Purdue Geotechnical Society Workshop Program

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Application of Life Cycle Assessment to Geotechnical and Geoenvironmental Projects

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Presentation Outline

- Introduction
- Life Cycle Assessment (LCA)
- Examples/Case Studies
  - Landfill cover
  - Foundation
- Final Comments

Introduction

- Currently, engineering practice is based on sound technical design, costs, and ease of construction/preference

- Sustainability is rarely considered in the design (consequences of climate change +population growth!)

- Moreover, life cycle stages (raw material acquisition, material production, system construction/use and demolition/recycle/disposal) are not considered

What is Sustainability?

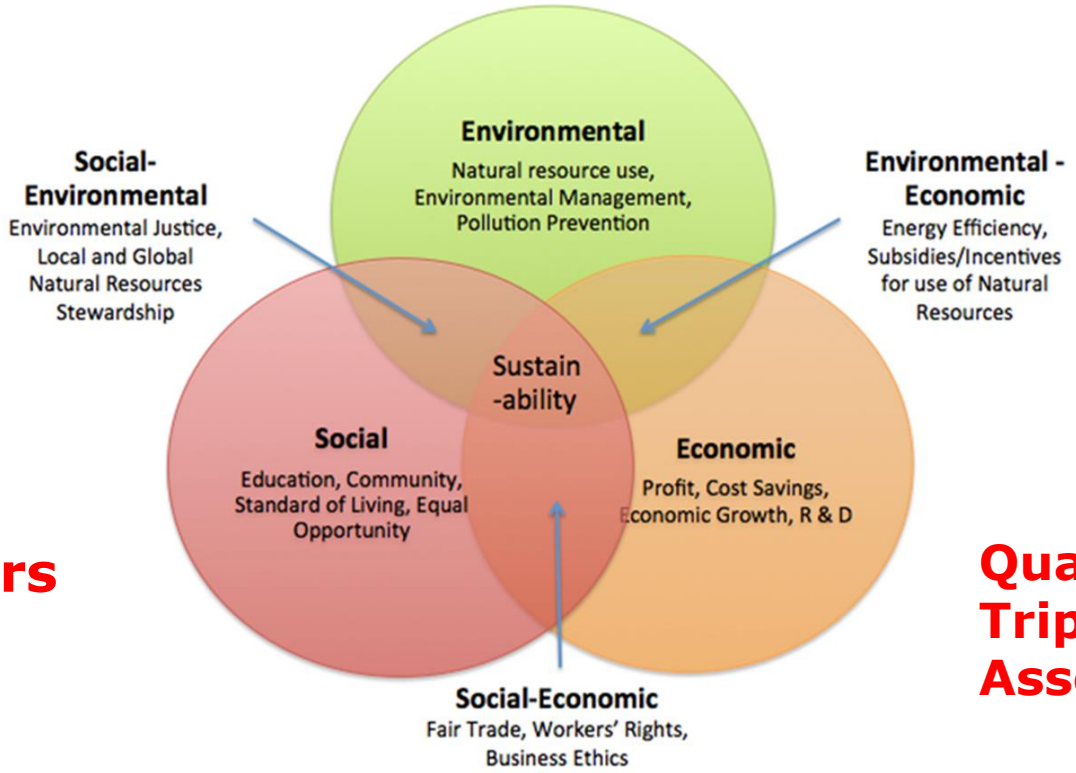
World Commission on Environment and Development report (UN, 1987) entitled, *Our Common Future* (also known as the *Brundtland Report*)

> *"…development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

Triple Bottom Line

- The essence of sustainability can be captured by the concept of “triple bottom line” or “three pillars” of sustainability

- Environmental, economic, and social



- **Indicators**
- **Metrics**
- **Tools**

Quantitative Triple Bottom Line Assessment

Life Cycle Assessment (LCA)

- Tool to assess **environmental sustainability** of triple bottom line
  - Note that economic and social dimensions are also equally important for sustainability

- Useful to estimate the environmental impacts (indicators and metrics) that can be induced by a geotechnical and geoenvironmental system considering life cycle stages

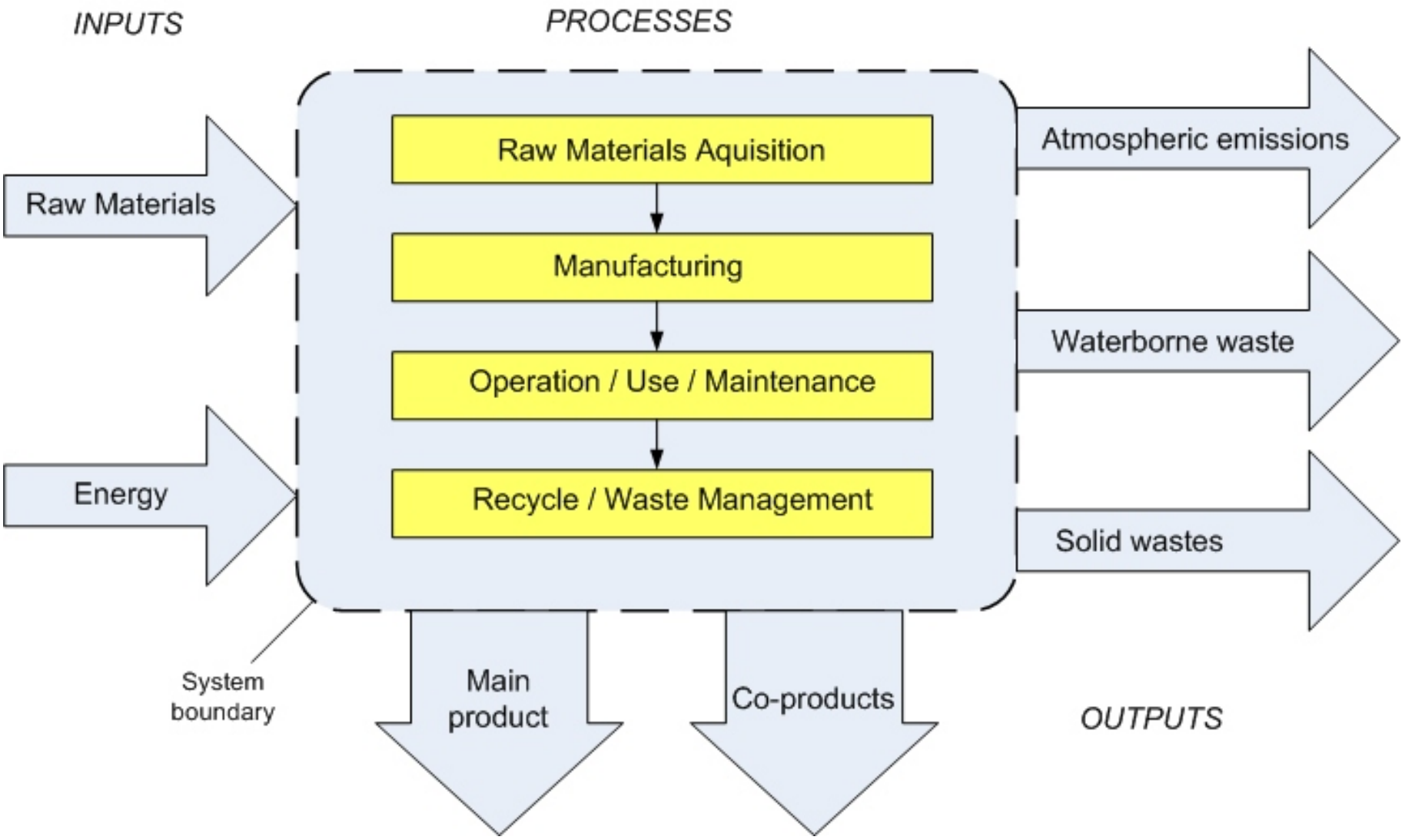
LCA Framework

- ISO LCA guidance documents:
  - ISO 14040: Principles and framework
  - ISO 14044: Requirements and guidelines

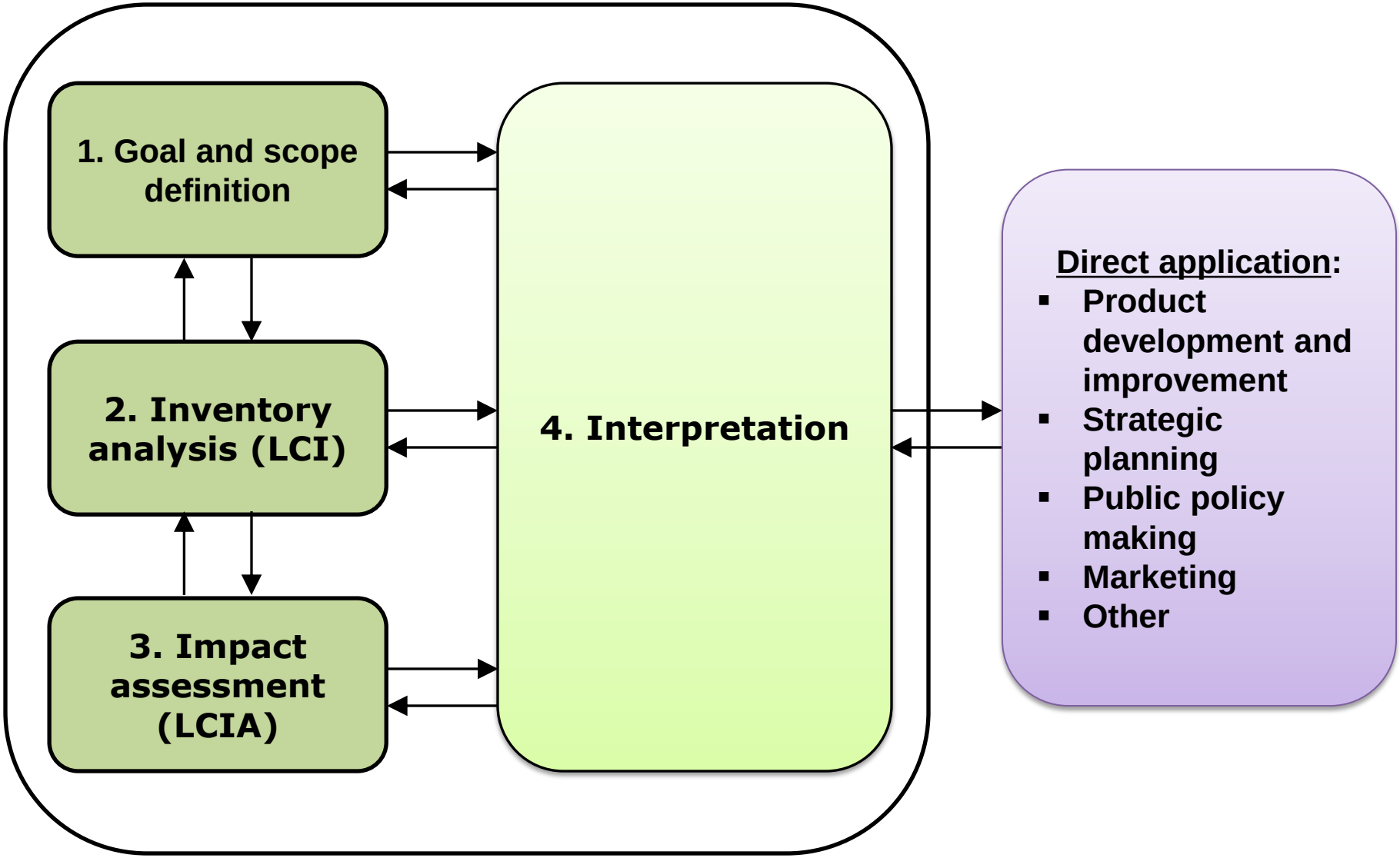
- ISO 14040 definition of LCA:

  LCA is the “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.”

Life Cycle Assessment (LCA)



Four Phases of LCA



Examples of LCA Application

LCA of Landfill Final Covers

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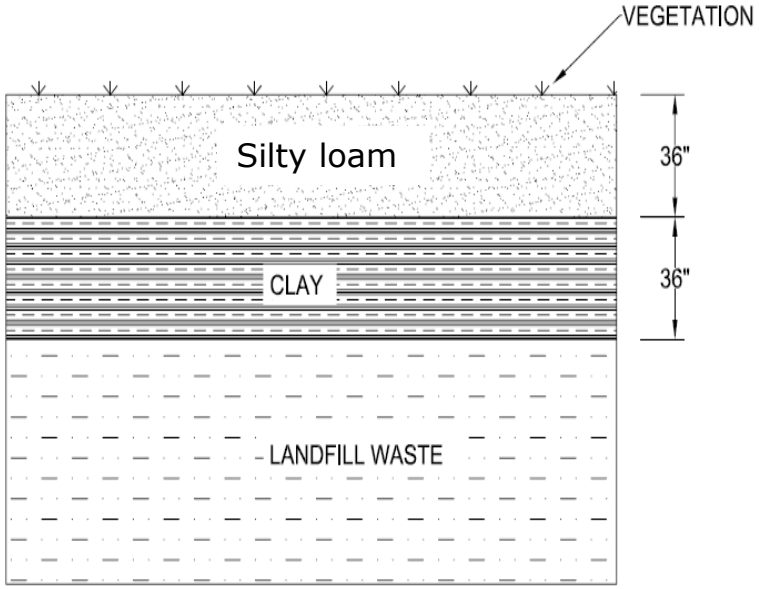
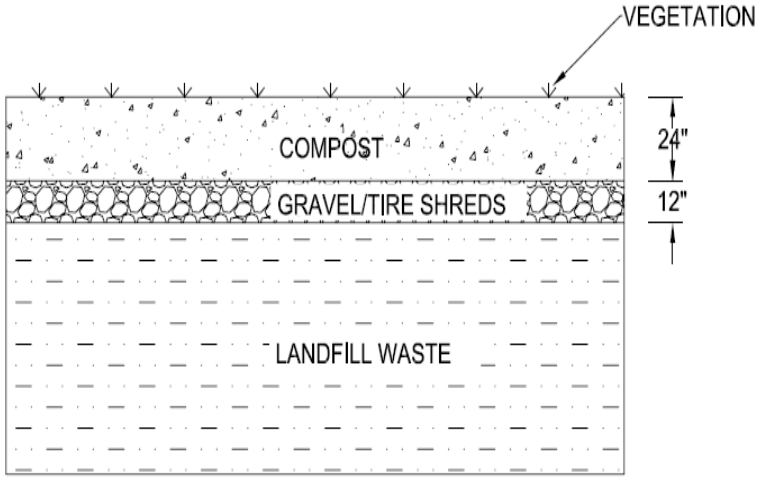
Subtitle D Cover



1 SOIL COVER
SCALE: 1/4" = 1'

Biocover



2 COMPOST BIO COVER
SCALE: 1/4" = 1'

Sadasivam, B.Y., and Reddy, K.R. (2014). "Sustainability assessment of Subtitle D cover versus biocover for methane oxidation at municipal solid waste landfills." Geotechnical Special Publication 234, *Proc. of the Geo-Congress 2014*, Editors: Abu-Farsakh, M., Yu, X., and Hoyos, L.R., American Society of Civil Engineers, Reston, VA.PDF File.

Scope of LCA

Life Cycle Stages for LCA

- Manufacture/acquisition of cover materials
- Transport of materials to site
- Placement of cover materials (compaction)
- Monitoring emissions & cover maintenance

Functional unit – 1 acre of LF site

Design life – 50 years

Life Cycle Inventory

SimaPro (Version 7) – Professional tool for LCA ('PRé Consultants')

Five cover system options analyzed:

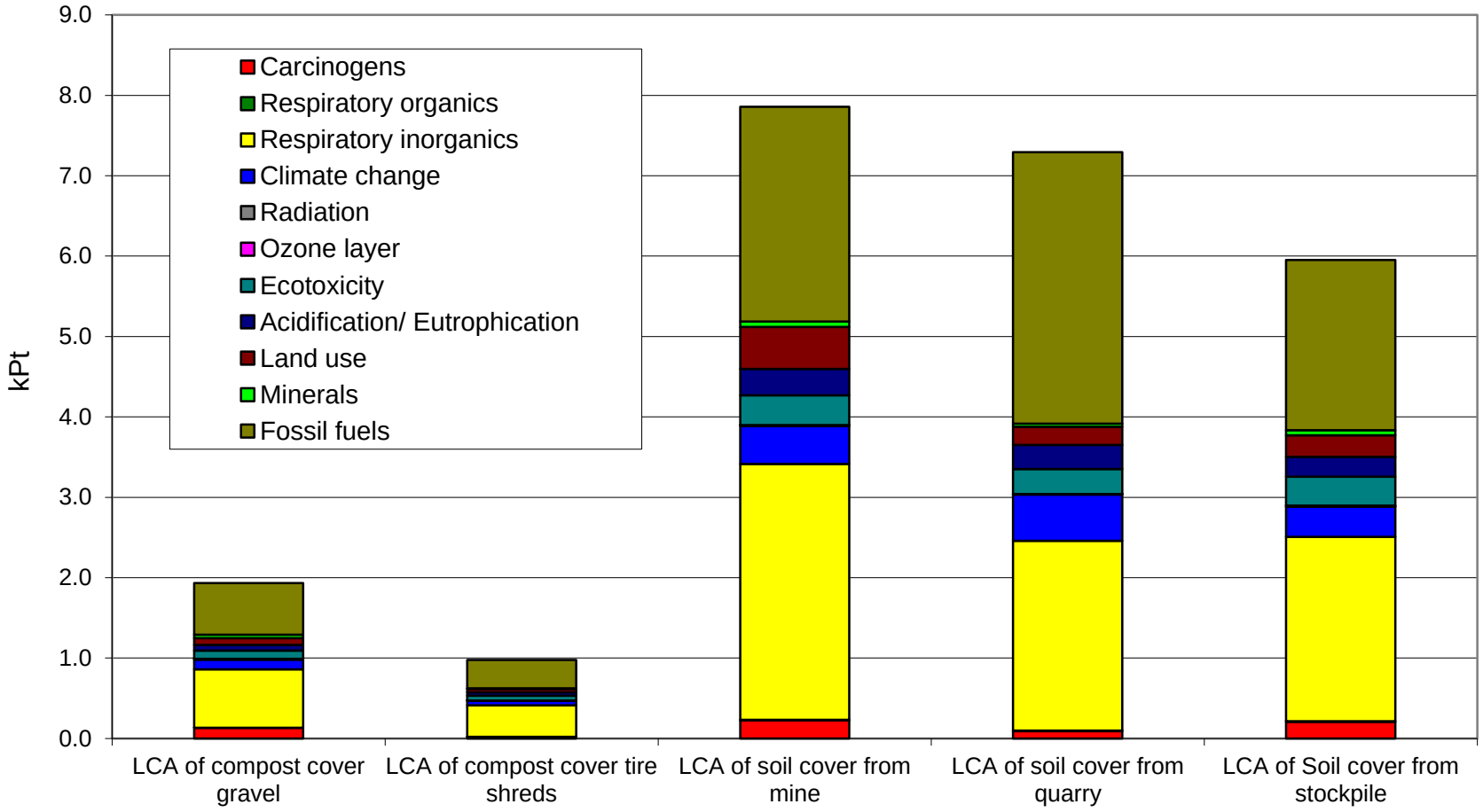
- ❑ Subtitle D (clay from stockpile on site)
- ❑ Subtitle D (silty loam & clay mined)
- ❑ Subtitle D (silty loam & clay from quarry)
- ❑ Biocover (tire shreds as GDL)
- ❑ Biocover (gravel as GDL)

Emissions monitoring & cover maintenance assumed to be similar for cover systems

Material Specification	Volume (m^3)	Material Density (kg/m^3)	Weight (tons)	Distance (Km)	tkm (ton-kilometer)
Compost	2,467	500	1,234	17.1	21,044
Gravel	1,233	1,600	1,973	2.1	4,143
Tire shreds	1,233	450	1,989	3.2	6,364
Clay	3,700	1,250	4,625	16.0	74,000
Silty loam	3,700	1,380	5,107	16.0	81,705

Life Cycle Impacts

Eco-Indicator 99(E) V2.08 method (European standards for normalization of impact values)



LCA of Deep Foundation

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Alternate Deep Foundations

Piles

Caissons

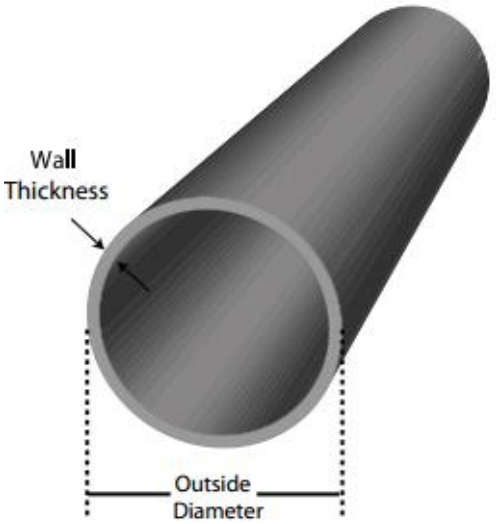
Functional Unit: 1000 kips design column load

Giri, R.K., and Reddy, K.R. (2014). "LCA and sustainability assessment for selecting deep foundation system for high-rise buildings." *Proc. International Conference on Sustainable Infrastructure*, Long Beach, CA, November 6-8, ASCE, Reston, VA.PDF File.

Technical Design

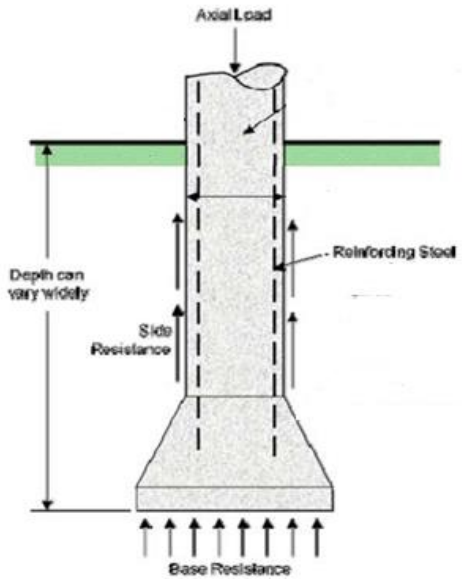
Piles:

- 14 PP OD = 20” TH = 0.375”
- Depth = 55’
- Capacity = 1040.6 Kips

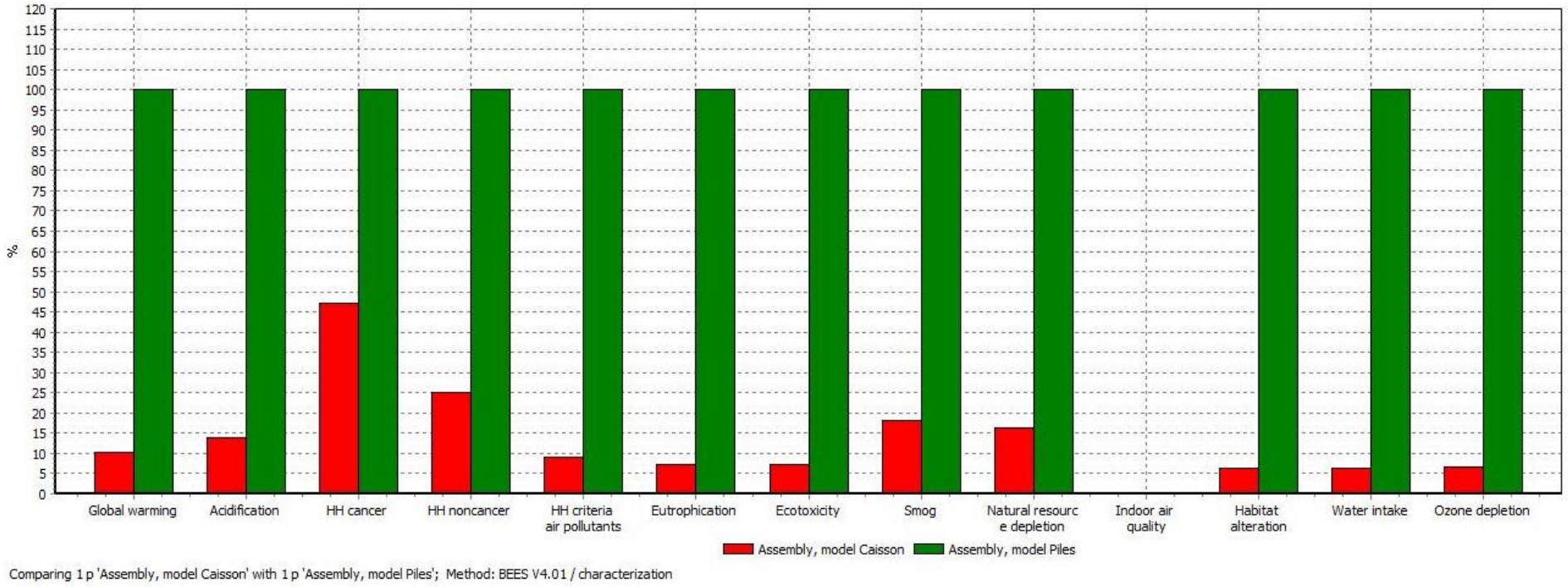


Caissons:

- Diameter = 3’ Depth = 55’
- Bell: H_b = 4’; D_b = 8’
- Capacity = 1019.7 Kips



Life Cycle Impacts

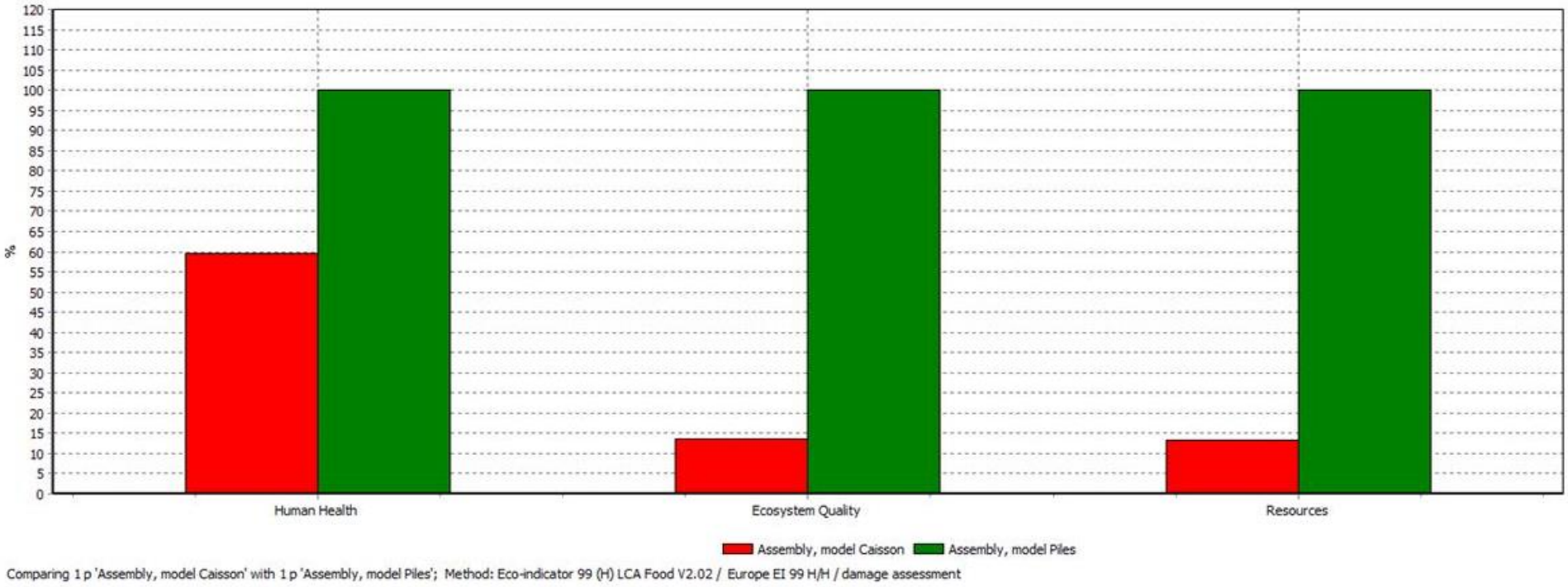


Comparing 1 p 'Assembly, model Caisson' with 1 p 'Assembly, model Piles'; Method: BEES V4.01 / characterization

Red: Caisson (Drilled Shaft)

Green: Piles

Damage Potential

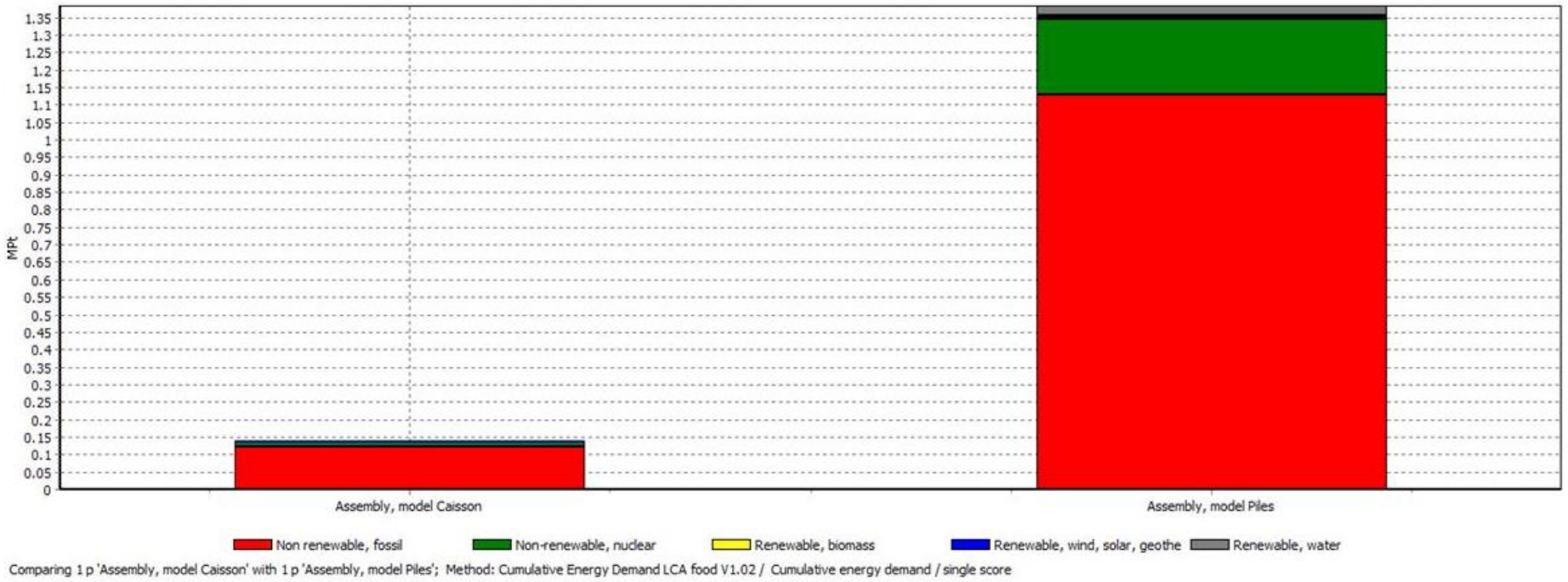


Comparing 1 p 'Assembly, model Caisson' with 1 p 'Assembly, model Piles'; Method: Eco-indicator 99 (H) LCA Food V2.02 / Europe EI 99 H/H / damage assessment

Red: Caisson (Drilled Shaft)

Green: Piles

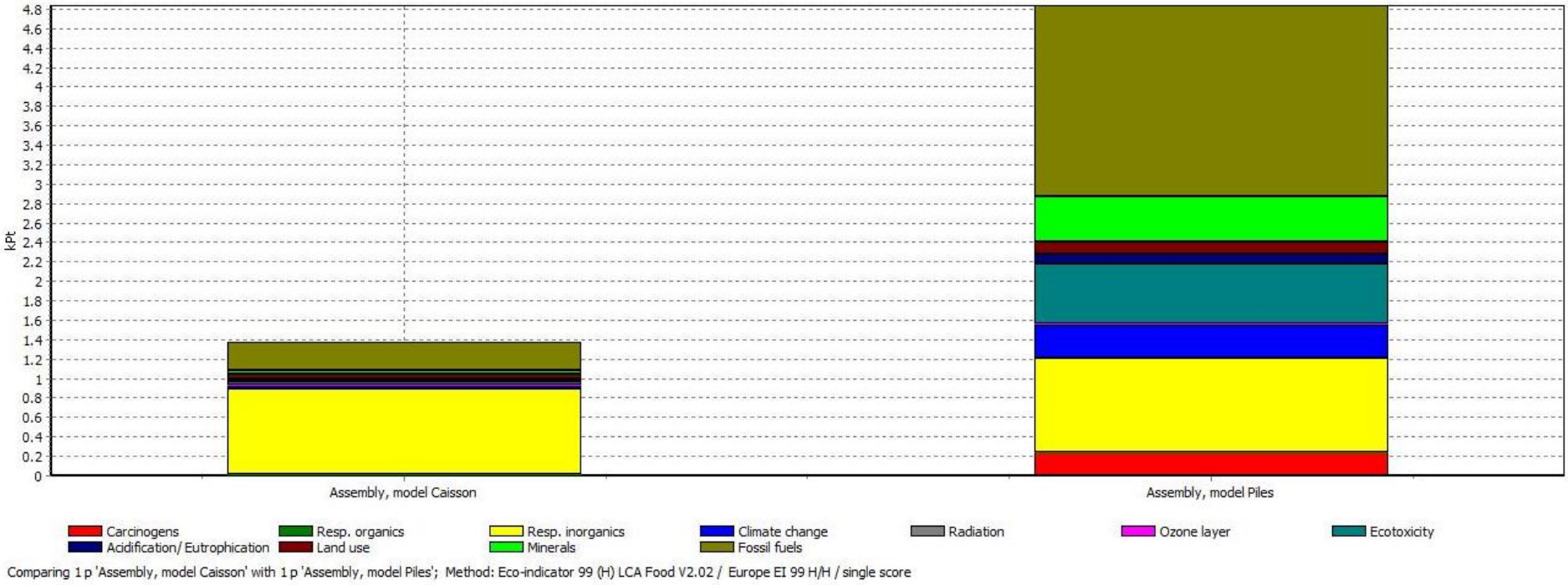
Energy Requirements



Caisson (Drilled Shaft)

Piles

Environmental Impact: Overall Single Score



Overall Point Count

Caisson: 1.4 kpt

Piles: 4.8 kpt (60% more)

Major Impacts: Human Health (H.H.) H.H, Resources

Caisson is more sustainable according to the LCA Study

Other LCA Examples

- Giri, R.K., and Reddy K.R. (2015). "Sustainability assessment of two alternate earth-retaining structures." IFCEE2015, San Antonio, TX, March 17-21, 2015.PDF File.
- Sadasivam, B.Y., and Reddy, K.R. (2014). "Sustainability evaluation of alternate drainage materials in landfill liner and cover systems." *Proc. International Conference on Sustainable Civil Infrastructure 2014*, Indian Institute of Technology, Hyderabad, India, pp. 519-530.PDF File.
- Reddy, K.R., Sadasivam, B.Y., and Adams, J.A. (2014). "Social sustainability evaluation matrix (SSEM) to quantify social aspects of sustainable remediation." *Proc. International Conference on Sustainable Infrastructure*, Long Beach, CA, November 6-8, ASCE, Reston, VA.PDF File.
- Goldenberg, M., and Reddy, K.R. (2014). "Sustainability assessment of excavation and disposal versus in-situ stabilization of heavy metal contaminated soil at a Superfund site in Illinois." Geotechnical Special Publication 234, *Proc. of the Geo-Congress 2014*, Editors: Abu-Farsakh, M., Yu, X., and Hoyos, L.R., American Society of Civil Engineers, Reston, VA.PDF File.
- Yargicoglu, E.N., and Reddy, K.R. (2013). "Green and sustainable remediation of contaminated Indian Ridge marsh site in Chicago, USA." Proc. Coupled Phenomena in Environmental Geotechnics (CPEG), Politecnico Di Torino, Torino, Italy.PDF File.
- For other publications, visit: **www.uic.edu/labs/geotech**

Final Comments

- LCA can be used to assess environmental sustainability as demonstrated for different geotechnical/geoenvironmental engineering projects

- Few case studies/examples are presented:
  - Results depend on the site-specific/project-specific conditions
  - Demonstrated the general LCA methodology
  - Keep the purpose of assessment in mind!!!

- Life cycle triple bottom line sustainability framework for design!

Contact Information

UIC

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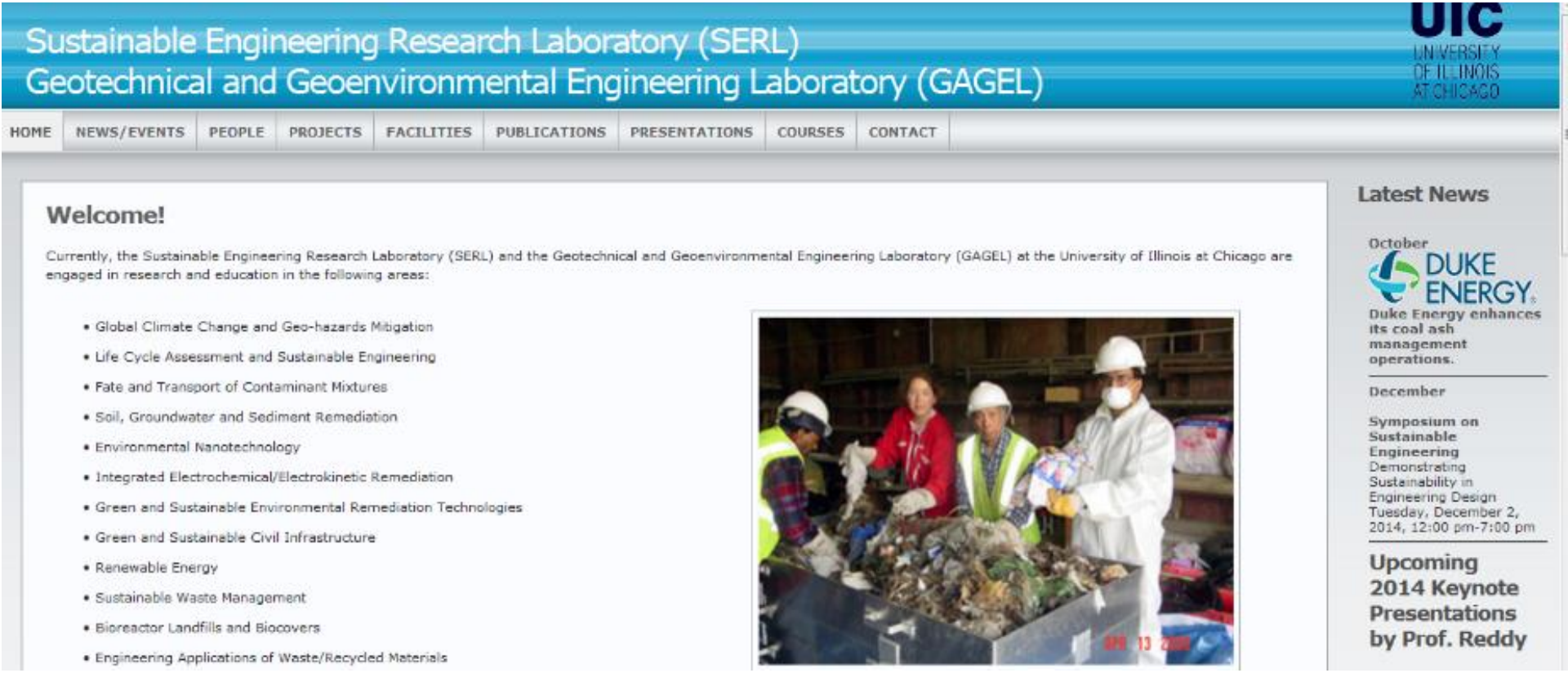

Published papers on our research projects can be found on this website