ARPA-E Advanced Buildings Workshop

Breakout Group:

Active and Passive Thermal Components #2 (Chair: Sam Baldwin, EERE/DOE)

What are some control modeling simulation issues that we need to think about for every device that is put in place?
What response time is appropriate?
How will they be integrated into a larger system?
How will we keep the systems from competing with each other?

- Taking into account outside environment is important
- Time constants
- System response time (i.e. time for an electrochromic window to respond versus a thermal system)
- Actual amount of energy savings changes with time
- Thermal storage- discharge rate versus leakage and storage issues
- Note that time constants for buildings range from very quick (lights) to days or weeks long (ground temperature)
- If users can program (characterize) their activities, buildings can adjust and deal with time constants
- Note- for cars temperature can be adjusted within 60 seconds for buildings there is a longer acceptable time but the idea of a small buffer and then longer lead time for main systems (like computers)
- For an office space- ideas about what an acceptable time? 10 minutes for a seminar room? For US- need to manage time constant by starting temperature change 10 minutes before meeting begins → possible with computerized scheduling of rooms
- What is expected is a big part of it- no one expects to walk into a warm car, but they expect (in the US) a room to be heated/cooled already
- Need to look at how loads will change as buildings change- as energy efficient lighting comes in, a heat source goes away – as density for offices becomes higher, humidity control will become more important – etc

Slides 2 and 3

What are the active and passive thermal components in a building? What are the transformational concepts to create new thermal devices?

- Challenges: HVAC & humidity—low-GHG, high efficiency systems; Lighting, IAQ, External Humidity, etc.
- Challenges: Integration with measurement, control, communication systems
- Challenges: Time constants for response—electrochromic windows and daylight integration/glare control. Thermal response times vs peak demands; Value of well-characterized/predictable demands.
- Novel Technologies:
  - Thermo-acoustics (traveling wave—COPs of 6/7/8?),
  - Thermo-electrics and novel thermodynamic cycles;
  - Magnetocalorics; Electrocalorics; Thermionics
  - advanced dessiccants;
  - heat exchangers
  - Thermal storage technologies
- Applications:
  - Zonal control
  - Heat/cooling from chairs to people

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- Spectrally-selective roof and wall coatings; self-cleaning coatings (roofs)
- Lower-cost evacuated tubes for solar systems; and/or dessiccant systems;
- Absorption cooling systems that can operate at lower temperatures

Innovative opportunities for active and passive thermal components, where does the R&D need to be driven forward?

- Material that changes phase at 68F, need phase change materials that are not flammable, act more reliably, consistently, etc.
- Non HVAC based latent and sensible heat systems
- Intelligent controls- ability to skip reheat steps when the outside conditions are acceptable
- Passive humidity control – systems which wick away moisture when it is wet and release it when the outside air is dry, could be installed on walls or in the carpet
- Why has US not used solar thermal? 200 m sq meters installed, in U.S. cost and aesthetics are issues
- Can dynamically control vaporization with capillary pore size changes

Slide 4

How do we leverage ventilation to decrease HVAC requirements and increase overall system level efficiency?

- Solve the humidity control problem
- Air-air heat exchangers
- Advanced membranes with dynamic control of moisture transport
- Climate adapted ventilation systems

Extensions on conventional HVAC systems? Working fluids? Staged intermediate temperature set points? Thermoelectrics? Electrocoloris? Thermalacoustics?

- GHG impact on working fluids is almost 100% an efficiency issue (going to CO_2 is good but if the cycle is not as efficient as the current system, it will not make sense)
- Thermoelectrics – generally have lower efficiencies but for small temperature changes (i.e. people entering a room) the COP can be 6-10 → could be used for small perturbations
- If humidity can be controlled- systems needed are significantly easier to control, no need for larger chillers and other systems- only addressing temperature change, also if the size of the space a system is servicing is reduced, the complexity of the system can be reduced
- Progress in thermoelectrics – intrinsic materials (ZT) improvement, alternative thermodynamic cycles, cost effectiveness (amount of material required for a given amount of heating/cooling)
    - Progress in materials development for thermoelectrics has moved very fast in the last 10 years, panels can be produced which are competitive (better) on a cost basis than solar panels
    - With a thermal desiccant system – thermal system can be built which can accept as much heat as can be captured by a system such as a thermoelectric
- Thermalacoustics- explored at PARC, sound waves in a pressurized gas which transport heat early systems were a standing wave (no chance of reaching high efficiency), now traveling waves have leftover (lost) energy, if

lost energy can be caught – higher efficiencies can be found by using the lost energy for cooling, hoping to demonstrate next year

- Giant magnetocoloric effect – using SiG alloys which go through a 1st order phase change in a strong magnetic field which produces an entropy change and produces very high COPs, but material is brittle so there is degredation over time, each material has a different operating temperature (ordering and disordering ions → few tesla change induced)
- Disrupting laminar air flow over cooling barriers
- Shape memory materials for passive thermal management (could sit on a wall)

Leveraging ventilation to increase HVAC performance?

- Air-to-air heat exchangers on german systems
- Total ventilation rate- i.e. for an airplane the rate is ½ of what it is for a building (but the airplane has a HEPA filter…) – best ventilation rate for a building for air quality is sill ideal
- Why do we always try to reduce the amount of outdoor air? Reduce the cooling and heating – not true in all cases. Allows for change of complete change of gas (air) in a system and therefore the air

Slide 5

What are the passive thermal components in a building? How do we tailor their properties to get the broadest operating range?

- How does one improve the properties of the passive thermal components such as insulation and other building materials?
  - Dynamic/tunable (multi-functional) windows – (non-thermal) ; spectrally-tunable windows and integration with lighting and heating systems
  - Thermal storage/Water; Phase change materials
  - Heat-pipes (load balancing)—North-South temperature balancing
  - Internal heat pump
  - Performance of cooled roof? 0.95→0.65 in two years

Passive components in a building – what are the opportunities? New approaches which might be incorporating in to new buildings?

- Managing phase change
- Cannot control IR and invisible – active window system could possibly help this, ideally if it can be made tunable
- Need tunable light sources – pubic perception is a big hurdle for this technology

North south heat balancing using the north side to do

- Seems like a small opportunity
  - Could put a cool roof on one side, a hot roof or wall on the other side and potentially get a meaningful thermal gradient
  - Aging of cool roves is an enormous issue- degradation over the course of a few years, then steady at new lower value (68 down from 99+%)

Are there materials like aerogels, which can, after significant improvement, be an enabling technology for reduced HVAC systems

- Insulating attics is a large energy sink which can have a significant improvement

Slide 6

How do we exploit the relationship between the active and passive components in new ways? What are the relevant trade-offs?

- Matching the zones – for example HVAC and Window Zones
- Lighting zones matching
- Thermal zone matching/exchanges—heat pipes

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Relationships between active and passive components in new ways?

- Matching the zones is one huge improvement
- Ice storage- created at night and used for passive cooling during the day can produce significant changes in loads… also possible with lighting
- Q: are buildings designed with smaller systems on the south side? A: probably not…

Closing thoughts: - what should ARPA-E be spending $$ on:

- Cost efficient electricity storage, use grid as a damper
- On site storage for renewables in a form other than hot water (electrons)
- Distributed systems (i.e. building integrated PV, CHP)
- Spectrally selective heating and lighting (higher efficiency LEDs, others)
- Actively switchable thermal materials
- Very cheap evacuated tube collector
- How to keep air suitable for humans (# of times the air is turned over)
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