MISSION INNOVATION
Accelerating the Clean Energy Revolution

Innovation Challenge #7: Affordable Heating & Cooling for Buildings

Workshop, 1-2 November 2017, Abu Dhabi, UAE

Workshop Summary

This ***Workshop Summary*** concisely reports on the technical findings of the Mission Innovation – Innovation Challenge #7 (IC#7) Workshop which was held in Abu Dhabi (UAE) on 1 -2 Nov 2017. The Workshop brought together 65 experts from 13 Mission Innovation Members, the Rocky Mountain Institute and the International Renewable Energy Agency (IRENA).

The Workshop first explored five priority areas and the main challenges and actions required for each of them:

- Thermal Energy Storage
- Heat Pumps
- Non-Atmospheric Heat Sinks and Sources
- Predictive Maintenance and Control Optimization
- Physiological Studies for Thermal Comfort

Following this activity the Workshop considered building level integration. The experts identified and discussed a number of cross-cutting issues judged relevant for the IC#7 developments:

- Big and open data platform & build and operational standards
- Dynamic controls
- Non-air-conditioned buildings
- Heat system integration/ prosumer networks - Climate box
- Non-technological issues

Thermal Energy Storage

The challenge:

One of the biggest problems faced in low-carbon heating and cooling is the mismatch between supply and demand associated with the utilization of variable renewable sources. Thermal energy storage (TES) solves this problem and can be adapted in a variety of settings inside buildings and building components, and as part of wider networks grids.

Action areas:

Develop ***more compact thermal energy storage*** for domestic applications of storage periods typically up to 4 weeks long. This will require materials that have virtually no heat losses but can take advantage of optimized solar and wind sources without district heating and cooling network connection.

Re-design ***large scale TES for district heating and cooling*** in order to match the seasonal supply and demand of a large number of renewable sources on a district level. This calls for new designs and novel materials to be used to achieve minimal surface area and double use of the top of the storage.

Develop ***compact thermal energy storage for electricity load shifting.*** These storage devices will take up electricity from the grid at the peak times in a day, to be used in the building for heating, cooling or hot tap water at later times. Typical charging power is in the order of 3 kW, for periods of up to three hours. The key development aspects here are: integration into the building heating system and in the smart electricity grid and then storage materials and technologies.

Heat Pumps

The challenge:

This priority area covers potential research to accelerate the uptake of both electrically and thermally driven heat pumps by improving performance, reducing cost and achieving more effective integration.

Action areas:

The main insight from the group was to think radically about heat pumps; no longer simply as a box on the wall but instead as a market enabler, merging energy vectors and delivering new services such as balancing.

Four key activities were identified that needed to be overcome:

1. Converting ***low grade heat to power*** (Target 60 °C heat to power at 10-20% efficiency)
2. Efficient ***gas to heat and cold*** (Target Gas Utilisation Efficiency of 1.6 (air source), 1.7 (water source) and 2.0 (in lab))

3. ***Integrated heating and cooling solutions*** (COP of 5.0 is currently achievable theoretically but better deployment needed to achieve this in practice)
4. Improved ***demand side management*** (targets are highly grid specific but aim to ensure security and stability of supply)

The workshop then focussed on the concept of a "Better-Box". This would be tailored to the specific application and geographic region but would take multiple energy sources as inputs and transform these into heating, cooling and power demands in the most optimal way (be that lowest carbon, lowest cost or lowest impact on the electricity grid). Internal components could include: electrically driven heat pump; thermally or gas driven heat pump; fuel cell; refrigeration; control system; and energy storage. The aspirational target for any "Better Box" would be to make it as cheap to buy, as easy to install and as cheap to run as the existing, most prevalent, high carbon alternative (e.g. gas boiler).

Non-Atmospheric Heat Sinks and Sources

The Challenge:

In hot climates, conventional air-cooled air conditioning system efficiency is penalized by the high ambient air temperatures and the same is true of heat pumps in low ambient temperatures. This priority looks to improve performance using the most promising technologies of evaporative cooling of chiller condenser, ground/sea/aquifer/wastewater sources/sinks interconnected via thermal network and low-wavelength radiation to deep space.

Action Areas:

Develop ***indirect evaporative cooling*** of chiller by rejection of chiller waste heat against the wet bulb temperature of the building exhaust air. The basic principles are well understood but implementation and system integration challenges remain. Pilot projects should be conducted.

Improve system integration and precise balancing of ***district-wide thermal networks*** connecting non-atmospheric sinks and sources with thermal energy storage. This will involve extensive case-specific modelling and simulation to improve system design and operation. Establish the feasibility of adding active takers/providers of heat to address heating/cooling imbalance in the system.

Introduce ***low-wavelength radiation to deep space*** using a special high emissivity and high albedo film to enhance direct radiative loss from chiller condenser coils. This technology circumvents the atmosphere and directly transfers the heat to the cooler deep space. Detailed physical modelling and pilot projects are required as the material is still undergoing research and development.

In all cases, the emphasis will be on modelling, designing and testing generic solutions that can be easily adapted to specific conditions of participating countries. Metrics include lift reduction, COP improvement, life-cycle cost, life-cycle environmental impact, market penetration potential, present/future TRL (Technology Readiness Level), and generality versus regionality.

Predictive Maintenance and Control Optimization

The challenge:

Poorly maintained, degraded, and improperly controlled HVAC equipment can waste up to 30% of the space conditioning energy used in buildings. Manual intervention from skilled practitioners can be highly cost effective but there is a general shortage of such skills. A variety of other barriers also exist such as split incentives and proprietary control systems. The challenge is to overcome these barriers by using emerging ICT technology and data science to automate this role.

Action areas:

Develop a ***Knowledge Hub*** as a way of pooling the collective international knowledge on the topic and commission studies and surveys to supplement knowledge across different countries and climates. (Knowledge Hub website established and existing literature reviewed and published – June 2019 Longitudinal studies of split system/package-unit performance degradation completed – December 2021)

Develop ***Data Standards*** to reduce the level of investment required to benchmark buildings and compare performance to allow innovators to identify opportunities and develop solutions with wide applicability. (Frameworks, protocols and schema adopted for standardized collection of data – December 2019)

Establish an ***Open Data/ Building Emulator Platform*** to enable the development and testing of new solutions at much lower cost. (Cloud based, open-data/building emulator platform established – December 2019)

Enable and drive ***Innovation;*** while the actions above will encourage a myriad of new innovation opportunities to be explored, there is the potential to seed Grand Challenges to the innovator community to further accelerate activity. (Control and predictive maintenance algorithms developed and validated; automated diagnosis demonstrated and maintenance strategies commercialized – December 2021).

Physiological Studies for Thermal Comfort

The Challenge:

Application of various heating and cooling technology needs appropriate understanding about human comfort needs. These needs depend upon physiological, psychological and behavioral conditions. Various climate and context need various approaches for cooling and heating. Methods to customize heating and cooling comfort technologies for design, installation and operation have been identified as a primary challenge.

Action Areas:

Develop ***methods to understand human thermal comfort needs*** using advancement in Information Technology (IT). Based on knowledge generated, enhance HVAC systems capabilities to provide thermal comfort. HVAC systems should be capable of responding to changing human needs during time of day and seasons. IT technology should be able to facilitate HVAC operations based on adaptive thermal comfort model based on various climate contexts.

Develop ***metrics*** combining heating / cooling energy performance with thermal comfort performance. Such metric also should include human behavior and mode of building operations such as mixed mode building operation.

Develop ***data platform*** helping innovators and investors to take informed decisions; to disseminate information about capabilities of various technologies at concept stage to attract investment; by informing about performance gaps of HVAC systems, encourage innovators to apply their skills to meet challenges. Such platform also will be useful to map socio-behavioral implications of thermal comfort on building's energy use and may help new business model for HVAC services and products.

Develop ***HVAC / Sensors & Control technologies*** that understand short period human comfort requirements. Temporary comfort or understanding of thermal aesthesia should be explored to find solutions which can provide thermal comfort for short period of time; this could be applicable to transitional areas, or in the event of change in metabolic rate or change in immediate environment. Development of technology also can help reaching 'Rock Bottom' optimization during operation phase of buildings.

Building-Level Integration and Cross Cutting Issues

The Challenge:

Integrating different technologies together, either at the building level or district level was identified as one of the potentially greatest opportunities to improve the overall performance of heating and cooling systems. Following discussions in the workshop, five cross cutting areas were identified for further action.

Action Areas:

Develop a ***big and open data platform*** for build and operational standards – the Open Data Sharing Project. One of the largest problems in moving the HVAC industry forward is that performance data sets are owned primarily by private industry and trade organizations that do not make them publically available. As a result, there is very little comparable concrete data in the public domain to benchmark the performance of HVAC assets in the field versus in the lab. In the Gulf Cooperation Council (GCC) region it has been estimated that high end western style maintenance would be worth a 25% reduction in energy consumption and 50% reduction in HVAC carbon footprint. Project needs are:

- Gain government and industry support behind the concept
- Create a standardized data set
- Create a standardized way to share, store and analyse this data
- Analysis of the data by academic organizations

Use ***automation and dynamic controls*** to tap into the potential for low-cost demand response from building HVAC systems. Approaches include smart thermostats, ripple control of hot water storage or ice banks and behavioural approaches such as “cool biz” (Japan), and peak pricing incentives. Actions to unlock opportunities include:

- Develop more sophisticated control and engagement technologies to enable demand response, through the advent of Internet of Things, cloud computing, model predictive control and associated data sciences, including
    - Activate thermal storage
    - Widen comfort bands and utilise more sophisticated comfort sensors
    - Alternative pricing models, behavioural science nudge and peer-to-peer trading solutions
- Develop an autonomous solar cooling box that simultaneously takes both solar PV and air conditioning off the grid, while still managing comfort.

Develop solutions for ***non-air-conditioned buildings*** that do not use highly potent refrigerants and consume dramatically less energy, yet provide consumers with the cooling that they increasingly need. The energy demand and atmospheric impact of refrigerants under a business as usual scenario represents the single largest end use risk to meeting our climate goals. Two pathways were identified to pursue:

- A grand challenge or prize for the development and demonstration of extreme efficiency cooling solutions that can be implemented at market acceptable cost.
- Demonstrate mid-rise, low income, multi-family building prototypes incorporating market desirable features combined with low cost passive ‘comfort’ measures (i.e. balcony for shading, reflective surfaces) and easy incorporation of renewable energy and plug in future extreme efficiency cooling systems as developed under the first pathway.

Improve ***system integration / prosumer networks*** focused around taking forward the concept of a “Better Box” described under the "Heat Pump" priority area. The concept was renamed (working title) "the Comfort and Climate Box" and was further elaborated as an integrated heating and/or cooling unit to include the various elements developed under the separated priority areas. Such a “new” – decarbonized system:

- Needs to have adequate system output (in terms of heating and cooling).
- Should anticipate its impact on the overall energy systems in transition.
- Will form part of the solutions in a smart energy grid.
- Must enhance new business models for developing “heating and cooling services”.
- Should achieve consumer acceptance.

- Should be deployable on a mass market basis.

The Technology Collaboration Programmes ECES and HPT were asked to develop the idea further in collaboration with other IEA-TCPs. It could be connected to several “super projects” to be developed as cross-cutting the borders of the various TCP’s.

A number of ***non-technological issues*** need to be addressed in order to successfully make the transition from technology development to actual market implementation. Further work is required on these activities:

- End-user acceptance and end user use.
- Bridging the gap between R&D and industry.
- Opening up markets.
- Skills and training.