Offshore concrete LCA

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OFFwind

Interreg Aurora

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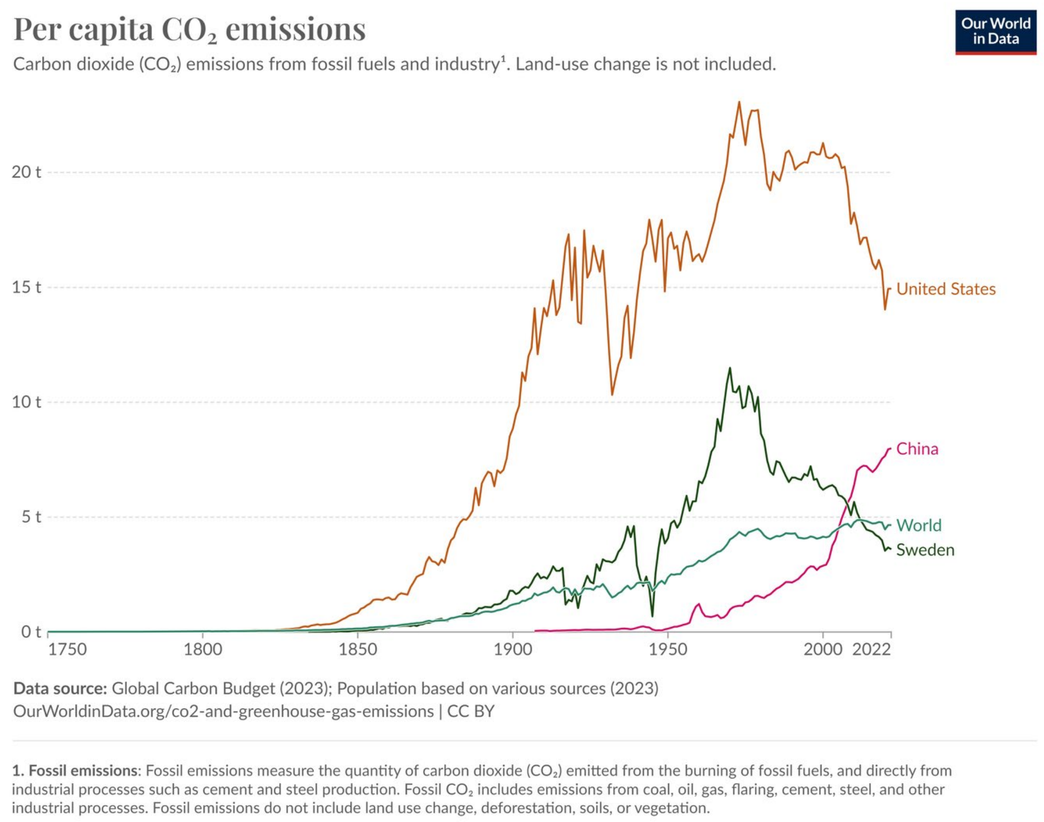
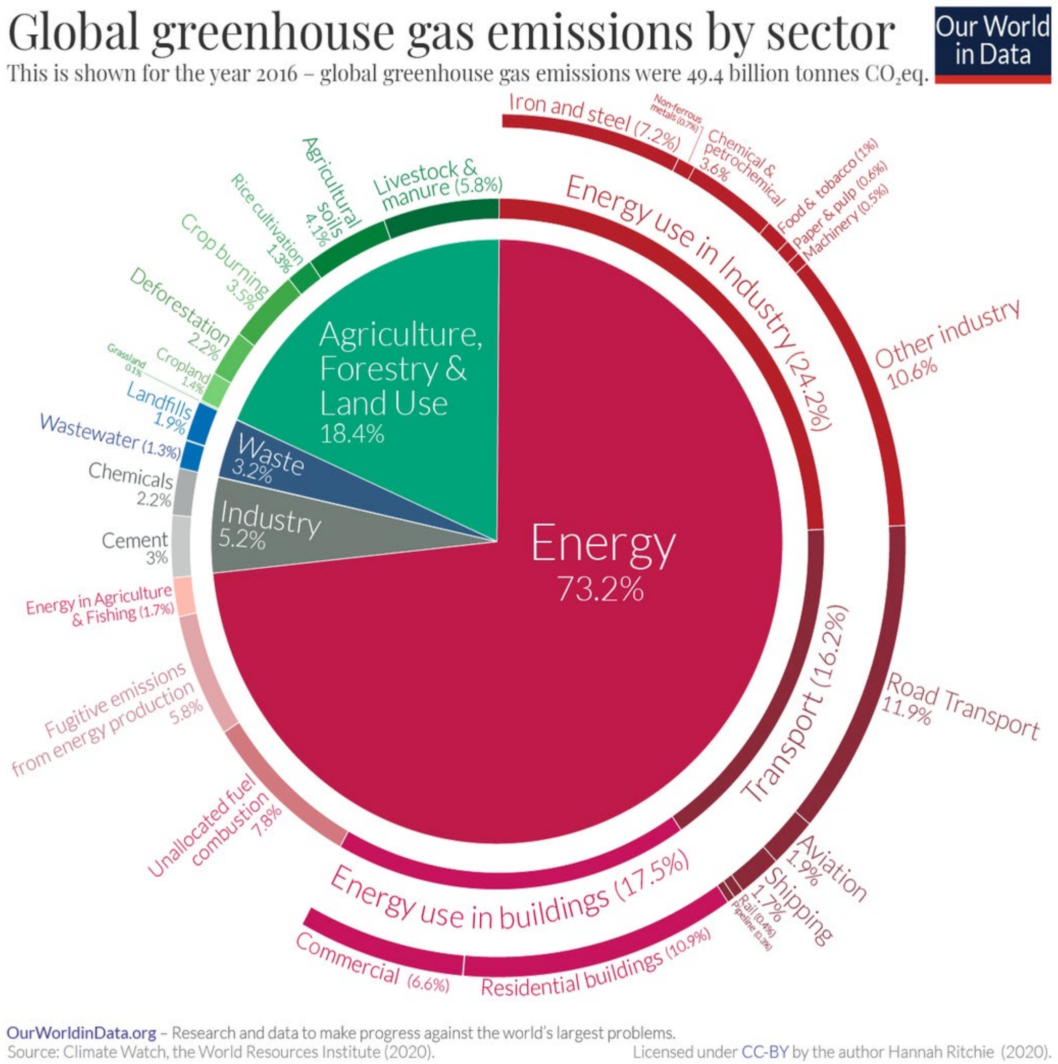
Carbon footprint





THE BUILT ENVIRONMENT IS RESPONSIBLE FOR 40% OF GLOBAL CO2 EMISSIONS, 33% OF GLOBAL WASTE, AND NEARLY 50% OF ALL EXTRACTED MATERIALS.

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Life cycle assessment

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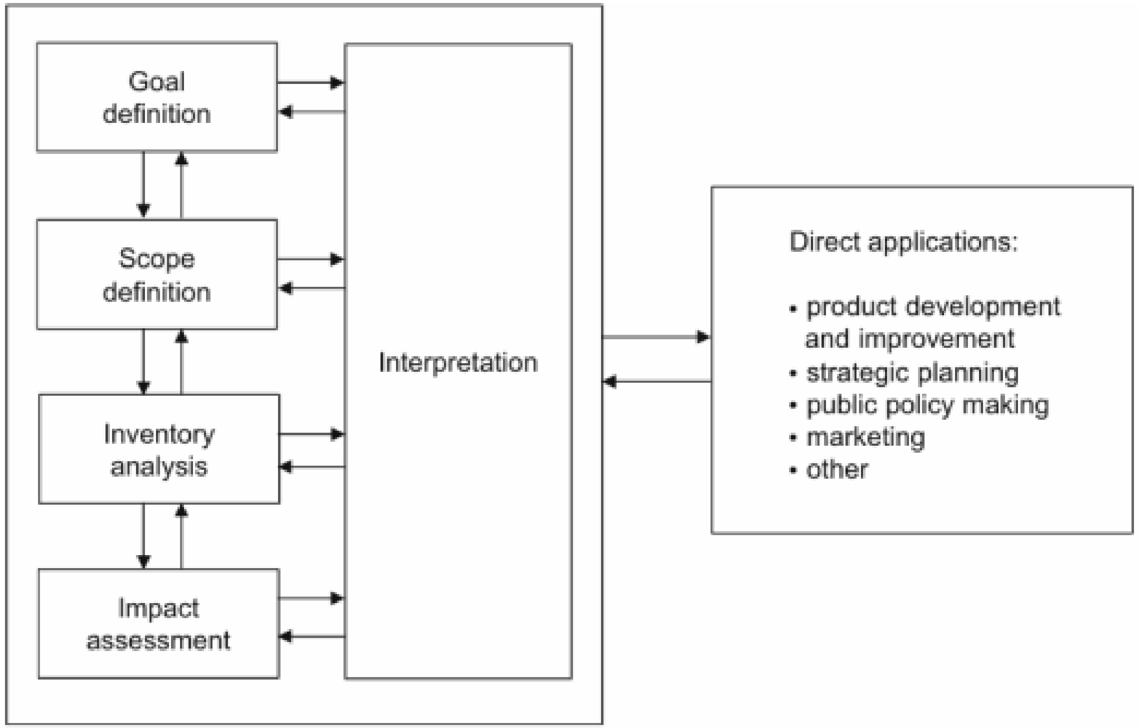
Life cycle assessment

Life Cycle Assessment (LCA) is a systematic method for evaluating the environmental impacts of a product, process, or service throughout its life cycle, from raw material extraction to disposal. It involves analyzing various stages, including production, usage, and end-of-life, to identify and quantify energy use, resource consumption, and emissions. LCA helps understand the sustainability and environmental footprint, guiding more informed and eco-friendly decision-making.

LCA structure

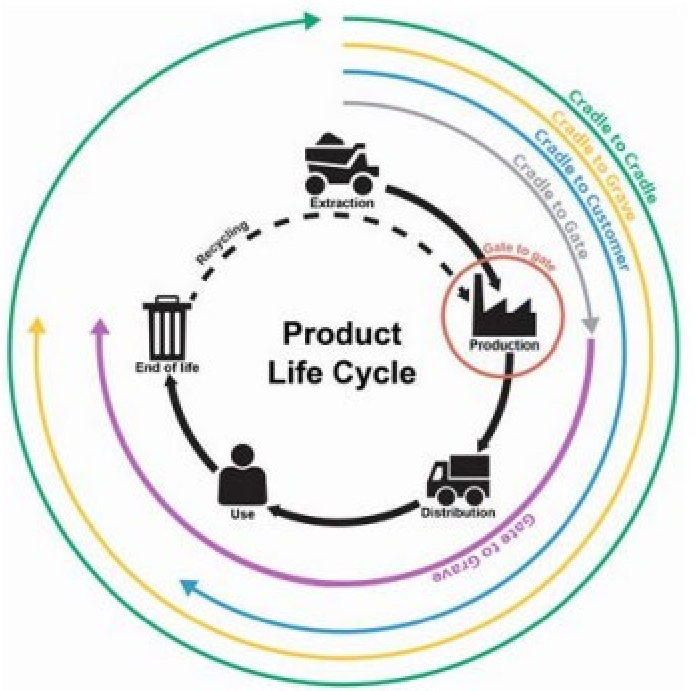
Standards: ISO 14040:2006 (SS-EN ISO 14040, 2006), ISO 14044:2006 (SS-EN ISO 14044, 2006), and EN 15804:2012 (SS-EN 15804, 2012)



System boundries

System boundaries define which processes and stages of a product's life cycle are included in the assessment. These boundaries are crucial for determining the scope and comprehensiveness of the LCA.

- **Cradle-to-Gate:** Covers all stages from raw material extraction (cradle) to the factory gate (before the product is distributed). Does not include the use or disposal phases.
- **Cradle-to-Grave:** Includes the full life cycle, from raw material extraction (cradle) to the end of life (grave), including disposal or recycling.
- **Cradle-to-Cradle:** A circular model where materials are reused or recycled at the end of life, contributing to a closed-loop system.
- **Gate-to-Gate:** Focuses on a specific stage or segment of the product’s life cycle (e.g., only manufacturing processes).



Impact categories

Energy Use: Total energy consumption, including both renewable and non-renewable sources (e.g., fossil fuels, electricity).

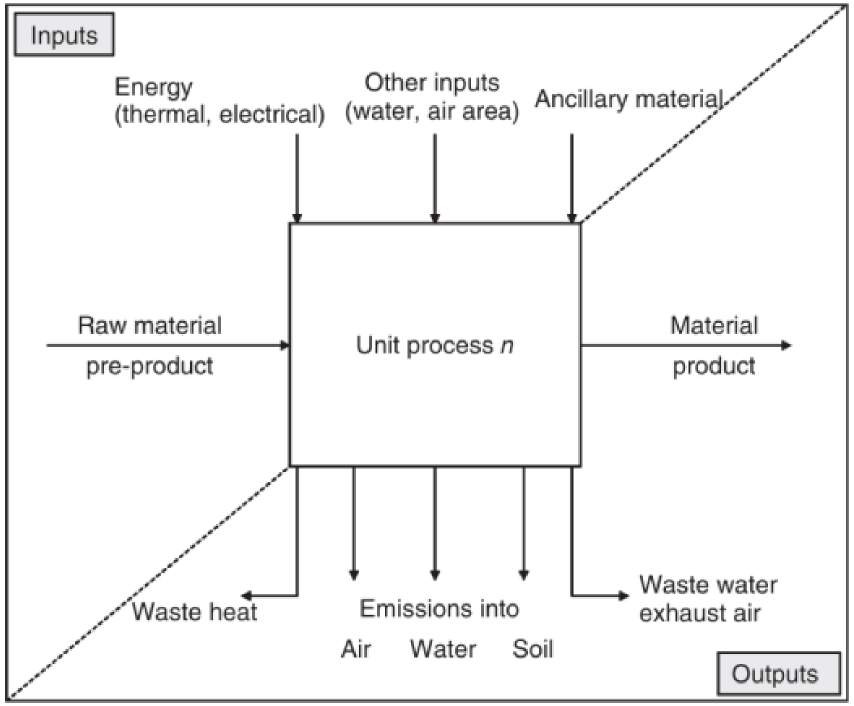
Resource Use: Amount of raw materials and water consumed throughout the life cycle.

Climate change (CO_2eq): Contribution to climate change based on the release of carbon dioxide and other greenhouse gases

Air and Water Pollutants: Emissions of particulate matter (PM), nitrogen oxides (NOx), sulfur oxides (SOx), and pollutants affecting water bodies (e.g., heavy metals, nitrates).

Waste Generation: Amount of solid waste produced, including material waste and end-of-life disposal.

Land Use and Biodiversity: Impact on ecosystems, including habitat destruction and biodiversity loss.



LCA methodology

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Goal and scope

Assess the environmental impacts (and potential benefits) associated with the use of low-carbon concrete in offshore wind farm foundations

Compare these impacts with those of traditional concrete

System Boundaries: cradle-to-gate
Given the significant environmental impact of cement production, especially calcination emissions, focusing on cradle-to-gate captures the most critical phase, allows for a fair comparison between the countries

Functional unit: per cubic meter of concrete used in the foundation of an offshore wind turbine

Database: Ecoinvent

Software: SimaPro

Method: CML-IA baseline V3.10

Scenario 1 Binder replacement

Case Study: Varying Supplementary Cementitious Materials (SCMs) content

Objective: Assess the environmental impacts of low-carbon concrete mixes with different percentages of SCMs replacing Portland cement.

- REF CEM I
- REF CEM II (6-20% SCM)
- 20% SCM replacement
- 40% SCM replacement
- 60% SCM replacement

Scenario 1 Binder replacement

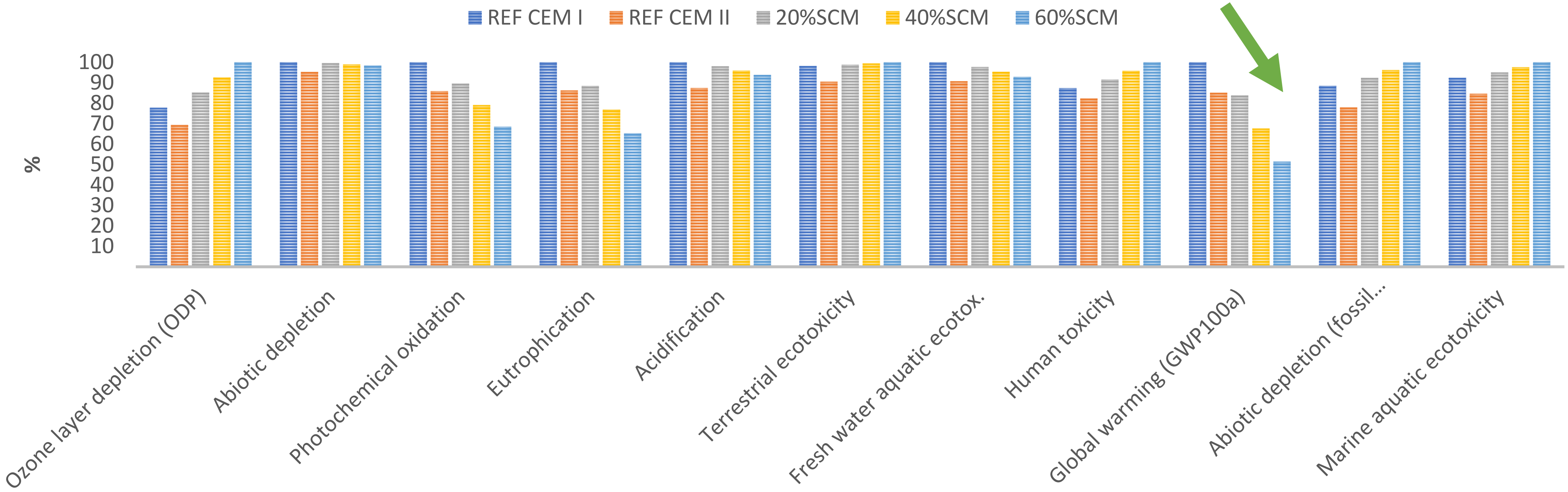
SCM

- considered a waste product, emissions are primarily from processing,
- In calculation – ground granulated blast furnace slag
- From the Ecoinvent database: This activity includes the process steps (i) quenching/granulation, (ii) dewatering and/or drying, (iii) crushing, (iv) grinding, and (v) storage in pile and silo.

Binder (PC+SCM)	400 kg
Fine aggregate	268 kg
Coarse aggregate	1523 kg
Water	160 kg

Electricity for mixing 0.3 kWh

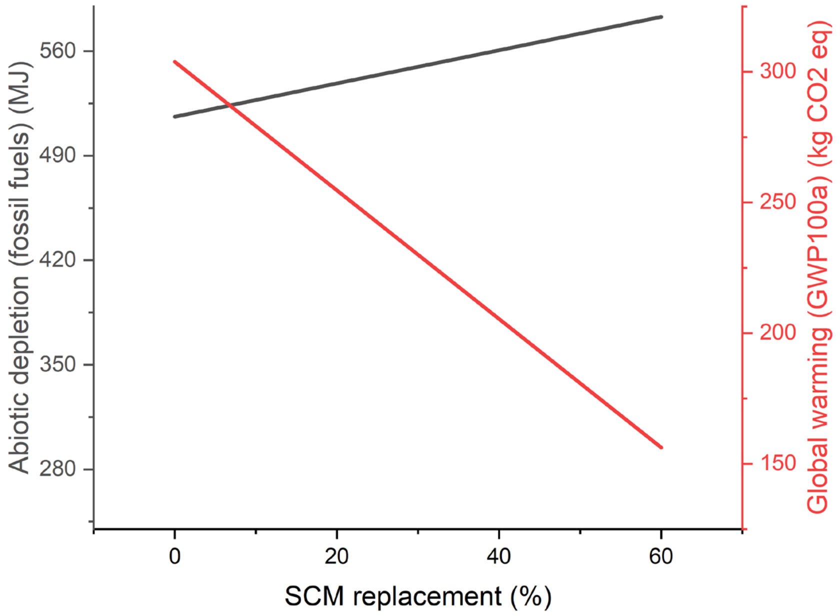
Scenario 1 Binder replacement



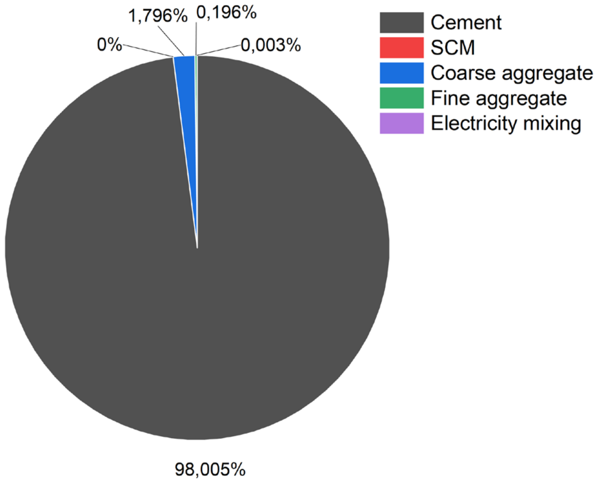
Comparing product stages;
Method: CML-IA baseline V3.10 / EU25 / Characterization

Scenario 1 Binder replacement

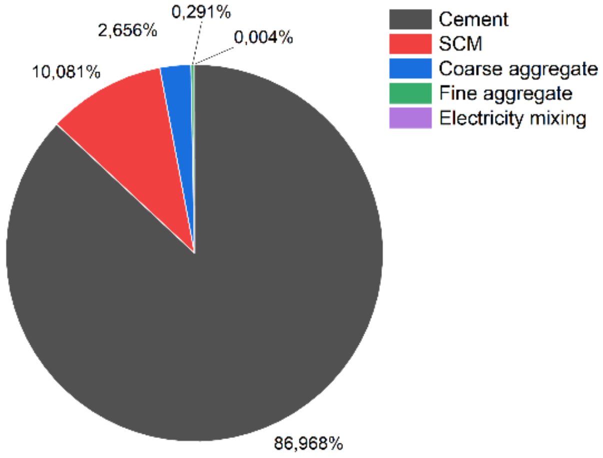
Impact category	Unit	REF CEM I	REF CEM II	20%SCM	40%SCM	60%SCM
Abiotic depletion	kg Sb eq	3.31E-04	3.15E-04	3.29E-04	3.27E-04	3.26E-04
Abiotic depletion (fossil fuels)	MJ	516	454	538	561	583
Global warming (GWP100a)	**kg CO2 eq**	**304**	**258**	**255**	**205**	**156**
Ozone layer depletion (ODP)	kg CFC-11 eq	3.36E-07	2.99E-07	3.68E-07	3.99E-07	4.31E-07
Human toxicity	kg 1,4-DB eq	183	172	192	201	210
Fresh water aquatic ecotox.	kg 1,4-DB eq	46	41	45	44	42
Marine aquatic ecotoxicity	kg 1,4-DB eq	102234	93472	105008	107782	110557
Terrestrial ecotoxicity	kg 1,4-DB eq	1.34	1.24	1.35	1.36	1.37
Photochemical oxidation	kg C2H4 eq	0.03	0.03	0.03	0.03	0.02
Acidification	kg SO2 eq	0.38	0.33	0.37	0.37	0.36
Eutrophication	kg PO4--- eq	0.18	0.16	0.16	0.14	0.12



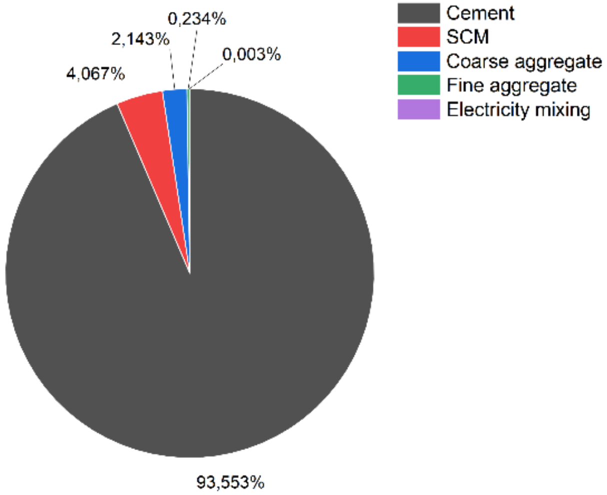
REF CEM I



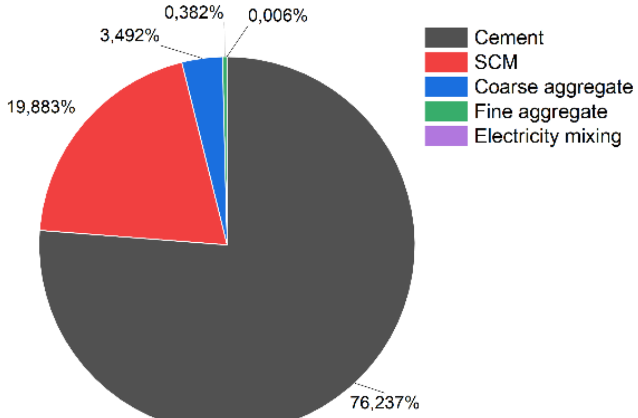
40% SCM



20% SCM



60% SCM



Scenario 1

Binder replacement

PC as main contributor

Type of SCM and processing matters

Scenario 2 Transportation logistics and emissions

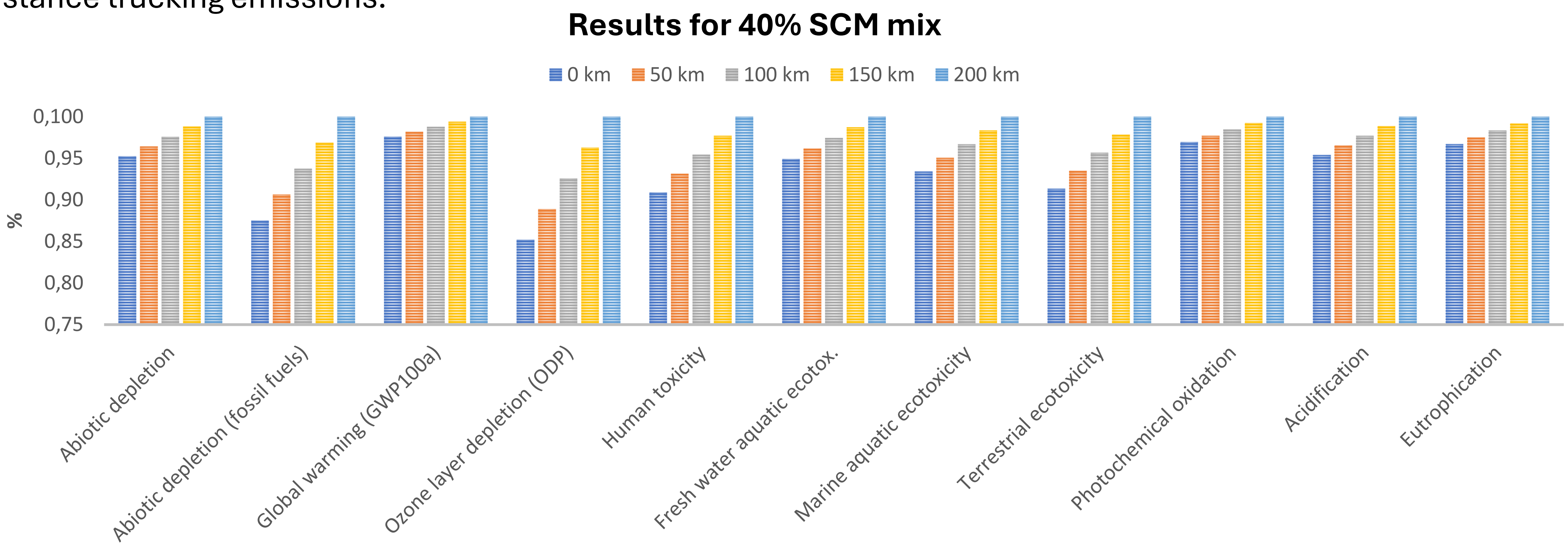
Case Study: Local vs. imported SCM sourcing

Objective: Compare the environmental impacts of sourcing aggregates and SCMs locally versus importing them from distant locations.

- **Scenario 2.1 (Local):** Local sourcing within 200 km, Short-distance trucking emissions.
- **Scenario 2.2 (Domestic Import)::** Importing binder from 1,000 km away, Longer trucking distances, possibly involving rail.
- **Scenario 2.3 (International Import):** Importing SCMs internationally (e.g., fly ash from 5,000 km away), Combination of marine and land transport.

Scenario 2 Transportation logistics and emissions

Scenario 2.1 (Local): Local sourcing within 200 km, Short-distance trucking emissions.



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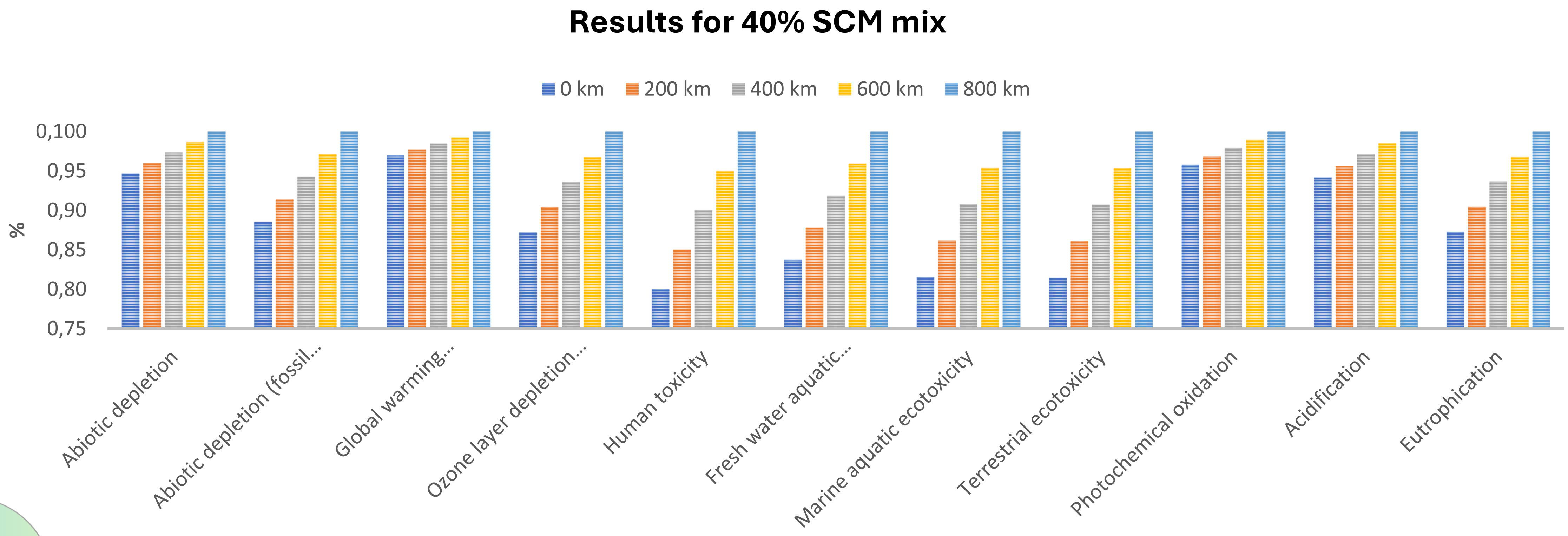
Scenario 2 Transportation logistics and emissions

Scenario 2.2 (Domestic Import): Importing binder from up to 1,000 km away, Truck 200 km + rail



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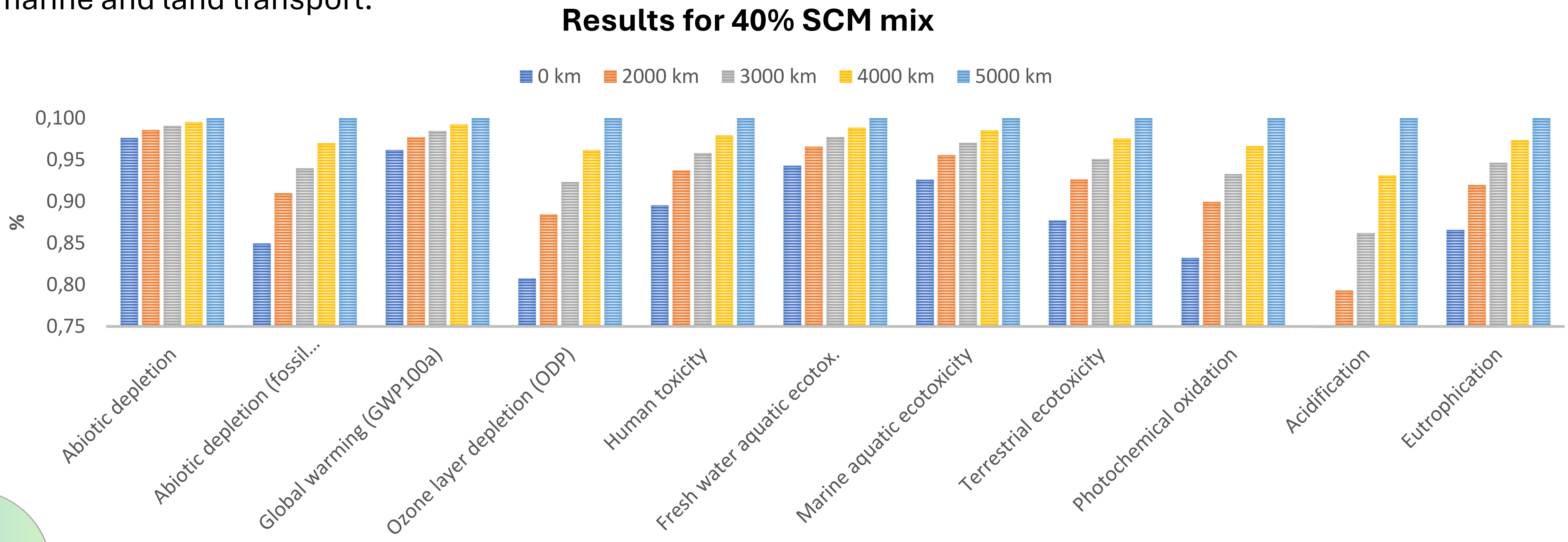
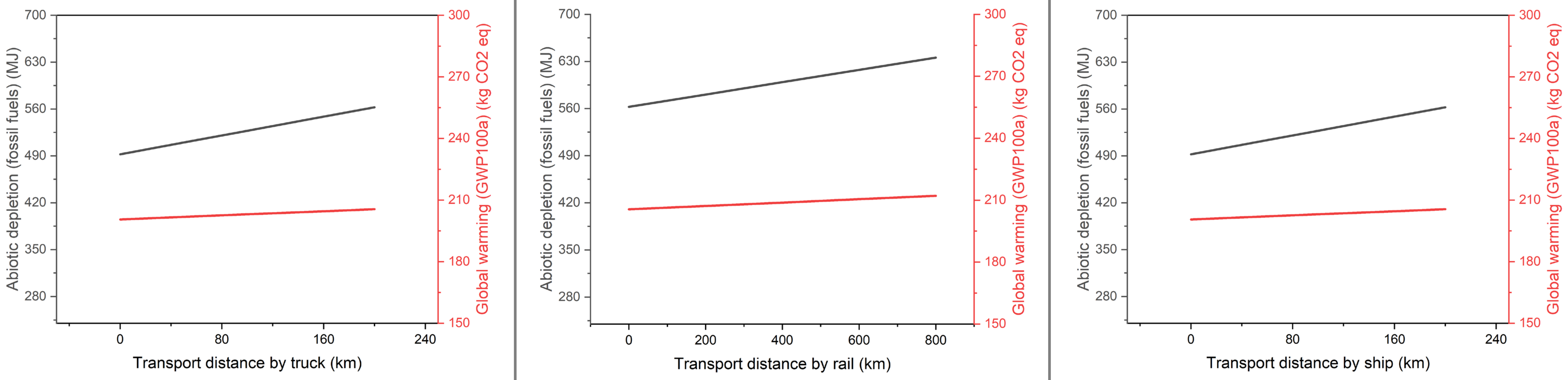
Scenario 2 Transportation logistics and emissions

Scenario 2.3 (International Import): Importing SCMs internationally (e.g., from 5,000 km away), Combination of marine and land transport.



Scenario 2 Transportation logistics and emissions



Follow up

Influence of recycled aggregates

Analysis of types of SCMs available in Sweden, Norway, Finland

Possibly more “local” data, less dependence on generic database

White paper?

Scenario 3 Influence of recycled aggregates

System Boundaries: cradle-to-gate
Given the significant environmental impact of cement production, especially calcination emissions, focusing on cradle-to-gate captures the most critical phase, allows for a fair comparison between the countries

Functional unit: per cubic meter of concrete used in the foundation of an offshore wind turbine

Database: Ecoinvent

Software: SimaPro

Method: CML-IA baseline V3.10

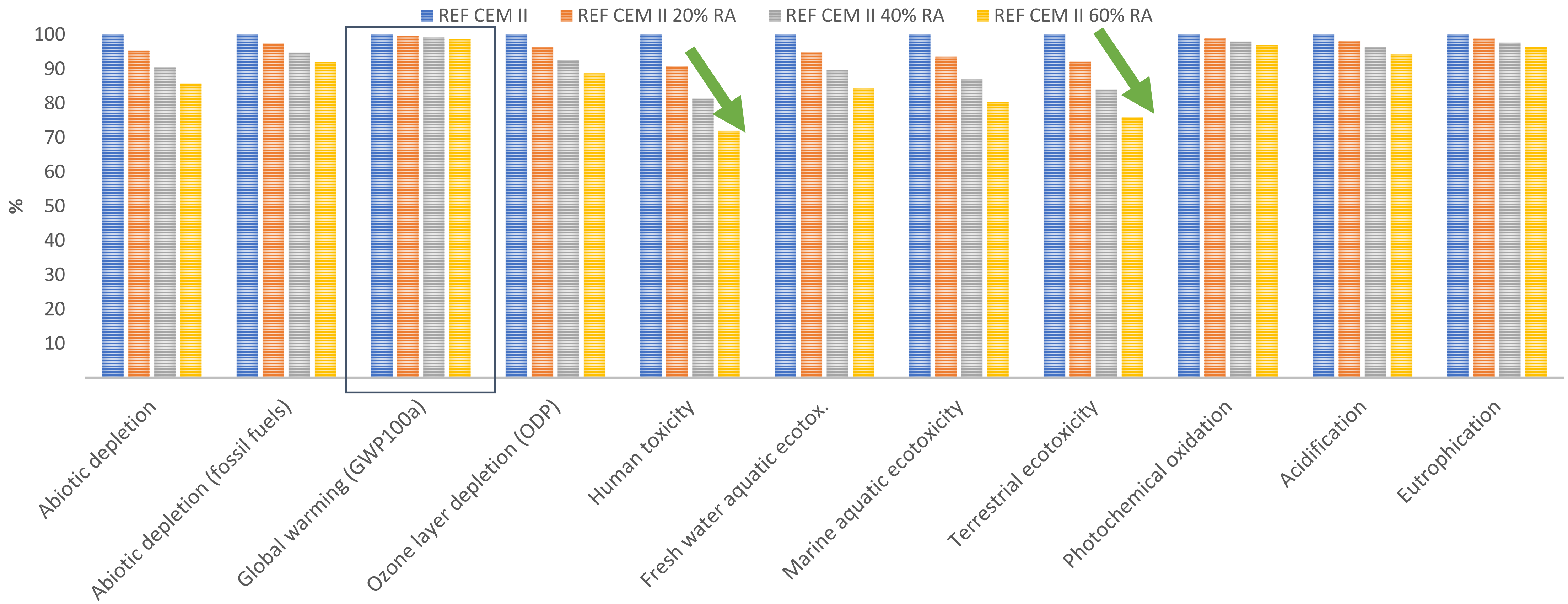
Scenario 3 Influence of recycled aggregates

Case Study: Varying amount of replacement of coarse aggregate with recycled aggregate (RA)

Objective: Assess how replacing aggregate affects the overall impact of the concrete mix

- REF CEM II (6-20% SCM)
- 20% RA replacement
- 40% RA replacement
- 60% RA replacement

Scenario 3 Influence of recycled aggregates



Scenario 3 Influence of recycled aggregates