INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1837-TRP, "The Effects of Ventilation in Sleeping Environments"

Attached is a Request-for-Proposal (RFP) for a project dealing with a subject in which you, or your institution have expressed interest. Should you decide not to submit a proposal, please circulate it to any colleague who might have interest in this subject.

Sponsoring Committee: TC 2.1, Physiology and Human Environment

Budget Range: $250,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2019,** or later.

All proposals must be received at ASHRAE Headquarters by 8:00 AM, EST, December 17, 2018. NO EXCEPTIONS, NO EXTENSIONS. Electronic copies must be sent to rpbids@ashrae.org. Electronic signatures must be scanned and added to the file before submitting. The submission title line should read: 1837-TRP, "The Effects of Ventilation in Sleeping Environments", and "*Bidding Institutions Name*" (electronic pdf format, ASHRAE's server will accept up to 10MB)

If you have questions concerning the Project, we suggest you contact one of the individuals listed below:

For Technical Matters
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Contractors intending to submit a proposal should so notify, by mail or e-mail, the Manager of Research and Technical Services, (MORTS) by December 3rd, 2018 in order that any late or additional information on the RFP may be furnished to them prior to the bid due date.

All proposals must be submitted electronically. Electronic submissions require a PDF file containing the complete proposal preceded by signed copies of the two forms listed below in the order listed below. **ALL electronic proposals are to be sent to rpbids@ashrae.org.**

All other correspondence must be sent to ddaniel@ashrae.org and mvaughn@ashrae.org. Hardcopy submissions are not permitted. **In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, December 17, 2018. NO EXCEPTIONS, NO EXTENSIONS.**

The following forms (Application for Grant of Funds and the Additional Information form have b een combined) must accompany the proposal:

(1) ASHRAE Application for Grant of Funds (electronic signature required) and
(2) Additional Information for Contractors (electronic signature required) ASHRAE Application for Grant of Funds (signed) and

ASHRAE reserves the right to reject any or all bids.

State of the Art (Background)

Recent studies (Bekö et al., 2010; Sekhar and Goh, 2011) have found that ventilation in bedrooms is frequently much lower than is recommended by current ventilation standards. This is often the result of occupants attempting to reduce HEAT GAIN (in the Tropics) and HEAT LOSS (in cold countries). In urban environments this may be made worse by attempting to improve privacy and security in the bedroom and reduce noise from outdoors. Poor ventilation results in increased exposure to any pollutants generated indoors, which may cause discomfort and an increased risk of acute health symptoms (Sundell et al., 2011); it also reduces cognitive performance (Wargocki and Wyon, 2012; 2017). A recent field intervention study has shown that a small reduction in bedroom ventilation can reduce sleep quality and next-day performance (Strøm-Tejsen et al. 2016). That bedroom ventilation affects sleep quality was supported by a field intervention study by Mishra et a. (2018). Apart from these two studies in one climatic zone, in a student residence, there is no information on the effects of low ventilation rates or poor air quality in sleeping environments on sleep quality or how this might be affecting health and productivity, although there is more and more evidence suggesting that sleep plays an important role in healthy living, providing time not only to rest but to unconsciously process memories, and is thus essential for proper cognitive performance, proper metabolism and diet, and even for reducing the risk of cancer (Walker, 2017). The studies of Tynjälä et al. (1999) and Meijer et al. (2000), in Finland and Holland respectively, found a strong correlation between sleep quality and the ability of children to concentrate the next day. If ventilation plays a role in sleep quality, as the results of Strøm-Tejsen et al. (2016) suggest, ASHRAE should quickly determine the minimum ventilation requirements for sleeping environments.

Justification and Value to ASHRAE

The project will provide a rational basis for the ventilation requirements for bedrooms that already appear in Standards 62.1 and 62.2. At present, it is simply assumed that sleep places no special requirements on air quality.

Objective:

The overall objective of the proposed work is to document the effects of poor ventilation in sleeping environments and the consequences for healthy living and working. Specific objectives include: (1) measurement of the actual ventilation rate in bedrooms and comparison with the requirements prescribed by the standards; (2) examination of the effects of ventilation on the air quality in sleeping environments, and how this affects sleep, next-day well-being and next-day ability to work; (3) determination of the minimum outdoor air supply rate to eliminate negative effects of poor bedroom IAQ on sleep quality; and (4) revision of ventilation requirements in sleeping environments. As recommendations for changes in ASHRAE Standards might have to be specific to climatic areas, the proposed research should be carried out in more than one climatic area.

Scope:

Scientific approach: In traditional sleep research, subjects have to sleep in an unfamiliar environment, under constant surveillance, with numerous electrodes taped to the skin, and the focus is on individual sleep problems such as apnea. The experiments reported by Strøm-Tejsen et al. (2016) were performed in the subjects' own bedrooms, using simple interventions (windows open/closed, inaudible exhaust fans idle/active) to modify the ventilation rate and small wristbands to monitor sleep. It is proposed to use this approach in the present project, to ensure that the findings will apply to normal sleep in real life. Field intervention experiments are proposed because they are a very efficient way of proving causation - the exposure conditions created by interventions differ only in terms of the variable that is changed by the intervention, in this case the outdoor air supply rate to the bedroom. The effects on sleep of all other factors can in such an experiment be neglected because any differences in these factors between conditions are due to chance and any differences between conditions in their effects on sleep will therefore average to zero. That is why it is not necessary that any of the other factors that affect sleep should be exactly the same under all of the experimental exposures, or even that any of them should be measured. Additionally, effects on sleep are to be evaluated by comparing records obtained from the same subject under different bedroom ventilation conditions. There are obviously large individual differences in sleep and scores of known and unknown factors that affect sleep, and to examine their effects in a survey would cost 10-100 times more than the proposed intervention experiments, in which they contribute to the variance but not to differences between conditions, so they need not be identified, recorded or measured. The intervention experiments are to be performed in two very different climatic regions, one of which must be Hot/humid, in areas that have clean outdoor air, and in identical bedrooms that are similarly furnished. Adult subjects without illness, allergy or sleep disorders are to sleep for one week at a time under each

condition, in balanced order, each in their habitual bedroom (the sleep of children and elderly subjects differs systematically from that of working adults and will have to be the subject of future research). The outdoor air supply rate is to be manipulated without informing the subject of which condition has been established in a given week. The effects are to be quantified with the following subjective and objective criteria: questionnaires concerning sleep quality (Mulder-Hajonides et al. 1980) and general well-being (Wyon, 1994); Actimeters that monitor sleep quality (Sadeh et al. 1995; Kushida et al. 2001), preferably of the more recent type that continuously monitor heart rate as well as movement and can distinguish between sleep phases as well as between asleep and awake (e.g. "FitBit Alta HR"); cognitive tests and tasks typical of everyday office work, applied on the day following each experimental night. The scientific community has not yet agreed on the minimum total duration of sleep, REM sleep or non-REM sleep, so it is currently necessary to define a good night's sleep as one that improves next-day performance. This has the merit of providing an objectively measurable dependent variable that will supplement the subjective evaluations of the subjects as acquired by questionnaire.

Technical approach: Bidders must describe in their proposal how they will increase the outdoor air supply rate without altering the room temperature. Without full air conditioning this will be confounded with a small change in bedroom RH (a decrease in cold/dry climates and an increase in hot/humid climates), as indeed occurred in the experiment that was recently reported by Strøm-Tejsen at al. (2016). In the climate where this experiment was conducted the effect was negligible and in a hot/humid climate the main effect would be an increase in condensation in the split-cooling unit. If room temperatures are subjectively comfortable in both conditions, any effect of humidity on thermal comfort and the heat loss rate of a sleeper will be very small, but bidders must describe in their proposal how the change in RH imposed by the change in outdoor air supply rate will be kept close to what would occur in practice. The resulting CO2 levels, T and RH are to be monitored continuously. At least two improved ventilation conditions must be compared with existing ventilation conditions in at least 20 bedrooms, either in independent cross-over experiments comparing each improved condition with the reference condition, or in a single, more complex experimental design in which the conditions are established in balanced order. The conditions whose effects on sleep are to be compared in each experiment must always be established simultaneously in different bedrooms, in order to balance out any effects of external events such as severe weather or loud noise that may affect sleep on a given day and whose effects on sleep could otherwise be attributed incorrectly to a single condition.

Task 1: A review of the relevant Standards and Building Regulations where the subjects of the proposed study are living, to identify design levels of ventilation in sleeping environments.

Task 2: A field survey of existing temperatures and outdoor air supply rates in the proposed subjects' bedrooms. Subjects who habitually sleep in bedrooms with poor ventilation should be selected, so the increased ventilation caused by the intervention will be an improvement.

Milestone 1: A Research Protocol is to be submitted for approval by the PMS, based on the results of Tasks 1 and 2, and containing all the information, locations and dates stipulated by the PMS.

Task 3: The intervention experiments are performed as described above.

Milestone 2: Completion of the data acquisition phase is to be reported to the PMS

Task 4: Analysis of the experimentally acquired data.

Task 5: Proposed revision of the relevant parts of Standards 62.1 and 62.2

Milestone 3: Final report on Tasks 1-5 submitted to the PMS.

Deliverables:

IRB approval: There is a legal requirement that all experiments involving human subjects must be pre-approved by an Institutional Review Board (known in some countries as an Ethics Review Board). Every university and research institute must have one. Documentation that IRB/ERB approval has been obtained must be submitted together with the research proposal. Bidders are reminded that for this project, IRB approval should be almost automatic as the intervention calls for subjects to be experimentally exposed to a bedroom ventilation rate that has been IMPROVED

in comparison with their normal bedroom conditions, not to a reduction in their bedroom ventilation. This does not require the same level of justification as experimental exposure to painful or potentially noxious procedures, the original reason for requiring IRB/ERB approval.

Items *a* through *e* below are generic ASHRAE requirements that a contractor is required to provide on every ASHRAE research project. These cover:

- Quarterly progress and financial reports to MORTS (to be reviewed by the Project Monitoring Subcommittee (PMS)).
- A final report.
- A research or technical paper, submitted for peer review and publication in the ASHRAE *Transactions* or *Science and Technology for the Built Environment.*
- One or more peer-reviewed research papers submitted to *Indoor Air Journal*, *Building and Environment*, or other comparable international peer-reviewed research journals.
- An accessible database archiving the experimental data obtained from the research.
- A project summary.

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the deliverables ("Deliverables") under this Agreement and shall be provided as follows:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically on or before each January 1, April 1, June 10, and October 1 of the contract period.

The following deliverables shall be provided to the Project Monitoring Subcommittee (PMS) as described in the Scope/Technical Approach section above, as they are available:

Furthermore, the Institution's Principal Investigator, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Final Report

A written report, design guide, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement, including a summary of the control strategy and savings guidelines. Unless otherwise specified, the final draft report shall be furnished, electronically for review by the Society's Project Monitoring Subcommittee (PMS).

Tabulated values for all measurements shall be provided as an appendix to the final report (for measurements which are adjusted by correction factors, also tabulate the corrected results and clearly show the method used for correction).

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

-An executive summary in a form suitable for wide distribution to the industry and to the public.
-Two copies; one in PDF format and one in Microsoft Word.

c. *Science & Technology for the Built Environment* or ASHRAE Transactions Technical Papers

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted as either Research Papers for HVAC&R Research or

Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value, ASHRAE Conference papers are not acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in "Manuscript Central" for an ASHRAE Transactions Technical or HVAC&R Research papers. The paper title shall contain the research project number (1837-RP) at the end of the title in parentheses, e.g., (1837-RP).

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

d. Data

Data is defined in General Condition VI, "DATA"

e. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE Insights

The Society may request the Institution submit a technical article suitable for publication in the Society's ASHRAE JOURNAL. This is considered a voluntary submission and not a Deliverable. Technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort

The project anticipates 8 professional-months for the principal investigator and 24 professional-months for postgraduate assistants at the MSc or PhD level. The estimated cost is $250,000 and the project is expected to take 30 months, as it may be advisable to delay experiments until a target season or until suitably stable weather conditions are forecast, to minimize external disturbance of bedroom conditions and sleep.

Other Information to Bidders (Optional):

1) Research protocol: The PMS-stipulated format for the Research Protocol required at Milestone 1 will be supplied to bidders on request.

2) Technical realization of the intervention: Bidders must describe in some detail how they propose to conduct the required field intervention (increasing the outdoor air supply rate to each bedroom). Opening or closing a window is not regarded as a suitable intervention, as in addition to increasing the outdoor air supply rate, an open window might allow wind strength and direction to increase the variance of the main independent variable (IAQ). More importantly in many areas, opening a window confounds the imposed change in IAQ with uncontrolled admission to the bedroom of random amounts of external noise, ambient air pollution and insects, any of which could have major effects on sleep, increasing the variance between subjects and thus rendering it more difficult to prove causation.

3) Climate zones: To address the stated objective of obtaining a basis for recommended changes to Standards that are currently assumed by ASHRAE to be appropriate for many different climatic zones, the bedroom IAQ measurements in Task 2 and the field intervention experiments in Task 4 must be carried out in two very different climatic regions, either by the same team or by two teams working closely together. As the former would be easier for bidders located in a large country, no penalty should be attached to proposals from collaborating bidders in two or more countries in different climatic zones.

4) HIPAA compliance: All research that accesses individual health records must follow HIPAA rules to ensure privacy. IRB/ERB approval is usually conditional upon this. Bidders are reminded that the research proposed here does not involve accessing individual health records, and although subject recruitment should use any pre-existing sleep disorder or allergy as an exclusion criterion, subjects should simply be asked to withdraw from participation in

the experiments “if they are currently experiencing any sleep disturbance or allergy or change their minds about participating”. In this way, withdrawal from the experiment does not convey any information about sleep disorders or allergy. HIPAA compliance regarding the privacy of sleep records obtained in the experiments must be ensured by the usual procedure of anonymizing each data record (assigning a number rather than a name to it) once the physical measurements, questionnaire responses, performance results and sleep records have been combined in a single file for each subject. There is no intention to contact subjects again after the experiment, and this procedure would make it impossible for anyone to do so.

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Research protocol and reports on Task 1 (Standards review) and Task 2 (field survey)	12
2	Report on Task 3 (conduct of the data acquisition phase of the experiments)	24
3	Report on Task 3 (conduct of the data acquisition phase of the experiments)	36

Proposal Evaluation Criteria

Proposals submitted to ASHRAE for this project should include the following minimum information:

No.	Proposal Review Criterion	Weighting Factor
1	Contractor's understanding of Work Statement as revealed in the proposal. a) Logistical problems associated b) Technical problems associated	15%
2	Quality of methodology proposed for conducting research. a) Organization of project b) Management plan	25%
3	Contractor's research capability. a) Managerial support b) Data collection c) Technical expertise	15%
4	Qualifications of personnel for this project. a) Project team 'well rounded' in terms of qualifications and experience in related work b) Project manager person directly responsible, experience and corporate position c) Team members' qualifications and experience d) Time commitment of Principal Investigator	20%
5	Student involvement 5% a) Extent of student participation on contractor's team b) Likelihood that involvement in project will encourage entry into HVAC&R industry	5%
6	Probability of contractor's research plan meeting the objectives of the Work Statement. a) Detailed and logical work plan with major tasks and key milestones b) All technical and logistic factors considered c) Reasonableness of project schedule	15%
7	Performance of contractor on prior ASHRAE or other projects. (To avoid a penalty for new contractors, assign zero but increase weighting of Item 3 to 20%	5%

References

1. ASHRAE, ANSI/ASHRAE Standard 62.1-2016. Ventilation for acceptable indoor air quality. 2016, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.: Atlanta, GA.
2. ASHRAE, ANSI/ASHRAE Standard 62.1-2016. Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential. 2016, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.: Atlanta, GA.

3. Bekö, G., Lund, T., Nors, F., Toftum, J., & Clausen, G. (2010). Ventilation rates in the bedrooms of 500 Danish children. Building and Environment, 45(10), 2289-2295.
4. Kushida CA, Chang A, Gadkary C, Guilleminault C, Carrillo O, and Dement WC. 2(001) Comparison of actigraphic, polysomnographic and subjective assessment of sleep parameters in sleep-disordered patients. Sleep Medicine, 2(5), 389-396.
5. Meijer AM, Habekothé HT, and van den Wittenboer GL. (2000) Time in bed, quality of sleep and school functioning of children. Journal of Sleep Research, 9(2), 145-153.
6. Mishra, A.K., van Ruitenbeek, A.M., Loomans, M.G.L.C. and Kort, H.S.M. (2018) Window/door opening-mediated bedroom ventilation and its impact on sleep quality of healthy, young adults. Indoor Air, 28, 339-351 (DOI: 10.1111/ina.12435)
7. Mulder Hajonides van der Meulen WREH, Wijnberg JR, Hollander JJ, De Diana IPF, and van den Hoofdakker RH. (1980) Measurement of subjective sleep quality. European Sleep Research Society Abstracts, 5, 98.
8. Sadeh A, Hauri PJ, Kripke DF, Lavie P (1995) The role of actigraphy in the evaluation of sleep disorders. Sleep, 18, 288-302.
9. Sekhar, S. C., & Goh, S. E. (2011). Thermal comfort and IAQ characteristics of naturally/mechanically ventilated and air-conditioned bedrooms in a hot and humid climate. Building and Environment, 46(10), 1905-1916.
10. Sleep America (2004) Survey of children's sleeping habits and arrangements. National Sleep Foundation, USA.
11. Sundell, J., Levin, H., Nazaroff, W. W., Cain, W. S., Fisk, W. J., Grimsrud, D. T., Gyntelberg, F., Li, Y., Persily, A. K., Pickering, A. C., Samet, J. M., Spengler, J. D., Taylor, S. T. and Weschler, C. J. (2011). Ventilation rates and health: multidisciplinary review of the scientific literature. Indoor air, 21(3), 191-204.