



Shaping Tomorrow's
Built Environment Today

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TO: John Craig Elson, Chair TC 2.1, johnce10@gmail.com
Jorn Toftum, Research Subcommittee Chair TC 2.1, jt@byg.dtu.dk
CC: Pawel Wargocki, Research Liaison Section 2.0, paw@byg.dtu.dk
FROM: Michael Vaughn, MORTS, mvaughn@ashrae.org
DATE: November 6, 2018
SUBJECT: Research Topic Acceptance Request (1861-RTAR), "US / Canadian residences: Indoor conditions, thermal comfort, occupant behavior and energy demand"

During their fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to accept it with comments for further development into a work statement (WS) provided that the key comment(s) and question(s) below are addressed to the satisfaction of your Research Liaison, Pawel Wargocki, paw@byg.dtu.dk, or RL2@ashrae.net, in the work statement draft.

1. The duration of this project is almost three years. How was its duration calculated? Split into two parts.
2. Detail the duration of each single phase of the project.
3. Reduce the scope and budget.

The work statement draft must be approved by the Research Liaison prior to submitting it to RAC.

An RTAR evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on specific review criteria. This should give you an idea of how your RTAR is being interpreted and understood by others. Some of these comments may indicate areas of the RTAR and subsequent WS where readers require additional information or rewording for clarification.

The first draft of the work statement should be submitted to RAC no later than **August 15, 2020** or it will be dropped from display on the Society's Research Implementation Plan. The next likely submission deadline for a new work statement on this topic is **May 15, 2019** for consideration at RAC's 2019 Annual meeting. The submission deadline after that for work statements is **August 15, 2019** for consideration at the RAC's 2019 fall meeting.

Project ID	1861	
Project Title	US / Canadian residences: Indoor conditions, thermal comfort, occupant behavior and energy demand	
Sponsoring TC	TC 2.1, Physiology and Human Environment	
Cost / Duration	\$200,000 / 34 Months	
Submission History	1st Submission	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2018 Fall Meeting Review		
Essential Criteria	Voted NO	Comments & Suggestions
Background: The RTAR should describe current state of the art with some level of literature review that documents the importance/magnitude of a problem. References should be provided. If not, then note it in your comments.		9 - As a co-author of this RTAR, I declare a conflict of interest, and so have not commented on it. 10 - The authors state that "There are comparatively few studies for the US and Canada ..." but they do not list even a single one. Please include also some references for studies in US and Canada.
Research Need: Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected.		8 - useful list of environmental conditions and comfort
Relevance and Benefits to ASHRAE: Evaluate whether relevance and benefits are clearly explained in terms of: a. Leading to innovations in the field of HVAC & Refrigeration b. Valuable addition to the missing information which will lead to new design guidelines and valuable modifications to handbooks and standards. Is this research topic appropriate for ASHRAE funding? If not, Reject.		4 - The project is developing and validating the protocol. The protocol is potentially going to be used in future studies characterizing thermal environment and behavior in dwellings. It is unclear whether this study will take place at all. The protocol will not become (or at least it is not proposed by the Authors) a part of ASHRAE standard or ASHRAE recommended measuring method. I am not sure whether ASHRAE should invest USD 200k to develop the measuring protocol. The project would not answer one of the fundamental questions raised by the Authors on whether the range of acceptable temperatures in dwelling is larger than in commercial buildings and whether this means that thermal models for residential environments should differ from the models for commercial buildings.
IF ABOVE THREE CRITERION ARE NOT ALL SATISFIED - MARK "REJECT" BELOW & CONTINUE REVIEW BELOW		
Other Criteria	Voted NO	Comments & Suggestions
Project Objectives: Based on the background and need, evaluate whether the project objectives are: 1. Aligned with the need 2. Specific 3. Clear without ambiguity 4. Achievable If not, then appropriate feedback should be provided.		8 - this may be too ambitious for a single project -- can the project be descoped into smaller objectives?
Expected Approach and Budget: Is there an adequate description of the approach in order for RAC to be able to evaluate the appropriateness of the budget? If not, then the RTAR should be returned for revision. Anticipated funding level and duration:		2 - The project in the RTAR is rather pilot study and is difficult to understand why so much money and time are required. As stated in the back ground of the study, there were many similar researches outside US and Canada. Those study should be good suggestions for the project. 10 - The field study description should include a minimum sample size, minimum number of homes. The duration of this project is almost three years. How was its duration calculated? Wouldn't it better to split it into shorter projects to increase the likelihood to meet the objectives?
References: Are the references provided?		
Decision Options	Initial Decision?	Final Approval Conditions
ACCEPT AS-IS		2 - The term and budget should be decreased. 4 - The project should better describe the relevance for ASHRAE or add more field campaigns. 7 - RTAR is well written and need is well established. Developing a protocol to monitor IEQ and survey occupant perception, behavior and demographic information is well aligned with ASHRAE's mission. Results from these type of surveys would allow us to locally tailor building designs that would be sustainable and still meet occupant needs. 10 - Detail the duration of each single phase of the project and consider shorten its whole duration, if necessary by splitting it into two parts. 12 - This is important research to see how tastes have changed since the original col determination! Please don't forget the common problem of women being cold even though they wear a light dress and open toed shoe while men's business wear includes leather shoe, long pants, long sleeve shirt, with or without a undershirt. Let the dueling thermostat research commence! 8 - reduce scope and cost and refine objectives.
ACCEPT W/COMMENTS		
REJECT		

ACCEPT Vote - Topic is ready for development into a work statement (WS).

ACCEPT W/COMMENTS Vote - Minor Revision Required - RL can approve RTAR for development into WS without going back to RAC once TC satisfies RAC's approval condition(s)

REJECT Vote - Topic is not acceptable for the ASHRAE Research Program

Research Topic Acceptance Request Cover Sheet

Date: **31-July-2018**

(Please Check to Insure the Following Information is in the RTAR)

- A. Title
- B. Executive Summary
- C. Background
- D. Research Need
- E. Project Objectives
- F. Expected Approach
- G. Relevance and Benefits to ASHRAE
- H. Anticipated Funding Level and Duration
- I. References

Title: **US / CANADIAN RESIDENCES: INDOOR CONDITIONS, THERMAL COMFORT, OCCUPANT BEHAVIOR AND ENERGY DEMAND**

RTAR # **1861**
(To be assigned by MORTS)

Research Classification:
 Basic/Applied Research
 Advanced Concepts
 Technology Transfer

Results of this Project will affect the following Handbook Chapters, Special Publications, etc.:
Handbook of Fundamentals – Chapter 9

Responsible Committee: **TC 2.1**

Date of Vote: **28-July 2018**

For		7
Against	*	0
Abstaining	*	0
Absent or not returning Ballot	*	0
Total Voting Members	(CNV)	7

RTAR Authors
 Lead: **Dennis Loveday / Marianne Touchie**
 Others: **TBD**

Co-sponsoring TC/TG/MTG/SSPCs (give vote and date)
Residential Building Committee (RBC): 13-0-1-1 (15) CNV, July 30, 2018;
TC 7.6: 12-0-2-1 (15) CNV, Aug 8, 2018

Expected Work Statement Authors
 Lead: **Dennis Loveday / Marianne Touchie**
 Others: **TBD**
TBD

Potential Co-funders (organization, contact person information):
TBD (TBD)

Has an electronic copy been furnished to the MORTS?
 Has the Research Liaison reviewed the RTAR?

Yes	No
X	
X	

* Reasons for negative vote(s) and abstentions

Reason for RBC abstention: Comments relate to whether RBC involvement adds benefit, since the TC should have the full set of experts, and to lack of clarity on value of effort in relation to Std 55.

Title:

US / Canadian residences: Indoor conditions, thermal comfort, occupant behavior and energy demand

Executive Summary

Describe in summary form the proposed research topic, including what is proposed, why this research is important, how it will be conducted, and why ASHRAE should fund it. (50 words maximum)

Indoor environmental data on occupant thermal sensations, behaviors, socio-economic data and related energy demand is limited in US and Canadian residences. This project is proposed to develop, test and validate a method for gathering and analyzing these data which are essential for ASHRAE Standard 55 to incorporate residential conditions.

Background

Provide the state of the art with key references (at the end of this document) substantiating it. (300 words maximum)

Residential field studies have been conducted in countries including Denmark [1], Finland [2], China [3-8], Israel [9], Portugal [10], UK [11-15] and India [16] focusing on thermal comfort, IEQ [1, 4, 5] or the use of devices such as air-conditioners [15]. There are comparatively few studies for the US and Canada particularly those that focus on thermal sensations and preferences of occupants, but these data are necessary to guide future design of comfortable and energy-efficient residences.

A number of studies support the idea [16] that, in residences, a wider range of thermal conditions are considered comfortable compared to conditions typically seen in commercial spaces due to the greater range of available adaptive opportunities at home.

For example:

- A study of the thermal sensations, adaptation mechanisms and practices in Indian apartments [16] showed the comfort band (-1 to +1) to be 26-32°C as a result of air movement, well above limits (23-26°C) set by Indian standards, with PMV higher than actual sensation vote;
- Studies in China [6, 7] show air motion driven by natural ventilation to be effective for comfort, without use of fans or air-conditioners;
- A study in Finland [2] with over 3000 participants confirmed thermal comfort in offices is poorer than in homes due to greater adaptive opportunities in residential environments;
- Recent work in the UK [17] suggests that residential activity could contribute to achievement of thermal comfort.

Whilst the available degree of adaptation in residences appears wider than in offices, models included in standards are based on laboratory and office studies.

There are also consequences for energy demand evaluations and policy. A review of actual indoor temperatures in UK homes [18] revealed temperatures lower than those assumed in national energy performance prediction. Unobtrusive sensors and remote data gathering via smartphone are already used in residential evaluations [19].

Research Need

Use the state of the art described above as a basis to specify the need for the proposed effort. (250 words maximum)

Knowledge about environmental conditions and occupant comfort in US and Canadian residences is limited compared to other countries. Field data will determine actual conditions in practice and report on subjective responses which can be used for standard and policy development for building design and refurbishment and to improve modeling. For example, the economic and environmental impact of thermally unusable floor area can be determined or the indoor conditions typically assumed for energy performance prediction (TCs 4.1, 7.6) can be verified. Given the complexity of the required data collection and analysis including confounding variables, sample and researcher bias, measurement accuracy, utility of survey responses etc. as well as the sheer size and variability in the population, the proposed scope of this project is to develop the study methodology and data analysis plan. Then, a field validation study will be conducted and data analyzed according to the plan to ensure the study goals are met by the proposed methodology. This study will yield a tested and refined monitoring and survey methodology and data analysis plan as well as a plan for the future field studies required to systematically gather a statistically representative sample across the US and Canada. This project will facilitate larger field studies which can follow this newly established methodology and data analysis plan for each population subset identified to cover the various housing types and climate zones.

Project Objectives

Based on the identified research need(s), specify the objectives of the solicited effort that will address all or part of these needs. (150 words maximum)

1. Develop a protocol to monitor the indoor environmental quality parameters in Standard 55 including local variations in bedroom and living rooms, space-conditioning energy consumption and outdoor temperatures.
2. Develop a protocol to simultaneously gather occupant data on thermal sensations, acceptability, preference, clothing and activities as well as HVAC system type, household expenditure on space-conditioning energy, and basic demographic information and building features.
3. Conduct a field study to validate the above protocols, thereby determining which methods need refinement.
4. Develop a data analysis plan and conduct preliminary analysis on the field data, focused primarily on the physical factors, but also developing analysis approaches to social/behavioral factors that can be implemented with future larger samples.
5. Develop a sampling strategy and prescriptive plan to collect a data set representative of the various housing types and climate zones across the US and Canada through future research projects.

Expected Approach

Describe in a manner that may be used for assessment of project viability, cost, and duration, the approach that is expected to achieve the proposed objectives (200 words maximum).

Check all that apply: Lab Testing Computations Surveys Field Tests
Analyses and modeling Validation efforts Other (specify) ()

The monitoring protocol should: employ methods that are minimally intrusive to occupants; incorporate relevant housing features; and demonstrate how general and local discomfort will be characterized. The survey protocol should: be subject to IRB approval; enable collection of seasonably representative responses concurrent with monitored data; and be sensitive to survey fatigue by occupants. The protocols should include provisions to ensure the data are anonymized, suitably quality-assured and stored for subsequent analysis according to data protection laws. Participant attrition should be addressed. The field study, conducted in a well-justified sample of occupied homes, should be conducted for at least one complete year to ensure data is collected during all seasons. The data analysis plan must clearly layout how the analysis following future data collection efforts will be conducted and integrated between the larger field studies. The plan for the future larger field studies must include a power analysis to determine the number of homes required for a statistically significant sample size in the selected building population. The budget must include adequate resources for study promotion, survey preparation and data analysis, and support for numerous visits to each study site. The proposed schedule should allow sufficient time for IRB approvals, participant recruitment, the study period and data analysis and protocol refinement.

Relevance and Benefits to ASHRAE

Describe why this effort is of specific interest to ASHRAE, its impact, and how it will benefit ASHRAE and the society. How does it align with ASHRAE Strategic Plans and Initiatives? How does it advance the state of the art in this area in general? Are there other stakeholders that should be approached to obtain relevant information or co-funding? (350 words maximum)

The work aligns with ASHRAE's Research Strategic Plan, 2010-2015, extended to 2018, in the following ways.

"Goal 3: To reduce significantly the energy consumption for HVAC&R, water heating and lighting in existing homes". The work will add to better understanding of occupant behaviours, leading to greater energy efficiency for space conditioning.

"Goal 7: Support development of tools, procedures and methods suitable for designing low-energy buildings". Understanding of residential thermal comfort will enable improved energy efficient design to enhance occupant comfort, based on modified tools and methods informed by field evidence.

"Goal 9: Support the development of improved HVAC&R components ranging from residential through commercial to provide improved system efficiency, affordability, reliability and safety". The modified tools will inform design and selection of residential HVAC&R components.

Specific benefits to ASHRAE include:

1. Development and validation of a standard field protocol to collect data on indoor environments and occupant perceptions in US & Canadian residences
2. A tested data analysis plan to ensure usable data are gathered from the field protocol
3. A prescriptive plan for conducting future field studies throughout the US/Canada to gather a large dataset that is representative of the various sectors of the residential housing market in a range of climate zones

This study is the first important step in generating a comprehensive, statistically significant data set to evaluate the complex relationships between enclosure characteristics, thermal conditions, occupant sensations and preferences, space-conditioning types and energy consumption, and expenditure relative to income in the residential sector. These data are essential for the development of future residential policies and standards as well as more accurate modeling approaches.

Anticipated Funding Level and Duration

Funding Amount Range: \$200,000

Duration in Months: 34

References

List the key references cited in this RTAR.

- [1] M. Frontczak, R. V. Andersen, and P. Wargocki, "Questionnaire survey on factors influencing comfort with indoor environmental quality in Danish housing," *Building and Environment*, vol. 50, pp. 56-64, 2012.
- [2] S. Karjalainen, "Thermal comfort and use of thermostats in Finnish homes and offices," *Building and Environment*, vol. 44, no. 6, pp. 1237-1245, 2009.
- [3] L. Huang, Q. Ouyang, Y. Zhu, and L. Jiang, "A study about the demand for air movement in warm environment," *Building and Environment*, vol. 61, pp. 27-33, 2013.
- [4] A. C. K. Lai, K. W. Mui, L. T. Wong, and L. Y. Law, "An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings," *Energy and Buildings*, vol. 41, pp. 930-936, 2009.
- [5] A. C. K. Lai and F. W. H. Yik, "Perception of importance and performance of the indoor environmental quality of high-rise residential buildings," *Building and Environment*, vol. 44, pp. 352-360, 2009.
- [6] Z. Wang, L. Zhang, J. Zhao, and Y. He, "Thermal comfort for naturally ventilated residential buildings in Harbin," *Energy and Buildings*, vol. 42, no. 12, pp. 2406-2415, 2010.
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- [8] Y. Song, Y. Sun, S. Luo, J. Hou, J. Kim, T. Parkinson and R. de Dear, "Indoor environment and adaptive thermal comfort models in residential buildings in Tianjin, China" *Procedia Engineering*, vol 205, pp 1627-1634, 2017.
- [9] R. Becker and M. Paciuk, "Thermal comfort in residential buildings - Failure to predict by Standard model," *Building and Environment*, vol. 44, no. 5, pp. 948-960, 2009.
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- [11] N. A. Oseland, "Predicted and reported thermal sensation in climate chambers, offices and homes," *Energy and Buildings*, vol. 23, pp. 105-115, 1995.
- [12] S. H. Hong, J. Gilbertson, T. Oreszczyn, G. Green, and I. Ridley, "A field study of thermal comfort in low-income dwellings in England before and after energy efficient refurbishment," *Building and Environment*, vol. 44, pp. 1228-1236, 2009.
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- [15] A. Pathan, A. Young, and T. Oreszczyn, "UK domestic air conditioning: a study of occupant use and energy efficiency," in *Air Conditioning and the Low Carbon Cooling Challenge*, no. July, 2008.
- [16] M. Indraganti, "Thermal comfort in naturally ventilated apartments in summer: Findings from a field study in Hyderabad, India," *Applied Energy*, vol. 87, no. 3, pp. 866-883, 2010.
- [17] K Vadodaria, "Thermal Comfort in UK Homes: How suitable is the PMV approach as a prediction tool?," PhD Thesis, Loughborough University, UK, 2014.
- [18] K Vadodaria, DL Loveday and VJ Haines, Measured winter and springtime indoor temperatures in UK homes over the period 1969-2010: a review and synthesis. *Energy Policy*, 64, pp252-262, 2014
- [19] DL Loveday et al, The role of air motion for providing thermal comfort in residential / mixed mode buildings: a multi-partner Global Innovation Initiative (GII) project. *Proc of 9th Windsor Conference 'Making Comfort Relevant'*, Windsor UK, 7-9 April, 2016.

Feedback to RAC and Suggested Improvements to RTAR Process

Now that you have completed the RTAR process, RAC is interested in getting your feedback and suggestions here on how we can improve the process.

TBD.....