Interview Guide: DOE/EERE Building Technologies Office Economic Impact Study Alternative Refrigerants and Heat Pump Design Model Research

The U.S. Department of Energy (DOE) has contracted with RTI International to study the impact of Building Technologies Office (BTO) research and development investments and ancillary activities. This survey looks at the impact of U.S. government R&D activities, and specifically at the impact of DOE's R&D efforts, on the energy performance of air conditioners and heat pumps. Two major technological contributions enabling the improvements in energy performance were the Heat Pump Design Model (HPDM) developed and maintained by Oak Ridge National Laboratory (ORNL) and the DOE and other government agencies (EPA, NIST) research on alternative refrigerants that supported industry in successfully phasing out chlorofluorocarbons (CFCs) in accordance with the Montreal Protocol.
Your perspective will help guide DOE's planning and investment process. Participation in this study is confidential; only aggregated information will be included in any deliverables or communications. Your name and your company's/organization's name will not be disclosed.

Our research products will be an economic analysis, final report, and presentation materials. All deliverables will be publicly available in late summer 2016, and these will be shared with you as soon as they are released.

If you have questions, please contact:

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Paperwork Reduction Act Burden Disclosure Statement

This data is being collected to evaluate DOE Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Office R&D investments. The data you supply will be used for estimating the economic benefits and costs of R&D investments.
Public reporting burden for this collection of information is estimated to average 60 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Office of the Chief Information Officer, Records & Privacy Management Division, IM-23, Paperwork Reduction Project 1910-NEW, U.S. Department of Energy, 1000 Independence Ave SW, Washington, DC, 20585-1290; and to the Office of Management and Budget (OMB), OIRA, Paperwork Reduction Project 1910-NEW, Washington, DC 20503.
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Submission of this data is voluntary.

Background on Alternative Refrigerants and Heat Pump Design Model

Over the past 15 years the average efficiency of air conditioners and heat pumps has almost doubled. Federal Minimum Energy Performance Standards (MEPS) rose from about 9.5 SEER in 1990 to over 15 SEER today. These trends, as depicted in Figure 1, were influenced by a wide range of public and private sector investments and activities which included DOE and other major government research activities.

Since 1981, DOE has conducted and funded technical research that played a key role in the industry-wide phaseout of CFCs—an ozone-depleting greenhouse gas commonly used in refrigerants—from refrigerators, air conditioners, and other applications. Major DOE activities include the following:

- Mixed Refrigerants Research (1981–1992)
- Generic Research on New Refrigerants (1986–1992)
- Alternative Fluorocarbons Environmental Acceptability Study (AFEAS) Collaborative R&D Agreement (1989–1997)
- Materials Compatibility and Lubricants Research (MCLR) Program (1991–1999)

DOE also developed the Heat Pump Design Model (HPDM) which been used by ORNL and industry (often in collaboration) to develop next-generation products. The HPDM also played a part in transitioning to non-CFC refrigerants, modeling system design modifications that were needed to accommodate and optimize for the new fluids.

Figure 1 shows the trend in U.S. shipment-weighted average SEER of air conditioners and heat pumps since 1990.

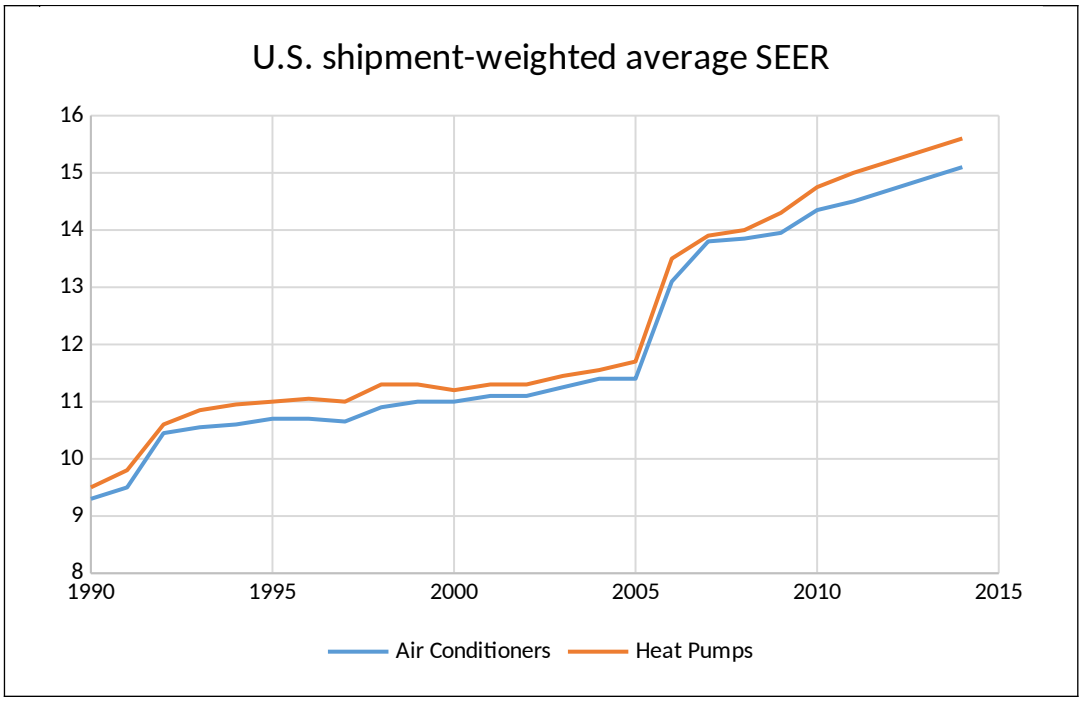

Figure 1. U.S. shipment-weighted average SEER.

Research activities that were happening during the development of the HPDM and Alternative Refrigerants. Some major milestones include:

- 1982-1991: Mixed Refrigerants Research – DOE investigated the heat transfer characteristics and the system performance, design, and operability of zeotropic refrigerant mixture.
- 1986-1992: ORNL conducts generic research on CFC alternative refrigerants resulted in a public domain performance data from an experimental vapor compression cycle system. DOE also funded the National Institute for Standards and Technology (NIST) [1982-1986] to evaluate the availability of thermophysical properties of alternative refrigerants and develop consensus property formulations internationally.
- 1988: ORNL updates the HPDM to model variable-speed designs.
- 1989-1997: DOE contributes major role to the Alternative Fluorocarbons Environmental Acceptability Study (AFEAS) CRADA established by 17 of the world's Chemical companies. DOE tested alternatives to CFC refrigerants for their environmental, health, and safety characteristics. DOE/ORNL developed the Total Equivalent Warming Impact (TEWI) metric.
- 1991-1999: DOE funds and participates in the Materials Compatibility and Lubricants Research (MCLR) Program, researching refrigerant and lubricant properties and related system design issues.
- 1992: DOE establishes Minimum Energy Performance Standards (MEPS) of 10 SEER for both air conditioners and heat pumps.
- Driven by the Montreal Protocol, DOE, NIST, EPA and industry conduct R&D to develop alternative (non CFC) refrigerants.
- ASHRAE, AHRI and other research organizations contribution to the knowledge base.
- 1995: ORNL updates the HPDM to model non-chlorinated refrigerant mixtures.
- 2006: DOE establishes Minimum Energy Performance Standards (MEPS) of 13 SEER for both air conditioners and heat pumps.
- Financial incentives were provided by electric utilities for installing energy-efficient equipment.

Section I. The first set of questions pertains to your background and involvement in the development or use of the heat pump design model, efficiency improvements in vapor-compression equipment, and/or development of CFC alternative refrigerants.

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Respondent Background

1. Please give a brief description of your background in relation to the HPDM, efficiency improvements in vapor-compression equipment and/or alternative refrigerants research:

2. If your background involves research/development/testing/other technical/engineering efforts, on which of the following types of vapor compression equipment have you worked?
   - ☐ Heat pump equipment
   - ☐ Worked for a manufacturer that conducted research/testing/other technical efforts
     - __ Refrigerant manufacturer
     - __ HVAC equipment manufacturer
     - __ Other: _____
   - ☐ Led public-private collaboration on technical efforts
   - ☐ Participated in public-private collaboration on technical efforts
   - ☐ Led industry-only technical efforts
   - ☐ Participated in industry-only technical efforts
   - ☐ Employed in a federal agency or research lab
   - ☐ Employed in a state energy office
   - ☐ Worked for a trade association
   - ☐ Worked for a university or research institute
   - ☐ Other: _____

3. Were you involved in or familiar with any of the DOE programs/activities related to alternative refrigerants? Check all that apply.

	Directly Involved	Very Familiar	Somewhat Familiar
▪ Mixed Refrigerants Research	☐	☐	☐
▪ Generic Research on New Refrigerants	☐	☐	☐
▪ AFEAS CRADA	☐	☐	☐
▪ MCLR Program	☐	☐	☐
▪ Other	☐	☐	☐

   Please give a brief description:

4. Have you ever received DOE funding for your work or participated in collaborative R&D activities with a DOE-funded laboratory such as Oak Ridge National Laboratory or the National Energy Technology Laboratory?
   ☐ No ☐ Yes. Please give a brief description:

5. In the past 15 years, have you been involved in commercial R&D related to refrigerants, air conditioning, or heat pumps?

   ☐ No (please skip down to Section III)
   ☐ Yes

SECTION II. This next set of questions pertains to DOE's involvement in and impact on the R&D activities that you were involved in. We will be asking you to quantify these impacts to the best of your ability.
Ask these questions if the respondent answered Yes to Question 5.

We are trying to isolate the impact of DOE R&D investments and activities as much as possible, and this poses some challenges. For example, efficiency standards and regulated phaseout of certain refrigerants affect companies' incentives to perform R&D and commercialize new products, and the DOE R&D activities we are focused on have indirect effects on the evolution of standards and regulations. Similarly, EnergyGuide labeling, ENERGY STAR qualification and rebates rely on test methods linked to DOE R&D activities.

Therefore, if we were to hold fixed the exact timeline of these factors (for instance, the timing of updates to standards) we would be assuming away a part of the impact we are trying to estimate. What we would like to try to do instead is to think about holding constant the environment—the institutional frameworks—in which standards, labeling, and subsidies evolve, and consider what would happen without the DOE R&D-related activities and investments described in Question 6:

6. In what ways has your R&D work been influenced by DOE?

   Provide a number from 0 to 3 (0 = DOE did not contribute in this way; 1 = minimal DOE contribution; 2 = moderate DOE contribution; 3 = major DOE contribution).

   _____Through DOE's contributions to the knowledge base on which R&D work drew (e.g., formal science literature, conference presentations and discussions, patents, knowledge and training of yourself and your colleagues)

   _____Through access to scientific and engineering data produced by DOE laboratories

   _____Through the licensing/transfer of technology that DOE helped to develop

   _____Through consultations with DOE scientists and engineers

   _____Through access to DOE laboratory facilities

   _____Through equipment/component testing performed at DOE laboratories

   _____Through direct R&D funding from DOE

   _____Other: _____

   ☐ DOE had no influence (please skip down to question 8)

   Please give a brief description of DOE influences:

7. Would your R&D work have been undertaken without the DOE factors identified above? (please select the most likely scenario)

   ☐ The work would not have been undertaken

   ☐ At least some of the work would still have been undertaken, but the effort levels, costs, timelines, and/or outcomes would have been different

   ☐ The work would still have been undertaken, without significant difference in effort levels, costs, timelines, or outcomes (please skip down to question 9)

Please give a brief description of how effort levels, costs, timelines, and/or outcomes would have been different (or why the work would not have been undertaken). (Note: If the work would not have been undertaken at all, please skip down to question 8):

8. Without the DOE factors identified above:

   ☐ The level of effort, in terms of research personnel years, would have been

   _____ research personnel years [☐ MORE ☐ LESS] (a range is fine).

   OR _____ % [☐ MORE ☐ LESS] (a range is fine).

   ☐ The cost of the work would have been

   $_____ x1000 $ [☐ MORE ☐ LESS] (a range is fine).

   OR _____ % [☐ MORE ☐ LESS] (a range is fine).

   ☐ To reach the same outcomes (in terms of energy efficiency and other performance attributes) would have taken

   _____ calendar years [☐ MORE ☐ LESS] (a range is fine).

   OR _____ % [☐ MORE ☐ LESS] (a range is fine).

   If any of the DOE factors identified in question 6 were especially important for one or more of these impacts, please give a short explanation:

9. What were the technical outcomes of your R&D work? Where possible, please provide the baseline parameter and improved parameter (e.g., pre and post energy efficiency, or pre and post equipment cost).

   ☐ Improvements in energy efficiency

   Please describe:

   ☐ Improvements in other performance attributes

   Please describe:

☐ Improvements in equipment cost for which these levels of energy efficiency or other performance attributes could be achieved

Please describe and include cost savings:

10. If DOE factors identified above had any impact on these outcomes, what was the DOE effect in terms of the proportion of the improvements you view were attributable to DOE activities?

Improvements in Energy Efficiency	**Improvements in performance attributes**	**Improvements in equipment costs**
☐ Less than 10%	☐ Less than 10%	☐ Less than 10%
☐ Between 10-24%	☐ Between 10-24%	☐ Between 10-24%
☐ Between 25-49%	☐ Between 25-49%	☐ Between 25-49%
☐ Between 50-75%	☐ Between 50-75%	☐ Between 50-75%
☐ Greater than 75%	☐ Greater than 75%	☐ Greater than 75%

Please give a short explanation of your reasoning. Please note if any of the DOE factors checked above were especially important for one or more of these impacts:

11. Was a new product commercialized as a result of this R&D work?
    ☐ No (please skip down to Section III)
    ☐ Yes

12. Without the DOE factors identified in question 6, taking into account the impacts on energy efficiency, other performance attributes, and equipment cost described above:
    a. How likely is it that your company would have commercialized the product in the same time frame (please select one)?
        ☐ No chance the product would have been commercialized.
        ☐ 0% to 25% chance
        ☐ 25% to 50% chance
        ☐ 50% to 75% chance
        ☐ 75% to 100% chance
        ☐ The product would have been commercialized in the same time frame without the DOE factors identified above.
    b. If your company had commercialized the product without the DOE factors identified above, how would its sales volume today compare with that of the product actually commercialized?

☐ No difference in sales (i.e., any difference in price, energy efficiency, and performance attributes would have negligible effect on sales)

☐ Sales would have been lower by roughly _____% (a range is fine).

☐ Sales would have been higher by roughly_____% (a range is fine).

Please give a short explanation of your reasoning:

(Respondents answering Section II questions skip to Section IV)

SECTION III. This next set of questions pertains to your opinion of DOE's influence on the market and industry trends for refrigeration systems in general.

We are trying to isolate the impact of DOE R&D investments and activities as much as possible, and this poses some challenges. For example, efficiency standards and regulated phaseout of certain refrigerants affect companies' incentives to perform R&D and commercialize new products, and the DOE R&D activities we are focused on have indirect effects on the evolution of standards and regulations. Similarly, EnergyGuide labeling, ENERGY STAR qualification and rebates rely on test methods linked to DOE R&D activities.

Therefore, if we were to hold fixed the exact timeline of these factors (for instance, the timing of updates to standards) we would be assuming away a part of the impact we are trying to estimate. What we would like to try to do instead is to think about holding constant the environment—the institutional frameworks—in which standards, labeling, and subsidies evolve, and consider what would happen without the DOE R&D-related activities and investments described in Question 13:

13. How did DOE impact the commercial R&D (performed in the last 15 years) necessary for companies to bring new refrigerants and more energy-efficient air conditioning and heat pump systems to market?

    Provide a number from 0 to 3 (0 = DOE did not contribute in this way; 1 = minimal DOE contribution; 2 = moderate DOE contribution; 3 = major DOE contribution).

    _____Through DOE's contributions to the knowledge base on which R&D work drew (e.g., formal science literature, conference presentations and discussions, patents, knowledge and training of yourself and your colleagues)

    _____Through access to scientific and engineering data produced by DOE laboratories

    _____Through the licensing/transfer of technology that DOE helped to develop

    _____Through consultations with DOE scientists and engineers

    _____Through access to DOE laboratory facilities

    _____Through equipment/component testing performed at DOE laboratories

    _____Through direct R&D funding from DOE

    _____Other: _____

    _____DOE had no influence (please skip down to question 16)

Please give a brief description of DOE influences:

14. Without the DOE impacts discussed in Question 13, would the commercial R&D necessary to bring new refrigerants and more energy-efficient air conditioning and heat pump systems to market still have been undertaken within the same time frame?

☐ The commercial R&D would not have been undertaken.

☐ At least some of the commercial R&D would still have been undertaken, but the effort levels, costs, timelines, and/or outcomes would have been different.

☐ The commercial R&D would still have been undertaken, without significant difference in effort levels, costs, timelines, or outcomes.

Please give a brief explanation:

15. Given your answers to Question 13, how would the market for refrigerants, air conditioning systems, and heat pumps look different than it does today without the DOE impacts discussed above?

☐ Average energy use would be: ☐ higher
☐ lower
by roughly _____ %.

☐ Average price would be: ☐ higher
☐ lower
by roughly _____ %.

☐ Average sales volume would be: ☐ higher
☐ lower
by roughly _____ %.

☐ There would be no difference (the market would be exactly as it is today).

Please give a brief explanation:

Section IV. Additional Comments

16. Are there any additional comments you would like to share?

Respondent Contact Information (optional)
Name: _____
Title: _____
Division: _____
Company/Organization: _____
Location, if not USA:
_____

Would you be willing to be contacted for a brief follow-up discussion of your responses to this survey?

- ☐ Yes, by phone _____
- ☐ Yes, by email _____
- ☐ No

THANK YOU for contributing your time and insight to the study.