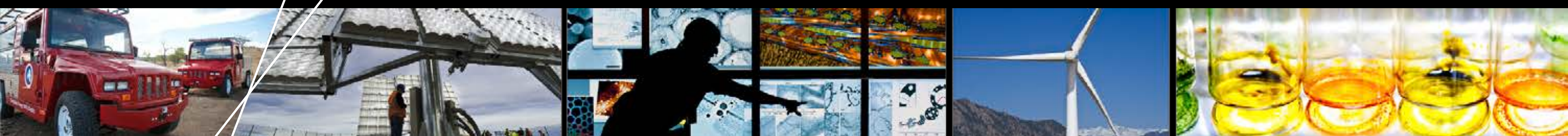
NATIONAL RENEWABLE ENERGY LABORATORY

Building America Roadmap Overview

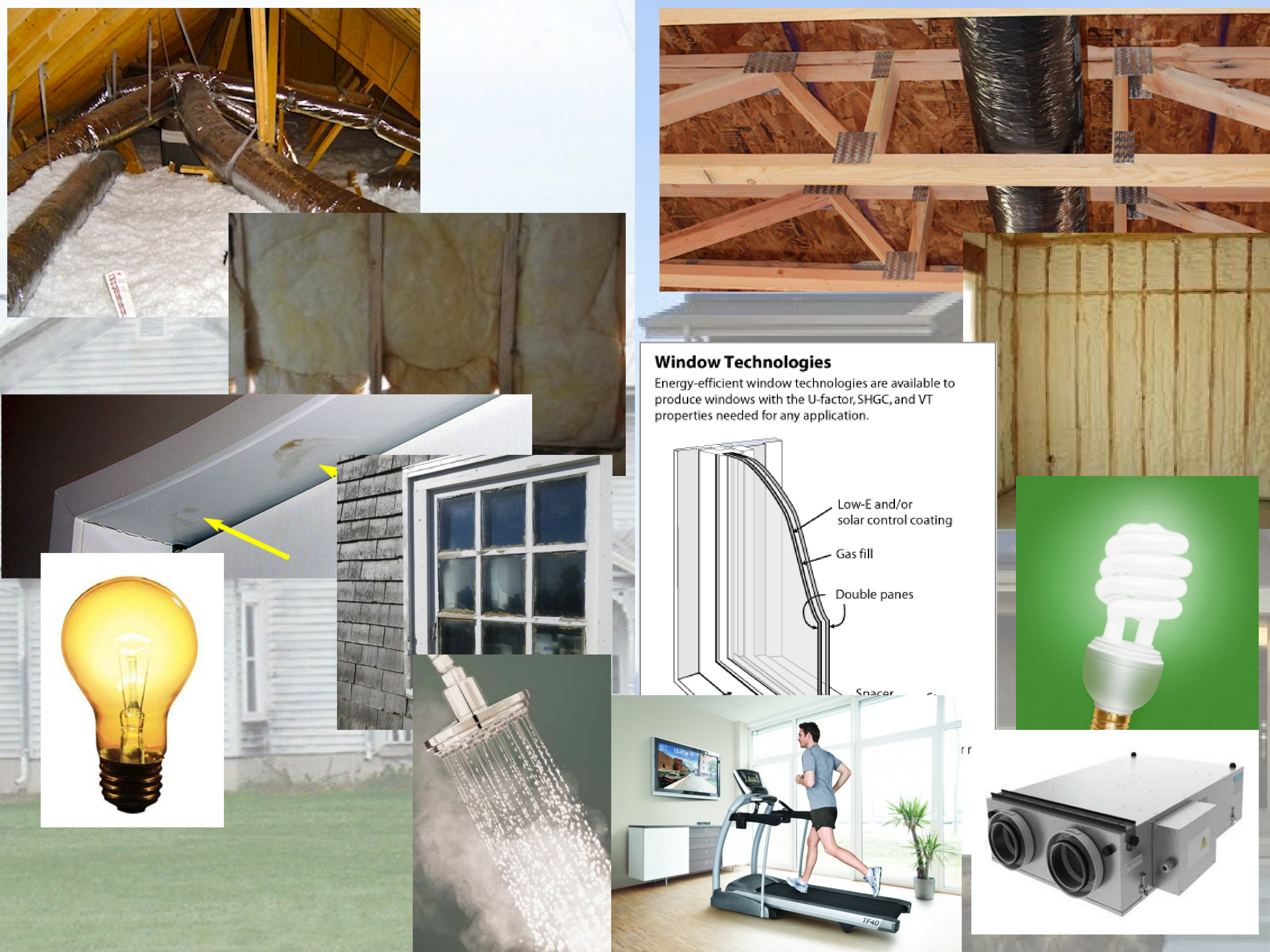
Optimal Comfort Systems for Low-Load Homes



Jon Winkler

Senior Engineer

Residential Buildings



Window Technologies
Energy-efficient window technologies are available to produce windows with the U-factor, SHGC, and VT properties needed for any application.
Low-E and/or solar control coating
Gas fill
Double panes
Spacer

HVAC Loads Are Changing

Current Practice

- Ducts in attic
- Code thermal enclosure
- Intentional mechanical ventilation not included
- Standard appliances and lighting

- **400 → 1,000 sq. ft. per ton of cooling**

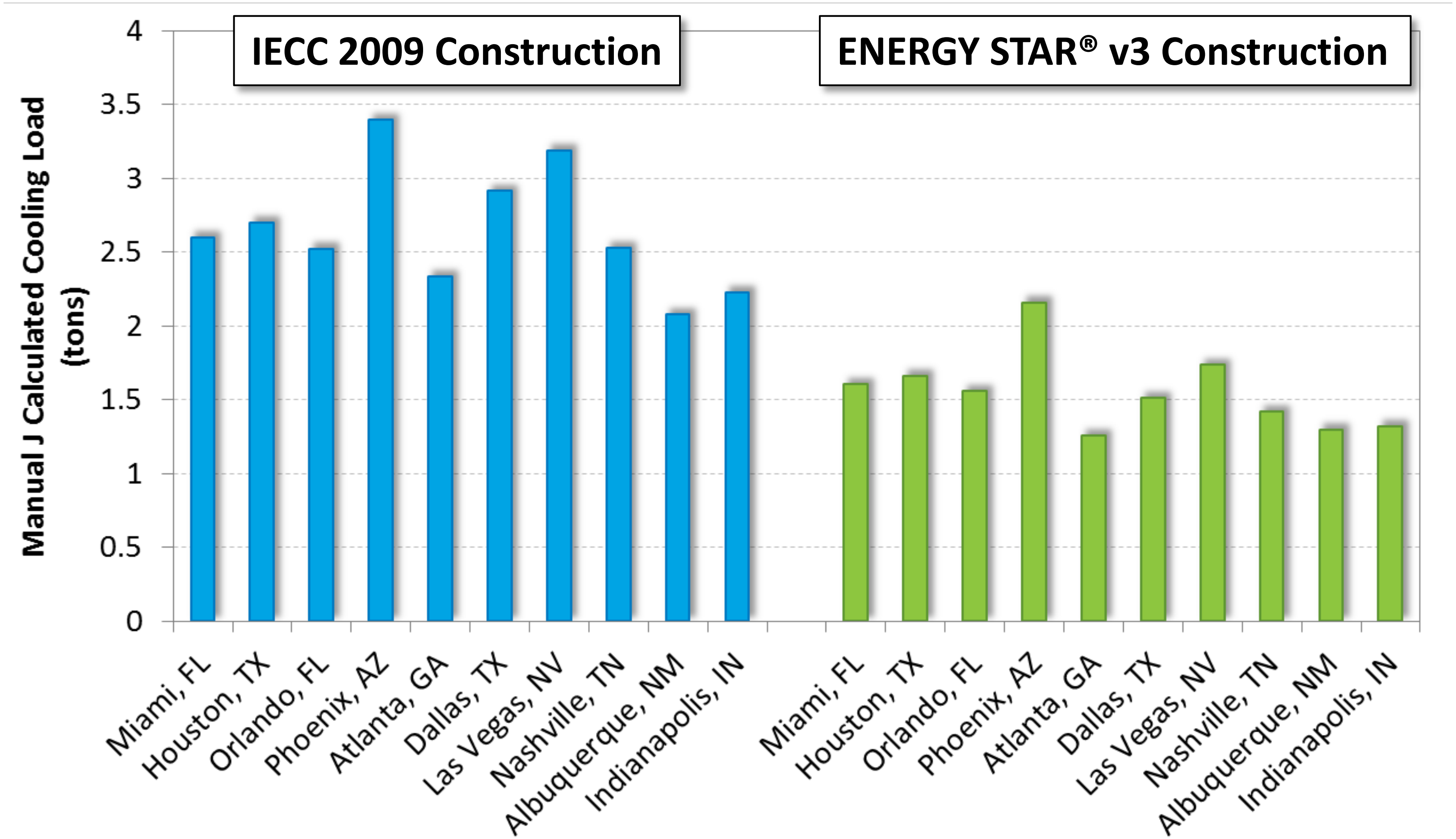
High Performance

- Ducts in conditioned space
- High-R thermal enclosure
- Air tight construction requires mechanical ventilation
- ENERGY STAR appliances and lighting

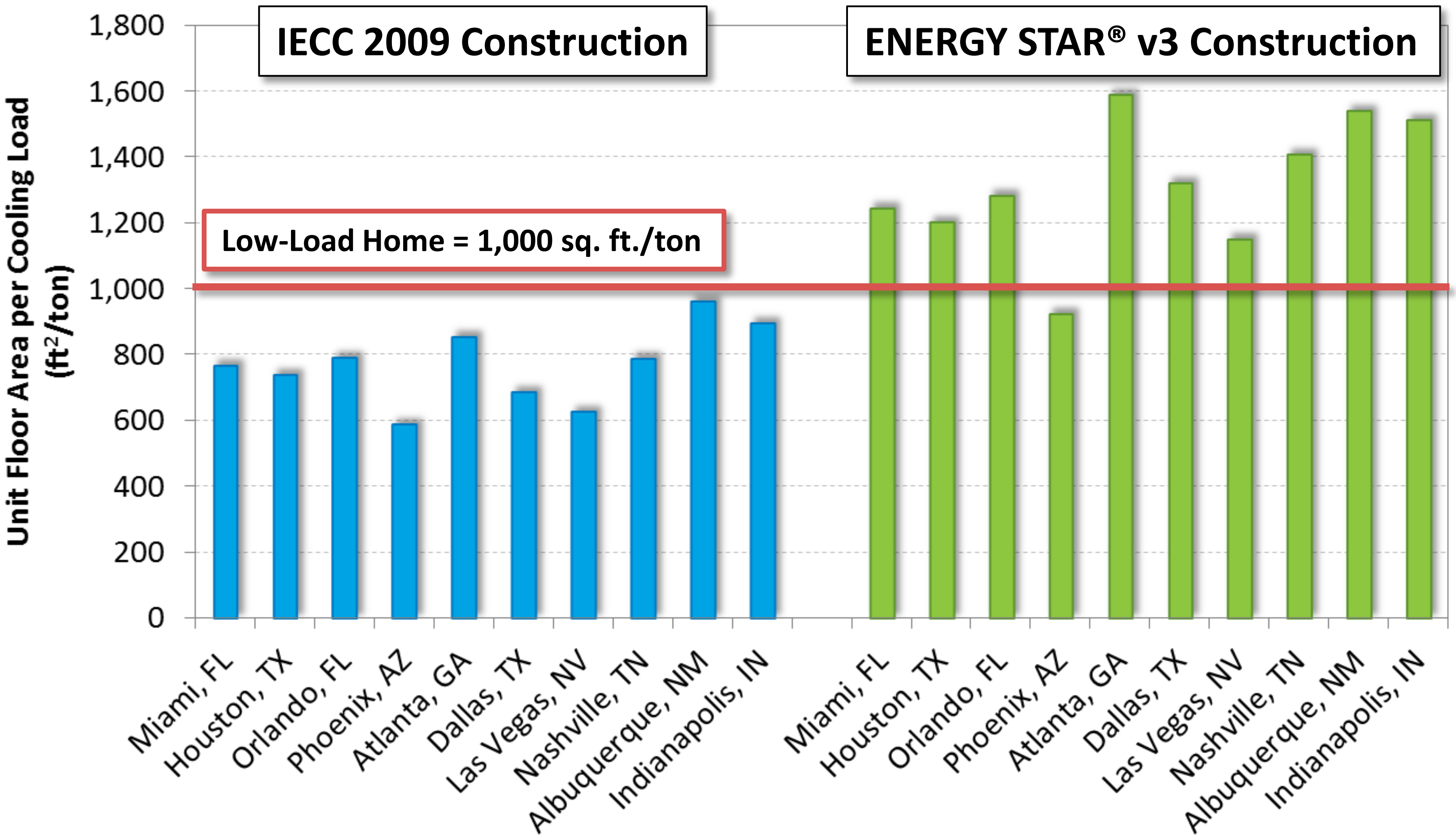
- **1,200 → 2,000 sq. ft. per ton of cooling**
- **Supplemental dehumidification may be required**

Heating and cooling loads are shrinking…

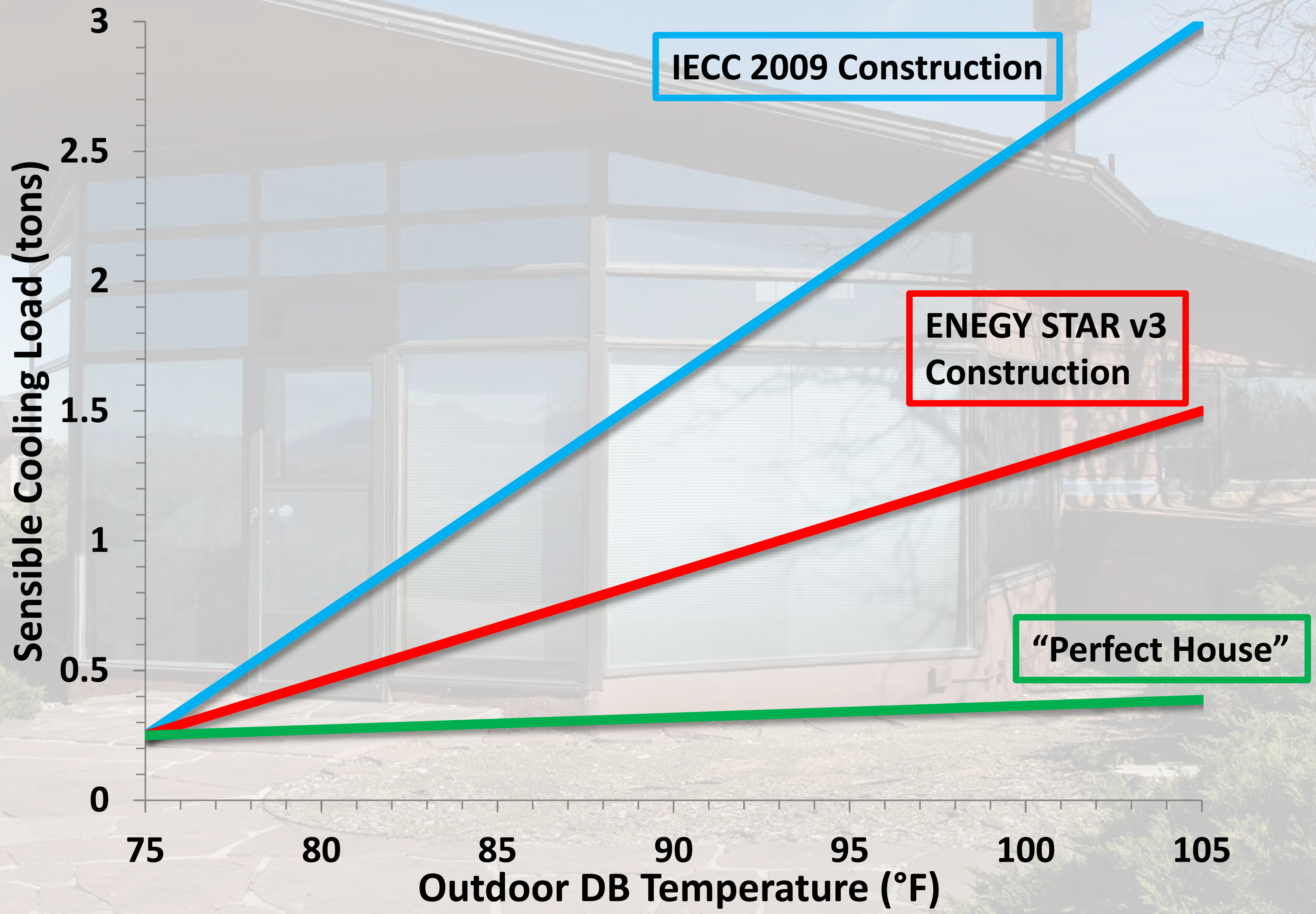
Take a typical 2,000 sq. ft. house…



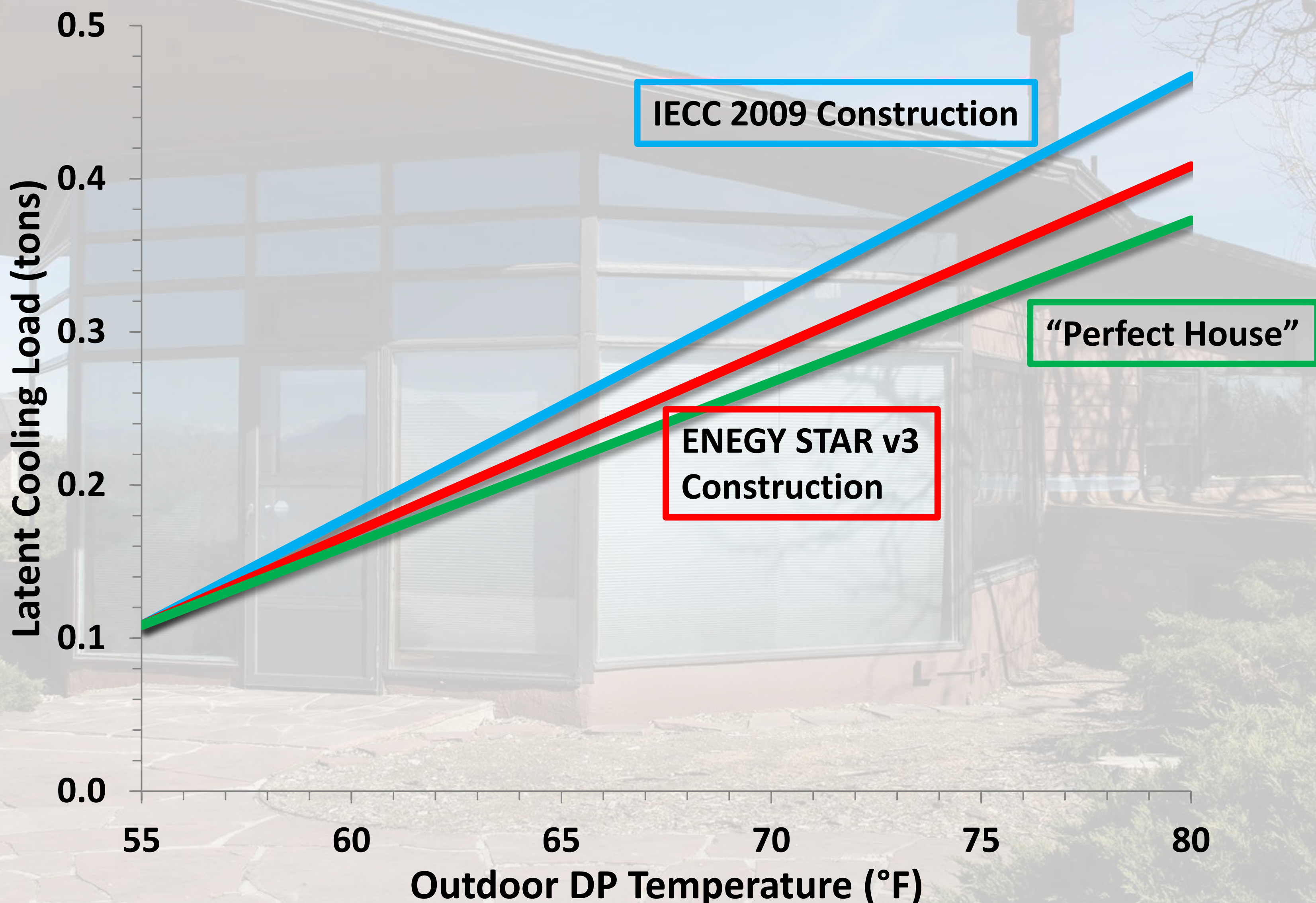
Normalized Cooling Loads



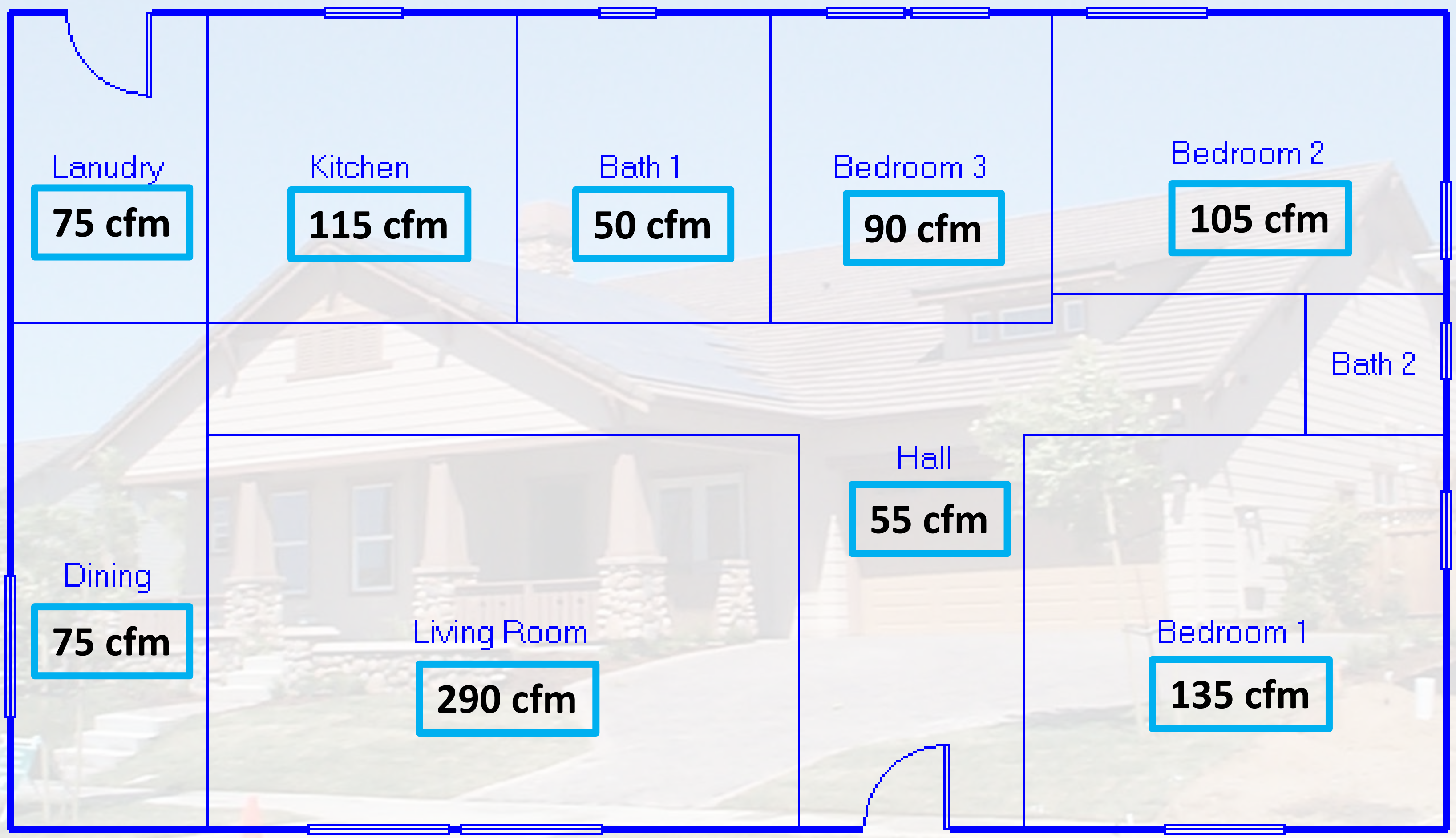
Load-Load Homes Behave Differently



Load-Load Homes Behave Differently

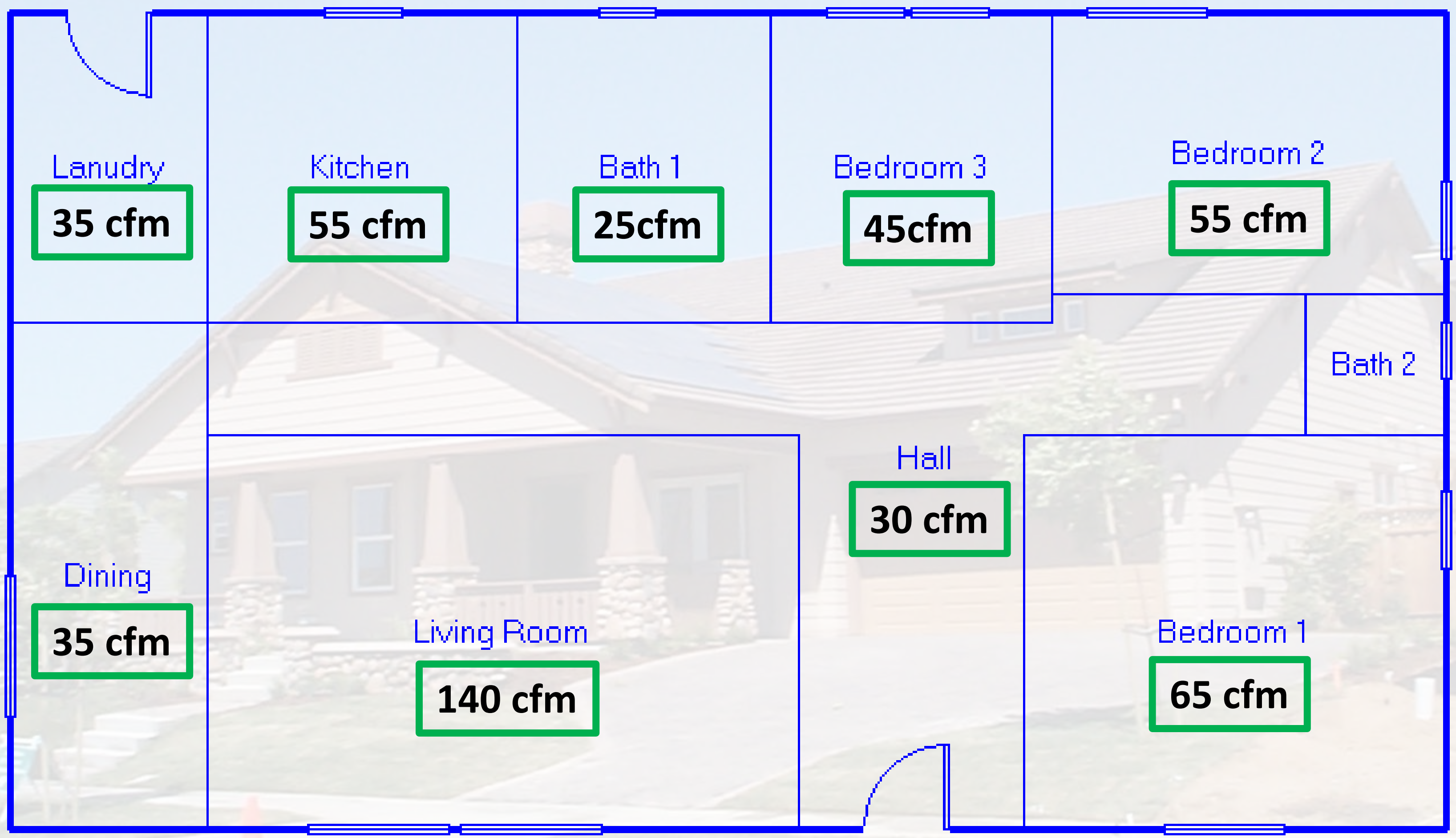


Load-Load Homes Require Less Air Flow



IECC 2009 Construction

Load-Load Homes Require Less Air Flow

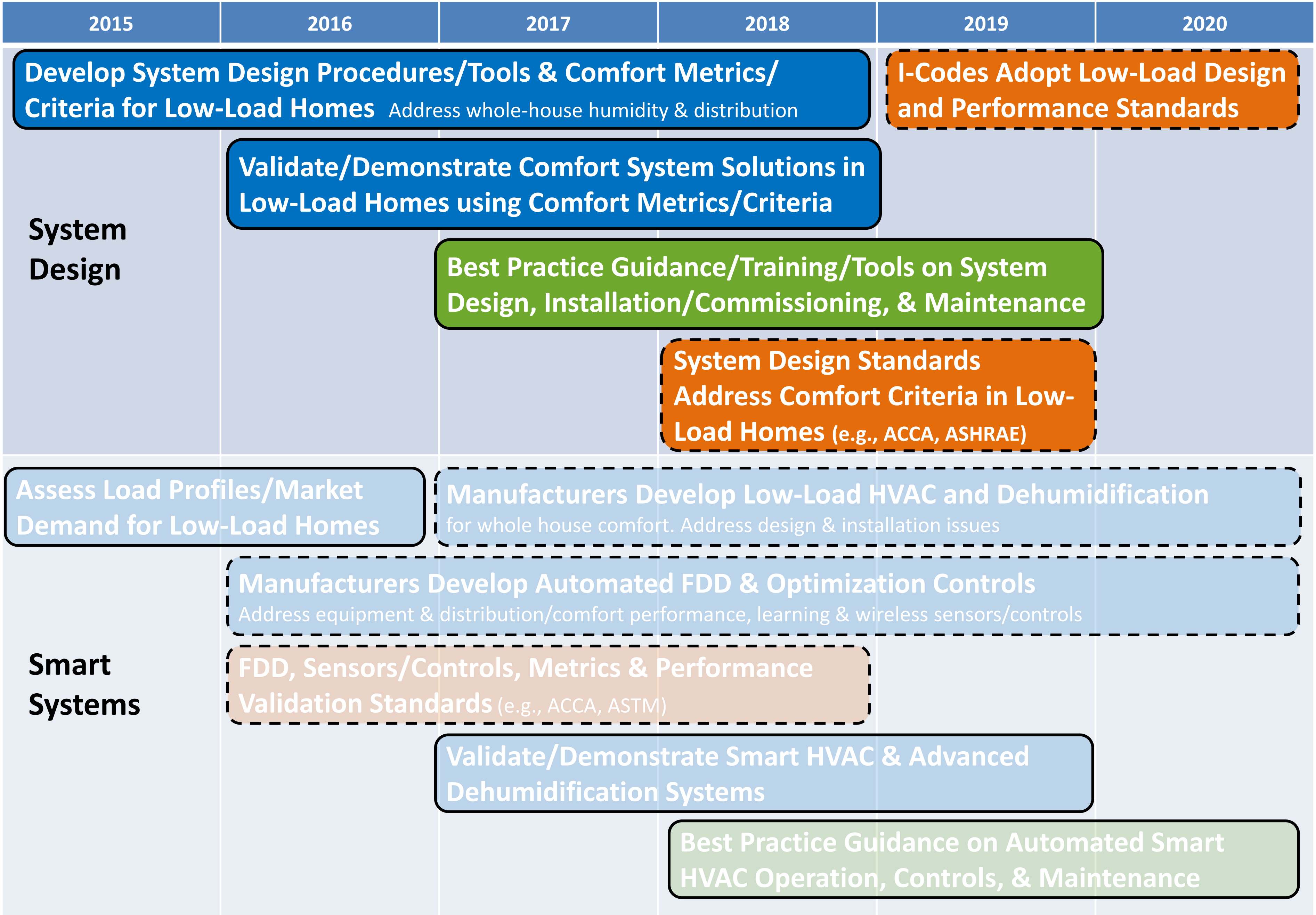


ENERGY STAR v3 Construction

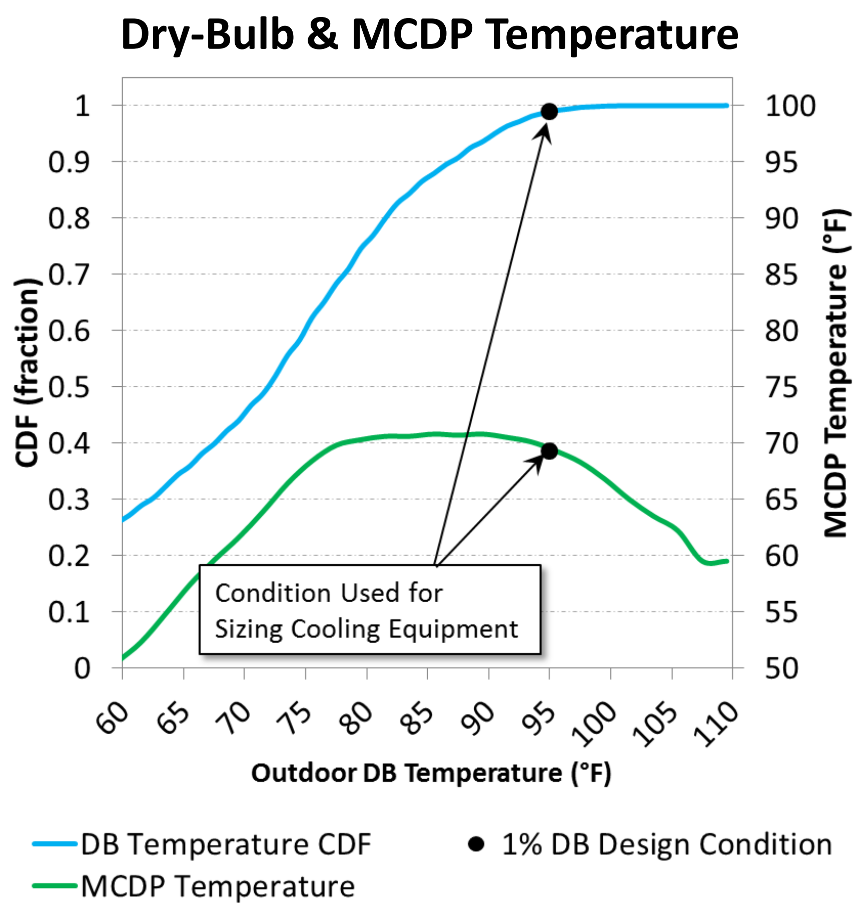
Comfort Issues Facing Low-Load Homes

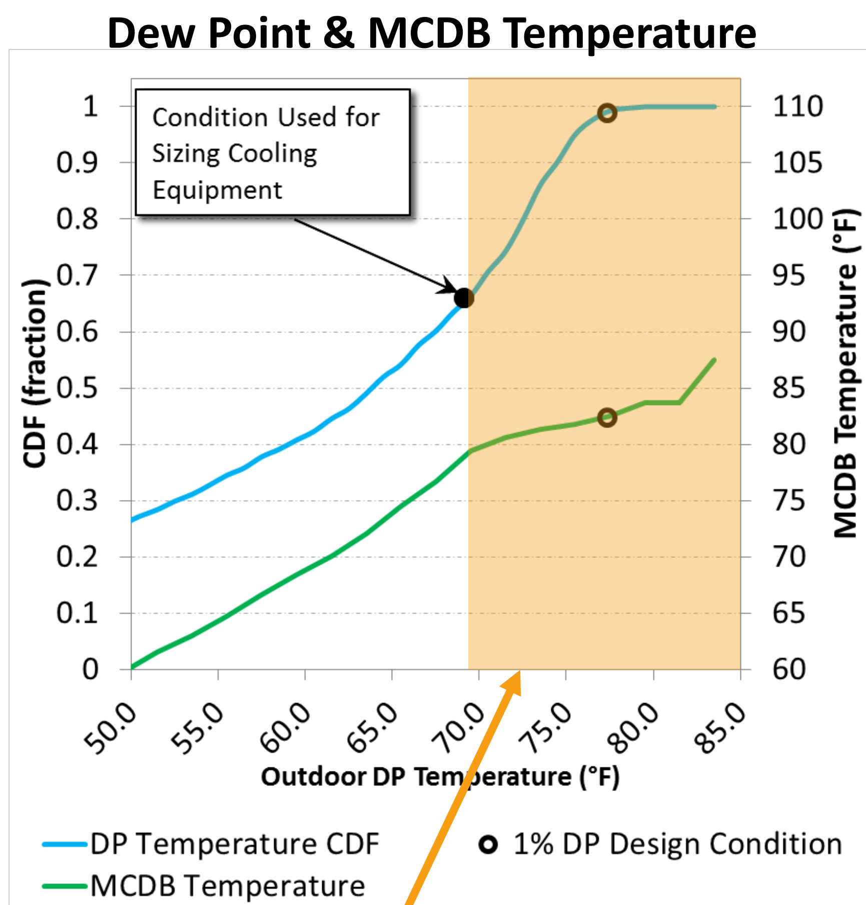
- **Part-load cooling humidity control**
  - Conventional equipment operation and selection procedures limit latent capacity
- **Room air flow and mixing**
  - Lower room sensible loads require less delivered air flow
- **Temperature non-uniformity**
  - Low-load homes can have large variation in room cooling loads due to local solar and internal gains
  - Single thermostat results in over- and under-conditioning of spaces

Optimal Comfort Systems for Low-Load Homes



Design Approaches for Year-Round Comfort



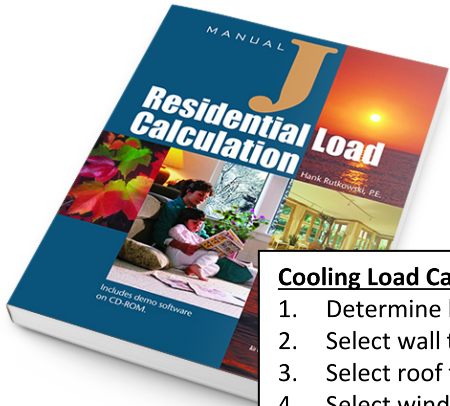


Latent loads are higher than the cooling design latent load for ~30% of the year

Source: ASHRAE Weather Data Viewer v5.0; Houston, TX

Selecting Dehumidification Equipment

Calculate building loads using 1% DB temperature



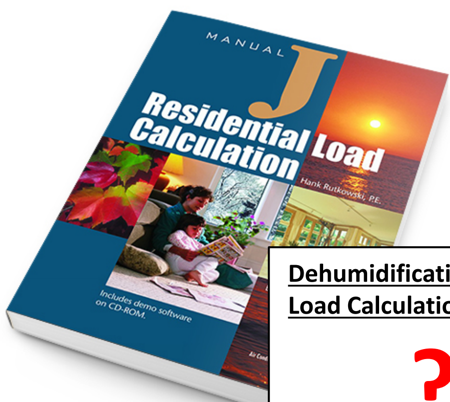
Cooling Load Calculations

1. Determine building size…
2. Select wall types…
3. Select roof types…
4. Select window types…
5. Select ducts…

Select the equipment

Install the equipment

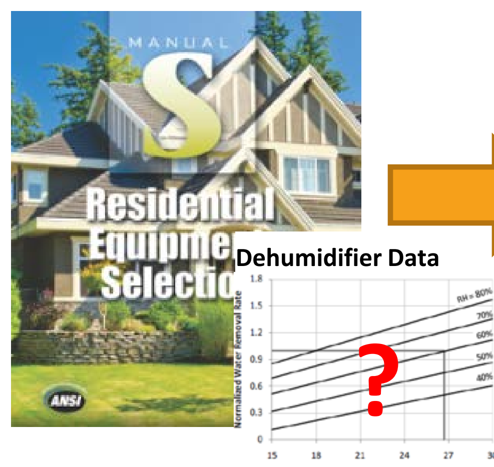
Calculate building loads using ?% DP temperature



Dehumidification Load Calculations

?

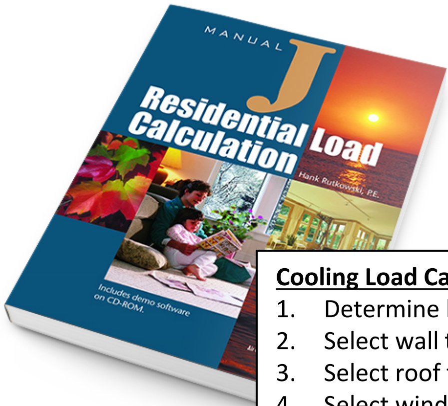
Select the equipment



Install the equipment

Selecting Dehumidification Equipment

Calculate building loads using 1% DB temperature



Cooling Load Calculations

1. Determine building size…
2. Select wall types…
3. Select roof types…
4. Select window types…
5. Select ducts…

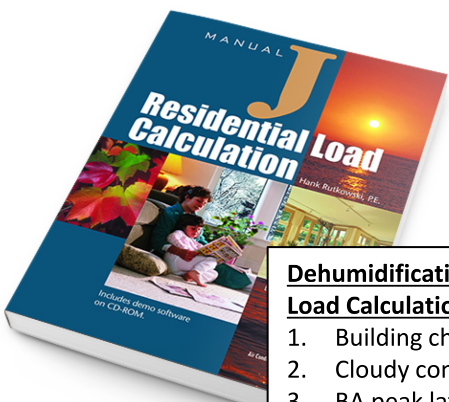
Select the equipment

COOLING CAPACITY - XP14-024 with

Entering Wet Bulb Temperature	Total Air Volume cfm	Total Air Volume L/s	85°F (29°C) Total Cooling Capacity kBtuh	85°F (29°C) Total Cooling Capacity kW	85°F (29°C) Comp Motor kW Input	85°F (29°C) Sensible To Total Ratio (S/T) Dry Bulb 75°F 24°C	80°F 27°C	85°F 29°C	95°F (35°C) Total Cooling Capacity kBtuh	95°F (35°C) Total Cooling Capacity kW	95°F (35°C) Comp Motor kW Input	95°F (35°C) Sensible To Total Ratio Dry Bulb 75°F 24°C
63°F (17°C)	670	315	23.4	6.9	1.35	.75	.89	1.00	22.2	6.5	1.54	.77
	820	385	24.4	7.2	1.36	.80	.96	1.00	23.2	6.8	1.55	.82
	820	385	24.4	7.2	1.36	.80	.96	1.00	23.2	6.8	1.55	.82
67°F (19°C)	670	315	24.8	7.3	1.36	.59	.72	.85	23.6	6.9	1.55	.60
	820	385	25.8	7.6	1.36	.62	.78	.92	24.6	7.2	1.56	.63
	820	385	25.8	7.6	1.36	.62	.78	.92	24.6	7.2	1.56	.63
71°F (22°C)	670	315	26.2	7.7	1.37	.45	.58	.70	24.8	7.3	1.56	.45
	820	385	27.2	8.0	1.37	.46	.61	.75	25.8	7.6	1.57	.47
	820	385	27.2	8.0	1.37	.46	.61	.75	25.8	7.6	1.57	.47

Install the equipment

Calculate building loads using **2**% DP temperature



Dehumidification Load Calculations

1. Building characteristics…
2. Cloudy conditions…
3. BA peak latent internal gains…
4. Etc…

Select the equipment

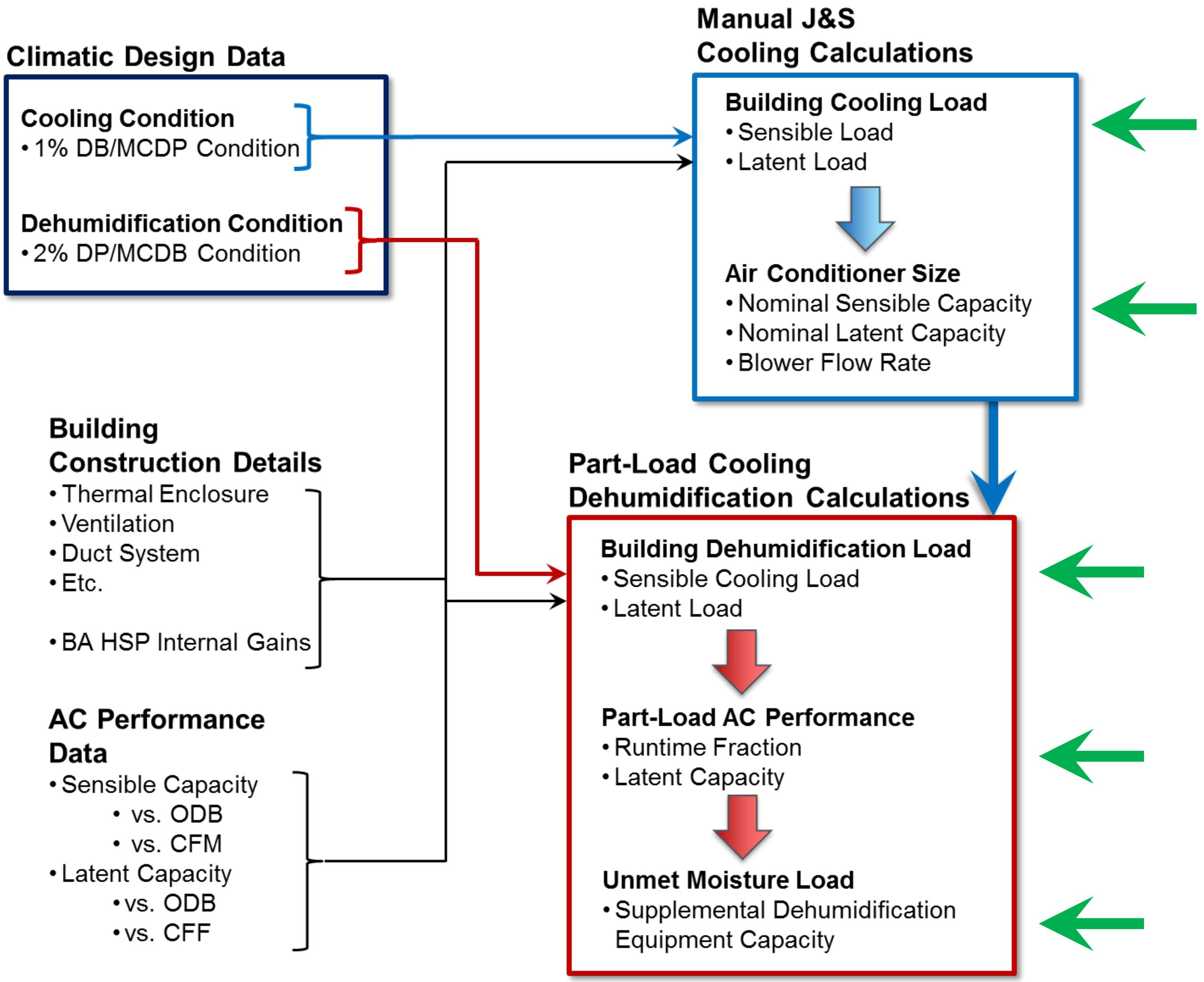
NREL

Laboratory Test Report for Six ENERGY STAR® Dehumidifiers

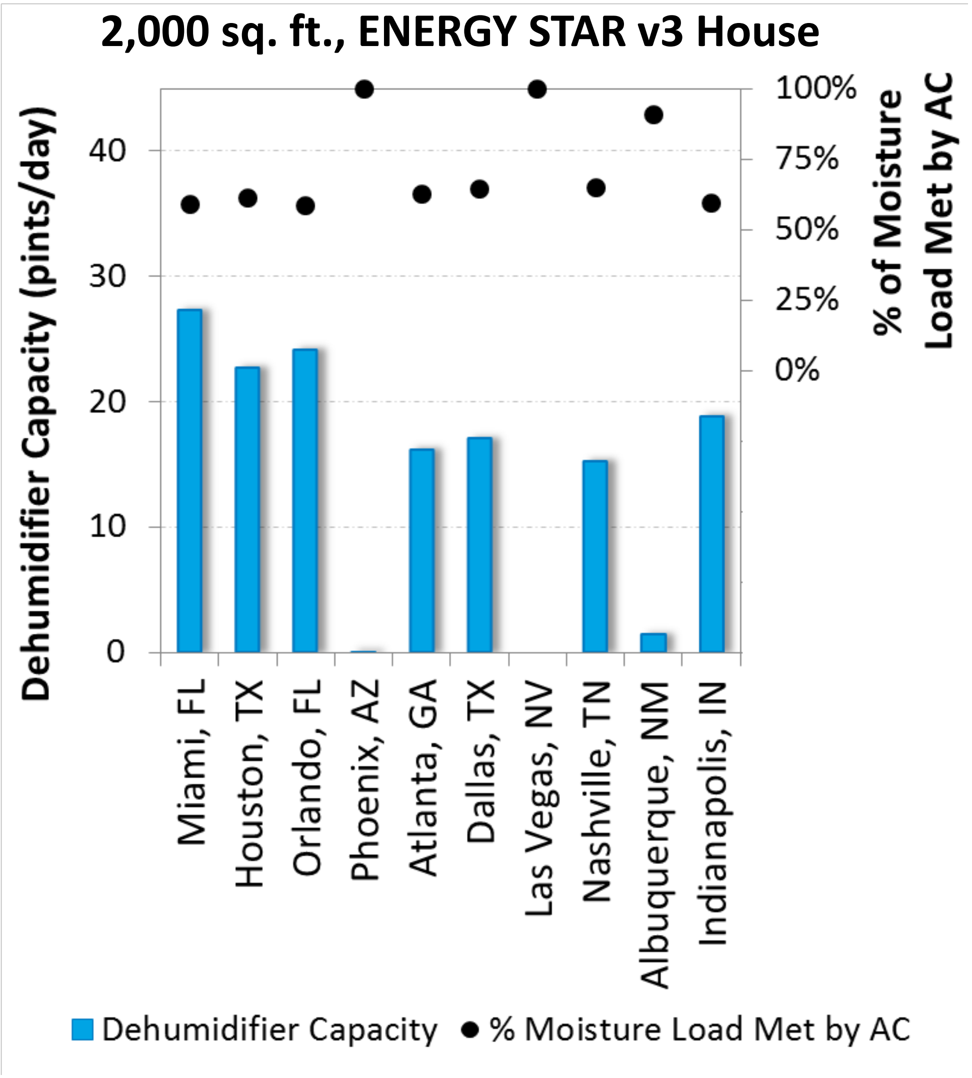
COOLING CAPACITY - XP14-024 with

Install the equipment

Dehumidification Load Calculation



Selecting Dehumidification Equipment



- **Parametric analysis comparing procedure to EnergyPlus annual simulations**
  - 3 constructions, 10 cities
- **Smaller dehumidifiers than "expected"**
- **Dehumidifiers met the load 94% of the time**
- **With an RH setpoint of 55%, indoor RH never exceed 60%**

Optimal Comfort Systems for Low-Load Homes

2015	2016	2017	2018	2019	2020

System Design

Develop System Design Procedures/Tools & Comfort Metrics/ Criteria for Low-Load Homes Address whole-house humidity & distribution

I-Codes Adopt Low-Load Design and Performance Standards

Validate/Demonstrate Comfort System Solutions in Low-Load Homes using Comfort Metrics/Criteria

Best Practice Guidance/Training/Tools on System Design, Installation/Commissioning, & Maintenance

System Design Standards Address Comfort Criteria in Low-Load Homes (e.g., ACCA, ASHRAE)

Smart Systems

Assess Load Profiles/Market Demand for Low-Load Homes

Manufacturers Develop Low-Load HVAC and Dehumidification
for whole house comfort. Address design & installation issues

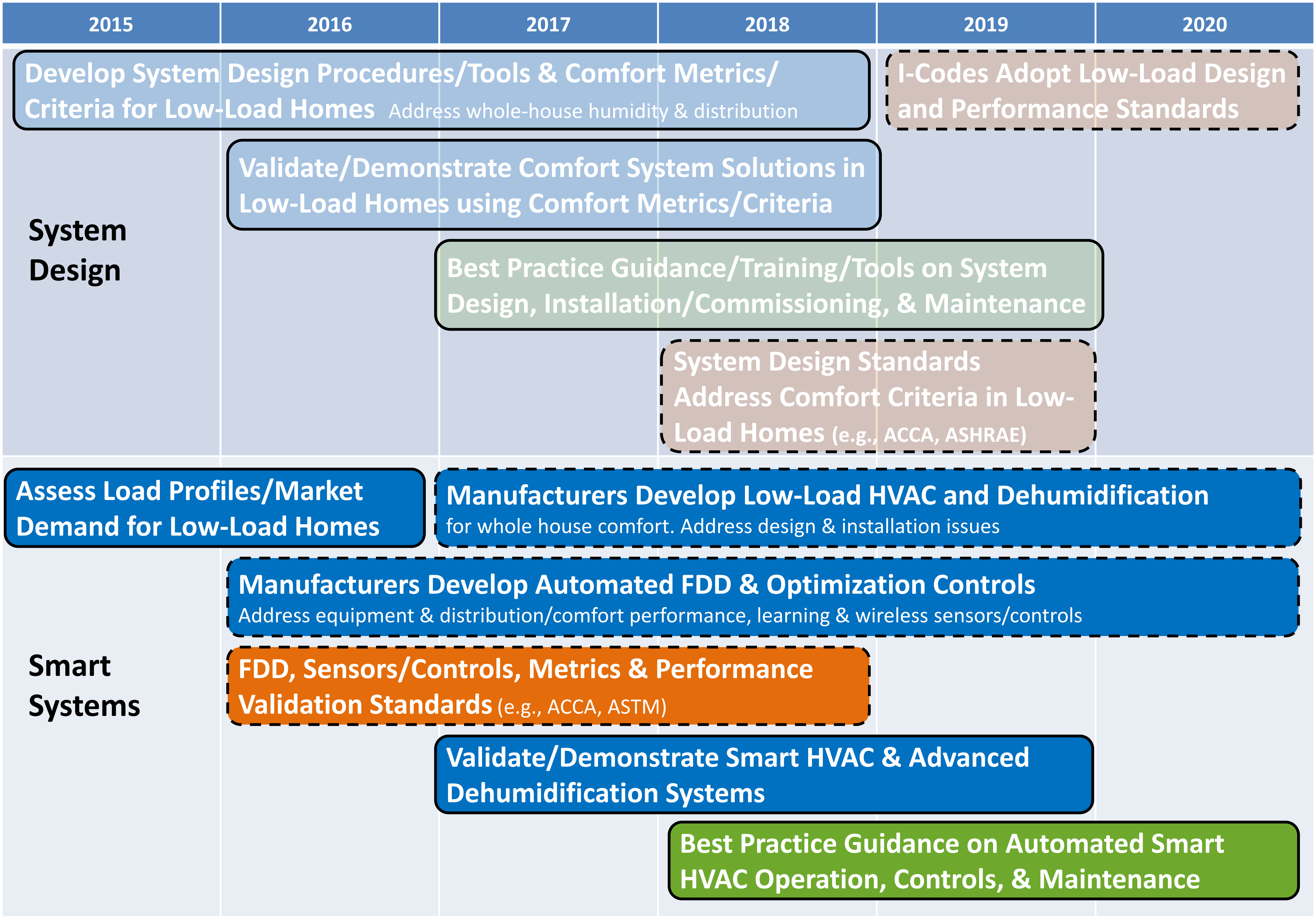
Manufacturers Develop Automated FDD & Optimization Controls
Address equipment & distribution/comfort performance, learning & wireless sensors/controls

FDD, Sensors/Controls, Metrics & Performance Validation Standards (e.g., ACCA, ASTM)

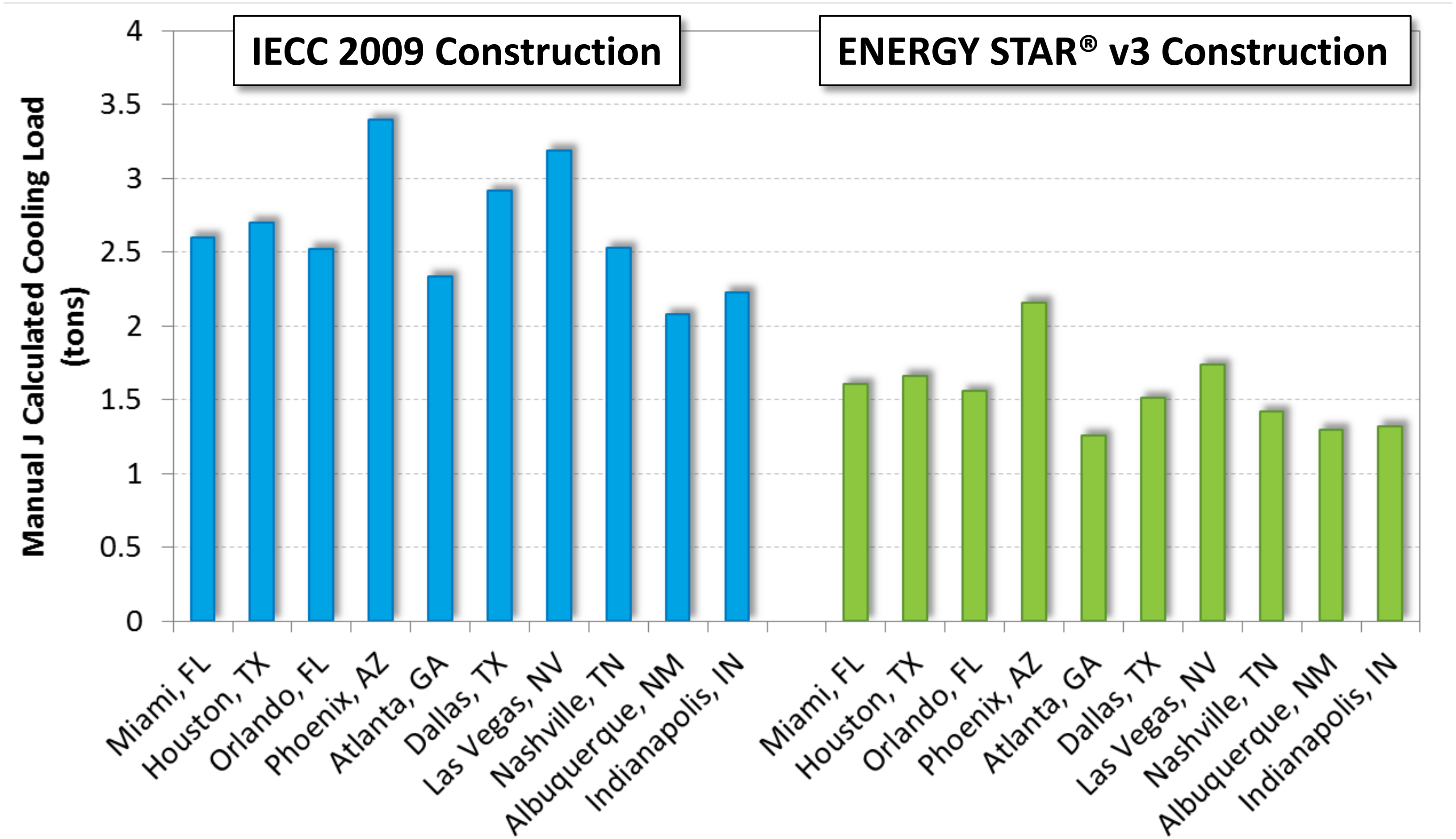
Validate/Demonstrate Smart HVAC & Advanced Dehumidification Systems

Best Practice Guidance on Automated Smart HVAC Operation, Controls, & Maintenance

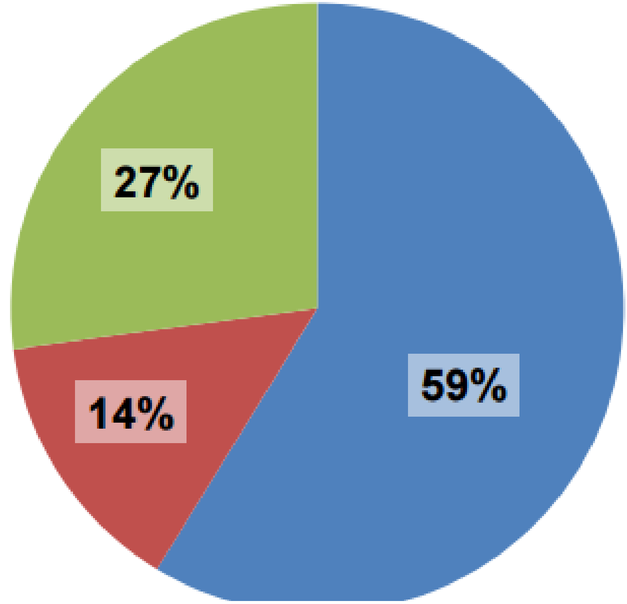
Optimal Comfort Systems for Low-Load Homes



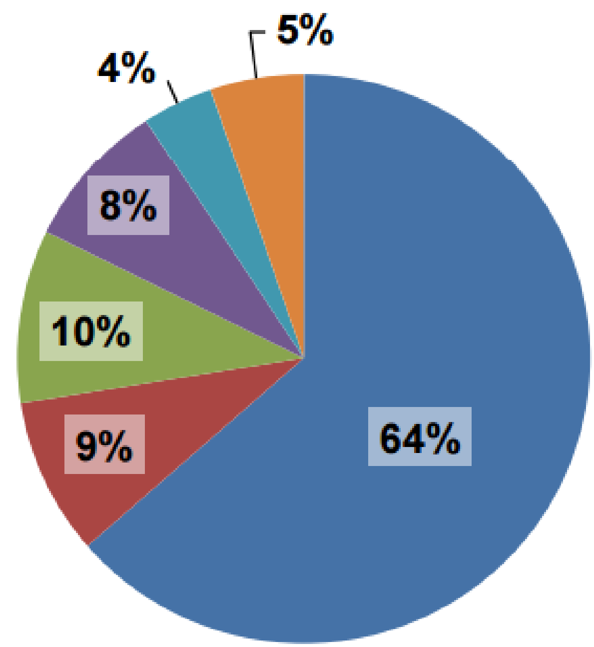
Take a typical 2,000 sq. ft. house…



Equipment Type	# of units (millions)
Central AC	56.1
Central Heat Pump	13.5
Window/Wall	25.9
TOTAL	**95.5**



Equipment Type		# of units (millions)
Forced-Air Furnace		70.0
Gas	44.3	
Electric	19.1	
Propane	3.9	
Fuel Oil	2.7	
Heat Pump		9.8
Steam or Hot Water		10.8
Gas	6.9	
Fuel Oil	3.9	
Distributed Electric		9.3
Distributed Gas		4.4
Other Fuels (Wood, Kerosene, etc.)		5.8
TOTAL		**110.1**

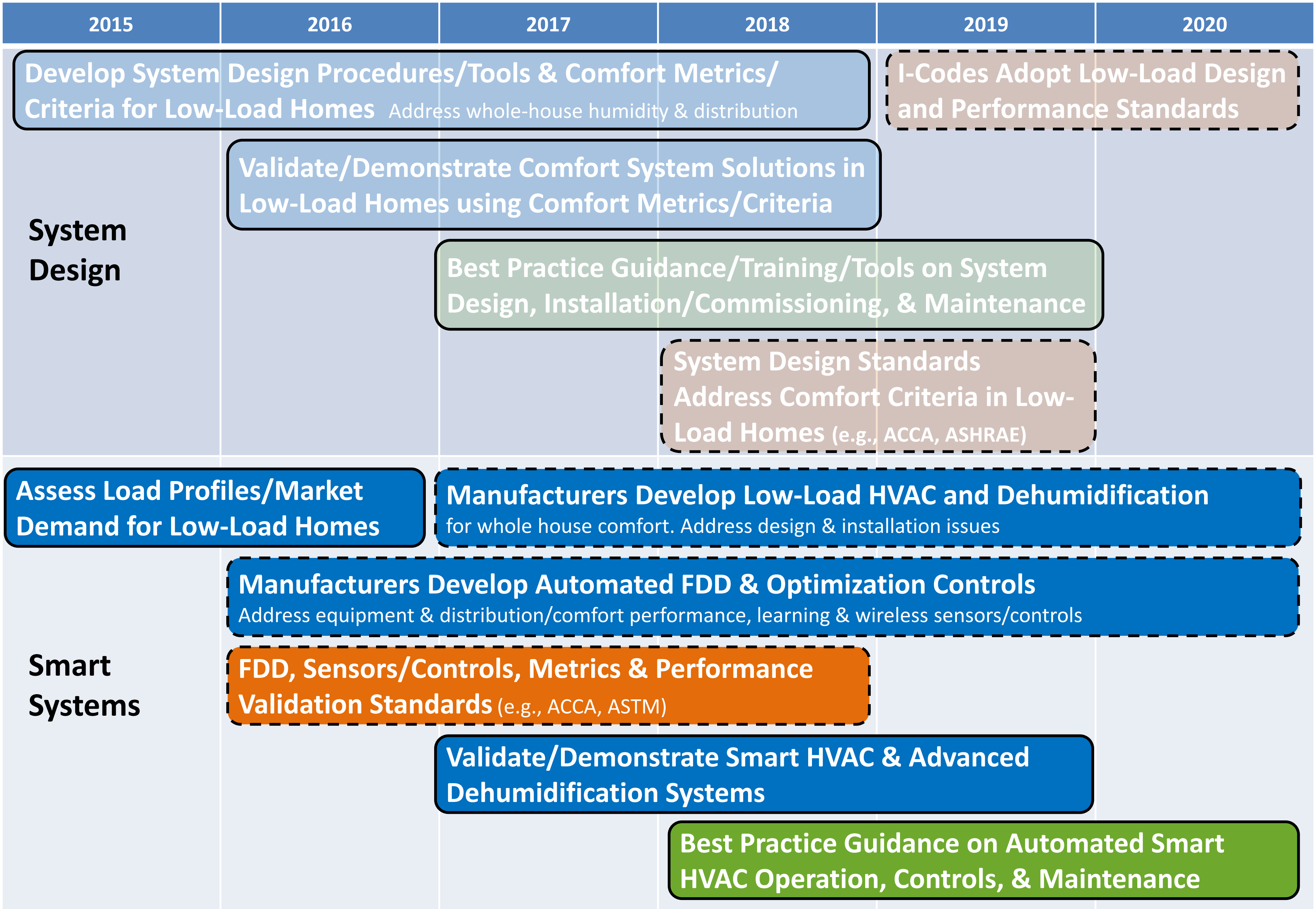


Source: Brown, Thorton, Widder, Baechler. 2013. Review of Residential Low-Load HVAC Systems.

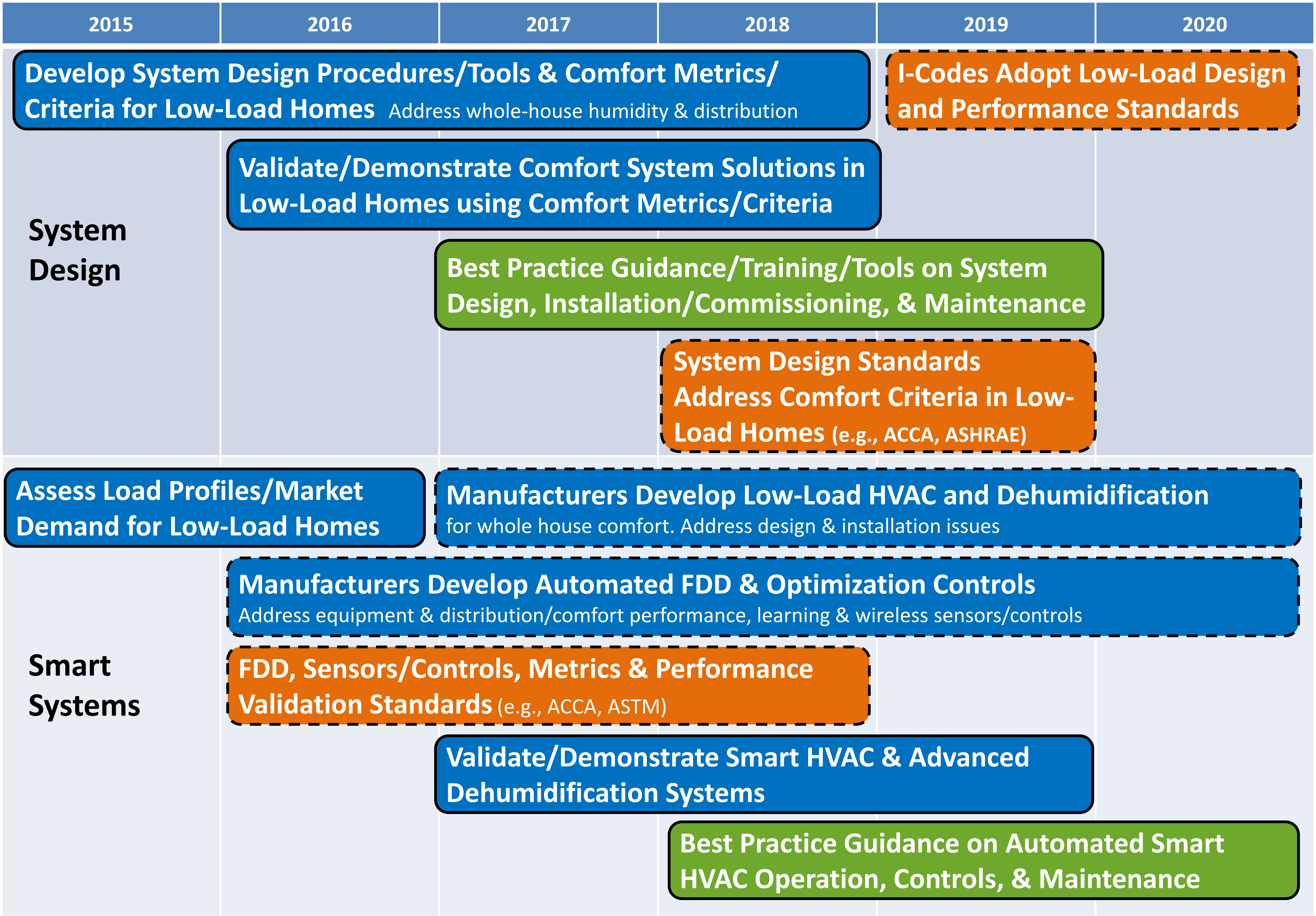
"… major HVAC manufacturers will not become interested in offering conventional central equipment with smaller capacities until hard numbers can show a significant low-load market …"

– Brown et al. (2013): Review of Residential Low-Load HVAC Systems. PNNL.

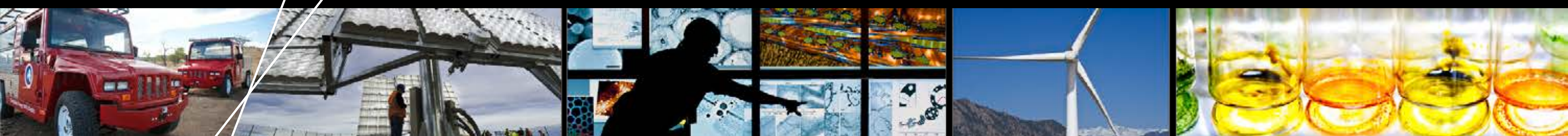
Optimal Comfort Systems for Low-Load Homes



B. Optimal Comfort Systems for Low-Load Homes



Questions?



Jon Winkler

Senior Engineer
Residential Buildings
jon.winkler@nrel.gov
303.275.4356