DE-FOA-0001590: Request for Information: Advanced HVAC&R Research and Development (R&D)

DATE: June 20, 2016
CLOSING DATE: July 25, 2016
SUBJECT: Request for Information (RFI) on Research and Development (R&D) topics and approaches for advanced residential and commercial heating, ventilation, and air conditioning (HVAC) and refrigeration equipment

Description

The United States (U.S.) Department of Energy (DOE) Building Technologies Office (BTO) is seeking information from the public on the technical metrics and goals, and organizational structure of advanced heating, ventilation, air conditioning, and refrigeration (HVAC&R) research and development (R&D). In particular, BTO is interested in feedback on near-term and long-term performance and cost metrics, and on the structure of this proposed R&D effort.

Background

The Building Technologies Office (BTO) of the U.S. Department of Energy (DOE) seeks to accelerate the development of the next generation of heating, ventilation, air-conditioning, and refrigeration (HVAC&R) technologies, including both electric- and heat-driven solutions. HVAC is the largest energy end-use for U.S. buildings, consuming approximately 40% (15.5 Quads) of total energy in 2015.[1] Vapor-compression systems have effectively and efficiently served HVAC&R needs for residential and commercial buildings for close to 100 years. Vapor compression technologies are currently the dominant HVAC&R technology due to their scalability, relatively compact size, high reliability, and other attributes. However, the refrigerants used in these systems have detrimental effects on the environment when released into the atmosphere.

In total, the operation of HVAC&R technologies in the United States in 2013 resulted in the release of 474 million metric tonnes of equivalent CO_2 ($MMTCO_2e$). This represented 9% of all US emissions.[2] Of these emissions, 35% (164 $MMTCO_2e$) were classified as direct emissions – emissions resulting mainly from refrigerant leaks. The remaining 65% (310 $MMTCO_2$-e) were

[1] *Annual Energy Outlook 2015, U.S. Energy Information Administration, Table A4 Residential Sector Key Indicators and Consumption and Table A5 Commercial Sector Key Indicators and Consumption*, http://www.eia.gov/forecasts/aeo/, accessed 3/1/16.
[2] See Table 3 for HVAC&R emissions; and for total US emissions: *EPA Overview of Greenhouse Gases: Emissions and Trends*, http://www3.epa.gov/climatechange/ghgemissions/gases/co2.html, accessed 3/4/16.

classified as indirect emissions – emissions resulting from the generation of electricity used by HVAC&R systems.

Direct emissions may be reduced by: 1) Minimizing refrigerant leakage throughout the life of air conditioning and refrigeration equipment and/or; 2) Using refrigerants with lower global warming potential (GWP) or no refrigerants at all (non-vapor compression equipment). Indirect emissions, on the other hand, may be reduced by improving the energy efficiency of HVAC&R equipment. Developing more energy efficient, low or near-zero GWP solutions and non-vapor compression solutions is therefore critical, because both direct and indirect emissions have substantial environmental impacts.

Leaders from around the world are working to reduce both indirect and direct emissions in their respective countries. Proposals have already been crafted to phase down hydrofluorocarbon refrigerants (HFCs) for HVAC equipment over the next 20 years.[3] In the United States, BTO's Emerging Technologies (ET) Program has the broad aim of supporting the development of cost-effective technologies that can reduce aggregate building energy use intensity by 30% by 2020, and 45% by 2030, relative to the consumption of 2010 energy-efficient technologies. For HVAC technologies, the goal is to reduce technical potential energy consumption (as measured by energy use intensity) by 60%, again relative to 2010 energy-efficient technologies.[4] BTO's goal is to achieve these energy consumption targets using low or near-zero GWP solutions.

BTO maintains a two-pronged approach for achieving these goals:

1) Accelerate the development of near-term technologies that have the potential to save significant amounts of energy (which may include cost reduction activities); and,
2) Accelerate the development of the next generation of technologies that have the potential of "leapfrogging" existing technologies by pursuing entirely new approaches (including crosscutting efforts).

BTO plans to pursue an Advanced HVAC&R Research and Development effort to execute this approach in an interdisciplinary way. The technical scope of the effort spans all advanced HVAC&R technologies that may help achieve DOE goals, including activities with crosscutting applications or end-uses. This research focus is intended to initiate a new cycle of innovation across all HVAC&R technology categories. BTO expects cross-disciplinary approaches to the research, because solutions will require breakthroughs in multiple technical disciplines.

[3] http://www.state.gov/r/pa/prs/ps/2015/04/240730.htm

[4] *DOE Building Technology Office's Multi Year Program Plan (MYPP) for Fiscal Years 2016 – 2020,* http://energy.gov/eere/buildings/downloads/multi-year-program-plan, accessed 3/1/16.

BTO held two stakeholder workshops in late 2015 to gather ideas surrounding near-term and long-term technology needs in advanced HVAC&R and to explore best practices in structuring and managing an R&D effort of this kind.[5] Between the two workshops, over 65 different organizations were represented. Over 250 technology needs and ideas, as well as structure and management best practices, were discussed. Following careful examination of the key insights offered, BTO is publishing this RFI as a means for stakeholders to clarify and expand on specific ideas offered in the two workshops. If BTO's requested funding for fiscal year 2017 is approved, BTO anticipates publishing a Funding Opportunity Announcement (FOA) in late CY2016.

Purpose

The purpose of this RFI is to solicit feedback from industry, academia, research laboratories, government agencies, and other stakeholders, including building owners and operators, on questions related to residential and commercial HVAC&R technologies and strategies. This information will be used by BTO for strategic planning of the advanced HVAC&R R&D effort and to help guide BTO to craft the potential FOA in a manner that is most effective and optimally targeted at key needs in the industry, in order to achieve DOE's goals related to HVAC&R (see background, above). More information on the current portfolio can be found at [http://energy.gov/eere/buildings/hvac-water-heating-and-appliances]. This is solely a request for information and not a Funding Opportunity Announcement (FOA). EERE is not accepting applications.

Disclaimer and Important Notes

This RFI is not a Funding Opportunity Announcement (FOA); therefore, EERE is not accepting applications at this time. EERE may issue a FOA in the future based on or related to the content and responses to this RFI; however, EERE may also elect not to issue a FOA. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if EERE chooses to issue a FOA regarding the subject matter. Final details, including the anticipated award size, quantity, and timing of EERE funded awards, will be subject to Congressional appropriations and direction.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. EERE will review and consider all responses in its formulation of program strategies for the identified materials of interest that are the subject of this request. EERE will

[5] http://energy.gov/eere/buildings/downloads/workshop-1-advanced-hvacr-research-effort, http://energy.gov/eere/buildings/downloads/workshop-2-advanced-hvacr-research-effort

not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that EERE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind EERE to any further actions related to this topic.

Proprietary Information

Because information received in response to this RFI may be used to structure future programs and FOAs and/or otherwise be made available to the public, **respondents are strongly advised to NOT include any information in their responses that might be considered business sensitive, proprietary, or otherwise confidential.** If, however, a respondent chooses to submit business sensitive, proprietary, or otherwise confidential information, it must be clearly and conspicuously marked as such in the response.

Responses containing confidential, proprietary, or privileged information must be conspicuously marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Federal Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

If your response contains confidential, proprietary, or privileged information, you must include a cover sheet marked as follows identifying the specific pages containing confidential, proprietary, or privileged information:

> **Notice of Restriction on Disclosure and Use of Data:**
> Pages [List Applicable Pages] of this response may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for the purposes described in this RFI DE-FOA-0001590.The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

In addition, (1) the header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: “Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure” and (2) every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

Evaluation and Administration by Federal and Non-Federal Personnel

Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may seek the advice of qualified non-Federal

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personnel. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response, consent to EERE providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given access. Submissions may be reviewed by support contractors and private consultants.

Request for Information: Categories and Questions

Information is sought in response to questions in each of three (3) categories:

Category 1: Overall structure and approach for effort

1. Given the distinctions of the near-term targets (Table 1) and long-term targets (Table 2), BTO proposes different goals for each effort:
   Near-term: Introduce into the marketplace five advanced vapor compression, low-GWP solutions that meet the targets in Table 1 (See question 5 for discussion of "low-GWP" requirements) within 5 years.
   Long-term: Demonstrate in the laboratory five promising non-vapor compression technologies, that meet the targets stated in Table 2 and can be introduced into the marketplace within 10 years.
   - How well do these goals match the needs of the program?
   - In what ways could BTO improve these goals?

2. Can BTO's goals best be achieved through 1 or 2 large awards ($5M - $10M total each for example), or through several smaller awards as is a more typical FOA process ($1M - $2M total each for example)? This is all subject to Congressional appropriations and direction.
   - Can the near-term and long-term goals (see below) be better addressed by a single award (i.e., a single team), rather than with two awards (i.e., two teams)? Or alternatively would they be better addressed by more than two awards?
   - How much, if any, interaction should the teams have with each other to advance the overall program mission?

3. BTO would like to encourage active collaboration with both international partners and non-DOE domestic partners.
   - Would international collaboration add value to this effort? Why or why not?
   - If affirmative to the above, is there a significant risk that the value added would not be commensurate with the heightened effort of working internationally? If so, how might that be mitigated?

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- In what specific ways could international partners be leveraged?

Category 2: Metrics with Targets

4. BTO proposes to use technology performance and cost metrics (see Table 1 and Table 2) as measures of program performance.
   - How well do the listed performance and cost metrics and targets capture the needs for this effort?
   - What performance and cost metrics and targets would you consider adding or changing?

Table 1: Performance and cost metrics with targets for near-term technology areas

Targets for near-term technology areas				
Project area	**Metric**	**Building Type**	**Current Best on Market**	**2020 Targets**
Advanced vapor compression technologies	Primary seasonal COP; Installed cost per kBtu/hr. in 2013$	Residential & commercial	2.30; $141.67	2.00; $82.90
Natural-gas-driven heat pumps		Residential & commercial	0.98; $36.00	1.38; $57.90
Cold climate heat pumps		Residential & commercial	0.96; $125.00	1.07; $59.00
Air-source integrated heat pump	Primary energy savings; Installed cost per sq. ft.	Residential	Not on market	49%; $3.32
Multi-function natural gas driven heat pump		Residential & commercial	30%; $9.40	44%; $3.40
Note: Please refer to Appendix A for key assumptions and sources.				

Table 2: Performance and cost metrics with targets for long-term technology areas

Targets for long-term technology areas				
Project area	**Metric**	**Building Type**	**Status (Best)**	**2020 Target**
Non-vapor compression technologies	Primary seasonal COP; Installed cost per kBtu/hr. in 2013$	Residential & commercial	Not on market	2.28; $80.30
Note: Please refer to Appendix A for key assumptions and sources.				

5. BTO proposes to limit the 100-year GWP of the working fluids, as defined and tabulated in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,[6] in

[6] Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M.

all proposed technology solutions to less than **ten** (10). BTO is aware that life-cycle climate performance (LCCP)[7] is a more comprehensive metric for understanding the impacts of a technology solution. Due to the complexities of the LCCP metric and the fact that it changes with generation mix and local climate, BTO feels that a single GWP-based metric leads to a less complex and more objective approach. Estimates of the direct and indirect contributions to greenhouse gas emissions for each HVAC&R sector in the USA are provided in Table 3.

- How well does this proposed refrigerant GWP metric serve the objectives of the program?
- What changes to this metric, if any, would you recommend to help reduce direct global warming impacts of HVAC systems?

Table 3: Estimated greenhouse gas emissions impacts (direct and indirect) of each sector/application in the USA in millions of metric tons of CO_2–equivalent per year [MMT CO_2e/yr.]

Application	Indirect [MMTCO_2/yr.]	Direct [MMTCO_2e/yr.]	Total [MMTCO_2e/yr.]
Air Conditioning			
Residential AC	109	47	156
Light Commercial AC	41	22	63
Large Commercial AC	41	22	63
Refrigeration			
Supermarket Refrigeration	34	33	67
Self-contained Refrigeration	19	2	21
Walk-in Coolers and Freezers	7	2	9
Residential Refrigeration	59	36	95
Note: Please refer to Appendix B for key assumptions and sources.			

Category 3: Other Issues

6. What other recommendations or relevant information would you like to provide BTO?

Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; accessed 3/1/16

[7] See, e.g., http://lccp.umd.edu/ornllccp/

Request for Information Response Guidelines

Responses to this RFI must be submitted electronically to RFI-ADV-HVACR@ee.doe.gov no later than 5:00pm (ET) on July 25, 2016. Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25MB be compressed (i.e., zipped) to ensure message delivery. Responses must be provided as a Microsoft Word (.docx) attachment to the email, and no more than 10 pages in length (excluding appendices), 12 point font, 1 inch margins. Only electronic responses will be accepted.

Please identify your answers by responding to a specific category and question if applicable. Respondents may answer as many or as few questions as they wish.

BTO will not necessarily respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

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Appendix A: Assumptions and Sources for Tables 1 and 2

General sources for baseline and 'Best' technology cost and performance:

- EIA. (2015). Updated Buildings Sector Appliance and Equipment Costs and Efficiencies. Available online: https://www.eia.gov/analysis/studies/buildings/equipcosts/pdf/full.pdf
- ENERGY STAR. (2016). Energy Star Most Efficient. Available online: https://www.energystar.gov/products/energy_star_most_efficient
- EIA SEER and HSPF estimates for heating/cooling technologies are divided by 3.412 to convert to PCOP, in accordance with EIA NEMS documentation (e.g., see http://www.eia.gov/forecasts/aeo/nems/documentation/residential/pdf/m067(2014).pdf, p. 17)
- Factor of 3.06 used to convert electric site energy use to electric primary energy use, in accordance with 2013 electricity related losses in Annual Energy Outlook residential data table A4: http://www.eia.gov/forecasts/aeo/data/browser/#/?id=4-AEO2015
- Per square foot installed costs are normalized to the 2010 median U.S. home square footage of 2,169 square feet: http://www.census.gov/const/C25Ann/sftotalmedavgsqft.pdf

General source for 2020 target cost and performance numbers:

Each project area technology was represented as a 'target measure' in the BTO Prioritization Tool measures database.[8] Given a stock-wide energy savings objective for the area, the target measure's unit costs were varied until it achieved less than a 5-year payback in the year 2030, assuming 2020 market introduction and accounting for savings overlaps with competing measures in the database.

References:

Project area	References
Advanced vapor compression technologies	EIA, Appliance Costs and Efficiencies, Residential Central AC (South), p.36, 2013 Typical (baseline cost/performance) and 2013 High ('Best' cost/performance)
Natural-gas-driven heat pumps	Ibid, Residential Gas-Fired Furnaces, p.23, 2013 Typical (baseline cost/performance) and 2013 High ('Best' cost/performance)
Cold climate heat pumps	Ibid, Residential Air Source Heat Pumps (heat mode), p.40, 2013 Typical (baseline cost/performance and 'Best' cost); ENERGY STAR, Most Efficient 2016 - Central Air Conditioners and Air Source Heat Pumps, Coleman Echelon Series 3 ton unit ('Best' performance)
Air-source integrated heat pump	EIA, Appliance Costs and Efficiencies, combination of: Residential Electric Resistance Water Heaters, p.14; and Residential Air Source Heat Pumps (cool mode), p.40, 2013 Typical (baseline cost/performance); 'Best' figures based on expert assessment for commercial market

[8] http://energy.gov/eere/buildings/prioritization-tool

Project area	References
Multi-function natural gas driven heat pump	Ibid, combination of: Residential Gas-Fired Water Heaters, p.9; Residential Gas-Fired Furnaces, p.23; and Residential Central AC (South), p.36, 2013 Typical (baseline cost/performance); no product on the market yet for 'Best' category
Non-vapor compression technologies	Ibid, Residential Central AC (South), p.36, 2013 Typical (baseline cost/performance) and 2013 High ('Best' cost/performance)

Appendix B: Assumptions and Sources for Table 3

Table 4: Key assumptions and sources used to generate Table 3

<table>
<tr><th>Application</th><th>Indirect
[MMTCO$_2$/yr.]</th><th>Direct
[MMTCO$_2$e/yr.]</th></tr>
<tr><td colspan="3">Air Conditioning</td></tr>
<tr><td>Residential AC</td><td>"Residential Space-cooling", 2013[1]</td><td rowspan="2">% split between direct/indirect emissions constant since 2010[4]</td></tr>
<tr><td>Light Commercial AC</td><td rowspan="2">Distribution of energy consumed is proportional to total building floor space within each application[1,2]</td></tr>
<tr><td>Large Commercial AC</td><td>% split between direct/indirect emissions equal to 2010 light com AC[4]</td></tr>
<tr><td colspan="3">Refrigeration</td></tr>
<tr><td>Supermarket Refrigeration</td><td rowspan="3">Distribution of energy consumed within each application constant since 2009[1,2,3]</td><td rowspan="3">% split between direct/indirect emissions constant since 2010[4]</td></tr>
<tr><td>Self-contained Refrigeration</td></tr>
<tr><td>Walk-in Coolers and Freezers</td></tr>
<tr><td>Residential Appliances</td><td>"Residential Refrigeration", 2013[1]</td><td>"Refrigeration - New Equip", 2014[4]</td></tr>
<tr><td colspan="3">Sources:
[1] 2015 Annual Energy Outlook: http://www.eia.gov/forecasts/aeo/
[2] EIA Commercial HVAC report: http://www.eia.gov/consumption/commercial/data/2012/#b8
[3] DOE Commercial Refrigeration Report:
http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_refrig_report_10-09.pdf
[4] Split between direct and indirect based on underlying modeling used for DOE Refrigerants Roadmap:
http://www.energy.gov/sites/prod/files/2014/12/f19/Refrigerants%20Roadmap%20Final%20Report%202014.pdf</td></tr>
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