Life Cycle Assessment Analysis of Various Active and Passive Acid Mine Drainage Treatment Options

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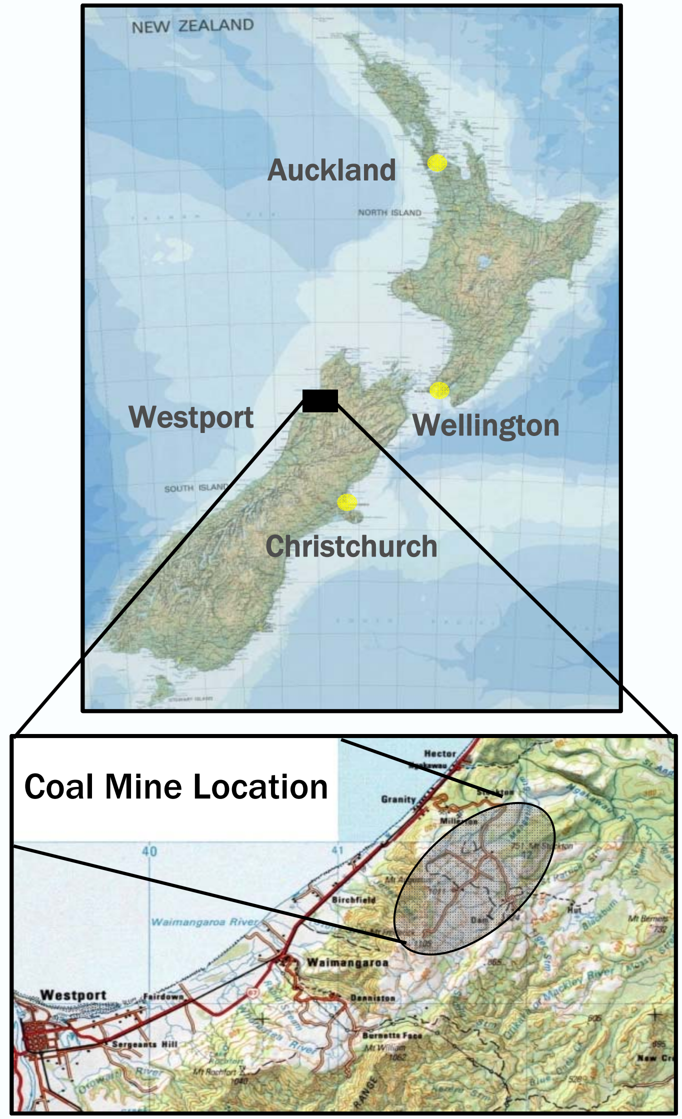
- Coal Association of New Zealand
- University of Canterbury
  - Department of Civil & Natural Resources Engineering

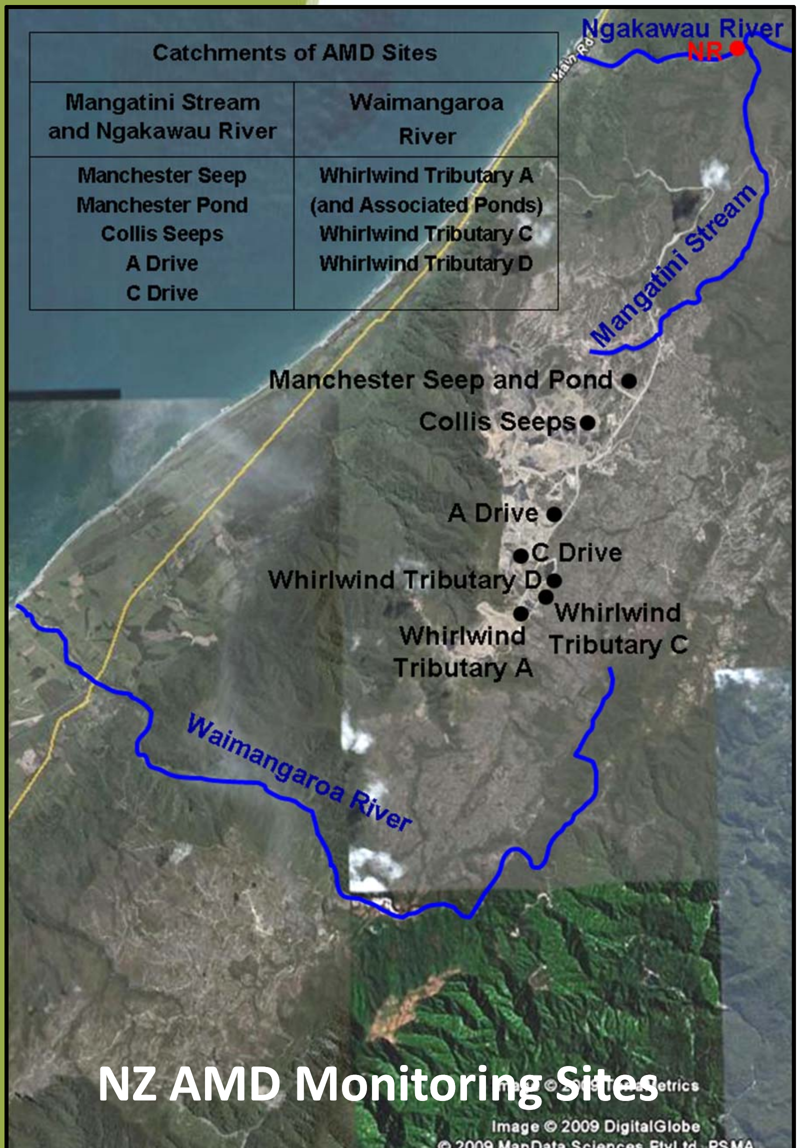
Project Location

- Stockton Coal Mine, New Zealand
- West Coast on the South Island
- New Zealand's largest open cast coal mine

McCauley et al (2010)



AMD Monitoring Sites



McCauley et al (2010)

- 13 Sites
  - 10 seep locations
  - Effluent from 3 sediment ponds
- Primary water chemistry parameters
  - Dissolved metals
  - pH
  - Sulfate
  - Acidity
- Community agreed on compliance levels of pH≥4.0 and 1 mg/L Al 99% of the time

Manchester Seep Description

- Candidate site for assessing AMD treatment methods
- Reportedly not influenced by active or future mining

McCauley et al (2010)

	Median	Min	Max
Flow (L/s)	1.84	0.35	10.5
pH	2.8	2.5	3.3
DO (mg/L)	9.6	8.1	10.9
DO (% Saturation)	82	73	94
Eh (mV)	709	691	744
Calculated Acidity (mg/L as $CaCO_3$)	426	88	728
Diss Fe (mg/L)	63	4.3	143
Diss Al (mg/L)	33	7.4	57
Sulphate (mg/L)	428	101	692

AMD Treatment Scenario Overview

- Passive Treatment Methods
  - Mussel Shell Bioreactor
    - Waste product in NZ from large fishery industry
    - Adds alkalinity and reduces metal concentrations

- Active Treatment Methods
  - Lime Dosing
  - Lime Slaking Plant

Environmental analysis of treatment methods using LCA… What is LCA?

McCauley et al (2010)

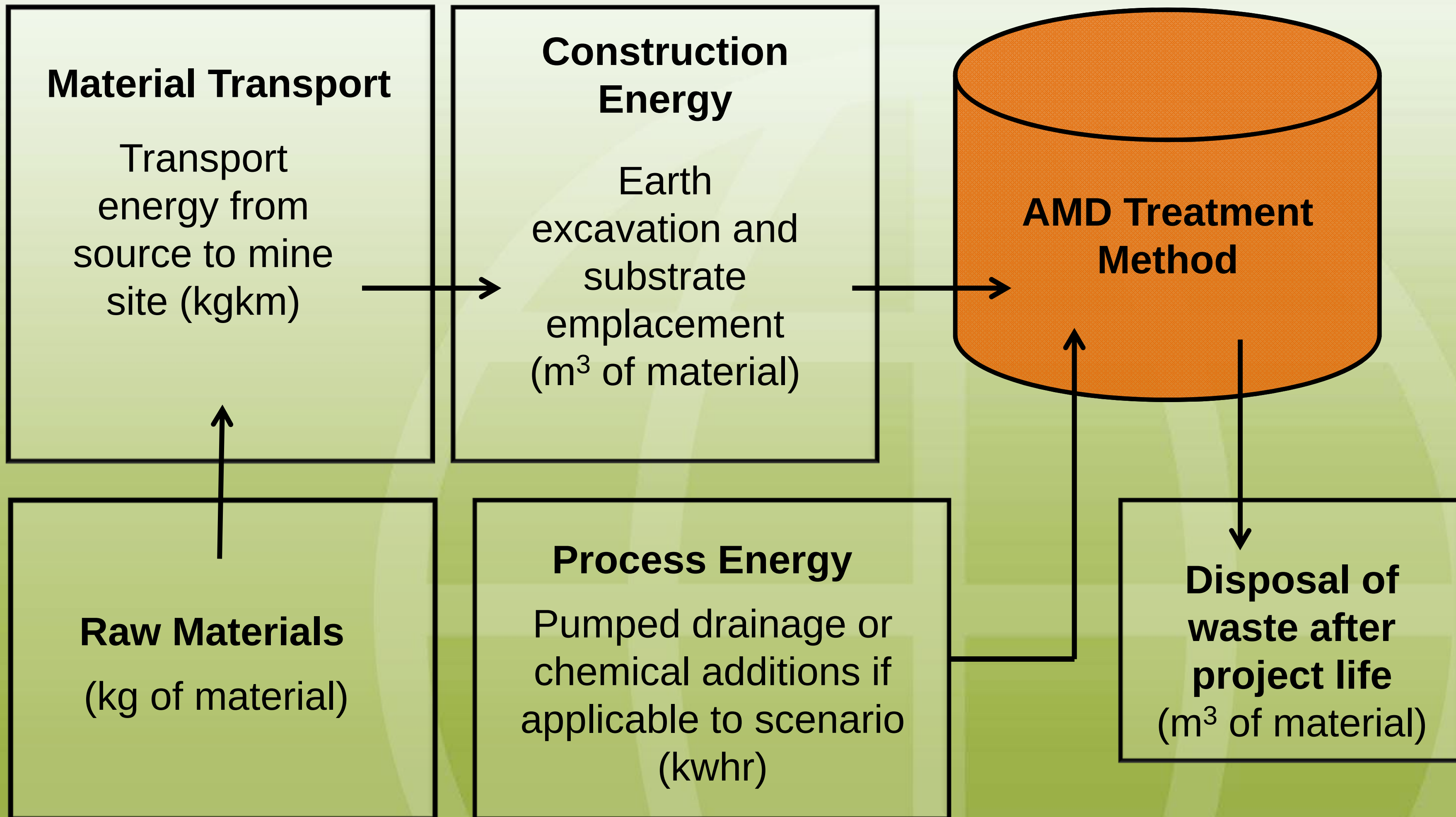
Mussel shells used as bioreactor substrate

LCA History and Background

- Life Cycle Assessment (LCA) - approach to quantifying the environmental impacts of a scenario
- "Cradle to Grave"
  - Compile inventory
  - Evaluating potential impacts
  - Interpreting results to make informed decision

www.solidworks.com

LCA Input Value Definitions



Functional Unit: kg acidity removed/day

Impact Category Selection and Functional Unit

- SimaPro 7.3 (Netherlands)
- Midpoint category selection:
  - Indicators chosen between inventory results and endpoints
  - Impact assessment translated into environmental themes
  - Less uncertainty
- Endpoint category selection:
  - Environmental relevance linked into issues of concern
  - Higher uncertainty- easier to understand and interpret

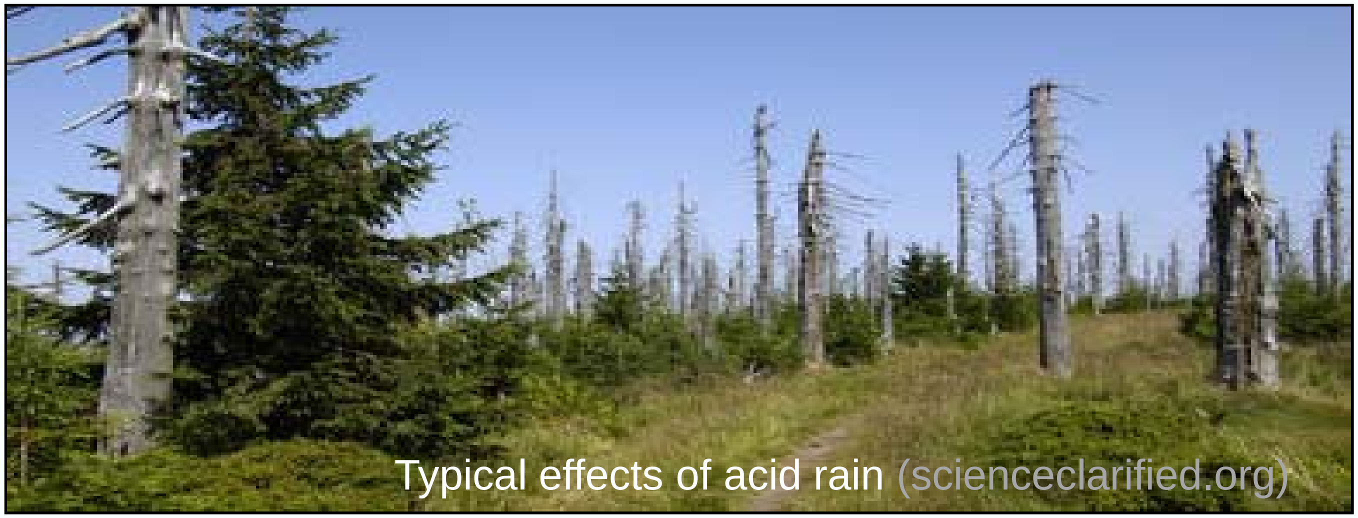
SimaPro Category Definitions

Midpoint Categories

- Climate Change
  - Change in weather patterns
- Terrestrial Acidification
  - Deposition of wet and dry acidic components

Endpoint Categories

- Damage to Human Health
  - Respiratory diseases
  - Cancer
- Damage to Ecosystems
  - Dying forests
  - Extinction of species



Typical effects of acid rain (scienceclarified.org)

Bioreactor Scenario

McCauley et al (2010)

- Sulfate reducing environment in bioreactor lowers acidity and precipitates metal
- Dimensions: 32 m (w) x 40 m (l) x 2 m (d)
- Substrate: 30 vol. % mussel shells, 30 vol. % bark, 25 vol. % post peel, 15 vol. % compost
- AMD gravity-fed from sedimentation pond receiving Manchester Seep AMD
- Flow into bioreactor is 2.29 L/s
- Designed to remove 85.2 kg acidity as $CaCO_3$/day
- 16.9 year lifetime

Bioreactor Scenario Modifications

- Mussel shell bioreactor with modified transport
  - ½ transport distances for all materials
- Mussel shell bioreactor with process energy
  - Pump added for non-gravity fed AMD
- Modified substrate bioreactor
  - Volume of mussel shell substrate replaced by limestone
- Mussel shell leaching bed
  - Mussel shells only substrate included in bioreactor design

Lime-Dosing Scenario

McCauley et al (2010)

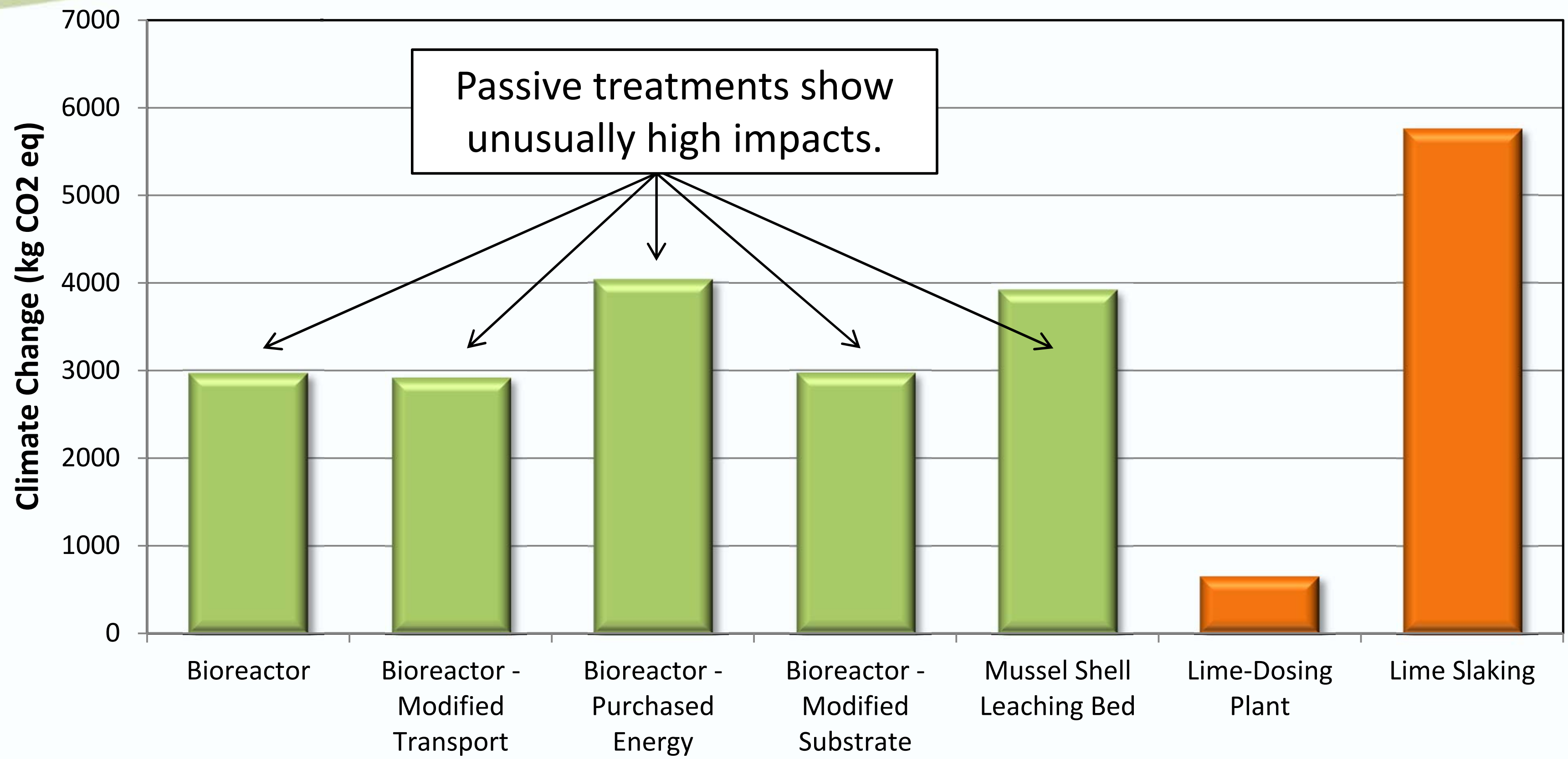
- Ultra-fine limestone (UFL) neutralizes acidity and precipitates metals from Mangatini stream
  - Finely ground limestone ($CaCO_3$)
  - Gravity fed slurry fed into stream
- Natural flow of Mangatini stream is 0.4 m^3/s
- Treats 17,800 kg acidity as $CaCO_3$/day
- Consumes 11,000 tonnes UFL per year
- Only material inputs are ultrafine limestone and a prefabricated silo for storing the limestone

Lime Slaking Plant Scenario

http://www.aditnow.co.uk

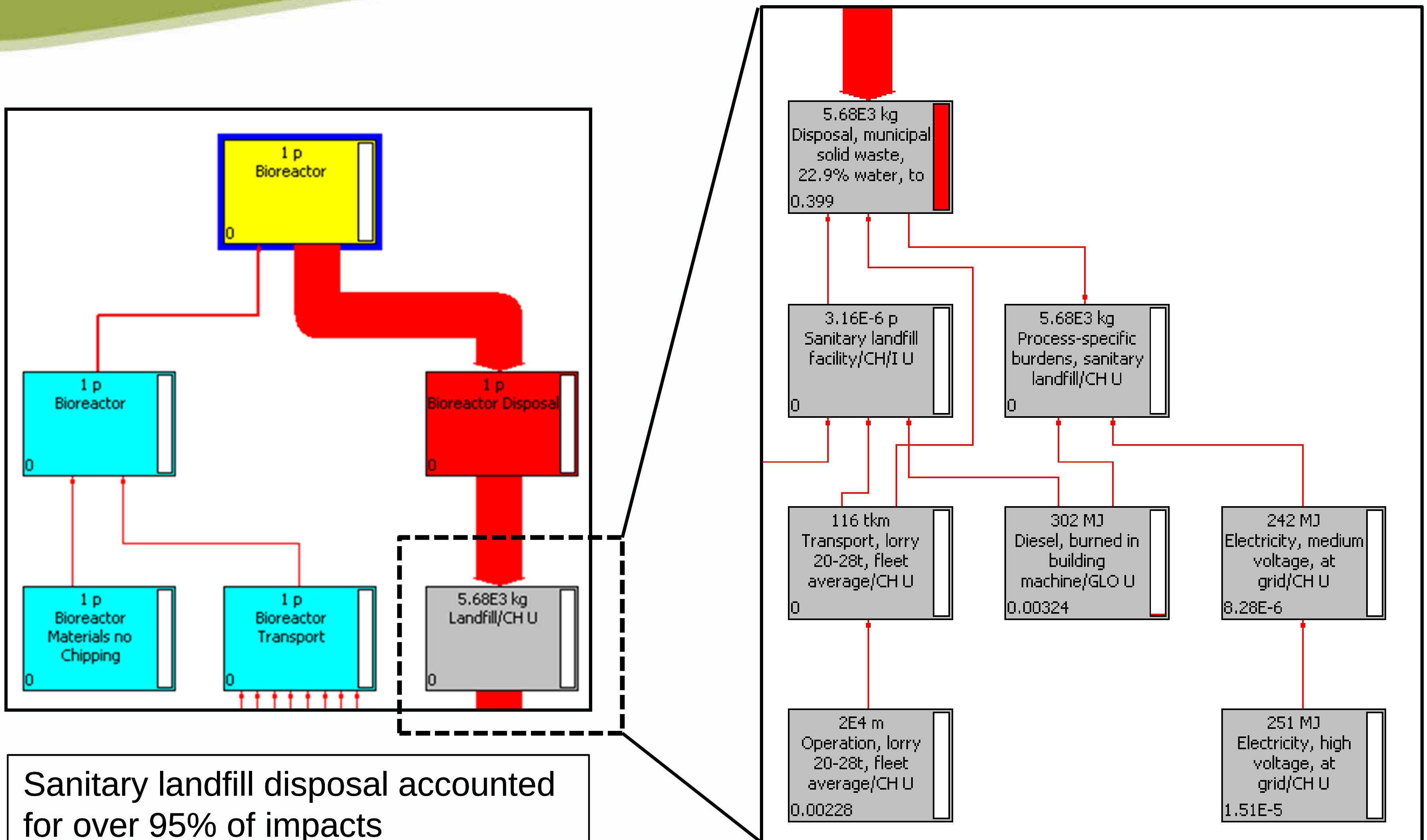
- Lime slaking utilizes hydrated lime for AMD treatment
  - Calcium oxide slaked with water
  - Hydrated Lime: $Ca(OH)_2$
- EPA Design Manual: Neutralization of Acid Mine Drainage
- Designed using parameters from lime dosing scenario
- Consumes 6,200 tonnes hydrated lime/year
- Includes: Equalization basin, lime storage and feed system, flash mix tank, aeration tank, settling basin with sludge removal

Preliminary Climate Change Results



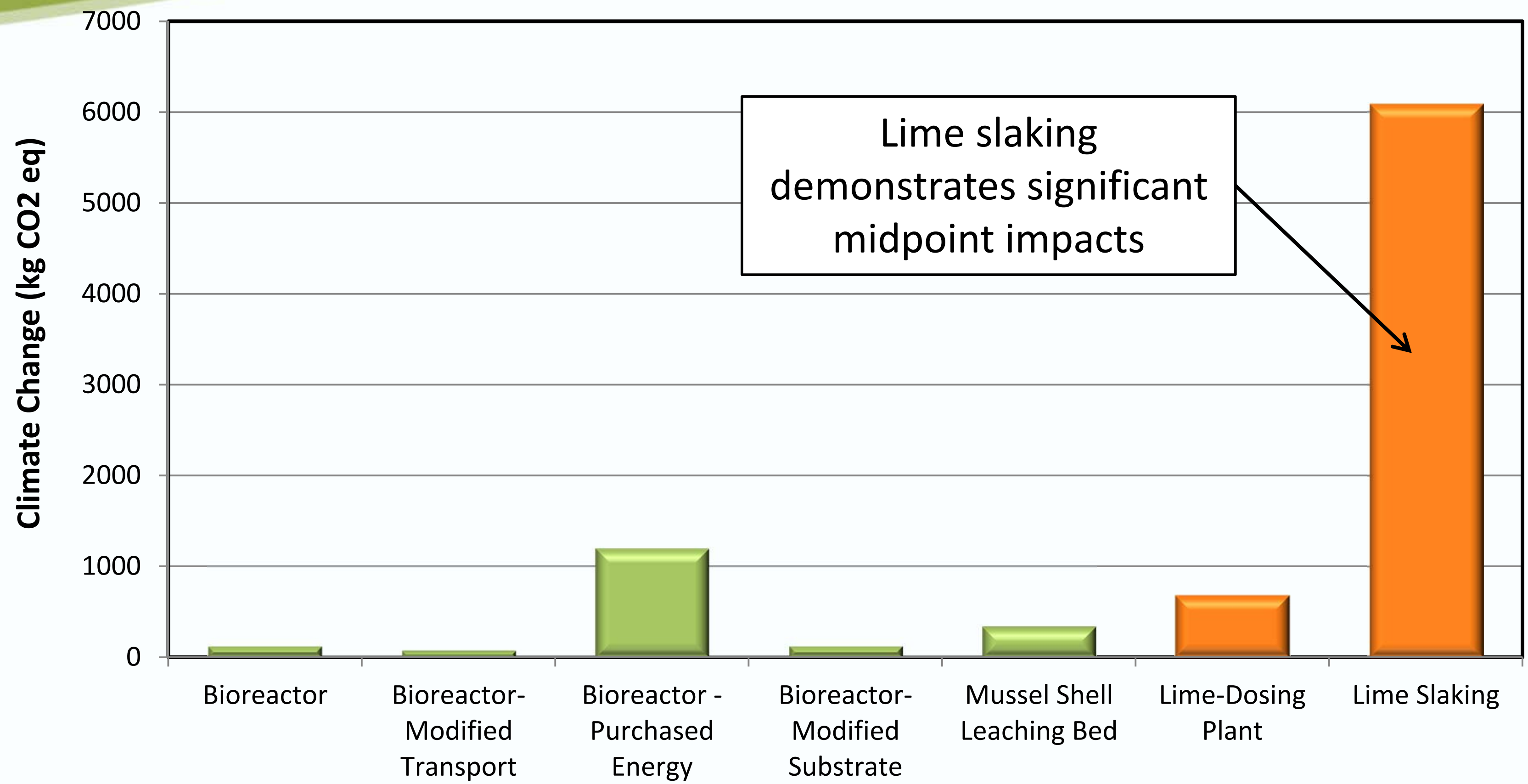
- Disposal for passive treatment buried in sanitary landfill
- Lime-dosing proved to have the least environmental effect

Preliminary Climate Change Bioreactor Network



Sanitary landfill disposal accounted for over 95% of impacts

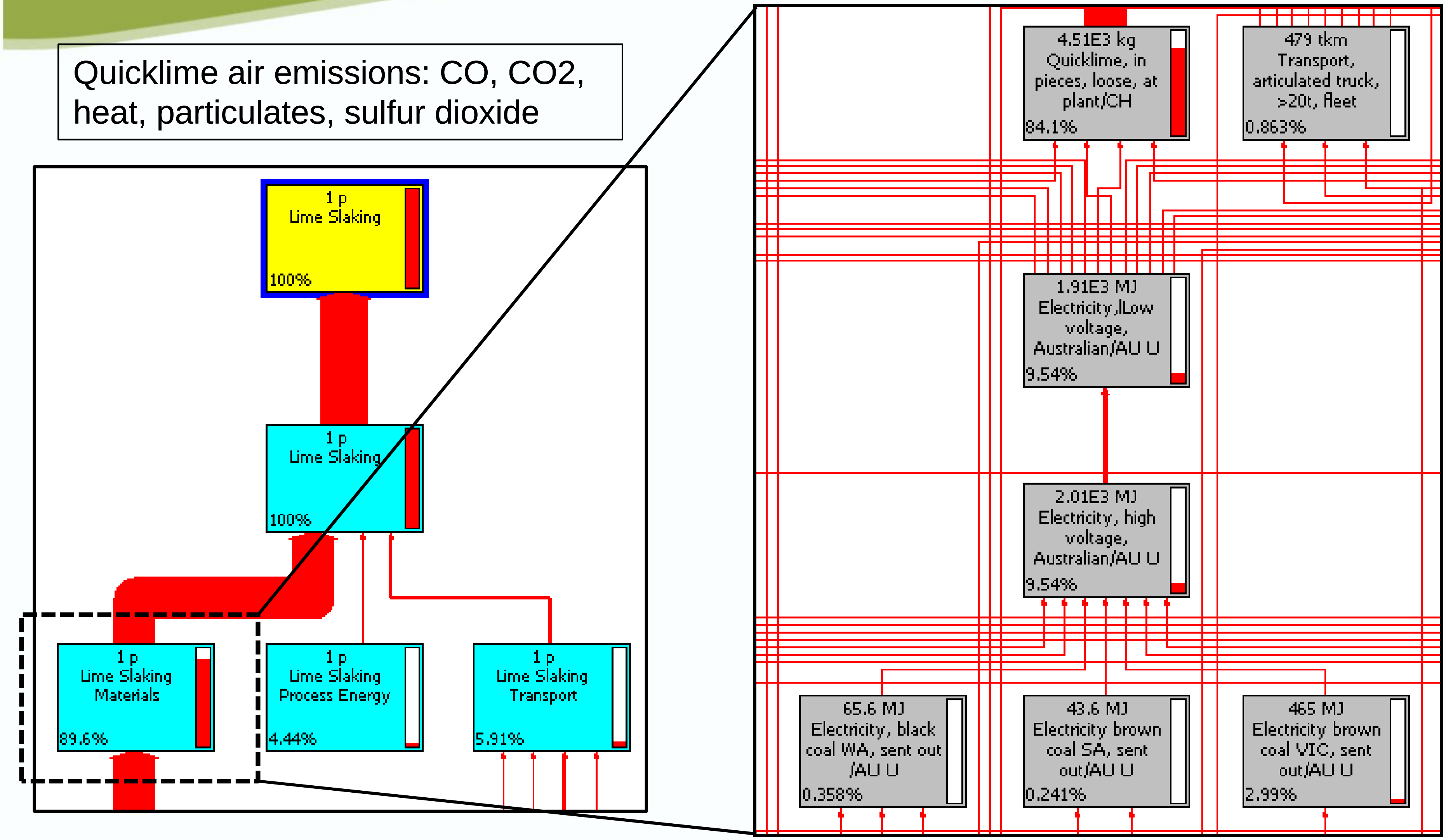
Climate Change Results - Onsite Disposal



- Redesigned scenario for on-site disposal – more realistic
- Significantly reduced passive treatment impacts

Climate Change Lime Slaking Network

Quicklime air emissions: CO, CO2, heat, particulates, sulfur dioxide



Limestone vs. Quicklime Material Preparation

http://leattach.com

Crushed Limestone

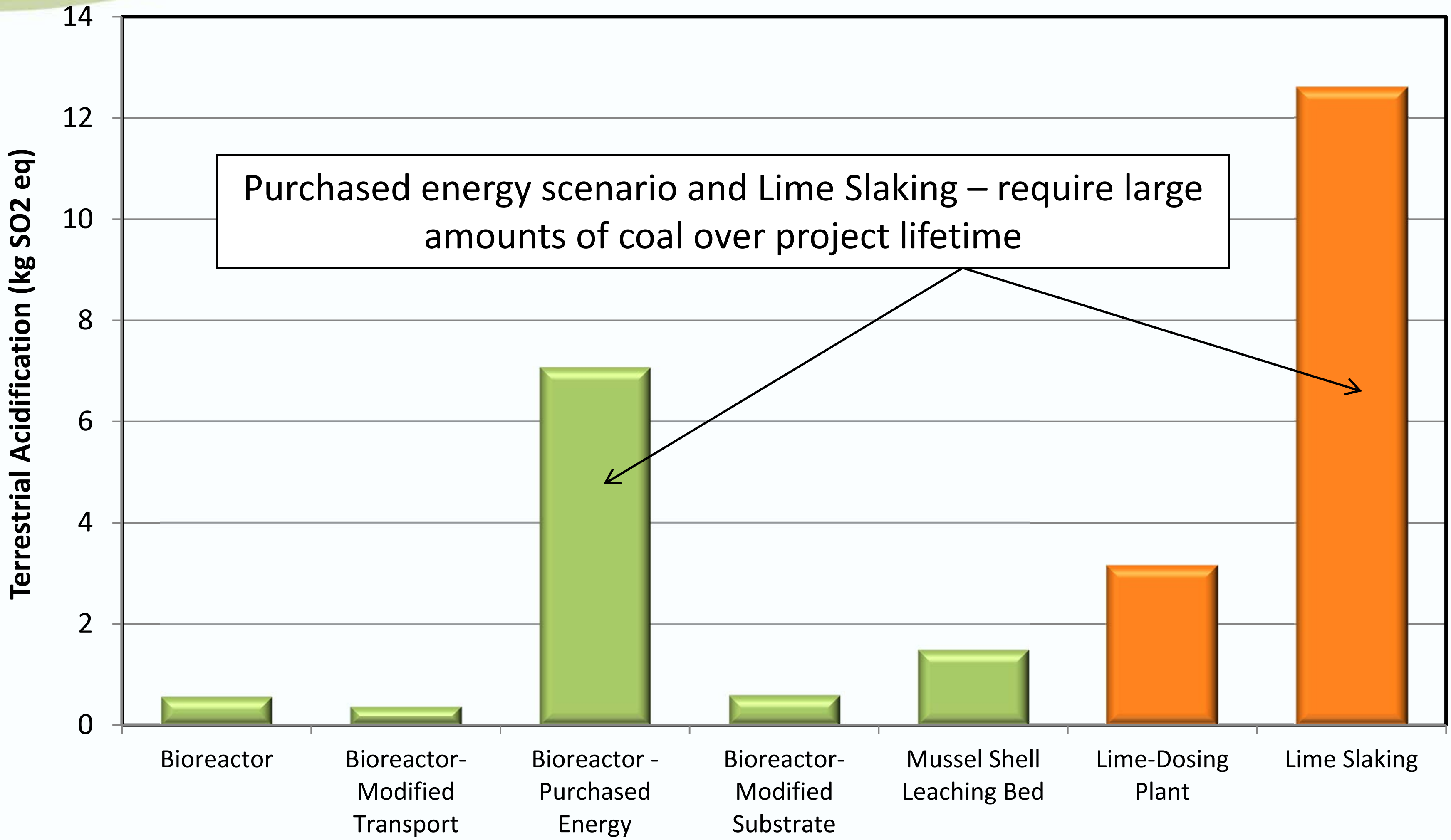
- Process Energy
  - Crushing
  - Washing
  - Transportation by conveyor belt
- Heavy Machinery
  - 2 crushers
  - 2 sieves
  - 2 small silos

http://leattach.com

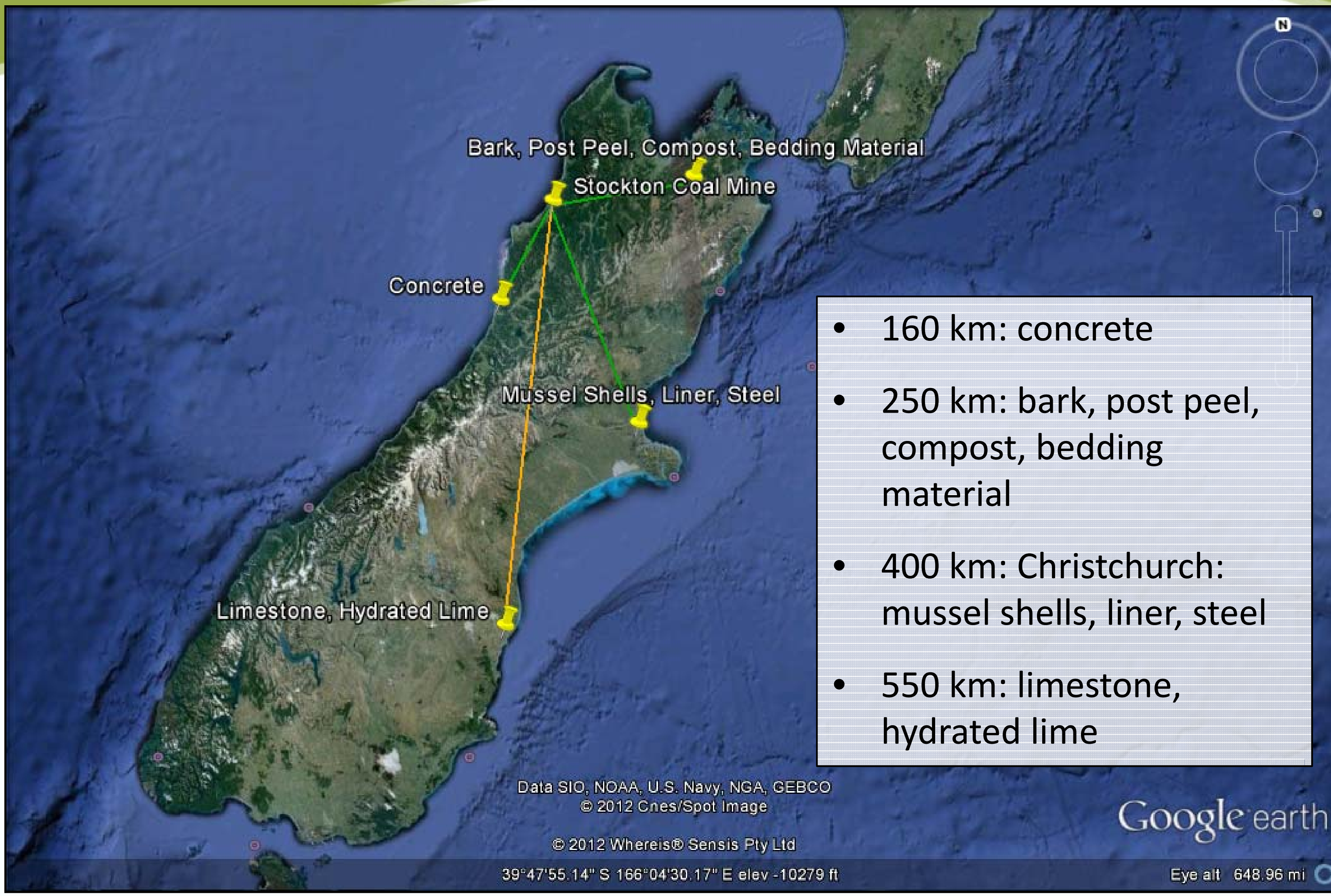
Quicklime

- 17x the process energy of crushed limestone
  - Crushing, milling, cyclone filtering, dedusting, storage,
- 10x the weight of heavy machinery
  - Crusher, roller mill, dedusting plant, cyclone, small silo

Terrestrial Acidification Results



Transportation Distances

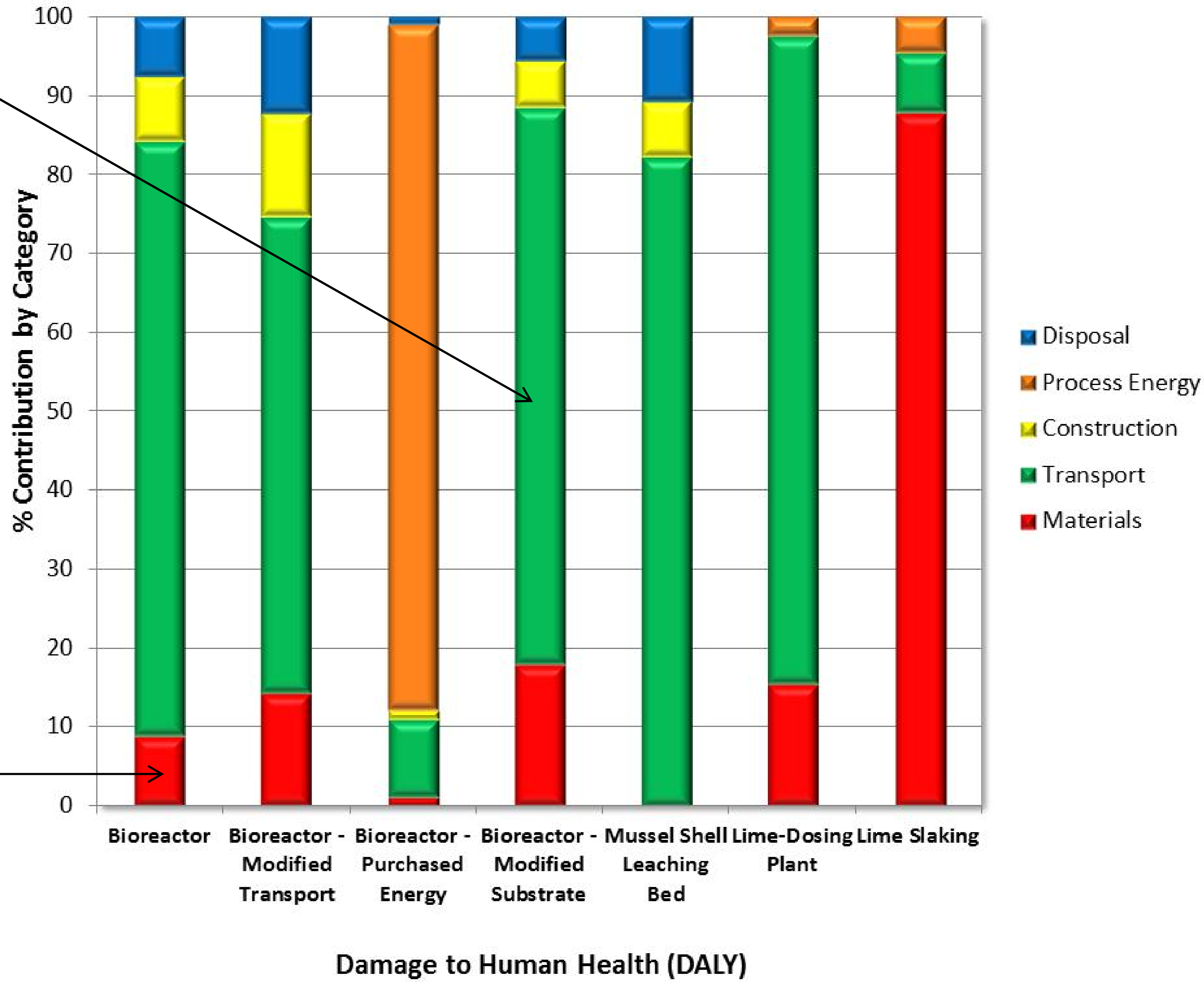


- 160 km: concrete
- 250 km: bark, post peel, compost, bedding material
- 400 km: Christchurch: mussel shells, liner, steel
- 550 km: limestone, hydrated lime

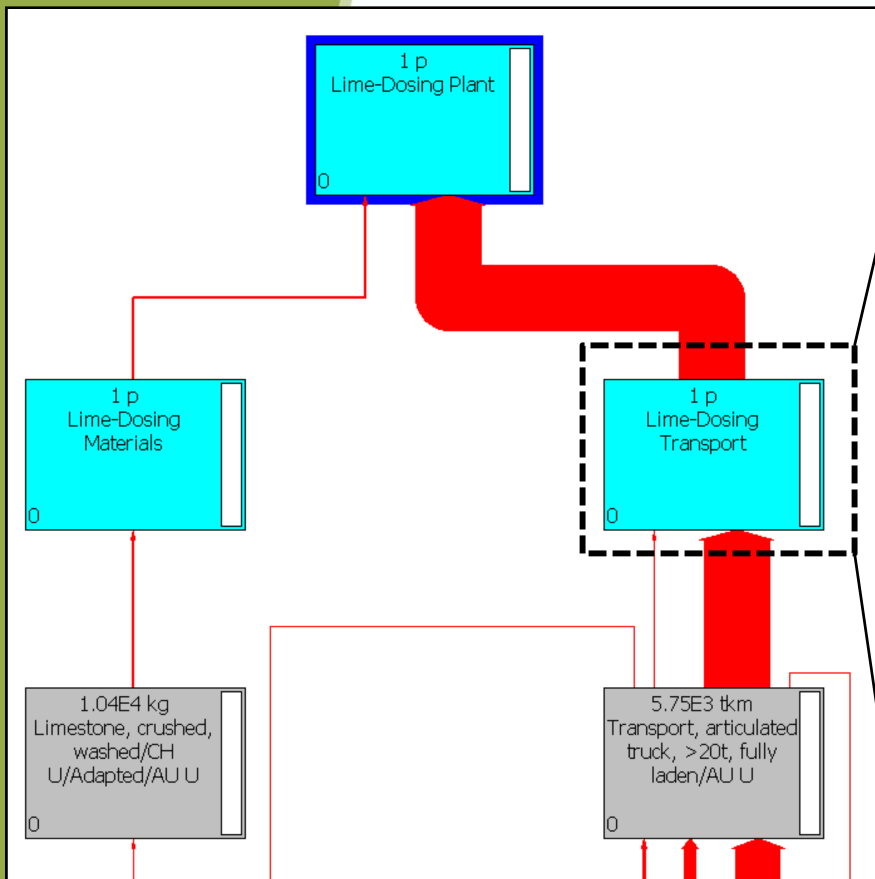
Endpoint Results - Damage to Human Health

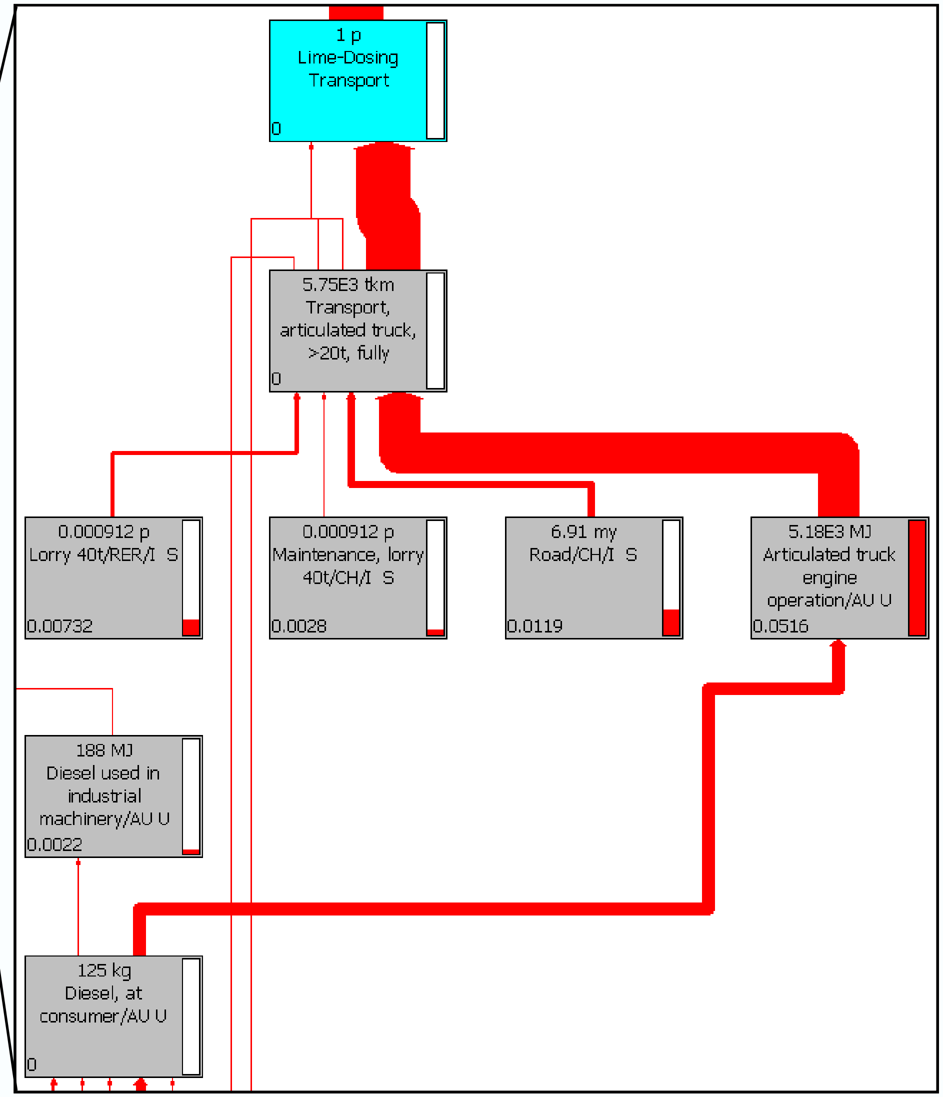
Transport is the main contributor to damage to human health in most scenarios

Bioreactor uses waste materials – shows minimal impact



Lime Dosing Damage to Human Health Network

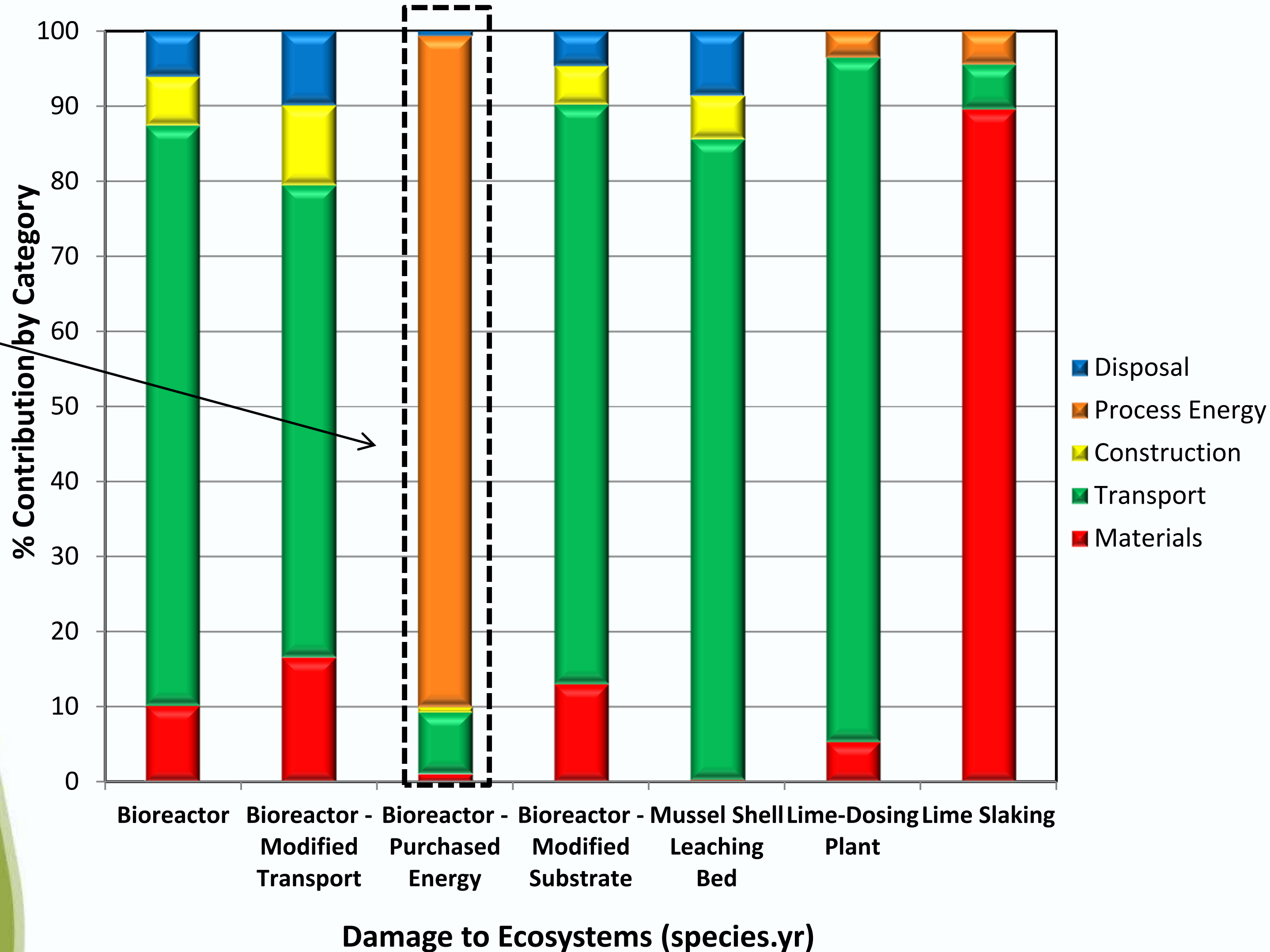




Air emissions associated with articulated engine: carbon dioxide, nitrogen oxides, carbon monoxide, methane; minimal soil and water emissions

Endpoint Results - Damage to Ecosystems

Process energy larger contributor to bioreactor versus lime dosing and lime slaking



Process Energy Breakdown

- Bioreactor with Purchased Energy
  - Pumps AMD constantly
  - 3822 kWh/kg acidity removed per day
- Lime Dosing
  - Pumps only chemical addition, AMD gravity fed
  - 83 kWh/kg acidity removed per day
- Lime Slaking
  - Pumps chemical addition and AMD
  - 911 kWh/kg acidity removed per day

Bioreactor: $260/ kg acidity removed per day
Lime Dosing: $6/ kg acidity removed per day
Lime Slaking: $62/ kg acidity removed per day

Picture: *earthmagazine.org* Energy Costs: *eia.gov*

Conclusions

- Passive versus Active Treatments
  - Efficiency based on treatment abilities
  - Environmental impacts
- Limestone vs. quicklime
- Utilize locally sourced and waste materials
- On-site disposal vs. sanitary landfill
- Largest contributor- gravity fed AMD and chemical additions in placement of pumps
- Factors to consider- economic, social, environmental
  - Scope of LCA

Recommendations

- AMD Treatment approach dependent on a number of items:
  - Amount of AMD
  - Material costs
  - Available sources of alkalinity
  - Local waste materials
  - Site suitability for feeding AMD
- Use LCA as a piece of the puzzle to determine the best treatment option for the site

http://www.earthlife.org

Thank you for your time.

Questions?

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