Life cycle assessment of remediation approaches for a remote diesel-contaminated site

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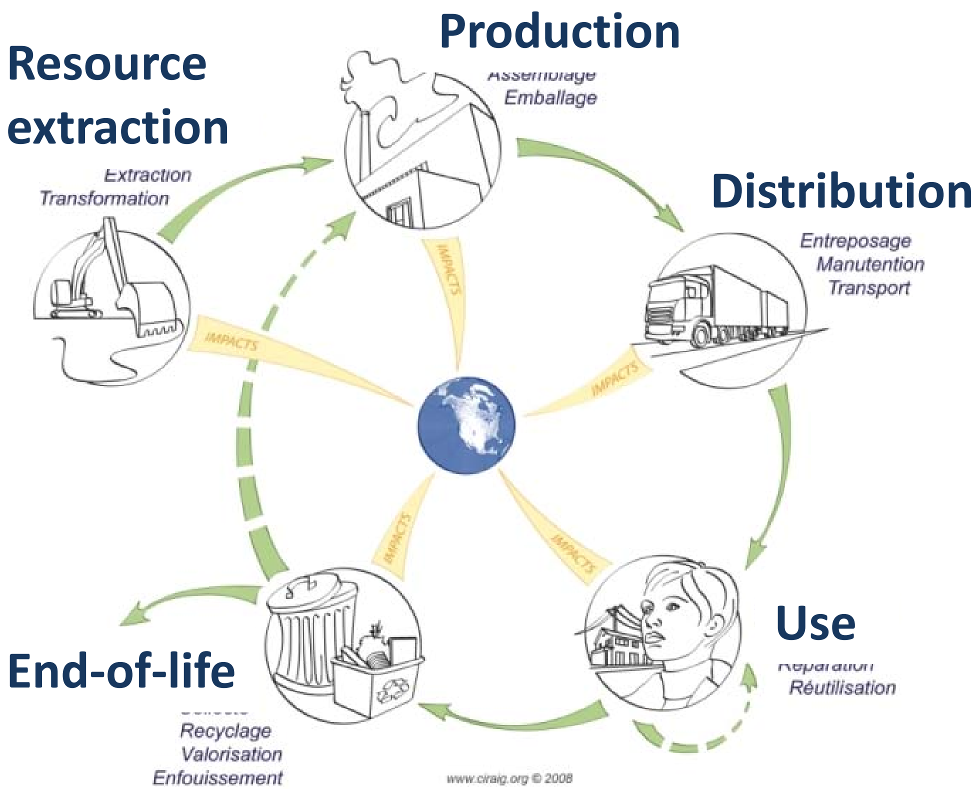
Presentation outline

- LCA
- Application of LCA to site remediation
- Description of the case-study
- Methodology
- Results and discussion
  - Life cycle inventory (LCI)
  - Life cycle impact assessment (LCIA)
  - Improvement scenarios
- Summary and conclusions

Life cycle assessment (LCA)

- Established system analysis tool
- Used to quantify the inputs, outputs and potential environmental impacts of systems over their entire life cycle
- Applied at different levels of complexity

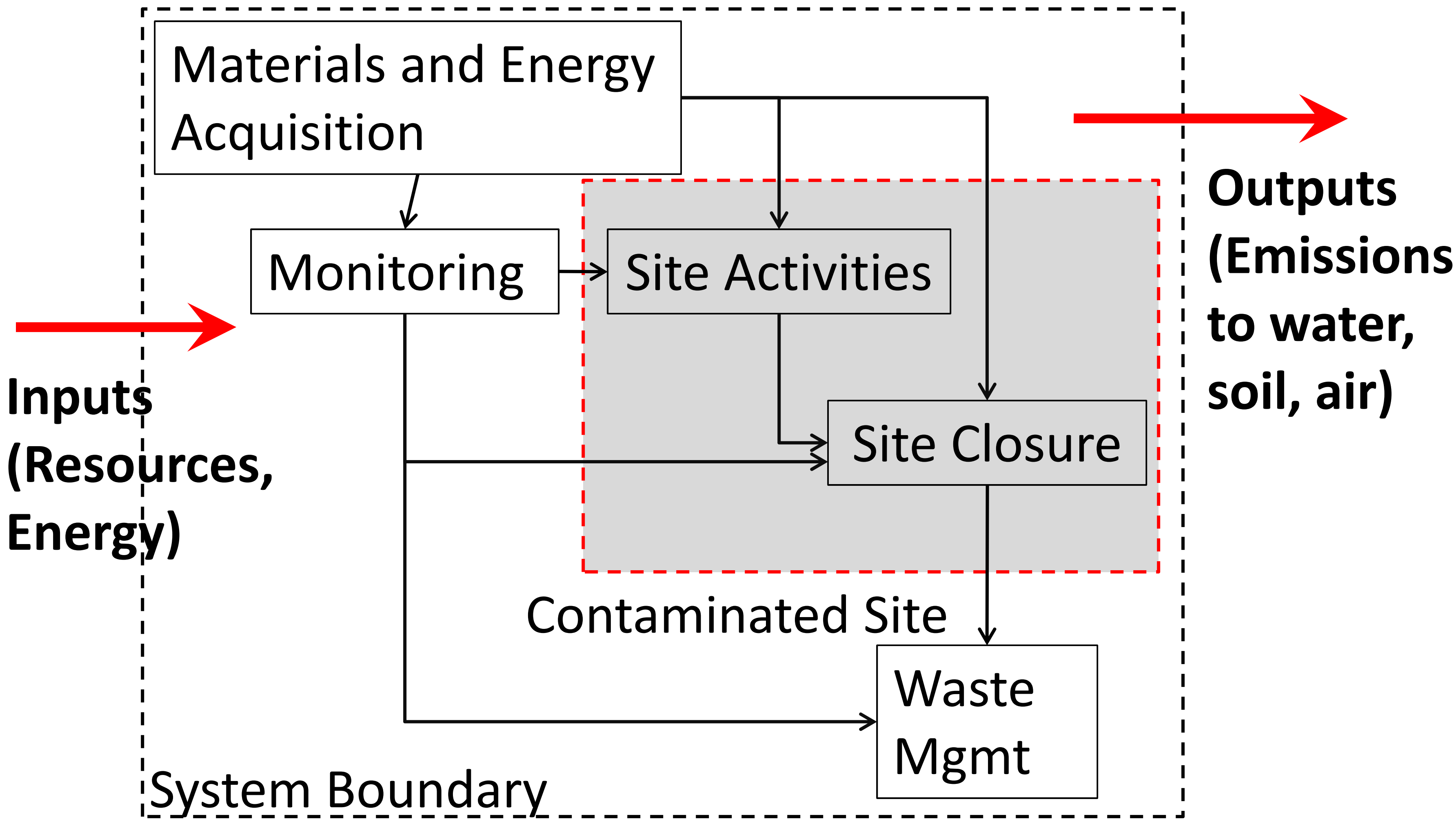


(Modified from http://www.ciraig.org/)

LCA of site remediation

- Published studies demonstrated:
  - Applicability of LCA for site remediation
  - Envtl. footprint differ among technologies
- LCA can estimate overall footprint of cleanup activities or specific metrics (e.g., CO_2eq, SOx, energy)
- But, cannot replace existing impact assessment methods to evaluate local risks

Typical life cycle process flow diagram of site remediation projects



(based on Volkweing et al. 1999)

Types of impacts associated with site remediation

- Primary : associated with envtl. quality of the site (contaminants)
- **Secondary** : associated with remediation activities
- Tertiary : associated with change in land use and ultimate fate of the site

Case Study:

- Diesel spill in Hopedale
- Risks identified to site residents
- Soil contaminated > site-specific criteria had to be removed
- Treatment option selected: On-site in passively aerated biopile

Goal and scope of LCA

- Goal: Comparison of the secondary impacts of 3 options achieving the functional unit :

  "treatment of 110m³ of soil contaminated with diesel to an acceptable risk level over the short term"

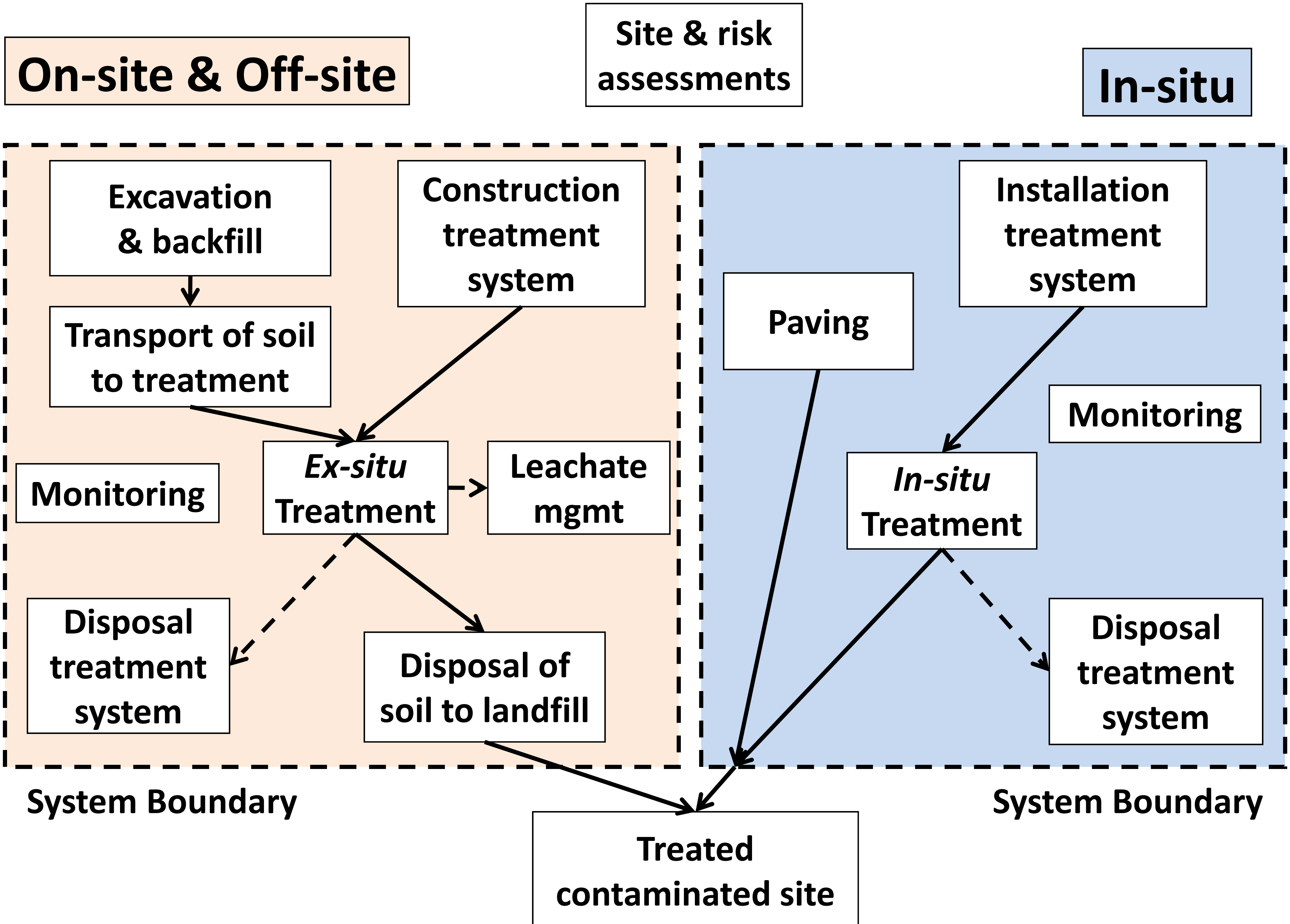
- Approach combined risk assessment (RA) and LCA:
  - Handling of primary impacts (contaminants) through RA and comparison with guidelines
  - LCA focuses on secondary impacts

Remediation options examined

1. On-site: temporary passively-aerated biopile

2. Off-site: transport soil by barge to Goose Bay (800 km) for treatment in permanent facility

3. *In-situ*: capping in place (paving) and bioventing with wind-powered pump


On-site & Off-site
Site & risk assessments
In-situ
Excavation & backfill
Construction treatment system
Transport of soil to treatment
Ex-situ Treatment
Leachate mgmt
Monitoring
Disposal treatment system
Disposal of soil to landfill
Paving
Installation treatment system
Monitoring
In-situ Treatment
Disposal treatment system
System Boundary
System Boundary
Treated contaminated site

LCA methodology

- Detailed LCA with SimaPro (LCA software)
- Life cycle inventory based on:
  - Ecoinvent (European database) for > 4000 processes (e.g., transport, PVC pipes production)
  - Processes modified with US EPA NONROAD (e.g., front-end loader)
- Life cycle impact assessment (Impact 2002+)
  - 4 damage categories: Human health, Ecosystem quality, Climate change, Resources

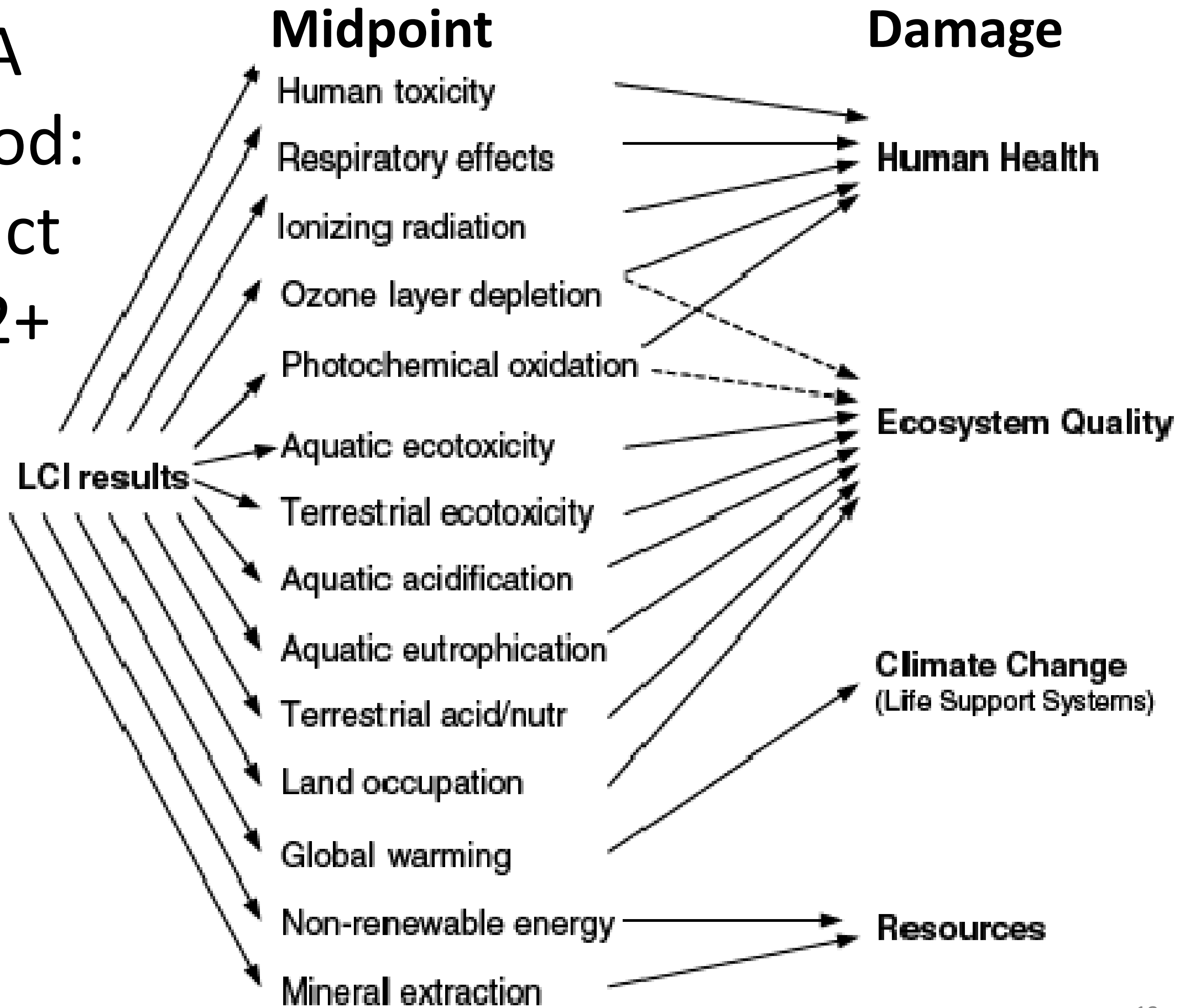
Selected life cycle inventory (LCI) results

	On-site	Off-site	*In-situ*
Material			
Diesel (kg)	1190	3290	260
Kerosene (kg)	546	258	1540
Emissions to the air			
CO_2, fossil (metric ton)	8.0	16.4	8.4
Dioxins (μg)	76	5	106
NO_x (kg)	64	154	37
$PM_{2.5}$ (kg)	2.3	6.1	1.0
SO_2 (kg)	13	27	12
Emission to the soil			
Aluminum (g)	59	119	63
Zinc (g)	2.5	6.1	1.3

4X 8X 4X

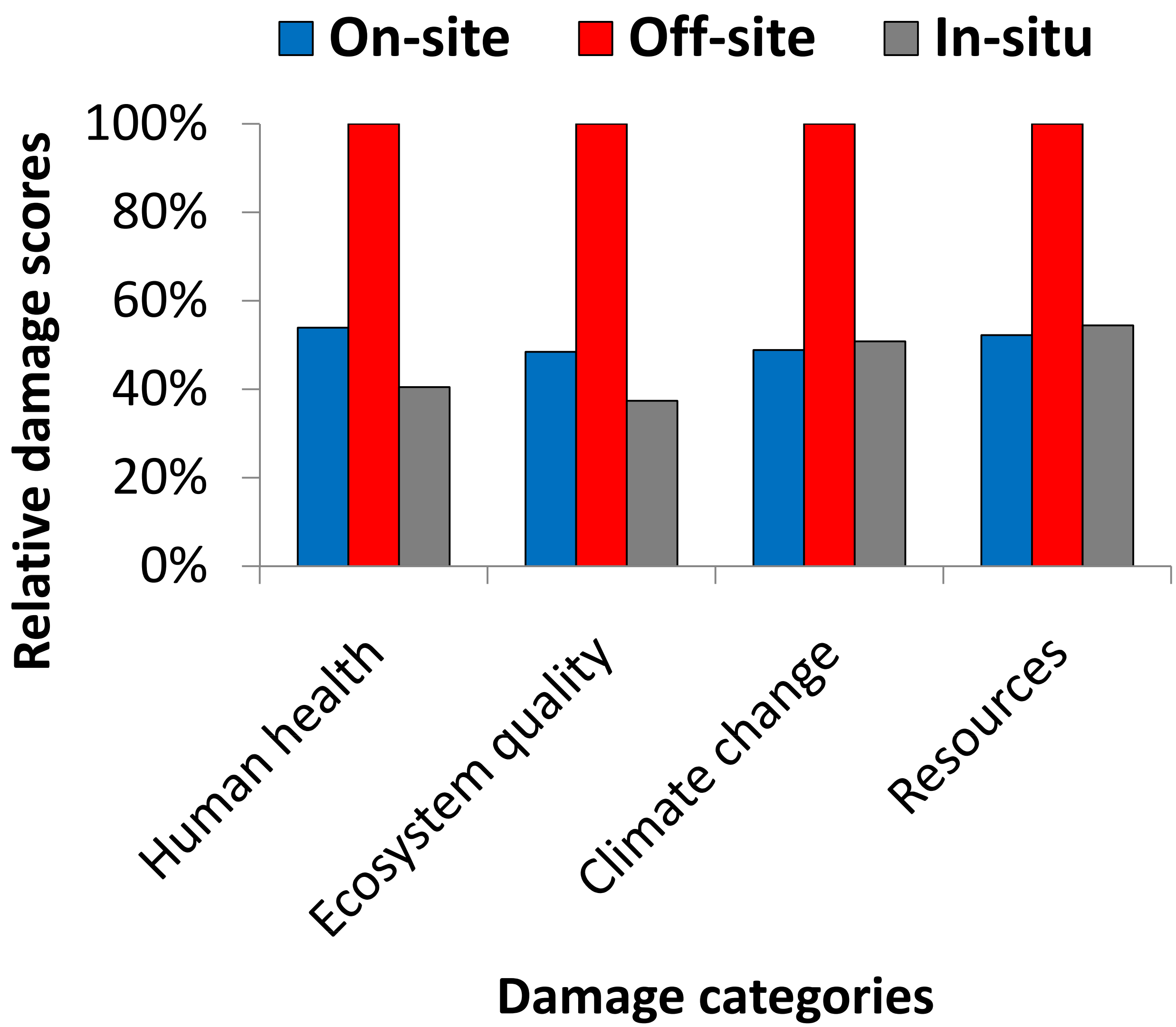
Mass of diesel initially in soil ~430 kg

LCIA method: Impact 2002+

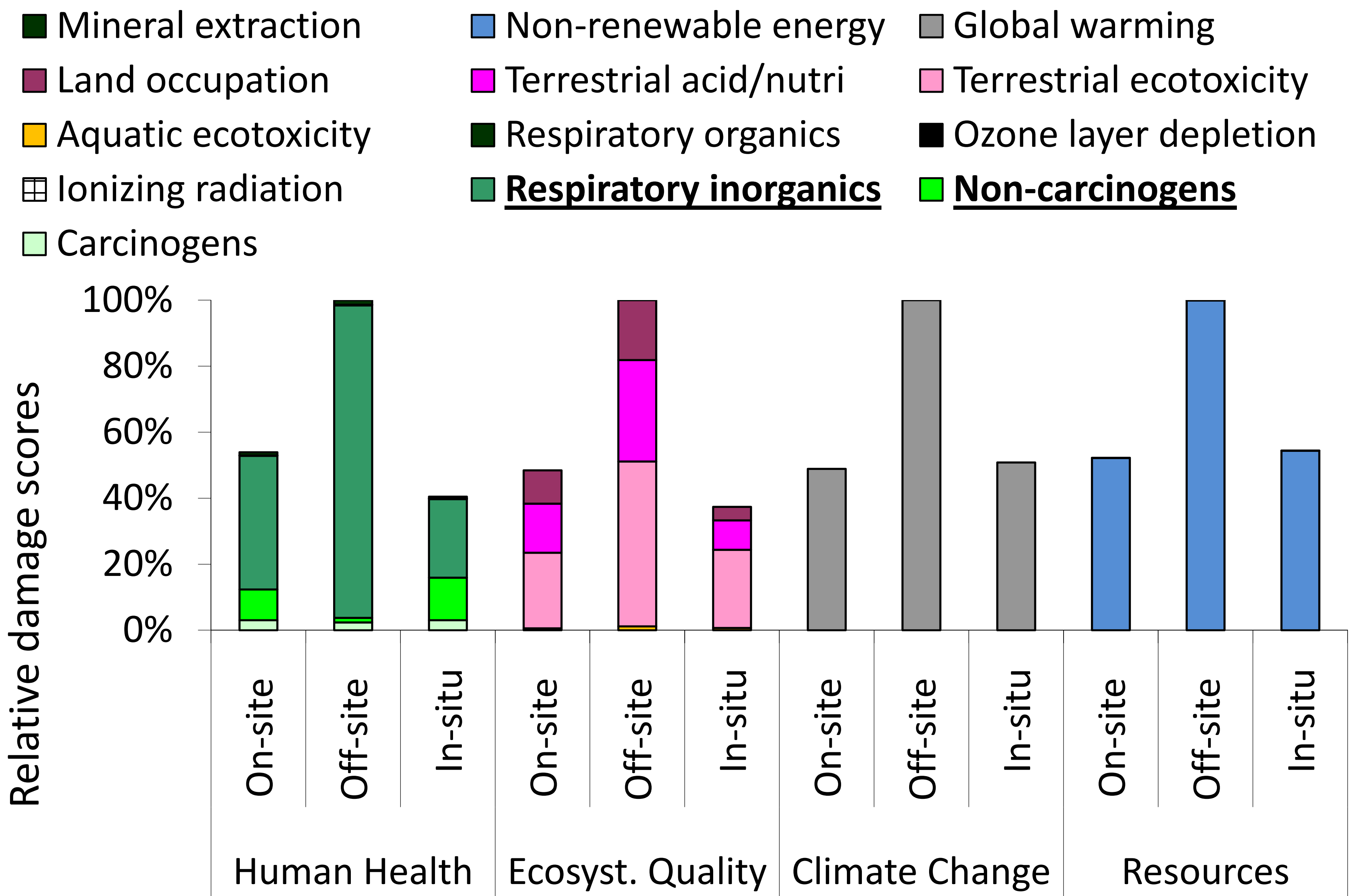


(Jolliet *et al.*, 2003)

Impact assessment results



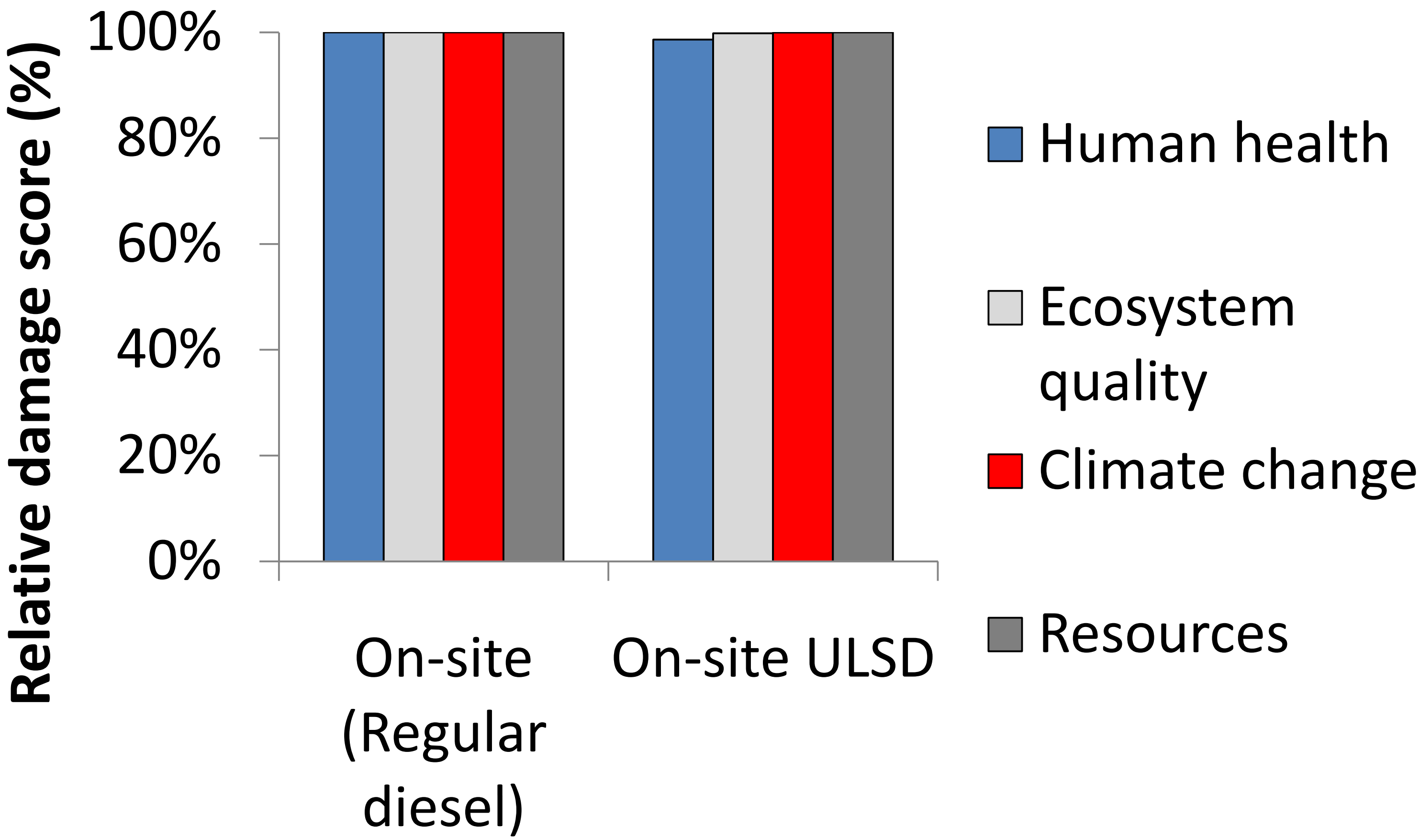
Impact contribution of midpoint categories



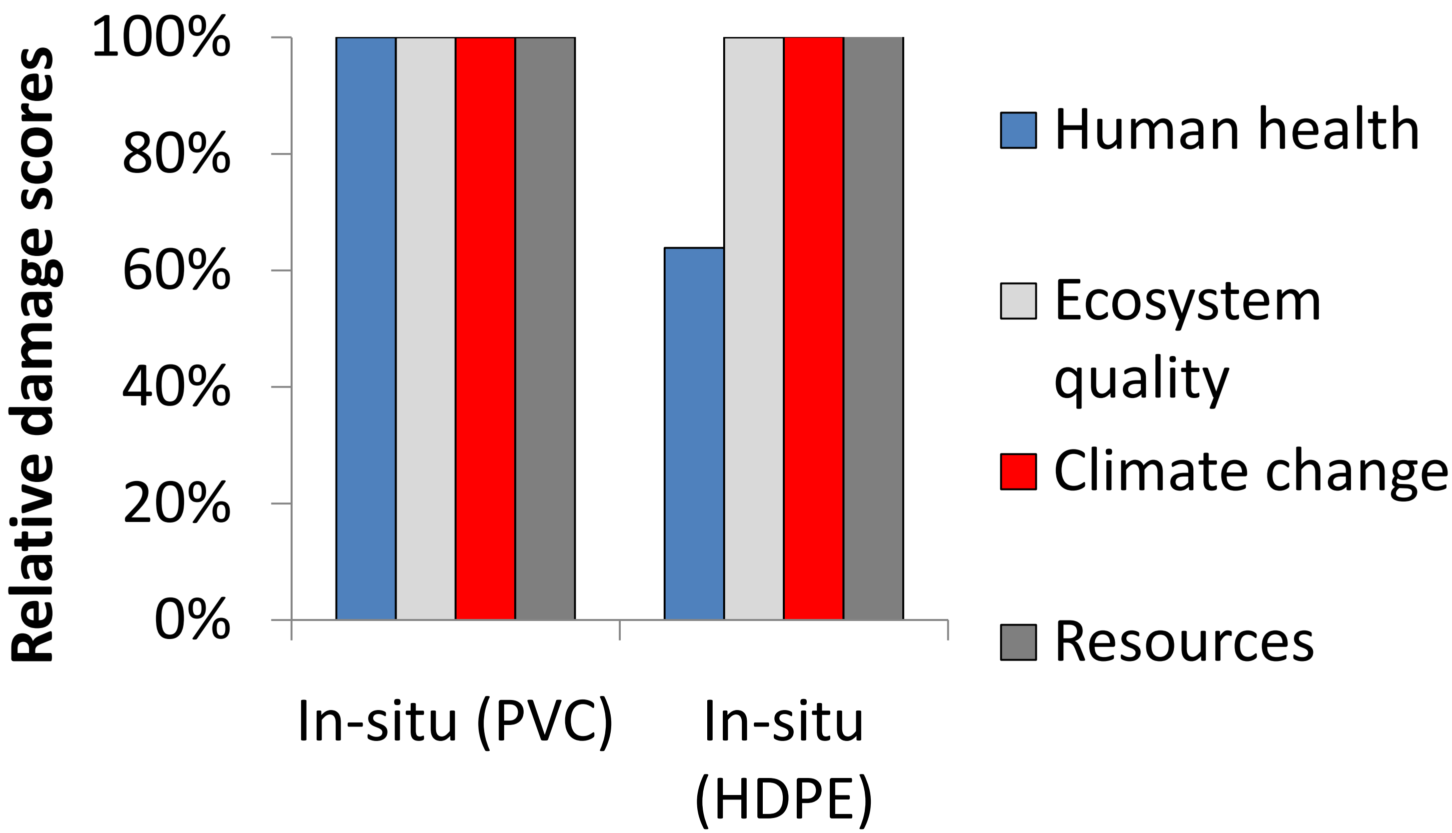
Impact contribution of major processes

Processes	Human Health			Ecosystem Quality			Climate change			Resources		
	On-site	Off-site	*In-situ*	On-site	Off-site	*In-situ*	On-site	Off-site	*In-situ*	On-site	Off-site	*In-situ*
Transport, barge	45%	65%	10%	51%	66%	11%	47%	60%	7%	41%	57%	6%
Transport, aircraft, passenger	10%	3%	39%	18%	4%	70%	26%	6%	76%	28%	7%	79%
Transport, dump truck	3%	4%	-	8%	10%	-	5%	6%	-	5%	6%	-
Operation, forklift	5%	9%	-	6%	8%	-	8%	11%	-	7%	11%	-
Operation, backhoe	7%	14%	1%	3%	6%	1%	4%	8%	1%	4%	8%	1%
Production, PVC	20%	-	37%	-	-	-	-	-	-	1%	-	1%
Production, HDPE	2%	2%	-	-	0	-	3%	2%	1%	9%	7%	-
Production, asphalt	-	-	4%	-	-	5%	-	-	3%	-	-	6%

Improvement Scenario 1 – Use of ultra-low sulfur diesel and particulate filter for heavy machinery in On-site option



Improvement Scenario 2 – Use of HDPE pipes in place of PVC pipes for *in-situ* bioventing system



Summary

Remediation of diesel contaminated remote sites:

- Secondary impacts of on-site ≈ in-situ < off-site
- Modeled options use > 4X fuel in soil
- Main contributor: fossil energy use
- Remoteness is a key factor (trade-offs)

Risk Assessment and LCA – Complementary tools:

- Risk assessment : protection of local envt.
- LCA: minimization of overall footprint of remediation

Conclusions for the application of LCA to sustainable remediation

- Advantages of LCA
  – Established holistic tool
  – Consider activities « beyond the fence »
  – Prevent/reduce pollution shifting
  – LCA principles can be integrated early without full LCAs
- Limitations of LCA
  – Additional step that requires data, time, expertise, $
  – Limited site-specificity
  – Caution warranted when extrapolating results of studies
- Applied to multi-criteria analysis framework, LCA can support the objectives of sustainable remediation.

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Publications and cited references

Publications related to this work:

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