Using Systems Thinking and Waste Materials to Improve the Sustainability Footprint of a Cleanup – The Drive for a Zero Footprint Cleanup Technology

Paul Favara - Gainesville, FL

Jeff Gamlin - Denver, CO

ch2m[SM]

Delivering Sustainable Solutions to Complex Local Challenges, Worldwide

Fourth International Symposium on Bioremediation and Sustainable Environmental Technologies

Agenda and Key Points

Agenda

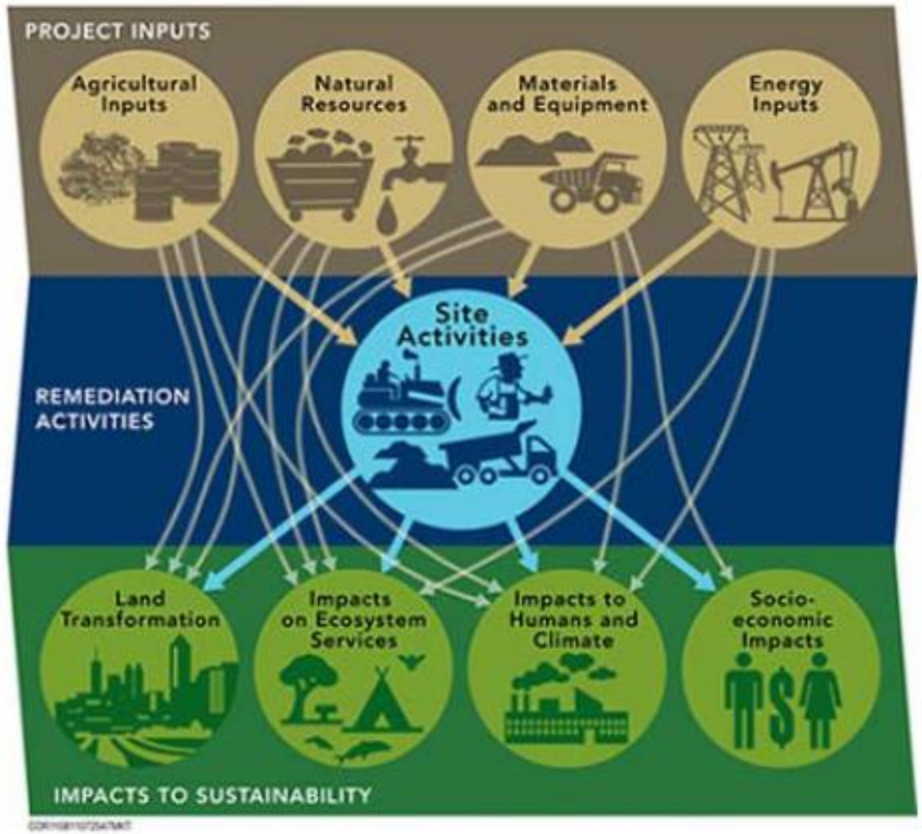
- Introductory Remarks
- Top Down VS Bottom Up approach
- Technology overview and performance
- LCA of SBGR VS EISB
- Optimization opportunities for EISB and SBGR
- Summary

Key Points

- Top-down VS Bottom-Up thinking
- Use of waste materials in cleanup avoids impacts to the
  - environment and society
  - saves money
- LCA provides a lens to identify optimization opportunities
- If you challenge conventional thinking, you can get better results

Introduction → Top Down & Bottom Up → SBGR Overview → LCA → Optimization → Summary

“Tug on anything at all and you will find it connected to everything in the universe” – John Muir

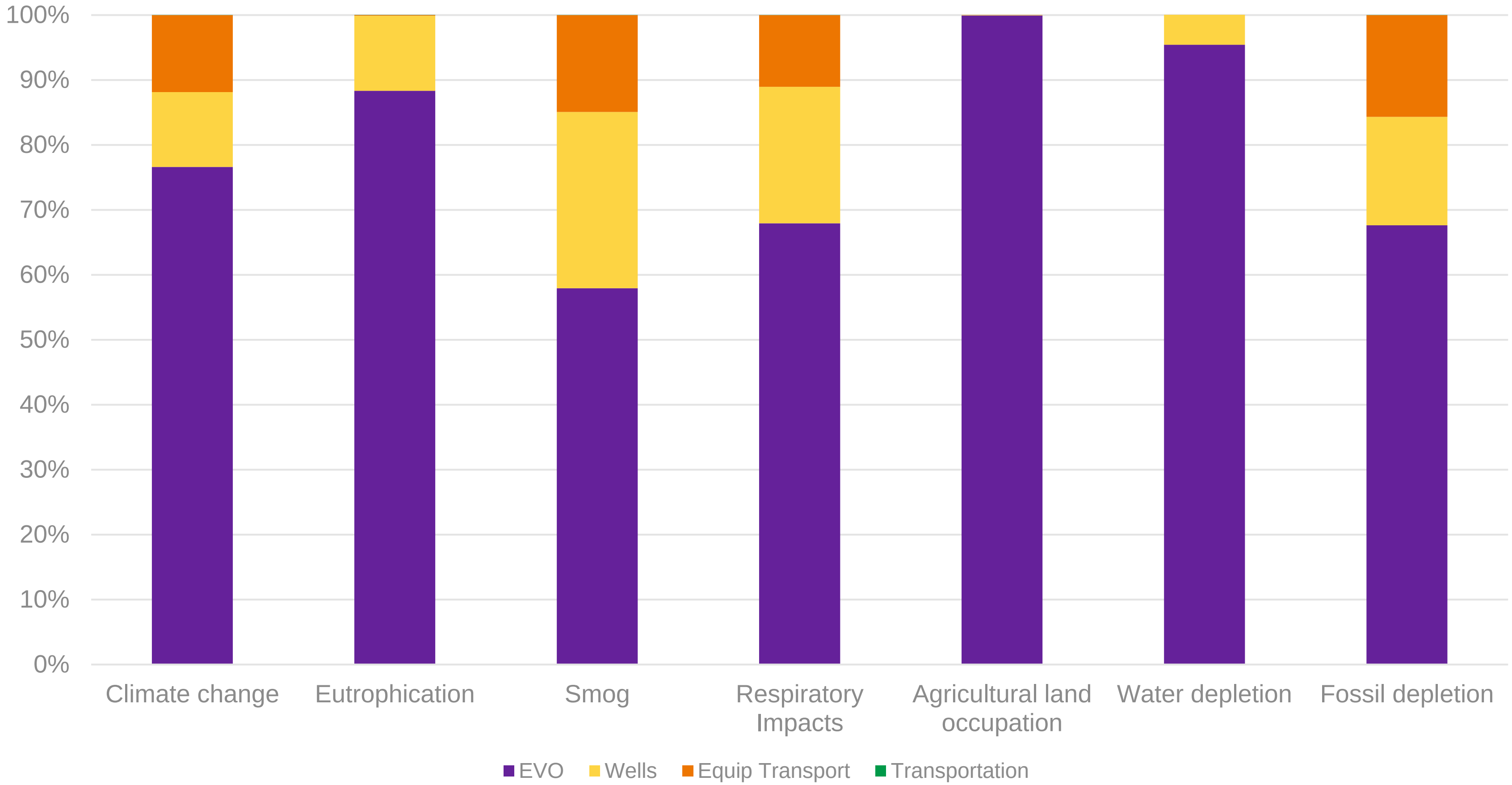


How do you define sustainability?

- Is it carbon only?
- Energy?
- Or does it address other environmental impact factors too?
- Cost?
- Society?
- If you look at a project with a wider lens, you see more opportunity to improve

EVO Impacts

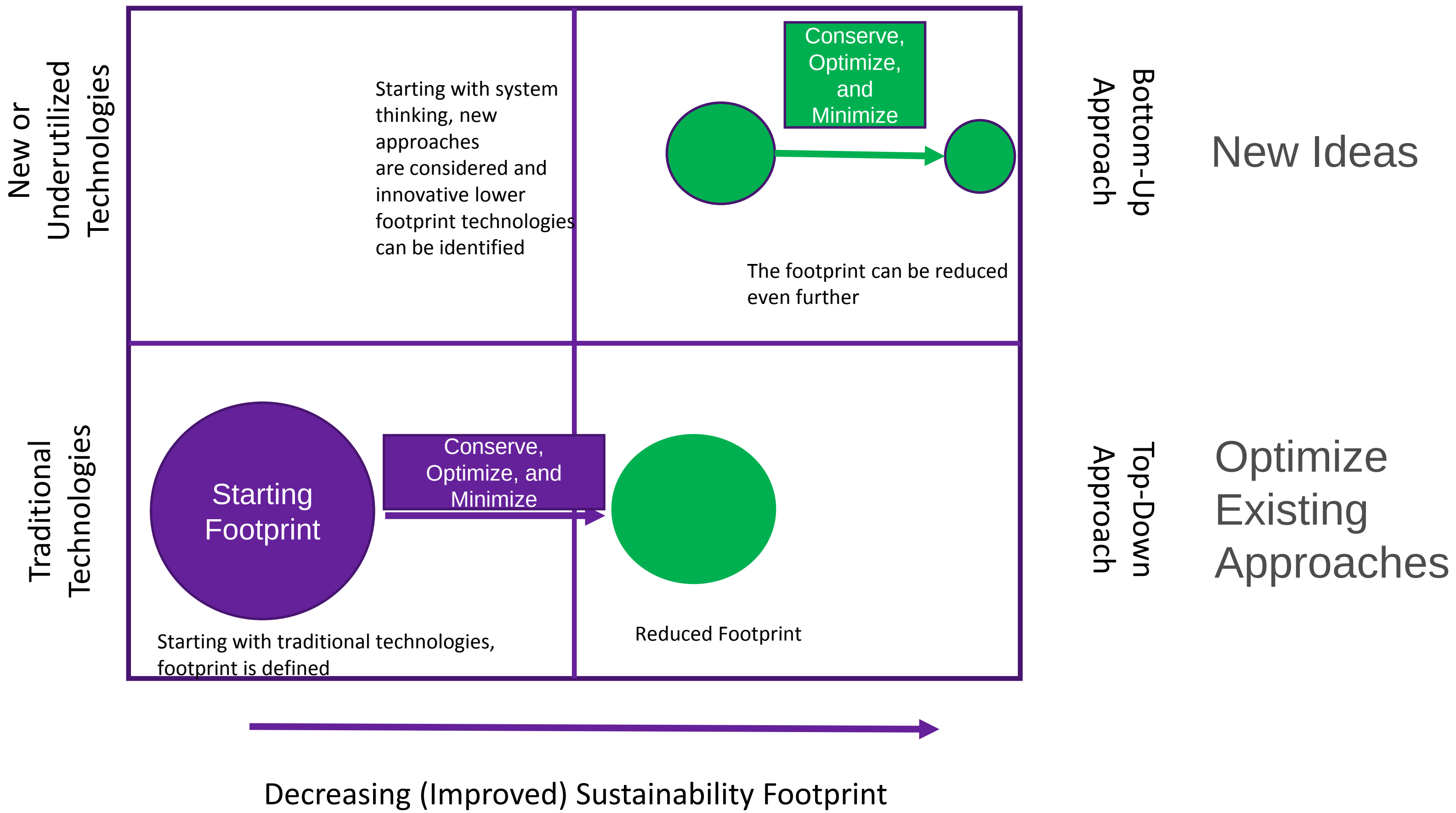
Could we deliver a robust insitu bioremediation system and avoid some of these impacts?



Examples of cleanups where waste material has been used

- Waste materials have been used in bioreactors for years
- Mulch walls have been used at several sites (e.g., Altus AFB, NWIRP McGregor)
- Fly-ash and slag have been used as pozzolans for stabilization and solidification
- Demolition concrete has been used for site topography

Top-Down or Bottom-Up?



What are Subgrade Biogeochemical Reactors?

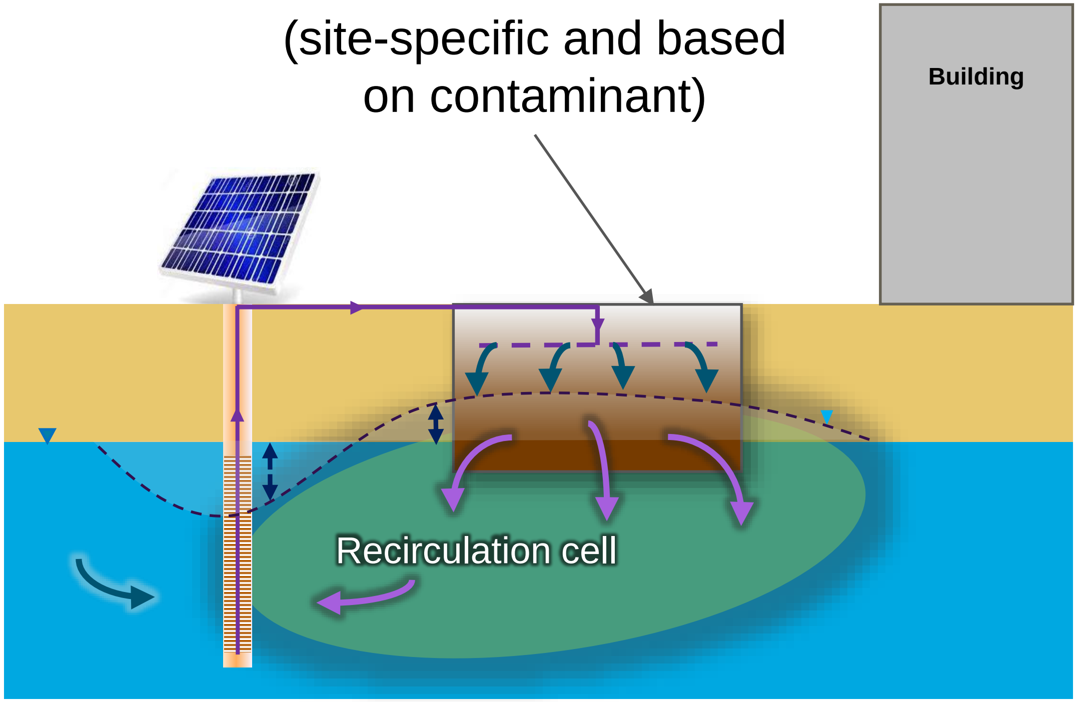
- Partial excavation of contaminant source area
- Backfill with a mixture of composted mulch, gravel, and other sources of organic carbon for chlorinated VOCs
- Iron amendments (such as iron pyrite) are added to promote abiotic dechlorination of chlorinated compounds
- Recirculate contaminated groundwater through the bioreactor using solar/wind power
- Contaminant removal occurs through:
  - Physical removal during excavation
  - Biotic and abiotic dechlorination of impacted water within the bioreactor
  - Dissolved organics can stimulate reductive dechlorination in the subsurface outside the bioreactor
- Unique technical innovation for sustained remediation of soil and groundwater impacted by chlorinated solvents and other organics

What is a Subgrade Biogeochemical Reactor (SBGR)?

Source Area Excavation/Backfill

Infiltration Pipe Installation

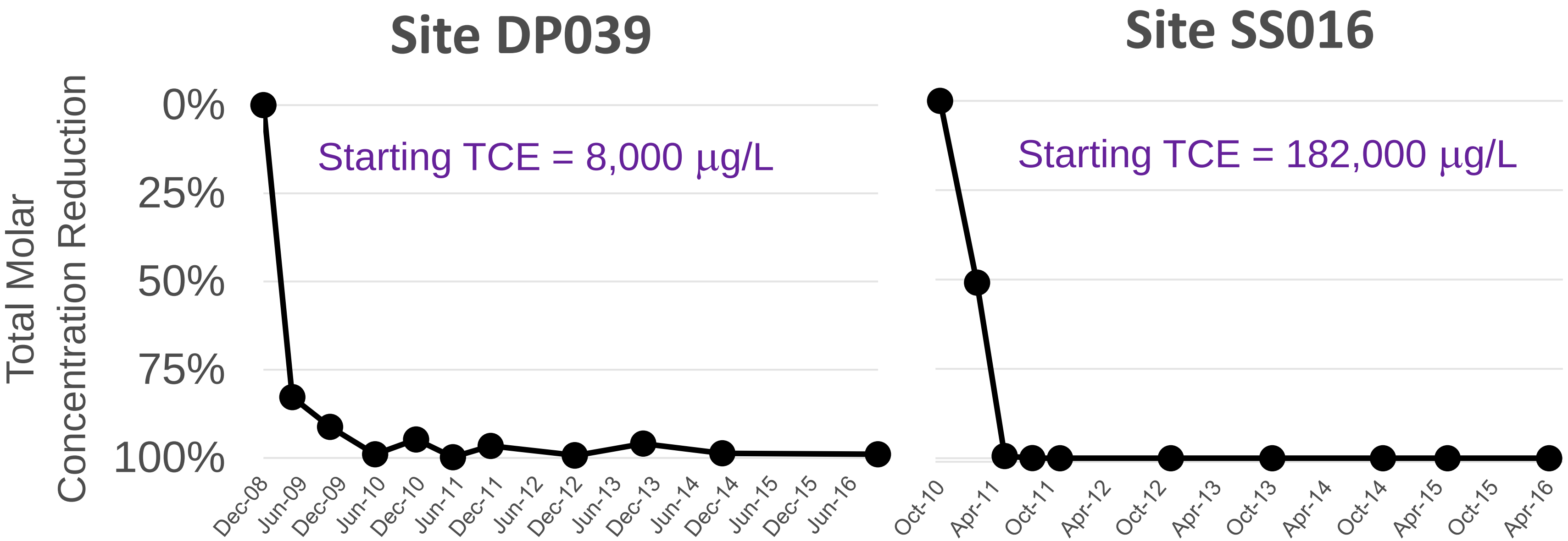
SBGR is filled with gravel and amendments (site-specific and based on contaminant)



2013 Environmental Business Journal Technology Merit Award

2015 NICOLE Technology Innovation Award

Sites DP039 and SS016 SBGR Performance



Performance from wells located within aquifer, between SBGR and extraction well

Site	Treatment Inside SBGR	Treatment ~25 feet from SBGR	Treatment ~100 feet from SBGR	Treatment ~200 feet from SBGR
DP039 (left)	96-98%	99%	99%	85%
SS016 (right)	99%	99%	47-97%	N/A

Green and Sustainable Results

- Annual electricity reduction of ~790,000 kWh/yr
  - Equivalent to annual consumption of ~120 CA homes
  - Saved over $50,000/year in electrical costs

- Greenhouse gas reduction of ~930 tons per year
  - Equivalent to annual emissions of ~200 cars

- Use of non-refined, recycled, or waste materials
  - Avoid impacts from manufacturing new materials
  - Used fast food fryer oil, recycled drywall, bark mulch, straw, repurposed pump and treat system components

Performance Results

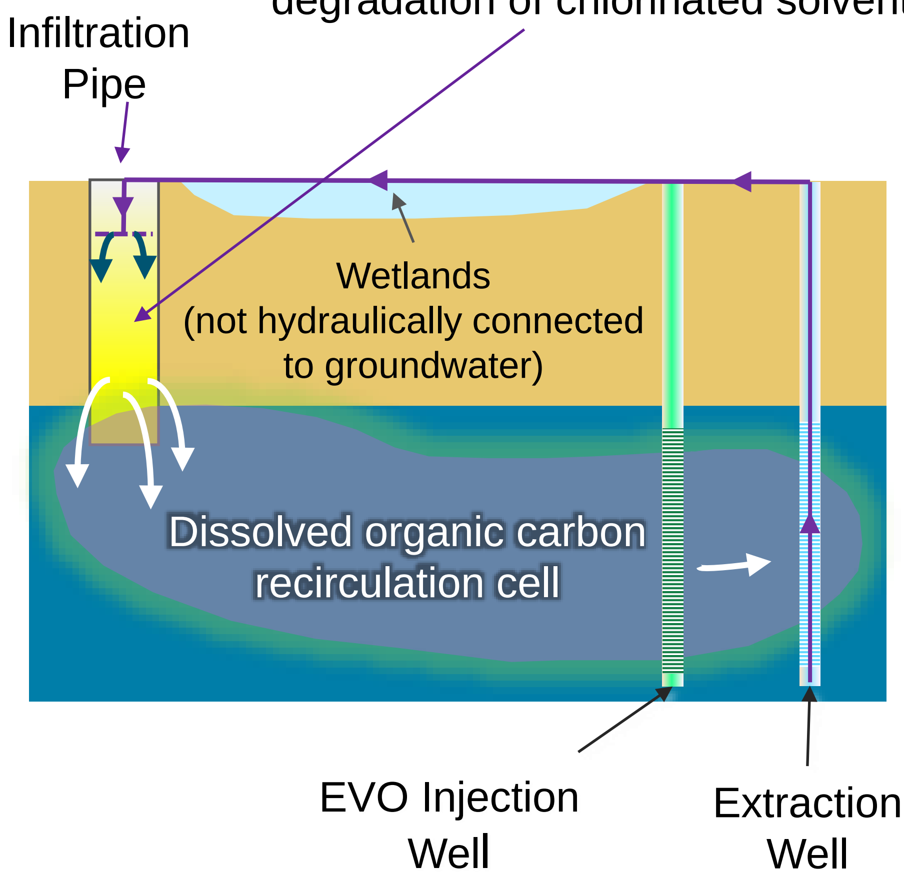
- 26 sites on track for closure by 2021
  - ~16-19 sites to achieve closure by end of 2017
- Predicted cleanup timeframe for ten (10) sites reduced by range of ~10 to 120 years
- Source area treatment example:
  - Site SS016 subgrade biogeochemical reactor (SBGR) reduced TCE source area from 182,000 µg/L in 2010 to 0.29 J µg/L in 2016

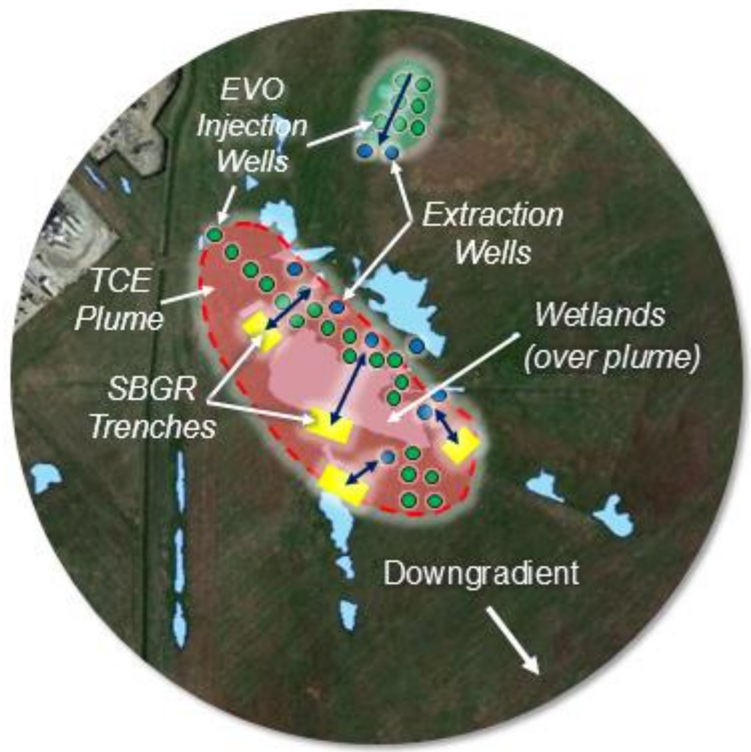
Cost Savings

- Central Groundwater Treatment Plant
  - 12-month rolling average reduced from $250,000 to $35,000 (6.5-times return on investment)
- North Groundwater Treatment Plant
  - 12-month rolling average reduced from $66,000 to $15,000 (3-times return on investment)
- Site SS016 Optimization
  - Approximately $4.6 million saved over projected 30 year period of operations and maintenance

Site FT004 Recirculation System
(a different configuration)

SBGR trench is filled with gravel, bark mulch, iron pyrite sand, and used fast food fryer oil to support biotic and abiotic degradation of chlorinated solvents





Literature Related to SBGRs

- SERDP/ESTCP Environmental Restoration Wiki
  - http://www.environmentalrestoration.wiki (and then click on SBGR) Or Google "SBGR ER Wiki"
- "Design and Performance of Subgrade Biogeochemical Reactors" in *Journal of Environmental Management*
- "Utilization of waste materials, non-refined materials, and renewable energy in in situ remediation and their sustainability benefits" in *Journal of Environmental Management*
- "Travis Air Force Base: A Greener Cleanups Case Study" to be published soon in *Remediation Journal*

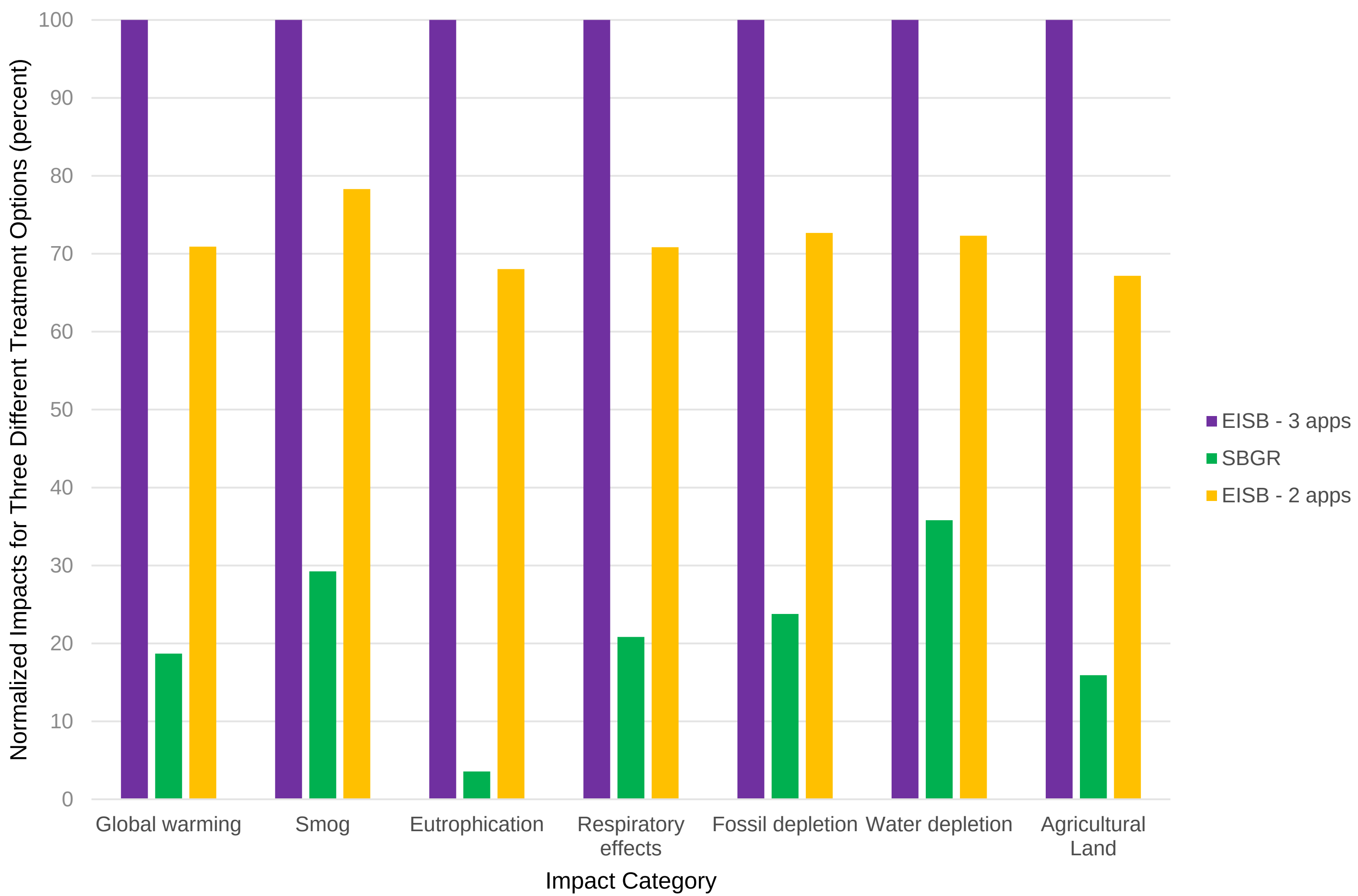
Compare Same Target Treatment Area (TTA) and Same Treatment Time

SBGR (5,000 sq ft TTA)	EISB with EVO (5,000 sq ft TTA)
• Bioreactor excavation • Backfill with bark mulch (mixed with locally available waste vegetable oil), gravel, and iron pyrite sand • Solar panels powering two extraction wells • Recirculation piping • Transportation of materials, equipment, and personnel • Operation for 6 years	• Installation of twenty 30-foot groundwater injection wells • Three applications of EVO product dosed (0.003 pound vegetable oil to pound of soil) • Transportation of materials, equipment, and personnel • Target application time every 18 months with remediation to be completed in 6 years.

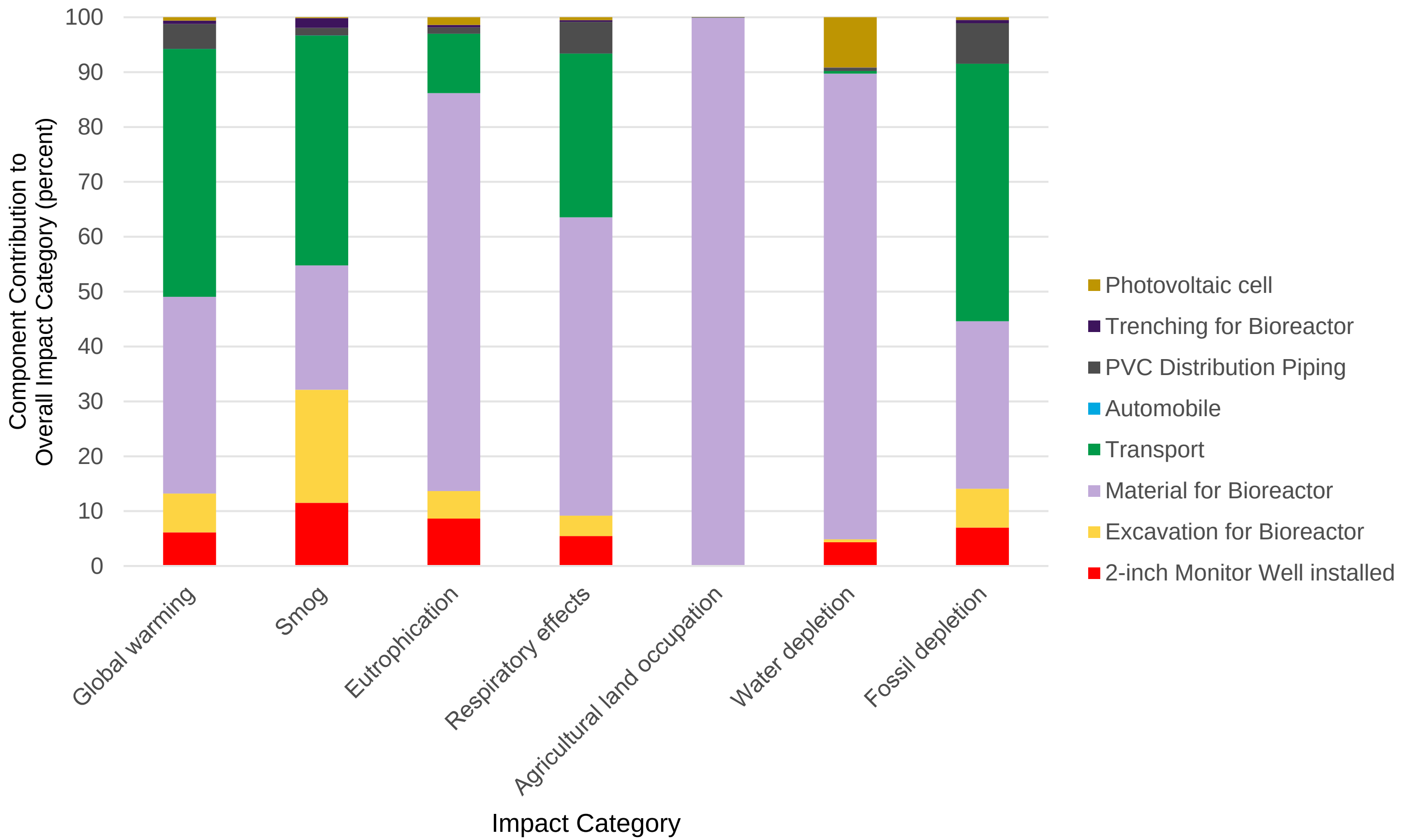
Impact Results and Population Equivalents, EISB VS SBGR

	Impacts		Population Equivalents	
Impact category	EISB	SBGR	EISB	SBGR
Global warming (kg CO_2 eq)	6.07E+04	1.14E+04	2.51E+00	4.70E-01
Smog (kg O_3 eq)	5.71E+03	1.67E+03	4.10E+00	1.20E+00
Eutrophication (kg N eq)	4.08E+02	1.45E+01	1.89E+01	6.77E-01
Respiratory effects (kg $PM_{2.5}$ eq)	2.90E+01	6.05E+00	1.20E+00	2.50E-01
Fossil depletion (kg oil eq)	1.56E+04	3.72E+03	2.26E+00	5.37E-01
Water depletion (m^3)	3.61E+04	1.14+04	Not Available	Not Available
Agricultural Land (acres)	4.63E+01	7.37E+00	Not Available	Not Available

Normalized Impact Results



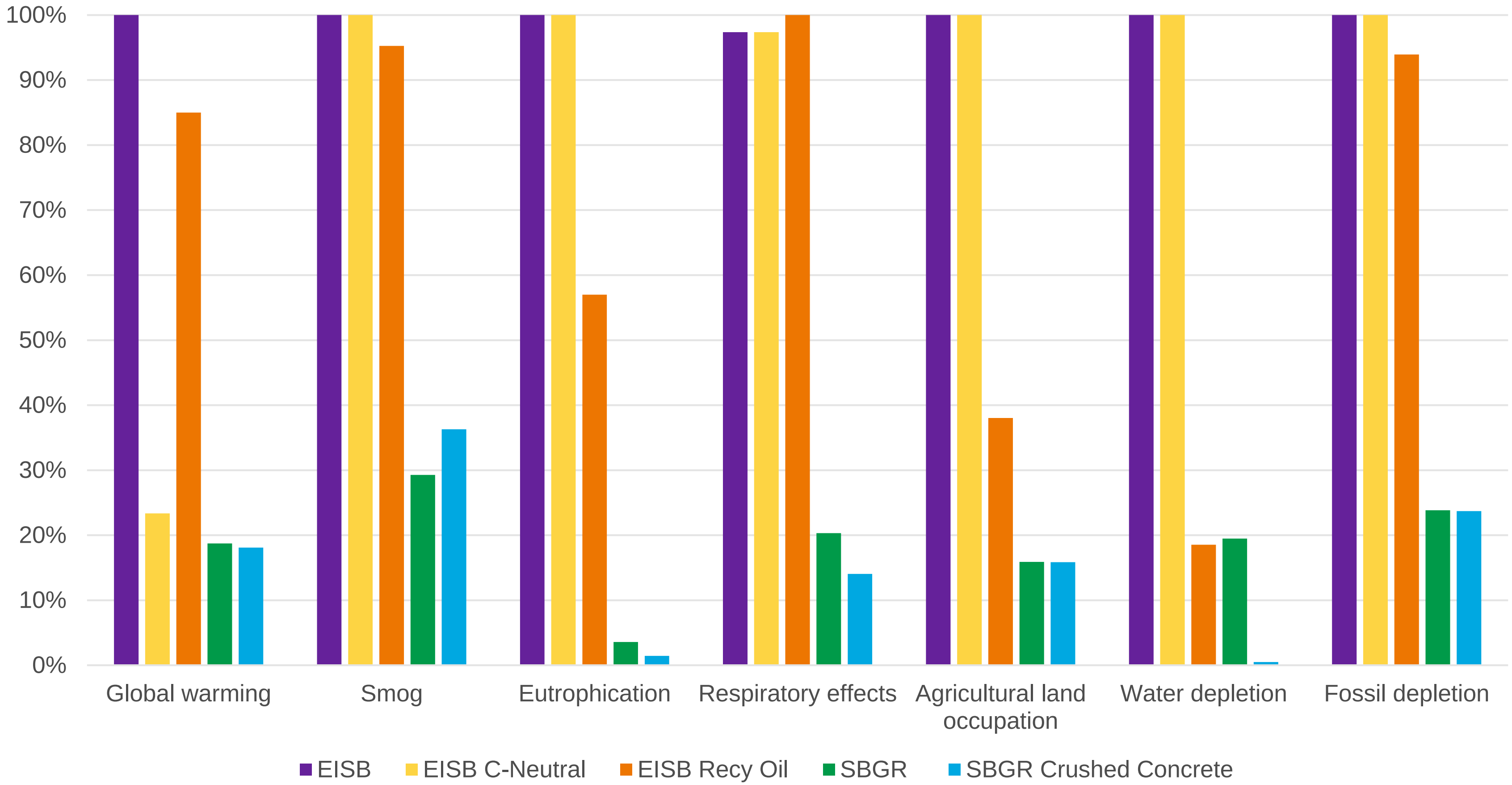
Contribution Analysis



Other Optimization Options Evaluated

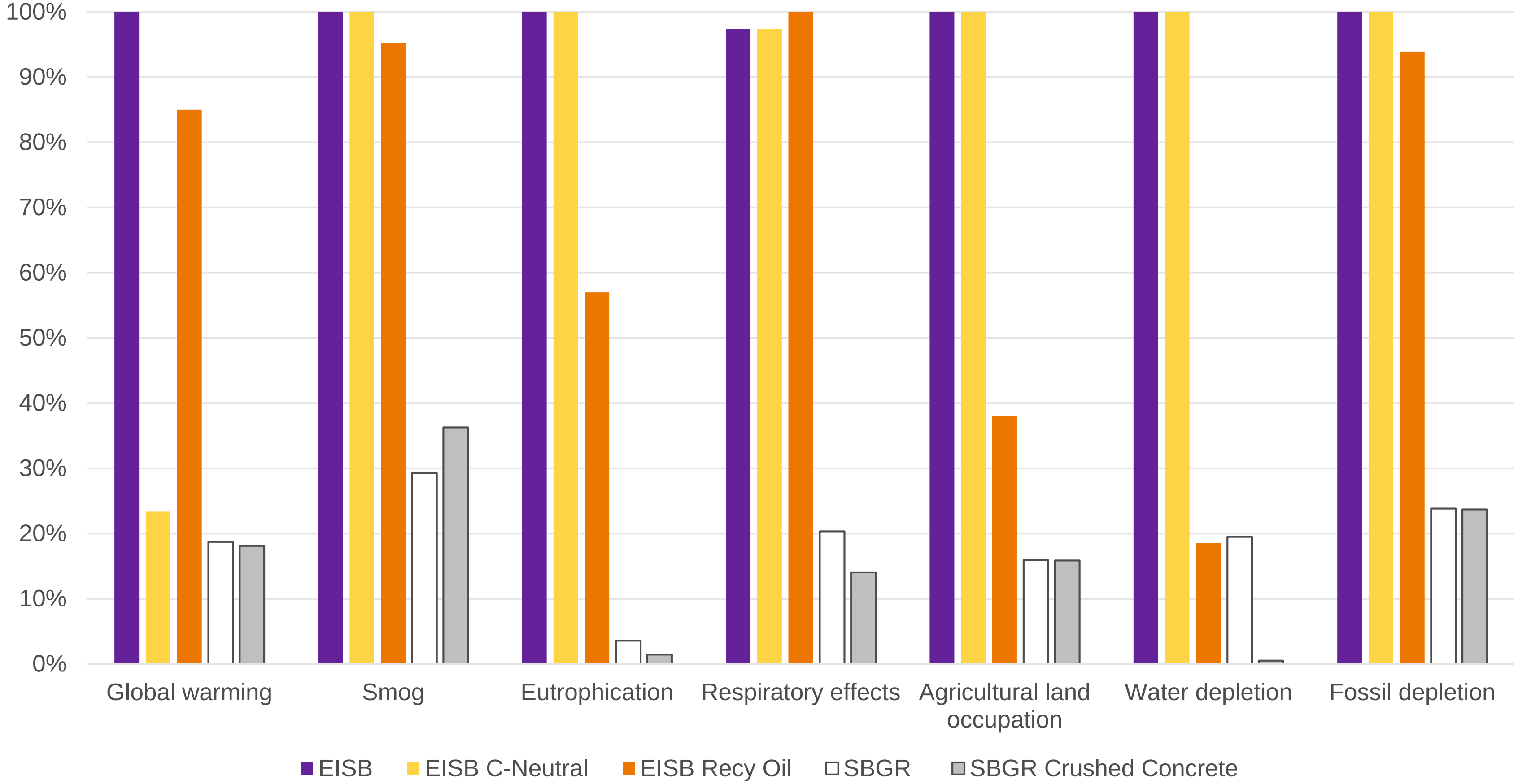
- ISB
  - Use of recycled oil in EVO, instead of unused oil – would avoid agricultural impacts
  - Carbon neutral EVO – avoids carbon dioxide emissions only
- SBGR
  - Crushed concrete replacing quarry stone – avoid water footprint associated with mining (need to be careful about pH)
  - Use of wind turbine instead of solar panels – compare another renewable energy source (considered less reliable)
    - Not shown as greater than solar energy

Comparison of New Options with Original SBGR and EISB



EISB Options

Carbon neutral EVO only changes CO2 emissions
Recycled oil – minor CO2 smog, energy reductions – bigger reductions with agricultural impacts (eutrophication, ag land, and water)



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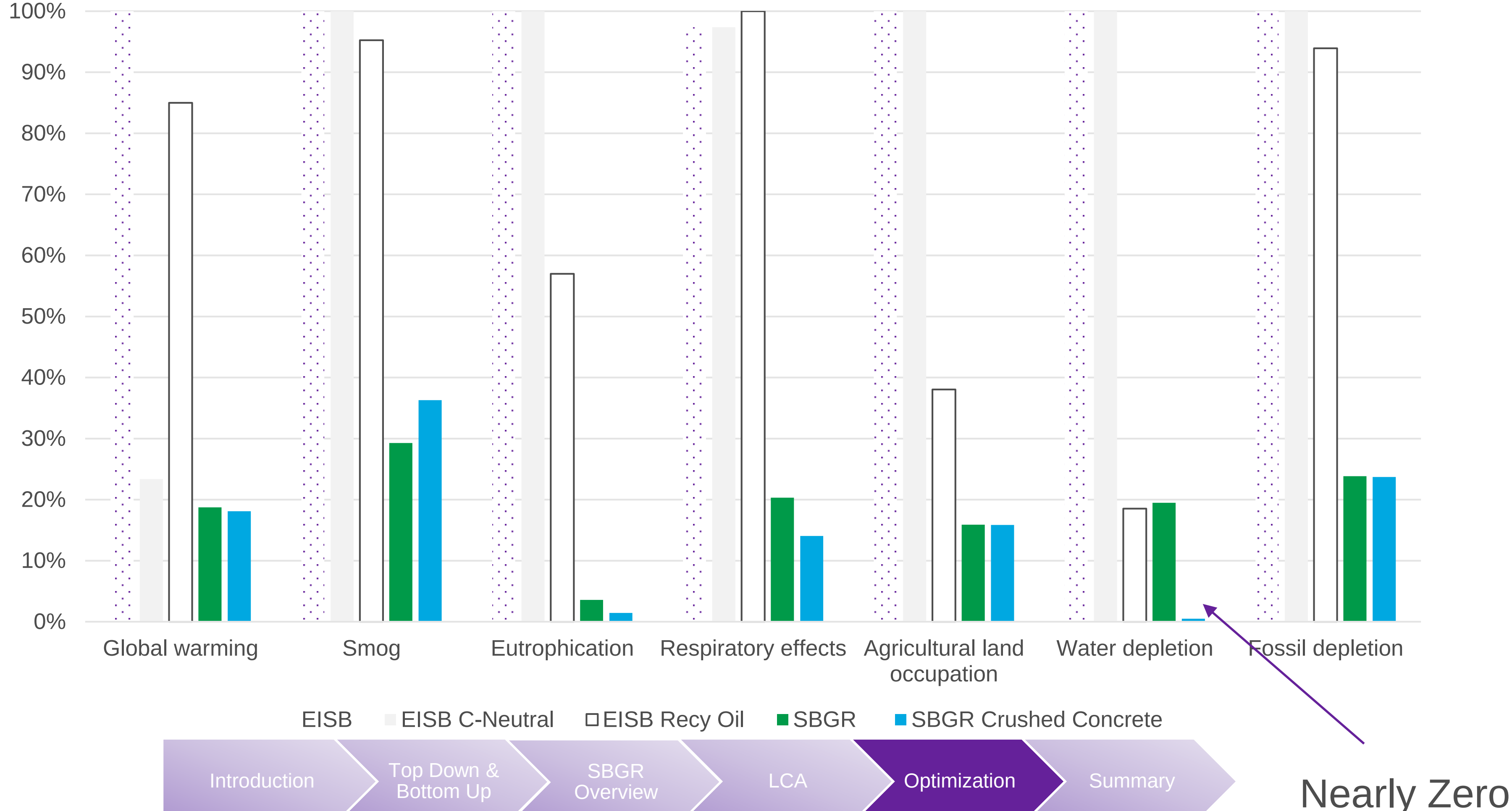
SBGR Options

Significant reduction in water use and some in eutrophication
Minor increase in smog related to concrete crushing



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Summary

- Top-down VS Bottom-Up thinking
  - LCA thinking helped identify burdens and opportunities to reduce impacts
- Use of waste materials in cleanup avoids impacts to the
  - Avoids production footprint component and waste generation
- LCA provides a lens to identify optimization opportunities
  - By understanding where burdens exist, you can focus on reducing them
- If you challenge conventional thinking, you can get better results
  - Maybe even getting to “Net Zero”

Thank you!

Paul Favara
Paul.Favara@ch2m.com

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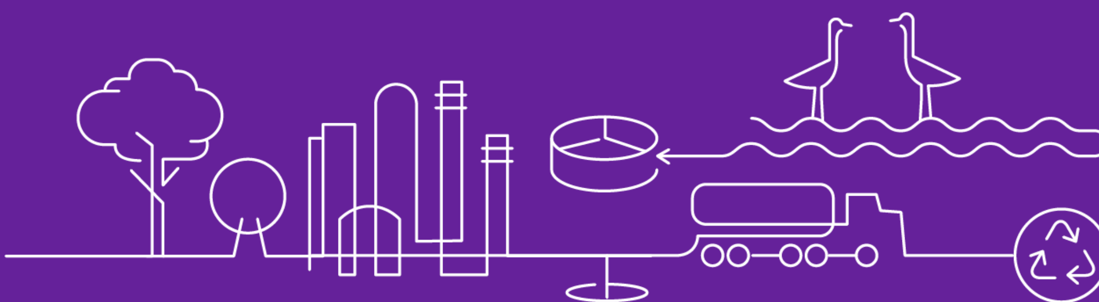

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