Hot and Humid Texas

- Texas
<table>
<thead>
<tr>
<th>Cities</th>
<th>Population Metro area</th>
<th>Pop. growth (past 10 yrs)</th>
<th>Household growth (5 yrs)</th>
<th>$ Median House prices</th>
<th>Power Outages’08-’17</th>
<th>Small Building Rooftop Solar Potential in MW:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin</td>
<td>2.42 M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houston</td>
<td>7.34 M</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Dallas</td>
<td>7.94 M</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>San Antonio</td>
<td>2.65M</td>
<td></td>
<td></td>
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<tr>
<td>US Average</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Annual **New Privately Owned Housing Units** Authorized by State:

17,400 units - 80% of all Texas and 12.3% of all US.
## Certification Growth

- **Final Certified**
  - Theresa Passive House; Single-Family Addition 2A, 2218 sq. ft. (Austin)
  - Casa La Vista, Single-Family New Construction 2A, 2990 sq. ft. (Spicewood)
  - Blaise House, Single-Family Retrofit 2A, 1473 sq. ft. (Austin)

- **Design Certified**
  - Abbate House, Single-Family New Construction 2A, 1130 sq. ft. (Austin)

- **Registered**
  - Lareina Guesthouse, Single-Family New Construction 2A, 1033 sq. ft. (Austin)
  - 1118 W 7th, Single-Family New Construction 2A, 5000 sq. ft. (Austin)
  - Clutch City, Multi Family (Jesse Hunt) New Construction 2A, 4674 sq. ft. (Houston)
  - Raimer Guest House, Single-Family New Construction 3A, 898 sq. ft. (Celeste)
  - Ocean Front Villas, Single-Family New Construction 2A, 2399 sq. ft. (Porter)
  - Kananbatch Residence, Single-Family New Construction 2A, 2500 sq. ft. (Santa Fe)

- **Application:** 3 Projects
Hot and Humid Texas

- Houston, TX
• Houston, TX

**Hot and Humid Texas**

*Heating degree days by census division in 2021*

*Cooling degree days by census division in 2021*

Hot and Humid Texas

Characteristics of the Climate:
- High temperatures
- High humidity
- Long periods of hot weather

Design Strategies:
1. Farming/Rooms
2. Sun Shading of Windows (0 hrs)
3. High Thermal Mass (0 hrs)
4. High Thermal Mass Night Flushed (0 hrs)
5. Direct Evaporative Cooling (0 hrs)
6. Two-Stage Evaporative Cooling (0 hrs)
7. Natural Ventilation Cooling (0 hrs)
8. Fan-Forced Ventilation Cooling (0 hrs)
9. Internal Heat Gain (0 hrs)
10. Passive Solar Direct Gain Low Mass (0 hrs)
11. Passive Solar Direct Gain High Mass (0 hrs)
12. Wind Protection of Outdoor Spaces (0 hrs)
13. Humidification Only (0 hrs)
14. Dehumidification Only (0 hrs)
15. Cooling, add Dehumidification if needed (0 hrs)
16. Heating, add Humidification if needed (0 hrs)

Comfort Zones:
- Summer clothing on right
- Winter clothing on left

Legend:
- Comfort Indoors
- Comfortable
- Not Comfortable

Locations:
- Houston William P Hobby Ap, TX, USA
- Latitude/Longitude: 29.65° North, 96.28° West, Time Zone from Greenwich -6
- Data Source: TXY3 722435 WMO Station Number, Elevation 42 ft
Hot and Humid Texas

PSYCHROMETRIC CHART
ASHRAE Standard 55-2004 using PMV

LOCATION:
Houston William P Hobby Ap, TX, USA
Latitude/Longitude: 29 65° North, 95 28° West, Time Zone from Greenwich -6
Data Source: TMY3 722435 WMO Station Number, Elevation 42 ft

DESIGN STRATEGIES: JANUARY through DECEMBER
9.8% 1 Comfort(<99 hrs)
17.1% 2 Sun Shading at Windows(1609 hrs)
3 High Thermal Mass(4 hrs)
2.4% 4 High Thermal Mass Night Flushed(214 hrs)
5 Direct Evaporative Cooling(0 hrs)
6 Two-Stage Evaporative Cooling(0 hrs)
7 Natural Ventilation Cooling(0 hrs)
8 Fan Forced Ventilation Continually(0 hrs)
24.6% 9 Internal Heat Gain(2158 hrs)
10 Passive Solar Direct Gain Low Mass(0 hrs)
7.6% 11 Passive Solar Direct Gain High Mass(880 hrs)
0.3% 12 Wind Protection of Outdoor Spaces(22 hrs)
13 Humidification Only(0 hrs)
25.4% 14 Dehumidification Only(2036 hrs)
23.6% 15 Cooling, add Dehumidification if needed(2093 hrs)
12.6% 16 Heating, add Humidification if needed(1131 hrs)

100.0% Comfortable Hours using Selected Strategies
(8760 out of 8760 hrs)

Comfort Zones show:
Summer clothing on right,
Winter clothing on left.
“Everything is bigger in Texas”

- Single Family 1 Story
- ~ 6000 sq ft
- 5 bed/7 bath
- 3 car garage
- Large envelope size and multiple wings
- Distributed nature of hot water use
- Combustion safety – 5 fireplaces
- Gas appliances
<table>
<thead>
<tr>
<th>Houston</th>
<th>Austin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal Enclosure</strong></td>
<td><strong>Thermal Enclosure</strong></td>
</tr>
<tr>
<td>5.1.1a</td>
<td>Fenestration / Openings</td>
</tr>
<tr>
<td></td>
<td>Walls &amp; Overhang Floors - Effective R-Value</td>
</tr>
<tr>
<td>5.1.1b</td>
<td>Roofs / Ceilings</td>
</tr>
<tr>
<td></td>
<td>Walls &amp; Overhang Floors - Effective R-Value</td>
</tr>
<tr>
<td>5.1.1c</td>
<td>Whole Slab Foundations, Below-Grade Walls, Floors of Conditioned Basements &amp; Crawls Spaces</td>
</tr>
<tr>
<td>5.1.1d</td>
<td>Ceilings of Unconditioned Basements or Crawls Spaces &amp; Pier and Beam Floors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dallas</th>
<th>San Antonio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal Enclosure</strong></td>
<td><strong>Thermal Enclosure</strong></td>
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<td>5.1.1a</td>
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<td>Walls &amp; Overhang Floors - Effective R-Value</td>
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<td>5.1.1b</td>
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</tr>
<tr>
<td>5.1.1d</td>
<td>Ceilings of Unconditioned Basements or Crawls Spaces &amp; Pier and Beam Floors</td>
</tr>
<tr>
<td>5.1.1e</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1.1f</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Single Family 1 story
• Sqft: approx. 2,500
• Project Status: Permitting
• Positive Impact Homes

Images by Stella Maris Architecture
### Positive Impact Homes: Criteria vs Results

**Phius 2021 Performance Criteria Calculator v3.2**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope Area (ft²)</td>
<td>12,905.6</td>
</tr>
<tr>
<td>ICFA (ft²)</td>
<td>3,200.0</td>
</tr>
<tr>
<td>Dwelling Units (Count)</td>
<td>1</td>
</tr>
<tr>
<td>Total Bedrooms (Count)</td>
<td>4</td>
</tr>
</tbody>
</table>

**Space Conditioning Criteria**

- Annual Heating Demand: 2.8 kBTU/ft²/yr
- Annual Cooling Demand: 19.3 kBTU/ft²/yr
- Peak Heating Load: 3.2 Btu/ft²/hr
- Peak Cooling Load: 4.2 Btu/ft²/hr

**Source Energy Criteria**

- Phius CORE: 5000 kWh/person.yr
- Phius ZERO: 0 kWh/person.yr

### Graphs

- Heating demand: 2.14 kBTU/ft²/yr
- Cooling demand: 7.95 kBTU/ft²/yr
- Heating load: 3.18 Btu/hr ft²
- Cooling load: 3.4 Btu/hr ft²
- Source energy: 51 kWh/person yr
- Site energy: 0.1 kBTU/ft²/yr

**Status Indicators**

- Heating demand: Green checkmark
- Cooling demand: Green checkmark
- Heating load: Green checkmark
- Cooling load: Green checkmark
- Source energy: Green checkmark
- Site energy: Green checkmark
Palm Street Development

• Two Unit Residence
• Sqft: Unit 1 1,950; Unit 2 3,600
• Project Status: Permitting
• SunRoof USA PV System offering 24.96 kWp (29.6k lbs/yr CO2 reduction)
• Emphasis on carbon neutral, energy positive construction practices
• Bridge above easement that connects the two residences
• Two additional 1st floor bedrooms w/ exterior entrances

Image courtesy of Mint Homes / Raj Development Corporation
Palm Street: Criteria vs Results

Phius 2021 Performance Criteria Calculator v3.2

**Building Function:** Residential

**Project Type:** New Construction

**State/Province:** Texas

**City:** Houston William P. HK

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope Area (ft²)</td>
<td>16,032.0</td>
</tr>
<tr>
<td>ICF (ft²)</td>
<td>5,254.0</td>
</tr>
<tr>
<td>Dwelling Units (Count)</td>
<td>2</td>
</tr>
<tr>
<td>Total Bedrooms (Count)</td>
<td>5</td>
</tr>
</tbody>
</table>

**Space Conditioning Criteria**

- **Annual Heating Demand:** 2.7 kBtu/ft²yr
- **Annual Cooling Demand:** 19.1 kBtu/ft²yr
- **Peak Heating Load:** 3.1 Btu/ft²hr
- **Peak Cooling Load:** 4.1 Btu/ft²hr

**Source Energy Criteria**

- **Phius CORE:** 5600 kWh/person.yr
- **Phius ZERO:** 0 kWh/person.yr
• Single Family 1 Story
• Sqft: Unit 1 9,600
• Project Status: Construction Documents
• Windows and Air Tightness (acc. ASTM E283 @75Pa – Industry standard limits is at 0.3cfm/sq.ft.)
  - Casements: Results between 0.03 cfm/sq.ft. - 0.06 cfm/sq.ft – manufacturer lists 1.1 cfm/sq.ft.
  - Double Hung: Results between 0.1 - 0.24 cfm/sq.ft.
• Cost Effectiveness
### Austin Development

#### IECC 2021

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>FENESTRATION U-FACTOR&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>SKYLIGHT&lt;sup&gt;b&lt;/sup&gt; U-FACTOR</th>
<th>GLAZED FENESTRATION SHGC&lt;sup&gt;b,e&lt;/sup&gt;</th>
<th>CEILING R-VALUE</th>
<th>WOOD FRAME WALL R-VALUE&lt;sup&gt;g&lt;/sup&gt;</th>
<th>MASS WALL R-VALUE&lt;sup&gt;h&lt;/sup&gt;</th>
<th>FLOOR R-VALUE</th>
<th>BASEMENT C&lt;sup&gt;c,g&lt;/sup&gt; WALL R-VALUE</th>
<th>SLAB&lt;sup&gt;d&lt;/sup&gt; R-VALUE &amp; DEPTH</th>
<th>CRAWL SPACE C&lt;sup&gt;c,g&lt;/sup&gt; WALL R-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.40</td>
<td>0.65</td>
<td>0.25</td>
<td>49</td>
<td>13 or 0 &amp; 10ci</td>
<td>4/6</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Austin TX Code Compliant (ish)**

- Air Infiltration Limit: 0.215 cfm<sub>50</sub>/ft<sup>2</sup> 3.00 ACH<sub>50</sub>

**Austin TX Optimum (ish)**

- Air Infiltration Limit: 0.06 cfm<sub>50</sub>/ft<sup>2</sup> 0.83 ACH<sub>50</sub>
<table>
<thead>
<tr>
<th>Assembly</th>
<th>Case 1 Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab</td>
<td>Uninsulated 4” Concrete Slab = R 0.42</td>
</tr>
<tr>
<td>Walls</td>
<td>R13 (2x4 w/ Batt Insulation)</td>
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<tr>
<td>Roof</td>
<td>R38 (Not including framing)</td>
</tr>
<tr>
<td>Windows</td>
<td>U-Value 0.4 BTU/ft² h F SHGC 0.25</td>
</tr>
<tr>
<td>Airtightness</td>
<td>ACH50: 5 per hour CFM50: 0.36 per ft² (Envelope Area)</td>
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</table>

<table>
<thead>
<tr>
<th>Case 1</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Energy Use</td>
<td>38993.07 kWh</td>
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<tr>
<td>Energy Cost (Monthly in $)</td>
<td>$454.92</td>
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<tr>
<td>PV Required for Zero</td>
<td>39,000 kWh</td>
</tr>
<tr>
<td>Estimated DC System Size</td>
<td>26.4 kW</td>
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<tr>
<td>Estimated Number of Panels</td>
<td>72</td>
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</table>
### Austin Development

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>FENESTRATION U-FACTOR&lt;sup&gt;b, i&lt;/sup&gt;</th>
<th>SKYLIGHT&lt;sup&gt;b&lt;/sup&gt; U-FACTOR</th>
<th>GLAZED FENESTRATION SHGC&lt;sup&gt;b, e&lt;/sup&gt;</th>
<th>CEILING R-VALUE</th>
<th>WOOD FRAME WALL R-VALUE&lt;sup&gt;g&lt;/sup&gt;</th>
<th>MASS WALL R-VALUE&lt;sup&gt;h&lt;/sup&gt;</th>
<th>FLOOR R-VALUE</th>
<th>BASEMENT&lt;sup&gt;c, g&lt;/sup&gt; WALL R-VALUE</th>
<th>SLAB&lt;sup&gt;d&lt;/sup&gt; R-VALUE &amp; DEPTH</th>
<th>CRAWL SPACE&lt;sup&gt;f, g&lt;/sup&gt; WALL R-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.40</td>
<td>0.65</td>
<td>0.25</td>
<td>49</td>
<td>13 or 0 &amp; 10cl</td>
<td>4/6</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Austin TX</strong> Code Compliant (ish)**</td>
<td>0.25</td>
<td>0.25</td>
<td>.25 cog</td>
<td>38</td>
<td>18.1</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>.42</td>
<td>n/a</td>
</tr>
</tbody>
</table>

**Air Infiltration Limit:**
- **0.215 cfm<sub>50</sub>/ft<sup>2</sup>**
- **3.00 ACH<sub>50</sub>**

**Air Infiltration Limit:**
- **0.06 cfm<sub>50</sub>/ft<sup>2</sup>**
- **0.83 ACH<sub>50</sub>**

---

**Energy savings due to Air Tightness:** 5376 kwh/year of site energy

Results in a 15.6% energy savings for the building and a cost savings of $806.40/year or $67.20/month @ $0.15/kwh
• In many cases, insulation continuous under the slab is not required or even recommended.
• There are some cases where approximately R-8 would provide meaningful results.
  *See Phius Prescriptive Requirements*

• Situations where this is the case:
  1. Where the building has lower internal and solar gains (benefits less from free ground contact)
  2. In climates where the ground temperature is lower
  *For example: Houston vs Dallas*
What happens when a slab is insulated?
Heat loss through the slab is reduced
• In the winter, this heat loss to the ground adds to the heating demand
• In the summer, this heat loss to the cool ground is beneficial

These effects can look balanced!
Note the relative similarity between the source energy in kwh.

Positive Impact Homes: With R4 Slab Insulation

Positive Impact Homes: Without Slab Insulation
Slab Insulation: Austin

IECC 2021 Baseline:
- Slab R = .42
- Wall R = 18.1
- Roof R = 38
- Slab Per. = R5, 2'

- Window U = 0.25
- Window SHGC = 0.25
- Airtightness = 0.06 cfm_{50}/ft^{2}

- Slab R-Value: None (.42)
- Slab R-Value: 4.42

Energy savings due to increased R-value: 2007.8 kwh/year of site energy
Results in a 6.92% energy savings for the building and a cost savings of $301.17/year or $25.10/month @ $0.15/kwh
What happens when a slab is insulated?

Heat loss through the slab is reduced

- In the winter, this heat loss to the ground adds to the heating demand
- In the summer, this heat loss to the cool ground is beneficial
- The heat loss to the ground is sensible heat loss
- The latent heat demand stays the same, but sensible has been cut dramatically
- The demands are similar, but the efficiency of the mechanical system determines the annual source energy use!!

With R4 Slab Insulation

Without Slab Insulation
Slab Insulation Revisited

Dehumidification COP at 2

Positive Impact Homes: With R4 Slab Insulation
Positive Impact Homes: Without Slab Insulation

Dehumidification COP at 1.2

Positive Impact Homes: With R4 Slab Insulation
Positive Impact Homes: Without Slab Insulation
### Slab Insulation: Austin

**Baseline:**
- Slab $R = 0.42$
- Wall $R = 18.1$
- Roof $R = 38$
- Slab Per. = R5, 2’

Window $U = 0.25$
Window SHGC = 0.25
Airtightness = 0.06 cfm$_{50}$/ft$^2$

### Energy Savings

Energy savings are due to substituting a COP of 1.2 for Dehumidification with a COP of 5.28 for Cooling

### Table

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Fenestration $U$-Factor$^{b, c}$</th>
<th>Skylight$^b$ $U$-Factor</th>
<th>Glazed Fenestration SHGC$^b, e$</th>
<th>Ceiling $R$-Value</th>
<th>Wood Frame Wall $R$-Value$^g$</th>
<th>Mass Wall $R$-Value$^h$</th>
<th>Floor $R$-Value</th>
<th>Basement$^{c,g}$ Wall $R$-Value</th>
<th>Slab$^d$ $R$-Value &amp; Depth</th>
<th>Crawl Space$^{c,g}$ Wall $R$-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.40</td>
<td>0.65</td>
<td>0.25</td>
<td>49</td>
<td>13 or 0 &amp; 10cl</td>
<td>4/6</td>
<td>13</td>
<td>0</td>
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<td>0</td>
</tr>
</tbody>
</table>

Energy savings due to increased $R$-value: 2007.8 kwh/year of site energy

Results in a 6.92% energy savings for the building and a cost savings of $301.17/year or $25.10/month @ $0.15/kwh
Slab Insulation: Perimeter

WHAT? / WHY!

- Uninsulated slabs have very little thermal resistance.
- The overlap of the wall and slab at the corner creates what is typically called double counting” of the heat loss, but in this case, it replaces concrete with additional insulation.

Wall extends down for THERM Protocol

PHIUS recommends against taking negative thermal bridges in the design phase. See Thermal Bridges section in Certification Guidebook.
No Slab Edge Insulation

2” CI Continued Down Past Slab Edge
Slab Insulation: Perimeter

Component

<table>
<thead>
<tr>
<th>Component</th>
<th>U (btu/hr.sqft)</th>
<th>dT (°F)</th>
<th>L (in)</th>
<th>U*dT (btu/hr.ft)</th>
<th>error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior</td>
<td>0.025</td>
<td>54</td>
<td>488.27</td>
<td>33.72</td>
<td>3.36%</td>
</tr>
<tr>
<td>Interior</td>
<td>0.1050</td>
<td>54</td>
<td>73.00</td>
<td>33.80</td>
<td>3.86%</td>
</tr>
</tbody>
</table>

Component A

<table>
<thead>
<tr>
<th>Component</th>
<th>dT (°F)</th>
<th>L (in)</th>
<th>U*dT (btu/hr.ft)</th>
<th>error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall</td>
<td>54.00</td>
<td>52.00</td>
<td>6.60</td>
<td>0.00%</td>
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</tbody>
</table>

Component B

<table>
<thead>
<tr>
<th>Component</th>
<th>dT (°F)</th>
<th>L (in)</th>
<th>U*dT (btu/hr.ft)</th>
<th>error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall</td>
<td>54.00</td>
<td>52.00</td>
<td>6.60</td>
<td>0.00%</td>
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</tbody>
</table>

PSI

<table>
<thead>
<tr>
<th></th>
<th>dT (°F)</th>
<th>PSI</th>
<th>PSI for WUFI</th>
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</thead>
<tbody>
<tr>
<td>Exterior</td>
<td>54.00</td>
<td>-0.443</td>
<td>-0.443</td>
</tr>
</tbody>
</table>

PHIUS recommends against calculating thermal bridges in slab designs. See Thermal Bridges section in Certification Guidebook.

No Slab Edge Insulation

Glavel Slab Edge Insulation
Slab Insulation: Perimeter

No Slab Edge Insulation

58.7°F

1" Slab Edge Insulation

58.9°F
Slab Insulation: Perimeter

58.7°F

No Slab Edge Insulation

60.4°F

4” of R4 EPS Adjacent to Slab Edge
(1” Vertical R4 EPS)
Slab Insulation: Perimeter

58.7°F

No Slab Edge Insulation

59.9°F

1” of R4 EPS – Almost Continuous

1” of R4 Slab Insulation
Slab Insulation: Perimeter

No Slab Edge Insulation

58.7°F

1” of R4 EPS – Continuous

62.0°F

If this is kept as concrete, temperature is 61.8°F
Analyzing the climate with the Phius created ISO13788 Interior Surface fRsi Calculator v1.1

This calculator shows the temperatures are warm enough that the surface condensation risk potential should not be concern.

Issues seen at slab edges in TX are (likely) related to air movement!

Cold exterior air meeting warm/humid air can cause moisture risk and damage.

<table>
<thead>
<tr>
<th>Critical Month</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Walls (°F)</strong></td>
<td>56.1</td>
<td>57.0</td>
<td>58.1</td>
<td>65.3</td>
<td>71.4</td>
<td>77.0</td>
<td>79.5</td>
<td>78.6</td>
<td>73.6</td>
<td>68.2</td>
<td>57.9</td>
<td>52.7</td>
</tr>
<tr>
<td><strong>Ground (°F)</strong></td>
<td>61.3</td>
<td>63.0</td>
<td>63.5</td>
<td>64.0</td>
<td>67.6</td>
<td>70.7</td>
<td>73.4</td>
<td>74.7</td>
<td>74.3</td>
<td>71.7</td>
<td>69.0</td>
<td>63.9</td>
</tr>
<tr>
<td><strong>Roof, simplified (°F)</strong></td>
<td>56.1</td>
<td>57.0</td>
<td>58.1</td>
<td>65.3</td>
<td>71.4</td>
<td>77.0</td>
<td>79.5</td>
<td>78.6</td>
<td>73.6</td>
<td>68.2</td>
<td>57.9</td>
<td>52.7</td>
</tr>
</tbody>
</table>
Exterior Wall Approaches

• Target R-Values lead to “No Exotic Materials or Techniques Required”
• “4 City” range for the Prescriptive Path is: R23 – R26
• Framing conservatively (accurately) modeled with a double top plate @ 16” o.c.

Positive Impact Homes: R30.475
Palm Street: R 29.684
Positive Impact Homes: R30.475

- Inhomogeneous layers
  - Thermal resistance: 30.475 \(\text{hr ft}^2/\text{Btu} \text{ EN ISO 9946 / homogenous layers}
  - Heat transfer coefficient (U-value): 0.032 \text{Btu/hr ft}^2 \text{ °F}
  - Thickness: 8.625 in

Positive Impact Homes: R 24.358

- Inhomogeneous layers
  - Thermal resistance: 24.358 \(\text{hr ft}^2/\text{Btu} \text{ EN ISO 9946 / homogenous layers}
  - Heat transfer coefficient (U-value): 0.039 \text{Btu/hr ft}^2 \text{ °F}
  - Thickness: 7.625 in
Baseline:
- Slab R = .42
- Wall R = 18.1
- Roof R = 38
- Slab Per. = R5, 2'

Window U = 0.25
Window SHGC= 0.25
Airtightness = 0.06 cfm

Energy savings due to increased R-value: 109.8 kwh/year of site energy
Results in a 0.38% energy savings for the building and a cost savings of $16.47/year or $1.3725/month @ $0.15/kwh
Exterior Wall Approaches

Cost:
- 2x6 Framing is standard practice.
- Sheathing is standard as well
- Thin layers of CI are not standard, but fairly easy to accomplish
- 2" of foam can work well with almost all cladding materials
- Difference in cost between 2" and 1" is reasonable and can give advantages to meeting Phius Criteria (See previous slides)

Foam/No Foam
- Embodied Energy and Carbon come into play.
- Palm Street is based on a foam free assembly using rockwool
- Positive Impact Homes uses Polyisocyanurate foam
- Note: polyisocyanurate works very well in warmer climates
- Rockwool requires a thicker layer to get to equivalent R-values than some foam products.

All in one panel solutions:
- ZIP R Sheathing can be an excellent solution, the R9 panel would generally meet the requirements for Phius Certification (with 2x6 insulated framing)
- EPS “nailbase” panels are also an option and have roof applications (more on this soon)
Positive Impact Homes: Insulation under the roof deck
Spray polyurethane foam, AeroBarrier
R40 Estimated

Palm Street: External Insulation
Eave overhangs framed overtop
R45 Calculated in WUFI

The IECC Roof Insulation requirements for Climate Zone 2 is R38.
This is also very close to what modeling has shown is required for Phius Certification.

Note: The Phius Prescriptive Path requires approx. R55
IECC 2021

Baseline:
Slab R = 0.42
Wall R = 18.1
Roof R = 38
Slab Per. = R5, 2’

Window U = 0.25
Window SHGC = 0.25
Airtightness = 0.06 cfm\textsubscript{50}/ft\textsuperscript{2}

Exterior Roof Approach: Austin

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>FENESTRATION U-FACTOR\textsuperscript{b, l}</th>
<th>SKYLIGHT\textsuperscript{b} U-FACTOR</th>
<th>GLAZED FENESTRATION SHGC\textsuperscript{b, e}</th>
<th>CEILING R-VALUE</th>
<th>WOOD FRAME WALL R-VALUE\textsuperscript{g}</th>
<th>MASS WALL R-VALUE\textsuperscript{h}</th>
<th>FLOOR R-VALUE</th>
<th>BASEMENT\textsuperscript{c, g} WALL R-VALUE</th>
<th>SLAB\textsuperscript{d} R-VALUE &amp; DEPTH</th>
<th>CRAWL SPACE\textsuperscript{c, g} WALL R-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.40</td>
<td>0.65</td>
<td>0.25</td>
<td>49</td>
<td>13 or 0 &amp; 10cl</td>
<td>4/6</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</table>

Energy savings due to increased R-value: 106.3 kwh/year of site energy
Results in a 0.37% energy savings for the building and a cost savings of $15.95/year or $1.33/month @ $0.15/kwh
Project Teams

Where are all the Rater/Verifiers?

Grand total of:
3 Phius Raters in Texas
1 each in Houston (not active), Austin, Dallas
0 Phius Verifiers in Texas

Builders?
If we remove the listings with 3+ States served, there are:
11 Phius Certified Builders in Texas
Questions?

Thank You!

We have additional data on windows, ventilation systems, hot water, PV integration, etc.!
Let’s meet to discuss!

Ryan Abendroth, M.Arch, CPHC
Co-Founder and Consultant

Stefan Goebel, M.Eng., CPHC
Co-Founder and Consultant
Back Up
### Phius CORE Prescriptive 2021 Snapshot

**State:** New York

**City:** New York, Laguardia ARP

**Climate Zone:** 4A

**Number of Bedrooms:** 4

**Number of Stories:** 2

---

**1 General**

<table>
<thead>
<tr>
<th>IDFA divided by Number of Bedrooms</th>
<th>Maximum Limit</th>
<th>OK, SWAG LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Calculated Value based on inputs)</td>
<td>900 ft²</td>
<td>300 ft²</td>
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</table>

**3 Compactness**

<table>
<thead>
<tr>
<th>Envelope Area (Maximum Envelope to Floor Area Ratio)</th>
<th>Maximum</th>
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<tbody>
<tr>
<td></td>
<td>6545 ft²</td>
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</table>

**4 Solar Protection**

<table>
<thead>
<tr>
<th>Whole Window SHGC</th>
<th>Maximum</th>
</tr>
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<tr>
<td></td>
<td>0.49</td>
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</table>

**5 Thermal Envelope**

<table>
<thead>
<tr>
<th>Fenestration / Openings</th>
<th>Maximum Whole U Value</th>
<th>Minimum Effective R Value</th>
<th>Maximum Whole U Value</th>
<th>Minimum Effective R Value</th>
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<tbody>
<tr>
<td></td>
<td>0.29</td>
<td>26</td>
<td>0.31</td>
<td>23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Whole Slab Foundations, Below Grade Walls, Floors of Conditioned Basements &amp; Crawls Spaces</th>
<th>Maximum Effective R Value</th>
<th>Maximum Effective R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17</td>
<td>8</td>
</tr>
</tbody>
</table>

**6 Moisture Risk Limitation**

<table>
<thead>
<tr>
<th>Fenestration Condensation Resistance</th>
<th>Minimum</th>
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<tr>
<td></td>
<td>60%</td>
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</table>

**7 Mechanical Ventilation**

<table>
<thead>
<tr>
<th>Minimum HSPF (Heating Season Performance Factor)</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>78%</td>
</tr>
</tbody>
</table>

**8 Mechanical Systems**

<table>
<thead>
<tr>
<th>Select System Type</th>
<th>Minimum COP @ 5F</th>
<th>Minimum SEER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.8</td>
<td>15.9</td>
</tr>
</tbody>
</table>

© Phius 2021

(www.phius.org)
Provide double pane high performance glazing (Low-E) on west, north, and east, but clear on south for maximum passive solar gain.

In this climate air conditioning will always be needed, but can be greatly reduced if building design minimizes overheating.

For passive solar heating face most of the glass area south to maximize winter sun exposure, but design overhangs to fully shade in summer.

Traditional passive homes in warm humid climates used high ceilings and tall operable (French) windows protected by deep overhangs and verandas.

Keep the building small (right-sized) because excessive floor area wastes heating and cooling energy.

Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning.

Traditional passive homes in hot humid climates used lightweight construction with openable walls and shaded outdoor porches, raised above ground.

Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth).

Raise the indoor comfort thermostat setpoint to reduce air conditioning energy consumption (especially if occupants wear seasonally appropriate clothing).

Lower the indoor comfort temperature at night to reduce heating energy consumption (lower thermostat heating setback) (see comfort low criteria).

Extra insulation (super insulation) might prove cost effective, and will increase occupant comfort by keeping indoor temperatures more uniform.

Screened porches and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems.

Long narrow building floorplan can help maximize cross ventilation in temperate and hot humid climates.

Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes.

High Efficiency air conditioner or heat pump (at least Energy Star) should prove cost effective in this climate.

Trees (neither conifer or deciduous) should not be planted in front of passive solar windows, but are OK beyond 45 degrees from each corner.

In wet climates well ventilated attics with pitched roofs work well to shed rain and can be extended to protect entries, porches, verandas, outdoor work ...

Use light colored building materials and cool roofs (with high emissivity) to minimize conducted heat gain.

Carefully seal building to minimize infiltration and eliminate drafts, especially in windy sites (house wrap, weather stripping, tight windows).

High Efficiency furnace (at least Energy Star) should prove cost effective.
The thermal envelope area is not overly large in plan, but there is a conditioned space over the attic that greatly adds to the overall envelope to iCFA ratio.
Positive Impact Homes: Criteria

**PhiUS 2021 Performance Criteria Calculator v3.2**

**Units:** Imperial (IP)

**Building Function:** Residential

**Project Type:** New Construction

- **State/Province:** Texas
- **City:** Houston William P Hobby

- **Envelope Area (ft²):** 12,905.6
- **ICFA (ft²):** 3,200.0
- **Dwelling Units (Count):** 1
- **Total Bedrooms (Count):** 4

**Space Conditioning Criteria**

- **Annual Heating Demand:** 2.8 kBTU/ft²yr
- **Annual Cooling Demand:** 14.3 kBTU/ft²yr
- **Peak Heating Load:** 3.1 BTU/ft²hr
- **Peak Cooling Load:** 5.7 BTU/ft²hr

**Source Energy Criteria**

- **PhiUS CORE:** 5000 kWh/person.yr
- **PhiUS ZERO:** 0 kWh/person.yr

**PHIUS+ 2018 Space Conditioning Criteria Calculator v2**

**Method:** Calculator

**Units:** Imperial (IP)

- **State/Province:** Texas
- **City:** Houston William P Hobby

- **Envelope Area (ft²) / ICFA (ft²):** 4.03
- **ICFA (ft²) / Person:** 640

*Calculator method is used for official certification targets.*

**Space Conditioning Criteria**

- **Annual Heating Demand:** 3.4 kBTU/ft²yr
- **Annual Cooling Demand:** 24.3 kBTU/ft²yr
- **Peak Heating Load:** 3.1 BTU/ft²hr
- **Peak Cooling Load:** 5.7 BTU/ft²hr

Typed entry will override sliding scale.
The results of the CALCULATOR method take precedence over the ESTIMATOR method.
Palm Street Development

1st Floor

2nd Floor

Images courtesy of Mint Homes / Raj Development Corporation
### Phius 2021

**Performance Criteria Calculator v1.2**

<table>
<thead>
<tr>
<th>UNITS:</th>
<th>IMPERIAL (IP) ↓</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUILDING FUNCTION:</td>
<td>RESIDENTIAL ↓</td>
</tr>
<tr>
<td>PROJECT TYPE:</td>
<td>NEW CONSTRUCTION ↓</td>
</tr>
</tbody>
</table>

- **STATE/PROVINCE:** TEXAS
- **CITY:** HOUSTON WILLIAM P. HOBBS

| Envelope Area (ft²) | 16,032.0 |
| Dwelling Units (Count) | 2 |
| Total Bedrooms (Count) | 5 |

**Space Conditioning Criteria**

- **Annual Heating Demand:** 2.7 kBTU/ft²yr
- **Annual Cooling Demand:** 19.1 kBTU/ft²yr
- **Peak Heating Load:** 3.1 Btu/ft²hr
- **Peak Cooling Load:** 4.1 Btu/ft²hr

**Source Energy Criteria**

- **Phius CORE:** 6600 kWh/person.yr
- **Phius ZERO:** 0 kWh/person.yr

---

### phius 2021

**Performance Criteria Calculator v2**

<table>
<thead>
<tr>
<th>UNITS:</th>
<th>IMPERIAL (IP) ↓</th>
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<td>BUILDING FUNCTION:</td>
<td>RESIDENTIAL ↓</td>
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<tr>
<td>PROJECT TYPE:</td>
<td>NEW CONSTRUCTION ↓</td>
</tr>
</tbody>
</table>

- **STATE/PROVINCE:** TEXAS
- **CITY:** HOUSTON WILLIAM P. HOBBS

| Envelope Area (ft²) | 16,032 |
| Dwelling Units (Count) | 2 |
| Total Bedrooms (Count) | 5 |

**Space Conditioning Criteria**

- **Annual Heating Demand:** 2.6 kBTU/ft²yr
- **Annual Cooling Demand:** 17.3 kBTU/ft²yr
- **Peak Heating Load:** 3.1 Btu/ft²hr
- **Peak Cooling Load:** 4.0 Btu/ft²hr

**Source Energy Criteria**

- **phius CORE:** 5612 kWh/person.yr
- **phius ZERO:** 0 kWh/person.yr

---

### PHIOUS 2018

**Space Conditioning Criteria Calculator v2**

- **METHOD:** CALCULATOR
- **UNITS:** IMPERIAL (IP)

| STATE/PROVINCE | TEXAS |
| CITY | HOUSTON WILLIAM P. HOBBS |

- **Envelope Area (ft²) / ICFA (ft²):** 3.06
- **ICFA (ft²) / person:** 761

*Note: The results of the CALCULATOR method take precedence over the ESTIMATOR method.*
Cooling has tightened significantly while heating has tightened marginally. Source Energy is just different!
Performance criteria for windows in a predominately cooling climate are highly varied. Like in colder climates, the best thing to do is to have excellent shading control for passive solar gain in the winter and complete shading in the summer.

U-values in the Prescriptive Path vary from: U 0.24 (Dallas) to U 0.31 (Houston)
The WUFI model results shown to this point vary from U 0.2 to U 0.25

Glazing specifications is still a balance as it gets cold enough to warrant some passive solar gain, but for the majority of the year strategies to limit gain is best.
  Limit West Windows
  North Windows

SHGC vs U-value vs Shading
  The better shading you have, the higher SHGC would be possible.
  SHGC is VERY Important. In testing, a SHGC reduction from .3 to .25 allowed the window to go from U .2 to U .5 and achieve the same cooling demand.
  Heating Performance suffered in the above example.

Triple Pane windows for acoustics, better performance, etc.
  Watch code requirements for SHGC (NFRC vs Center of Glass)
• With a high degree of certainty, I will state that Point Source Cooling is NOT EFFECTIVE (while point source heating often is – or can be)
• Distribution of cooling energy (and probably heating energy too) should be ducted to each room
  Central AHU not necessarily required.
  Ducted mini-splits with short runs located in conditioned attic may be sufficient pending overall design constraints.
  Dedicated Dehumidification should be provided.

Questions - that need some more clarifying, discussion, or research:
• Impact of glass surface temperature for thermal comfort – “Mean Radiant Temperature”
• Effects of air leakage, stratification and air movement.
  Ceiling fans being planned for in both projects.
Airtightness

Baseline Target

0.03 CFM50 / .48 ACH

- Heating demand: 2 kBtu/ft² yr
- Cooling demand: 7.39 kBtu/ft² yr
- Heating load: 2.83 Btu/ft²
- Cooling load: 3.37 Btu/ft²
- Source energy: 0 kWh/Person yr
- Site energy: -0.3 kBtu/ft² yr

0.05 CFM50 / .81 ACH

- Heating demand: 2.14 kBtu/ft² yr
- Cooling demand: 7.95 kBtu/ft² yr
- Heating load: 3.18 Btu/ft²
- Cooling load: 3.4 Btu/ft²
- Source energy: 51 kWh/Person yr
- Site energy: 0.1 kBtu/ft² yr

0.06 CFM50 / .97 ACH

- Heating demand: 2.21 kBtu/ft² yr
- Cooling demand: 8.24 kBtu/ft² yr
- Heating load: 3.36 Btu/ft²
- Cooling load: 3.42 Btu/ft²
- Source energy: 157 kWh/Person yr
- Site energy: 0.3 kBtu/ft² yr

0.15 CFM50 / 2.42 ACH

- Heating demand: 2.89 kBtu/ft² yr
- Cooling demand: 13.21 kBtu/ft² yr
- Heating load: 4.95 Btu/ft²
- Cooling load: 3.58 Btu/ft²
- Source energy: 974 kWh/Person yr
- Site energy: 1.85 kBtu/ft² yr
### Ventilation

#### Baseline:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Sensible recovery efficiency</td>
<td>8</td>
</tr>
<tr>
<td>Humidity recovery efficiency</td>
<td>68</td>
</tr>
<tr>
<td>Electric efficiency [W/ft²]</td>
<td>5</td>
</tr>
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</table>

#### Lower Sensible Recovery:

<table>
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<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Sensible recovery efficiency</td>
<td>6</td>
</tr>
<tr>
<td>Humidity recovery efficiency</td>
<td>68</td>
</tr>
<tr>
<td>Electric efficiency [W/ft²]</td>
<td>5</td>
</tr>
</tbody>
</table>

#### Lower Humidity Recovery:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Sensible recovery efficiency</td>
<td>8</td>
</tr>
<tr>
<td>Humidity recovery efficiency</td>
<td>5</td>
</tr>
<tr>
<td>Electric efficiency [W/ft²]</td>
<td>5</td>
</tr>
</tbody>
</table>

**Zero Humidity Recovery = Cooling Demand @ 13.4 kBtu/ft²yr!**
Large buildings and slab on grade construction leads to longer DHW piping runs and wait times for hot water (ZERH requirement can be challenging).

Preference to:
- On-demand recirculation systems
- Instantaneous water heaters for specific locations

Hot water heaters sometimes located in attics to save space on main floor

Heat Pump Water Heater inside vs Split system:
- Non-Split HPWH provide free cooling inside the project.
  - This is a big advantage compared to the split system.
  - The cost is substantially less as well and easier to replace.
- Acoustics and cold air distribution / location of the HPWH are a concern.
System Considerations

System Requirements:
Heating, Cooling, Dehumidification

Both projects plan on using Mini-Split Heat Pump technologies as the primary heating and cooling system.

Dehumidification is being specified using a dedicated dehumidifier and duct system.

Positive Impact Homes is specifying an additional air filtration system in addition to the filters on the rest of the mechanical equipment.

Electrification
Both projects are pursuing full electrification, but there are some issues.

Backup Energy
A main drawback to full electrification is the requirement for backup and resiliency. This is especially a concern regarding recent events with grid outages during frosts and hurricane season. For this reason, Positive Impact Homes has been specifying Natural Gas supply or Propane Tank for a backup generator.
### System Considerations

**PV Potential:**

- **Houston:** 20deg Tilt
- **Houston:** 40deg Tilt
- **Chicago:** 40deg Tilt

---

#### Houston Tx: 20deg Tilt

**Results:** 14,113 kWh/Year

<table>
<thead>
<tr>
<th>Month</th>
<th>AC Energy (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>901</td>
</tr>
<tr>
<td>February</td>
<td>956</td>
</tr>
<tr>
<td>March</td>
<td>1,196</td>
</tr>
<tr>
<td>April</td>
<td>1,303</td>
</tr>
<tr>
<td>May</td>
<td>1,346</td>
</tr>
<tr>
<td>June</td>
<td>1,337</td>
</tr>
<tr>
<td>July</td>
<td>1,043</td>
</tr>
<tr>
<td>August</td>
<td>1,311</td>
</tr>
<tr>
<td>September</td>
<td>1,271</td>
</tr>
<tr>
<td>October</td>
<td>1,239</td>
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<tr>
<td>November</td>
<td>992</td>
</tr>
<tr>
<td>December</td>
<td>917</td>
</tr>
<tr>
<td><strong>Annual</strong></td>
<td><strong>14,112</strong></td>
</tr>
</tbody>
</table>

#### Houston Tx: 40deg Tilt

**Results:** 13,990 kWh/Year

<table>
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<th>AC Energy (kWh)</th>
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<td>1,024</td>
</tr>
<tr>
<td>February</td>
<td>1,041</td>
</tr>
<tr>
<td>March</td>
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<tr>
<td>July</td>
<td>1,178</td>
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<tr>
<td>August</td>
<td>1,211</td>
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<tr>
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<td>October</td>
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<tr>
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<tr>
<td>December</td>
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<tr>
<td><strong>Annual</strong></td>
<td><strong>13,987</strong></td>
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#### Chicago IL: 40deg Tilt

**Results:** 13,291 kWh/Year

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<th>AC Energy (kWh)</th>
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<td>797</td>
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<tr>
<td>February</td>
<td>3.87</td>
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<td>March</td>
<td>4.79</td>
<td>1,209</td>
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<tr>
<td>April</td>
<td>5.38</td>
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<td>5.41</td>
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<td>July</td>
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<td>1,371</td>
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<tr>
<td>August</td>
<td>5.91</td>
<td>1,300</td>
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<td>September</td>
<td>5.47</td>
<td>1,214</td>
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<tr>
<td>November</td>
<td>3.20</td>
<td>815</td>
</tr>
<tr>
<td>December</td>
<td>2.52</td>
<td>672</td>
</tr>
<tr>
<td><strong>Annual</strong></td>
<td><strong>4.66</strong></td>
<td><strong>13,292</strong></td>
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