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Introduction

Construction personnel are exposed to a variety of uncomfortable and unhealthy elements on construction sites.

These elements are primarily **thermal, lighting, acoustics, air quality** and **ergonomics** related. Uncomfortable noise levels on construction sites result from power generators, equipment, and heavy machinery which averages 99 decibels (dBA)^[3] - 9 dBA above OSHA regulations

- More than 420,000 US construction workers are potentially exposed to hazardous noise ^[6]
- The construction industry has the highest reported occupational fatalities in the US by the Bureau of Labor Statistics ^{[2][6]}

Background on Environmental and Health Impacts from Construction Sites: Findings from Literature Review

The construction industry has the lowest energy consumption by sector, but generates almost double its consumption in CO2 emissions. Largest when compared to other sectors

Power generators, equipment, machinery use, transportation, temporary lighting, and heating and cooling consume large amounts of energy ^[5]

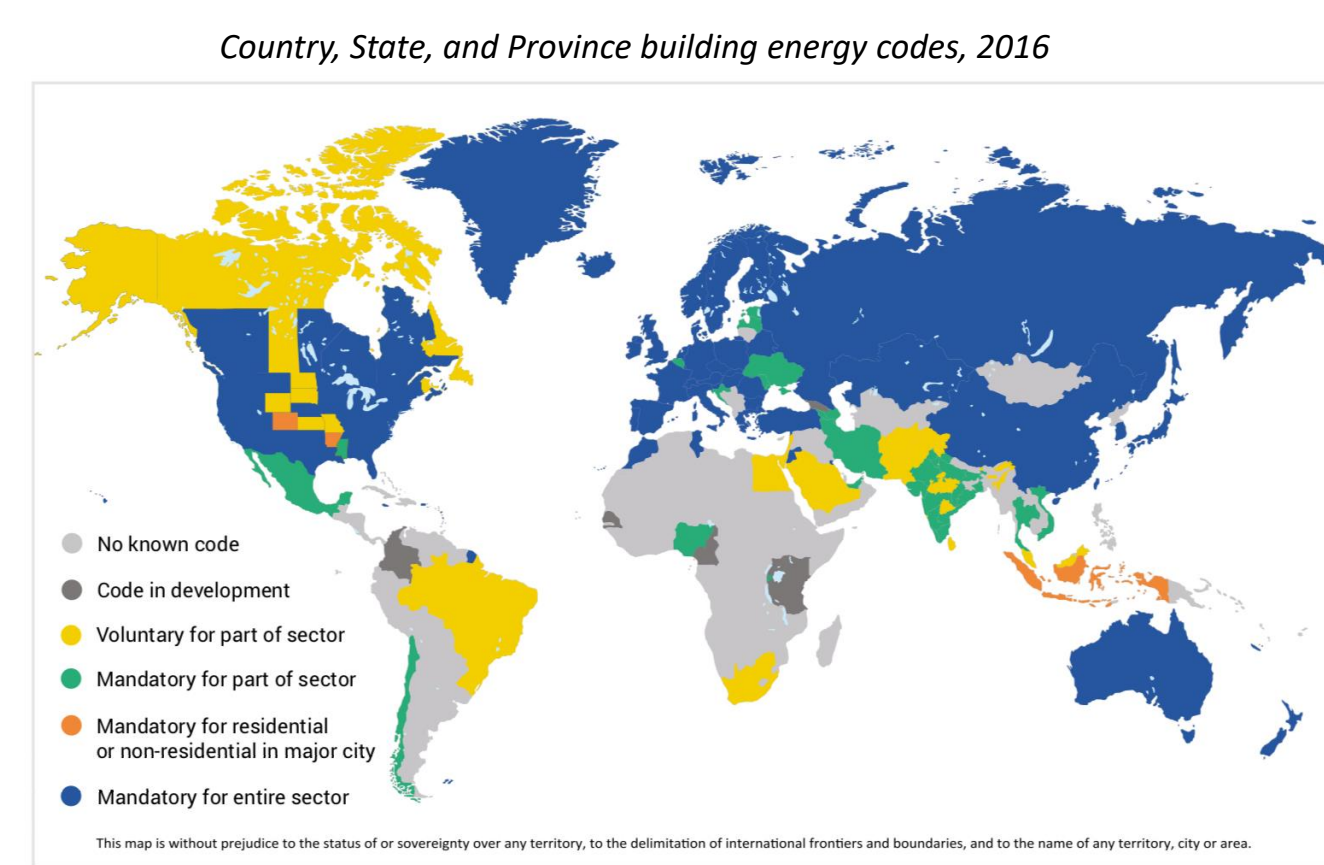
Site energy consumption generates environmental emissions

Health complications abound from site environmental emissions

Inefficient site management impacts energy use

Decentralized energy reporting mechanism leads to inefficient energy use monitoring

~ 2/3rd of countries lack mandatory building energy codes. Even less have construction energy codes



Construction activities and equipment generate

- Particle Matter PM10
- Sulphur Dioxide SO₂
- Nitrogen Dioxide NO₂

PM 2.5 causes heart and lung problems

*Source: Abergel, Dean, & Dulac (2017)

Frequent exposure to noise levels upwards of 84 dBA leads to chronic physiological problems

- Increased noise induces stress that could affect mental health ^[3]

If green construction is to be sustainable and safety is a key component of sustainability, evaluating and considering worker safety within the construction phase is important

Energy use, environmental emissions and health impacts are linked, reaffirming the importance of energy efficiency standards towards the support of the 'healthy trifecta'

Objectives

Determine gaps in sustainable metrics in relation to pre-occupancy stage of construction, i.e. "ground-breaking" to "substantial completion"

Open a discussion about thermal, lighting, ergonomic, acoustic and air quality

Identify opportunities to improve the conditions of the construction labor force that are underrepresented in the current standards

Methodology



Reviewed two U.S green building codes and nine voluntary U.S building standards – texts.



A systematic review of research studies consisting of peer reviewed literature, white papers, and reports between the years 2002 and 2018 provides further substantive support of the gap in guidelines towards contractor health and safety and the impacts on productivity, and construction budgets.



Pilot surveys of 10-questions were sent to contractors in all sectors of the construction industry. The questionnaires consider how satisfied workers were with their work spaces and health conditions from site work.

Codes Alias	Applicable Sections
International Energy Conservation Code (2018)	2
International Green Construction Code (2015)	10
Standards Alias	Applicable Sections
WELL Building Standard (v2), U.S	18
BREEAM (2016), International	25
LEED (v4.1), International	43
Green Building Initiative (2010), U.S	23
ICC/ASHRAE (2015), US	26
Living Building Challenge, version 3.1 , U.S	20
ASHRAE Standard 90.1 (2016), International	3
ISI Envision Version 3, U.S	20
ASHRAE Standard 189.1 (2017), International	5

Discussion

Results show that regulations that impact the health of construction personnel is limited in texts

Temporary lighting is a key term in text, but in the post-occupancy context

- Not addressed in pre-occupancy use

Results from the pilot survey indicates three common trends of concern on site: **hot temperatures, lighting, and acoustics**

Literature supports the importance of **lighting and noise on contractors' health and productivity**

Literature substantiates claim on lack of metrics for pre-occupancy phase

Health sections were primarily concerned with IEQ and ergonomics, leaving a large gap in energy use, environmental impacts, and contractor well-being

Envision is the only text to explicitly focus on contractor safety and well-being: guidelines go beyond OSHA – however, Envision focuses only on infrastructure

Individual site energy consumption could not be determined due to limited research studies

EPA emission standards which regulates engine hp size for nonroad diesel fuel for generators is a solution for reduced gas emissions on sites

Conclusion

Modifications in codes will have great impact – large numbers of projects in the US employ LEED, WELL, Living Building Challenge, and ASHRAE Standards

Preliminary results indicate that more data is needed to ascertain individual construction activities and site energy use, in order to determine management plan

Two key terms, **temporary lighting** and **Energy STAR portfolio** show a way for improvement

Energy STAR portfolio, is required by majority of standards for calculating GHG emissions consistently across the building sector. Changes towards construction inclusion may rely upon changes in the tools such as ENERGY STAR, as much as the standards and codes themselves.

Temporary lighting is relevant for the frequency of night construction, working in spaces void of fenestration, or requiring task specific lighting. Reduced nighttime work was at the foreground of reduced carbon footprints of construction sites in Malaysia ^[5]

References

- Abergel, T., Dean, B., & Dulac, J. (n.d.). GLOBAL STATUS REPORT 2017 (Rep.). Retrieved [https://www.worldgbc.org/sites/default/files/UNEP_188_GABC_en_\(web\).pdf](https://www.worldgbc.org/sites/default/files/UNEP_188_GABC_en_(web).pdf)
- Census of Fatal Occupational Injuries (CFOI) - Current and Revised Data. (2018, December 18). Retrieved from <https://www.bls.gov/iif/oshcfoi1.htm>
- Sellappan, E., & Janakiraman, K. (2014). Environmental Noise from Construction Site Power Systems and its Mitigation. *Noise & Vibration Worldwide*, 45(3), 14-20. doi:10.1260/0957-4565.45.3.14
- Estimating Particulate Matter Emissions From Construction Operations: Final Report (pp. 1-52, Rep.). (1999). Environmental Protection Agency: National Service Center for Environmental Publications (NSCEP).
- Esmailifard, R., Samari, M., Mirzaei, N. F., & MohdShafiei, M. W. (2015). How is electricity consumption on construction sites in Malaysia related to sources of CO₂? *Advances in Environmental Biology*, 95, 160-163. Retrieved from http://www.academia.edu/11164412/How_is_electricity_consumption_on_construction_sites_in_Malaysia_related_to_sources_of_CO2
- Gambatese, J. A., Rajendran, S., & Behm, M. G. (2007). Green design & construction: Understanding the effects on construction worker safety and health. *Professional Safety*, 52(5), 28-35. Retrieved from <https://search-proquest-com.proxy.library.cmu.edu/docview/200410131?accountid=9902>
- Neitzel, R. (2002). Construction noise strategies. *Occupational Health & Safety*, 71(6), 72-76. Retrieved from <https://search-proquest-com.proxy.library.cmu.edu/docview/221058750?accountid=9902>
- Sharrard, A. L., Matthews, H. S., & Roth, M. (2007). Environmental Implications of Construction Site Energy Use and Electricity Generation. *Journal of Construction Engineering and Management*, 133(11), 846-854. doi:10.1061/(asce)0733-9364(2007)133:11(846)

Acknowledgements

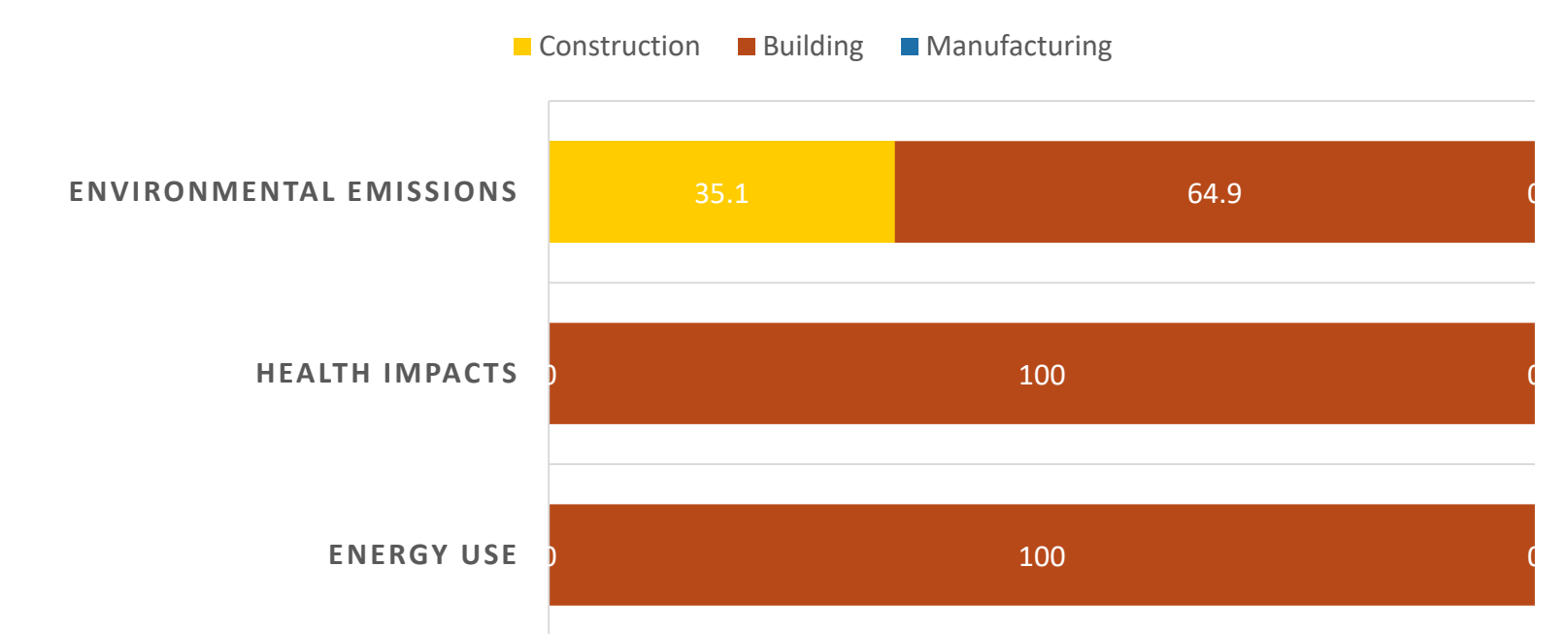
The authors would like to thank the contractors and construction firms for their participation in the pilot survey.

Results

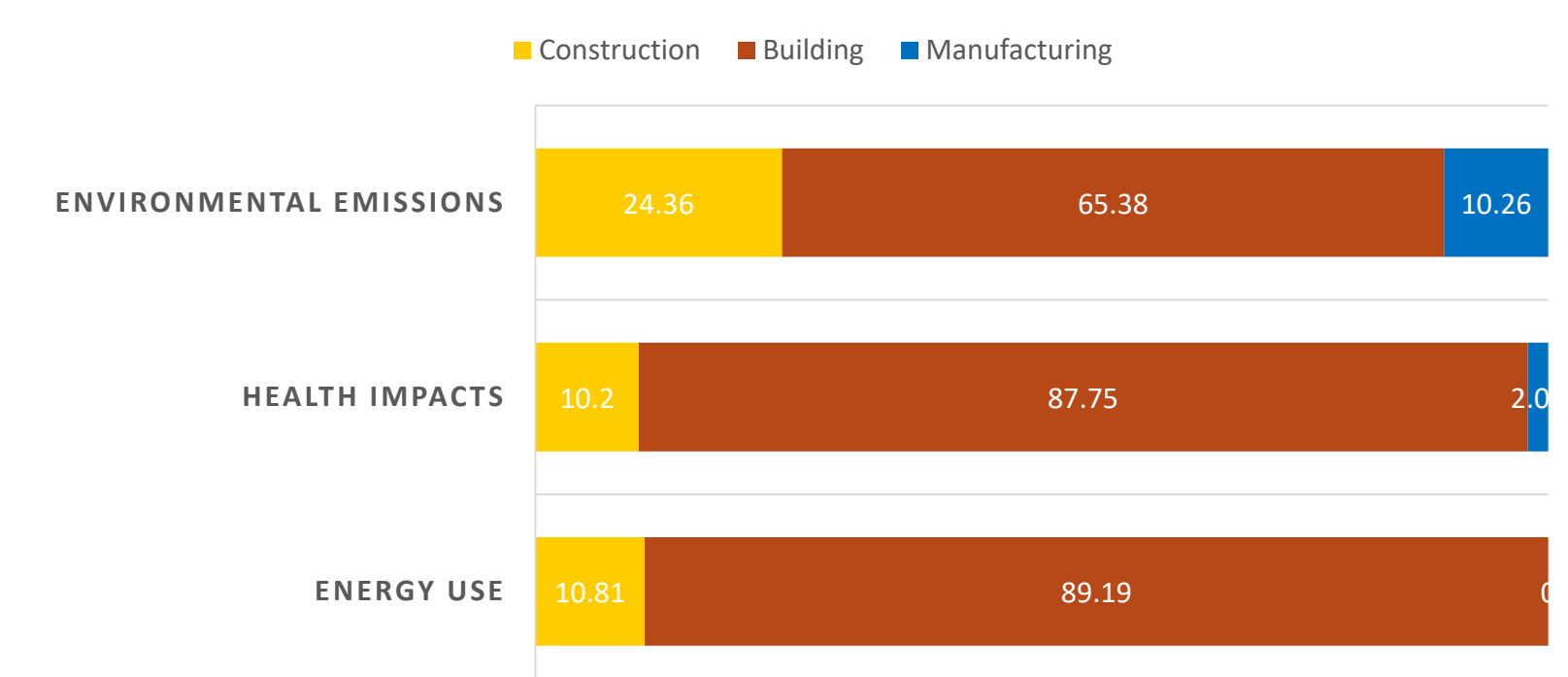
Texts were reviewed for key terms related to energy efficiency and/or sustainable construction. Context was grouped into:

- Manufacturing: Resource sourcing to supply
- Construction: Ground breaking to substantial completion
- Building: Substantial Completion to end of life

NORMALIZED PERCENT "HITS" OF KEY TERMS PER GROUPING FROM TOTAL CODES

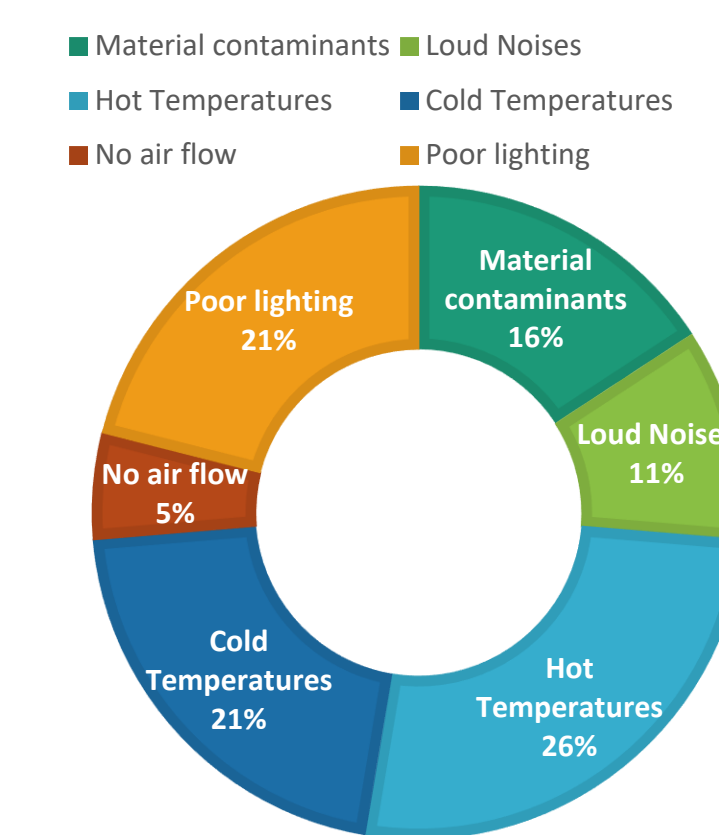


NORMALIZED PERCENT "HITS" OF KEY TERMS PER GROUPING FROM TOTAL STANDARDS

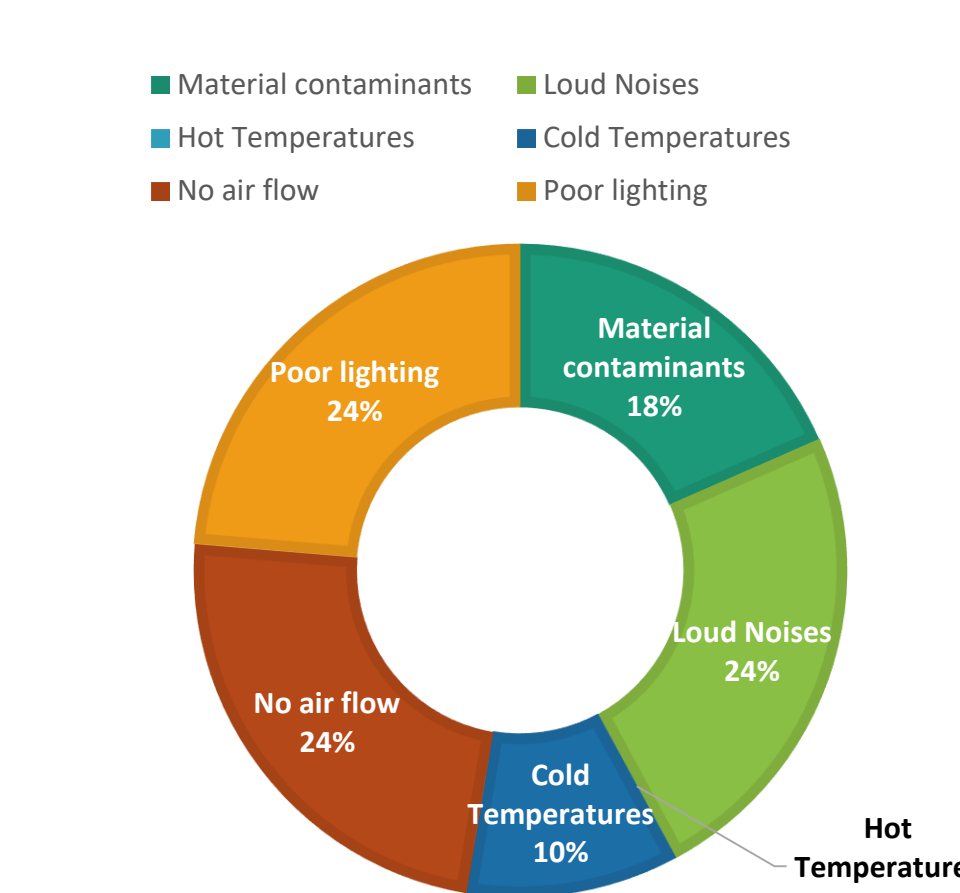


Common Key Terms
 IEQ, IAQ, Lighting pollution, Lighting, Thermal comfort, Acoustic comfort, Energy, Energy Star Portfolio, site energy, ASHRAE

CONTRACTOR PRODUCTIVITY SURVEY RESULTS



CONTRACTOR HEALTH SURVEY RESULTS



Further Work

- Determine the connection between inefficient lighting and health implications on construction workers
- Larger survey to determine trends and investigate the correlation between different methods of site coping strategies for thermal comfort and contractor comfort and productivity
- Estimate reductions in environmental emissions from energy efficiency standards