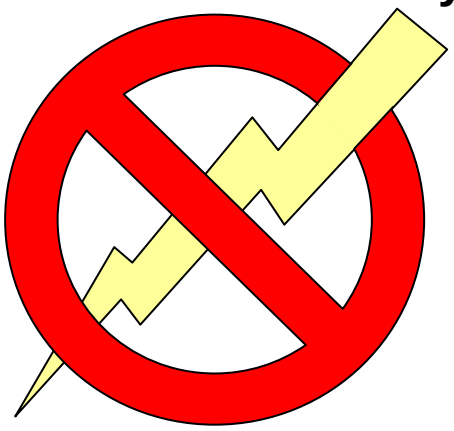
Tucson/Pima County Net-Zero Energy Building Standard

Cash flow positive on day 1

June 6, 2012

Tucson/Pima County



Net Zero Energy Standard

The purpose of this standard is to provide both prescriptive and performance paths for designing *net-zero energy building*s and net-zero energy remodels within the Tucson/Pima County climate. The prescriptive path is comprised of a series of high performance energy efficiency improvements that each building must incorporate. The performance path is based on the use of energy modeling tools that are either free, or readily available. A *net-zero energy building* is a high performance building. Project teams are encouraged to use the performance path in the design of the building. The prescriptive path is conservative in employing the highest energy efficiency improvements thus ensuring that net-zero can be achieved.

Four important concepts in this standard are:

1) The development of a primary metric called Energy Use Intensity (EUI) to measure the predicted and actual energy use. This is analogous to miles per gallon for a car.
2) The embedded energy to deliver water to the building must be offset by on-site energy production to achieve net-zero status.
3) The development of an energy budget and the net-zero potential is defined by the ability of the building to generate on-site energy with the energy producing area limited to the building roof (and covered parking in commercial buildings). This requires that buildings be energy efficient.
4) The net-zero certification will be issued after one year of performance demonstrates net-zero achievement.

Meeting the requirements in either the prescriptive path or performance path shall be deemed to be in compliance with the requirements of the 2012 IECC without regard to the issuance of the net-zero certificate.

Section 1 Residential Net-Zero Energy Building Alternative

1.1. Scope. This section establishes criteria for compliance with the 2012 IECC using the *net-zero energy building* alternative. Minimum requirements in of the 2012 IECC shall be met as applicable. Each building shall be designed per Section 1.4, 1.5 or 1.6.

Exception: buildings located at 4,000 feet elevation and above shall use section 1.5.

Note: *Net-zero energy buildings* are high performance buildings. It is recommended that building teams use the simulated performance path (section 1.5). The prescriptive path (section 1.4) provides an alternative path with a conservative (low) estimate of the *energy budget factor* and a conservative estimate (high) of the *energy use intensity factor*.

1.2. Definitions. See IECC Chapter 2 for additional definitions

Building Axis. *Building axis* is a line drawn through the plan view at the approximate centroid of the plan and parallel to the longest axis of exterior walls. [See Appendix C, Sketch 1 and 2]

Energy Budget. Annual useful energy production of on-site renewable energy producing equipment including photo-voltaic panels and solar thermal panels. The prescriptive path is based on the following values:

- Photo-voltaic panels at 14% efficiency = 22 kWh/sf of panel-yr * 3.412 ≈ 75 kBtu/sf of panel-yr
- Solar thermal hot water = 75 kWh/sf of panel-yr * 3.412 = 256 kBtu/sf of panel-yr

Energy Budget Factor. The estimated *energy budget* per square foot of *conditioned floor area*.

Energy Use Intensity (EUI). Total building site energy use divided by the building's gross floor area. The units of building *energy use intensity* are typically kBtu/sf-yr[1]. Total building site energy use includes all energy using systems in the building, including appliances and plug loads, consisting of, but not limited to: computers, lamps, microwaves, office equipment, radios, stereos, TVs, pool pumps, etc., and the embedded energy of water used in the building and exterior to the building for landscaping as measured at the building site without regard to the energy required at the site of energy generation required to compensate for systemic losses.

Energy Use Intensity Factor. The estimated *energy use intensity* per square foot of *conditioned floor area*.

Embedded energy in water. The average amount of energy required for pumping and processing to deliver water to the building site. The *embedded energy in water* value for the purposes of this section is determined as follows:

The *embedded energy in water* shall be as follows:

- 4,800 kWh of electricity to deliver 1 acre foot of water
- 4800 kwh/AF ÷ 325,851 gallons/AF = .01473 kwh/gal
- 0.01473 kwh/gal * 3.412 = 0.0503 kBtu/gal

Residential Group R-2, R-3, and R-4 the *embedded energy in water* shall be as follows

- 0.0503 kBtu/gal * 42 gal/sf-yr = 2.1 kBtu/sf-yr

Business Group B the *embedded energy in water* shall be as follows:

- 0.0503 kBtu/gal * 26 gal/sf-yr = 1.3 kBtu/sf-yr

Mercantile Group M the *embedded energy in water r* shall be as follows:

- 0.0503 kBtu/gal * 61 gal/sf-yr = 3.1 kBtu/sf-yr

All other uses the *embedded energy in water* shall be as follows:

- 0.0503 kBtu/gal * 61 gal/sf-yr = 3.1 kBtu/sf-yr

Exception: An alternate factor for the *embedded energy in water* may be presented to the building official based on an alternative *Water Use Intensity Factor*.

Exterior Corner. A portion of exterior building wall where two wall planes meet and the angle described by the walls on the interior side of the wall is <135 degrees, or where multiple walls and angles within ten linear feet of wall describe an interior angle of <135 degrees.

kBtu/sf. A measure of energy use per square foot of *conditioned floor area.* kBtu equals one-thousand British Thermal Units. All units of energy shall be expressed in kBtu unless otherwise noted.

Net-Zero Energy Building. For the purposes of this section, *net-zero energy building* is a building that produces at least as much energy as it uses in a year, including the *embedded energy in water*, when accounted for at the site[2].

Total on site renewable energy production (kBtu/yr) – [Total building site energy use (kBtu/yr) + (*Embedded energy in water* * conditioned floor area] ≥0

Water Use Intensity Factor. The estimated annual water use both interior and exterior in gallons per square foot of conditioned floor area per year.

Water use intensity factors are as follows:

- Residential Group R-2, R-3, and R-4 = 42 gal/sf-yr

[1] ASTM E2797-11 Building Energy Performance
[2] Zero Energy Buildings: A Critical Look at the Definition, Torcellini, NREL; p 7
http://www.nrel.gov/docs/fy06osti/39833.pdf

- Business Group B = 26 gal/sf-yr
- Mercantile Group M = 61 gal/sf-yr
- All other uses = 61 gal/sf-yr

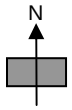
Exception: An alternate *water use intensity factor* for occupancy groups not specifically listed may be presented to the building official based on calculations or historical data on similar uses.

Window Floor Area Ratio (WFA). The total area of skylights, roof windows, vertical windows, glazed doors, glazed block and the glazed areas of combination opaque/glazed doors area divided by the above-grade *conditioned floor area*.

1.3. Energy Budget Development. Each building shall have an *energy budget factor* based on the following criteria:

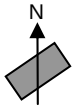
1.3.1.1. Orientation. The alignment of the longest *building axis* with respect to geographical compass points shall be classified as one of the following:

1. E-W (east-west) is any long *building axis* that is within plus or minus 15 degrees of true east-west. [See Appendix C, Sketch 1]



2. N-S (north-south) is any long *building axis* that is within plus or minus 15 degrees of true north-south. [See Appendix C, Sketch 1]

3. Off Axis is any orientation that is not E-W or N-S.



1.3.1.2. Type of Roof. Each roof type shall be classified as one of the following:

1. Flat Perimeter Parapets only. A roof that is ≤ 2:12 pitch with a parapet only at the exterior walls

2. Flat Perimeter and Interior Parapets. A roof that is ≤ 2:12 pitch with a parapet at the exterior walls and vertical changes of level < six inches and/or additional parapets inside the exterior wall parapets and/or mechanical equipment with a footprint > 5% of the roof area.

3. Low Pitch ≤ 2:12. A roof that is ≤ 2:12 pitch without parapets

4. High Pitch > 2:12. A roof that is > 2/12 pitch without parapets

1.3.1.3. Shape: The building plan floor plan shape shall be categorized as one of the following:

1. Rectangle: The floor plan long *building axis* is > 1.3 times the length of the short *building axis* and no more than eight *exterior corners*. [See Appendix C, Sketch 2]

2. Square: The floor plan long *building axis* is ≤ 1.3 times the length of the short *building axis* of the home and no more than eight *exterior corners*. [See Appendix C, Sketch 2]

3. Irregular: Floor plans that are not a Rectangle or a Square and buildings with curved exterior walls.

1.3.1.4. Number of stories

1. One story use tables in section 1.3.1.5.

2. Two stories use tables in section 1.3.1.5 to determine the *energy budget factor* and divide by two

3. Three stories or more use section 1.5

1.3.1.5. Each building shall have an *energy budget factor* which shall be the lower of 1) 29 kBtu/sf-yr, or 2) the value from tables 1.3.1.5 (1) or (2). Based on the *energy budget factor*, buildings shall comply as follows:

1. If the *energy use intensity factor* per table 1.4.1 (1) is less than or equal to the *energy budget factor*, use Section 1.4 or 1.5
2. All other *energy use intensity factors*, Section 1.5

The residential *energy budget* calculator at http://www.pima.gov/netzero/energy-calc.shtml may be used to calculate the *energy budget factor* and *energy use intensity factor*. Complete the on-line calculator and include the "recipe card" with the plan review submittal.

Table 1.3.1.5(1) One Story Residential *Energy Budget Factor* kBtu/sf-yr – Rectangle or Square

Orientation	Type of Roof			
	Flat-Perimeter Parapets Only	Flat- Perimeter and Interior Parapets	Pitch ≤ 2:12	Pitch > 2:12
E-W	37.5[1](50%)	22.5 (30%)	67.6 (90%)	33.8 (45%)
N-S	33.8 (45%)	22.5 (30%)	67.6 (90%)	33.0 (44%)
Off Axis	30 (40%)	18.8 (25%)	67.6 (90%)	Use Section 1.5

1) The first number is kBtu/sf-yr. (Number in parenthesis is the percentage of roof to be covered with photovoltaic and/or solar thermal panels used to model the *energy budget*).

Table 1.3.1.5 (2) One Story Residential *Energy Budget Factor* kBtu/sf-yr – Irregular

Orientation	Type of Roof			
	Flat-Perimeter Parapets Only	Flat- Perimeter and Interior Parapets	Pitch ≤ 2:12	Pitch > 2:12
E-W	28.1 (38%)	16.9 (23%)	50.7 (68%)	25.3 (34%)
N-S	25.3 (34%)	16.9 (23%)	50.7 (68%)	24.8 (33%)
Off Axis	22.5 (30%)	14.1 (19%)	50.7 (68%)	Use Section 1.5

1.3.1.6. Each building shall have solar photovoltaic panels installed on the roof of the building that shall produce on an annual basis sufficient electrical energy to equal or exceed the *energy budget factor* multiplied by the conditioned square feet of the building.

1.4. Prescriptive Path Compliance

1.4.1. Energy Use Intensity Factor Development. Each Building using section 1.4 shall have an *energy use intensity factor* based on table 1.4.1 (1).

1.4.1.1. The *energy use intensity* factor per Table 1.4.1 (1) may be adjusted as follows:

1. Evaporative Cooler: For mass and insulated mass construction, if cooling is provided only by evaporative cooler, the initial *energy use intensity factor* above may be decreased by 2.50 kBtu/sf-yr.

   Note this factor is based on the sum of: 2.75 kBtu/sf-yr cooling energy reduction plus a 0.24 kBtu/sf-yr *embedded energy in water* increase[3].

2. Passive Solar. For mass and insulated mass construction, in addition to the requirements of section 1.4.2, if all of the following passive solar elements are included, the initial *energy use intensity factor* may be decreased by 1.0 kBtu/sf-yr.

   a. Orientation per 1.3.1.1 is E-W

[3] See the report Energy versus Water, Evaporative Coolers as part of a Net-Zero Home for more information.

b. Vertical Fenestration. Allowable vertical fenestration as a percent of *conditioned floor area*:

- South: Minimum 5% and Maximum 7%
- North ≤ 8%
- East plus West Orientation ≤ 2%
- Skylights. ≤ 1%

c. Incorporate the design principles of the Arizona Solar Center "Passive Solar Heating & Cooling Manual".

Table 1.4.1 (1) *Energy Use Intensity* (EUI) *Factor* – kBtu/sf-yr

Construction Type[1]	Orientation	*Energy Use Intensity*	*Energy Use Intensity* with Bonus Measure
Frame	E-W	28.76	28.49
	N-S	28.68	28.55
	Off Axis	28.63	28.63
Mass	E-W	29.10[2]	28.27
	N-S	29.42[2]	29.42[2]
	Off Axis	29.49[2]	29.05[2]
Insulated Mass	E-W	26.48	25.61
	N-S	26.67	26.51
	Off Axis	26.65	26.21

1) See section 1.4.2.1 for definitions of construction type
2) Must use section 1.5, unless EUI is adjusted per 1.4.1.1

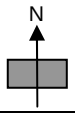
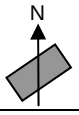
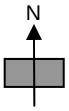
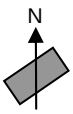
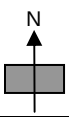
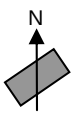
1.4.2. Requirements by building orientation and construction. Each building shall be classified according to its orientation per section 1.3.1.1 and construction as defined below.

1.4.2.1. Construction type: buildings are classified based on the exterior wall system as:

1. Frame: More than 10% of the exterior wall structure is wood or metal stud construction.
2. Mass: 90% or more of the exterior wall area is mass wall meeting the requirements of table 1.4.3 (1) #18.
3. Insulated Mass: 90% or more of the exterior wall area is mass wall meeting the requirements of table 1.4.3 (1) #18 and the exterior surface of the exterior wall is insulated per table 1.4.3 (1) #4.2.

1.4.2.2. Building Strategy Requirements: Based on the building orientation and construction type the building shall comply with the building strategy requirements in table 1.4.2.2 (1). The building strategy requirements required by table 1.4.2.2 (1) are listed in section 1.4.3. If the *energy use intensity* with bonus measure is being used, then the bonus strategy requirements shall be used in addition to the building strategy requirements.

Table 1.4.2.2 (1) Building Strategy Requirements

Construction Type	Orientation	Building Strategy Requirements	Bonus Strategy
Frame	E-W 	Design: 1.1, 2.1, 2.2.1 Building: 3, 4.1, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 16, 21 Operation: 11, 13, 14, 15, 25	10
	N-S 	Design: 1.2, 2.1, 2.2.2 Building: 3, 4.1, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 16, 21 Operation: 11, 13, 14, 15, 25	10
	Off Axis 	Design: 1.3, 2.1, 2.2.3 Building: 3, 4.1, 5, 6, 7, 8.5, 8.6, 9, 16, 21 Operation: 11, 13, 14, 15, 25	10
Mass	E-W 	Design: 1.1, 2.1, 2.2.1 Building: 3, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 16, 17, 18, 20, 21 Operation: 11, 13, 14, 15, 19, 25	10
	N-S 	Design: 1.2, 2.1, 2.2.2 Building: 3, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 16, 17, 18, 20, 21 Operation: 11, 13, 14, 15, 19, 25	10
	Off Axis 	Design: 1.3, 2.1, 2.2.3 Building: 3, 5, 6, 7, 8.5, 8.6, 9, 16, 17, 18, 20, 21 Operation: 11, 13, 14, 15, 19, 25	10
Insulated Mass	E-W 	Design: 1.1, 2.1, 2.2.1 Building: 3, 4.2, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 16, 17, 18, 20, 21 Operation: 11, 13, 14, 15, 19, 25	10
	N-S 	Design: 1.2, 2.1, 2.2.2 Building: 3, 4.2, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 16, 17, 18, 20, 21 Operation: 11, 13, 14, 15, 19, 25	10
	Off Axis 	Design: 1.3, 2.1, 2.2.3 Building: 3, 4.2, 5, 6, 7, 8.5, 8.6 , 9, 18, 16, 17, 20, 21 Operation: 11, 13, 14, 15, 19, 25	10

1.4.3. Building Strategies. The following building strategies shall be incorporated into the design, construction and operation of the building as required by table 1.4.2.2 (1).

Table 1.4.3 (1) Building Strategies

Element No.		**Strategy Name**	**Description**
1.		Orientation	
	1.1.	East/West	Per Section 1.3.1.1(1) E-W is any long *building axis* that is within plus or minus 15 degrees of true east-west.
	1.2.	North/South	Per Section 1.3.1.1(2) N-S is any long *building axis* that is within plus or minus 15 degrees of true north-south.
	1.3.	Off-Axis	Per Section 1.3.1.1(2) off Axis is any orientation that is not E-W or N-S
2.		Window Area	
	2.1.	*Window Floor Area Ratio*	WFA shall not exceed 20% of conditioned floor area.

	2.2.	Distribution	Window area shall be distributed according to building orientation as follows: 2.2.1. East/West Orientation: S≤18%, N≤6%, E and/or W≤2%. 2.2.2. North/South Orientation: S≤6%, N≤2%, E≤6%, and W≤6%. 2.2.3. Off-Axis: follow 1.1 or 1.2 recommendations depending on proximity to their orientation.
3.		Roof/ceiling Insulation	3.0.1. Total insulation value is R-50 with minimum R-12 continuous exterior insulation. 3.0.2. (Mandatory) Roof cavity insulation installation requirements: Insulation shall be installed at the roof deck. Joists or rafter cavities shall be filled with batt insulation intended for the depth of the joist or rafter. The remainder of the required R-value shall be achieved by batts installed perpendicular to the joists or rafters. Exception: foam or fill insulation applications and insulation above the roof deck
4.		Wall Insulation	
	4.1		Total insulation value is R-30 with minimum R-9 continuous exterior insulation.
	4.2		Mass walls per 1.3.4 (10) R-9 continuous exterior insulation.
5.		Roof Reflection	Roof exterior shall have minimum short wave reflection value of 0.65 for specific materials, textures, or colors.
6.		Wall Reflection	Wall exterior shall have minimum short wave reflection value of 0.60 for specific materials, textures, or colors.]
7.		Window Type	
	7.1.	Assembly U-value	Window assembly (frame and glass) shall have a maximum U-value of 0.24.
	7.2.	Assembly Solar Heat Gain Coefficient (SHGC)	Window assembly (frame and glass) shall have a maximum SHGC of 0.25.
	7.3.	Glass Visual Transmittance (VT)	Window glass shall have a maximum visual transmittance value of 0.40.
8.		Window Shading	See Appendix A
	8.1.	South	Choose between 8.1.1 or 8.1.2.
		8.1.1. Overhang Only	Window overhang depth shall have a projection factor equal to 0.4 x window height and overhang extensions on both sides equal to 1.0 x window height.
		8.1.2. Overhang and Vertical Fins	Window overhang depth shall have a projection factor equal to 0.4 x window height and vertical fins depth projection factor equal to 0.4 x window width on both sides of that window.
	8.2.	North Vertical Fins	Window vertical fins depth shall have a projection factor of 0.2 x window width.
	8.3.	East	Choose between 8.3.1 or 8.3.2.
		8.3.1. Overhang Only	Window overhang depth shall have a projection factor equal to 1.0 x

			window height and left overhang extension equal to 0.875 x window height.
		8.3.2. Overhang and Vertical Fins	Window overhang depth shall have a projection factor equal to 1.0 x window height and left vertical fin depth projection factor equal to 1.0 x window width.
	8.4.	West	Choose between 8.4.1 or 8.4.2.
		8.4.1. Overhang Only	Window overhang depth shall have a projection factor equal to 1.0 x window height and right overhang extension equal to 0.875 x window height.
		8.4.2. Overhang and Vertical Fins	Window overhang depth shall have a projection factor equal to 1.0 x window height and right vertical fin depth projection factor equal to 1.0 x window width.
	8.5.	South East and South West	Choose between 8.5.1 or 8.5.2.
		8.5.1. Overhang Only	Window overhang depth shall have a projection factor equal to 0.7 x window height and overhang extensions on both sides equal to 0.7 x window height.
		8.5.2. Overhang and Vertical Fins	Window overhang depth shall have a projection factor equal to 0.7 x window height and vertical fins depth projection factor equal to 0.7 x window width on both sides of that window.
	8.6.	North East and North West Vertical Fins	Window vertical fins depth shall have a projection factor of 0.6 x window width.
9.		Infiltration	(Mandatory) Building envelope tightness shall be ≤3 air changes per hour (ACH) when tested with a blower door at a pressure of 50 pascals (0.15 ACH natural).
10.		Daylight	
	10.1.	Number of Sensors	Each day lit zone shall be equipped with a minimum of 1 sensor centrally located with a maximum 10 ft. distance from exterior wall.
	10.2.	Light Intensity	Sensors shall be activated at a minimum daylight intensity of 30 foot candles (fc) or higher.
	10.3.	Light Control	Sensors shall operate using on/off mode and controlling 100% of electric lights in each zone.
11.		Interior Light Power Density (LPD)	(Mandatory) All lighting shall be high efficacy compact florescent (CFL) or LED. The maximum installed wattage of all installed interior lamps shall not exceed 0.3 watts/square foot per gross square feet. Formula: Total Installed Wattage / Gross Square Feet ≤ 0.30 watt/gsf
12.		Exterior Light Power Density	NA
13.		Equipment Power Density	All non heating ventilating and air conditioning (HVAC) appliances and interior equipment shall be energy star qualified. Equipment power density for all non-HVAC appliances and interior equipment shall not exceed 0.40 watts/gross square foot calculated as follows: Formula: (equipment 1 wattage x annual time of use 1) +. (equipment 2 wattage x annual time of use 2) + (equipment n wattage x annual time of use n) / Gross Square Feet ≤

<table>
<tr><td></td><td></td><td></td><td>0.40 watt/gsf
The following tools can be used to calculate the to calculate the equipment power density:
1. Wisconsin Public Service Electric appliance calculator at: http://www.wisconsinpublicservice.com/home/electric_calculator.aspx
2. Department of Energy Home Energy Saver, use the Describe tab and detailed input and Compare: details</td></tr>
<tr><td>14.</td><td></td><td>Interior Blinds/Drape</td><td>All windows shall have an interior horizontal light colored shading device that is 20% closed on all orientations when occupied and 80% closed on all orientations when unoccupied.</td></tr>
<tr><td>15.</td><td></td><td>Thermostat</td><td>An energy star qualified programmable thermostat shall be installed. The thermostat shall initially be programmed with the following set points[4].
Exception: the set points for Saturday and Sunday may have a Heat-Day set point of 66 and a Cool-Day set point of 78.
Thermostat Set points
<table>
<tr><th>Setting</th><th>Time</th><th>Set point Temperature (Heat)</th><th>Set point Temperature (Cool)</th></tr>
<tr><td>Wake</td><td>6:00 a.m.</td><td>66°F (alt 248 for °)</td><td>78°F</td></tr>
<tr><td>Day</td><td>8:00 a.m.</td><td>65°F</td><td>80°F</td></tr>
<tr><td>Evening</td><td>6:00 p.m.</td><td>66°F</td><td>78°F</td></tr>
<tr><td>Sleep</td><td>10:00 p.m.</td><td>65°F</td><td>80°F</td></tr>
</table></td></tr>
<tr><td>16.</td><td></td><td>HVAC Efficiency</td><td></td></tr>
<tr><td></td><td>16.1</td><td>Equipment Efficiency</td><td>Minimum HVAC operating efficiency for cooling shall be SEER 19.1 or equivalent, and for heating HSPF 10.3 or equivalent. All air handlers shall be installed within the thermal envelope.</td></tr>
<tr><td></td><td>16.2</td><td>Duct work Efficiency</td><td>(Mandatory) All duct work shall be installed within the thermal envelope and sealed with mastic. Tape is not permitted.</td></tr>
<tr><td></td><td>16.3</td><td>Exhaust Fan Efficiency</td><td>17.0.1. (Mandatory) Bathroom exhaust fans and kitchen hood fans shall be energy star qualified.
17.0.2. (Mandatory) Ceiling Fans shall be energy star qualified.</td></tr>
<tr><td>17.</td><td></td><td>Exposed Concrete Slab</td><td>Concrete slab surfaces, or ceramic tile directly adhered to concrete slab with mortar, surfaces located in direct day lit zones shall be exposed 80% or more (e.g., eliminate wall to wall carpeting and allow minimum area rugs). Slab surfaces in indirect day lit zones shall be exposed 50% or more.</td></tr>
<tr><td>18.</td><td></td><td>Exterior Thermal Mass Walls</td><td>Exterior thermal mass walls shall use materials that have volumetric heat capacity values between 18 to 30 Btu/ft^3.°F, and a thickness of at least 12 inch minimum or 8 hour time lag.
Exception: water walls may be used for Mass or Insulated Mass construction complying with section 1.4.1.1(2) Passive Solar.
Formula: Specific Heat (Btu/lb.°F) x Density (lb/cubic foot) = Volumetric</td></tr>
</table>

[4] Energy Star has a higher heating wake set point (70) and a more aggressive set backs (heating 62, cooling 85 day, 82 night). See: http://www.energystar.gov/ia/partners/product_specs/eligibility/thermostats_elig.pdf

			Heat Capacity Example: Adobe = 0.22 Btu/lb.°F x 95 lb/ft^3 (density) = 20.9 Btu/ft^3.°F See Appendix B for sample calculations and calculator
19.		Night Ventilation	Thermal mass designs shall be provided with a means of venting the interior building air to the outside at night during the months of May through October to discharge daytime stored heat in the mass to avoid overheating. Operable windows totaling at least 20 percent of the total glazing area, equally divided between inlet and outlet (10% each), and located for effective natural cross ventilation. At a minimum each room except bathrooms shall have at least one operable opening. Or, a whole-house ventilation system designed to provide at least 20 air changes per hour shall be installed.
20.		Interior Thermal Storage Capacity	Add interior thermal mass materials such as ceramic countertops, 5/8" gypsum board, interior masonry features or heavy furniture that will have a volumetric heat capacity (calculated per #18) per inch thick of 0.5 Btu/in.ft^2.°F per square foot of the building. Formula: Volumetric Heat Capacity / 12 = volumetric heat capacity per inch Volumetric heat capacity per inch * thickness in inches = Installed material heat capacity Installed material heat capacity / 0.5 = Area Factor Conditioned Square feet / Area Factor = Required amount of material See Appendix B for sample calculations and calculator
21.		Plumbing	
	21.1	Domestic Solar Hot Water (DSHW)	21.1.1. (Mandatory) Install high efficiency domestic solar hot water heater with a solar fraction ≥ 75. The solar fraction is calculated as follows: Solar Fraction = $\frac{1 - \text{Energy Factor}_{\text{back up}}(EF)}{\text{Solar Energy Fraction (SEF)}}$ A solar fraction calculator is located at: http://www.pimaxpress.com/Documents/Green/Solar%20Fraction%20Calculator%20for%20Solar%20Hot%20Water%20Systems.xls 21.1.2 Backup hot water heating equipment if installed, shall be energy star qualified.
	21.2	Hot water distribution	(Mandatory) All domestic hot water piping, including sub-slab pipes, shall have R-4 insulation. Insulation shall be properly installed on all piping elbows to adequately insulate the 90-degree bend. Recirculating pumps, if installed, shall be demand controlled.
	21.3	Plumbing Fixtures.	(Mandatory) 21.3.1. Lavatory Faucets: Each faucet or faucet aerator shall be WaterSense Certified and meet an average rated flow volume of ≤ 1.25 gallons per minute (gpm) across all lavatory faucets. 21.3.2. Showerheads: Each fixture/fitting shall be WaterSense Certified and meet an average rated flow volume of ≤ 1.75 gallons per minute (gpm) per shower compartment. 21.3.3. Toilets: Each fixture/fitting shall be WaterSense Certified and meet

			an average rated flush volume of ≤ 1.1 gallons per flush (gpf) across all toilets. 21.3.4. Clothes Washer: Each clothes washer shall be Energy Star qualified with a water factor ≤6.0.
22.		Economizer	N/A
23.		Variable Air Volume Fan (VAV)	N/A
24.		Energy Recovery Ventilators (ERV)	N/A
25.		Landscaping	(Mandatory) All landscape plant material shall be from the Arizona Department of Water Resources (ADWR) Tucson Active Management Area (TAMA) plant list Water Use Factor 1 or 2. http://www.azwater.gov/AzDWR/StatewidePlanning/Conservation2/Documents/documents/2010_TAMA_DYWU_PLANTLIST.pdf Exception: a. An oasis area that complies with City of Tucson Development Standard 2-06.3.2 Oasis Allowance is permitted. b. Fruit trees and vegetable gardens watered with rain water and/or grey water as follows: Install a rainwater catchment system that meets the requirements per the calculations per Texas A&M Rainwater Harvesting online calculator at http://rainwaterharvesting.tamu.edu/files/2011/05/Tucson.xls. Use a plant water use coefficient of high. Result shall indicate that no potable water is required in year 2. If a grey water system is installed per the following, the available rainwater storage value in the calculation above maybe reduced by ½. Install a grey water system sized per California Plumbing Code, Title 24, Part 5, Chapter 16, Sections 1606A.0, 1607A, 1608A, 1611A, 1611B. http://www.hcd.ca.gov/codes/shl/2007CPC_Graywater_Complete_2-2-10.pdf

1.4.4. Pools and Spas. If a pool and/or spa is to be installed, the following requirements shall be met.

1.4.4.1. Provide cover to prevent evaporation per Pima County amendment to the IRC Appendix G section AG 101.

1.4.4.2. Water heating if provided, by solar system only.

1.4.4.3. *Energy use intensity* shall be as follows:

Pumping energy:

Pool = 5,000 kWh/yr x 3.412 = 17,060 kBtu/yr

Spa = 2,500 kWh/yr x 3.412 = 8,530 kBtu/yr

Embedded energy in water:

Capacity of the pool/spa in gallons[5] x 0.0503 kBtu/gal = *Embedded energy in water* kBtu/yr

[5] "Water Conservation in Pima County." *Water Resources Research Center*. University Of Arizona, 2001. Web. 06 Sept. 2011. p.9 <http://ag.arizona.edu/AZWATER/publications/conservation/conserve.pdf>. This study indicates that the annual water use is approximately the capacity of the pool

Pumping Energy + *Embedded Energy in Water* / conditioned square feet = EUI_{pool}

Exception: An alternative EUI_{pool} may be presented to the building official for approval.

1.4.4.4. Photo voltaic panels shall be installed to produce on an annual basis sufficient electrical energy to meet the EUI_{pool} as follows: If EUI factor per 1.4.1 + EUI_{pool} ≤ *Energy Budget* Factor per Tables 1.3.1.5, install panels on roof of building. Otherwise install panels on a shade structure or ramada adjacent to the pool.

1.4.5. Documentation. Construction documents shall clearly indicate all requirements of section 1.3 including but not limited to:

1. On the cover page a clearly delineated note section with the following information:
   a. *Energy budget* development per section 1.3 with orientation, type of roof, shape, number of stories and the *energy budget* factor.
   b. *Energy use intensity* (EUI) *factor* per 1.3.2, including any adjustments claimed.
   c. Calculation of the WFA and distribution.
   d. Roof and wall reflectance.
   e. Calculated light power density.
   f. Calculated equipment power density.
   g. For mass and insulated mass construction: provide the percent of exposed concrete slab and location of interior thermal storage capacity.
2. The building strategy requirements per section 1.4.3 shall be clearly shown in the drawings and noted using the phrase "strategy #" where "#"is the number that corresponds to the required strategy, e.g. "strategy 3" = Roof/ceiling insulation requirements.
3. If installed, the location of fruit trees and area of vegetable garden, rainwater harvesting calculation and grey water calculation.

1.5. Simulated Performance Path Compliance

1.5.1. Scope. This section establishes the criteria for compliance using an energy simulation tool.

1.5.2. Compliance with this section requires that the mandatory provisions identified in Section 401.2 of the IECC (2006) and section 1.3.4 if this standard be met.

1.5.3. *Energy Budget* Simulation. Photo-voltaic panels and/or solar thermal panels shall be limited to the roof area of the building including porches, garages and carports.

1.5.4. *Energy Use Intensity* Simulation. *Energy use intensity* simulation of the proposed building shall be modeled per section 405 with the following exceptions:

1. All energy consuming systems, including plug load, pools and spas shall be included.
2. The *embedded energy in water* shall be included as 2.1 kBtu/sf-yr.

   Exception: the individual completing the compliance report (energy modeler) may provide alternate calculations for interior and exterior *embedded energy in water* demonstrating a lower value.
3. Results shall be reported in kBtu/sf-yr site energy

1.5.5. The simulated *energy use intensity* minus the simulated *energy budget*, including the *embedded energy in water* shall be equal to or less than zero to comply with this section.

1.5.6. Approved energy performance simulation software: eQuest, Energy 10, REM/Rate, REM/Design, Home Energy Saver and BEOpt are approved for use.

1.5.7. Documentation. Provide documentation per section 405.4.3. The plans shall clearly indicate all of the building elements noted in the building file output of the energy modeling software.

1.6. Net-Zero Energy Upgrade:

1.6.1. Scope. The provisions of this section shall apply to the alteration, movement, enlargement, replacement, repair, equipment, of existing buildings.

1.6.2. All work contributing to the net-zero energy upgrade shall be permitted at one time.

1.6.3. Prescriptive Path: (Due to the variation in existing building construction, there is no express or implied warranty that compliance with section will result in net-zero.) Each net-zero energy upgrade shall, at a minimum, complete the following building strategy requirements[6]. Additional work not listed in the tables shall comply with Section 1.4.3.

Table 1.6.3(1) Upgrade Building Strategy Requirements

Building Age	Building Strategy Requirements
Buildings with original construction prior to 1940	1, 2, 3, 4 ,5, 6, 7, 8, 9, 10, 11, 12,13
Buildings with original construction from 1940 to 1975	1, 2, 3, 4 ,5, 7, 8, 10, 11, 12,13
Buildings with original construction after 1975	1, 2, 4 , 7, 8, 10, 11, 12,13

1.6.4. Upgrade Building Strategies. The following building strategies shall be incorporated into the design, construction and operation of the building as required by table 1.6.3 (1).

Table 1.6.4 (1) Upgrade Building Strategy Requirements

Element No.	**Strategy Name**	**Description**
1.	Indoor Lights	Indoor Lights per 1.4.3 (11)
2.	Infiltration	(Mandatory) Building envelope tightness shall be ≤5 air changes per hour (ACH) when tested with a blower door at a pressure of 50 pascals (0.25 ACH natural) Exception: Buildings built in or before 1975 shall be ≤7 ACH_{50} (0.35 ACH Natural)
3	Duct Insulation	Duct Insulation shall be R6, unless ducts are completely within the building thermal envelope.
4.	Duct Sealing	(Mandatory) Ducts shall be sealed per IECC Section R403.2.2
5.	Attic Insulation	Attic insulation shall be a minimum of R38
6.	Wall Insulation	Wall insulation shall be a minimum of R19. Exception: Mass walls shall be R-9 continuous exterior insulation.
7.	Clothes Dryer	(Mandatory) Clothes Dryer, if installed shall be energy star qualified.
8.	Plumbing Fixtures	(Mandatory) Plumbing fixtures shall comply with 1.3.4 (22.3)
9.	Windows	Windows shall comply with 1.3.4 (7)

[6]The source of data for tables 1.6.4 is: "Reducing Home Energy Costs by Combining Solar and Energy Efficiency." Westinghouse Solar, Nov. 2010. Web. 26 Aug. 2011. <http://www.westinghousesolar.com/images/stories/Resources/Whitepaper.pdf>. All elements with a payback of less than 20 years are included.

10.	HVAC	Replace HVAC per 1.4.3 (16.1) Exception HVAC with a SEER > 13 or < 10 years old and proper sizing confirmed by ACCA Manual J. Programmable thermostat per 1.4.3 (15)
11.	Domestic Solar Hot Water System	(Mandatory) DSHW System shall be installed per 1.3.4 (21.1)
12.	Solar Photovoltaic System	Install a solar photovoltaic system sized to meet 60% of the pre-renovation three year average annual energy plus 60% of the three year average annual *embedded energy in water*. Use formula 1.8.1 to determine each year's energy use.
13.	Landscaping	(Mandatory) Install landscaping per section 1.3.4 (25) Exception: Existing trees 20 or more feet in height that are not on the ADWR TAMA plant list, may remain if they are watered in part per 1.3.4 (25) exception b: Rainwater and/or grey water system.

1.6.5. Upgrade Performance Path: Comply with section 1.5. (Project teams are strongly encouraged to use the performance path for the design of net-zero energy upgrades.)

1.7. General Documentation Requirements:

1.7.1. When submitting a permit application, clearly note on the submittal that the project is attempting net-zero certification per section 1 of the IECC.

1.7.2. Clearly note the compliance path and all necessary calculations on the submittal documents. If the on-line calculator was used, include the "recipe card."

1.7.3. Include specific documentation requirements per 1.4.5 or 1.5.7.

1.7.4. Operator and Occupant training and education**:**

1.7.4.1. Provide a copy of the building owner's manual that explains the benefits, features and operation of the net-zero strategies.

1.7.4.2. Provide either 1) documentation of a one-hour training session or, 2) a copy of the builders plan for a minimum one hour training session with the owner or occupant that explains the benefits, features and operation of the net-zero strategies.

1.8. Performance Documentation. After one year of continuous operation by applicant, submit a calculation and utility bills confirming net-zero as follows:

1.8.1. Formula: PV production – [Gas + Electric + (water * energy)] ≥ 0

Note: A positive number means that the building is an annual net positive producer of energy.

PV production = AC electrical production of on site photovoltaic panels in kBtu (kWh * 3.412 = kBtu)

Gas = gas use for the year in kBtu

Electric = electricity use for the year in kBtu (kWh * 3.412 = kBtu)

Water = gallons of water used for the year

Energy = 0.0503 kBtu/gal for the energy embedded in water

Note: solar thermal production is automatically accounted for by the deferment of gas or electrical consumption.

1.8.2. If the result of formula 1.8.1 is zero or a positive number, the building official will issue a certificate of net-zero compliance.

Section 2 Commercial Net-Zero Energy Building Alternative

2.1. Scope. This section establishes criteria for compliance with the 2012 IECC using the *net-zero energy building* alternative. Minimum requirements in of the 2012 IECC shall be met as applicable. Each building shall be designed either per section 2.4, 2.5 or 2.6.

Exception: buildings located at 4,000 feet elevation and above shall use section 2.5.

Note: *Net-zero energy buildings* are high performance buildings. It is recommended that building teams use the simulated performance path (section 2.5). The prescriptive path (section 2.4) provides an alternative path with a conservative (low) estimate of the *energy budget factor* and a conservative estimate (high) of the *energy use intensity factor*.

2.2. Definitions. See Section 1.2

2.3. Energy Budget Development. Each building shall have an *energy budget factor* based on the following criteria:

2.3.1.1. Orientation. The alignment of the longest *building axis* with respect to geographical compass points shall be classified as one of the following:

1. E-W (east-west) is any long *building axis* that is within plus or minus 15 degrees of true east-west. [See Appendix C, Sketch 1]

2. N-S (north-south) is any long *building axis* that is within plus or minus 15 degrees of true north-south. [See Appendix C, Sketch 2]

3. Off axis is any orientation that is not E-W or N-S.

2.3.1.2. Type of Roof. Each roof type shall be classified as one of the following:

1. Flat Perimeter Parapets only. A roof that is ≤ 2:12 pitch with a parapet only at the exterior walls.

2. Flat Perimeter and Interior Parapets. A roof that is ≤ 2:12 pitch with a parapet at the exterior walls and vertical changes of level < six inches and/or additional parapets inside the exterior wall parapets and/or mechanical equipment with a footprint > 5% of the roof area.

3. Low Pitch ≤ 2:12. A roof that is ≤ 2:12 pitch without parapets.

4. High Pitch > 2:12. A roof that is > 2/12 pitch without parapets

2.3.1.3. Shape: The building plan floor plan shape shall be categorized as one of the following:

1. Rectangle: The floor plan long *building axis* is > 1.3 times the length of the short *building axis* and no more than eight *exterior corners*. [See Appendix C, Sketch 2]

2. Square: The floor plan long *building axis* is ≤ 1.3 times the length of the short *building axis* of the home and no more than eight *exterior corners*. [See Appendix C, Sketch 2]

3. Irregular: Floor plans that are not a rectangle or a square and buildings with curved exterior walls.

2.3.1.4. Number of stories

1. One story use tables in section 2.3.1.5.

2. Two stories use tables in section 2.3.1.5 to determine the *energy budget factor* and divide by two.

3. Three stories or more use section 2.5.

2.3.1.5. Each building shall have an *energy budget factor* which shall be the lower of the value from Tables 2.3.1.5 (1), (2), or 2.3.1.5 (3). Based on the *energy budget factor* buildings shall comply as follows:

1. If the *energy use intensity factor* per table 2.4.1 is less than or equal to the *energy budget* factor, Section 2.4 or 2.5.
2. All other *energy use intensity factors*, section 2.5.

The commercial *energy budget* calculator at http://www.pima.gov/netzero/energy-calc.shtml may be used to calculate the *energy budget factor* and the *energy use intensity factor*. Complete the on-line calculator and include the "recipe card" with the plan review submittal.

Table 2.3.1.5 (1) One Story *Energy Budget Factor* kBtu/sf-yr – Rectangle or Square

Orientation	Type of Roof			
	Flat-Perimeter Parapets Only	Flat- Perimeter and Interior Parapets	Pitch ≤ 2:12	Pitch > 2:12
E-W	37.5[1] (50%)	22.5 (30%)	67.6 (90%)	33.8 (45%)
N-S	33.8 (45%)	22.5 (30%)	67.6 (90%)	33.0 (44%)
Off Axis	30 (40%)	18.8 (25%)	67.6 (90%)	Use Section 2.5

1) First number is kBtu/sf-yr (Number in parenthesis is the percentage of roof covered with photo voltaic and/or solar thermal panels used to model the *Energy Budget*)

Table 2.3.1.5 (2) One Story *Energy Budget Factor* kBtu/sf-yr – Irregular

Orientation	Type of Roof			
	Flat-Perimeter Parapets Only	Flat- Perimeter and Interior Parapets	Pitch ≤ 2:12	Pitch > 2:12
E-W	28.1 (38%)	16.9 (23%)	50.7 (68%)	25.3 (34%)
N-S	25.3 (34%)	16.9 (23%)	50.7 (68%)	24.8 (33%)
Off Axis	22.5 (30%)	14.1 (19%)	50.7 (68%)	Use Section 2.5

Table 2.3.1.5 (3) Maximum *Energy Budget Factor* kBtu/sf-yr by Occupancy

Building Occupancy Types	*Energy Budget Factor* kBtu/sf-yr	*Embedded Energy in Water*	Total
Business Group B	18.70	1.30	20.00
Mercantile Group M	18.70	3.10	21.80
Residential Group R[1]	21.40	2.10	23.50
All other occupancies	Use Section 2.5		

1) Except Detached one-and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories above grade plane in height with a separate means of egress, use section 1.

2.3.1.6. Each building shall have solar photovoltaic panels installed on the roof of the building that shall produce on an annual basis sufficient electrical energy to equal or exceed the *energy budget* factor multiplied by the conditioned square feet of the building.

2.4. Prescriptive Path Compliance

2.4.1. Energy Use Intensity Factor Development. Each building shall have an *energy use intensity factor* based on occupancy, construction type and orientation as follows:

Table 2.4.1 (1) Group B *Energy Use Intensity* (EUI) *Factor* – kBtu/sf-yr

Construction Type[1]	Orientation	*Energy Use Intensity*	*Energy Use Intensity* with Bonus Measure		
			Economizer	VAV	ERV
Frame	E-W	17.54	17.49	13.55	16.62
	N-S	18.11	18.06	14.09	17.15
	Off Axis	17.94	17.89	13.87	17.02
Mass	E-W	19.64	17.49	16.48	18.79
	N-S	18.29	18.28	15.48	17.32
	Off Axis	20.87[2]	20.85[2]	17.97	19.29
Insulated Mass	E-W	18.21	18.20	15.34	17.37
	N-S	16.78	16.77	14.09	15.79
	Off Axis	16.55	16.53	13.74	15.59

1) See section 2.4.2.1 for definitions of construction type
2) Must use section 2.5

Table 2.4.1 (2) Group M *Energy Use Intensity* (EUI) *Factor* – kBtu/sf-yr

Construction Type[1]	Orientation	*Energy Use Intensity*	*Energy Use Intensity* with Bonus Measure		
			Economizer	VAV	ERV
Frame	E-W	19.34	19.29	15.35	18.42
	N-S	19.91	19.86	15.89	18.95
	Off Axis	19.74	19.69	15.67	18.82
Mass	E-W	21.44	19.29	18.28	20.59
	N-S	20.09	20.08	17.28	19.12
	Off Axis	22.67[2]	22.65[2]	19.77	21.09
Insulated Mass	E-W	20.01	20.00	17.14	19.17
	N-S	18.58	18.57	15.89	17.59
	Off Axis	18.35	18.33	15.54	17.39

1) See section 2.4.2.1 for definitions of construction type
2) Must use section 2.5

Table 2.4.1 (3) Group R[1] *Energy Use Intensity* (EUI) *Factor* – kBtu/sf-yr

Construction Type[2]	Orientation	*Energy Use Intensity*	*Energy Use Intensity* with Bonus Measure Economizer
Frame	E-W	21.53	21.35
	N-S	20.96	20.08
	Off Axis	21.17	21.00
Mass	E-W	23.99[3]	23.98[3]
	N-S	23.30	23.29
	Off Axis	23.76[3]	23.75[3]
Insulated Mass	E-W	20.15	20.14
	N-S	19.96	19.95
	Off Axis	20.06	20.05

1) Except Detached one-and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories above grade plane in height with a separate means of egress, use section 1.
2) See section 2.4.2.1 for definitions of construction type
3) Must use section 2.5

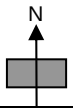
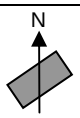
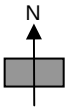
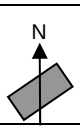
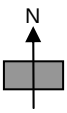
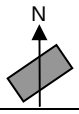
2.4.2. Requirements by building orientation and construction. Each building shall be classified according to its orientation per section 2.3.1.1 and construction as defined below.

2.4.2.1. Construction type: buildings are classifies based on the exterior wall system as:

1. Frame: More than 10% of the exterior wall structure is wood or metal stud construction.
2. Mass: 90% or more of the exterior wall area is mass wall meeting the requirements of table 2.4.3 (1) #18.
3. Insulated Mass: 90% or more of the exterior wall area is mass wall meeting the requirements of table 2.4.3 (1) #18 and the exterior surface of the exterior wall is insulated per table 2.4.3 (1) #4.2.

2.4.2.2. Building Strategy Requirements: Based on the building orientation and construction type the building shall comply with the Building Strategy Requirements in Table 2.4.2.2 (1). The building strategy requirements required by Table 2.4.2.2 (1) are listed in section 2.4.3. If the *Energy Use Intensity* with Bonus Measure is being used, then the Bonus Strategy Requirements shall be used in addition to the Building Strategy Requirements.

Table 2.4.2.2 (1) Building Strategy Requirements Groups B, M & R

Construction Type	Orientation	Building Strategy Requirements	Bonus Strategy
Frame	E-W 	Design: 1.1, 2.1, 2.2.1 Building: 3, 4.1, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 10, 16, 21 Operation: 11, 12,13, 14, 15, 25	22, 23, or 24 Group R = 22
	N-S 	Design: 1.2, 2.1, 2.2.2 Building: 3, 4.1, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 10, 16, 21 Operation: 11, 12,13, 14, 15, 25	22, 23, or 24 Group R = 22
	Off Axis 	Design: 1.3, 2.1, 2.2.3 Building: 3, 4.1, 5, 6, 7, 8.5, 8.6, 9, 10, 16, 21 Operation: 11, 12,13, 14, 15, 25	22, 23, or 24 Group R = 22
Mass	E-W 	Design: 1.1, 2.1, 2.2.1 Building: 3, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 10, 16, 17, 18, 20, 21 Operation: 11, 12,13, 14, 15, 19, 25	22, 23, or 24 Group R = 22
	N-S 	Design: 1.2, 2.1, 2.2.2 Building: 3, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 10, 16, 17, 18, 20, 21 Operation: 11, 12,13, 14, 15, 19, 25	22, 23, or 24 Group R = 22
	Off Axis 	Design: 1.3, 2.1, 2.2.3 Building: 3, 5, 6, 7, 8.5, 8.6, 9, 10, 16, 17, 18, 20, 21 Operation: 11, 12,13, 14, 15, 19, 25	22, 23, or 24 Group R = 22
Insulated Mass	E-W 	Design: 1.1, 2.1, 2.2.1 Building: 3, 4.1, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 10, 16, 17, 18, 20, 21 Operation: 11, 12,13, 14, 15, 19, 25	22, 23, or 24 Group R = 22
	N-S 	Design: *1.2, 2.1, 2.2.2 Building: *3, 4.1, 5, 6, 7, 8.1, 8.2, 8.3 8.4, 9, 10, 16, 17, 18, 20, 21 Operation: *11, 12,13, 14, 15, 19, 25	22, 23, or 24 Group R = 22
	Off Axis 	Design: *1.3, 2.1, 2.2.3 Building: *3, 4.1, 5, 6, 7, 8.5, 8.6 , 9, 16, 10, 17, 18, 20, 21 Operation: *11, 12,13, 14, 15, 19, 25	22, 23, or 24 Group R = 22

2.4.3. Building Strategies. The following building strategies shall be incorporated into the design, construction and operation of the building as required by table 2.4.2.2 (1).

Table 2.4.3 (1) Building Strategies

Element No.		**Strategy Name**	**Description**
1.		Orientation	
	1.1.	East/West	Per section 2.3.1.1 (1) E-W is any long *building axis* that is within plus or minus 15 degrees of true east-west.
	1.2.	North/South	Per section 2.3.1.1 (2) N-S is any long *building axis* that is within plus or minus 15 degrees of true north-south.
	1.3.	Off-Axis	Per Section 2.3.1.1 (3) off Axis is any orientation that is not E-W or N-S

2.		Window Area	
	2.1.	*Window Floor Area Ratio*	WFA shall not exceed the percentage of conditioned floor area as follows: Group B = 32% Group M = 32% Group R = 30%
	2.2.	Distribution	Window area shall be distributed according to building orientation as follows: 2.2.1. East/West Orientation: Group B & M: S≤18%, N≤18%, E and/or W ≤8%. Group R: S=12%, N=12%, E=4%, and W=2%. 2.2.2. North/South Orientation: Group B & M: S=6%, N=2%, E=12%, and W=12%. Group R: S=4%, N=2%, E=12%, and W=12%. 2.2.3. Off-Axis: follow 1.1 or 1.2 recommendations depending on proximity to their orientation. Note: Group R window orientation is per building
3.		Roof/ceiling Insulation	3.0.1. Total insulation value is R-50 with minimum R-12 continuous exterior insulation. 3.0.2. (Mandatory) Roof cavity insulation installation requirements: Insulation shall be installed at the roof deck. Joists or rafter cavities shall be filled with batt insulation intended for the depth of the joist or rafter. The remainder of the required R-value shall be achieved by batts installed perpendicular to the joists or rafters. Exception: foam or fill insulation applications and insulation above the roof deck
4.		Wall Insulation	
	4.1		Total insulation value is R-30 with minimum R-9 continuous exterior insulation.
	4.2		Mass walls per 1.3.4 (10) R-9 continuous exterior insulation.
5.		Roof Reflection	Roof exterior shall have minimum short wave reflection value of 0.65 for specific materials, textures, or colors.
6.		Wall Reflection	Wall exterior shall have minimum short wave reflection value of 0.60 for specific materials, textures, or colors.
7.		Window Type	
	7.1.	Assembly U-value	Window assembly (frame and glass) shall have a maximum U-value of 0.24.
	7.2.	Assembly Solar Heat Gain Coefficient (SHGC)	Window assembly (frame and glass) shall have a maximum SHGC of 0.25.
	7.3.	Glass Visual Transmittance (VT)	Window glass shall have a maximum visual transmittance value of 0.40.

8.		Window Shading	See Appendix A
	8.1.	South	Choose between 8.1.1 or 8.1.2.
		8.1.1. Overhang Only	Window overhang depth shall have a projection factor equal to 0.4 x window height and overhang extensions on both sides equal to 1.0 x window height.
		8.1.2. Overhang and Vertical Fins	Window overhang depth shall have a projection factor equal to 0.4 x window height and vertical fins depth projection factor equal to 0.4 x window width on both sides of that window.
	8.2.	North Vertical Fins	Window vertical fins depth shall have a projection factor of 0.2 x window width.
	8.3.	East	Choose between 8.3.1 or 8.3.2.
		8.3.1. Overhang Only	Window overhang depth shall have a projection factor equal to 1.0 x window height and left overhang extension equal to 0.875 x window height.
		8.3.2. Overhang and Vertical Fins	Window overhang depth shall have a projection factor equal to 1.0 x window height and left vertical fin depth projection factor equal to 1.0 x window width.
	8.4.	West	Choose between 8.4.1 or 8.4.2.
		8.4.1. Overhang Only	Window overhang depth shall have a projection factor equal to 1.0 x window height and right overhang extension equal to 0.875 x window height.
		8.4.2. Overhang and Vertical Fins	Window overhang depth shall have a projection factor equal to 1.0 x window height and right vertical fin depth projection factor equal to 1.0 x window width.
	8.5.	South East and South West	Choose between 8.5.1 or 8.5.2.
		8.5.1. Overhang Only	Window overhang depth shall have a projection factor equal to 0.7 x window height and overhang extensions on both sides equal to 0.7 x window height.
		8.5.2. Overhang and Vertical Fins	Window overhang depth shall have a projection factor equal to 0.7 x window height and vertical fins depth projection factor equal to 0.7 x window width on both sides of that window.
	8.6.	North East and North West Vertical Fins	Window vertical fins depth shall have a projection factor of 0.6 x window width.
9.		Infiltration	(Mandatory) Building envelope tightness shall be as follows: Group B & M ≤7 air changes per hour (ACH) when tested with a blower door at a pressure of 50 pascals (0.35 ACH natural) Group R: ≤3 air changes per hour (ACH) when tested with a blower door at a pressure of 50 pascals (0.15 ACH natural)
10.		Daylight	

	10.1.	Number of Sensors	Each day lit zone shall be equipped with a minimum of 1 sensor per section 505.2.2.3 without exception, centrally located with a maximum 10 ft.

			distance from exterior wall.
	10.2.	Light Intensity	Sensors shall be activated at a minimum daylight intensity of as follows: Group B & M: 40 foot candles (fc) or higher. Group R: 30 foot candles (fc) or higher.
	10.3.	Light Control	Sensors shall operate using on/off mode and controlling 100% of electric lights in each zone. Exception: sensors that continuously dim from 100% to 0% of electric lights, reaching 0% electric light at the values per #10.2
11.		Interior Light Power Density (LPD)	(Mandatory) All lighting shall be high efficacy compact florescent (CFL) or LED. The maximum installed wattage of all installed interior lamps shall not exceed as follows: Group B & M LPD: 0.78 watts/square foot per gross square feet. Group R LPD: 0.30 watts/square foot per gross square feet. Formula: Total Installed Wattage / Gross Square Feet ≤ LDP watts/gsf
12.		Exterior Light Power Density	(Mandatory) The maximum installed wattage of all exterior lighting shall be as follows: Group B & M: 0.63 watts/square foot per gross square foot of building area Group R: N/A Formula: Total Installed Wattage / Gross Square Feet ≤ 0.63 watts/gsf
13.		Equipment Power Density (EPD)	All non heating ventilation and air conditioning (HVAC) appliances and interior equipment shall be energy star qualified. Equipment power density (EPD) for all non-HVAC appliances and interior equipment shall not exceed: Group B & M: ≤0.46 watts/ gross square foot. Group R: ≤0.63 watts/gross square foot Equipment power density shall be calculated as follows: Formula: (equipment 1 wattage x annual time of use 1) + (equipment 2 wattage x annual time of use 2) + (equipment n wattage x annual time of use n) / Gross Square Feet ≤ EPD watts/gsf The following tools are residential based, but can be used to calculate the to calculate the equipment power density: 1. Wisconsin Public Service Electric appliance calculator at: http://www.wisconsinpublicservice.com/home/electric_calculator.aspx

<table>
<tr><td></td><td></td><td></td><td>2. and Compare: details</td></tr>
<tr><td>14.</td><td></td><td>Interior Blinds/Drape</td><td>All windows shall have an interior horizontal light colored shading device that is 20% closed on all orientations when occupied and 80% closed on all orientations when unoccupied.</td></tr>
<tr><td>15.</td><td></td><td>HVAC System Controls</td><td>Install heating ventilation and air conditioning (HVAC) system controls with the following initially programmed set points[7].
Thermostat Set points
<table>
<tr><th>Setting</th><th>Time</th><th>Set point Temperature (Heat)</th><th>Set point Temperature (Cool)</th></tr>
<tr><td>M-F</td><td>7:00 a.m.</td><td>66°F</td><td>78°F</td></tr>
<tr><td>M-F</td><td>5:00 p.m.</td><td>65°F</td><td>80°F</td></tr>
<tr><td>Weekend</td><td>7:00 a.m.</td><td>65°F</td><td>80°F</td></tr>
<tr><td>Weekend</td><td>5:00 p.m.</td><td>65°F</td><td>80°F</td></tr>
</table></td></tr>
<tr><td>16.</td><td></td><td>HVAC Efficiency</td><td></td></tr>
<tr><td></td><td>16.1</td><td>Equipment Efficiency</td><td>Minimum HVAC operating efficiency shall be as follows:
Group B & M: for cooling shall be EER 17.2 or equivalent, and for heating COP 5.0 or equivalent.
Group R: for cooling shall be SEER 19.1 or equivalent, and for heating HSPF 10.3 or equivalent. All air handlers shall be installed within the thermal envelope.</td></tr>
<tr><td></td><td>16.2</td><td>Duct work Efficiency</td><td>(Mandatory) All duct work shall be installed within the thermal envelope and sealed with mastic. Tape is not permitted.</td></tr>
<tr><td></td><td>16.3</td><td>Exhaust Fan Efficiency</td><td>17.0.1. (Mandatory) Bathroom exhaust fans and kitchen hood fans shall be energy star qualified.
17.0.2. (Mandatory) Ceiling fans shall be energy star qualified.</td></tr>
<tr><td>17.</td><td></td><td>Exposed Concrete Slab</td><td>Concrete slab surfaces, or ceramic tile directly adhered to concrete slab with mortar, surfaces located in direct day lit zones shall be exposed 80% or more (e.g., eliminate wall to wall carpeting and allow minimum area rugs). Slab surfaces in indirect day lit zones shall be exposed 50% or more.</td></tr>
<tr><td>18.</td><td></td><td>Exterior Thermal Mass Walls</td><td>Exterior thermal mass walls shall use materials that have volumetric heat capacity values between 18 to 30 Btu/ft^3.°F, and a thickness of at least 12 inch minimum or 8 hour time lag.
Exception: water walls may be used for Mass or Insulated Mass construction complying with section 1.4.1.1(2) Passive Solar.
Formula: Specific Heat (Btu/lb.°F) x Density (lb/cubic foot) = Volumetric Heat Capacity
Example: Adobe = 0.22 Btu/lb.°F x 95 lb/ft^3 (density) = 20.9 Btu/ft^3.°F
See Appendix B for sample calculations and calculator.</td></tr>
</table>

[7] Energy Star has a higher heating wake set point (70) and a more aggressive set backs (heating 62, cooling 85 day, 82 night). See: http://www.energystar.gov/ia/partners/product_specs/eligibility/thermostats_elig.pdf

19.		Night Ventilation	Thermal mass designs shall be provided with a means of venting the interior building air to the outside at night during the months of May through October to discharge daytime stored heat in the mass to avoid overheating. Operable windows totaling at least 20 percent of the total glazing area, equally divided between inlet and outlet (10% each), and located for effective natural cross ventilation. At a minimum each room except bathrooms and corridors and stairways serving as part of an exit, shall have at least one operable opening. Or, a whole-building ventilation system designed to provide at least 20 air changes per hour shall be installed.
20.		Interior Thermal Storage Capacity	Add interior thermal mass materials such as ceramic countertops, 5/8" gypsum board, interior masonry features or heavy furniture that will have a volumetric heat capacity (calculated per #18) per inch thick of 0.5 $Btu/in.ft^2.°F$ per square foot of the building. Formula: Volumetric Heat Capacity / 12 = volumetric heat capacity per inch Volumetric heat capacity per inch * thickness in inches = Installed material heat capacity Installed material heat capacity / 0.5 = Area Factor Conditioned Square feet / Area Factor = Required amount of material See Appendix B for sample calculations and calculator.
21.		Plumbing	
	22.1	Domestic Solar Hot Water (DSHW)	22.1.1. Install a high efficiency domestic solar hot water heater with a solar fraction ≥ 75. The solar fraction is calculated as follows: $\text{Solar Fraction} = \frac{1 - \text{Energy Factor}_{\text{back up}}(EF)}{\text{Solar Energy Fraction (SEF)}}$ A Solar Fraction calculator is located at: http://www.pimaxpress.com/Documents/Green/Solar%20Fraction%20Calculator%20for%20Solar%20Hot%20Water%20Systems.xls 22.1.2 Backup hot water heating equipment, if installed, shall be energy star qualified.
	21.2	Hot water distribution	(Mandatory) All domestic hot water piping, including sub-slab pipes, shall have R-4 insulation. Insulation shall be properly installed on all piping elbows to adequately insulate the 90-degree bend. Recirculating pumps, if installed, shall be demand controlled.
	21.3	Plumbing Fixtures.	(Mandatory) 22.3.1. Lavatory Faucets: Each faucet or faucet aerator shall be WaterSense Certified and meet an average rated flow volume of ≤ 1.25 gallons per minute (gpm) across all lavatory faucets. 22.3.2. Showerheads: Each fixture/fitting shall be WaterSense Certified and meet an average rated flow volume of ≤ 1.75 gallons per minute (gpm) per shower compartment. 22.3.3. Toilets: Each fixture/fitting shall be WaterSense Certified and meet an average rated flush volume of ≤ 1.1 gallons per flush (gpf) across all

			toilets. 22.3.4. Clothes Washer: Each clothes washer shall be Energy Star qualified with a water factor ≤6.0.
22.		Economizer	A supply air economizer shall be installed per section 503.3.1 with no exception. Economizer shall operate at hours where the maximum outdoor dry bulb temperature is 75 degrees or lower and shall not allow the compressor to operate during those hours.
23.		Variable Air Volume Fan (VAV)	VAV fan control shall be provided per 503.4.2 for all thermal zones.
24.		Energy Recovery Ventilators (ERV)	ERV shall be provided per 503.2.6 for all thermal zones.
25.		Landscaping	(Mandatory) All landscape plant material shall be from the Arizona Department of Water Resources (ADWR) Tucson Active Management Area (TAMA) plant list Water Use Factor 1 or 2. http://www.azwater.gov/AzDWR/StatewidePlanning/Conservation2/Documents/documents/2010_TAMA_DYWU_PLANTLIST.pdf. The landscaping shall comply with the City of Tucson Ordinance 10597 and Development Standard 10-03.0[8] Exception: For Group R: a. An oasis area that complies with City of Tucson Development Standard 2-06.3.2 Oasis Allowance is permitted. b. Fruit trees and vegetable gardens watered with rain water and/or grey water as follows: Install a rainwater catchment system that meets the requirements of the calculations per Texas A&M Rainwater Harvesting online calculator at http://rainwaterharvesting.tamu.edu/onlinecalculator/AZ/html/Tucson/Tucson.htm. Use a plant water use coefficient of high. Result shall indicate that no potable water is required in year 2. If a grey water system is installed per the following, the available rainwater storage value in the calculation above maybe reduced by ½. Install a grey water system sized per California Plumbing Code, Title 24, Part 5, Chapter 16, Sections 1606A.0, 1607A, 1608A, 1611A, 1611B. http://www.hcd.ca.gov/codes/shl/2007CPC_Graywater_Complete_2-2-10.pdf

2.4.4. Pools and Spas. If a pool and/or spa is to be installed, the following requirements shall be met.

2.4.4.1. Provide cover to prevent evaporation per Pima County amendment to the IRC Appendix G section AG 101.

2.4.4.2. Water heating if provided, by solar system only.

2.4.4.3. *Energy use intensity* shall be as follows:

Pumping energy:

[8] "Sustainability in Government: Water Resources." *City Of Tucson Office of Conservation and Sustainable Development*. City Of Tucson, 14 Oct. 2008. Web. 29 Aug. 2011. <http://www.tucsonaz.gov/ocsd/sustainability/water/rainwaterharvesting.php>.

Pool = 0.30 kWh/gallon of capacity/yr x 3.412 = 1 kBtu/gallon of capacity/yr

Spa = 2,500 kWh/yr x 3.412 = 8,530 kBtu/yr

Embedded energy in water:

Capacity of the pool/spa in gallons[9] x 0.0503 kBtu/gal = *Embedded energy in water* kBtu/yr

Pumping Energy + *Embedded Energy in Water* / conditioned square feet = EUI_{pool}

Exception: An alternative EUI_{pool} may be presented to the building official for approval.

2.4.4.4. Photo voltaic panels shall be installed to produce on an annual basis sufficient electrical energy to meet the EUI_{pool} as follows: If EUI factor per 2.4.1 + EUIpool ≤ *Energy Budget* Factor per Tables 2.3.1.5, install panels on roof of building. Otherwise install panels on a shade structure or ramada adjacent to the pool.

2.4.5. Documentation. Construction documents shall clearly indicate all requirements of section 2.3 including but not limited to:

1. On the cover page a clearly delineated note section with the following information:
   a. *Energy budget* development with per section 2.3 with orientation, type of roof, shape, number of stories and the *energy budget* factor.
   b. Energy use intensity (EUI) *factor* per 2.4.1 including any bonus claimed
   c. Calculation of the WFA and distribution
   d. Roof and wall reflectance
   e. Calculated interior and exterior light power density.
   f. Calculated equipment power density.
   g. For mass and insulated mass construction: provide the percent of exposed concrete slab and location of interior thermal storage capacity.
2. The building strategy requirements per section 2.4.3 shall be clearly shown in the drawings and noted using the phrase "strategy #" where "#"is the number that corresponds to the required strategy, e.g. "strategy 3" = Roof/ceiling insulation requirements.
3. If installed, the location of fruit trees and area of vegetable garden, rainwater harvesting calculation and grey water calculation.

2.5. Simulated Performance Path Compliance

2.5.1. Scope. This section establishes the criteria for compliance using an energy simulation tool.

2.5.2. Compliance with this section requires compliance with the mandatory provisions identified in section 2.4.3 of this standard..

2.5.3. *Energy budget* simulation. Photo voltaic panels and/or solar thermal panels shall be limited to the roof area of the building including porches, covered walkways, and covered parking.

2.5.4. *Energy use intensity* simulation. *Energy use intensity* simulation of the proposed building shall be modeled per section 506 with the following exceptions:

1. All energy consuming systems, including plug load, pools and spas shall be included.
2. The *embedded energy in water* shall be included as follows:

[9] "Water Conservation in Pima County." *Water Resources Research Center*. University Of Arizona, 2001. Web. 06 Sept. 2011. p.9 <http://ag.arizona.edu/AZWATER/publications/conservation/conserve.pdf>. This study indicates that the annual water use is approximately the capacity of the pool

Group B: 1.3 kBtu/sf-yr.

Group M: 3.1 kBtu/sf-yr

Group R: 2.1 kBtu/sf-yr

Exception: the individual completing the compliance report (energy modeler) may provide alternate calculations for interior and exterior *embedded energy in water* demonstrating a lower value.

3. Results shall be reported in kBtu/sf-yr site energy.

2.5.5. The simulated *energy use intensity* minus the simulated *energy budget*, including the *embedded energy in water* shall be equal to or less than zero to comply with this section.

2.5.6. Approved energy performance simulation software: eQuest.

2.5.7. Documentation. Provide documentation per Section 506.4.1 and 506.4.2. The plans shall clearly indicate all of the building elements noted in the building file output of the energy modeling software.

2.6. Net-Zero Energy Upgrade:

2.6.1. Scope. The provisions of this section shall apply to the alteration, movement, enlargement, replacement, repair, equipment, of existing buildings.

2.6.2. All work contributing to the net-zero energy upgrade shall be permitted at one time.

2.6.3. Prescriptive Path: There is no commercial upgrade prescriptive path due to the variation in existing building construction, occupancy and use.

2.6.4. Upgrade Performance Path: Comply with section 2.5.

2.7. General Documentation Requirements:

2.7.1. When submitting a permit application, clearly note on the submittal that the project is attempting net-zero certification per section 2 of the IECC

2.7.2. Clearly note the compliance path and all necessary calculations on the submittal documents. If the on-line calculator was used, include the "recipe card."

2.7.3. Include specific documentation requirements per 2.4.5 or 2.5.7.

2.7.4. Operator and occupant training and education**:**

2.7.4.1. Provide a copy of the building owner's manual that explains the benefits, features and operation of the net-zero building strategies.

2.7.4.2. Provide either 1) documentation of a one-hour training session or, 2) a copy of the builders plan for a minimum one hour training session with the owner or occupant that explains the benefits, features and operation of the net-zero strategies.

2.7.4.3. For buildings not primarily owner occupied, provide a copy of the proposed lease language that requires tenants to attend the one hour training session per section 2.7.4.2.

2.8. Performance Documentation. After one year of continuous operation with no more than a ten percent (10%) vacancy rate, the applicant shall submit a calculation and utility bills confirming net-zero as follows:

2.8.1. Formula: PV production – [Gas + Elec + (water * energy)] ≥ 0

Note: A positive number means that the building is an annual net positive producer of energy.

PV production = AC electrical production of on site photovoltaic panels converted to kBtu

Gas = gas use for the year in kBtu

Electric = electricity use for the year in kBtu

Water = gallons of water use for the year

Energy = 0.0503 kBtu/gal for the *energy embedded in water*

Note: solar thermal production is automatically accounted for by the deferment of gas or electrical consumption.

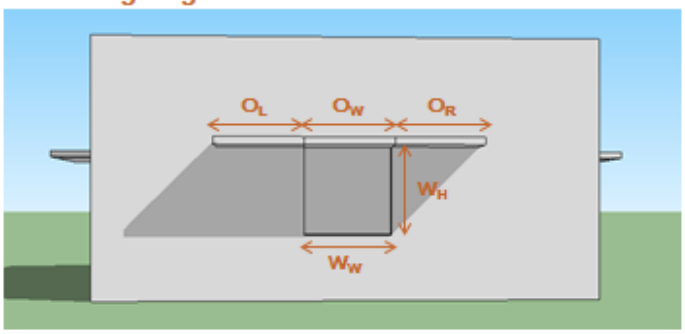
2.8.2. If the result of formula 2.8.1 is zero or a positive number, the building official will issue a certificate of net-zero compliance

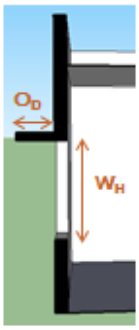
APPENDIX A: Window Overhang Diagrams

Orientation	Projection Factors				
	Overhang	Left Overhang Extension	Right Overhang Extension	Left Fin	Right Fin
North	NA	NA	NA	0.2 Window Width	0.2 Window Width
North East	NA	NA	NA	0.6* Window Width	0.6* Window Width
East	1.0 Window Height	0.875* Window Height	NA	1.0* Window Width	NA
South East	0.7 Window Height	0.7* Window Height	0.7* Window Height	0.7* Window Width	0.7* Window Width
South	0.4 Window Height	1.0* Window Height	1.0* Window Height	0.4* Window Width	0.4* Window Width
South West	0.7 Window Height	0.7* Window Height	0.7* Window Height	0.7* Window Width	0.7* Window Width
West	1.0 Window Height	NA	0.875* Window Height	NA	1.0* Window Width
North West	NA	NA	NA	0.6* Window Width	0.6* Window Width

* Either overhang extensions or fins should be employed.

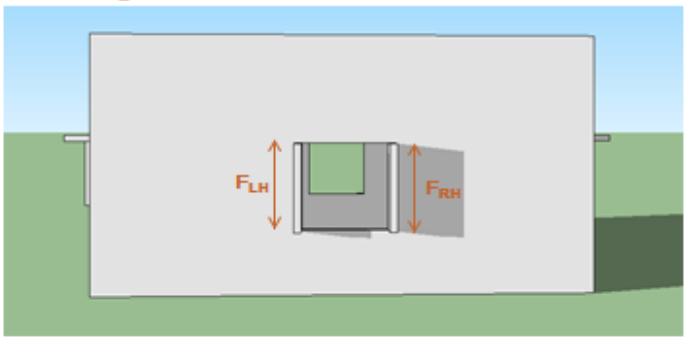
Overhang Diagram

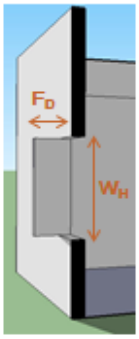




W_W= Window width
W_H= Window height
O_W= Overhang width
O_R= Overhang right extension
O_L= Overhang left extension
O_D= Overhang depth
F_D= Fin depth
F_{RH}= Right fin
F_{LH}= Left fin

Fins Diagram





APPENDIX B: Volumetric Heat Capacity

Heat Storage Properties of Materials

Material	Specific Heat (Btu/lb.°F)	Density (lb/ft^3)	Heat Capacity (Btu/in-sf-°F)
Poured Concrete	0.16-0.20	120-150	2.0 - 2.5
Clay Masonry	0.19-0.21		
Molded Brick		120-130	2.0 - 2.2
Extruded Brick		125-135	2.1 - 2.3
Adobe	0.20-0.24	80-106	2.2 - 2.3
Concrete Masonry	0.19-0.22		
CMU		80-140	1.3 - 2.3
Brick		115-140	1.9 - 2.3
Pavers		130-150	2.2 - 2.5
Gypsum Wallboard	0.26	50	1.1
Water	1.0	62.4	5.2

Because water has the highest specific heat, it has the highest thermal storage

Building Strategy #18: Volumetric Heat Capacity Formula

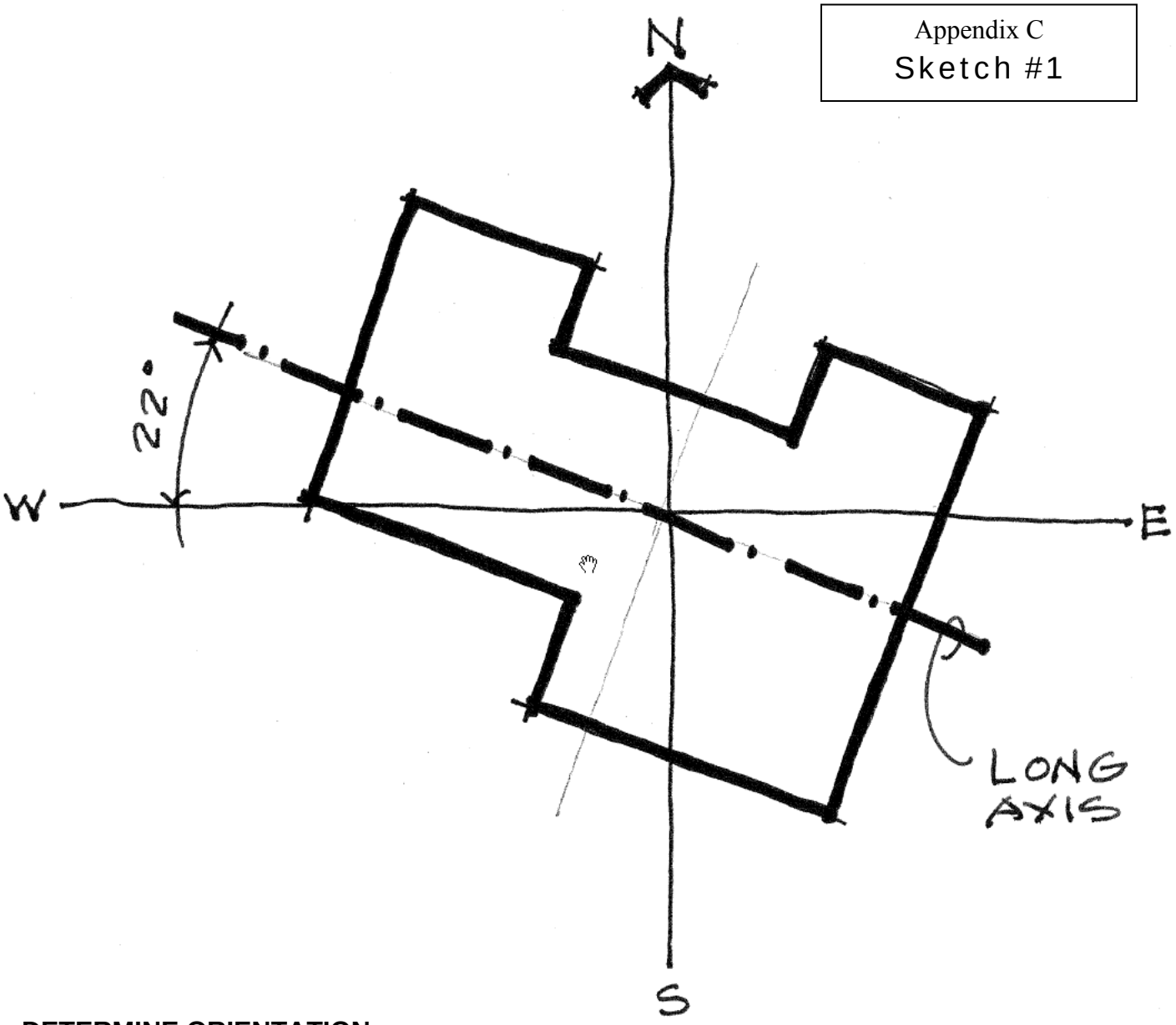
Formula			
Material Specific Heat		nn	Btu/lb.°F
Material Density		nn	lb/ft3
Volumetric Heat Capacity		nn	Btu/ft3.°F

Building Strategy #20: Interior Thermal Mass Area Required formula

Formula			
Material Specific Heat		nn	Btu/lb.°F
Material Density		nn	lb/ft3
Volumetric Heat Capacity		nn	Btu/ft3.°F
	÷	12	Inches
Volumetric Heat Capacity per inch		nn	Btu/in.ft^2.°F
Thickness of material			
x		nn	inches
Installed Material Heat Capacity Requirement		nn	Btu/ft^2.°F
÷		0.50	Btu/in.ft^2.°F
Area Factor		nn	dimensionless
Conditioned Floor Area		nn	sf
Area Factor	÷	nn	
		nn	sf

An excel spreadsheet to assist with these calculations is located on the Net-Zero web page at:
http://www.pimaxpress.com/Documents/Green/Net-Zero-Code-Volumetric-Heat-Capacity-Calculator.xls

Appendix C
Sketch #1



DETERMINE ORIENTATION

(SECTION 1.3.1.1, 2.3.1.1)

STEP 1: With the building oriented with true north to the top of the paper, layout true north-south and east-west geographical lines over the building footprint.

STEP 2: Draw the long *building axis* with approximately ½ of the area of the building footprint on each side of the axis line.

STEP 3: Determine the angle of the long axis from the closest of either the north-south or the east-west lines. In the example above the long axis is closest to the east-west line and the angle is 22 degrees.

STEP 4: Determine the orientation of the building

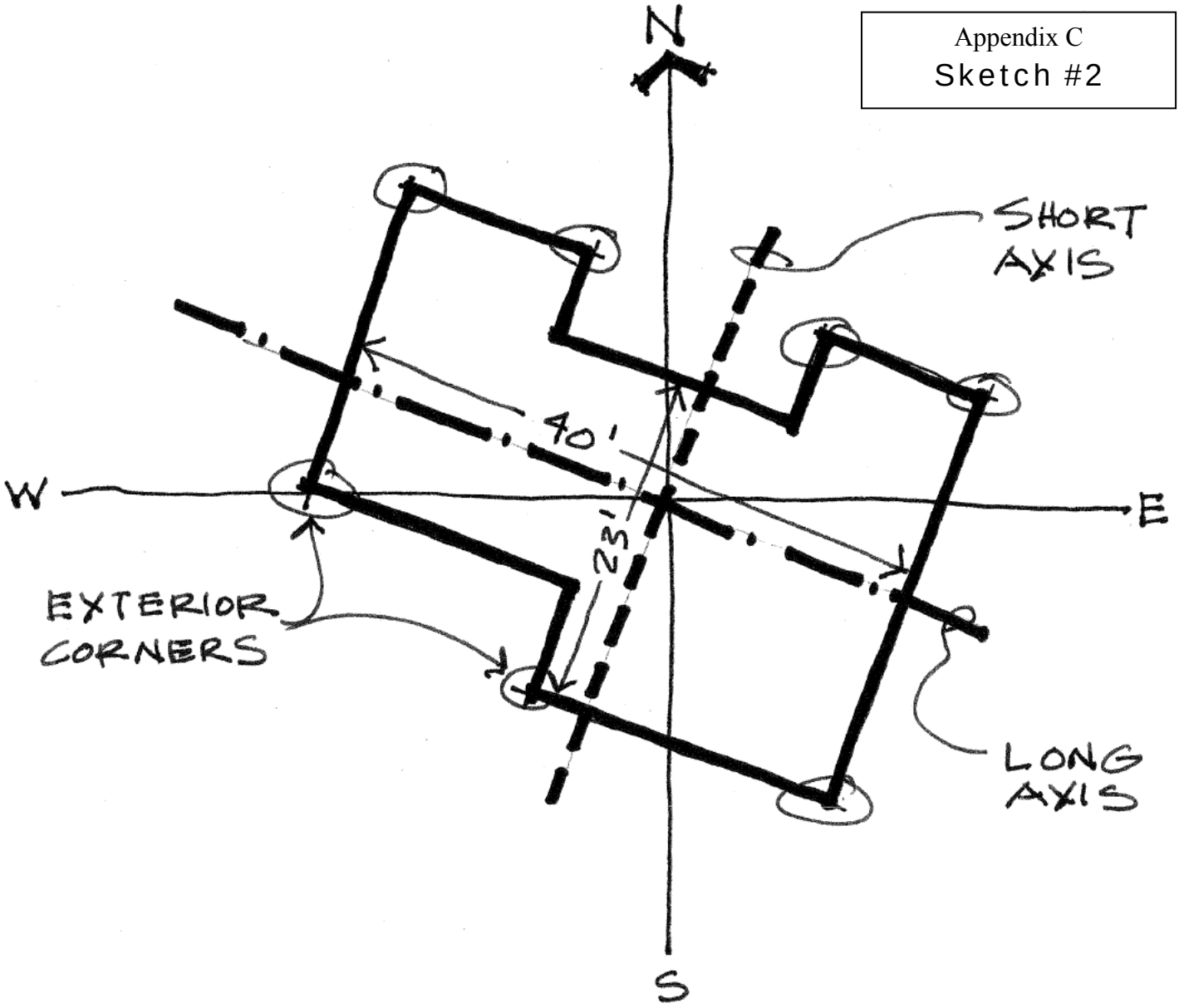
E-W is any long *building axis* that is within plus or minus 15 degrees of true east-west.

N-S is any long *building axis* that is within plus or minus 15 degrees of true north-south.

Off axis is any orientation that is not E-W or N-S.

In the example above the angle from the east-west line is greater than 15 degrees therefore the orientation is **off axis**.

Appendix C
Sketch #2



DETERMINE SHAPE

(SECTION 1.3.1.3, 2.3.1.3)

STEP 1: Count the exterior corners of the building. If the building has more than eight exterior corners the building shape is irregular. If the building has less than eight exterior corners, continue.

STEP 2: After determining orientation per sketch, draw the short building axis with approximately ½ of the area of the building footprint on each side of the axis line.

STEP 3: Measure the length of the long axis and the short axis. In the case of the example above, the long axis is 40 feet and the short axis is 23 feet.

STEP 4: Divide the long axis length by the short axis length.

If the floor plan long building axis is > 1.3 times the length of the short building axis the building is a rectangle.

If the floor plan long building axis is ≤ 1.3 times the length of the short building axis the building is a square.

In the example above: $40 \div 23 = 1.74$. $1.74 > 1.3$ therefore the building is a rectangle.