Shaping Tomorrow's Built Environment Today

1791 Tullie Circle NE ▪ Atlanta, Georgia 30329-2305 ▪ Tel 678.539.1211 ▪ Fax 678.539.2211 ▪ http://www.ashrae.org

Michael R. Vaughn, P.E.
Manager
Research & Technical Services

mvaughn@ashrae.org

TO: William Stafford, Chair TC 2.8, sstafford@integralgroup.com
Joy Altwies, Research Subcommittee Chair TC 2.8, altwies@wisc.edu
Pawel Wargocki, Research Liaison 2.0, paw@byg.dtu.dk

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

DATE: November 6, 2018

SUBJECT: Research Topic Acceptance Request (1863-RTAR), "A Toolkit for the Evaluation of the Life Cycle Energy and Greenhouse Gas Emissions for Buildings, Buildings Components and Equipment"

---

During their fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted 5-0-0 to reject it. The following list summarizes the consensus review comments and questions on this RTAR:

1. This is not written in a way that engages the reader or explains things clearly enough.
2. It is unclear which criteria have to be fulfilled so that the simplified toolkit is considered to be sufficiently robust.
3. What will be taken from the literature, what framework for this, then how will this be used to construct the 'toolkit' and how will this be evaluated?
4. Scope too broad.

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 May 15, 2019 for consideration at the Society's 2019 annual meeting. The submission deadline after that is August 15, 2019 for the RAC fall meeting.

| | | |
|---|---|---|
| **Project ID** | **1863** | |
| **Project Title** | **A TOOLKIT FOR THE EVALUATION OF THE LIFE CYCLE ENERGY AND GREENHOUSE GAS EMISSIONS FOR BUILDINGS, BUILDING COMPONENTS AND EQUIPMENT** | |
| **Sponsoring TC** | TC 2.8, Building Environmental Impacts and Sustainability | |
| **Cost / Duration** | $180,000/ 18-20 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** - Problem described and positioned with some literature |
| **Research Need:** Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected. | | **7** - I accept that building owners and designers use Life-Cycle Energy (LCE) to make building design decisions. But, I am not convinced that they use Greenhouse Gas Emissions (GHGE) to make building design decisions. Demonstrate the meta-analytics on LCE only. The meta-analytics can be applied to GHGE in a later project. **9** - This is not written in a way that engages the reader or explains things clearly enough. **PT** - It is not clear what is the gap to be filled in by the proposed research project. |
| **Relevance and Benefits to ASHRAE:**<br>Evaluate whether relevance and benefits are clearly explained in terms of:<br>a. Leading to innovations in the field of HVAC & Refrigeration<br>b. Valuable addition to the missing information which will lead to new design guidelines and valuable modifications to handbooks and standards.<br>Is this research topic appropriate for ASHRAE funding? If not, Reject. | | **9-** Mentions relevance to Goal 7, but then goes into generalized discussion. If a simplified tool can be produced that is validated and reliable, then there would clearly be benefits. **10** - The software tool mentioned is generically described. The software would implement one or more models to be clearly developed and made publicly available. It is not clear why ASHRAE should support the development of a software tool competing with other software tools on the market. |
| **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:<br>1. Aligned with the need<br>2. Specific<br>3. Clear without ambiguity<br>4. Achievable<br>If not, then appropriate feedback should be provided. | | **2** - In this project, the data of the world trade become important. In the different countries have different data and sometimes it is quite difficult to estimate the life time emissions. The RTAR does not state this difficult work. For example, the life cycle assessment of iron is quite difficult. Where is iron made? Where is iron raw material is mined? And so on. **9** = Still a rather broad description, with little specification or details. **10** - The section discussed the approach and does not describe the objectives to be accomplished. It is necessary to specify what is the simplified approach and what are the required characteristics of the toolkit. **8** - would like further clarification of the methods and the proposed methods for techniques for development of the toolkit for the evaluation of building LCE and GHGE. |
| **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.<br>Anticipated funding level and duration: | | **9**- Explain how the 'meta-analysis' will be conducted…what's the framework and metrics to be used to frame the study? What form will the 'toolkit' take? Again, lacks detail of approach in a step by step manner. $180k, 18-20 months, but not easy to see its connection to the approach. **10** - It should be mentioned whether the 6 case studies will represent specific categories. |
| **References:** Are the references provided? | | |
| **Decision Options** | **Initial Decision?** | **Final Approval Conditions** |
| ACCEPT AS-IS | | **2** - The RTAR should state the effect of the globalization, i.e. import trade effect in the evaluation. **4 -** It is unclear which criteria have to be fulfilled so that the simplified toolkit is considered to be sufficiently robust. 7 - I accept that building owners and designers use Life-Cycle Energy (LCE) to make building design decisions. But, I am not convinced that they use Greenhouse Gas Emissions (GHGE) to make building design decisions. Demonstrate the meta-analytics on LCE only. The meta-analytics can be applied to GHGE in a later project. **9** - Somewhere between 'accept with comments' and 'reject'. RTAR is broad and sketchy. To be acceptable in my view, this needs clearer explanation, alongside more detailed and specific step-by-step explanation. What will be taken from the literature, what framework for this, then how will this be used to construct the 'toolkit' and how will this be evaluated? Can RL work with the team to re-submit? **10** - The RTAR should contain more specific information about the gaps to be filled in by the research project avoiding generic statements like "simplified approach". The development of a software tool should be done only after developing models to be implemented in the software. It is necessary to specify who would be the owner of the software copyright. The authors should provide a description of the characteristics of the software with expected minimum performance requirements. **12** - RTAR was written above my head by leveraging literature met analysis, but LCCP studies are important enough to warrant drafting a possible work statement. **8** - address project 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: **7/26/2018**

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

Title:

| | |
|---|---|
| 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 |

**A TOOLKIT FOR THE EVALUATION OF THE LIFE CYCLE ENERGY AND GREENHOUSE GAS EMISSIONS FOR BUILDINGS, BUILDING COMPONENTS AND EQUIPMENT**

**RTAR # 1863**
(To be assigned by MORTS)

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

**Handbook of Fundamentals – Chapter 9**

Research Classification:

| | |
|---|---|
| Basic/Applied Research | X |
| Advanced Concepts | X |
| Technology Transfer | X |

---

Responsible Committee: **TC 2.8**

Date of Vote: **August 8, 2018**

| | | |
|---|---|---|
| For | | 7 |
| Against | * | 1 |
| Abstaining | * | 1 |
| Absent or not returning Ballot | * | 3 |
| Total Voting Members | (CNV) | 12 |

RTAR Authors

Lead: **James F Sweeney**

Others: **Advisor: Kevin Cross**

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

Expected Work Statement Authors

Lead: **James F. Sweeney**

Others: **TBD**
**TBD**

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

**TBD (TBD)**

| | 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 "No vote" wanted to revise the RTAR further having seen comments from others and adding their own comments.

**RTAR # 1863**

**Title:**

A TOOLKIT FOR THE EVALUATION OF THE LIFE CYCLE ENERGY AND GREENHOUSE GAS EMISSIONS FOR BUILDINGS, BUILDING COMPONENTS AND EQUIPMENT

**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 project will develop a toolkit to estimate the life cycle energy (LCE) and associated greenhouse gas emissions (GHGE) for buildings and their associated components and equipment. The project will provide a tool that estimates building design and component tradeoffs related primarily to the impact on total life cycle energy and the attendant GHGE. This will be accomplished by leveraging a meta-analysis of the literature and advances in data-driven analysis to develop a generalized building life cycle energy tool that will assist building engineers and architects in a simplified evaluation of building design choices from a life cycle energy and emissions perspective.

**Background**

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

The total energy used by a building and its constituent parts over its life time is generally known as building life cycle energy (LCE), and the study of the building energy consumption is a common and practical means to analyze building design alternatives, components, and systems (Sartori and Hestnes, 2007, Monaha and Powell, 2011). The construction, operation and maintenance, in addition to the demolition phase of a building over its lifetime all contribute to building LCE and GHGE (Ramesh et al. 2010). Analyzing building life cycle consists of performing a life cycle energy analysis and is typically performed with sophisticated life cycle impact tools such as GaBi, Impact Estimator, EcoVent among others. Building operational energy is estimated using building energy simulation tools such as BeOpt, Energy Plus, or other modeling approaches. Both the life cycle and building operational energy tools are very robust and require a modest to high level of skill to execute effectively, and as such are costly to perform.

Building energy is a common concern world-wide, and operational and embodied energy comprise most of a building's LCE and GHGE but these analyses are time consuming and thus costly to estimate. Simplified approaches to estimate and compare building components and equipment are scattered in the literature (Caduff et al. 2010, Caduff et al. 2014, Mastrucci, et al. 2017, Favi et al. 2017). These studies vary in their approach and scale, from the urban scale retrofitting life cycle analysis (Mastrucci, et al. 2017), to urban development construction practices impacts on ozone formation (Li, et al. 2007), to equipment-mass-energy scaling relationships (Caduff et a. 2014). Additionally, literature in sensitivity analysis of building components and equipment and their impact of life-cycle energy is beginning to emerge (Favi, 2017). Utilizing a meta-analysis of the building and equipment life cycle literature, along with data-driven analytics, a simplified analysis approach could be developed to produce a more cost-effective evaluation of the energy and emissions related to building design and building component selection. This research project will help facilitate this effort.

**Research Need**

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

The life cycle energy literature typically focuses on case studies on the analysis of the various life cycle stages of buildings of various types. Studies focus on the life cycle energy of buildings, typically focused on operational energy distributions relative to other life cycle stages (Ramesh et al. 2010), or building type and size (Sartori and Hestnes, 2007, Monahan and Powell, 2011). Additionally, some studies focus on specific building designs and system components. Few studies focus on the utilization of methods such as scaling or power law models, probabilistic-based investigations or machine-learning derived models that are used in the building design and engineering processes and in addition to how design decisions impact the building life cycle energy. The most similar "scale-like" investigations are life cycle costs or EUI-based projections focused on life-cycle costs or operational energy indices per square foot. Life cycle operational energy phase and GHGE analysis could be simplified to general heuristics based on observations from the data analysis of the building LCE and LCA literature. Utilizing these data-sets and advances in machine-learning based predictive analytics, a more simplified approach can be developed for the optimization building life cycle energy. This may be especially useful in early building design phases when data and budgets are limited.

**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)

This research will result in a literature review of building LCE and GHGE studies that are focused on simplified or alternative approaches of building energy use estimation. Utilizing the data-sets, methods or techniques found in the literature and advances in machine-learning based predictive analytics, a more simplified approach maybe developed for the optimization building LCE and GHGE. The project researcher will evaluate the methods and propose method(s) or techniques for the development of toolkit for the simplified evaluation of building LCE and GHGE. The researcher will then work with the sponsoring TC's to approve the approach, then the project researcher will develop the toolkit, and evaluate 6, well-documented, building case studies for the demonstration and validation of the simplified toolkit. Finally, the project will discuss and explore how the associated toolkit or method(s), will or could, with further development, integrate with existing building energy software workflows.

**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) (Development of Software tool)

1: Assess building and equipment life cycle energy literature with a focus on simplified methods of estimating life cycle energy and identify variations in different approaches specifically focusing on the complexity of analysis, accuracy, tradeoffs and analytical cost (time). In addition, identify the critical conceptual elements, and parameters that produce most of the LCE consumed and GHGE produced over the life cycle.

2: Part a) Utilizing the meta-analysis in step 1, list the method(s) that could be used in a simplified LCE analysis for building components and equipment. Part b) Work with the sponsoring TCs to propose an analysis method and associated software design or approach. Part c) identify the methods to estimate GHGE from the building LCE gathered in Parts a & b. Part d) Develop the toolkit.

3: Provide **6** case studies illustrating the simplified building LCE and GHGE approach, method analysis, analysis results and associated analytical costs. The simplified method results will also be compared with traditional building energy analysis simulations to assess the model robustness.

4: Identify how the associated method(s), software or software method will or could, with further development, integrate with existing building energy software workflows.

**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)

This research will serve ASHRAE's commitment to the design and operation of energy-efficient buildings and the promotion and production of net and near net-zero buildings. This RTAR aligns with Goal 7: Support development of tools, procedures, and methods for design low-energy buildings. The state of the art of building energy analysis is typically limited to in-depth, complex analyses of the operational energy of a building. This project is focused on the development of a software tool to incorporate other phases of the building life cycle and to assist the building design process in the evaluation of building components and equipment.

The research will seek to maximize operational energy performance of buildings and equipment by including a framework for the evaluation of the trade-offs of up-front investments in advance building designs and systems and their impact on building LCE. A simplified approach will be warranted to minimize the complexity of the analysis, and will provide decision support that reaches beyond the operational phase of the building by addressing embodied energy, and end of life stages for a complete LCE and GHGE evaluation.

Finally, the research will significantly increase the understanding of building LCE and GHGE and the associated trade-offs in the design of low-energy building, and provide a generalized framework for the further evaluation of other building life cycle impacts beyond energy, such as life cycle water.

**Anticipated Funding Level and Duration**

Funding Amount Range: $180,000

Duration in Months: 18 – 20 months

**References**

List the key references cited in this RTAR.

[1] Monahan, J. and Powell, J. C. 2011. An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework. Energy and Buildings 43(1):179-188.

[2} Sartori, I. and Hestnes, A. G. 2007. Energy use in the life cycle of conventional and low-energy buildings: A review article. Energy and buildings 39(3):249-257.

[3] Ramesh, T., Prakash, R. and Shukla, K. K. 2010. Life cycle energy analysis of buildings: An overview. Energy and Buildings 42(10):1592-1600.

[4] Mastrucci, A., Marvulglia, A., Benetto, E., Leopold, U. 2017. Spatially and temporally explicit Life Cycle Assessment of building stock retrofitting actions at the urban scale. Proceedings of the 21st Conference of the Environmental and Sustainability Management Accounting Network (EMAN), Liege, 2017.

[5] Caduff, M., Huijbregts, M. A. J., Koehler, A., Althaus, H-J, Hellweg, S. 2014. Scaling Relationships in Life Cycle Assessment – The case of Heat production form biomass and heat pumps. Journal of Industrial Ecology 18(3): 393-406.

[6] Li, K. et al. 2007. Development of a Framework Quantifying the Environmental Impacts of Urban Development and Construction Practices. Environmental Science and Technology 41: 5130-5136.

[7] Caduff, M., Huijbregts, M. A. J.,Althaus, H-J, Hendriks, A. I. 2011. Power-law Relationships for Estimating Mass, Fuel Consumptions and Cost of Energy Conversion Equipments. Environmental Science and Technology 45:751-754.

[8] Favi, C., Meo, I., Di Giuseppe, E., Iannaccone, M., D'Orazio, M., Germani, M. 2017.Towards a probabilistic approach in LCA of building retrofit measures. Procedia Engineering 134: 394-403.

**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……

## Cost Estimate for proposed

## A toolkit for the evaluation of the life cycle energy and greenhouse

| A. | Scope and hourly rate data | |
|---|---|---|
| 1 | Case studies | 6 |
| 2 | Principal researcher rate | $150 |
| 3 | Research assistant rate | $60 |

**B. Cost estimate**

| | Task/item | Princ hrs |
|---|---|---|
| 1 | Initial meetings - develop research plan | 16 |
| 2 | Project update meetings | 16 |
| 3 | Literature review | 8 |
| 4 | Analysis of literature and find six case studies for analysis and validation work | 16 |
| 5 | Report on literature fiindings, propose simplifed methods, and proposed case studies to the TC | 32 |
| 6 | Perform analysis with simplied method and tradition building simulation analysis, compare analyticsl results for each case study | 32 |
| 10 | Research and report on how the simplifed method software will or could be implemented in the standard buidling simulation workflows | 24 |
| 15 | Final analysis and report writing | 24 |
| 16 | Presentation of results | 16 |
| 17 | Travel costs associated with results presentation | |
| 18 | Per diem costs associated with results presentation | |
| | Subtotals | 184 |
| | Contingency @ 15% | |
| | Profit and or overhead @ 30% | |
| | Grand total | |

**RTAR**

**emissions for buildings, building compoents and equipment**

| | |
|---|---|
| | Nunber of case studies |
| /hr | Fully burdened rate - principal of engineering firm |
| /hr | Fully burdened rate - junior engineer |

| RA hrs | Task/item cost |
|---|---|
| 32 | $4,320 |
| 32 | $4,320 |
| 120 | $8,400 |
| 160 | $12,000 |
| 160 | $14,400 |
| 700 | $46,800 |
| 160 | $13,200 |
| 160 | $13,200 |
| 16 | $3,360 |
| | $1,500 |
| | $600 |
| 1,540 | $122,100 |
| | $18,000 |
| | $42,000 |
| | $182,000 |