Life Cycle Screening (LCA) to Assess the Climate Change Impact for Remediation of Chlorinated Solvents

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Focus for the presentation

1 → 2 → 3 → 4

1. Introduction to the megasite
2. Introduction to LCA
3. LCA for the megasite
4. Summary

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The urban Megasite

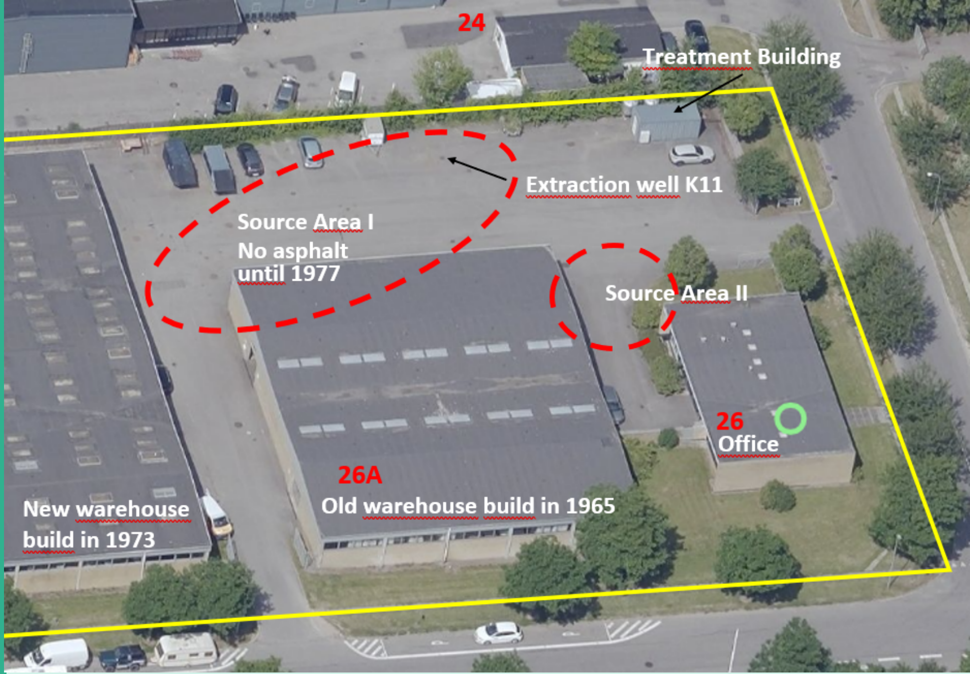
The megasite is contaminated with chlorinated solvents in soil and groundwater

Handling of around 5000 tons of PCE and 1700 tons of TCE in the period 1965–1983

Investigations indicate two source areas

Contamination is partly located under two warehouses

Pump and Treat from extraction well K11 was initiated in 2008



Geology

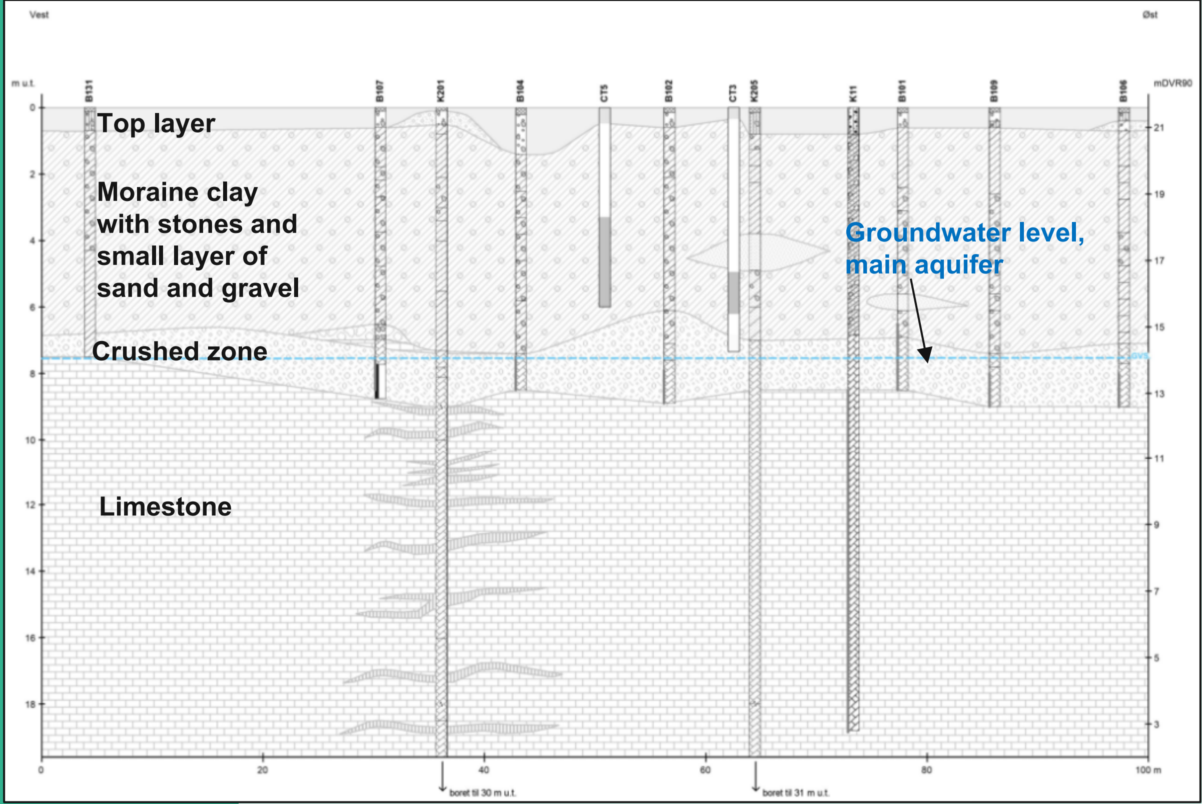
and hydrogeology

Top layer of mixed fill and moraine clay down to around 7 m bgs

Below 1- 2 m thick crushed zone, which consists of sand, gravel, crushed flint and limestone

Below the crushed zone is the limestone

The crushed zone is in hydraulic contact with the main aquifer in the limestone



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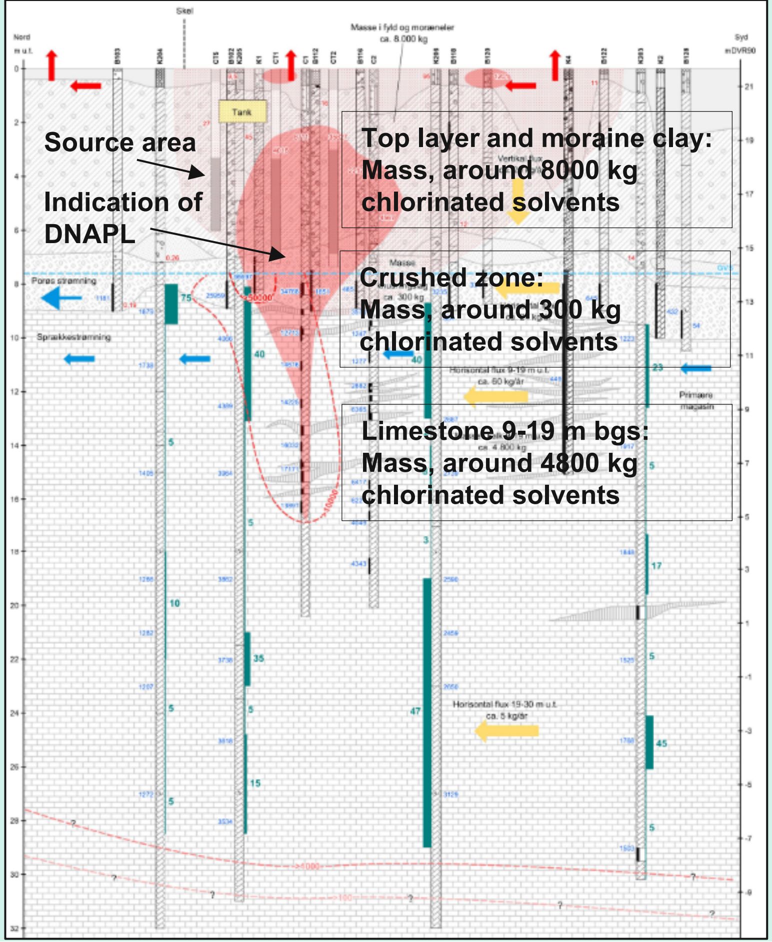
Target treatment zones

Target treatment zone in the top layer, the moraine clay and the crushed zone, is defined as:

The zone, where the concentration of chlorinated solvents is greater than 1 mg/kg TS

Target treatment zone in the limestone is defined as:

The zone, where there is an indication of DNAPL (free phase)



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Strategies

Remediation - Strategy A

100% thermal remediation
Pump and Treat for 10 years for the removal of dissolved contamination.

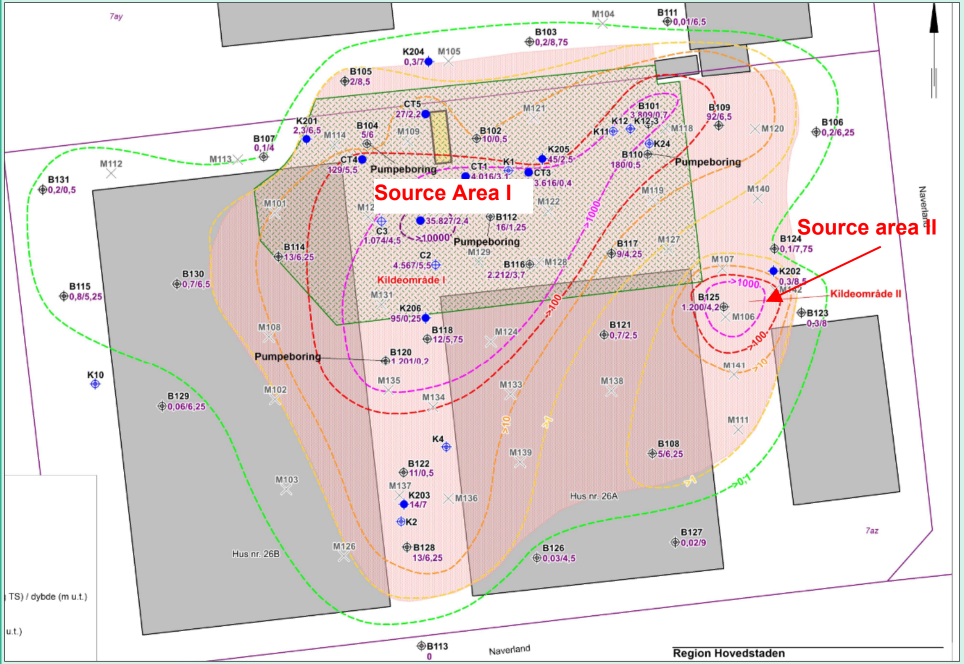
Remediation - Strategy B

Warehouses are removed
Thermal remediation combined with excavation
Pump and Treat for 10 years for the removal of dissolved contamination
Reconstruction of warehouses.

Containment of the plume zone – Strategy C

Continuation of Pump and Treat from extraction well K11 for 30 years
Already etablished at the site.

Horizontally



Target treatment area, Glacial deposits (0-9 m bgs)
Target treatment area, Glacial deposits + Limestone (9-20 m bgs)

How can LCA contribute to decision-making on remediation strategies ?

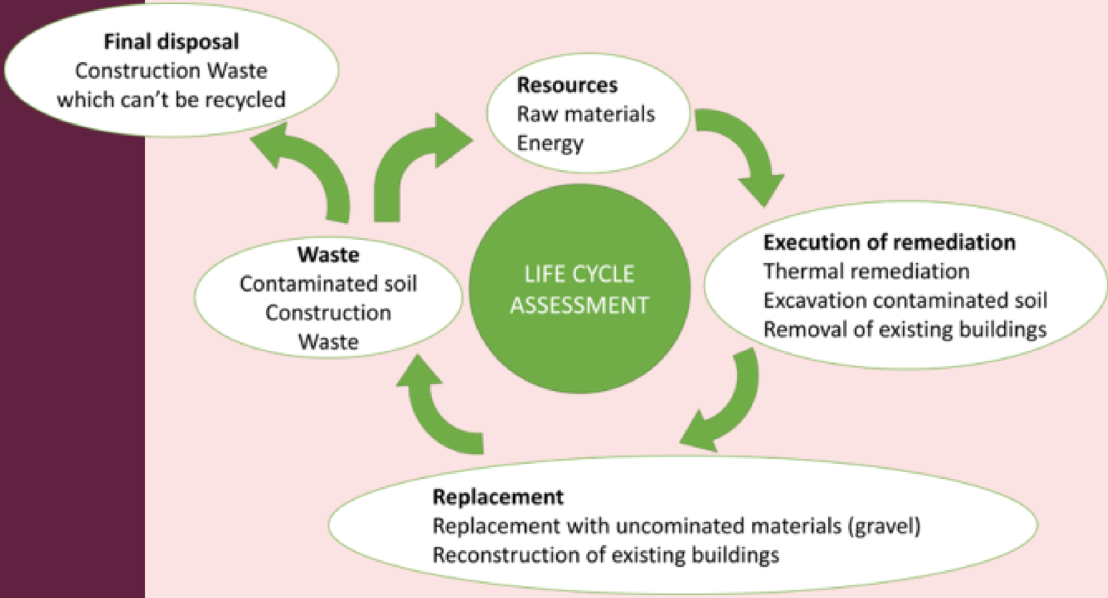
Compare the **potential environmental impact** from alternative remediation strategies (e.g., climate change and resource use)

Inform about the **balance** between environmental impacts, economy and social aspects.

Support **decision makers** in choosing the most environmentally-friendly option among different alternatives.

Phases of life cycle

Strategi B



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LCA for the megasite

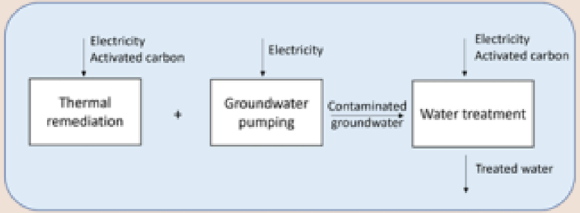
The goal was to compare the **climate change impact from energy -** and **raw material consumption** for 3 remediation strategies.

Scope of study:

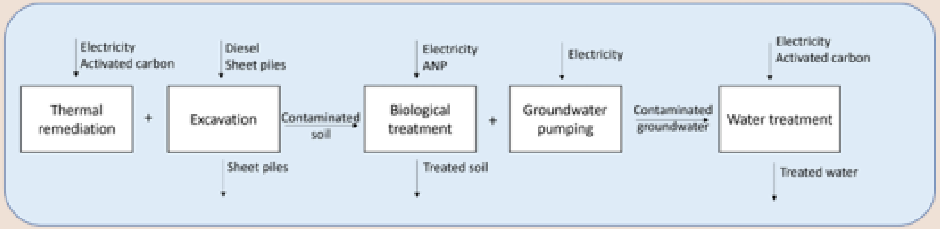
- Contaminated megasite in Denmark
- Operation for the next 30 years
- Functional Unit: “Establishment and operation of a remediation method, that remove or contain chlorinated solvents in a defined contaminated area, to keep these contaminants away from the nearby water supply for a period of 30 years”.

Functional units

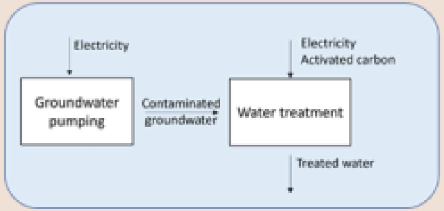
Strategy A – 100% thermal remediation followed by Pump and Treat:



Strategy B – Thermal remediation combined with excavation followed by Pump and Treat:



Strategy C – Continuation of Pump and Treat:



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Approach

- The LCA model is build in a commercial LCA tool called “LCA for Experts 2023 (GABI)” and a related database.
- **Input data** comes from a database called RemS, inspection of the site and from contracters
- **Input** for energy and material consumption, transport, waste treatment, etc. for the three strategies (A, B and C).
- The data inputs are converted to total **kg CO_2-eq** per functional unit (FU).

Example: Data inputs for strategy B (soil excavation)

Data type	Material/activity	Unit	Quantity
Investigations			
Input	Passenger car	km	1000
Input	Truck	km	200
Input	PE pipe	kg	392
Input	Concrete	kg	1500
Output	Soil	kg	19800
Establishment and operation			
Input	Diesel	kg	28067
Input	Passenger car	km	2000
Input	Truck	km	100
Input	Sand and gravel	kg	38475000
Input	Truck, sand and gravel	km/load	50
Output	Soil	kg	30375000

Climate change impact: kg material/FU × kg CO_2-eq/kg material = kg CO_2-eq/FU

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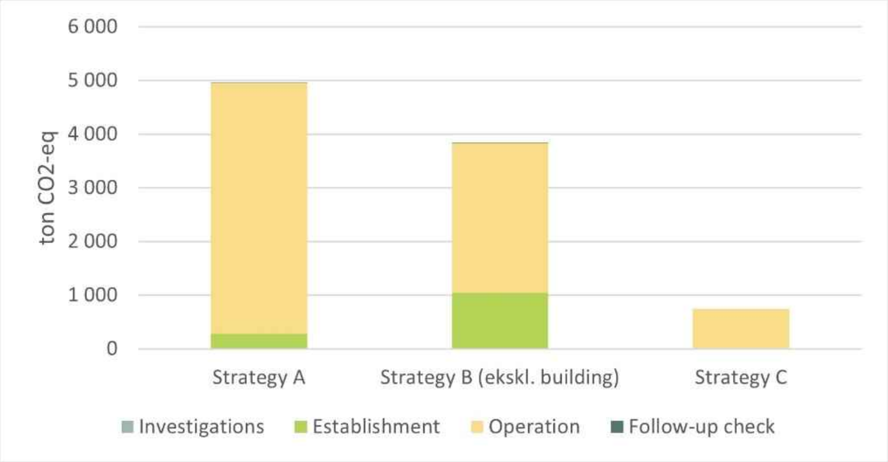
Results for project phases

- For all three remediation strategies, the remediation phase contributes to the highest impacts
- For strategy A and B, it is primarily due to the consumption of electricity from thermal remediation
- For strategy C, it is due to the consumption of electricity for extraction wells and water treatment

Potential climate impact for strategies A, B and C divided into project phases

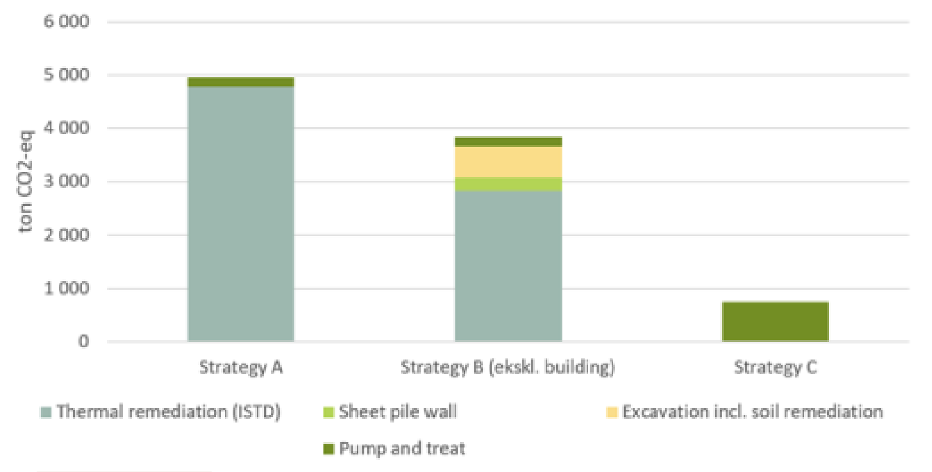


Strategy	Energy consumption, power [MJ]
Strategy A	64.797.761
Strategy B	36.535.959
Strategy C	8.825.787

Results for methods (i)

- Strategy A has the greatest impact, followed by strategy B - power consumption for thermal remediation dominates
- Strategy C has the lowest impact, but it can`t be compared with strategy A and B.
- Strategy C is only used to contain the plume, and is not a remediation strategi in the same way as strategy A and B.

Potential climate change impact for strategies A, B and C divided into remediation methods



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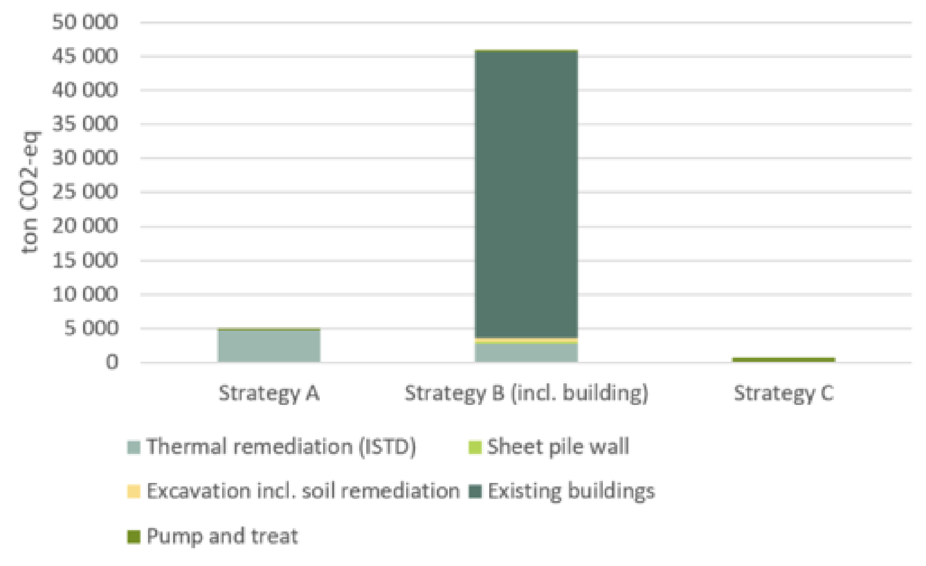
Results for methods (ii)

- Existing constructions need to be removed due to the excavation in strategy B
- Assuming full removal of buildings and assuming use of new "raw materials" (concrete, rockwool, bricks) for the reconstruction

Raw material consumption in the form of building materials is crucial for the comparison of the three remediation strategies

Potential climate impact for strategies A, B and C divided into remediation methods - importance of building materials consumption



Unit process analysis

- Focus on the unit processes that contribute most to the climate impact
- Result can be used for design optimization with focus on environmental effects

Unit process analysis for Strategy A (example)

Unit process	Part of total [%]
Electricity consumption for ISTD in operation phase	73.3%
Activated carbon for ISTD in operation phase	14.5%
Steel	4.4%
Electricity consumption for Pump and Treat in the operation phase	1.8%
Truck	1.7%
Car for supervision	1.1%
Activated carbon for Pump and Treat	0.8%
Stainless steel	0.8%
Truck	0.4%
Van	0.3%
Total	99%

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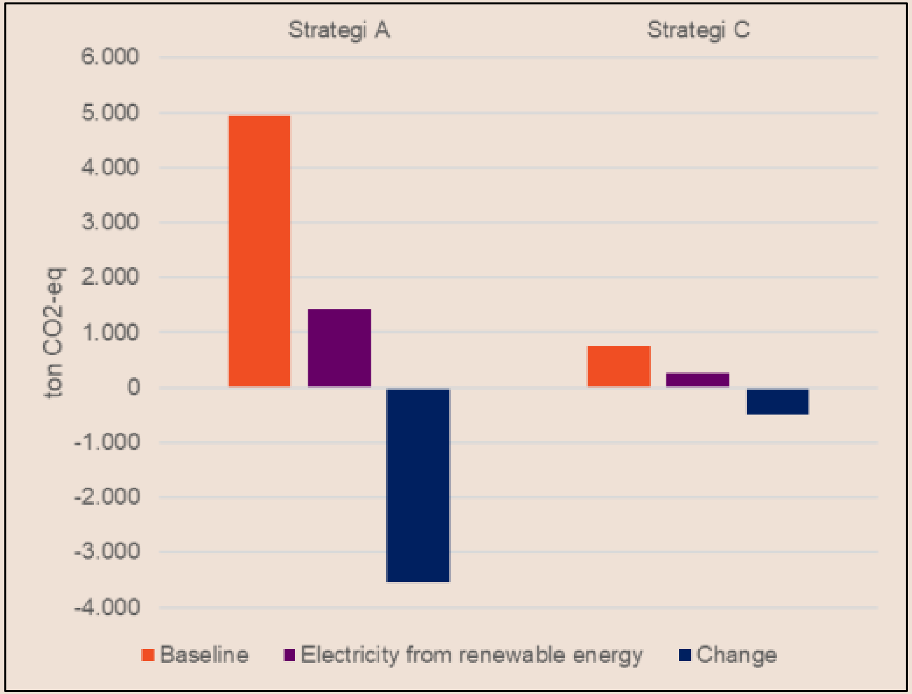
Sensitivity analysis

- For Strategy A and C, electricity consumption is the main driver for the climate change impact
- Sensitivity analysis to assess the influence of buying electricity from renewable energy

! **Electricity from renewable energy reduces the climate impact very much**

Sensitivity analysis for change in climate impact according to power consumption for strategy A and C



Summary

What can LCA be used for?

- It can rank the most contributing processes for the climate impacts
- It can support the decision-making for choosing between different remediation strategies
- It can also support decision makers towards a more sustainable development

Take-aways from use of LCA

- From a climate point of view, it is best to apply strategy A if the contamination needs to be remediated here and now
- Climate impact from strategy A can be reduced very much by buying electricity from renewable energy
- Strategy B has the largest impact, mainly due to new raw materials related to reconstruction of buildings at the site
- From a climate point of view, it is best to apply strategy C. Strategy C is only used to contain the plume zone, and is not a remediation strategi in the same way as strategy A and B.

Questions?

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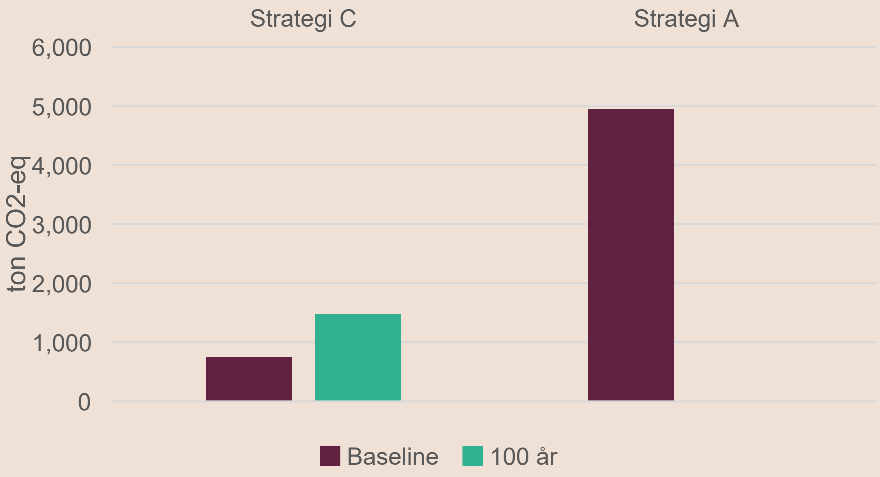
Backup slide Sensitivity analysis (ii)

- The influence of the time duration for the continuation of remediation pumping (strategy C) is investigated.
- With a time period of 100 years, the ranking between Strategy A and C is not changed.

! **Bear in mind that Strategy C is not a remediation strategy**

Sensitivity analysis for change in climate impact according to power consumption for strategy A and C



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Backup slide

Strategies

Remediation - Strategy A

100% thermal remediation followed by Pump and Treat for 10 years for the removal of dissolved contamination

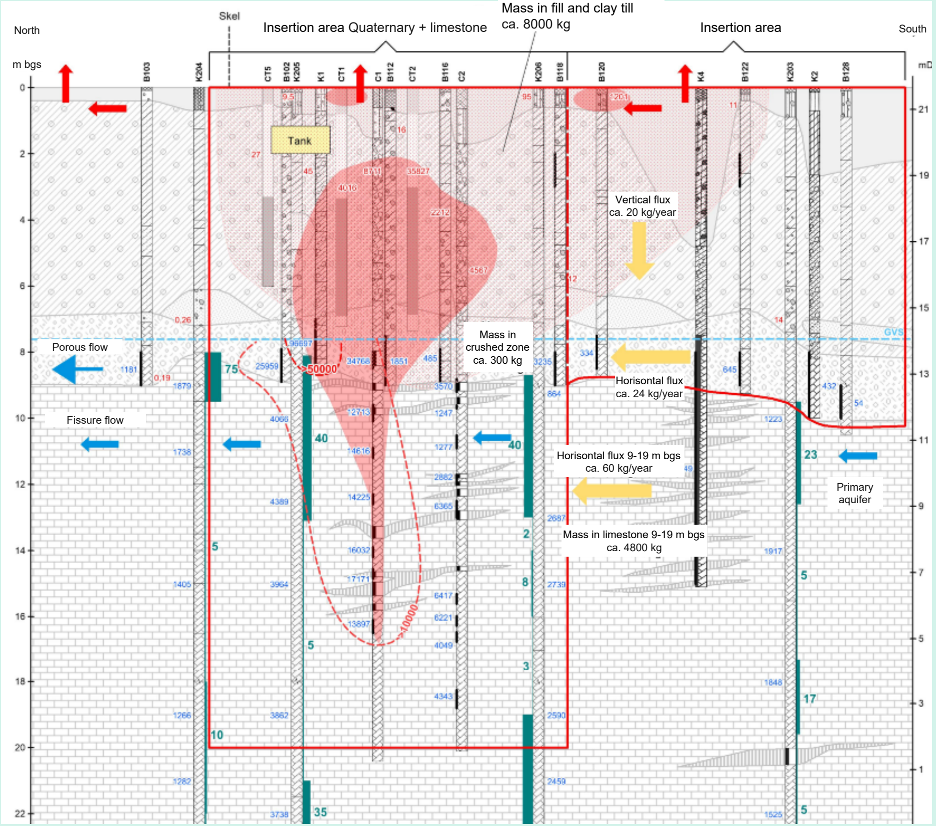
Remediation - Strategy B

Thermal remediation combined with excavation followed by Pump and Treat for 10 years, including removal and reconstruction of existing buildings.

Containment – Strategy C

Continuation of Pump and Treat from extraction well K11 for 30 years.
Already etablished at the site.

Vertically



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