CHAPTER 4

RESIDENTIAL BUILDING DESIGN BY SYSTEMS ANALYSIS AND DESIGN OF BUILDINGS UTILIZING RENEWABLE ENERGY SOURCES

SECTION 401 GENERAL

401.1 Scope. This chapter establishes design criteria in terms of total energy use by a residential building, including all of its systems.

SECTION 402 SYSTEMS ANALYSIS

402.1 Analysis procedure. Except as explicitly specified by this chapter, the standard design home shall be configured and simulated using identical methods and techniques as are used in the configuration and simulation of the proposed design home.

402.2 Energy analysis. Compliance with this chapter will require an analysis of the annual energy usage, hereinafter called an "annual energy analysis."

Exception: Chapters 5 and 6 establish criteria for different energy-consuming and enclosure elements of the building which, if followed, will eliminate the requirement for an annual energy analysis while meeting the intent of this code.

402.2.1 Standard design. A building designed in accordance with this chapter will be deemed as complying with this code if the calculated annual energy consumption is not greater than a similar building (defined as a "standard design") whose enclosure elements and energy-consuming systems are designed in accordance with Chapter 5. Specific building envelope elements of the standard design shall comply with Sections 402.2.1.1 through 402.2.1.4.

402.2.1.1 Exterior walls. The exterior wall assembly *U*-Factors for the standard design shall be selected by climate in accordance with Table 402.2.1.1.

402.2.1.2 Fenestration *U*-factor. The fenestration system *U*-Factor used in the standard design shall be selected by climate in accordance with Table 402.2.1.2.

402.2.1.3 Window area. The window area of the standard design, inclusive of the framed sash and glazing area, shall be equal to 18 percent of the conditioned floor area of the proposed design.

402.2.1.4 Skylights. Skylights and other nonvertical roof glazing elements shall not be included in the standard design, and ceiling *U*-factors used in the standard design shall not include such elements in their computation.

402.2.2 Proposed design. For a proposed alternative building design (defined as a "proposed design") to be considered similar to a "standard design," it shall utilize the same nonrenewable energy source(s) for the same functions and have equal conditioned floor area and the same ratio of thermal envelope area to floor area (i.e., the same geometry), exterior design conditions, occupancy, climate data, and usage operational schedule as the standard design. Where an energy end use (such as space heating or domestic water) is to be provided entirely from renewable energy sources in a proposed design, the standard design shall assume an equipment type using a nonrenewable energy source common to that region for that end use as approved by the code official.

402.2.2.1 Orientation for groups of buildings. The worst possible orientation of the proposed design, in terms of annual energy use, considering north, northeast, east, southeast, south, southwest, west and northwest orientations, shall be used to represent group of otherwise identical designs.

TABLE 402.2.1.1
STANDARD DESIGN WALL ASSEMBLY *U*-FACTORS (U_w)

HEATING DEGREE DAYS[a]	U_w (air to air)[b]
≥ 13,000	0.038
9,000 - 12,999	0.046
6,500 - 8,999	0.052
4,500 - 6,499	0.058
3,500 - 4,499	0.064
2,600 - 3,499	0.076
< 2,600	0.085

a. From Table 302.1.
b. Including framing effects.

TABLE 402.2.1.2
STANDARD DESIGN FENESTRATION SYSTEM *U*-FACTORS (U_g or U_f)

HEATING DEGREE DAYS[a]	U_g FOR SECTION 502.2.1.1 AND U_f FOR SECTION 502.2.3.1 (air to air)[b]
≥ 13,000	0.25
9,000 - 12,999	0.26
6,500 - 8,999	0.28
4,500 - 6,499	0.30
3,500 - 4,499	0.41
2,600 - 3,499	0.44
700 - 2,599	0.47
< 700	0.74

a. From Table 302.1.
b. Entire assembly, including sash.

402.2.3 Input values for residential buildings. The input values in Sections 402.2.3.1 through 402.2.3.11 shall be used in calculating annual energy performance. The requirements of this section specifically indicate which variables shall remain constant between the standard design and proposed design calculations. The standard design shall be a base version of the design that directly complies with the provisions of this code. The proposed building shall be permitted to utilize a design methodology that is demonstrated, through calculations satisfactory to the code official, to have equal or lower annual energy use than the standard design.

402.2.3.1 Glazing systems. The input values in Sections 402.2.3.1.1 through 402.2.3.1.4, specific to glazing systems, shall be used in calculating annual energy performance.

402.2.3.1.1 Orientation, standard design. As a minimum, equal areas on north, east, south and west exposures shall be assumed.

402.2.3.1.2 Exterior shading, standard design. Glazing areas in the standard design shall not be provided with exterior shading such as roof overhangs. Energy performance impacts of added exterior shading for glazing areas which are accounted for in the proposed design for a specific building shall be permitted, provided that the code official approves the actual installation of such systems.

402.2.3.1.3 Fenestration system solar heat gain coefficient, standard design. The fenestration system solar heat gain coefficient (SHGC), inclusive of framed sash and glazing area, of the glazing systems in the standard design shall be 0.40 during periods of mechanical heating and cooling operation. These fenestration system SHGC values shall be multiplied together with (added in series to) the interior shading values as specified in Section 402.2.3.1.4 to arrive at an overall solar heat gain coefficient for the installed glazing system.

Where the SHGC characteristics of the proposed fenestration products are not known, the default SHGC values given in Table 102.5.2(3) shall be used for the proposed design.

402.2.3.1.4 Interior shading, standard design and proposed design. The same schedule of interior shading values, expressed as the fraction of the solar heat gain admitted by the fenestration system that is also admitted by the interior shading, shall be assumed for the standard and proposed designs.

The values used for interior shading shall be 0.70 in summer, and 0.90 in winter.

402.2.3.2 Heat storage (thermal mass). The following input values, specific to heat storage (thermal mass), shall be used in calculating annual energy performance:

Internal mass: 8 pounds per square foot (39 kg/m^2)

Structural mass: 3.5 pounds per square foot (17 kg/m^2)

402.2.3.3 Building thermal envelope — surface areas and volume. The input values in Sections 402.2.3.3.1 through 402.2.3.3.4, specific to building thermal envelope surface areas, shall be used in calculating annual energy performance.

402.2.3.3.1 Floors, walls, ceiling. The standard and proposed designs shall have equal areas.

402.2.3.3.2 Foundation and floor type. The foundation and floor type for both the standard and proposed designs shall be equal.

402.2.3.3.3 Doors. The opaque door area of the standard design shall equal that of the proposed design and shall have a *U*-factor of 0.2 Btu/hr · ft^2 · °F [1.14 W/(m^2 · K)].

402.2.3.3.4 Building volume. The volume of both the standard and proposed designs shall be equal.

402.2.3.4 Heating and cooling controls. Unless otherwise specified by local codes, heating and cooling thermostats shall comply with Table 402.2.3.4 for the standard and proposed designs. The input values specific to heating and cooling controls, shall be used in calculating annual energy performance.

TABLE 402.2.3.4
HEATING AND COOLING CONTROLS

PARAMETER	STANDARD DESIGN VALUE	proposed DESIGN VALUE
Heating	68°F	68°F
Cooling	78°F	78°F
Setback/setup	5°F	Maximum of 5°F
Setback/setup duration	6 hours per day	Maximum of 6 hours per day
Number of setback/setup periods per unit[a]	1	Maximum of 1
Maximum number of zones per unit[a]	2	2
Number of thermostats per zone	1	1

For SI: °C = [(°F) -32]/1.8

a. Units = Number of dwelling units in standard and proposed designs.

402.2.3.5 Internal heat gains. Equation 4-1 shall be used to determine the input values, specific to internal heat gains, that shall be used in both the standard design and the proposed design in calculating annual energy performance:

$$I\text{-}Gain = 17{,}900 + (23.8 \cdot CFA) + (4140 \cdot BR) \quad \textbf{(Equation 4-1)}$$

where:

I-Gain = Internal gains in Btu/day (kWh/day) per dwelling unit.

CFA = Conditioned floor area.

BR = Number of bedrooms.

402.2.3.6 Domestic hot water (calculate, then constants). The following input values, specific to domestic hot water, shall be used in calculating annual energy performance.

Temperature set point	120°F (49°C)
Daily hot water consumption	Gallons = (30 · *a*) + (10 · *b*)

where:

a = Number of dwelling units in standard and proposed designs.

b = Number of bedrooms in each dwelling unit.

402.2.3.7 Site weather data (constants). The typical meteorological year (TMY2), or its "ersatz" equivalent, from the National Oceanic and Atmospheric Administration (NOAA), or an approved equivalent, for the closest available location shall be used.

402.2.3.8 Forced-air distribution system loss factors (DLF). The heating and cooling system efficiency shall be proportionately adjusted for those portions of the ductwork located outside or inside the conditioned space using the values shown below:

System Operating Mode	Duct Location	
	Outside	Inside
Heating	0.80	1.00
Cooling	0.80	1.00

Note: Ducts located in a space that contains a positive heating supply or cooling supply, or both, shall be considered inside the building envelope.

Impacts from improved distribution loss factors (DLF) shall be accounted for in the proposed design only if the entire air distribution system is specified on the construction documents to be substantially leak free, and is tested after installation to ensure that the installation is substantially leak free."Substantially leak free" shall be defined as the condition under which the entire air distribution system (including the air handler cabinet) is capable of maintaining a 0.1-inch w.g. (25 Pa) internal pressure at 5 percent or less of the air handler's rated airflow when the return grilles and supply registers are sealed off. This test shall be conducted using methods and procedures as specified in Section 3 of the SMACNA *HVAC Air Duct Leakage Test Manual*, or by using other, similar pressurization test methods and as approved by the code official.

Where test results show that the entire distribution system is substantially leak free, then seasonal DLFs shall be calculated separately for heating and cooling modes using engineering methods capable of considering the net seasonal cooling energy heat gain impacts and the net seasonal heating energy heat loss impacts that result from the portion of the thermal air distribution system that is located outside the conditioned space. Once these heating and cooling season "distribution system energy impacts" are known, then heating and cooling mode DLFs for the proposed design shall be calculated using Equations 4-2 and 4-3:

Total Seasonal Energy = Seasonal Building Energy + Distribution System Energy Impacts

(Equation 4-2)

DLF = Seasonal Building Energy/Total Seasonal Energy

(Equation 4-3)

Once the DLFs for the heating and cooling seasons are known, the total "adjusted system efficiency" is calculated using Equation 4-4:

Adjusted System Efficiency = (Equipment Efficiency · DLF · Percent of Duct Outside) + (Equipment Efficiency · DLF · Percent of Duct Inside)

(Equation 4-4)

Equation 4-4 shall be used to develop adjusted system efficiency for each heating and cooling system included in the standard design. Where a single system provides both heating and cooling, efficiencies shall be calculated separately for heating and cooling modes.

402.2.3.9 Air infiltration. Annual average air changes per hour (ACH) for the standard design shall be determined using the following equation:

ACH = Normalized Leakage × Weather Factor

(Equation 4-5)

where:

Normalized leakage = 0.57

and

Weather factor is determined in accordance with the weather factors (*W*) given by ASHRAE 136, as taken from the weather station nearest the building site.

Where the proposed design takes credit for reduced ACH levels, documentation of measures providing such reductions, and results of a post-construction blower-door test shall be provided to the code official using ASTM E 779. No energy credit shall be granted for ACH levels below 0.35.

402.2.3.10 Foundation walls. When performing annual energy analyses for buildings with insulated basement or crawl space walls, the design *U*-factors taken from Table 502.2 for these walls of the standard building shall be permitted to be decreased by accounting for the *R*-values of the adjacent soil, provided that the foundation wall *U*-factor of the proposed building also accounts for the *R*-value of the adjacent soil.

402.2.3.11 Heating and cooling system equipment efficiency, standard design. The efficiency of the heating and cooling equipment shall meet, but not exceed the minimum efficiency requirement in Section 503.2. Where the proposed design utilizes an electric resistance space heating system as the primary heating source, the standard design shall utilize an air-cooled heat pump that

meets but does not exceed the minimum efficiency requirements in Section 503.2.

Exception: Zonal electric-resistance space heating equipment in buildings in Climate Zones 1a through 4b as indicated in Table 302.1

402.3 Design. The standard design, conforming to the criteria of Chapter 5 and the proposed design, shall be designed on a common basis as specified in Sections 402.3.1 through 402.3.3.

402.3.1 Units of energy. The comparison shall be expressed as Btu input per square foot (W/m^2) of gross floor area per year at the building site.

402.3.2 Equivalent energy units. If the proposed design results in an increase in consumption of one energy source and a decrease in another energy source, even though similar sources are used for similar purposes, the difference in each energy source shall be converted to equivalent energy units for purposes of comparing the total energy used.

402.3.3 Site energy. The different energy sources shall be compared on the basis of energy use at the site where: 1 kWh = 3,413 Btu.

402.4 Analysis procedure. The analysis of the annual energy usage of the standard and the proposed alternative building and system designs shall meet the criteria specified in Sections 402.4.1 and 402.4.2.

402.4.1 Load calculations. The building heating and cooling load calculation procedures used for annual energy consumption analysis shall be detailed to permit the evaluation of effect of factors specified in Section 402.5.

402.4.2 Simulation details. The calculation procedure used to simulate the operation of the building and its service systems through a full-year operating period shall be detailed to permit the evaluation of the effect of system design, climatic factors, operational characteristics, and mechanical equipment on annual energy usage. Manufacturer's data or comparable field test data shall be used when available in the simulation of systems and equipment. The calculation procedure shall be based on 8,760 hours of operation of the building and its service systems and shall utilize the design methods specified in the ASHRAE *Fundamentals Handbook.*

402.5 Calculation procedure. The calculation procedure shall include the items specified in Sections 402.5.1 through 402.5.7.

402.5.1 Design requirements. Environmental requirements as required in Chapter 3.

402.5.2 Climatic data. Coincident hourly data for temperatures, solar radiation, wind and humidity of typical days in the year representing seasonal variation.

402.5.3 Building data. Orientation, size, shape, framing, mass, air, moisture and heat transfer characteristics.

402.5.4 Operational characteristics. Temperature, humidity, ventilation, illumination and control mode for occupied and unoccupied hours.

402.5.5 Mechanical equipment. Design capacity and part-load profile.

402.5.6 Building loads. Internal heat generation, lighting, equipment and number of people during occupied and unoccupied periods.

402.5.7 Use of approved calculation tool. The same calculation tool shall be used to estimate the annual energy usage for space heating and cooling of the standard design and the proposed design. The calculation tool shall be approved by the code official.

402.6 Documentation. Proposed alternative designs, submitted as requests for exception to the standard design criteria, shall be accompanied by an energy analysis comparison report. The report shall provide technical detail on the standard and proposed designs and on the data used in and resulting from the comparative analysis to verify that both the analysis and the designs meet the criteria of Chapter 4.

Exception: Proposed alternative designs for residential buildings having a conditioned floor area of 5,000 square feet (464 m^2) or less are exempted from the hourly analysis described in Sections 402.4 and 402.5. However, a comparison of energy consumption using correlation methods based on full-year hourly simulation analysis or other engineering methods that are capable of estimating the annual heating, cooling and hot water use between the proposed alternative design and the standard design shall be provided.