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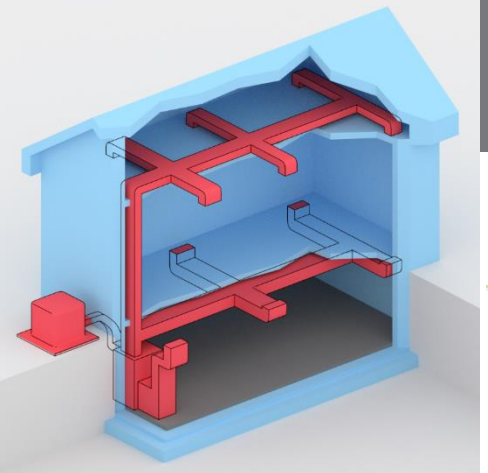

September 28, 2016

EEBA Excellence in Building Conference

EEBA™

Residential HVAC Systems and Strategies:

Line of Sight and Horizons

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Speaking Today

Timothy R. Beggs, PE, CEM, LEED AP

Program Manager, Innovation Programs,

IBACOS, Inc.

- 20+ years of commercial and institutional HVAC design experience with a major A/E design firm
- A background in residential energy and performance research, systems design and integration, project management and delivery, building diagnostics and building commissioning
- Member of ASHRAE's Residential Building Systems Technical Subcommittee
- Recently rejoined IBACOS

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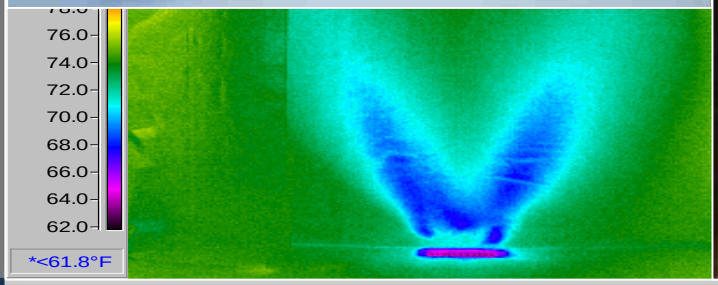

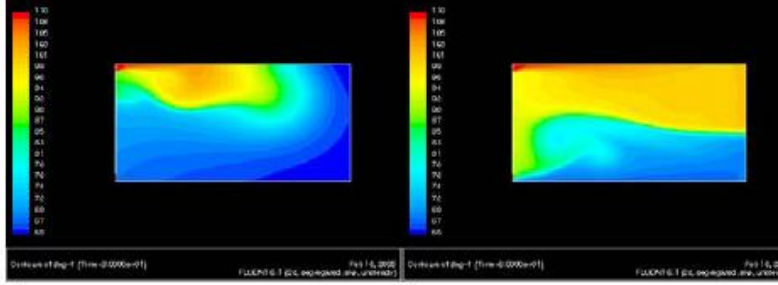

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Diffuser research work with IBACOS in 1997

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IBACOS Is About… Collaborative Innovation for the Homebuilding Industry

- Innovation in the homebuilding industry must be embraced and driven strategically. Game-changing innovation cannot be achieved alone.
- IBACOS connects the right mix of people, intelligence and tools to drive the research of new ideas and to develop meaningful value propositions for new products and technologies.
- Innovation involves and impacts consumers, builders, suppliers, policy makers and the world.

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Key Tenets

Seek to make homes:

- Safe
- Healthy
- Durable
- Comfortable
- Efficient
- Responsible
- Affordable

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Learning Objectives

- Outline common performance issues that persist with conventional residential HVAC systems despite ongoing improvements in home energy efficiency.
- Recognize current residential sector trends and practices that impact HVAC system selection and performance, and ultimately influence customer expectations.
- Identify some of the latest residential HVAC systems solutions and strategies that can be implemented today to raise the bar towards high performance.
- Recognize ways that the residential construction market is changing and how residential HVAC systems and strategies can be expected to evolve over the next 5-10 years.

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Topics for Today

- Common residential HVAC performance issues
- Residential trends impacting design and practices
- Latest high-performance HVAC programs, strategies and systems
- Evolving markets and expected HVAC impacts, with some glimpses of what may be on the horizon..

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Common Residential HVAC Performance Issues

Common Residential HVAC Performance Issues

- Struggles to save energy
- Lack of comfort
- Poor indoor air quality (IAQ)
- Intrusive noise
- Excessive cost to operate
- Ongoing reliability issues

These are homeowner experiences, and builders risks, but what are contributing root issues and causes?

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Common Residential HVAC Performance Issues

Root Causes for Performance Issues

1. Inaccurate load assessments
    - Calculations and reality don't match
2. Incorrect equipment or setup
3. Incorrect system airflows
4. Duct system leakage
    - Less air to spaces
    - Space loads unmet
    - Temperature excursions
    - Longer run time possible if Tstat impacted
    - Less mixing into space
    - Excessive heating /cooling to unintended areas
    - Energy loss to outdoors

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Common Residential HVAC Performance Issues

Root Causes for Performance Issues

5. Duct design
    - Supply or return
6. Inadequate duct insulation
    - Excessive supply air temperature gain or loss “in transit”
    - Space loads unmet
    - Temperature excursions
    - Cooler supply air in winter may cause feeling of draftiness
7. Improper or inadequate balancing
8. Refrigerant charge
9. Mixing issues impact space temperatures and ventilation effectiveness
10. Unbalanced exterior loads

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Residential Trends Impacting Design and Practices

Residential Trends Impacting Design and Practices

- What drives trends?
- What are some trends and impacts to HVAC systems?

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Residential Trends Impacting Design and Practices

What Drives Housing Industry Trends?

1. Consumer demand, values, beliefs and preferences
    A. Dollar value (microeconomic)
    B. Convenience
    C. Health
    D. Sustainability
    E. Happiness and peace of mind

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Residential Trends Impacting Design and Practices

What Drives Housing Industry Trends?

2. Demographics - Widening range of demands
    A. Family types
    B. Millennials
    C. Gen X
    D. Boomers
    E. Aging in place

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Residential Trends Impacting Design and Practices

What Drives Housing Industry Trends?

3. Technology developments
    A. Materials
    B. Equipment and systems
    C. Home automation and sensors
    D. Information systems, including user interfaces
    E. Other industries

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Residential Trends Impacting Design and Practices

What Drives Housing Industry Trends?

4. Economic factors (macroeconomic)
    A. Overall (sense of) health of the economy = consumer confidence
    B. Relative housing costs
    C. Interest rates and lending environment
    D. Energy costs

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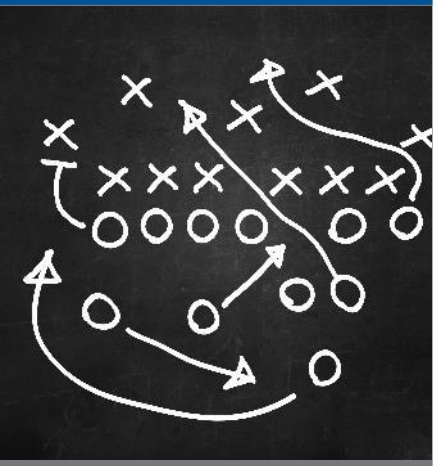

Residential Trends Impacting Design and Practices

What Drives Housing Industry Trends?

4. Economic factors *(continued)*
    E. Competition (opportunity)
        - Among builders
        - Among manufacturers and suppliers
        - Results in marketing and advertising strategies
    F. Risks for builders and contractors

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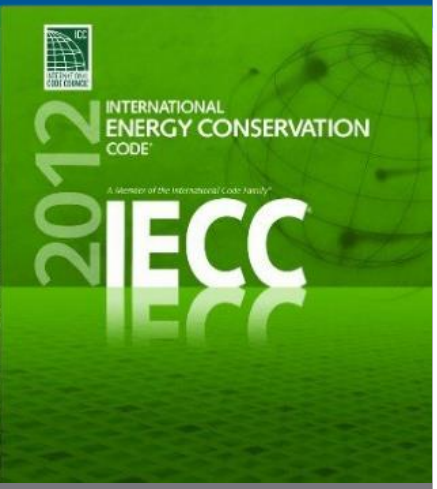
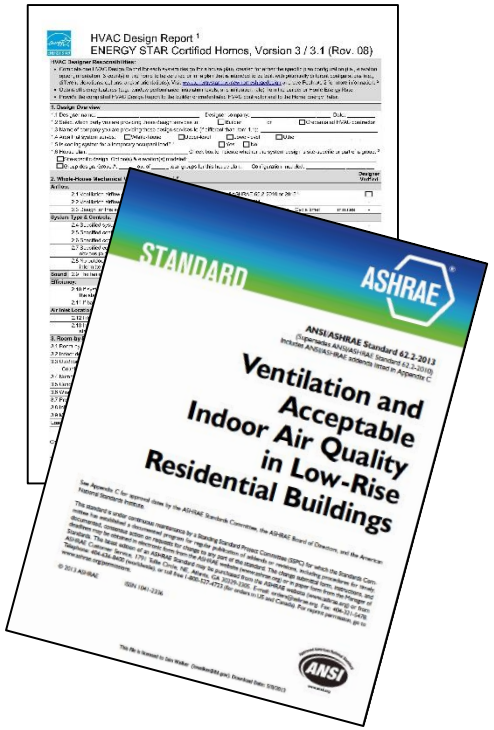


Residential Trends Impacting Design and Practices

What Drives Housing Industry Trends?

5. Government, utilities, and standards organizations
    A. Policy and codes
    B. Programs
    C. Subsidies and credits
    D. Consumer guidance
    E. Standards



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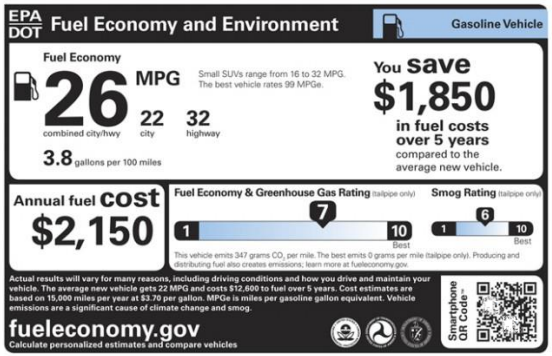
Residential Trends Impacting Design and Practices

Trends Impacting HVAC Systems and Strategies

1. Homebuyers are generally more savvy
    A. Society: Information-rich
    B. Use of gadgets & measurements
    C. Desire for user interaction
    D. Connectivity & smart technologies
    E. Seeking forward compatibility
    F. Cost-consciousness
    G. Verification of added value
    H. Choices: important
    I. Some demographics shun complexity

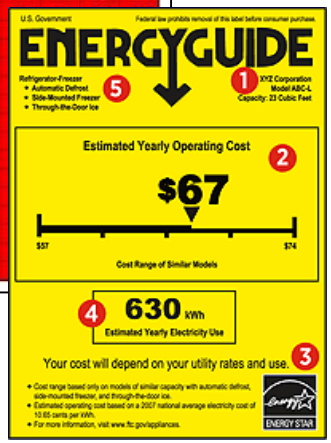
Information-Rich Society

Gadgets & Measurements



BMI Body Mass Index

	Healthy						Overweight					Obese				
BMI	19	20	21	22	23	24	25	26	27	28	29	30	35	40	45	50
Height	Weight in Pounds															
4'10"	91	96	100	105	110	115	119	124	129	134	138	143	167	191	215	239
4"11"	94	99	104	109	114	119	124	128	133	138	143	148	173	198	222	247
5'0"	97	102	107	112	118	123	128	133	138	143	148	153	179	204	230	255
5'1"	100	106	111	116	122	127	132	137	143	148	153	158	185	211	238	264
5'2"	104	104	115	120	126	131	136	142	147	153	158	164				
5'3"	107	113	118	124	130	135	141	146	152	158	163	169				
5'4"	110	116	122	128	134	140	145	151	157	163	169	174				
5'5"	114	120	126	132	138	144	150	156	162	168	174	180				
5'6"	118	124	130	136	142	148	155	161	167	173	179	186				
5'7"	121	127	134	140	146	153	159	166	172	178	185	191				
5'8"	125	131	138	144	151	158	164	171	177	184	190	197				
5'9"	128	135	142	149	155	162	169	176	182	189	196	203				
5'10"	132	139	146	153	160	167	174	181	188	195	202	209				
5'11"	136	143	150	157	165	172	179	186	193	200	208	215				
6'0"	140	147	154	162	169	177	184	191	199	206	213	221				
6'1"	144	151	159	166	174	182	189	197	204	212	219	227				
6'2"	148	155	163	171	179	186	194	202	210	218	225	233				
6'3"	152	160	168	176	184	192	200	208	216	224	232	240				
6'4"	156	164	172	180	189	197	205	213	221	230	238	246				



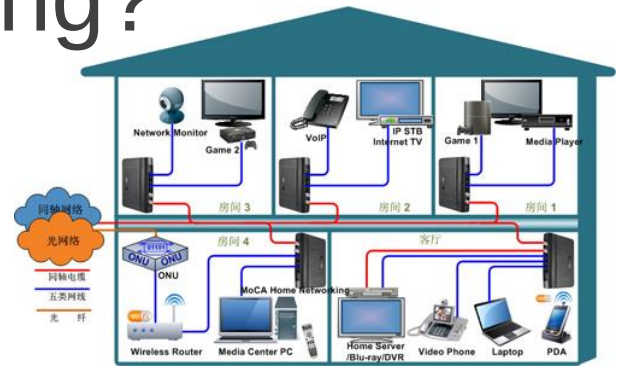
User Interaction, Controllability

Eager for Connectivity, Smart(er) Homes, Internet of Things

Home Automation:
Lighting

Sponsored by: LEVITON

Impact on housing?

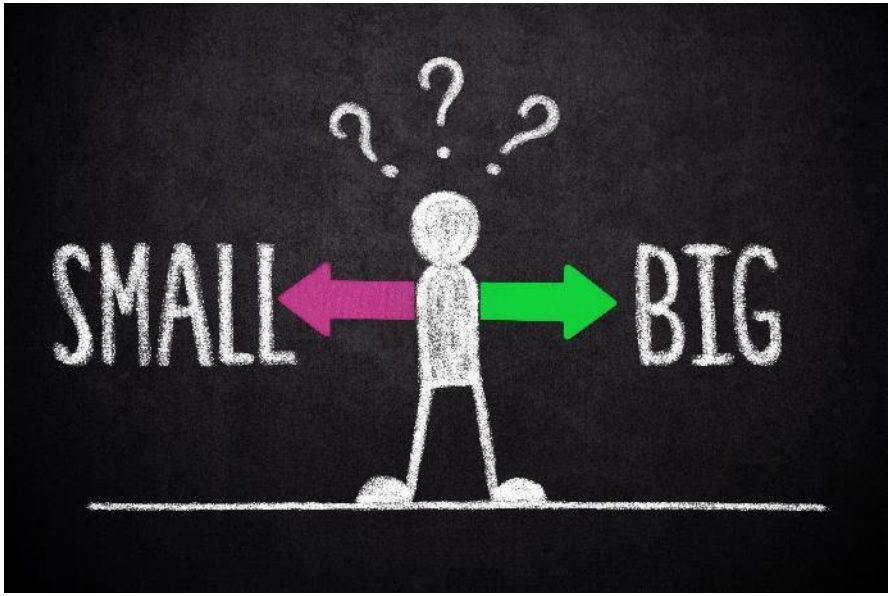


Forward Compatibility in a World of Change

Cost Conscious Consumers

Verification of Value

Choice Is Important, Don't Want to Compromise



Complex User Interfaces Not Universally Preferred

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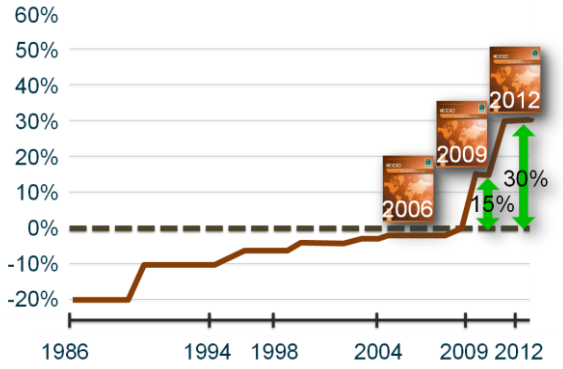
Residential Trends Impacting Design and Practices

Industry Trends Impacting HVAC Systems and Strategies

2. Lower heating and cooling loads
    A. Code and program driven
    B. Insulation
    C. Airtightness
    D. Windows
    E. Appliance and lighting efficiency standards



Source: US DOE Zero Energy Ready Home Program literature

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Residential Trends Impacting Design and Practices

Industry Trends Impacting HVAC Systems and Strategies

3. Emphasis on performance beyond energy use: lots of “-ilities”
    A. Comfort quality
    B. Indoor air quality
    C. Sound quality
    D. Maintainability
    E. Adjustability (individualized control)
    F. Reliability
    G. Durability
    H. Installability

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Residential Trends Impacting Design and Practices

Industry Trends Impacting HVAC Systems and Strategies

4. Marketing benefits more than features
    A. Builders
    B. Manufacturers
    C. Retrofit Contractors
5. Labor issues – availability and quality of workforce

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Residential Trends Impacting Design and Practices

Industry Trends Impacting HVAC Systems and Strategies

6. Energy conservation and environmental standards for equipment manufacturers, such as:
    A. Emerging new Fan Efficiency Rating (FER) requirements for residential furnaces, as mandated by the Energy Policy and Conservation Act (EPCA), to take effect in 2019
    B. Overall furnace energy conservation standards being amended
    C. Amended test procedures for energy performance of central AC units and air source heat pumps (ASHPs).
    D. Continued emphasis on refrigerants (EPA).

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Residential Trends Impacting Design and Practices

Industry Trends Impacting HVAC Systems and Strategies

7. Progressive construction and business models
    A. Modularized and manufactured construction
    B. Customer-for-life models
    C. Energy-efficient mortgages

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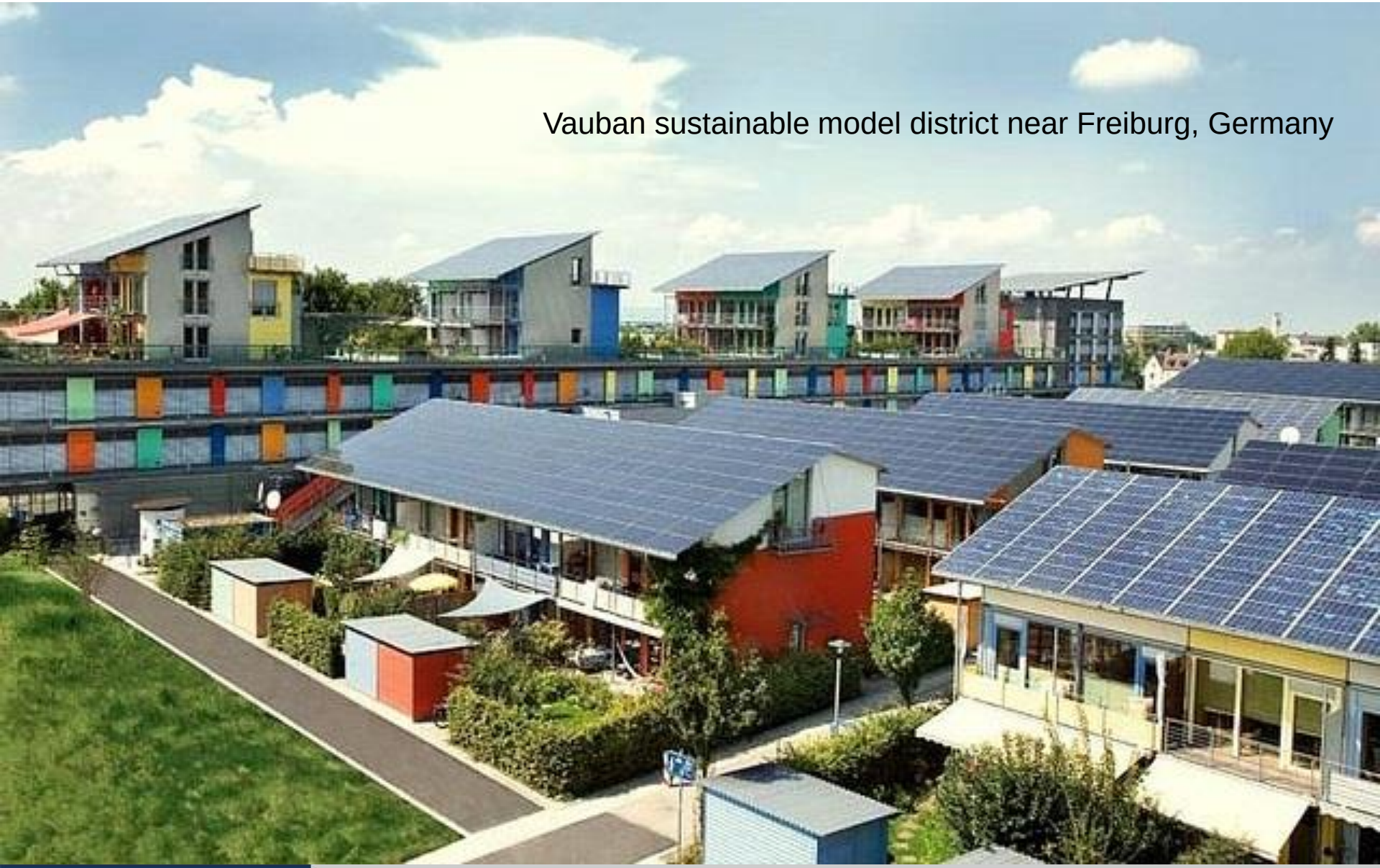
Residential Trends Impacting Design and Practices

Industry Trends Impacting HVAC Systems and Strategies

8. Responsible focus on renewables and community
    A. Recognize strains on resources
    B. Increased self-sufficiency at the home or community level
    C. Move toward carbon neutral
    D. Low embodied energy materials and systems with low life-cycle impact

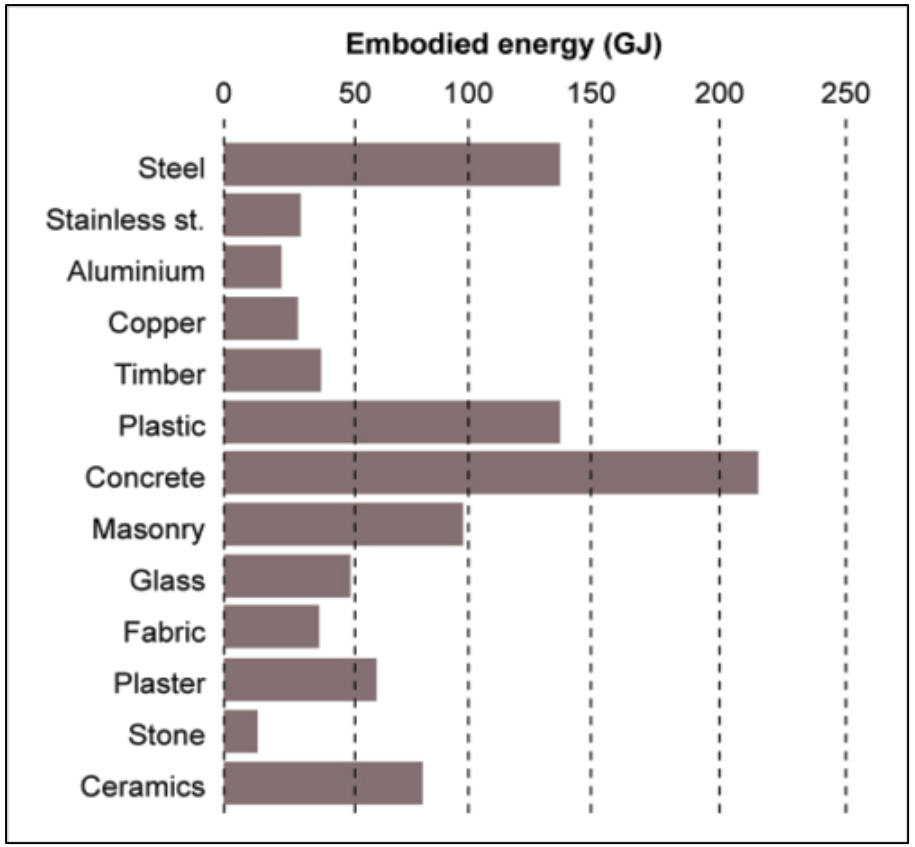
Community-Based Self-Sufficiency

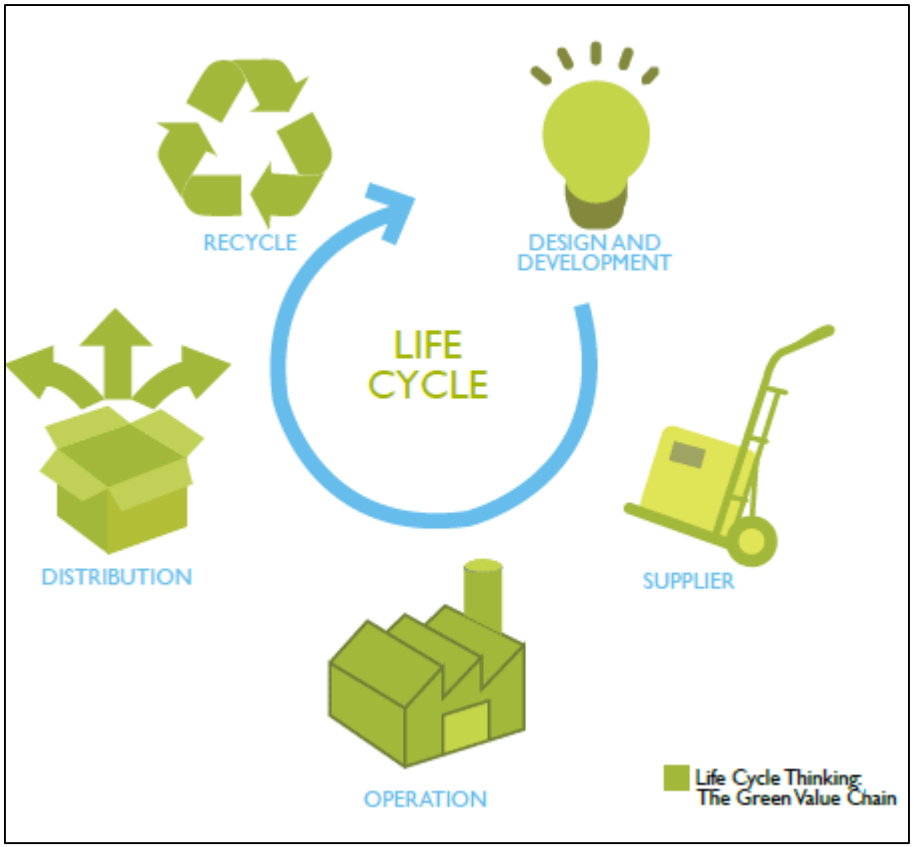


Vauban sustainable model district near Freiburg, Germany

Move Toward Carbon Neutral

Reduced Embodied Energy and Life-Cycle Impact





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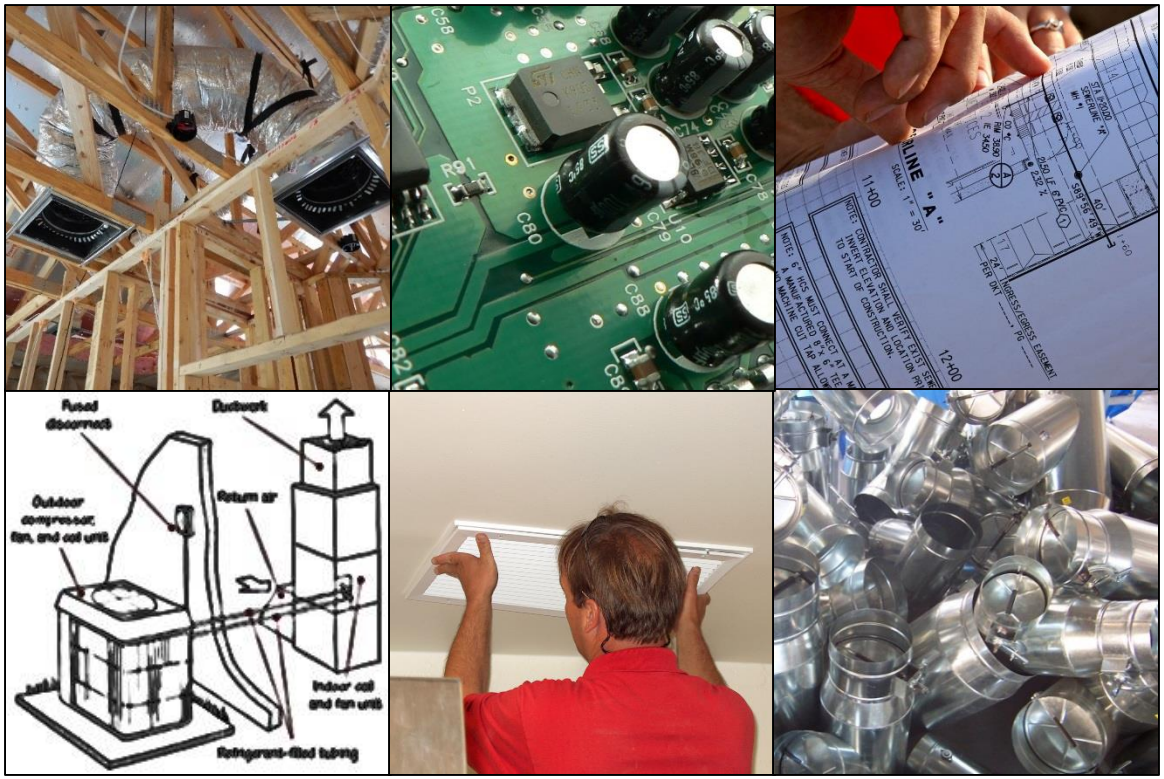
Latest High-Performance HVAC Programs, Strategies and Systems

Latest High-Performance HVAC Programs, Strategies and Systems



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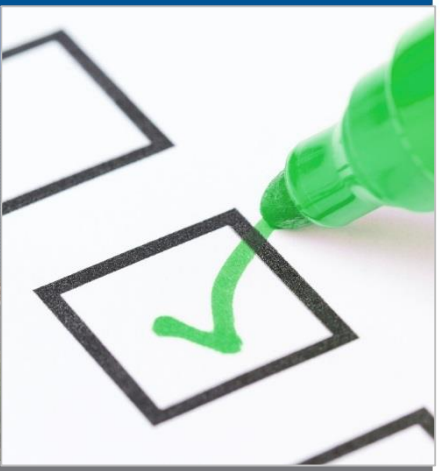
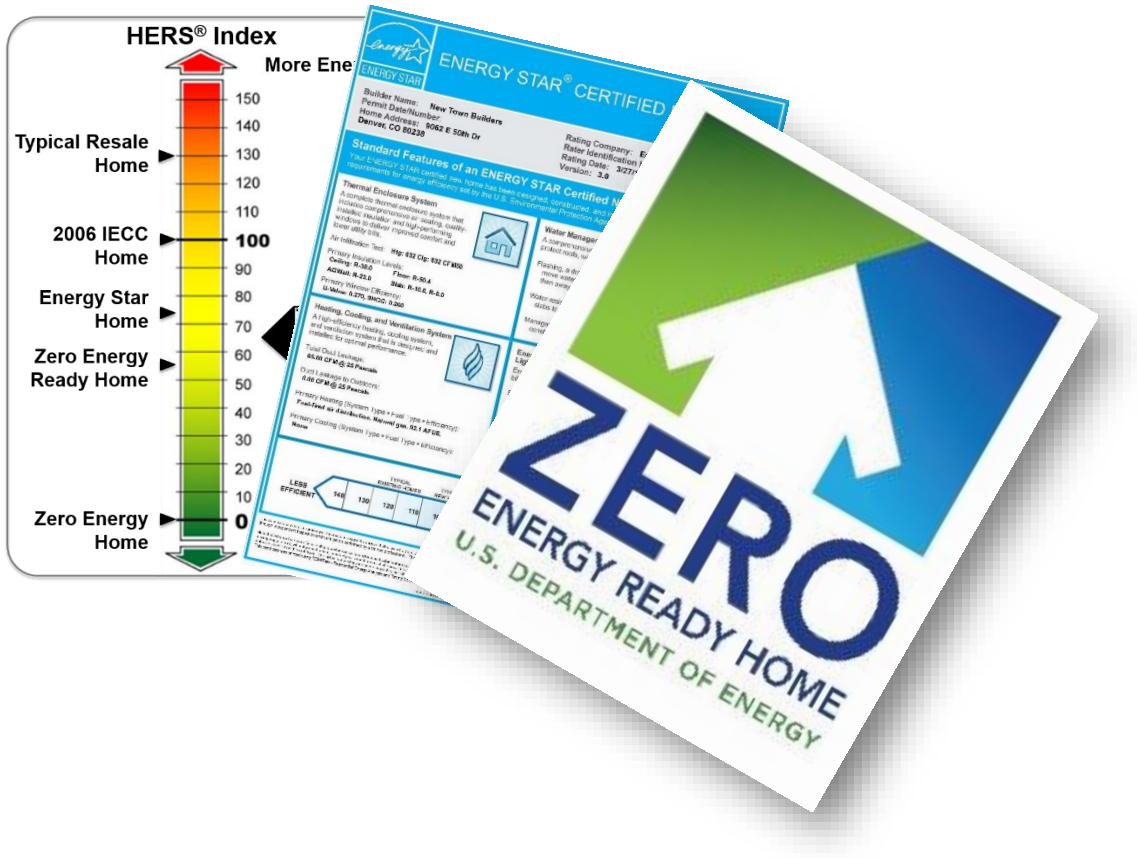


Programs



Latest High-Performance HVAC Programs, Strategies and Systems

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Latest High-Performance HVAC Programs, Strategies and Systems

Strategies

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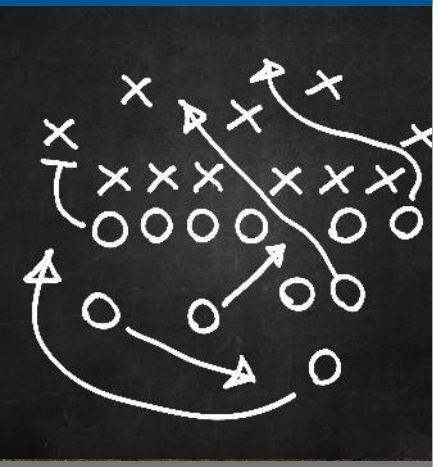
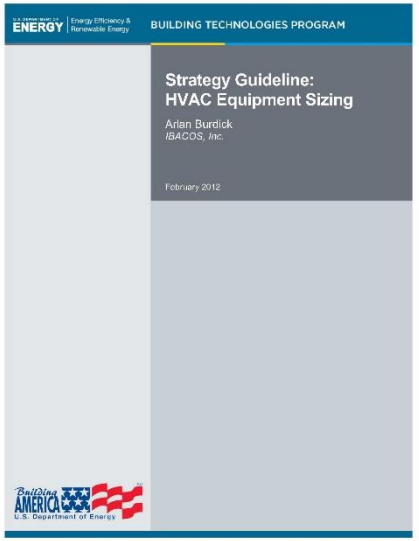


Latest High-Performance HVAC Programs, Strategies and Systems

Right Sizing

- Affects energy cost, comfort, IAQ, noise and reliability
- Shorter run times reduce mixing, increase remote room temperature float, and provide less effective latent removal



http://www.nrel.gov/docs/fy12osti/52991.pdf

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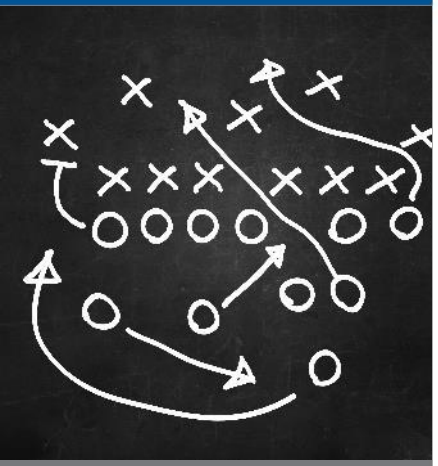

Latest High-Performance HVAC Programs, Strategies and Systems

Advanced Thermostats

- Affect energy cost +; comfort +
- Dead band between heating and cooling
- Programmable
- “Smart”
- Equip with adaptive recovery for air source heat pumps to save energy
- Feedback on energy use, runtime, filter and humidifier maintenance

https://basc.pnnl.gov/resource-guides/thermostat-controls#quicktabs-guides=0

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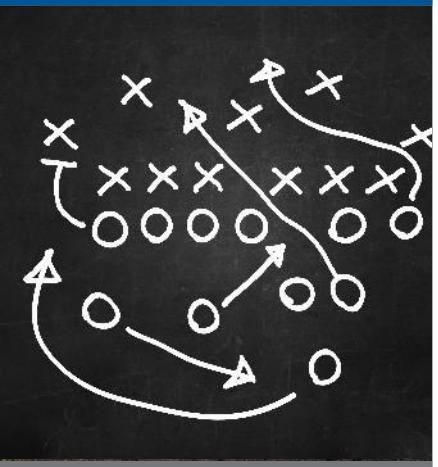
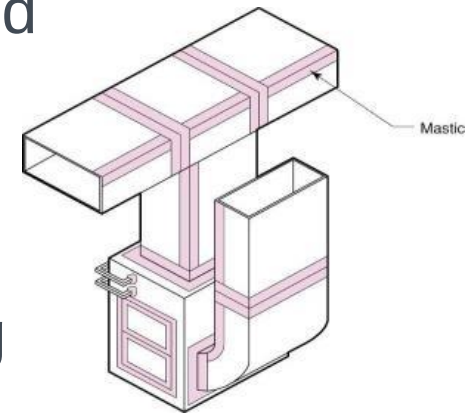


Latest High-Performance HVAC Programs, Strategies and Systems

Duct System Sealing and Testing

- Impacts: energy cost, IAQ and comfort
- Seal all seams, gaps, and holes of all trunk duct connections before insulating duct
- Mastic seals well and is visible
- Seal blower cabinet seams, leave tape behind
- Perform visual inspection before pressure test



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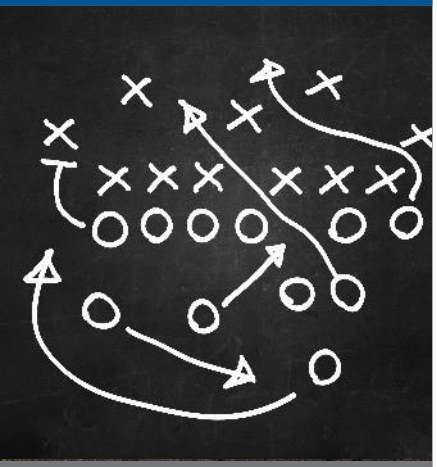

Latest High-Performance HVAC Programs, Strategies and Systems

Duct System Sealing and Testing *(continued)*

- Duct blaster: target leakage age to outdoors is <= 4 cfm25 per 100 sf of conditioned floor area (5 cfm25 for for homes <1200 sf)
- Max total leakage is 8 cfm25 per 100 sf
- Injected aerosol spray sealant is another option

https://basc.pnnl.gov/resource-guides/duct-leakage-outdoors#quicktabs-guides=6

https://basc.pnnl.gov/resource-guides/total-duct-leakage-tests

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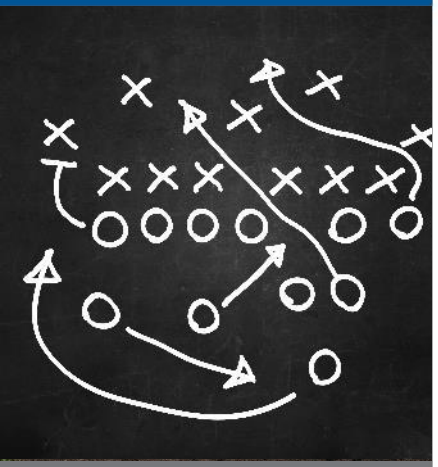
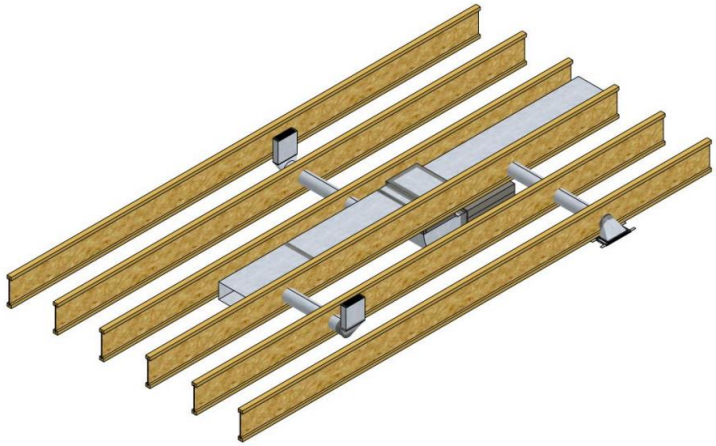


Latest High-Performance HVAC Programs, Strategies and Systems

Bring Ducts and Equipment into Conditioned Space

- Impacts: comfort; energy cost
- Sealed crawlspace or basement
- Unvented attic space
- Integrated with interior framing system: stud bays, open web joists, etc.
- Furr-downs, soffits, bulkheads, dropped ceilings
- Inverted soffits



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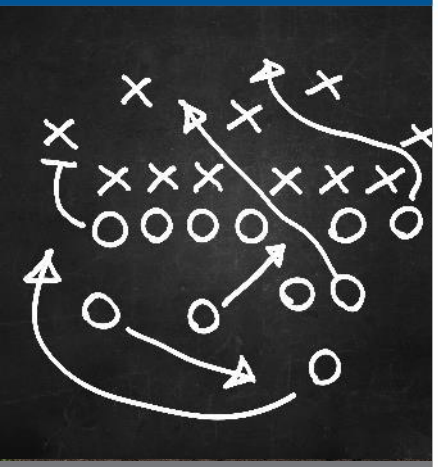
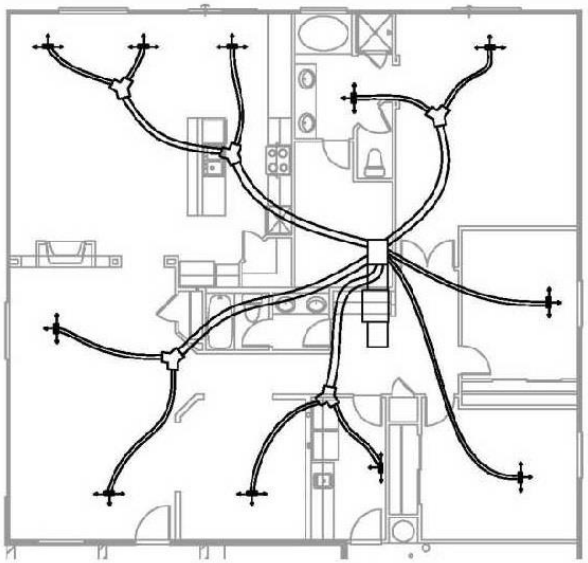


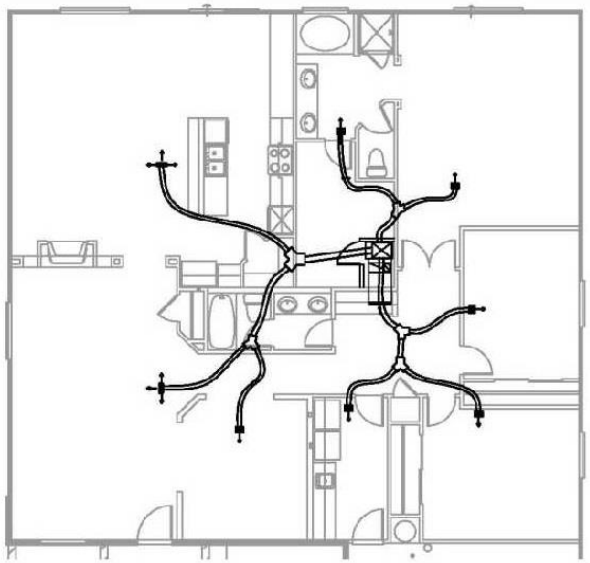
Latest High-Performance HVAC Programs, Strategies and Systems

Compact Ducts

- Impacts comfort, energy costs
- Saves material, time, cost
- For better enclosures, better diffusers



TRADITIONAL DUCT DESIGN



COMPACT DUCT DESIGN

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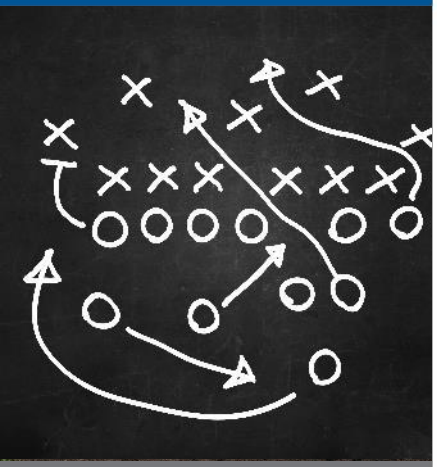
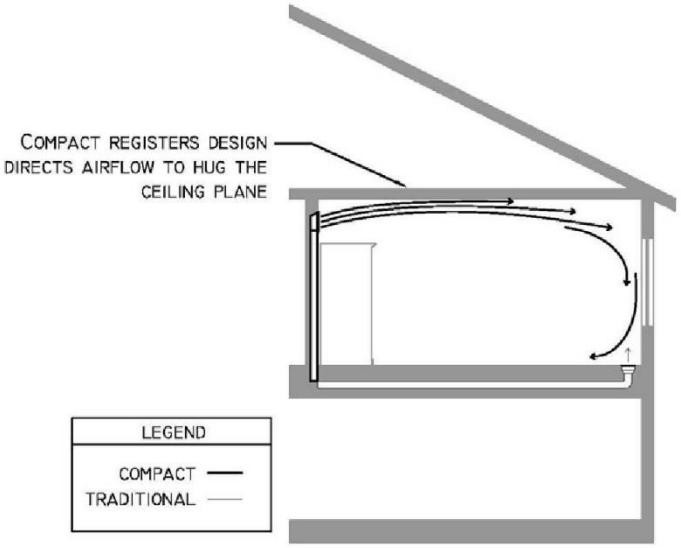


Latest High-Performance HVAC Programs, Strategies and Systems

Compact Ducts *(continued)*



http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/strategy_guide_compact_air_dist.pdf

https://basc.pnnl.gov/resource-guides/compact-air-distribution

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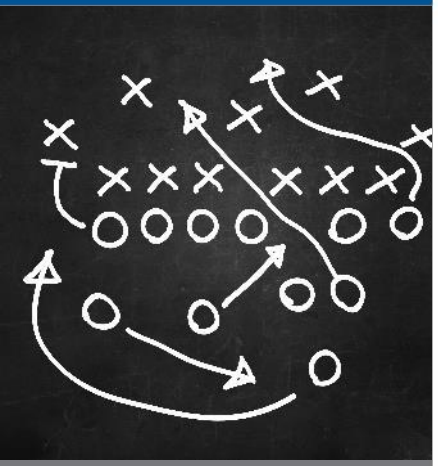

Latest High-Performance HVAC Programs, Strategies and Systems

Zoned Ducted HVAC

- Impacts: comfort; energy cost
- Adds convenience, individualized control, flexibility for occupants
- But can increase energy use if constant setpoints are applied across zones
- Can increase noise, reduce moisture control, or cause system instability if misapplied

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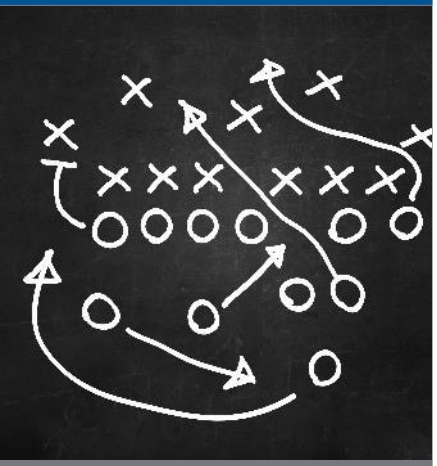
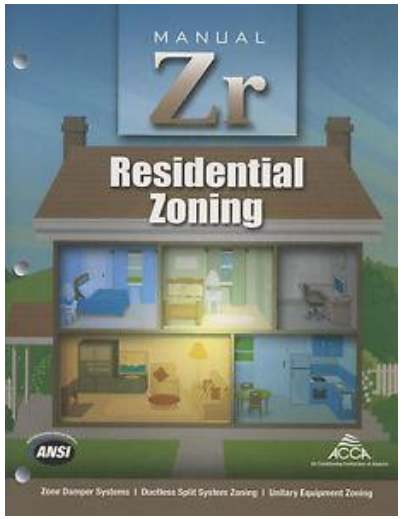


Latest High-Performance HVAC Programs, Strategies and Systems

Zoned Ducted HVAC *(continued)*

- Adds some complexity and limitations for designer to provide a system that performs well overall
- Better systems have no bypass, 350 cfm/ton in all modes, <= 0.58 watt/cfm
- ACCA Manual Zr and CA Title 24 offer guidance



https://www.acca.org/store?webproductid=f878500f-bc20-e511-80fa-c4346bacebf4

http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/HVAC/2013_CASE_R_Zoned_Ducted_HVAC_Sept_2011.pdf

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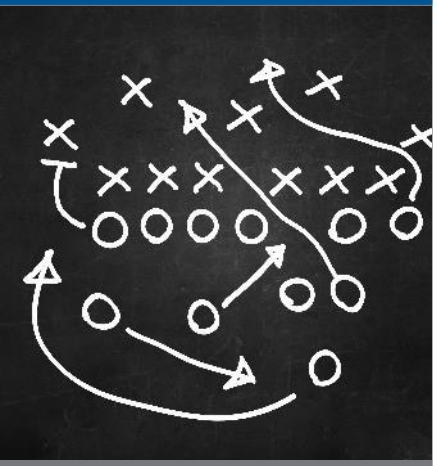

Latest High-Performance HVAC Programs, Strategies and Systems

Zoned Ducted HVAC *(continued)*

- At a minimum, coordinate the duct system design to permit access to seasonal adjustment dampers
- Indicate summer and winter damper positions
- Don't leave homeowner with hands tied from making adjustments

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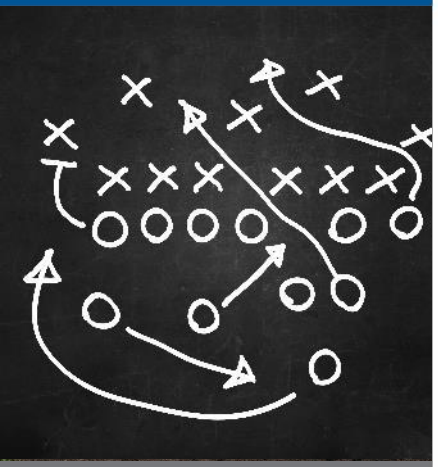

Latest High-Performance HVAC Programs, Strategies and Systems

Designed Return Air Paths

- Affect comfort, IAQ, noise
- Over-the-door transfer
- Offset privacy transfer
- Jump duct
- Dedicated return
- Door undercut is traditionally inadequate

https://basc.pnnl.gov/resource-guides/jump-ducts

https://basc.pnnl.gov/resource-guides/transfer-grilles

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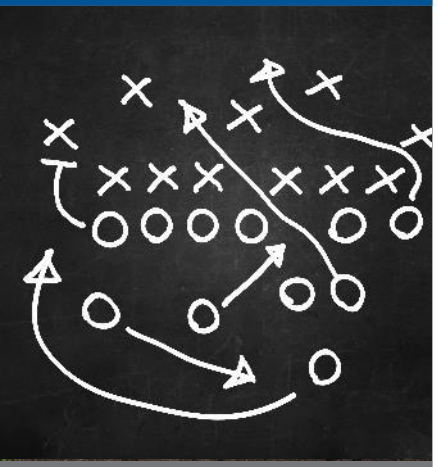
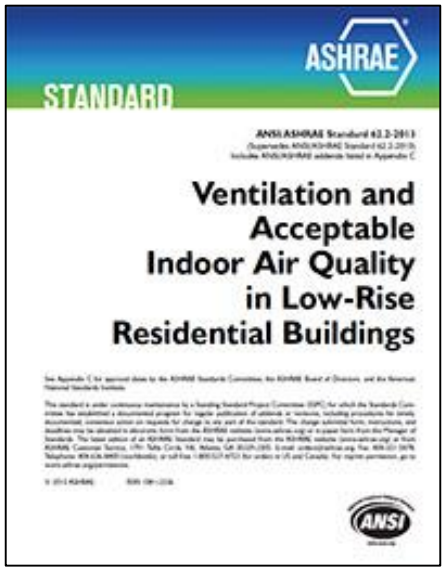


Latest High-Performance HVAC Programs, Strategies and Systems

Ventilation

- Impacts IAQ, energy cost
- Install mechanical ventilation
- Tighten house to threshold
- Confirm flow
- Positive
- Negative
- Balanced
- Climate dependent
- Distribute
- Consider scheduling



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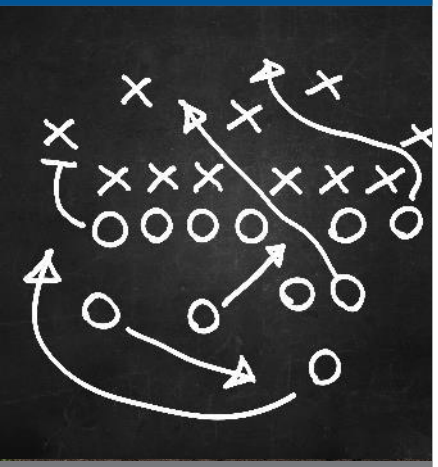

Latest High-Performance HVAC Programs, Strategies and Systems

Air Filtration

- Affects IAQ, energy cost
- MERV = Minimum Efficiency Reporting Value
- Filtration in air handler requires efficient air distribution and controls
- Don't need HEPA
  - MERV16 almost as good
  - MERV13 gets you most of the benefit – use for filtering outdoor air

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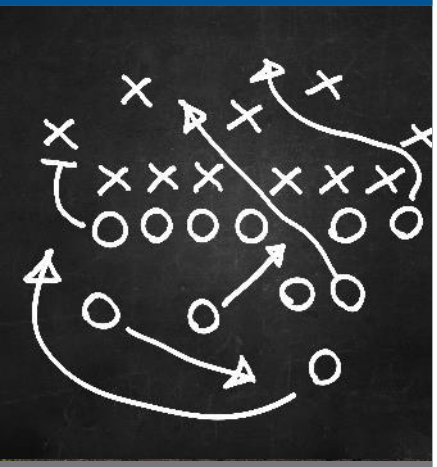

Latest High-Performance HVAC Programs, Strategies and Systems

Air Filtration *(continued)*

- Be careful about supply filtration
  - Run-time vent systems may only operate when heating/cooling
  - MERV-6 generally accepted
  - MERV-8 required for ZERH per EPA Indoor airPLUS program
- Airtight shell serves like MERV13 or better

https://basc.pnnl.gov/resource-guides/high-merv-filter

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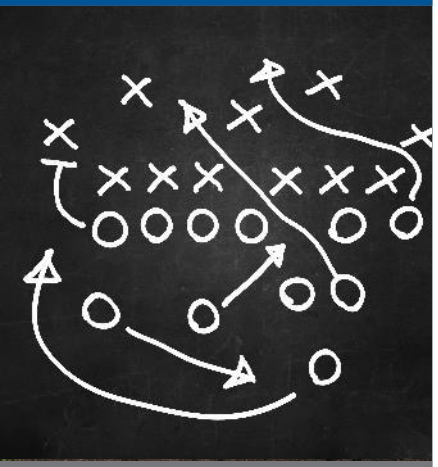

Latest High-Performance HVAC Programs, Strategies and Systems

Energy Recovery Ventilators

- Impact: comfort, IAQ, energy cost
- Up to 93% efficient heat (temperature) recovery between exhaust and ventilation airstreams – claims of higher
- ~80% efficient total energy recovery
- Options for energy recovery including moisture exchange using enthalpic cores
- Typically a fixed-plate cross-counterflow heat exchanger core arrangement – low leakage

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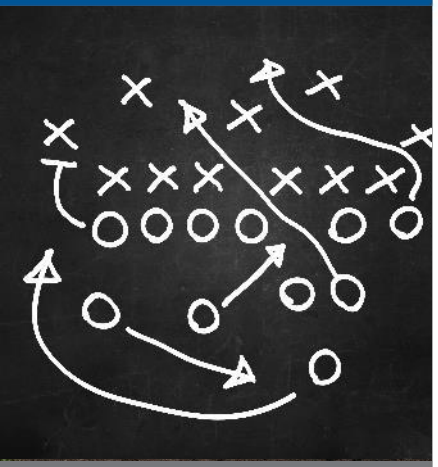
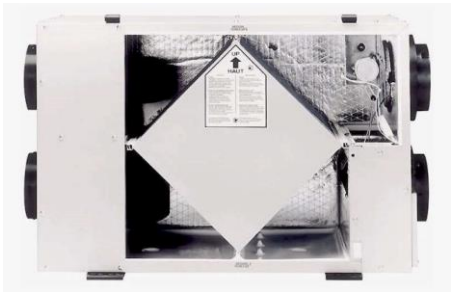


Latest High-Performance HVAC Programs, Strategies and Systems

Energy Recovery Ventilators *(continued)*

- ECM motors
- 75 – 300+ cfm capacities
- Single point and ducted distribution units available
- Switchable modes: HRV to ERV
- Tight homes in humid climates – consider dehumidifiers over ERV for better performance



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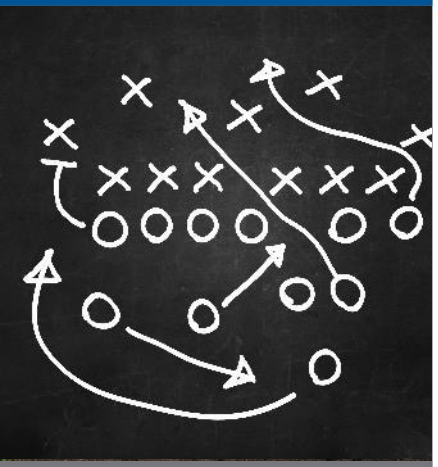

Latest High-Performance HVAC Programs, Strategies and Systems

Ceiling Fans

- Impact comfort, energy cost, noise
- Simple,inexpensive, convenient, multi-speed, quiet, efficient designs, remote controlled
- Soon can be integrated into a connected home's control system

https://basc.pnnl.gov/resource-guides/ceiling-fans-energy-star

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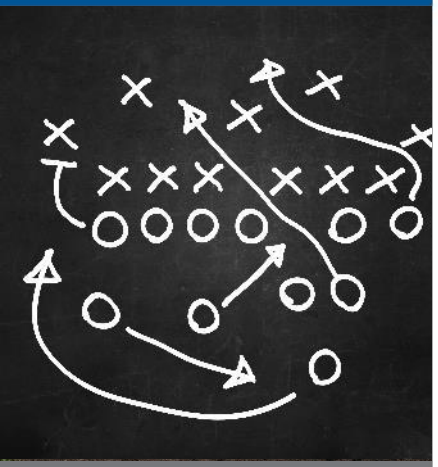

Latest High-Performance HVAC Programs, Strategies and Systems

"Commissioning"

- A collection of tasks that are presently each a part of high performance home delivery, i.e.:
  - System checks
  - Startup
  - Airflow, refrigerant charge
  - Balancing?
  - Rater evaluations
  - Verify program requirements

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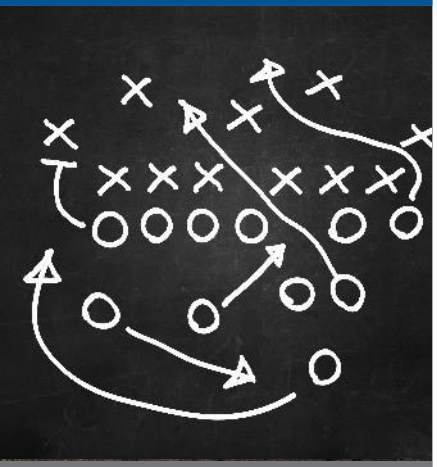

Latest High-Performance HVAC Programs, Strategies and Systems

"Commissioning"

- Impacts: comfort; IAQ; noise; energy cost; reliability
- Overall quality control opportunities

https://basc.pnnl.gov/information/energy-star-hvac-commissioning-checklist-3-indoor-hvac-fan-airflow

https://basc.pnnl.gov/information/energy-star-hvac-commissioning-checklist-2-refrigerant-charge

https://basc.pnnl.gov/information/energy-star-hvac-commissioning-checklist-4-air-balancing-supply-registers-return-grilles

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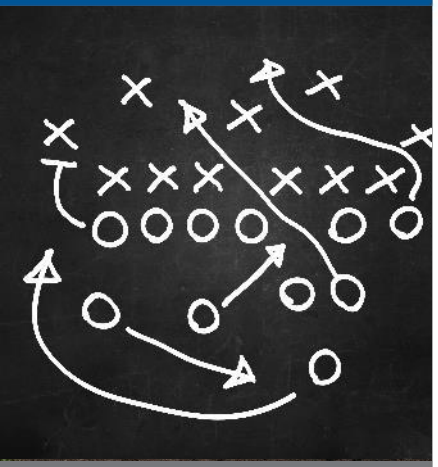

Latest High-Performance HVAC Programs, Strategies and Systems

"Aftermarket" In-Room Zoning System

- Adds room-by-room airflow and temperature control
- Intelligent, automatic adjusting vents replace room supply air registers
- In-room temperature sensors, plug into wall outlet
- Hub to network all sensors and actuators
- Controls central HVAC system
- Senses system pressure to avoid equipment damage
- DIY install if desired
- Mobile app

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Latest High-Performance HVAC Programs, Strategies and Systems

Small Capacity Equipment

- Furnaces
  - 18,000 btuh
- Condensing units
  - 1 ton
- Helps zoning
  - Analogous to distributed instantaneous water heaters
- Small ducts
  - High velocity
  - Medium velocity
  - Metal
  - Flexible
  - Acoustic

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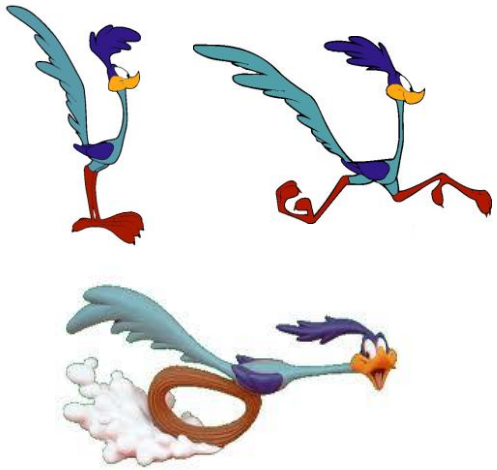
Latest High-Performance HVAC Programs, Strategies and Systems

Variable Speed and Capacity

- ECM Motors
- Blowers
- Multistage and variable capacity furnaces
- Multistage and variable capacity condensing units and heat pumps
- Can help right sizing issues and latent removal
- Good with latent-based control algorithms



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Latest High-Performance HVAC Programs, Strategies and Systems

Mini-Split Heat Pumps

- Small capacity
  - 9,000, 12,000, and 15,000 btuh
  - Multiple indoor head units per outdoor unit
  - Each room has its own air handler connected to a compact outside unit
  - Good for low loads, low square footage
  - No ductwork required but optional: ductless and ducted
- Help stratification issues

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Latest High-Performance HVAC Programs, Strategies and Systems

Mini-Split Heat Pumps

- Traditionally unsightly but improving
- Low ambient air source heat pumps
  - Higher COP's at lower outdoor temperatures than in past
- Ducted versions can be concealed

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Latest High-Performance HVAC Programs, Strategies and Systems

Ground Source Heat Pumps

- Can provide heating and cooling
- Uses basic refrigeration cycle for heating and cooling
- Earth, ground water or surface water is the heat sink
- Can be used for heat only in colder climates
- Getting lots of press, additional research, creative financing and ownership models for loop field
- Possible opportunities for loop as a community utility

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Evolving Markets and Expected HVAC Impacts

Evolving Markets and Expected HVAC Impacts

- Look to California for changes: Zero Energy by 2020
- Net Positive Homes – Homes that Give Back
- Site Manufactured Homes

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Evolving Markets and Expected HVAC Impacts

Refrigerant Changes

- Natural refrigerants, Hydrofluoroolefins (HFO's)
- Zero ozone depletion, low to no global warming potential
- Balance environmental benefits with energy efficiency
- Ripple effect: lubricants, manufacturing, service protocols, equipment characteristics

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Evolving Markets and Expected HVAC Impacts

Connected-Home HVAC Services

- Comprehensive HVAC monitoring service
- Real-time information provided to help occupant manage the heating and cooling systems
- Expert system to predict and diagnose problem conditions in home or with equipment
- Offers equipment protection, optimizes effectiveness and efficiency
- Monitoring service, homeowner, and service professional networked together
- Live data, regular reporting, alerts as needed

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Evolving Markets and Expected HVAC Impacts

Smart Whole House Ventilation (IAQ) Management Systems

- All air transferred in or out of home is managed
- Constant or interval air delivery
- Knowledge of ventilation provided over recent hours
- Knowledge of occupancy status
- Respond to intermittent exhausts: dryer, bathroom fans, kitchen hood
- Respond to outdoor temperature and moisture levels to minimize loads to house
- Sense contaminants and respond: particulates, Co2, VOC’s etc.
- Incorporate energy recovery

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Evolving Markets and Expected HVAC Impacts

Commissioning 2.0

- Commissioning is a quality- focused process for enhancing the successful delivery of a building or retrofit project. Focus on Process.
- The process focuses upon verifying and documenting that the home and its systems and assemblies are planned, designed, installed, tested, to meet the Project Requirements set forth by the Project Initiator, and the Design Intent.
- It also establishes a guidance program for operation and maintenance to reflect the Design Intent.
- It is a Managed, Systematic, and well-documented Process where communication is key
- It is not just a series of testing activities or a set of checklists
- What systems can be cx'd?
    - HVAC, Electrical, Plumbing, Architectural
    - Basically any System or Assembly that has performance characteristics and performance expectations
- Systems that directly utilize (and thus could waste) energy can benefit from Commissioning

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Evolving Markets and Expected HVAC Impacts

Horizon Items

- Variable refrigerant flow (VRF)
  - Extension of the mini-split heat pump concept
  - Simultaneous heating and cooling?
- Wearables
  - Sensing personal comfort and health
  - Thermally responsive clothing, devices
  - Optical head-mounted display
    - opportunities for service and communication with customers

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Evolving Markets and Expected HVAC Impacts

Horizon Items

- Dedicated Outdoor Air (DOAS) Systems for Homes
- Community Scale Heating / Cooling / Power
- 3D printing technology for customized solutions
- Simplified system packages requiring less labor
- Building-integrated HVAC systems and sensors
- Return of natural ventilation
- Occupant sensing system response
- Biological integration
    - Systems that scrub the air for example

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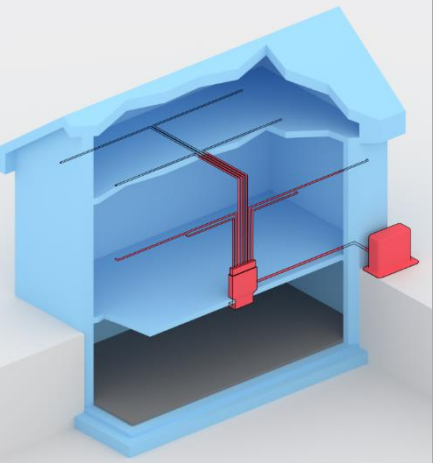
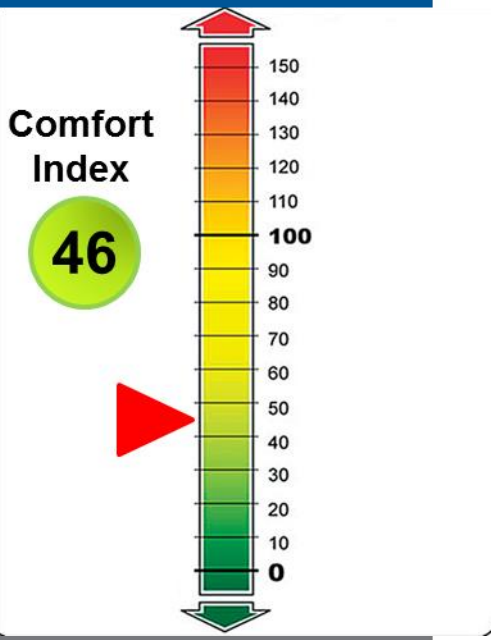


Evolving Markets and Expected HVAC Impacts

Plug-n-Play Duct System

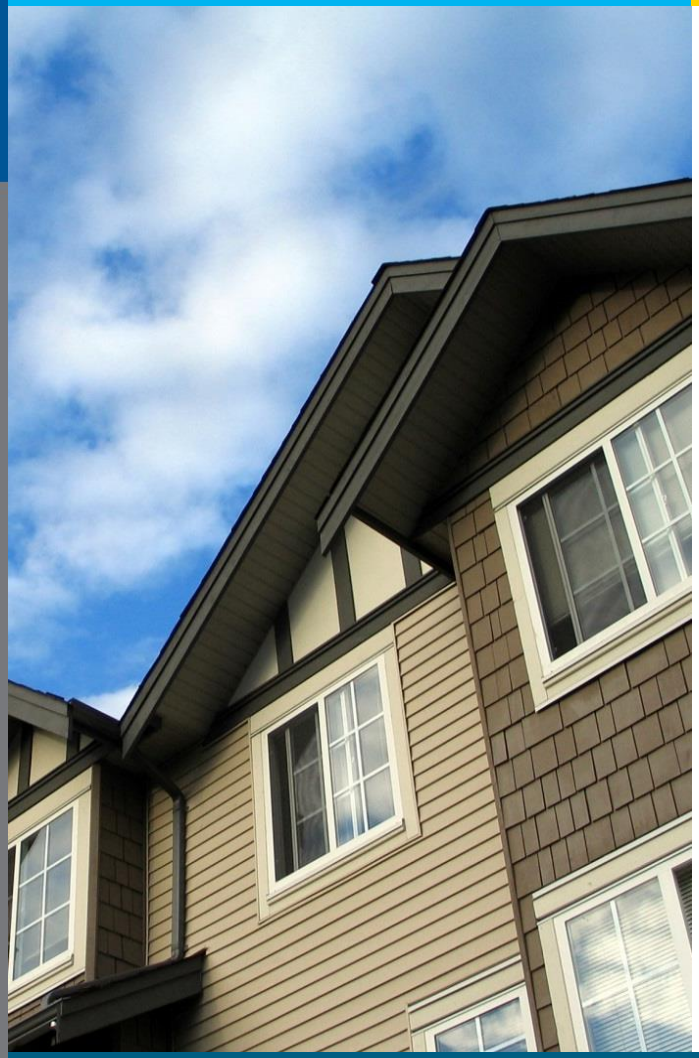
- Project Goal is to develop a simplified small-diameter residential air delivery system as a solution to the air distribution and comfort delivery issues in low-load production-built homes.
- System is assembled in a homerun arrangement from a kit-of-parts with a limited number of components.
- A straight-forward design methodology and companion guidance document accompany the system.
- Success Metrics: Duct system is easily integrated within the home's conditioned space, installed with less cost, error and waste, and offers predictable performance to help deliver comfort in low-load homes.

Thermal Comfort Rating Metric (TCRM)



- Evaluate the need for, and feasibility of, a Thermal Comfort Rating Method (TCRM) for the residential sector.
- The TCRM is envisioned as an asset rating system that represents, in simple terms, a home's overall ability to provide thermal comfort to its occupants under varying conditions and demands.
- The metric would give builders and homeowners a tool to make value-based decisions regarding thermal comfort performance in the context of energy efficiency.
- Vision: A comfort performance metric similar to, and able to work with, the Home Energy Rating System (HERS) index for energy efficiency and other developing residential sector asset ratings (IAQ, water efficiency, etc.)
- Use as a consistent comfort-based metric to evaluate and demonstrate value of concepts in Building America projects

U.S. Department of Energy Building America Program



The U.S. Department of Energy Building America Program has been a source of innovations in residential building energy performance, durability, quality, affordability, and comfort for more than 20 years.

This world-class research program partners with industry to bring cutting-edge innovations and resources to market.

Where can I find resources?

Building America Solution Center

Proven Innovations from World-Class Research…

at Your Finger Tips

https://basc.pnnl.gov

Building America Website

Research Projects, Webinars, Monthly Newsletter, Funding Opportunity Announcements

www.buildingamerica.gov

Zero Energy Ready Home Program

Tour Our Homes, Become a Partner, Promote Zero Energy Ready Homes

http://energy.gov/eere/buildings/zero-energy-ready-home

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