The role of early design decisions on sustainability of mid-rise office buildings from a comparative LCA perspective

Mohsen Zaker Esteghamati[1], Patricia Asiatco[1], Thea Diep Ton[2], Natalia Zhukova[3], , Madeleine M. Flint[1](PI)

[1]Virginia Tech, Department of Civil and Environmental Engineering, [2] University of Washington, Department of Civil and Environmental Engineering [3] John Hopkins University, Department of Civil Engineering

IMECE 2019-13234

IMECE Track 16-1

NSF Research Poster Competition

Project Objectives and Goals

-Providing benchmark data to aid the evaluation of the life-cycle impacts of mid-rise office buildings

-Comparing the environmental impacts of four professionally-designed archetypes➔ different combinations of **f**oundation, **s**tructure and **e**nvelopes (**FSE**) assemblies

-Detailed operational energy modeling using the *EnergyPlus* framework.

Background

-Minimizing environmental impacts over a building's life cycle is critical to achieving sustainable communities

-Early design is the most critical step to improve construction's sustainability, as the majority of important decisions have not yet been made [**1**].

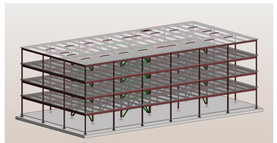
-The implementation of sustainability assessment in early design is data- and effort-intensive [**2**]

-The first step is to provide a dataset on environmental performance of different designs. [**3**]

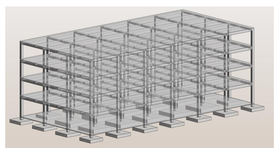
Conclusion

- Early decisions regarding structural and foundation systems significantly affect the production and construction phases.
- The choice of envelope system is the primary driver of the operational phase
- Operational phase dominates the life-cycle of the archetypes
- Early decisions associated with operational phase, such as envelope system and expected service life, should be prioritized
- Since all separate LCA of this study were conducted by REUs, it is shown that consistent LCA results are attainable through a standardized and transparent procedure.

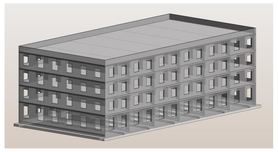
Numerical analysis



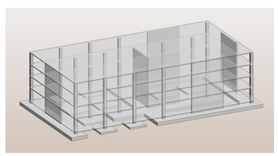
F: Mat foundation
S:Steel Bucking-restrained brace (BRB)
E:Mixed



F: Individual Spread footing
S: Concrete Moment resisting frames (MRF)
E:Mixed



F:Mat foundation
S: Masonry wall
E: Mixed*

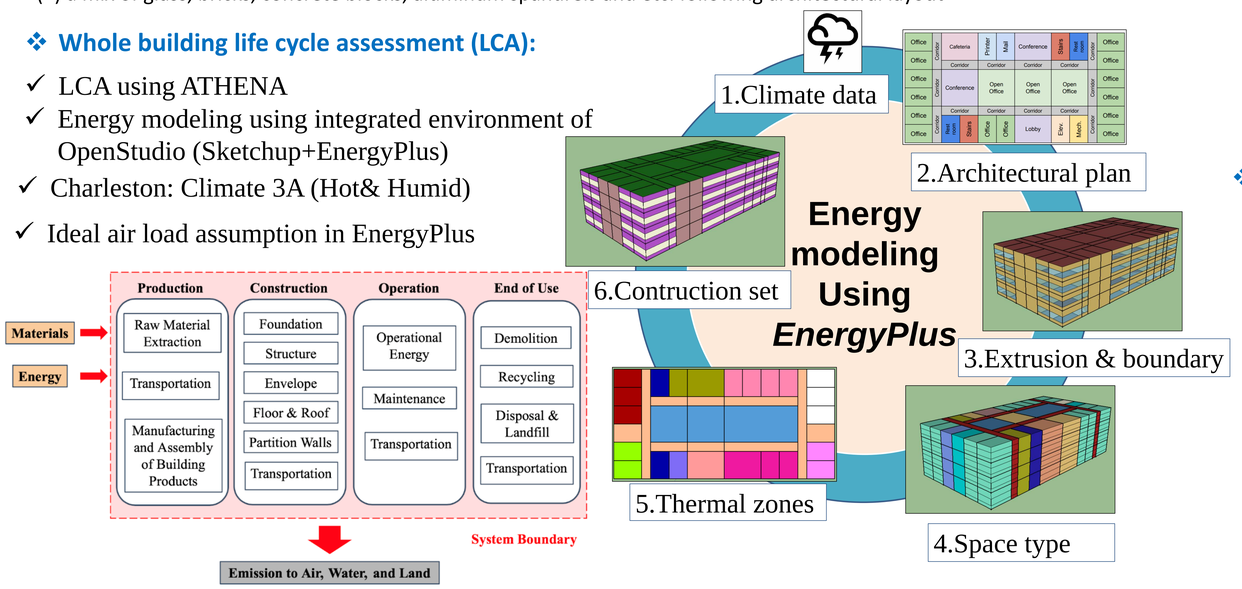


F: Single & Continuous footings
S: Concrete shear wall
E:Mixed

(*) a mix of glass, bricks, concrete blocks, aluminum spandrels and etc. following architectural layout

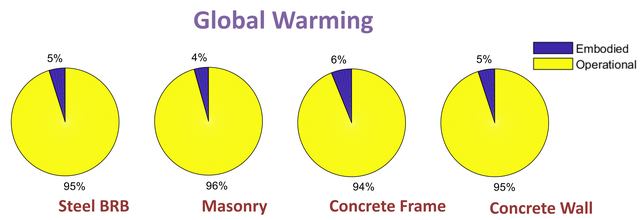
❖ Whole building life cycle assessment (LCA):

- ✓ LCA using ATHENA
- ✓ Energy modeling using integrated environment of OpenStudio (Sketchup+EnergyPlus)
- ✓ Charleston: Climate 3A (Hot& Humid)
- ✓ Ideal air load assumption in EnergyPlus

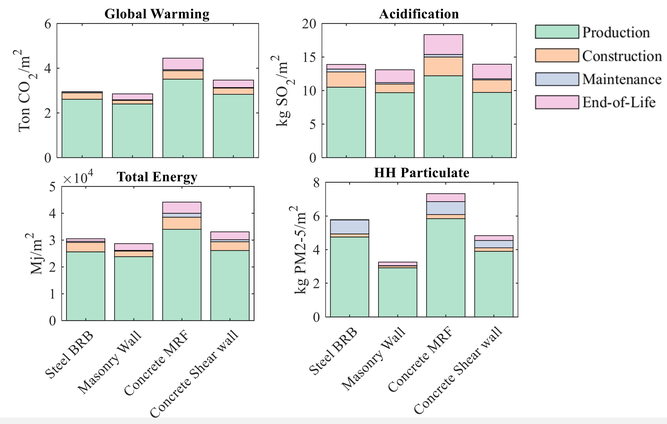


Data and Results

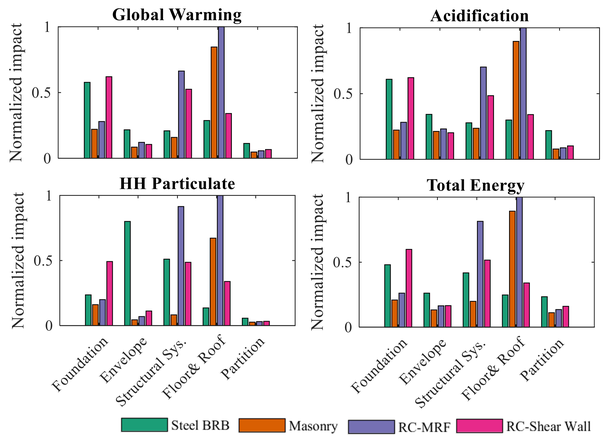
❖ Embodied VS. operational impacts:



❖ Comparison of different LCA stages (Embodied Only)



❖ Embodied impact by building assemblies



Future studies

- ✓ Quantifying the impact of natural hazards on sustainability of the archetypes
- ✓ Evaluating the uncertainties associated with LCA assessment through repeated LCA assessment and different LCA programs

Acknowledgement

This research is supported by the US National Science Foundation, Division of Civil, Mechanical, and Material Innovation, through Resilient Sustainable Buildings Award #1455466.

References

1. Basbagill J, Flager F, Lepech M, Fischer M. Application of life-cycle assessment to early stage building design for reduced embodied environmental impacts. Build Environ 2013. doi:10.1016/j.buildenv.2012.11.009

2. Flint MM, Dhulipala SLN, Shahtaheri Y, Tahir H, Ladipo T, Eatherton MR, et al. Developing a Decision Framework for Multi-Hazard Design of Resilient, Sustainable Buildings. 1st Int. Conf. Nat. Hazards Infrastruct., 2016.

3. D'Amico B, Myers RJ, Sykes J, Voss E, Cousins-Jenvey B, Fawcett W, et al. Machine Learning for Sustainable Structures: A Call for Data. Structures 2019. doi:10.1016/j.istruc.2018.11.013.

Publication

Zaker Esteghamati et al. (in prep)"The role of early design decisions on sustainability of mid-rise office buildings from a comparative LCA perspective"