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Report

Carbon footprint calculation for water pipeline renovation with pipe bursting and open-cut technique

This project is done for Hallingplast and Göteborgs stad. Aim of the study is to compare two water pipeline renovation techniques, pipe bursting (PB) and open-cut (OC), and the effect of using carbon neutral PE pipe. Calculation is divided into three cases. Case A is done with open-cut, Case B with pipe bursting and Case C with pipe bursting and carbon neutral PE pipe. This project was carried out by an experienced working group at FCG Finnish Consulting Group. Working group consisted of project manager Ella Havulinna, quality assurance Henri Haimi and design engineer Juuli Haapakoski.

General

Carbon neutral pipe manufacturing process

Bornewables products are plastics produced with renewable feedstocks from waste, residue vegetable oils [1] and forestry. If Bornewables polyethylene (PE) is used instead of fossil feedstock, the carbon footprint of plastic material (cradle-to-gate) is reduced from 1.5 to -0.24 kg CO_2e/kg [2]. Negative carbon footprint originates from the feedstock plants' ability to store carbon in the growth phase. If the plastic is recycled or reused, the carbon in it will stay in the loop instead of being released into the atmosphere through incineration[1].

[1] Borealis (2021). The Bornewables: a sustainable alternative to virgin polyolefins.
[2] Borealis (2022). Phase A1-A2 feedstock GHG values for Hallingplast.

Hallingplast processes this renewable plastic into PE pipes. Manufacturing phase is 0,01321 kg CO_2e/kg of pipe produced. [3] Total production of PE100 pipe is 1,51 kg CO_2e/kg for fossil feedstock pipes and -0,23 kg CO_2e/kg for renewable feedstock pipes.

Renovation techniques

Pipe bursting is a renovation technique that needs only small amounts of digging. The original pipe is bursted to fit same or bigger diameter pipe. Pipe bursting is used for pipe diameters 25-800 mm. Technique requires temporary pumping of wastewater for wastewater pipes and temporary water delivery for water pipes.[4] Open cut is a traditional renovation technique where the whole length of the pipe is excavated open and other infrastructure can be changed at the same time. Open cut also requires temporary pumping and/or water delivery.

Göteborg's methods to reducing carbon footprint in renovation activities

Göteborg uses diesel with 50 % reduction from fossil diesel. For this project, 50 % of trench materials for fill layer are recycled from site and 50 % new material. Because fill layer is the deepest, total amount of recycled masses in the trench is 21 % for both open-cut and pipe bursting.

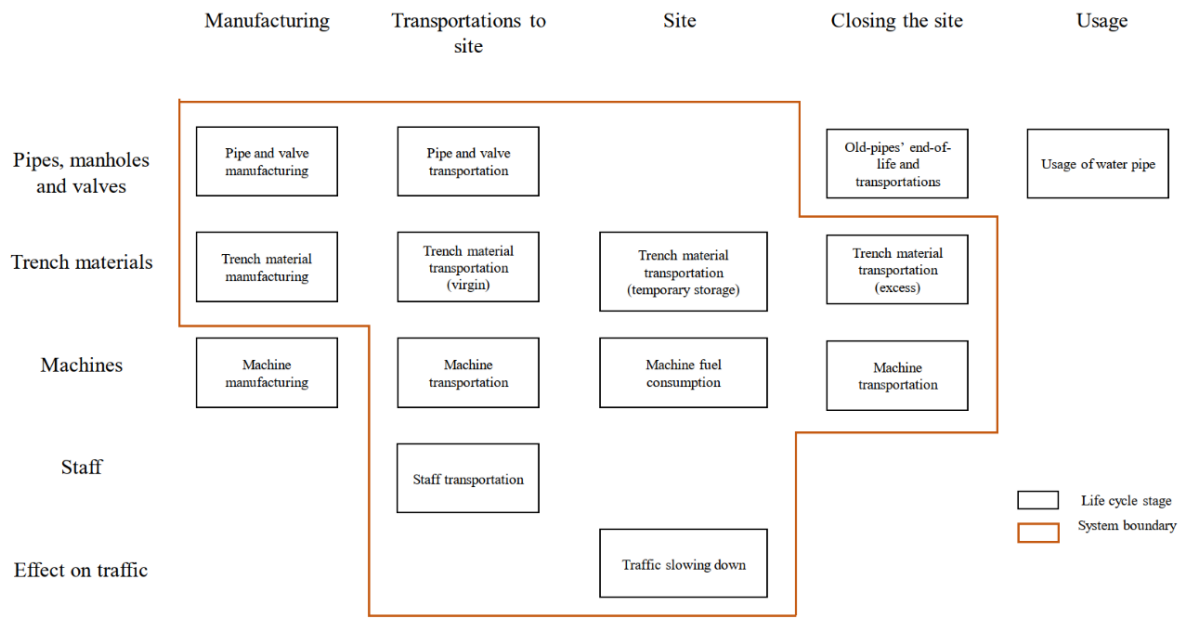
[3] Halllingplast (2022). Carbon footprint phase A1-A3.
[4] Infra 2013. Vesihuoltoverkkojen saneeraus.

Carbon footprint analysis

Carbon footprint analysis (CF) is a form of life cycle analysis (LCA) that focuses only on one impact category, climate change. LCA's have four stages: Goal and scope, Inventory analysis, Impact assessment and Interpretation. This carbon footprint analysis was performed with excel and according to standard SFS-EN ISO 14067:2018. Calculations are not approved by a third party.

Goal and scope

This calculation is for a case study in Göteborg Sweden. Aim of the study is to compare two water pipe renovation techniques, pipe bursting and open-cut, and the effect of using carbon neutral PE pipe. System boundary is presented in Picture 1.

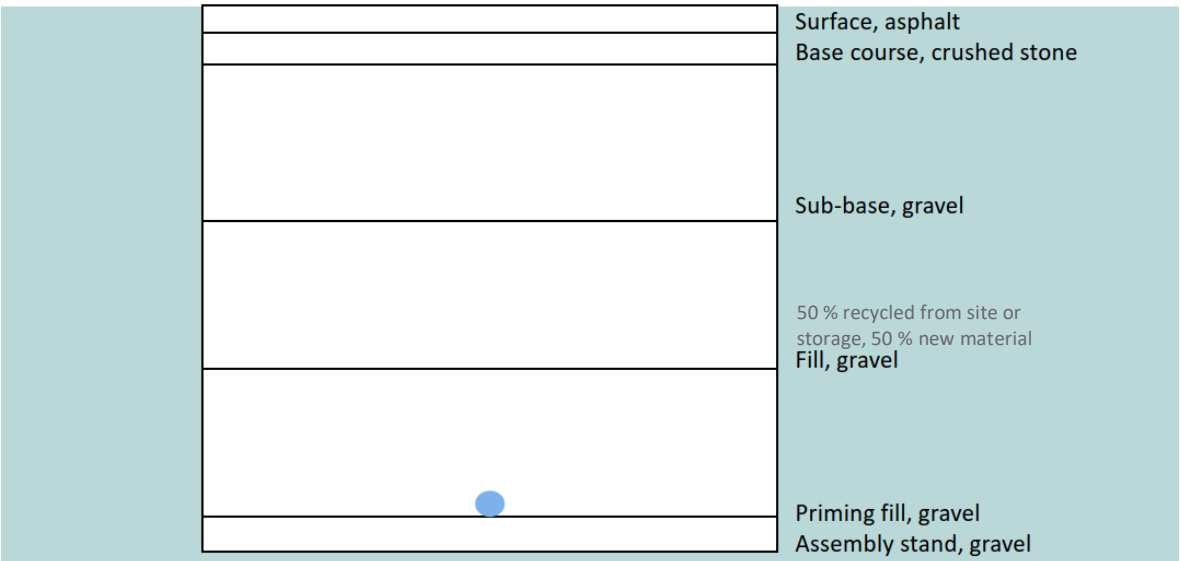


Picture 1. System boundary.

Calculations do not include machine manufacturing, end-of-life treatment for old pipes or usage of water pipe. Calculation is done for the whole length of renovation, 456 m.

Inventory analysis

Inventory analysis is a stage for collecting the emission factors for calculation. Input data comes from Göteborgs stad and Hallingplast. Some of the values come from Master's thesis in technology "Carbon footprint reduction in water and wastewater distribution networks' relining". Thesis values are collected from literature and interviews. Values are found in Appendix 1 Input data and Appendix 2 Calculation. Trench materials are calculated with the cross-section presented in Picture 2.



Walkway	[mm]	Street	[mm]	Park	[mm]
Surface: asphalt	45	Surface: asphalt	80	Surface: grass	
Base course: crushed stone	100	Base course: crushed stone	100		
Sub-base: gravel	360	Sub-base: gravel	500		
Fill: gravel	765	Fill: gravel	480	Fill: clay from site	1270
Priming fill: gravel	480	Priming fill: gravel	480	Priming fill: gravel	480
Assembly stand: gravel	150	Assembly stand: gravel	150	Assembly stand: gravel	150
Total depth [mm]	1900		1900		1900

Picture 2. Cross-section for calculating trench masses (not to scale).

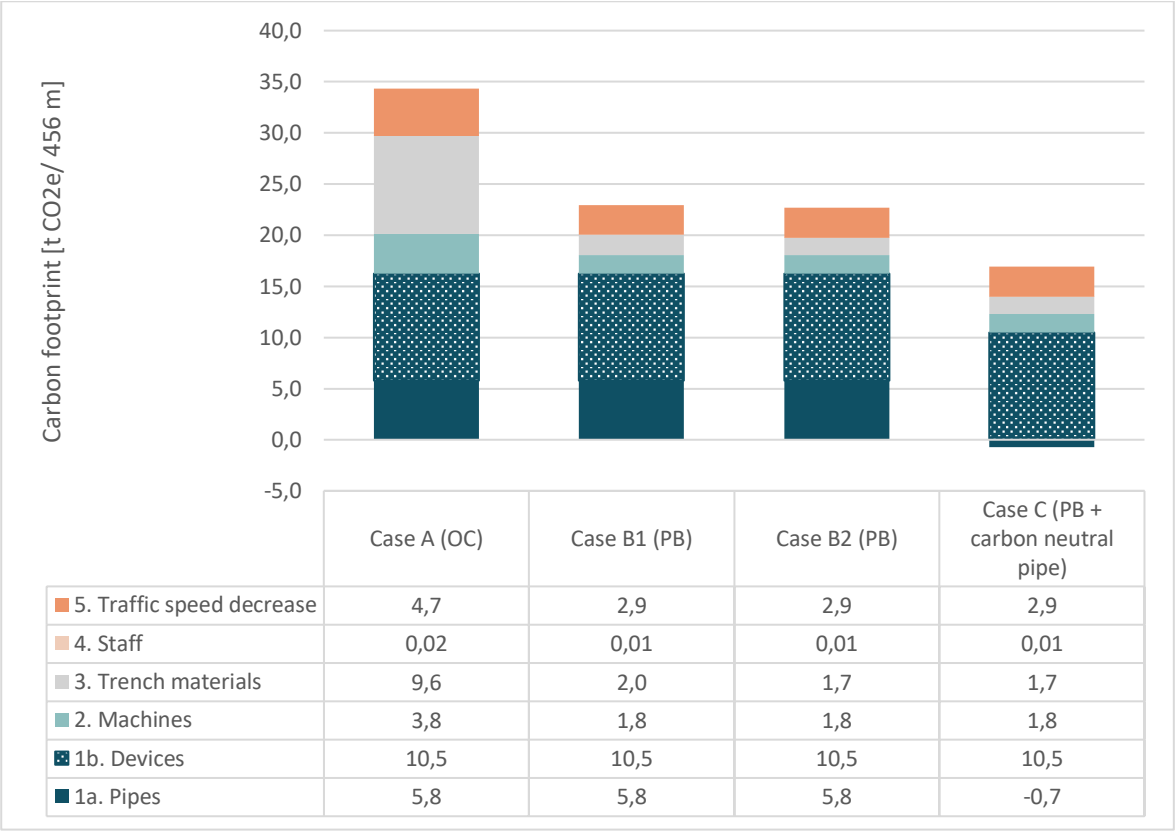
Impact assessment and interpretation

Impact assessment is a stage for assessing environmental impacts based on results. Interpretation is a stage for conclusions and assessing the factors that affect the results' completeness and consistency. Total carbon footprint is shown in Table 1.

Table 1. Total carbon footprint for the whole relined length and per 1 meter.

	t CO2e/456 m	t CO2e/m
Case A (OC)	34,3	0,075
Case B1 (PB)	23,0	0,050
Case B2 (PB)	22,7	0,050
Case C (PB + carbon neutral pipe)	16,2	0,036

Case B1 is pipe bursting without mass recycle and B2 is pipe bursting with mass recycle. In cases A, B2 and C, masses are recyled according to picture 2. Total carbon footprint for Case A is 34,3 t CO_2e/456 m, Case B1 23,0 t CO_2e/456 m, Case B2 22,7 t CO_2e/456 m, and Case C 16,2 t CO_2e/456 m. Carbon footprint per 1 meter is Case A 0,075, Case B1 0,050, Case B2 0,050 and Case C 0,036. Total carbon footprint is separated into five categories in picture 3.



	Case A (OC)	Case B1 (PB)	Case B2 (PB)	Case C (PB + carbon neutral pipe)
5. Traffic speed decrease	4,7	2,9	2,9	2,9
4. Staff	0,02	0,01	0,01	0,01
3. Trench materials	9,6	2,0	1,7	1,7
2. Machines	3,8	1,8	1,8	1,8
1b. Devices	10,5	10,5	10,5	10,5
1a. Pipes	5,8	5,8	5,8	-0,7

Picture 3. Carbon footprint separated into five categories: Pipes and devices (1), machines (2), trench materials (3), staff (4) and traffic speed decrease (5).

Largest carbon footprint is with open-cut and most of the carbon footprint come from trench materials (28 %) and pipes and devices (17 % + 31 %). If renovation is done with pipe bursting, the carbon footprint decreases 34 %. If pipe bursting is done with a carbon neutral PE pipe, the carbon footprint is reduced 53 % compared to open-cut.

Because Göteborg uses recycled materials in their renovations, trench materials' carbon footprint is already reduced in cases A, B2 and C. If renovation was done without recycled materials, the carbon footprint of category 3 for pipe bursting would be 2,0 t CO_2e (B1) instead of 1,7 CO_2e (B2) which is 15 % of category 3 emissions. Using recycled masses reduces total carbon footprint for Case A 4 %, Case B 1 % and Case C 2 %.

With pipe bursting and carbon neutral PE pipe all of the categories (1-5) are reduced compared to open cut. Main advantage with using pipe bursting comes from reduction of trench masses. Because it takes less time (estimated with working group OC 80 working days, PB 50 working days) to execute pipe bursting, the effect on traffic and usage of machines is reduced. Largest impact for pipe bursting comes from pipes and devices (25 % + 46 %) and this is reduced with using carbon neutral PE pipe (Case C). Category 1 includes pipe material, device materials and transportations to site (included in 1a and 1b). Pipe is carbon negative -0,8 t CO_2e, but the devices' impact is 10,2 t CO_2e and transportations' 0,4 t CO_2e which in total is 9,8 t CO_2e.

According to Swedish legislation, diesel should be mixed with renewable diesel to achieve at least 30 % reduced emissions from fossil diesel. This project used 50 % reduced diesel. Total carbon footprint when 30 % reduced diesel is used is shown in Table 2.

Table 2. Total carbon footprint for the whole relined length and per 1 meter with diesel 30 % reduction from fossil.

	t CO2e/456 m	t CO2e/m
Case A (OC)	40,5	0,089
Case B1 (PB)	25,5	0,056
Case B2 (PB)	25,1	0,055
Case C (PB + carbon neutral pipe)	18,6	0,041

Using 50 % reduced diesel reduces the carbon footprint for Case A 15 %, Case B1 10 %, Case B2 10 % and Case C 13 %.

Swedish average CO_2 carbon footprint per person is 10 t CO_2e and the goal for 2050 is 2 t CO_2e/person[5]. Carbon footprint of Case A is equal to 4 persons' yearly carbon footprint and Case C is equal to 2 persons' yearly carbon footprint. When choosing pipe bursting with carbon neutral pipe, the reduction of carbon footprint is more than 2 people reducing their carbon footprint to goal 2 t CO_2e/person. The cost of reducing carbon footprint with carbon neutral pipe was 1158 e/ t CO_2e reduced.

Conclusions

This study compared the difference of using pipe bursting and carbon neutral PE pipe instead of open-cut with fossil pipe. Carbon footprint Case A (OC) was 34,5 t CO_2e/456 m, Case B1 (PB without mass recycle) 23,0 t CO_2e/456 m, Case B2 (PB) 22,7 t CO_2e/456 m, and Case C (PB and carbon neutral pipe) 16,2 t CO_2e/456 m.

Most of the carbon footprint for Case A came from trench materials (28 %) and pipes and devices (17 % + 30 %). Using recycled trench masses reduced the carbon footprint of Case A 4 %, Case B 1 %, and Case C 2 %. If Case B2 was chosen the total carbon footprint reduced 34 % and if Case C was chosen the carbon footprint reduced 53 % compared to Case A. Using 50 % reduced diesel instead of 30 % reduced affected the total carbon footprint for Case C 13 %.

If Case C was chosen instead of Case A, the reduction of carbon footprint is more than 2 Swedish people reducing their yearly carbon footprint from 10 t CO_2e to Swedish goal for 2050 2 t CO_2e. The cost of reducing carbon footprint with carbon neutral pipe was 1158 e/ t CO_2e reduced.

[5] Naturvardsverket. How do I reduce my carbon footprint. Available (Cited 16.12.2022): https://www.naturvardsverket.se/en/topics/climate-transition/omraden/klimatet-och-konsumtionen/how-can-i-reduce-my-carbon-footprint/

Appendix 1. Input data

Appendix 2. Calculation