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TO: Tianzhen Hong, Chair MTG-OBB, thong@lbl.gov
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Pawel Wargocki, Research Liaison 2.0, paw@byg.dtu.dk

FROM: Michael Vaughn, MORTS, mvaughn@ashrae.org

DATE: January 23, 2019

SUBJECT: Research Topic Acceptance Request (1870-RTAR), "Investigating Occupant Energy Behavior and Building-Human Interaction in Office Buildings"

During their winter meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted 3-0-0 to reject it. The following list summarizes the consensus review comments and questions on this RTAR:

1. The objectives, approach and deliverables are not clear.
2. Not clear on advancement of art that this research would make.
3. Greater specification and focus are required, with better description of the expected tangible outcomes.

By rejecting this RTAR, RAC is strongly suggesting to the TC that this particular topic be dropped from the TC research plan based on the information that has been provided.

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.

If the TC wishes to pursue this topic further, please incorporate the above information into the RTAR with the help of your Research Liaison, Pawel Wargocki, RL2@ashrae.net, prior to submitting it to the Manager of Research and Technical Services for further consideration by RAC. In addition, a separate document providing a point by point response to each of these comments and questions must be submitted with the RTAR. The response to each item should explain how the RTAR has been revised to address the comment, or a justification for why the Technical Committee feels a revision is unnecessary or inappropriate. The RTAR and response to these comments and questions must be approved by the Research Liaison prior to submitting it to RAC.

The next realistic submission deadline for RTARs and WSs is March 15, 2019 for consideration at the Society's 2019 spring meeting. The submission deadline after that is May 15, 2019 for the RAC annual meeting.

Research Topic Acceptance Request Cover Sheet

Date: 12/3/2018

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

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

Title:

Investigating Occupant Energy Behavior and Building-Human Interaction in Office Buildings

RTAR # 1870

(To be assigned by MORTS)

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

ASHRAE Fundamentals, Chapter 19 Energy Estimating and Modeling Methods;
ASHRAE HVAC Applications, Chapter on Occupant Sensing and Controls

Research Classification:

Basic/Applied Research	X
Advanced Concepts	
Technology Transfer	

Responsible Committee: MTG.OBB

Date of Vote: August 6-15, 2018

For		11
Against	*	1
Abstaining	*	
Absent or not returning Ballot	*	4
Total Voting Members		16

RTAR Authors

Lead: Chien-fei Chen, Bing Dong

Others: Tianzhen Hong

Co-sponsoring TC/TG/MTG/SSPCs (give vote and date)

Expected Work Statement Authors

Lead: Chien-fei Chen, Bing Dong

Others: Tianzhen Hong

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

	Yes	No
Has an electronic copy been furnished to the MORTS?	X	
Has the Research Liaison reviewed the RTAR?	X	

* Reasons for negative vote(s) and abstentions

The following comments from the one negative vote were fully addressed in the revised RTAR. Proposed project budget is reduced to $160k and duration is reduced to 18 months.

Review comments:
The approach narrative does not include delivering any surveys, performing field tests, doing any modeling, analysis or validation. The numbered list only describes a review of literature and development of a method. I suggest the $180k budget is too high for that scope, and 24 months is too long. We should add to the scope in order to increase the overall value resulting from this project. The scope should probably include an IRB, identifying partner sites, conducting the survey, monitoring the building(s) and analyzing the results.

RTAR # ___1870_____

Title:

Investigating Occupant Energy Behavior and Building-Human Interaction in Office Buildings

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)

This research emphasizes human-building interactions and multi-dimensions of energy behaviors in commercial buildings through a large-scale online survey. The study attempts to broaden occupant behavior research and develop a new approach to investigate the drivers of sharing building control system and energy use behavior from social, behavioral and technological factors; which requires the integrated theories and methods from the disciplines of building engineering and social psychology. The proposed research will develop fundamental data to improve understanding of human-building interactions and their drivers, which will support design and operation of energy efficient buildings.

Background

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

Buildings consume more than one-third of the world's primary energy (IEA 2015). Reducing energy use in buildings is essential to reducing greenhouse gas emissions and mitigating global climate change. Occupant energy behavior is a key factor in building energy use. However, more knowledge is needed to improve the understanding of how occupant behaviors influence building performance and energy efficiency, especially from an interdisciplinary perspective. To improve building energy efficiency and reduce consumption, a more comprehensive understanding of occupant behavior from social-technical integration is necessary, in addition to the improvement of technology and building design (Bordass, Cohen, and Field, 2004). Within this context, this research establishes an interdisciplinary approach for the systematic identification of environmental, cognitive and behavioral factors (and their interrelations) influencing occupant behavior in office buildings. Occupant behavior in commercial buildings centers on how occupants choose to interact with the systems around them. This includes interactions with control settings such as thermostats and HVACs, physical building elements (e.g., windows, blinds, and shades), or appliances (Hong. et al, 2016; Masoso & Grobler, 2010; Lin & Hong. 2013; Chang, 2014). Additionally, psychological factors, such as an occupant's perceived behavioral control, social norms, or attitudes can predict their pro-environmental behaviors (Abrahamse & Steg, 2009; Abrahamse & Steg, 2011). An interdisciplinary research is needed which covers the influence of building characteristics, control options, social-psychological and demographic factors affecting shared control options and energy saving intention based on integrated theoretical framework (D' Oca et al. 2017).

Research Need

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

Previous research on occupant behavior in office buildings mainly focused on understanding cause/effect mechanisms driving human interaction with building systems. This approach established mathematical relations (Page et al. 2008; Yan et al. 2015) between specific variables – e.g., temperature, illuminance level, CO_2 concentration – and particular behavior (e.g., opening a window). Despite the importance of these previous research, researchers still have limited understanding (1) the process of occupant decision-making (2) motivational and psychological drivers including technological, social-psychological and contextual factors in the commercial building setting; (3) the knowledge on the decision making process leading to adaptive-action choices. These shortcomings led to the development of behavioral models that simulate actual decision-making process on adaptive actions in both individual and shared workspace. Behavioral patterns have been widely investigated using direct observations (Hong et al. 2015b). However, in the workplace, occupant behavior is often influenced by multiple and underlying factors, e.g., perceived behavioral control, group norms, energy saving attitudes, and the variables beyond building technology (Chen & Knight 2014; Xu, et al., 2017). Therefore, there is a need for occupant behavior researchers to adopt social science theories and concepts to better understand occupants' motivations, beliefs, emotions, and attitudes (D'Oca, et. al., 2017). Importantly, there is a need for further research by integrating the disciplines of mechanical, electrical and civil engineering, architecture and social psychology, to provide the possible solutions to address the current limitations of behavioral modeling and building simulations.

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)

The goal of this research is to determine and quantify the impact of occupant behavior on the building energy performance through a national wide large-scale survey and follow-up statistical analysis to improve energy modeling, building design and operation guidelines defined by ASHRAE. The specific objectives of this research include: (1) to investigate the environmental, social, and behavioral drivers motivating occupants to interact with building design (e.g., shared versus private office) and energy control systems (e.g., thermostat, windows, blinds and lighting); (2) to provide interdisciplinary knowledge of socio-technical focus by analyzing the barriers and drivers of energy use and adaptive actions by advancing behavioral modeling and building data analytic; (3) to provide building researchers the valid and reliable measurement of social psychological latent variables (e.g., attitudes) and demographics based on advanced survey methodology (e.g., sampling) and statistical analysis (e.g., structural equation modeling); and (4) to provide suggestions on building survey methodology and building design focusing on human-centered, low-capital investment and building performance optimization in office buildings.

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 [X], Field tests [X] Analyses and modeling [X] Validation efforts [X] Other (specify) ( )

1. Review current literature to develop a comprehensive list of social, psychological and behavioral factors influencing occupant behavior energy efficiency and share building control options.
2. Research the gap of social-technological aspects of human-building interaction in the literature.
3. Determine valid and reliable measurements for relevant social-psychological factors and latent variables, by demonstrating sampling strategies among office buildings and survey design for occupant behavior survey based on theories and empirical findings.
4. Investigate the challenges of integrating social science and computer engineering methodology in modeling and analyzing occupant behavior.
5. Develop an integrated modeling and statistical analysis tool based on survey methodology and engineering building modeling based on specific research questions. Statistical analyses will include structural equation modeling, linear regression modeling, the variance of analysis (ANOVA), and Chi-square testing. Expected sample size is approximately 10,000 occupants from office buildings including university and business buildings in the U.S. An internet-based questionnaire will be designed with Qualtrics survey software and administered through Qualtrics Paid Panel Service, a popular online data collection platform used by the survey researchers. There will be sources to recruit the patriciates including university buildings and non-university business buildings. For the university buildings, about 5000 participants, age 18 and older, will be recruited from university staff, faculty, researchers and graduate students regularly occupying a single building – from several universities (e.g., University of Tennessee, University of Washington, University of Michigan) located in several different climate zones. The occupant behavior researchers at the university in the U.S. will be recruited to patriciate this study's data collection upon receiving the approval of this proposal. For the non-university buildings, about 5000 participants will be recruited through Qualtrics Paid Panel Service ($5-$6 per participant) based on the size of office building (100-200, 201-300, 301-400, 401-500, or more than 500).
6. Data collection needs to follow ethics and institutional review board for each involved institution to protect participants' privacy. The data will be collected anonymously including not collecting personal identifiers, and building names. Researchers are expected to create a data management and sharing plan.
7. Results are expected to share with all ASHRAE members.

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 proposed work will look at sociological, personal and behavioral variables influencing behavior and energy use in buildings, which is often overlooked within the energy modeling, design standards and operation guidelines proposed by ASHRAE. If successful, the proposed research will not only lead to a better understanding on the building performance and design but also the energy saving potential. The proposed research will determine and quantify the impact of behavior drivers on the energy performance and compare to other drivers such as set-point temperature that are more commonly used. Specifically, this study aims to establish a framework that provides an interdisciplinary method and outcomes that benefit research and industry community regarding:

1. Important interdisciplinary knowledge of behavior research based on a large-scale survey data, in terms of: (a) valid behavioral models; (b) replicability of data collection and analysis; (c) efficient analytical process; and (d) provide data for modeling or building simulation.
2. Advancement of the knowledge and understanding of energy impact from occupancy behaviors through quantifications of behaviors associated energy savings at a large scale for various types of commercial buildings; which provide useful information for industry and academia.

The outcomes from this research will contribute to following Chapters in ASRHAE Handbooks:

- HVAC Applications Handbook: Chapter 39 – Operation and Maintenance Management
- HVAC Applications Handbook: Chapter 61 – Smart Buildings Systems

It is aligned with ASHRAE Strategic Plans and Initiatives:

- Goal 1: Maximize the actual operational energy performance of buildings and facilities
- Goal 2: Progress toward Advanced Energy Design Guide (AEDG) and cost-effective net-zero-energy (NZE) buildings;

Proposed Budget and Duration:

Funding Amount Range: $ 160K (including 10,000 participants' incentives, 3 research assistants' costs and 3 PIs' support, travel to conferences to report progress, present results and get feedback from PMS.

Duration in Months: 18

References

Abrahamse, W., & Steg, L. (2009). How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? Journal of economic psychology, 30(5), 711-720.

Abrahamse, W., and Linda Steg. (2011). Factors Related to Household Energy Use and Intention to Reduce It: The Role of Psychological and Socio-Demographic Variables. Human Ecology Review, 18(1).

Ajzen, I., 1991. The theory of planned behavior. *Orgnizational Behavior and Human Decision Processes*, 50, pp.179–211.

Bandura, A., 1986. *Social foundations of thought and action: A social cognitive theory*, Englewood Cliffs, NJ, US: Prentice-Hall, Inc.

Bordass, B. and R. Cohen, J. Field, Energy performance of non-domestic buildings: closing the credibility gap, Build. Perform. Congr. (2004). http://scholar.google.com/scholar?hl=en%26btnG=Search%26q=intitle:Energy+Performance+of+Non-Domestic+Buildings+: +Closing+the+Credibility+Gap#0.

Chen, C. & Knight, K., 2014. Energy at work: Social psychological factors affecting energy conservation intentions within Chinese electric power companies. *Energy Research & Social Science*, 4, pp.23–31.

D'Oca, S. et al., 2016. Introduction to an occupant behavior motivation survey framework. In *Clima 2016*.

Hong, T. et al., Ten questions concerning occupant behavior in buildings: The big picture, Building and Environment (2016), http://dx.doi.org/10.1016/j.buildenv.2016.12.006

Hong, T., D'Oca, S., Turner, W.J.N., et al., 2015a. An ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs Framework. Building and Environment, 92(P1), pp.764–777.

Hong, T., D'Oca, S., Taylor-Lange, S.C., et al., 2015b. An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAS framework using an XML schema. *Building and Environment*, 94(P1), pp.196–205.

IEA, World Energy Outlook, 2015, http://dx.doi.org/10.1787/weo-2005-en

Masoso, O.T. & Grobler, L.J. The dark side of occupants' behaviour on building energy use, Energy Build. 42 (2010) 173e177, http://dx.doi.org/10.1016/ j.enbuild.2009.08.009.

Lin, H.W. & Hong, T. On variations of space-heating energy use in office buildings, Appl. Energy 111 (2013) 515e528, http://dx.doi.org/10.1016/ j.apenergy.2013.05.040.

Sovacool, B.K. et al., 2015. Integrating social science in energy research. *Energy Research & Social Science*, 6, pp.95–99. Available at: http://linkinghub.elsevier.com/retrieve/pii/S221462961400139X.

Sovacool, B.K., 2014. What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research and Social Science*, 1, pp.1–29. Available at: http://dx.doi.org/10.1016/j.erss.2014.02.003.

Page, J. et al., 2008. A generalised stochastic model for the simulation of occupant presence. *Energy and Buildings*, 40(2), pp.83–98.

Wen-kuei Chang, T.H. Statistical Analysis and Modeling of Occupancy Patterns in Open-plan Offices Using Measured Lighting- Switch Data, 2014

Xu, X., Maki, A., Chen, C.-F. Dong, B., & Day, J. (2017). Investigating willingness to save energy and communication about energy use in the American workplace with the attitude-behavior-context model. *Energy Research and Social Science*, 32, 13-22.

Yan, D. et al., 2015. Occupant behavior modeling for building performance simulation: current state and future challenges. *Energy and Buildings*, 107, pp.264–278. Available at: http://www.sciencedirect.com/science/article/pii/S0378778815302164 [Accessed August 25, 2015].

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.

Project ID	**1870**	
Project Title	**Investigating Occupant Energy Behavior and Building-Human Interaction in Office Buildings**	
Sponsoring TC	MTG.OBB, MTG, Occupant Behavior in Buildings	
Cost / Duration	$160,000 - 18M	
Submission History	**1st Submission**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2019 Winter 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.		**2** - Many of the references relate to domestic (residential) buildings. But, is RTAR is for office buildings. **9-** The broad background picture is summarized. **7** - Not clear what "a more comprehensive understanding of occupant behavior from social-technical integration" means. The authors say that the RTAR was modified to address the negative vote. Does this mean that the final version of the RTAR was not voted by the MTG.OBB?
Research Need: Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected.		**2** - There is benefit to integrating social psychology with engineering disciplines. But, the RTAR is short on specific examples of how this will be done. **9** - The need is described, but from a broad, 'big-picture' perspective. A much tighter focus is needed. **4** - It is unclear how the large questionnaire survey will improve our understanding of occupant energy behavior and whether 10,000 responses will be sufficient to advance the knowledge.. The Authors propose the literature survey first. Perhaps before any attempt is made to perform questionnaire survey it would be a good idea to identify where the knowledge is lacking and insufficient. **7** - It is questionable that "there is a need for occupant behavior researchers to adopt social science theories and concepts to better understand occupants' motivations, beliefs, emotions, and attitudes". The authors should be more specific about what they are looking for. **6** - not sure this lines up with ASHRAEs abilities
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.		**9**- Useful for ASHRAE, once specific relationships are adequately quantified and established. This might require a number of further studies to build up a bigger picture, perhaps using a methodology established by the work proposed in this RTAR. **7** - The authors state that "The proposed research will determine and quantify the impact of behavior drivers on the energy performance and compare to other drivers such as set-point temperature that are more commonly used". How are "behavior drivers" quantified and how could they replace the set-point temperature? **6 -** I do not see the primary value in the relevance and benefits to ASHRAE section.
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.		**2** - The objectives are not clear. The discussion on Research Need suggests that research is needed to improve building energy simulations. Yet the objectives only address improvement in building designs and performance optimization (facilities management?). **9**- Objectives are too broad. It is important to know what will be done in more specific, focused settings. The aim mentions establishing a framework for an interdisciplinary method; if so, then what methods or approaches will be identified, trialed, and evaluated, and how? **7** - The objectives are generic. (1) is not an objective. (2), (3) and (4) do not specify what accomplishments shall be reached.
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** - It is not clear what task (5) of the Expected Approach section means: "Develop an integrated modeling and statistical analysis tool based on survey methodology and engineering building modeling based on specific research questions." Will the results will be directed toward building energy simulation, building design and/or building operation? **9** - This is too big and vague. Details are needed on: sample sizes, building types, and relation to 'populations'; the nature of the comparisons, relation to the research issues (and outcomes) being investigated. **4** - There is too much planned and promised. The Authors should focus on a specific aspect and clearly demonstrate that the proposed approach and population size would be sufficient to provide answer to the questions that they pose or want to answer. There are too many tasks and I doubt that they can be completed. **7** - It is strange to read about three PI. Why three and not just one?
References: Are the references provided?		
Decision Options	**Initial Decision?**	**Final Approval Conditions**
ACCEPT AS-IS		**2 -** The objectives, approach and deliverables are not clear. The comments from the one negative vote were not adequately address in the revised RTAR. Simply changing the budget and schedule does not address the underlying issues. It is still not clear whether the results will be directed toward improving building energy simulation, building design or building operation. The cover sheet says that the results will affect the following chapters: ASHRAE Fundamentals, Chapter 19 Energy Estimating and Modeling, and Methods, and ASHRAE HVAC Applications, Chapter (??) on Occupant Sensing and Controls. The Relevance and Benefits to ASHRAE section states that the outcomes form this research will contribute to the following Chapters in the Handbook: Applications Chapter 39, Operation and Maintenance Management and Chapter 61, Smart Buildings Systems. The RTAR should be clear on the deliverables and what ASHRAE Handbook Chapters will be affected. **9** - This is an important area, but the RTAR presents the work in too big and vague a manner. Greater specification and focus are required, with better description of the expected tangible outcomes. Key areas to pay attention to might be: i) The aim mentions establishing a framework for an interdisciplinary method; if so, then what methods or approaches will be identified, trialed, and evaluated, and how? ii) Details are needed on: sample sizes, building types, and relation to 'populations'; the nature of the comparisons, relation to the research issues (and outcomes) being investigated; how will this inform the questionnaires, etc.? PT - The authors should be more specific in stating the research needs and focusing on measurable results. **6** - need further information on relevance and benefits to ASHRAE. **12** - I like sociological studies. We need to figure out the non-engineering component in building energy usage - the occupants. Maybe then conttrol alagrothms will be adpative and predictive.
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