accordance with recent energy codes, and that use HVAC equipment with current efficiency levels. The Existing home choice is intended to represent homes with no or minimal insulation, and with less efficient HVAC equipment.

7.2.4 Foundation Type

Define the foundation type that covers the majority of the first floor area: basement, crawlspace, or slab-on-grade.

7.2.5 Insulation

Input the specific insulation values, if known, or select from the default insulation values for the reference house.

7.2.6 Fenestration Product Type

Use NFRC U-factors and SHGCs, and either NFRC or AAMA/WDMA/CSA Air Leakage ratings, to define the Fenestration Product Type. Where multiple fenestration products are used on the same orientation, use an area-weighted average for the U-factor, SHGC, and Air Leakage (see example in Appendix B). These properties can be obtained from NFRC's Certified Products Directory, NFRC labels on the product, or the manufacturer.

7.2.7 Fenestration Product Area and Distribution

Define the actual fenestration product area on each of the four primary orientations (for vertical fenestration) and roof (for skylights and/or other rooftop fenestration) in square meters (square feet), to the nearest 0.1 square meters (1 square foot). Include total fenestration product area (frame and glass – e.g. rough opening area).

7.2.8 Exterior Shading

Define the type of exterior shading from Table 1 that best describes the site for each of the four primary orientations.

7.2.9 HVAC System Type

For heating, choose between
(a) gas furnace,
(b) electric heat pump,
(c) electric resistance heat, or
(d) oil furnace.

For cooling, choose between
(a) electric air conditioner, or
(b) no air conditioning.

7.2.10 HVAC Efficiency

Either input the specific efficiency for the selected HVAC system, or use the values for the reference house from Table 1.

7.2.11 Dynamic Fenestration

If the home has dynamic fenestration in which the performance properties can be varied (e.g. fenestration with electrochromic glass, integral blinds between the glass, etc.), select the option from Table 2 that best matches how the occupant uses the fenestration. The choices are (a) use the fenestration seasonally with the more open or higher SHGC setting in the winter and the more closed or lower SHGC in the summer, (b) use the fenestration seasonally with the more closed or lower SHGC setting in the winter and the more open or higher SHGC in the summer, (c) use the more open or higher SHGC setting year-round, or (d) use the more closed or lower SHGC setting year-round.

7.2.12 Heating Temperature Thermostat Setpoint

Input the heating temperature thermostat setpoint, as well as the setback temperature at night, if any (11 p.m. – 6 a.m.).

7.2.13 Cooling Temperature Thermostat Setpoint

Input the cooling temperature thermostat setpoint, as well as the setup temperature during the day, if any (9 a.m. – 4 p.m.)

7.2.14 Interior Shading

Select the choice from Table 2 that best represents how the occupant uses interior shading (blinds, curtains, etc.). The choices are (a) interior blinds used seasonally more open in the winter and more closed in the summer, (b) interior blinds used seasonally more closed in the winter and more open in the summer, (c) interior blinds mainly closed year-round, or (d) interior blinds mainly open year-round.

7.2.15 Natural Ventilation

The software can simulate either the fenestration as always closed, or with the effect of opening fenestration for natural ventilation when it is advantageous (e.g. when it is cooler outside at night and the humidity is relatively low). Based on what best represents how the occupant uses the windows and skylights, choose to either consider the fenestration always closed, or to include natural ventilation

7.2.16 Utility Costs

As an option, the user may input local utility costs to estimate energy costs associated with the effects of fenestration on heating and cooling energy consumption. Recent local utility costs should be used

whenever possible, but users should also consider the expected escalation in such costs over the expected life of the fenestration products.

Users should also be cautious that cost estimates for different types of energy can be highly volatile and use of current prices can produce misleading results. Since the relationship between heating and cooling costs using different fuels (e.g., use of electricity for cooling and gas for heating) may change substantially over time, users should not combine heating and cooling energy costs.

8. SOFTWARE

NFRC shall approve building energy simulation software that allows for the specification and/or default of the parameters in Table 1 and Table 2. The software shall include the effects of solar incident angle for SHGC, and local climatic data for U-factor.

9. PRESENTATION OF RESULTS

9.1 Results Presented

The following results shall be presented:

- Total House Space Heating Site Energy Use (in MBtu)
- Total House Space Heating Source Energy Use (in MBtu)
- Total House Space Cooling Site Energy Use (in kWh)
- Total House Space Cooling Source Energy Use (in MBtu)
- Peak Cooling Energy (in kW)
- Peak Heating Energy (in kW or MBtu/hr depending on fuel type)

If the user inputs optional utility costs as described in section 7.3.15, the following results shall also be presented:

- Total House Space Heating Cost (in $)
- Total House Space Cooling Cost (in $)

Source energy use shall be calculated from the site energy use with an average source energy multiplier appropriate for the fuel source used for heating or cooling. The source energy multiplier for electricity shall be 3.16. The source energy multiplier for heating fuels other than electricity shall be 1.1.

Heating Energy Use and Cooling Energy Use results (and Cost where applicable) shall be reported separately, and a combined value for heating and cooling shall not be presented. It is recommended that users not attempt to combine heating and cooling values into total annual energy use for comparison purposes due to the risk of misleading results.

The following Note shall accompany the results:

> "Note: Estimated energy use results presented are solely for space heating and cooling and will not correlate to actual energy use in utility bills since space heating and cooling are typically, at most, half of total energy use. Total energy use for a house also includes water heating, appliances, lighting, and other miscellaneous uses. Comparing the total space heating and cooling energy use presented here will provide the user with some guidance on the approximate energy savings between different fenestration product types. Actual usage will vary."

Optionally, a statement may also accompany the results indicating whether the specified fenestration system does or does not meet the prescriptive code requirements of Table 402.1.1 of the 2006 International Energy Conservation Code (IECC). If the specified fenestration system does not meet the prescriptive requirements of Table 402.1.1 of the 2006 IECC, the statement shall also indicate that (a) the fenestration system may be in compliance with other local codes if those code requirements differ from the 2006 IECC, and (b) compliance under the 2006 IECC may still be demonstrated by using trade-offs from Section 402.1.4 (Total UA Alternative) or Section 404 (Simulated Performance Alternative), so long as the mandatory provisions of Section 402.6 establishing maximum fenestration U-factor or SHGC are satisfied.

9.2 Disclaimer

When results are presented, a disclaimer that explains how the results were determined shall be included.

The following note shall be used with simulations for the specific house, with items in brackets to be specified consistent with the chosen parameters from section 7.3:

> "The effects of fenestration on heating and cooling energy consumption figures reported here were generated using *[software name and version number]* for a *[new or existing] [1-story, 2-story, or 1½ -story split level] ["wood frame" or "masonry"] [floor area in m^2 or ft^2]* house with *[total fenestration area in m^2 or ft^2]* of fenestration area. The vertical fenestration is distributed as follows: *[north area in m^2 or ft^2]* facing north, *[east area in m^2 or ft^2]*facing east, *[south area in m^2 or ft^2]* facing south, and *[west area in m^2 or ft^2]* facing west. The area of skylights and/or other rooftop fenestration is *[roof area in m^2 or ft^2]*. Exterior shading is assumed to be *[insert appropriate choice*

from Table 1]. Interior shading is assumed to be *[insert appropriate choice from Table 1]*. Insulation is assumed to be *[wall R-value]* for walls, *[roof R-value]* for roofs, and *[foundation R-value]* for the foundation. The heating system is *["a natural gas furnace", "a heat pump", or "electric resistance"]* with *["air conditioning for cooling" or "no air conditioning"]*. The heating system efficiency is *[insert heating system efficiency]* and the cooling system efficiency is *[insert cooling system efficiency]*. The heating temperature setpoint is *[heating temperature]* with a nighttime setback of *[heating setback temperature, or state "no nighttime setback"]*, and the cooling temperature setpoint is *[cooling temperature]* with a daytime setup of *[cooling setup temperature, or state "no daytime setup"]*. Users should be cautioned that estimated energy consumption is only one of many parameters that should be considered in selecting a fenestration product. For example, this estimated energy consumption analysis does not factor in issues such as comfort, durability, visible light transmission and condensation.

Modifications to disclaimer:

(a) If the selected exterior or interior shading conditions vary by orientation, the appropriate condition for each orientation shall also be indicated.

(b) If dynamic fenestration is used, the following sentence shall be included: "Dynamic fenestration was assumed to be *[insert appropriate choice from Table 1]*.

TABLE 1 – USER-DEFINED, FIXED PARAMETERS FOR A SPECIFIC HOUSE

PARAMETER	SPECIFIC HOUSE
Floor Area	User inputs actual floor area to the nearest 10 square meters (100 square feet).
House Construction	User choice of: • New or Existing Construction • Frame or Masonry • 1-story, 2-story, or 1½-story split level
Aspect Ratio	Fixed: Square
Foundation	User choice of: • Basement • Crawlspace • Slab-on-Grade
Insulation	User inputs insulation values, if known, or For new construction, envelope insulation levels based on location using 2006 IECC requirements in Table 402.1.1. or For existing construction more than 15 years old, use the following insulation values: • Foundation insulation based on location: R-0 in climate zones 1-4 R-5 in climate zones 5-8 • Wall insulation R-7 • Roof insulation based on location: R-11 in climate zones 1-3 R-19 in climate zones 4-5 R-22 in climate zones 6-8

PARAMETER	SPECIFIC HOUSE
Fenestration Type	User inputs U, SHGC, AL (area-weighted average by orientation)
Fenestration Area & Distribution	User inputs specific fenestration area for each cardinal orientation (for vertical fenestration) and roof (for skylights and/or other rooftop fenestration).
Exterior Shading	User choice of set of conditions: • *None*: no solar gain reduction • *Overhang*: 2 ft overhang • *Obstruction*: completely opaque same-height obstruction 20 ft away intended to represent adjacent buildings • *Overhang + Obstruction*: 2 ft overhang and completely opaque obstruction 20 ft away • *Small Overhang plus Some Obstruction*: 1 ft overhang and 67% transmitting same-height obstruction 20 ft away
Structural Mass	Fixed: Based upon the following: Masonry Floor: 80% of floor area covered by R-2 carpet and pad, and 20% of floor directly exposed to room air. Basement walls: masonry, and include insulation located on the interior side of the walls Other walls, ceilings, floors: wood frame construction
Internal Furniture Mass	Fixed: 8.0 lb/ft^2 of floor area
Infiltration	New Construction: SLA = 0.00036 Existing Construction: SLA = 0.00054

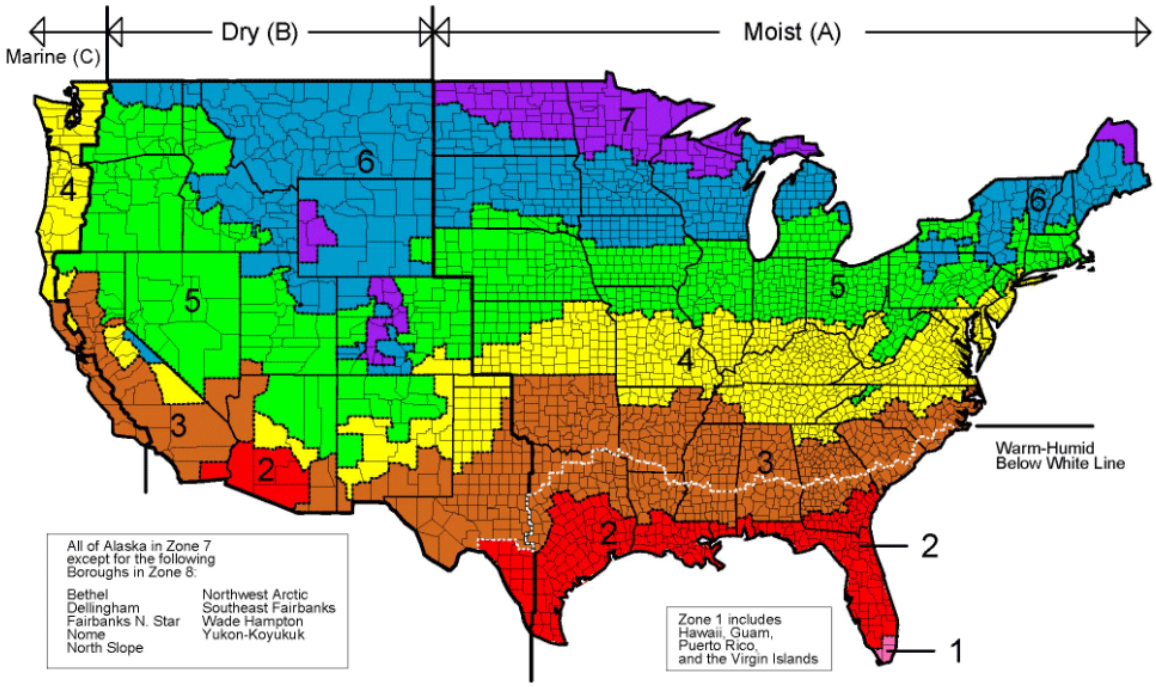
PARAMETER	SPECIFIC HOUSE
HVAC System	User choice of heating system: • gas furnace • electric heat pump • electric resistance • oil furnace: User choice of cooling system: • electric air conditioning • no air conditioning
HVAC System Sizing	Fixed: Sized in accordance with Section M1401.3 of the International Residential Code. Sizing multiplier safety factor of 1.0
HVAC Efficiency	User choice of: • input efficiency for each type of HVAC system or • default efficiency as follows: Gas furnace AFUE = 0.80 in climate zones 1-3, 0.90 in climate zones 4-8. A/C SEER = 13 Heat pump HSPF = 7.7 Oil furnace AFUE = 0.80
Duct Losses	Fixed: 12% for basement foundation 20% for crawlspace and slab-on-grade foundations
Part-Load Performance	Software shall reflect part-load performance for both new and existing construction.
Internal Loads	Internal gain (Btu/day) = 30,200 + 23.8×floor area (ft^2)

TABLE 2 – OPERATIONAL PARAMETERS FOR A SPECIFIC HOUSE

PARAMETER	SPECIFIC HOUSE
Dynamic Fenestration	If dynamic fenestration is specified, User choice of: • Dynamic fenestration used seasonally with high SHGC in winter and low SHGC in summer. • Dynamic fenestration used seasonally with low SHGC in winter and high SHGC in summer. • Dynamic fenestration in high SHGC setting year-round. • Dynamic fenestration in low SHGC setting year-round In all cases, if U is also variable, use U which corresponds with the specified high/low SHGC.
Heating Temperature Thermostat Setpoint	User inputs heating setpoint and nighttime setback temperature, if any. Basement (where applicable) is partially conditioned with a fixed setpoint of 62ºF.
Cooling Temperature Thermostat Setpoint	User inputs cooling setpoint and daytime setup temperature, if any. Basement (where applicable) is partially conditioned with a fixed setpoint of 85ºF.

PARAMETER	SPECIFIC HOUSE
Interior Shading	User choice of: • Interior blinds used seasonally. 2/3 closed in summer, 2/3 open in winter. • Interior blinds used seasonally. 2/3 open in summer, 2/3 closed in winter. • Interior blinds mainly closed (2/3 closed) year-round. • Interior blinds mainly open (2/3 open) year-round. • User inputs specific blind usage pattern for summer and winter. In all cases, a light colored, open weave curtain shall be assumed. The total shade SHGC multiplier shall be calculated based on the selected fenestration properties.
Natural Ventilation	User choice of: • Fenestration always closed. • Fenestration opened when advantageous based on 78ºF / 72ºF / 4-day history Enthalpic-Sherman-Grimsrud ventilation model.

APPENDIX A IECC CLIMATE ZONES



2006 International Energy Conservation Code, International Code Council Inc., February 2006.

Appendix B Area-Weighted Fenestration Properties

This appendix gives an example showing the determination of area weighted fenestration properties when multiple product types are used on the same orientation (see Section 7.2.3 and Section 7.3.5).

The total fenestration area (A_t) on the south side of the house is determined to be 75 ft^2. There are three different fenestration products used on this side of the house. They have the following properties:

Product #1 (Casement Windows):

Area (A_1) = 40 ft2

U-factor for product #1 (U_1) = 0.45 Btu/hr-ft^2-F

SHGC for product #1 ($SHGC_1$) = 0.60

Air Leakage for product #1 (AL_1) = 0.2 cfm/ft^2

Product #2 (Hung Windows):

Area (A_2) = 15 ft^2

U-factor for product #2 (U_2) = 0.51 Btu/hr-ft^2-F

SHGC for product #2 ($SHGC_2$) = 0.59

Air Leakage for product #2 (AL_2) = 0.3 cfm/ft^2

Product #3 (Door):

Area (A_3) = 20ft^2

U-factor for product #3 (U_3) = 0.63 Btu/hr-ft^2-F

SHGC for product #3 ($SHGC_3$) = 0.75

Air Leakage for product #3 (AL_3) = 0.1 cfm/ft^2

The area weighted factors to be used are calculated as:

Area weighted U-factor $= (U_1A_1 + U_2A_2 + U_3A_3) / A_t$
$= (0.45 \times 40 + 0.51 \times 15 + 0.63 \times 20) / 75$
$= 0.51$

Area weighted SHGC $= (SHGC_1A_1 + SHGC_2A_2 + SHGC_3A_3) / A_t$
$= (0.60 \times 40 + 0.59 \times 15 + 0.75 \times 20) / 75$
$= 0.64$

Are weighted Air Leakage $= (AL_1A_1 + AL_2A_2 + AL_3A_3) / A_t$
$= (0.2 \times 40 + 0.3 \times 15 + 0.1 \times 20) / 75$
$= 0.2$