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Climate Impact Assessment of Temporary Works in Urban Infrastructure

A Case Study of the West Link Project, Gothenburg

Master's thesis in Industrial Ecology

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Abstract

Temporary works are essential for the construction of permanent infrastructure but are often excluded from climate assessments and procurement requirements. In complex urban infrastructure projects, such as underground rail construction, these temporary constructions may involve substantial quantities of materials, transport activities and machinery use, resulting in potentially significant greenhouse gas emissions. This thesis investigates the climate impact of temporary works in the Västlänken railway tunnel project in Gothenburg and evaluates how well Trafikverket's climate calculation tool, Klimatkalkyl, represents these impacts. Four temporary constructions were selected for analysis: a diaphragm wall system, a crane foundation, a canal infill and an aqueduct. A life cycle assessment (LCA) was conducted using a three-scenario approach. Scenario A represents a standard Klimatkalkyl calculation based on generic default values. Scenario B adds construction activities that are structurally absent from standard calculations while maintaining the same emission factors. Scenario C applies project-specific Environmental Product Declarations (EPDs), transport distances and fuel data. The results show that the significance of omitted construction activities varies substantially between construction types. For the diaphragm wall system, the addition of previously excluded machinery activities increased total emissions by only 0.1%, whereas the aqueduct showed an increase of 137%. Applying project-specific data reduced calculated emissions by up to 45%, primarily due to lower-emission concrete mixes and the use of HVO100 in construction machinery. The findings indicate that current infrastructure climate calculations may underestimate the climate impact of machine-intensive temporary works and that a gap exists between reported and actual construction-phase emissions. While Klimatkalkyl can technically accommodate these activities, the current procurement framework does not systematically require their inclusion. The study concludes that this gap is structural rather than a question of data quality or compliance, and that temporary works require greater attention in climate reporting and procurement if long-term climate-neutral infrastructure ambitions are to be supported.

Keywords: Temporary works, climate impact, life cycle assessment, LCA, embodied carbon, infrastructure, Klimatkalkyl, The West Link Project, construction emissions, procurement.

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Olof Bähr, Gothenburg, June 2026

List of Acronyms

CO_2e	Carbon Dioxide equivalents
EPD	Environmental Product Declaration
HVO	Hydrotreated Vegetable Oil
HVO100	Fuel consisting entirely of hydrotreated vegetable oil
MK1	Miljöklass 1, Swedish environmental class 1 diesel
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
CEN	European Committee for Standardization
TWF	Temporary Works Forum
GWP	Global Warming Potential
PAS	Publicly Available Specification

Nomenclature

Klimatkalkyl**:** A climate calculation tool developed by Trafikverket, used to assess the climate impact from infrastructure projects.

Byggdel: The Swedish term for a building element in Klimatkalkyl, an individual pre-defined item in the tool library from which a calculation is done.

Typåtgärd: Pre-defined composite elements representing typical infrastructure features such as bus shelters or signalling systems.

Dotter-EPD: An EPD derived from a parent EPD, giving third-party verified values for one specific mix of concrete within the product family the parent covers.

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1 Introduction

The construction sector is one of the largest contributors to global greenhouse gas emissions, accounting for approximately 37% of global carbon dioxide emissions (UNEP & GlobalABC, 2025). Approximately 11% of global emissions comes from embodied carbon, emissions associated with the extraction and manufacturing of construction materials (WorldGBC, 2019). As operational energy use decreases through electrification and efficiency improvements, embodied carbon is becoming a proportionally larger share of total life cycle emissions, making it an increasingly critical area for climate action in the built environment (Röck et al., 2020).

Sweden has adopted ambitious national climate targets, aiming for net-zero greenhouse gas emissions by 2045, with intermediate milestones of 63% reduction by 2030 and 75% by 2040 compared to 1990 levels (Naturvårdsverket, 2026). The Swedish Transport Administration (Trafikverket) has set its own targets for transport infrastructure, aiming to reduce net climate impact to zero by 2040, with intermediate goals of 60% reduction by 2030 and 80% by 2035, compared to 2015 (Trafikverket, 2026b).

To support these goals, Trafikverket has developed Klimatkalkyl, which is a web-based tool for calculating the climate impact of infrastructure projects across their life cycle (Trafikverket, 2026b). The tool is mandatory in infrastructure procurement, for contractors working with Trafikverket and is used to set and verify climate reduction requirements for contractors (Trafikverket, 2026a). Klimatkalkyl relies on generic default values, for materials, transport distances and construction activities (Trafikverket, 2024). These simplifications enable consistent early-stage estimates but may not capture the full complexity of actual construction conditions, particularly in technically challenging urban projects.

A critical but systematically overlooked source of climate impact in complex urban infrastructure projects is temporary works. These are structures and activities required to enable the construction of a permanent asset, but that do not themselves form part of the finished project. In urban tunnel construction, examples include diaphragm wall systems, temporary crane foundations, canal infills and aqueducts. These elements can involve significant quantities of concrete, steel and heavy machinery, yet they often fall entirely outside the scope of conventional climate calculations. This gap exists at two levels: first, the temporary constructions themselves are typically excluded from climate reporting as they are treated as production prerequisites managed by the contractor; and second, even when such constructions are included, the machinery required to build them may have no corresponding building element in Klimatkalkyl's default library, making the gap structural rather than merely a question of data availability.

This gap is particularly relevant for Västlänken in Gothenburg, a railway tunnel of approximately 8 km running beneath central Gothenburg, currently under construction (Trafikverket, n.d.). The dense urban environment and complex geology may require extensive temporary works that would not be necessary in a less constrained setting. The question of how well Klimatkalkyl captures the actual climate impact of these elements has not previously been investigated with empirical production data from a real project.

This thesis addresses this question by comparing three scenarios for four selected temporary constructions from Västlänken. Scenario A uses Klimatkalkyl's generic default values throughout and serves as the reference case. Scenario B adds the machinery posts that are structurally absent from Klimatkalkyl's default calculations while keeping all emission factors identical to Scenario A, isolating the structural gap in the tool. Scenario C uses the best available project-specific data including EPDs, confirmed transport distances and confirmed fuel types, representing the most accurate estimate of actual climate impact. Together the three scenarios allow the study to separate what Klimatkalkyl misses structurally from the additional improvements achievable through better data.

1.1 Aim and Objectives

The aim of this thesis is to investigate the climate impact of temporary works in the Västlänken project. It also assesses how well Klimatkalkyl represents the climate impact of temporary works in a large urban infrastructure project. It specifically identifies which construction activities are structurally absent from the tool's default calculations.

The specific objectives of the study are to:

- quantify the climate impact of each selected construction using Klimatkalkyl's generic default values, covering life cycle modules A1-A5 and C1-C2 (Scenario A)
- identify and quantify construction activities present in the actual project but structurally absent from Klimatkalkyl's default calculations, keeping all material quantities and emission factors identical to Scenario A to isolate the structural gap in Klimatkalkyl’s standard calculations (Scenario B).
- produce the most complete project-specific climate assessment possible using confirmed production data from the contractor Peab, including EPDs, real transport distances, on-site machinery activities and confirmed fuel types (Scenario C).
- compare the three scenarios to separate Klimatkalkyl's structural limitations from the additional effect of improved data and fuel choices.
- assess the implications for how Klimatkalkyl is used in climate reporting and procurement for complex urban infrastructure projects, and provide recommendations for improvement.

1.2 Report Outline

Chapter 2 presents the theoretical and contextual background, covering LCA methodology, the Klimatkalkyl tool, temporary works in infrastructure, and descriptions of The West Link Project and the four temporary constructions studied. Chapter 3 describes the methodology, including the three-scenario structure, goal and scope definition, data collection approach, modelling procedure and key assumptions. Chapter 4 presents the results for each construction across all three scenarios. Chapter 5 analyses the results and examines their implications for Klimatkalkyl's use in complex projects. Chapter 6 discusses wider implications, addresses limitations and provides recommendations for future work. References and appendices follow. Chapter 7 presents the conclusion of the study.

2 Theory and Background

2.1 Climate Impact of the Construction Sector

The building and construction sector accounts for approximately 37% of global carbon dioxide emissions (United Nations Environmental Programme & Global Alliance for Buildings and Construction [UNEP & GlobalABC], 2025), with embodied carbon from material production representing approximately 11% of the total global emissions (World Green Building Council [WorldGBC], 2019). In Sweden, the construction sector accounts for approximately 22% of national greenhouse gas emissions (Boverket, 2025). As buildings and infrastructure become more energy-efficient through improved design and operational measures, the relative share of embodied carbon increases, making it a progressively more important focus for climate action (Röck et al., 2020).

Within the infrastructure sector, the construction, operation and maintenance of transport infrastructure represent a significant source of greenhouse gas emissions. In response, Trafikverket has committed to achieving climate-neutral infrastructure by 2040, with intermediate reduction targets of 60% by 2030 and 80% by 2035 compared to 2015 levels (Trafikverket, 2026b).

Studies of tunnel construction carbon footprints have found that material production dominates construction-phase emissions. In a case study of conventional tunnelling, materials accounted for approximately 85% of total CO_2 emissions, while loading and transport accounted for 5% and electricity generation for 10% (Rodríguez & Pérez, 2021). Notably, the same study explicitly neglects the energy consumed by machinery during support and lining installation, calculating only material production and transport for those tasks. The omission of on-site machinery is therefore not unique to Klimatkalkyl.

Despite progress in quantifying emissions from permanent infrastructure, the climate impact of temporary works remains largely absent from standard climate calculations. In practice, climate calculations for infrastructure projects focus on the permanent structure, the tunnel, the stations, the permanent concrete and steel. Temporary works are not included in the reference calculation against which procurement requirements are set (see Section 2.4). The result is a systematic gap between reported and actual climate impact and this study examines how that gap varies with the type of construction involved.

In one of few Swedish studies on the subject, Miliutenko et al. (2012) conducted a life cycle assessment of Norra Länken, a road tunnel in Stockholm, and noted that despite growing interest, LCA was rarely applied in infrastructure planning practice at the time. The picture has since changed somewhat. LCA has become increasingly used in infrastructure policy and procurement across several countries (Liljeström et al., 2022), with Sweden among the countries to have formalised climate calculations

in infrastructure procurement (Trafikverket, 2026b). However, the application of such calculations to temporary works remains limited (Temporary Works Forum [TWF], 2023).

2.2 Life Cycle Assessment

Life cycle assessment (LCA) is a methodology for evaluating the environmental impacts of a product, process or service across its entire life cycle, from raw material extraction through production, use and disposal (Baumann & Tillman, 2004). ISO 14040 defines the overall LCA framework and its four phases: goal and scope definition, inventory analysis, impact assessment and interpretation (ISO, 2006b). ISO 14044 provides detailed requirements and guidelines for each phase, covering functional units, system boundaries, data quality and allocation procedures (ISO, 2006c).

The European standard EN 15978 applies the LCA framework specifically to buildings and civil engineering works, introducing the standardised life cycle module structure used in this study (CEN, 2011). EN 15804 governs Environmental Product Declarations (EPDs), enabling standardised and third-party verified product-level emissions data that can be used as input to LCA calculations (CEN, 2012). Table 2.1 presents the EN 15978 life cycle module structure.

Table 2.1. Life cycle stages as defined by EN 15978 (CEN, 2011).

Stage	Module	Description
Product stage	A1	Raw material extraction and processing
	A2	Transport to manufacturer
	A3	Manufacturing
Construction process stage	A4	Transport to construction site
	A5	On-site construction activities and installation
Use stage	B1-B7	Use, maintenance, repair, replacement, operational energy and water
End-of-life stage	C1-C4	Demolition and dismantling, transport, waste processing, disposal
Beyond system boundary	D	Reuse, recovery and recycling potential

The four phases of an LCA are applied as follows in this study. Goal and scope definition establishes the functional unit, the complete construction of each temporary construction as built, and the system boundary covering modules A1 - A5, C1 and C2. Inventory analysis collects data on all material and energy flows within the system boundary, including both confirmed project data from the contractor, Peab and motivated assumptions where direct data is unavailable. Impact assessment translates inventory results into Global Warming Potential (GWP),

expressed in tonnes CO_2 equivalents ($tCO2_2e$), using emission factors from Klimatkalkyl and EPDs where available. Interpretation analyses the results relative to the study's objectives, identifies the most significant contributors and evaluates uncertainties.

2.2.1 Cut-off criteria

Both ISO 14044:2006 and EN 15978:2011 establish the principle that inputs and outputs below a defined threshold of environmental significance may be excluded from an LCA, a concept known as cut-off criteria (ISO, 2006c; CEN, 2011). Neither standard specifies a fixed percentage threshold, leaving the determination of significance to practitioner judgement. Cut-off criteria in infrastructure carbon assessment are more precisely defined in PAS 2080, which states that “the total excluded input or output per module shall be a maximum of 5% of energy usage and mass” (BSI, 2016, as cited in TWF, 2023). TWF applies this threshold to temporary works, noting that these are unlikely to fall below it in many infrastructure projects and therefore cannot be excluded on the basis of cut-off criteria (TWF, 2023).

2.2.2 EPD

Environmental Product Declarations (EPDs) are a key mechanism for introducing product-specific emissions data into LCA-based climate calculations. An EPD is a Type III environmental declaration under ISO 14025, meaning it is based on a full life cycle assessment and must be independently verified by a third party before publication (ISO, 2006a). For construction products in Europe, EN 15804 provides the core rules governing how EPDs are produced, defining which life cycle modules must be covered, which impact categories must be reported and how allocation between co-products is handled (CEN, 2012). In practice, EPDs allow contractors and designers to replace generic default emission factors, such as those in Klimatkalkyl with product-specific verified values.

Data quality is a central requirement in ISO 14044. The standard requires that studies must assess and document data quality across several dimensions including time-related coverage, geographical coverage, technological coverage, precision and completeness (ISO, 2006c). These requirements ensure transparency about the reliability of an LCA study's results and enable readers to assess the significance of uncertainties.

In practice, LCA studies of infrastructure construction typically combine primary data collected directly from the project with secondary data in the form of generic emission factors and industry averages. The interpretation phase of ISO 14044 requires a sensitivity check to assess how changes in key assumptions affect results, and an uncertainty analysis to evaluate the reliability of conclusions (ISO, 2006c).

2.2.3 Functional Unit

The functional unit is a central concept in LCA. It defines what is being studied and serves as the reference unit against which all material and energy flows are quantified (ISO, 2006b). It must be clearly defined and quantified, enabling consistent comparison between alternative systems or scenarios. The system boundary determines which life cycle stages and processes are included in the study. ISO 14044 requires that decisions about system boundary inclusions and exclusions are explicitly documented and justified, as these decisions can substantially affect results (ISO, 2006c).

For studies of construction works, the choice of system boundary is particularly consequential. Including or excluding the construction process stage module A5 can change total results significantly in projects involving intensive on-site activities. Similarly, the decision about whether to include temporary works within the system boundary is itself a system boundary decision with material consequences. EN 15978 requires that the system boundary be defined consistently across all life cycle modules and that any deviations from full life cycle coverage be explicitly justified (CEN, 2011).

2.3 Klimatkalkyl

Klimatkalkyl is a web-based tool developed by Trafikverket for calculating the climate impact and energy use of infrastructure projects over their life cycle. The tool covers life cycle modules A1-A5 for the construction phase, as well as reinvestment representing the climate impact of replacing components with a service life shorter than the design life of the infrastructure and operational maintenance including winter road maintenance, pavement upkeep and energy use. Results are presented both as a total for the construction phase and as an annualised figure combining construction, reinvestment and operation and maintenance (Trafikverket, 2024).

In practice, Klimatkalkyl is typically applied in the early stages of a project. A reference calculation is produced based on the planned permanent structure, and this calculation forms the baseline against which reduction requirements are set. The contractor then works within that framework, primarily by selecting lower-emission materials and demonstrating this through EPDs. The calculation covers the permanent asset, in this case the tunnel, the stations, the permanent concrete and steel, but temporary works are not included, as these are treated as production prerequisites managed by the contractor (Trafikverket, personal communication, March 2026).

Within each building element in Klimatkalkyl, climate impact is structured across three layers. Material production (A1-A3) is captured through the emission factor of the material itself, based on generic average values or EPDs. Transport to site (A4) is calculated using default transport distances that can be overridden with project-specific values. On-site machinery (A5) is calculated using default fuel consumption rates per unit of material placed, for example a fixed volume of diesel per cubic metre of fill material for an excavator. As identified in this study, the tool provides no

mechanism to flag that certain activities have no representation at all. A completed calculation appears comprehensive even when significant construction activities are entirely absent. This three-layer structure, and the way the on-site machinery layer can be empty by default, is shown in Figure 2.1.

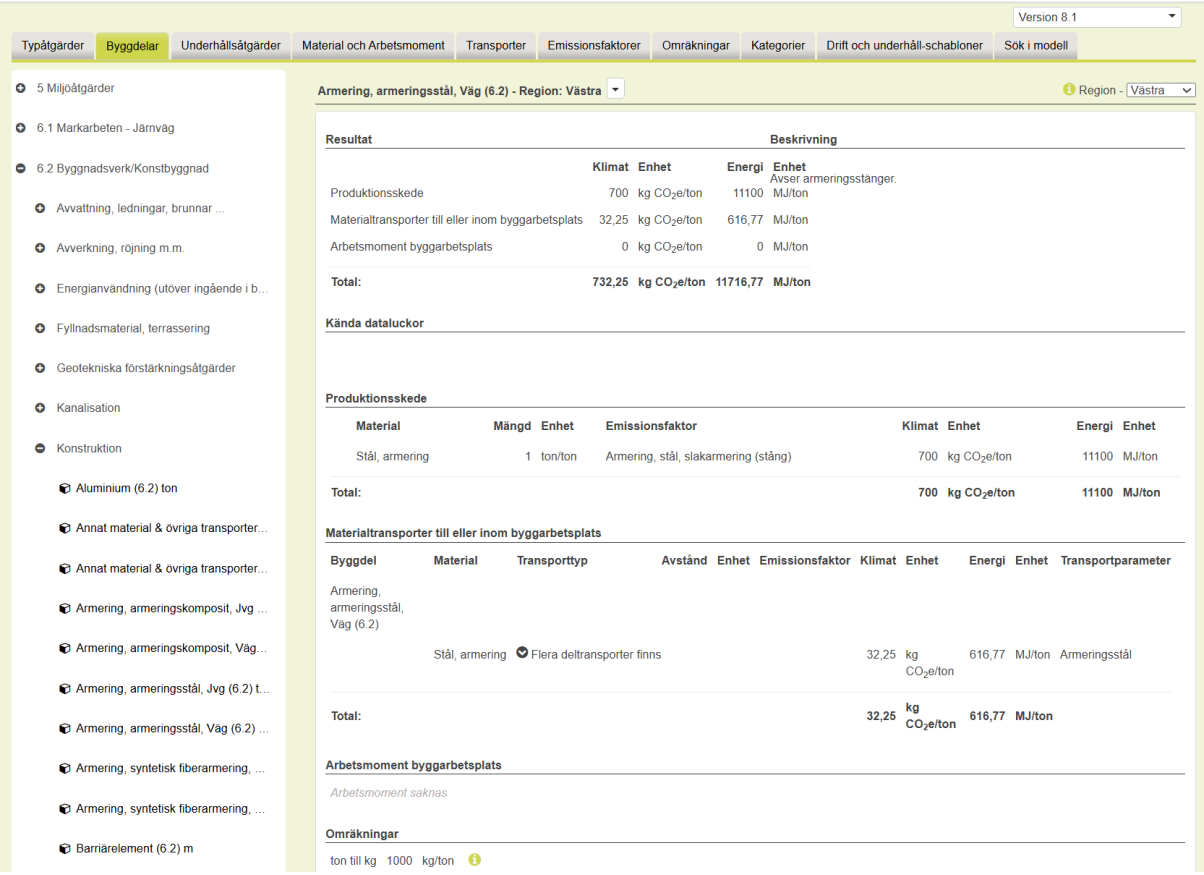


Figure 2.1. The Klimatkalkyl interface (version 8.1), showing how a calculation is assembled from predefined building elements. The left panel is the library of selectable elements, organised by category. The right panel shows one element, reinforcement steel, with its built-in values divided into production (A1-A3), material transport (A4) and on-site work (A5). For this standard element the on-site work module is empty (“Arbetsmoment saknas”, 0 kg CO_2e/ton): the predefined element contains no machinery activity by default. This illustrates the structural gap examined in this study, the absence of predefined on-site machinery for the specialised activities characteristic of temporary works.

Klimatkalkyl's limitations for complex urban projects are therefore twofold. First, its library of building elements may not include construction activities that are unusual or project-specific, such as the specialised machinery for diaphragm wall installation. Second, the generic default values are calibrated for typical infrastructure conditions and may not reflect the reality of heavily constrained urban sites. This study investigates both dimensions.

For the temporary constructions studied in this thesis, the reinvestment and operational maintenance modules are not applicable. The constructions have no conventional use or maintenance phase, and they are removed when the permanent

structure is complete. The scope of this study therefore covers modules A1-A5, C1 and C2, consistent with the system boundary defined in Section 3.3.

2.4 Temporary Works in Infrastructure Projects

In this study, temporary works are understood as structures and facilities constructed to enable the building of a permanent structure, but that do not form part of the finished asset. In tunnelling and underground construction, examples include diaphragm walls, crane foundations, cofferdams, dewatering systems and temporary bridges. In this report, the term "temporary works" refers to the overall category, while "temporary construction" is used for a specific structure within that category, for example the aqueduct or the diaphragm wall.

Two boundaries need to be drawn for this definition to be applied consistently. The first concerns the distinction between a temporary construction and construction equipment. A crane foundation is a temporary work: it is a structure built from materials on site, and those materials carry an embodied climate impact in modules A1-A5. The crane standing on it is not a temporary work but construction equipment; its climate impact arises from its operation, the fuel and hours of use, rather than from its production. In this study, the temporary construction itself is assessed as a product with its own material life cycle, while the machinery used to build and dismantle it is captured through its fuel use in modules A5, C1 and C2. The crane foundation is therefore included as a construction, and the crane is included only through the fuel it consumes.

The second boundary concerns the distinction from the permanent asset. Temporary works are defined by their temporary function during construction, not by whether they are physically removed afterwards. Most are dismantled once the permanent structure is complete, but some remain in place. The diaphragm wall system studied here, for example, stays permanently embedded in the ground, yet it is treated as a temporary work because its purpose is to enable construction of the permanent tunnel, not to form part of the finished railway.

A further point concerns whose life cycle the temporary works belong to. When the climate impact of the permanent railway is assessed, temporary works do not appear as separate items. Their entire impact, the materials, transport, on-site work and dismantling, falls within module A5, the construction process of the permanent asset. EN 15978 reflects this: it defines the boundary of module A5 to include 'temporary works, including temporary works located off-site as necessary for the construction installation process' (CEN, 2011, as cited in TWF, 2023). This study instead assesses each temporary work as a product with its own life cycle, covering modules A1-A5, C1 and C2. This is a deliberate choice: treating them as separate products is what makes their impact visible and allows it to be quantified module by module, rather than absorbed into a single A5 figure for the permanent structure.

In current Swedish infrastructure practice, there is no requirement to include temporary works in the climate calculation that forms the basis for procurement requirements (Trafikverket, personal communication, March 2026). The consequence is that even when a contractor has a detailed plan for temporary works involving significant quantities of concrete, steel and specialised machinery, none of this appears in the formal climate reporting.

Despite this, the exclusion of temporary works from infrastructure climate calculations is not a consequence of the standard's requirements, but of how the standard is applied in practice. EN 15978 explicitly places temporary works within the boundary of module A5 (CEN, 2011); the exclusion therefore arises in application, not in the standard itself.

2.5 The West Link Project

Västlänken is an approximately 8 km double-track railway tunnel running beneath central Gothenburg, constituting one of the largest infrastructure investments in Sweden's history (Trafikverket, n.d.). The project includes three new underground stations, Centralen, Haga and Korsvägen, and is designed to convert Gothenburg Central Station from a terminus into a through-station, enabling commuter and regional trains to pass through the city without reversing. Construction began in 2018, with the Centralen section expected to open in 2026 as a terminus station and full completion projected around 2030.

The dense urban environment of central Gothenburg and the complex geology, comprising a mix of rock and soft clay, require extensive temporary works that would not be necessary in a less constrained setting. The main contractor for the sections studied in this thesis is Peab. The project is well suited for this type of study because the scope and scale of temporary works are unusually large, and because detailed production data is available through direct collaboration with the contractor.

2.5.1 The Four Constructions Studied

Four temporary constructions from Västlänken were selected for this study, in consultation with Trafikverket and Peab. The Haga-Rosenlund section contains numerous temporary works, and the four studied here are a deliberate selection from many candidates. They were chosen to span the range of construction types that behave differently in a climate calculation, from material-dominated to machinery-dominated: the diaphragm wall at the material-intensive extreme, the aqueduct at the machinery-intensive extreme, and the canal infill and crane foundation as intermediate cases. Construction type, rather than the number of cases, is the decisive variable for how well Klimatkalkyl represents a construction, so additional constructions of the same types would have added little to the analysis of how impact varies by type. Estimating the total impact of temporary works across the project would require a far larger inventory, which was not an aim of this study but is identified as a direction for future research (Section 6.5). Each construction was instead assessed in depth, with material quantities, machinery hours, fuel types and transport distances confirmed directly with Peab.

2.5.2 Diaphragm Wall (Slitsmur)

A diaphragm wall system used to enable deep excavation in soft clay in central Gothenburg. The system consists of a concrete cast-in-place wall (C/D-wall), primary and secondary concrete piles, and a leanmix fill layer. The leanmix is a specialised concrete mix with a very low strength class (C1/2), designed to allow subsequent mechanical excavation. With approximately 47 000 m³ of structural concrete and over 4 400 tonnes of reinforcement steel, this is by far the largest construction studied.

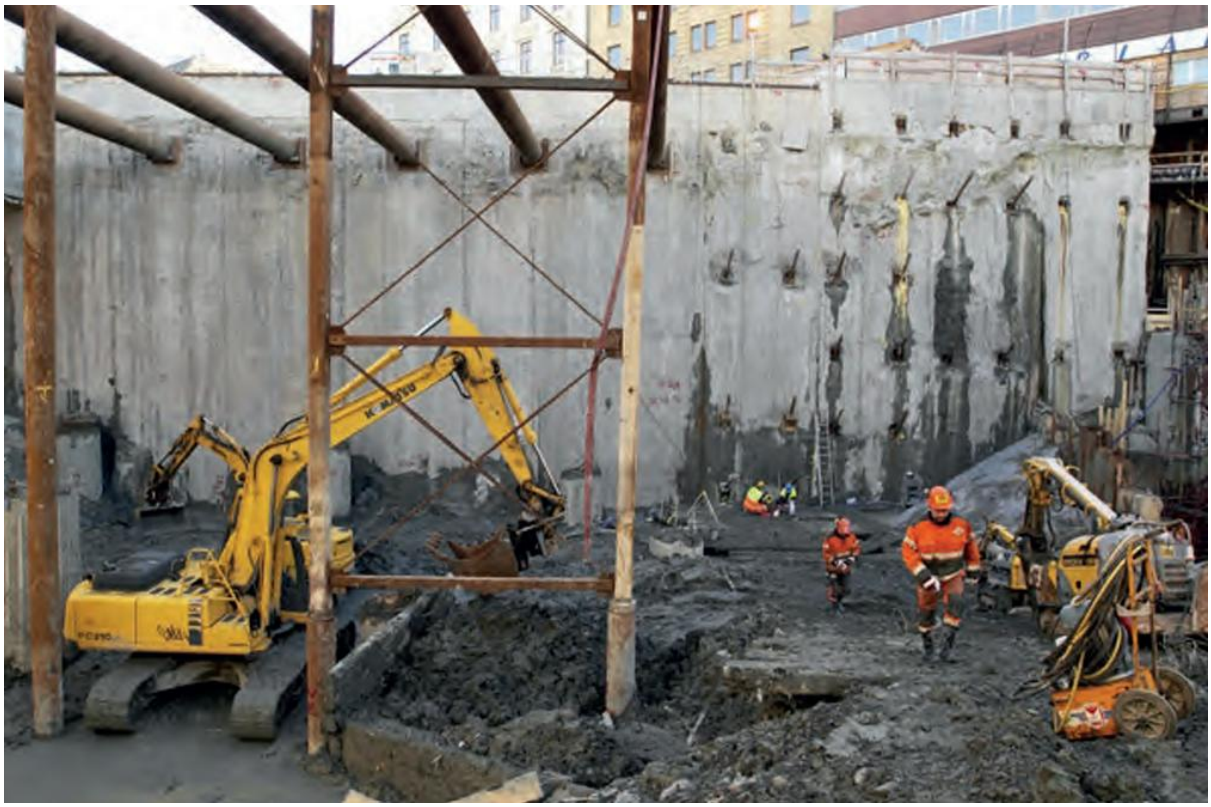


Figure 2.2. Diaphragm walls supported by struts (transverse steel pipes). Source: Trafikverket (2016).

2.5.3 Crane Foundation (Kranfundament)

A temporary reinforced concrete slab serving as the foundation for a large mobile crane used during tunnel construction. The slab consists of 317 m³ of concrete with approximately 71 tonnes of reinforcement steel, placed on a prepared subbase of crushed aggregate. The crane foundation is a typical example of a temporary construction that is entirely invisible in standard climate calculations: it involves significant quantities of concrete and steel, yet it serves no function in the finished structure.

2.5.4 Canal Infill (Utfyllnad av kanal)

A temporary infill of a canal section to the west of the construction area, required to extend the working platform and enable sheet pile installation for subsequent excavation works. The infill consists of approximately 5 167 m³ of crushed rock protected by a geotextile layer and sealing membrane, with sheet pile walls installed at the perimeter to retain the fill.

2.5.5 Aqueduct (Akvedukt)

A temporary construction built to maintain water traffic through the affected canal section during the construction period, while the canal infill occupies part of the waterway. The aqueduct consists of a cast-in-place concrete trough with reinforcement steel. It is an example of construction that would not exist in a less constrained urban setting, required not to enable the tunnel itself but to manage the consequences of building it in a densely used waterway.

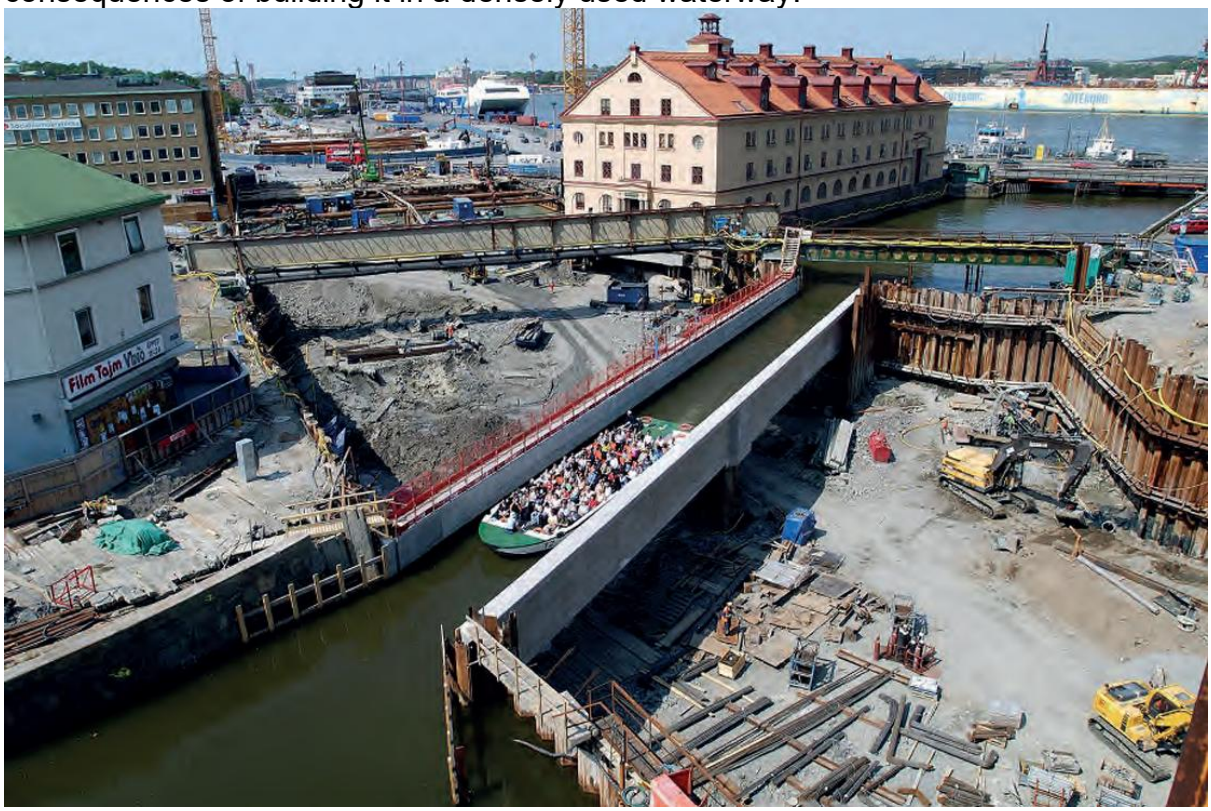


Figure 2.3. Example of a temporary aqueduct used during the construction of the Götatunnel. Source: Trafikverket (2016).

2.6 HVO and alternative fuels

Hydrotreated Vegetable Oil (HVO) is a renewable paraffinic diesel made by hydrotreating vegetable oils, animal fats or other bio-based feedstocks. The process yields a fuel chemically similar to fossil diesel, enabling its use as a direct drop-in replacement in conventional diesel engines without modification (Gomes et al., 2025). HVO100 denotes fuel consisting entirely of hydrotreated vegetable oil. Across its full life cycle, encompassing feedstock production, refining, transport and combustion, HVO100 achieves greenhouse gas emission reductions of 60 to 95% compared to fossil diesel, depending on feedstock origin and production pathway. For the construction sector, HVO100 therefore represents a practical near-term decarbonisation pathway for diesel-powered machinery, which cannot readily be electrified in the short term.

2.7 Climate Requirements in Infrastructure Procurement

The integration of climate requirements into public procurement of infrastructure has emerged as a key policy instrument for reducing embodied carbon in the construction sector. Sweden is among the countries that have progressed furthest in this area, having introduced mandatory climate requirements in infrastructure procurement since 2016 (Trafikverket, 2026b).

Trafikverket requires contractors to demonstrate a reduction in climate impact relative to a reference case calculated using Klimatkalkyl's generic default values. For investment projects with a total cost of at least SEK 150 million, that undergo formal planning, contractors must achieve a specified percentage reduction from this baseline; for smaller projects, material and fuel requirements apply instead. This threshold was raised from SEK 50 million in October 2025, which means that fewer projects are now covered by percentage reduction requirements (Trafikverket, 2025). A bonus of SEK 1 to 1.50 per kg CO_2e is applied when reductions exceed the required level, and a penalty, typically twice the bonus rate per kg, may be applied when requirements are not met (Trafikverket, 2026b). Trafikverket's intermediate targets require reductions of 60% by 2030 and 80% by 2035 compared to 2015 levels, with a long-term goal of climate-neutral infrastructure by 2040 (Trafikverket, 2026b).

The effectiveness of these requirements depends on how the reference case calculation is constructed. Trafikverket's procurement model takes the planned permanent infrastructure as its point of departure, and the reduction requirement is set against this calculated baseline. This is methodologically reasonable in a planning context: the permanent structure is defined by the design, whereas temporary works depend on the contractor's choice of production method and are therefore not fully determined when the requirement is set. Including them in the baseline against which contractors must reduce would require predictions about production choices that have not yet been made.

A consequence of this design, however, is that the climate impact of temporary works falls outside the incentive structure that the requirement creates. Contractors are rewarded for reducing the emissions of the permanent asset but face no formal incentive to reduce the emissions of the constructions and activities required to build it, even when these represent a substantial share of the project's total climate impact. This is a structural feature of the current model rather than a limitation of the Klimatkalkyl tool itself, and it raises a question this study returns to: whether climate management in infrastructure procurement needs to address production-phase emissions through a separate mechanism, parallel to the reduction requirement rather than within it.

3 Methodology

3.1 Research Design and Work Process

The study was conducted in four main steps. First, project documentation and production data were collected from the main contractor Peab through direct communication with site management, covering material quantities, transport distances, machinery types and hours, fuel consumption and fuel types for each of the four constructions, as well as machinery hours and fuel consumption for the dismantling phase (module C1) and transport of demolished materials (module C2). Second, each construction was modelled in Klimatkalkyl version 8.1 using the tool's generic default values to produce Scenario A. Third, the machinery posts absent from standard climate calculations were identified and quantified using project data, including on-site construction machinery (A5), dismantling machinery (C1) and demolition transport (C2), with all emission factors kept identical to Scenario A, to produce Scenario B. Fourth, the most complete project-specific calculation was assembled using confirmed EPDs, actual transport distances and confirmed fuel data to produce Scenario C. The three scenarios were then compared and analysed to separate the climate impact of construction activities systematically excluded from standard climate calculations in current infrastructure procurement practice from the additional effect of applying project-specific data in place of generic default values.

Where project-specific data was unavailable, motivated assumptions based on equipment specifications and industry typical values were used. All assumptions are documented and their impact on results is discussed in the limitations section. The calculations for modules A1-A3 were performed using Klimatkalkyl's own formulae, verified against the tool's output reports. For module A4, Klimatkalkyl's distance-based transport calculation is used for most materials. For leanmix, EPD-declared A4 values are incorporated into the emission factor in all three scenarios, with the transport distance set to zero in Klimatkalkyl. For C/D-wall concrete, primary and secondary pile concrete and reinforcement steel in Scenario C, the same approach is applied using their respective EPD-declared A4 values. Machinery posts absent from standard climate calculations were added as energy use posts within Klimatkalkyl for Scenarios B and C.

Modules C1 (dismantling) and C2 (transport of demolished materials) are calculated using the same approach as the added A5 machinery posts, entered as energy use posts within Klimatkalkyl and separated out in the manual module breakdown. This ensures C1 and C2 are treated consistently across Scenarios B and C, with diesel MK1 applied in Scenario B and confirmed fuel types in Scenario C. The diaphragm wall system remains permanently embedded in the ground after construction and has no dismantling or transport phase; C1 and C2 are therefore set to zero for this construction.

3.2 Three-Scenario Structure

The study is structured around three scenarios that serve distinct analytical purposes. The design of the scenarios is motivated by the need to separate two fundamentally different types of gap: the climate impact of construction activities systematically excluded from standard climate calculations in current infrastructure procurement practice, and the additional effect of using project-specific rather than generic data. Table 3.1 presents an overview of the three scenarios. For the diaphragm wall system, EPD-declared A4 transport values are incorporated directly into the emission factor for C/D-wall concrete, primary and secondary pile concrete and reinforcement steel in Scenario C, with the transport distance set to zero in Klimatkalkyl to avoid double counting. For leanmix, this approach applies in all three scenarios. This is documented in full in Sections 3.4.3 and 3.4.4.

Table 3.1. Overview of the three scenarios. The primary comparison is A vs B, which isolates the climate impact of construction activities systematically excluded from standard infrastructure procurement calculations, independent of fuel and data quality choices. B vs C shows the additional reduction achievable through project-specific data and lower-emission fuels. Scenario A reflects standard Klimatkalkyl output and excludes the added A5 machinery posts, module C1 and module C2; Scenarios B and C include all three.

	Scenario A	Scenario B	Scenario C
Description	Klimatkalkyl with all generic default values. No project-specific data.	Scenario A + machinery posts absent from standard climate calculations. All emission factors identical to A.	Fully project-specific. EPDs, real transport distances, confirmed fuel types.
Emission factors	Klimatkalkyl generic default values throughout	Klimatkalkyl generic default value throughout - identical to A	EPDs where available; HVO100 for Peab-operated machinery
Transport distances	Klimatkalkyl defaults	Klimatkalkyl defaults - identical to A	Project-specific confirmed distances and EPD-declared A4 values where available; Klimatkalkyl defaults otherwise
Missing machinery (A5)	Not included	Included - diesel MK1 (2.8 kg CO_2e/l) for all machines	Included - confirmed fuel type per machine
Dismantling (C1)	Not included	Included - diesel MK1 (2.8 kg CO_2e/l) for all machines	Included - confirmed fuel type per machine
Transport of demolished materials (C2)	Not included	Included - diesel MK1 (2.8 kg CO_2e/l) for all machines	Included - confirmed fuel type per machine
Key question	What does Klimatkalkyl report when applied as standard?	What is the climate impact of activities systematically excluded from standard calculations, independent of fuel and data choices?	What was the actual climate impact with best available data?

3.3 Goal and Scope Definition

3.3.1 Functional Unit

The functional unit is defined as the complete construction and subsequent dismantling of each temporary construction as built during the Västlänken project, including all materials, transports, on-site construction activities, dismantling activities and transport of demolished materials within life cycle modules A1-A5, C1 and C2. The diaphragm wall system is an exception: as it remains permanently embedded in the ground after completion of the tunnel works, modules C1 and C2 are not applicable and are set to zero for this construction.

3.3.2 System Boundary and Delimitations

Table 3.2. System boundary for this study, based on the EN 15978 life cycle modules. Modules A1-A5, C1 and C2 are included (green); the use phase (B1-B7), further waste processing and disposal (C3-C4) and reuse, recovery and recycling potential (module D) are excluded. For the diaphragm wall, C1-C2 are set to zero, as it remains permanently embedded in the ground.

Stage	Module	Description
Product stage	A1	Raw material extraction and processing
	A2	Transport to manufacturer
	A3	Manufacturing
Construction process stage	A4	Transport to construction site
	A5	On-site construction activities and installation
Use-stage	B1-B7	Use, maintenance, repair, replacement, operational energy and water
End-of-life stage	C1	Demolition and dismantling
	C2	Transport of demolished materials
	C3	Waste processing
	C4	Disposal
Beyond system boundary	D	Reuse, recovery and recycling potential

The system boundary covers life cycle modules A1-A5, C1 and C2: material production (A1-A3), transport to site (A4), on-site construction activities and installation (A5), demolition and dismantling (C1), and transport of demolished materials from site (C2). The impact category is Global Warming Potential (GWP), expressed in tonnes CO_2 equivalents (tCO_2e), consistent with Klimatkalkyl's primary output metric and with Trafikverket's climate reporting requirements.

The use phase (B1-B7) covers what happens to a completed, permanent product during its service life: maintenance, repair, replacement, and operational energy and water use over years of operation. Temporary works have no such service life. They

are built, they perform their function during the construction of the permanent asset, and they are then removed. The machinery that excavates, lifts and drives piles is part of building and dismantling the temporary work, and is captured in modules A5 and C1. For the constructions studied here, there is no significant operational phase of this kind: they require no maintenance, replacement or operational energy over a service life, and the use phase is therefore excluded.

Modules C3-C4 (waste processing and disposal) are excluded because the project-specific data required to model the final treatment and disposal of demolished materials was not available; the assessment ends at C2, the transport of demolished materials from site. Module D (reuse, recovery and recycling potential) lies outside the system boundary by definition in EN 15978, as it represents benefits beyond the assessed life cycle. This is relevant for the reusable sheet piles in the canal infill, which could in principle carry a module D credit, but since module D is outside the boundary it does not affect the A1-A5, C1 and C2 results presented (see Section 3.4.2).

The study covers four selected temporary constructions from Västlänken, selected to span a range of construction types and material intensities (see Section 2.5.1). Modules C1 and C2 are included in Scenarios B and C alongside the A1-A5 results, while Scenario A reflects standard Klimatkalkyl output and does not include C1 or C2.

3.4 Data Collection and Inventory Analysis

Project-specific data was collected from Peab through direct communication with site management, supplemented by project documentation and material orders. Three points about this data are important for anyone building on this work. First, the data varies in nature: material quantities are taken from project documentation and material orders, and material emission factors from EPDs where available, whereas a substantial part of the machinery data, in particular operating hours, fuel consumption rates and fuel types, consists of operational estimates from production personnel rather than independently verified measurements (the full machine-by-machine inventory is provided in Appendix A). Second, where data could not be obtained at all, a motivated assumption was used in its place, and each such case is stated explicitly at the relevant point together with the assumption made. Third, the term "confirmed" is used throughout to mean that a value was provided by the relevant party, not that it was independently verified. These limitations are inherent to studying a live construction project, where machine-level metering is not standard practice, and they are the reason the study relies on a comparative scenario design that is robust to absolute data uncertainty. This robustness, and the key assumptions together with their potential impact on results, are discussed in Section 3.8.

Table 3.3. Material quantities per construction and corresponding Klimatkalkyl building elements used in Scenarios A and B. All quantities are based on written communication or project documentation from Peab. The diaphragm wall excavation volume (46 500 m³) is estimated from the total concrete volume placed rather than directly measured. Klimatkalkyl version 8.1 was used for all calculations.

Construction	Material	Klimatkalkyl byggdel	Quantity	Unit
Crane Foundation (Betongplatta / Kranfundament)				
Crane foundation	Concrete C35/45	Betong, anläggning C32/40, Väg (6.2)	317	m³
	Reinforcement steel	Armering, armeringsstål, Väg (6.2)	71	tonnes
	Excavation	Jordschakt Fall B (6.4)	100	m³
	Crushed aggregate	Bärlager, obundet, Väg (6.2)	17	m³
Canal Infill (Utfyllnad av kanal)				
	Crushed rock fill	Berg Fall B, Fyll, Väg (6.4)	5 167	m³
	Geotextile	Lager av geotextil, Väg (6.2)	1 950	m²
	Rubber membrane	Tätskiktsmatta (6.3)	1 575	m²
	Sheet pile	Tätspont, Väg (6.2)	3 120	m²
Diaphragm Wall (Slitsmur)				
	Concrete C/D-wall C35/45	Betong, anläggning C32/40, Väg (6.2)	12 928	m³
	Concrete primary piles C20/25	Betong, anläggning C32/40, Väg (6.2)	7 967.5	m³
	Concrete secondary piles C35/45	Betong, anläggning C32/40, Väg (6.2)	7 967.5	m³
	Leanmix C1/2	Annat material & övriga transporter (6.1)*	17 700	m³

	Reinforcement steel - piles	Armering, armeringsstål, Väg (6.2)	1 689	tonnes
	Reinforcement steel - C/D-wall	Armering, armeringsstål, Väg (6.2)	2 779	tonnes
	Excavation	Jordschakt Fall B (6.4)	46 500	m³
Aqueduct (Akvedukt)				
	Concrete C35/45	Betong, anläggning C32/40, Väg (6.2)	180	m³
	Reinforcement steel	Armering, armeringsstål, Väg (6.2)	31.5	tonnes

* Leanmix is modelled using Annat material & övriga transporter (6.1) in all three scenarios with a combined A1-A4 emission factor of 0.0262 kg CO_2e/kg and transport distance set to zero; see Section 3.4.3.

3.4.1 Emission Factors for Fuel

The emission factor for diesel (MK1) is 2.8 kg CO_2e/litre, which is Klimatkalkyl's generic default value and is used in Scenarios A and B throughout. For Scenario C, HVO100 (hydrotreated vegetable oil) was used for the majority of on-site machinery. The emission factor for HVO100 is 0.38 kg CO_2e/litre, the generic default value in Klimatkalkyl. Where the fuel type could not be confirmed, diesel MK1 is assumed conservatively.

Table 3.4. Emission factors for fuel types applied in this study.

Fuel	Emission factor (kg CO_2e/litre)	Source
Diesel MK1	2.800	Klimatkalkyl generic default value
HVO100	0.38	Klimatkalkyl generic default value

3.4.2 Material Emission Factors and EPDs

For Scenario A, all material emission factors follow Klimatkalkyl's generic default values: 0.004 kg CO_2e/kg for crushed rock, 2.92 kg CO_2e/kg for geotextile, 0.742 kg CO_2e/kg for rubber membrane, 2.27 kg CO_2e/kg for structural steel, and 0.732 kg CO_2e/kg for reinforcement steel. For Scenarios B and C, the same generic default values are used for all materials except where a project-specific EPD is available.

The concrete specification for the crane foundation and the aqueduct is C35/45, with a declared climate impact of 270 kg CO_2e/m³ for modules A1-A3. No EPD document was available at the time of writing; the value was provided directly for this study. Transport (A4) for these constructions uses Klimatkalkyl's default distance. Scenario A uses the standard Klimatkalkyl building element Betong, anläggning C32/40 as the closest available approximation.

When assessing the embodied carbon of temporary works materials, the TWF guidance distinguishes between three categories: single-use materials, where all production and disposal carbon is attributed to the single use; finite reuse materials, where the carbon is divided by the number of uses; and high reuse or proprietary materials, where production carbon is considered negligible at the point of use (TWF, 2023). In this study, concrete and reinforcement steel are treated as single-use, as they form part of constructions that are demolished at the end of the construction period. The sheet piles in the canal infill are treated as finite reuse, as they are extracted after completion of the works and may be reused on other projects. For the purposes of this study, however, the distinction does not affect the A1-A5, C1 and C2 calculations presented, as module D is outside the system boundary.

Project-specific dotter-EPDs are available for leanmix, C/D-wall concrete and pile concrete from Swerock AB, and for reinforcement steel (B GROUP STEEL, EPD-IES-0017456). No project-specific EPD is available for geotextile or sheet pile; generic default values are used for these materials in all three scenarios. The resulting Scenario C emission factors are summarised in Table 3.5. Full documentation of each EPD and the assumptions applied is provided in Section 3.4.3.

Table 3.5. Emission factor changes applied in Scenario C

Material	Scen A (kg CO_2e/kg)	Scen C (kg CO_2e/kg)	Change (%)	Source - Scen C	Applies to
Concrete C35/45	0.1510	0.1149	−24%	Value provided by Peab (270 kg CO_2e/m³, A1-A3 only); density 2 350 kg/m³ (Klimatkalkyl default); default A4 transport retained	Crane foundation; Aqueduct
Concrete C/D-wall C35/45	0.1510	0.0698	−54%	Swerock dotter-EPD avg. (A1-A3: 161, A4: 5.78 kg CO_2e/m³); A1-A4 combined; transport zeroed in KK	Diaphragm wall

Concrete primary piles C20/25	0.1510	0.0701	−53%	Swerock dotter-EPD (A1-A3: 149 kg CO_2e/m³; A4: 4.30 kg CO_2e/m³; density: 2 188 kg/m³); A1-A4 combined; transport zeroed in KK	Diaphragm wall
Concrete secondary piles C35/45	0.1510	0.0770	−49%	Swerock dotter-EPD (A1-A3: 176 kg CO_2e/m³; A4: 4.61 kg CO_2e/m³; density: 2 347 kg/m³); A1-A4 combined; transport zeroed in KK	Diaphragm wall
Reinforcement steel	0.7320	0.5105	−30%	B GROUP STEEL EPD-IES-0017456; A1-A4 combined (432 + 78.5 = 510.5 kg CO_2e/tonne); transport zeroed in KK	All constructions

* Scen A: Klimatkalkyl C32/40 generic default value (0.151 kg CO_2e/kg × 2 350 kg/m³ = 354.85 kg CO_2e/m³). Reinforcement Scen A = 0.732 kg CO_2e/kg (Klimatkalkyl effective value). All Scen C diaphragm wall concrete and reinforcement values cover A1-A4 combined (transport zeroed in Klimatkalkyl). Crane foundation and aqueduct concrete covers A1-A3 only. Leanmix uses a combined A1-A4 emission factor of 0.0262 kg CO_2e/kg in all three scenarios and is therefore not shown. Scenario B uses identical emission factors to Scenario A.

3.4.3 EPDs and Assumptions Applied in Scenario C

Scenario C applies project-specific Environmental Product Declarations (EPDs) where available, replacing Klimatkalkyl's generic default emission factors (generic default values). This section documents the EPDs used, the assumptions required where EPD data was incomplete, and the rationale for each.

Concrete Crane Foundation and Aqueduct

A climate impact of 270 kg CO_2e/m³ was provided for the C35/45 concrete used in the crane foundation and aqueduct. No EPD document was available at the time of writing. The emission factor is calculated as 270 divided by Klimatkalkyl's standard density of 2 350 kg/m³, giving 0.1149 kg CO_2e/kg for modules A1-A3. No EPD-based A4 value is available; Klimatkalkyl's default transport distance of 35 km is retained.

Concrete Diaphragm wall

Two project-specific dotter-EPDs were available for the diaphragm wall concrete, both produced by Swerock AB at Kållered and valid until 2028-09-29: C-walls (158 kg CO_2e/m³, density 2 391 kg/m³, A4 = 5.78 kg CO_2e/m³) and D-walls (164 kg CO_2e/m³, density 2 389 kg/m³, A4 = 5.77 kg CO_2e/m³). A simple average is applied: A1-A3 = 161 kg CO_2e/m³, A4 = 5.78 kg CO_2e/m³, giving a combined A1-A4 value of 166.78 kg CO_2e/m³ at a density of 2 390 kg/m³, corresponding to 0.0698 kg CO_2e/kg. In Scenario C this combined value is entered in Klimatkalkyl and the transport distance is set to zero to avoid double counting.

Concrete Primary and Secondary Piles
Project-specific dotter-EPDs from Swerock AB (Angered, valid until 2028-09-29) are available for both pile types. Primary piles use a C20/25 mix, reflecting the lower strength requirements of the first-cast piles which are subsequently cut through by the secondary piles. Secondary piles use a C35/45 mix, consistent with higher structural and durability requirements. In Scenario C, A1-A3 and A4 values are combined: primary piles (149 + 4.30 = 153.30 kg CO_2e/m³) / 2 188 kg/m³ = 0.0701 kg CO_2e/kg; secondary piles (176 + 4.61 = 180.61 kg CO_2e/m³) / 2 347 kg/m³ = 0.0770 kg CO_2e/kg. Transport distance is set to zero in Klimatkalkyl for both pile types in Scenario C.

Reinforcement Steel
A verified EPD is available for all reinforcement steel in the study: B GROUP STEEL (EPD-IES-0017456, valid until 2029-10-30), giving 432 kg CO_2e/tonne (0.432 kg CO_2e/kg) for modules A1-A3. The EPD also declares an A4 value of 78.5 kg CO_2e/tonne, based on transport from Vilnius, Lithuania to Sweden by lorry (550 km) and ferry (270 km). In Scenario C, A1-A3 and A4 are combined into 0.5105 kg CO_2e/kg (= (432 + 78.5) / 1 000), and the transport distance in Klimatkalkyl is set to zero.

Fuel - On-Site Machinery
HVO100 (hydrotreated vegetable oil) was used for the majority of on-site machinery in Scenario C, with an emission factor of 0.38 kg CO_2e/litre based on Klimatkalkyl's generic default value. Where fuel type could be confirmed for external machinery, confirmed values are applied in Scenario C. For the aqueduct excavator, pile crane and mini-dumper, the fuel type could not be confirmed; diesel MK1 at 2.800 kg CO_2e/litre is assumed conservatively.

3.4.4 Transport Distances

Canal infill
Crushed rock was sourced from two origins: 778 m³ from the project's own excavation site at Halvorsäng (15 km one way) and 4 389 m³ purchased from Kållered (18 km one way). A weighted average transport distance of 17.6 km was calculated: (778 × 15 + 4 389 × 18) / 5 167 = 17.6 km. This replaces Klimatkalkyl's default of 30 km in Scenario C. Scenarios A and B use the 30 km default.

Crane foundation
Crushed aggregate was sourced from Kållered (18 km one way), replacing Klimatkalkyl’s default of 30 km, and excavated masses were transported to a tip at 18 km. These project-specific distances are used in Scenario C. The transport distance for concrete to the crane foundation is not available from project documentation; Klimatkalkyl's default of 35 km is retained for concrete in all three scenarios.

Diaphragm wall

For C/D-wall concrete, leanmix and both pile types, project-specific dotter-EPDs from Swerock AB declare A4 contributions based on actual transport: 5.78 and 5.34 kg

CO_2e/m^3 for C/D-wall concrete and leanmix (Kållered), and 4.30 and 4.61 kg CO_2e/m^3 for primary and secondary piles (Angered). In Scenario C, all A4 values are incorporated into the combined A1-A4 emission factor with transport distance set to zero in Klimatkalkyl. For reinforcement steel, the B GROUP STEEL EPD declares A4 = 78.5 kg CO_2e/tonne, similarly incorporated. Klimatkalkyl default transport distances are retained for crane foundation and aqueduct concrete.

Aqueduct
No project-specific transport distances have been confirmed for the aqueduct; Klimatkalkyl's default distances are retained for concrete and reinforcement steel in all three scenarios.

3.5 Modelling in Klimatkalkyl Scenario A

Scenario A uses Klimatkalkyl version 8.1 with all generic default values. For each construction, building elements were selected from Klimatkalkyl's library based on the materials identified from project documentation. Table 3.6 presents the building elements applied. In Scenario C, EPD-based emission factors are entered using Annat material & övriga transporter (6.1) for materials where project-specific data is available; see Sections 3.4.2 and 3.4.3 for documentation. Missing machinery posts for Scenarios B and C are added as energy use posts within Klimatkalkyl, as described in Section 3.6.

Table 3.6. Klimatkalkyl building elements applied in this study. Scenario A and B use C32/40 for all structural concrete. Scenario C uses Annat material & övriga transporter (6.1) for EPD-based materials with transport distance set to zero.

Klimatkalkyl Building Element	Applied to
Betong, anläggning C32/40, Väg (6.2)	Structural concrete - all constructions (Scenarios A and B)
Annat material & övriga transporter (6.1)	Leanmix - all scenarios; C/D-wall concrete, primary piles, secondary piles and reinforcement steel - Scenario C
Armering, armeringsstål, Väg (6.2)	Reinforcement steel - all constructions (Scenarios A and B)
Berg Fall B, Fyll, Väg (6.4)	Crushed rock fill - canal infill
Lager av geotextil, Väg (6.2)	Geotextile - canal infill
Tätskiktsmatta (6.3)	Rubber membrane - canal infill
Tätspont, Väg (6.2)	Sheet pile - canal infill

Klimatkalkyl Building Element	Applied to
Jordschakt Fall B (6.4)	Excavation - crane foundation; diaphragm wall
Bärlager, obundet, Väg (6.2)	Crushed aggregate - crane foundation

3.6 Identifying Missing Posts - Scenario B

Scenario B extends the Klimatkalkyl calculation by adding the machinery posts that are present in the actual project but structurally absent from Klimatkalkyl's default building elements. All emission factors, transport distances and fuel assumptions remain identical to Scenario A. For each construction, the building process was systematically reviewed to identify all machinery required, and each machine was checked against Klimatkalkyl's building element library to determine whether it was already captured or entirely absent. Table 3.7 presents the total fuel consumption by construction and fuel type for all identified A5 machinery. A full machine-by-machine inventory including operating hours, consumption rates and sources is provided in Appendix A.

Table 3.7. Total fuel consumption by construction for A5 machinery absent from Klimatkalkyl's default calculations. Scenario B applies diesel MK1 (2.8 kg CO_2e/l) for all machines. Scenario C applies confirmed fuel types per machine; the fuel type for excavator, pile crane and mini-dumper in the aqueduct is unconfirmed and diesel is assumed conservatively. Full machine-by-machine inventory in Appendix A.

Construction	HVO100 (litres)	Diesel MK1 (litres)
Canal infill	14 390	600
Crane foundation	3 320	96
Diaphragm wall	2 240	13 700
Aqueduct	2 600	20 062

Table 3.8. Total fuel consumption by construction for modules C1 (dismantling) and C2 (transport of demolished materials). All C1 and C2 fuel is confirmed as HVO100. The diaphragm wall system has no C1 or C2 contribution as it remains permanently embedded in the ground. Scenario B applies diesel MK1 (2.8 kg CO_2e/l); Scenario C applies HVO100 (0.38 kg CO_2e/l).

Construction	HVO100 (litres)	Diesel MK1 (litres)
Canal infill	19 400	0

Construction	HVO100 (litres)	Diesel MK1 (litres)
Crane foundation	3 920	0
Diaphragm wall	0	0
Aqueduct	21 200	0

3.7 Project-Specific Assessment - Scenario C

Scenario C represents the most complete estimate of actual climate impact. It uses the same building elements and material quantities as Scenarios A and B, but replaces generic values with project-specific data wherever confirmed information is available. The changes applied in Scenario C relative to Scenario A are:

- Material emission factors (A1-A4): EPD-based combined A1-A4 emission factors applied for C/D-wall concrete (0.0698), primary piles (0.0701), secondary piles (0.0770) and reinforcement steel (0.5105 kg CO_2e/kg), with transport distance set to zero in Klimatkalkyl. Leanmix uses 0.0262 kg CO_2e/kg in all three scenarios. Crane foundation and aqueduct concrete (0.1149 kg CO_2e/kg) uses A1-A3 only with Klimatkalkyl default transport (35 km).

- Transport distances (A4): Crushed rock in canal infill: 17.6 km confirmed (weighted average). Crushed aggregate crane foundation: 18 km confirmed. All other transport distances either incorporated into EPD-based emission factors (transport zeroed in Klimatkalkyl) or Klimatkalkyl default retained.

- Fuel type: HVO100 at 0.38 kg CO_2e/l (Klimatkalkyl generic default value) for confirmed machines. Diesel MK1 assumed conservatively where fuel type is unconfirmed.

- Missing machinery posts (A5), dismantling machinery (C1) and demolition transport (C2) as in Scenario B, with confirmed fuel types applied per machine.

Detailed machine-by-machine inventories are provided in Appendix A. The primary remaining uncertainty is the fuel type for three machines in the aqueduct (excavator 700 h, pile crane 60 h and mini-dumper 415 h), totalling approximately 19 550 litres. Diesel MK1 is assumed conservatively; if HVO100 is confirmed, Scenario C results for the aqueduct would decrease by approximately 47 tCO_2e.

3.8 Limitations and Sources of Uncertainty

Several limitations and sources of uncertainty apply to this study.

The fuel type for three machines in the aqueduct, which are the excavator (700 h, 19 l/h), the pile crane (60 h, 35 l/h) and the mini-dumper (415 h, 10 l/h), is unconfirmed, totalling approximately 19 550 litres. Diesel MK1 is assumed conservatively in all scenarios. If HVO100 is confirmed for these machines, Scenario C results for the aqueduct would be reduced by approximately 47 tCO_2e (= 19 550 × (2.8 - 0.38) / 1 000).

Two further gaps concern machinery that could not be fully quantified. A wheel loader was present during the canal infill but could not be attributed to specific hours or fuel consumption and is therefore excluded from the A5 calculation. Similarly, a wheel loader and a crane truck (4 hours) in the crane foundation could not be fully quantified and are excluded. These machines are expected to contribute a small share of total A5 emissions for these constructions.

A third gap concerns the combined C/D-wall concrete volume (12 928 m^3), which is not split by panel type in available project documentation. An equal split between C-walls (158 kg CO_2e/m^3) and D-walls (164 kg CO_2e/m^3) is assumed, giving an average of 161 kg CO_2e/m^3. The maximum error is approximately 39 tCO_2e.

Beyond these data limitations, two delimitations affect how the results should be interpreted. The four constructions studied do not represent the full scope of temporary works in Västlänken. The results therefore cannot be directly extrapolated to the total temporary works climate impact of the project. They were, however, selected to span the range of construction types encountered in urban tunnel construction, so the mechanism identified is expected to apply more broadly, even though the magnitudes are project-specific.

This study assesses climate impact expressed as Global Warming Potential (GWP) only, consistent with Klimatkalkyl's primary output metric and Trafikverket's reporting requirements. Other environmental impact categories - including acidification, eutrophication, resource depletion and human toxicity - are not assessed. The results therefore provide a partial picture of the total environmental impact of the temporary works studied.

4 Results

4.1 Overview

This chapter presents the climate impact results for each of the four temporary constructions studied. Results are reported across three scenarios as defined in Section 3.2. The primary comparison is Scenario A versus Scenario B, which isolates the climate impact of construction activities systematically excluded from standard Klimatkalkyl calculations. The comparison of Scenario B versus Scenario C shows the additional effect of applying project-specific EPDs, confirmed transport distances and lower-emission fuels. Detailed results including module breakdowns are presented in Sections 4.2 - 4.5.

Table 4.1. Total climate impact (tCO_2e) per construction and scenario. Δ A→B shows the relative change from adding missing machinery posts; Δ B→C shows the additional change from applying project-specific data.

Construction	Scen A (tCO_2e)	Scen B (tCO_2e)	Δ A→B	Scen C (tCO_2e)	Δ B→C
Canal Infill	958	1 052	+10%	956	−9%
Crane Foundation	171	191	+12%	131	−32%
Diaphragm Wall	15 302	15 321	+0.1%	8 430	−45%
Aqueduct	90	213	+137%	133	−38%
Total	**16 521**	**16 777**	**+2%**	**9 650**	**−42%**

The diaphragm wall system accounts for the largest share of total climate impact across all scenarios, driven by its large concrete volumes. The aqueduct shows the largest relative A→B increase, reflecting significant machinery and dismantling contributions absent from Scenario A. The diaphragm wall shows the largest absolute B→C reduction, driven by the application of project-specific EPDs for concrete.

4.2 Canal Infill

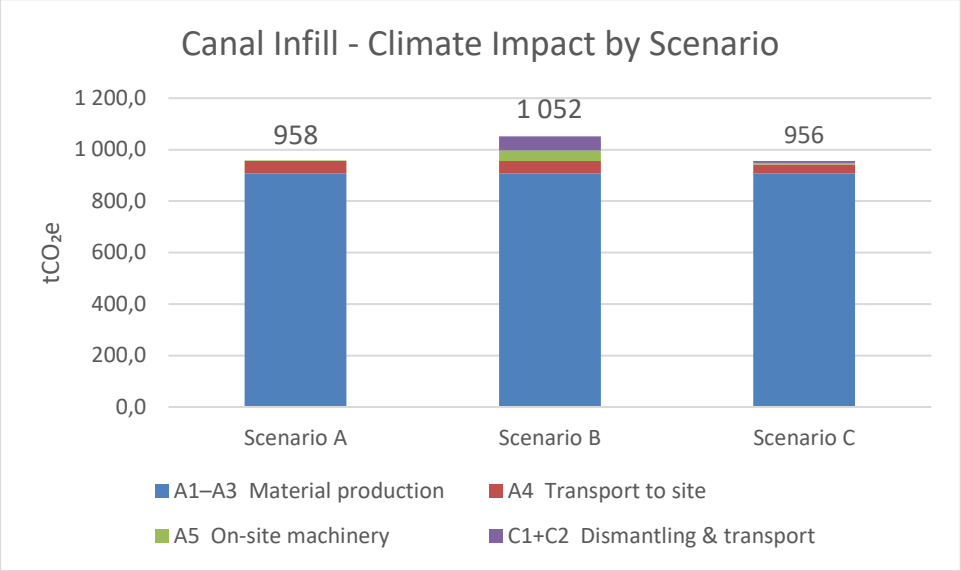


Figure 4.1 The canal infill is dominated by the sheet pile walls, which account for approximately 90% of A1-A3 emissions in all three scenarios. Scenario B is higher than Scenario A due to the addition of A5 machinery and C1+C2 posts absent from the standard calculation. Scenario C returns to a level close to Scenario A, as the confirmed HVO100 fuel for all on-site machinery and dismantling reduces the added emissions substantially.

Table 4.2. Module breakdown for the canal infill (tCO_2e).

Module	Scenario A	Scenario B	Scenario C	% of A	% of B	% of C
A1-A3 Material production	907.9	907.9	907.9	94.8%	86.3%	94.9%
A4 Transport to site	47.6	47.6	33.8	5,0%	4.5%	3.5%
A5 On-site machinery	2.7	42.0	7.1	0.3%	4.0%	0.7%
C1+C2 Dismantling & transport	0.0	54.3	7.4	0.0%	5.2%	0.8%
TOTAL	958.2	1 051.8	956.3	100%	100%	100%

4.3 Crane Foundation

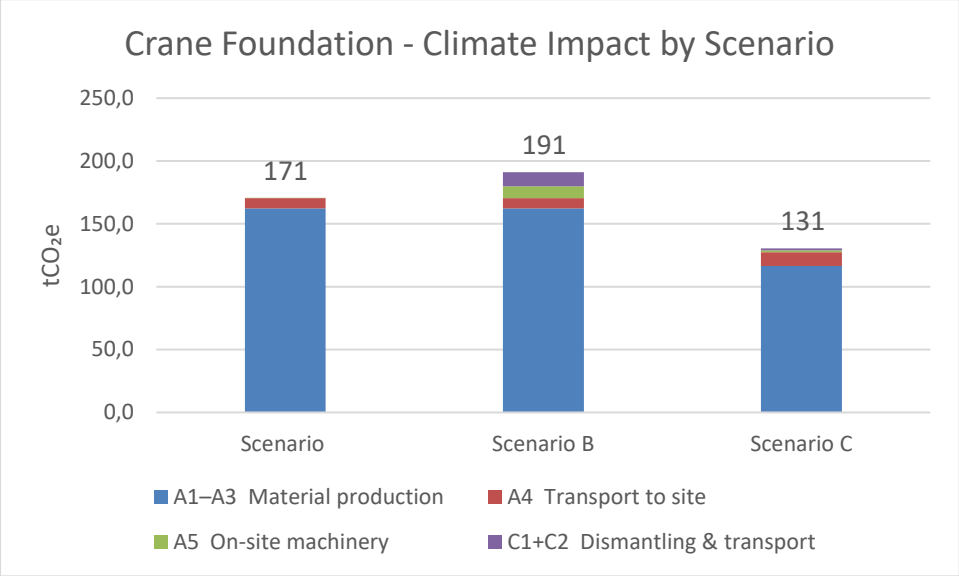


Figure 4.2 The crane foundation results are dominated by A1-A3 material production in all three scenarios, with concrete and reinforcement steel as the primary contributors. The A→B increase reflects the addition of excavation and construction machinery. The significant B→C reduction is driven by the application of project-specific EPDs for both concrete (270 kg CO_2e/m³ vs C32/40 generic default value) and reinforcement steel (B GROUP STEEL EPD), which together reduce A1-A3 by approximately 46 tCO_2e.

Table 4.3. Module breakdown for the crane foundation (tCO_2e).

Module	Scenario A	Scenario B	Scenario C	% of A	% of B	% of C
A1-A3 Material production	162.3	162.3	116.4	95.2%	85.0%	89.1%
A4 Transport to site	8.1	8.1	11.2	4.8%	4.3%	8.5%
A5 On-site machinery	0.1	9.6	1.5	0.0%	5.0%	1.2%
C1+C2 Dismantling & transport	0.0	11.0	1.5	0.0%	5.7%	1.1%
TOTAL	170.5	191.0	130.6	100%	100%	100%

4.4 Diaphragm Wall System

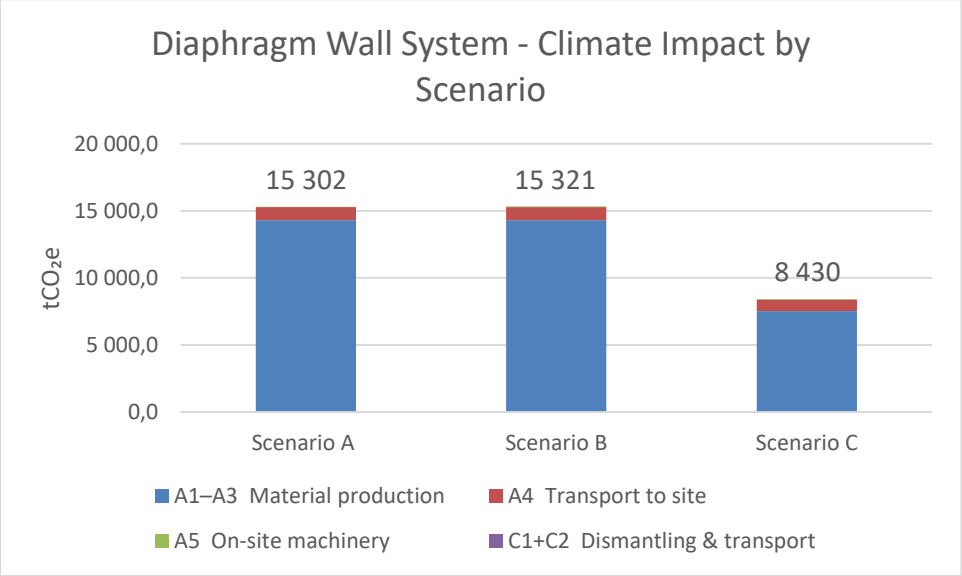


Figure 4.3 The diaphragm wall system is by far the largest contributor to total climate impact, driven by its extensive concrete volumes. The A→B difference is negligible (+0.1%), as the diaphragm wall has no C1 or C2 contribution and the added A5 machinery represents a small fraction of total emissions. The B→C reduction of 45% is the largest in the study and is entirely driven by the application of project-specific Swerock dotter-EPDs for C/D-wall concrete, primary piles, secondary piles and reinforcement steel, replacing Klimatkalkyl's C32/40 generic default value.

Table 4.4. Module breakdown for the diaphragm wall system (tCO_2e).

Module	Scenario A	Scenario B	Scenario C	% of A	% of B	% of C
A1-A3 Material production	14 299.2	14 299.2	7 533.8	93.4%	93.3%	89.4%
A4 Transport to site	977.2	977.2	857.1	6.4%	6.4%	10.2%
A5 On-site machinery	25.1	44.6	39.2	0.2%	0.3%	0.5%
C1+C2 Dismantling & transport	0.0	0.0	0.0	0.0%	0.0%	0.0%
TOTAL	15 301.5	15 321.0	8 430.1	100%	100%	100%

4.5 Aqueduct

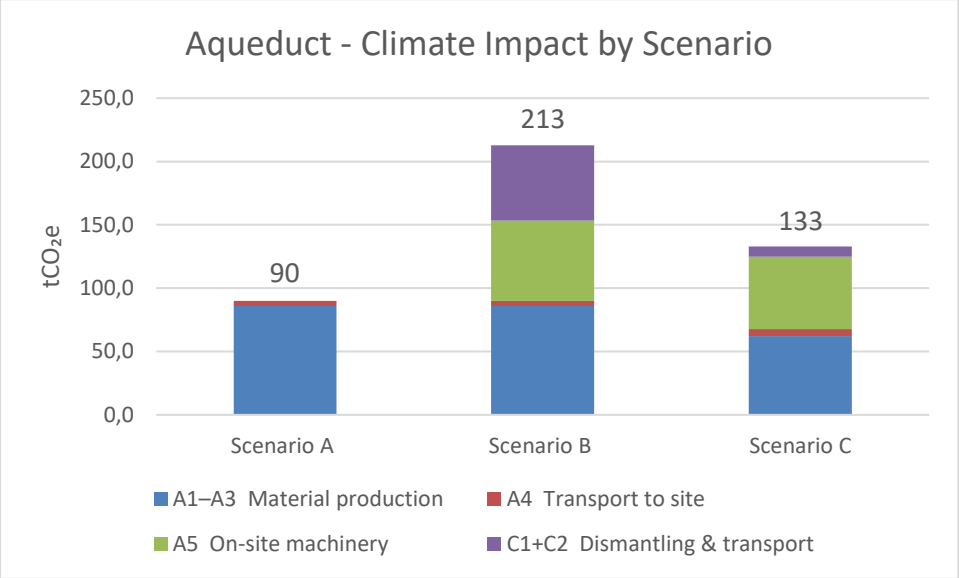


Figure 4.4 The aqueduct shows the most pronounced A→B increase of all four constructions (+137%), driven by substantial A5 machinery hours and significant C1+C2 contributions that are entirely absent from Scenario A. In Scenario B, A5 and C1+C2 together account for 58% of total emissions. The B→C reduction reflects the confirmed HVO100 fuel for most on-site machinery; however, three machines totalling approximately 19 550 litres remain unconfirmed and are assumed diesel conservatively.

Table 4.5. Module breakdown for the aqueduct (tCO_2e).

Module	Scenario A	Scenario B	Scenario C	% of A	% of B	% of C
A1-A3 Material production	85.9	85.9	62.2	95.6%	40.4%	46.8%
A4 Transport to site	4.0	4.0	5.4	4.4%	1.9%	4.1%
A5 On-site machinery	0.0	63.5	57.2	0.0%	29.8%	43.0%
C1+C2 Dismantling & transport	0.0	59.4	8.1	0.0%	27.9%	6.1%
TOTAL	89.9	212.7	132.8	100%	100%	100%

5 Analysis of the Results

This chapter analyses the results presented in Chapter 4 in relation to the study's aims and objectives. Section 5.1 examines the structural exclusions identified through the Scenario A versus Scenario B comparison. Section 5.2 analyses the effect of project-specific data through the Scenario B versus Scenario C comparison. Section 5.3 discusses the implications of the findings for the use of Klimatkalkyl in complex urban infrastructure projects.

5.1 Structural Exclusions in Standard Climate Calculations

The comparison between Scenario A and Scenario B isolates the climate impact of construction activities that are systematically absent from standard Klimatkalkyl calculations. Two distinct dimensions of this exclusion are visible in the results.

The first dimension is that entire constructions are simply absent from climate reporting. None of the four constructions examined here are included in the Klimatkalkyl calculation that Trafikverket uses as a reference for the Västlänken project. This is not a failure of the tool but a consequence of how the tool is applied: it calculates what is asked of it, and temporary works are not asked. The Scenario A results therefore represent not what is currently reported, but what would be reported if these constructions were entered into Klimatkalkyl using its generic default values. The actual gap relative to current practice is thus larger than the A→B comparison alone reveals.

The second dimension concerns what Klimatkalkyl can capture even when temporary constructions are included. For sheet pile installation in the canal infill, for example, a mobile crane and vibratory hammer are essential equipment that operate for hundreds of hours. Yet Klimatkalkyl has no building element for these machines. The sheet pile itself appears in the calculation with its material emission factor and transport distance, but the machine that drives it into the ground is absent. This is a structural limitation: the tool cannot capture these activities regardless of the quality of the data entered. The A→B comparison quantifies this gap for each construction. Table 5.1 summarises the absolute and relative A→B differences.

Table 5.1. Absolute and relative A→B differences across the four constructions.

Construction	Scenario A (tCO_2e)	Scenario B (tCO_2e)	Δ A→B (tCO_2e)	Δ A→B (%)
Canal Infill	958	1 052	+94	+10%
Crane Foundation	171	191	+20	+12%
Diaphragm Wall	15 302	15 321	+19	+0.1%
Aqueduct	90	213	+123	+137%

The variation across constructions is substantial and reflects fundamental differences in the balance between material and machinery contributions. For the

diaphragm wall, the A→B gap is negligible (+0.1%): the construction's enormous concrete volumes, totalling over 46 000 m³ across C/D-wall, piles and leanmix, mean that even significant absolute machinery contributions are small relative to the material baseline. The added A5 machinery amounts to 19 tCO_2e against a Scenario A total of 15 302 tCO_2e.

For the aqueduct, the situation is reversed. The construction involves limited material quantities but intensive ground works: excavation, sheet pile driving, foundation piling and concrete placement. In Scenario B, A5 on-site machinery and C1+C2 dismantling and transport together account for 58% of total emissions, a pattern consistent with research findings that on-site machinery can represent as much as 73% of construction-phase emissions in machine-intensive foundation operations (Li & Zheng, 2020). The aqueduct result illustrates that for construction types involving intensive ground works and heavy lifting, precisely the activities characteristic of temporary works in complex urban projects, the A5 module may represent a considerably more significant share of total climate impact than generic default calculations suggest. Standard Klimatkalkyl calculations may understate total climate impact by more than a factor of two for such constructions.

The canal infill and crane foundation show intermediate A→B gaps of +10% and +12% respectively. In both cases, A5 and C1+C2 posts represent a meaningful but not dominant share of the total, consistent with constructions that involve both significant material use and substantial machinery activity.

Taken together, the A→B results suggest that the significance of structural exclusions from standard calculations is strongly dependent on construction type. The exclusion is most consequential for machine-intensive constructions and least consequential for material-dominated ones. This distinction has direct implications for which types of temporary works represent the greatest risk of systematic underreporting in current practice.

5.2 The Effect of Project-Specific Data

The comparison between Scenario B and Scenario C isolates the additional effect of applying project-specific EPDs, confirmed transport distances and confirmed fuel types, independent of the structural completeness of the calculation. The B→C differences are summarised in Table 5.2.

Table 5.2. Absolute and relative B→C differences across the four constructions.

Construction	Scenario B (tCO_2e)	Scenario C (tCO_2e)	Δ B→C (tCO_2e)	Δ B→C (%)
Canal Infill	1 052	956	−96	−9%
Crane Foundation	191	131	−60	−32%
Diaphragm Wall	15 321	8 430	−6 891	−45%
Aqueduct	213	133	−80	−38%

Two distinct drivers account for the B→C reductions: an EPD effect operating through A1-A3 material emission factors, and a fuel effect operating through A5 and C1+C2 energy use. The relative importance of each driver varies by construction.

The data quality gap is most pronounced for the diaphragm wall system and the crane foundation. For the diaphragm wall, replacing Klimatkalkyl's C32/40 generic default value (354.85 kg CO_2e/m³) with project-specific Swerock dotter-EPDs for C/D-wall concrete, primary piles and secondary piles reduces A1-A3 emissions from 14 299 to 7 534 tCO_2e, a reduction of 47%. The magnitude of this difference reflects a systematic feature of Klimatkalkyl's default concrete: the C32/40 generic default value represents a standard structural concrete grade that is significantly more carbon-intensive than the ECO3 mixes specified for the diaphragm wall system, which incorporate supplementary cementitious materials. For the crane foundation, the combined application of EPDs for concrete and reinforcement steel reduces A1-A3 by 46 tCO_2e (−28%).

The fuel effect is most significant for the canal infill and the aqueduct, where confirmed HVO100 use across the majority of on-site and dismantling machinery substantially reduces the added posts relative to Scenario B. For the aqueduct, the reduction from confirmed HVO100 for the crane and demolition machinery accounts for the majority of the B→C difference, with C1+C2 decreasing from 59.4 to 8.1 tCO_2e. The residual uncertainty, the fuel type for the excavator, pile crane and mini-dumper totalling approximately 19 550 litres, means that the aqueduct's Scenario C result may be overstated by up to 47 tCO_2e if these machines also operate on HVO100.

Across all four constructions, the B→C reductions are exclusively reductions: project-specific data consistently yields a lower result than Klimatkalkyl's generic defaults. This is consistent with the general observation that Klimatkalkyl's generic default values are calibrated for typical rather than best-practice conditions, and that contractors on large projects with access to project-specific EPDs and renewable fuel commitments will in practice achieve lower emissions than default calculations suggest.

5.3 Implications for Klimatkalkyl in Complex Urban Projects

The results of this study illuminate both structural and data quality dimensions of how Klimatkalkyl performs when applied to temporary works in complex urban infrastructure. As noted in Section 2.3, the tool's limitations for this context are twofold: its building element library may not include construction activities that are unusual or project-specific, and its generic default values may not reflect the emissions profile of contractors operating with project-specific material specifications and fuel commitments.

Both dimensions are confirmed by the results. The A→B comparison demonstrates that Klimatkalkyl's building element library structurally cannot capture the on-site machinery for temporary constructions of the type studied, regardless of data quality. No building element exists for a mobile crane driving sheet piles, a vibratory hammer

installing a diaphragm wall panel, or a pile crane constructing a foundation. These absences are not addressable through better data: they reflect the scope of the tool's library. The B→C comparison demonstrates that when project-specific data is available and applied, results can differ substantially from generic defaults, by 45% for the most material-intensive construction studied.

The procurement implications are significant. As discussed in Section 2.7, Trafikverket's current climate requirements are structured around the permanent infrastructure, and temporary works fall outside the incentive mechanism that the reduction requirement creates. The results of this study suggest that this exclusion is not merely a theoretical gap: for the aqueduct, the emissions from on-site machinery and dismantling that fall outside standard calculations exceed the total emissions captured by the standard calculation by a factor of 1.4. Even for the less machine-intensive constructions, the structural exclusion represents a meaningful share of total climate impact that currently carries no formal reporting obligation and generates no procurement incentive for reduction.

A more fundamental observation follows from this. Trafikverket measures progress toward its reduction targets, 60% by 2030 and 80% by 2035 compared to 2015 levels, against a calculated baseline that systematically excludes the category of emissions examined in this study. The implication is that the gap between what is reported and what actually happens on site is not a marginal data-quality issue but a structural feature of how climate progress is currently measured in Swedish infrastructure procurement. Reductions can be reported against a baseline without the corresponding actual emissions falling in equivalent measure, because the activities most likely to grow with project complexity, the machine-intensive temporary works in constrained urban environments, sit outside the measurement frame entirely.

It should be noted that this study quantifies the gap for one specific project and four specific construction types. The results cannot be directly extrapolated to the full scope of temporary works in Västlänken or to other projects. However, the constructions were selected to span a range of types and material intensities, and the finding that structural exclusions are most significant for machine-intensive temporary works is consistent with existing research on construction-phase emissions more broadly.

6 Discussion

This chapter discusses the broader implications of the study's findings. Section 6.1 addresses the implications for climate reporting and procurement practice. Section 6.2 discusses the performance and limitations of Klimatkalkyl as a tool for this type of study. Section 6.3 examines the uncertainties identified in the study and their impact on the conclusions. Section 6.4 reflects on the three-scenario methodology as a contribution. Section 6.5 identifies directions for future research.

6.1 Implications for Climate Reporting and Procurement Practice

Before turning to the specific implications for reporting and procurement, it is worth establishing the scale of what is at stake. It is therefore useful to relate the results to the overall climate impact of the project, although such a comparison can only be approximate. No consolidated Klimatkalkyl baseline exists for the Haga-Rosenlund section alone: following the termination of the original contract, the section is now governed by several contracts with differing climate requirements, and the reduction target applied, a 50% reduction agreed between contractor and client, is itself defined without a clearly specified baseline (Trafikverket, personal communication, June 2026). The only publicly available figure is the 2016 environmental impact statement, which estimated the total climate impact of the Västlänken project, together with the Olskroken grade separation, at 300 000-400 000 tonnes CO_2e (Trafikverket, 2016).

Scenario B is the appropriate basis for this comparison. The 2016 baseline was produced in Klimatkalkyl using generic default values, and Scenario B is calculated on the same basis, the same type of generic emission factors, with the only difference being that it adds the temporary-works activities the standard calculation structurally omits. Relating Scenario B to the baseline therefore compares like with like in terms of method, while making visible the impact the baseline leaves out. Scenario C, by contrast, replaces these generic values with project-specific low-carbon data and is therefore not directly comparable to a generic baseline.

A key point follows from the central finding of this study. Because temporary works fall outside the baseline calculation, their emissions are best understood as additional to it, not as a share already contained within it. The diaphragm wall alone, at over 15 000 tCO_2e in Scenario B, is equivalent to roughly four to five percent of the size of the entire project baseline, yet it represents impact over and above that reported figure. Taking the four constructions together, and assuming the crane foundation recurs, for instance, around eight times while counting the others once, their combined impact is on the order of 18 000 tCO_2e, equivalent to approximately four to six percent of the baseline, again as an addition to it rather than a portion counted within it.

This figure is best understood as a conservative estimate of that addition. The four constructions come from the Haga-Rosenlund section alone, whereas the baseline covers the entire project together with Olskroken, and every other section contains its own temporary works of comparable type. Most constructions are also counted only once, although several recur. The true impact attributable to all temporary works

across the project is therefore substantially greater, though it cannot be quantified from this study.

Two points follow. First, the climate impact of temporary works is not marginal: even on conservative assumptions, a small subset is equivalent to several percent of the entire project baseline, while lying outside the calculation that the baseline represents. The impact is real and of a meaningful magnitude, yet it is added on top of the reported figure rather than captured within it. Second, the difficulty of performing this relativisation is itself part of the problem. The absence of a clear section-level baseline, and a reduction target defined without a specified starting point, are precisely the conditions under which a whole category of construction-phase emissions can remain unaccounted for. Establishing the true aggregate would require a project-wide inventory of temporary works, identified as a direction for future research (Section 6.5).

As shown in Section 5.1, the two dimensions of exclusion are both present and quantifiable in this project: entire temporary constructions are absent from reporting, and the standard building element library lacks elements for the machinery that drives their emissions.

As the relativisation above illustrates, the impact of the first dimension compounds across the project: each temporary construction contributes a quantity that, individually, may be small relative to the permanent infrastructure, but which accumulates across the many temporary constructions a project of this scale contains.

These findings have potential relevance to Trafikverket's climate reduction targets. As described in Section 2.7, contractors are required to demonstrate reductions of 60% by 2030 and 80% by 2035 relative to a 2015 baseline calculated using Klimatkalkyl. This baseline does not include temporary works. The structural consequence is that absolute emissions from temporary works fall outside the reduction mechanism. A contractor could in principle meet the reduction requirement against the calculated baseline while increasing emissions from temporary works, with no formal consequence. This is not a hypothetical concern: the machine-intensive constructions examined here can carry significant emissions that are not currently captured in any procurement-related calculation.

There is, in other words, a gap between what is reported and what actually happens on site. The gap is not the result of poor data or weak compliance: it is a structural feature of how the procurement framework is constructed. Closing it in practice is genuinely difficult. The baseline calculation is performed at a stage in the project life cycle when detailed information about temporary works does not yet exist, since these depend on production choices that the contractor makes later. Specifying reduction requirements for activities where typical practice varies considerably by site, contractor and project type is also non-trivial. The current approach, which addresses this difficulty by excluding construction-phase activities from the reduction mechanism, may be a pragmatic interim arrangement rather than a long-term position. As Trafikverket has set a long-term goal of climate-neutral infrastructure by 2040, a measurement framework that systematically omits a substantial category of emissions is unlikely to be a sustainable basis for that ambition.

A related observation concerns the relationship between contractor effort and procurement credit. The B→C comparison suggests that contractors operating with project-specific EPDs and renewable fuel commitments may achieve emissions substantially below what generic calculations suggest. Peab's confirmed use of HVO100 across the majority of on-site machinery in Västlänken provides a concrete example: for the canal infill, C1+C2 emissions in Scenario C are approximately 7 tCO_2e compared to over 54 tCO_2e in Scenario B, a reduction in the order of 86%. The contract requirement in this case may have specified a lower minimum proportion of renewable fuel, meaning that Peab's actual practice exceeds the formal requirement. Because these activities lie outside the calculated reduction mechanism, the additional effort generates no procurement credit. This may create a partial incentive misalignment: contractors who go beyond minimum requirements in the construction phase receive no formal recognition for doing so, while those who specify low-carbon materials in the permanent structure receive recognition through the baseline reduction.

The magnitudes observed here are consistent with the TWF (2023) position that temporary works, sitting within module A5, are likely to exceed the 5% cut-off threshold for that module and therefore cannot be excluded from assessment. The aqueduct is the clearest case: its A5 and C1+C2 emissions in Scenario B together exceed its entire Scenario A total.

The broader implication for procurement practice may be that current requirements, while effective in driving material specification choices, do not generate equivalent incentives for the operational decisions that shape construction-phase emissions. As Trafikverket is the largest infrastructure client in Sweden, it is in a position to develop procurement mechanisms that recognise improvements across both phases. Establishing how to do so in a manner that is administratively feasible and verifiable is itself a difficult design problem. Continued development of how Klimatkalkyl-based requirements interact with construction-phase emissions appears to be needed if the long-term goal of climate-neutral infrastructure is to be supported by procurement design rather than undermined by it.

6.2 Discussion on Klimatkalkyl as a Tool

The study's three-scenario structure allows the performance of Klimatkalkyl to be considered from two distinct angles: its structural completeness in capturing the relevant activities, and the accuracy of its default values relative to project-specific data.

On structural completeness, the findings indicate that the tool's standard building element library does not include pre-defined elements for the specialised machinery required by temporary constructions of the type studied. Klimatkalkyl can in principle capture these activities through manual energy posts, as demonstrated in Scenarios B and C of this study, but the data required to do so is typically not available at the planning stage when the standard calculations are performed, and the practice of adding such posts is not part of the standard procurement workflow.

It should be acknowledged that Klimatkalkyl was developed primarily for calculating the climate impact of permanent infrastructure at the planning stage, and its library

reflects construction activities typical of that context. In addition to the standard building elements, the tool offers what are termed typåtgärder, pre-defined composite elements representing typical infrastructure features such as bus shelters or signalling systems. These typåtgärder offer greater specificity than individual building elements but remain based on generic default values calibrated for typical conditions. They do not currently extend to the specialised machinery of temporary works in complex urban projects. The trade-off between simplicity and accuracy inherent in any design-stage tool is genuine: a library of pre-defined elements enables rapid and consistent calculations across projects, but achieves this efficiency by abstracting away project-specific construction activities. For permanent infrastructure with broadly typical construction methods, this trade-off may be reasonable. For complex urban projects with extensive temporary works, the trade-off becomes less favourable.

On default value accuracy, the B→C comparison suggests that Klimatkalkyl's C32/40 generic default value substantially overestimates the emissions of the concrete mixes used in the diaphragm wall system. The ECO3 mixes specified by Swerock have A1-A3 emission factors between 52% and 75% lower than the C32/40 generic default value on a per-kilogram basis, depending on the specific mix and EPD. This finding is consistent with the broader trend towards lower-carbon concrete in Swedish infrastructure procurement. As EPD databases expand and more contractors specify low-carbon concrete mixes, the divergence between the generic default and the actual materials used is likely to increase. The tool's generic default values are necessarily based on a snapshot of typical material specifications at the time of calibration; in a market segment moving rapidly towards lower-carbon products, this snapshot becomes outdated faster than the tool can practically be updated.

The tool update noted in Section 3.5, which prevented direct override of transport parameters in the C32/40 building element, required an alternative modelling approach using Annat material & övriga transporter for EPD-based concrete values. While this workaround produces equivalent results, it represents practical friction in applying project-specific data within the tool's framework.

The timing question is also relevant. In procurement, Klimatkalkyl is typically applied early; the calculated baseline forms part of the procurement documentation, and the reduction requirement is set against this baseline. At this point in the project life cycle, detailed data on temporary works is rarely available. By the time of construction, when more detailed information would become obtainable, the procurement calculation has long since been completed. The industry generally has reasonable tools and methods for performing more detailed calculations during the construction phase; contractors regularly track material quantities, machine hours and fuel consumption for production planning purposes. The technical capacity to perform more accurate calculations exists; what appears to be missing is a procurement structure that requires this data to be reported and reconciled against the original calculated baseline. Bridging this temporal gap may be one of the more practical avenues for improving the climate assessment of temporary works without requiring fundamental changes to the tool itself.

6.3 Uncertainties and Their Impact on Results

Several sources of uncertainty are relevant to the robustness of the study's conclusions.

The most significant quantified uncertainty concerns the fuel type for three machines in the aqueduct, the excavator, pile crane and mini-dumper, totalling approximately 19 550 litres. If these machines operate on HVO100 rather than the assumed diesel MK1, Scenario C results for the aqueduct would decrease from approximately 133 to approximately 86 tCO_2e, a reduction in the order of 35%. This uncertainty does not affect the A→B comparison, which applies diesel to all machines in both scenarios. It affects the B→C comparison for the aqueduct only. The direction of the uncertainty is towards an overstatement of Scenario C emissions; the conservative assumption of diesel MK1 means actual emissions may be lower than reported.

The C/D-wall panel split assumption introduces a maximum potential error of approximately 39 tCO_2e in A1-A3 emissions for the diaphragm wall in Scenario C. Given the total Scenario C diaphragm wall result of approximately 8 430 tCO_2e, the maximum error represents less than 1% of the total, insufficient to affect the study's conclusions.

More broadly, the input data for machinery operating hours and fuel consumption rates consist of estimates provided by Peab's production personnel based on operational experience rather than recorded measurements. As discussed in Section 3.4, ISO 14044 establishes that data quality should be characterised by the suitability of data for the study's purpose rather than by an abstract standard of measurement precision. Operational estimates from experienced production personnel are appropriate data for a climate assessment at this level of detail, but they are different in character from instrumented measurements. The study has been transparent about this distinction throughout, using the term confirmed to mean that a value has been provided by the relevant party rather than independently verified by measurement.

It should also be acknowledged that the Västlänken project context introduces specific data characteristics that may affect interpretation of the results. Peab took over the construction of this part of the project from a previous contractor whose contract was terminated, with some of the underlying contractual climate requirements dating from approximately 2018. Eight years is a non-trivial period in a sector where material specifications, fuel availability and climate practices have evolved rapidly. The result is that the operational data made available to this study reflects practices that, in some cases, exceed the formal contractual requirements set under earlier conditions. Whether the operational characteristics observed here would be representative of current procurement processes more broadly is an open question, and the findings should not be taken as a precise characterisation of what other contractors on other projects would achieve under different contractual conditions.

A further consideration is that the three-scenario structure itself functions as a partial response to absolute uncertainty. By comparing scenarios that differ in well-defined ways, the comparisons are robust to many absolute uncertainties that affect both

compared scenarios equally. The A→B gap for the aqueduct, for example, is not sensitive to whether machinery operating hours are estimated to within ±10% or ±30%, provided the same hours are used in both scenarios. This methodological feature means that the central comparative findings, the relative magnitudes of the structural and data-quality gaps, may be more robust than the absolute emissions values might suggest.

6.4 Reflections on the Three-Scenario Methodology

The three-scenario approach developed for this study represents a methodological choice that separates two distinct types of question often conflated in climate assessment debates: what activities are systematically excluded from the standard calculation, and how does real emissions differ from generic defaults when the activities are included.

These two questions correspond to different policy responses. The first, structural exclusion, would be addressed by changing what is calculated, expanding the scope of standard tools and procurement requirements. The second, default value accuracy, would be addressed by changing how it is calculated, increasing the use of project-specific EPDs and confirmed operational data. The two responses are at least partly independent: the procurement framework could in principle require that temporary works be included without prescribing how their emissions are calculated or could require project-specific data without expanding the scope of activities included.

The three-scenario structure attempts to quantify each effect separately. Scenario B isolates the structural gap by holding emission factors constant relative to Scenario A; Scenario C isolates the data-quality effect by holding the activity scope constant relative to Scenario B. This separation may be useful for diagnosing where in the system gaps exist, since the two effectsb have different drivers and different practical responses. For the aqueduct, the structural effect appears far larger than the data-quality effect; for the diaphragm wall, the relationship is reversed.

The approach has limitations. It assumes a clean separation between what is structurally missing and what is merely calibrated differently in the default values, but the boundary is not always sharp. The leanmix emission factor used in this study, for example, is treated as a data-quality issue (using Annat material with EPD values in all scenarios) but could equally be framed as a structural issue. Such framing choices affect how the gap between A and C is partitioned between B and C even when the total gap is unchanged. The methodology is therefore best understood as a tool for making different types of gap visible rather than as a definitive partition of underlying causes.

6.5 Future Research

This study examines four temporary constructions from one infrastructure project. Several directions for future research would strengthen the evidence base and extend the findings to broader contexts.

A natural extension would be a more complete inventory of temporary works in the Västlänken project, covering a larger share of the temporary constructions rather than the four examined here. This would allow the aggregate contribution of temporary works to the project's climate impact to be quantified and set in relation to the permanent infrastructure's calculated baseline. The relationship between the full temporary works contribution and the calculated baseline would directly inform whether and how the procurement framework should be adapted.

A cross-project study applying the same methodology to temporary works in other Swedish infrastructure projects would allow the generalisability of the findings to be assessed. The relative magnitude of A→B and B→C gaps is likely to vary considerably depending on project type, site conditions and contractor practices. Tunnel construction in urban environments is one of several infrastructure types where temporary works are likely to be substantial; bridge construction, viaduct construction and large-scale earthworks would be expected to show different patterns. Understanding this variation would provide a more robust basis for decisions about where to focus climate reporting requirements.

On the tool side, development of standard building elements or typåtgärder for specialised temporary works machinery within Klimatkalkyl, or within supplementary calculation frameworks, would reduce the need for manual energy post additions and improve the consistency of climate assessments across projects. Such elements could be calibrated against empirical data from projects like Västlänken where detailed machinery records are available.

The procurement mechanism itself warrants further research. The current model's limited treatment of temporary works creates a structural feature of the kind discussed in Section 6.1. Whether and how this should be addressed, through reporting requirements, separate incentive mechanisms, or integration into the existing baseline calculation, is a design question that requires both technical and institutional analysis beyond the scope of this study. Research that examines how comparable issues have been addressed in other regulatory contexts, both within infrastructure and in other sectors, would inform the design of an appropriate response.

7 Conclusions

This study has examined the climate impact of four temporary constructions in the Västlänken project, a canal infill, a crane foundation, a diaphragm wall system and an aqueduct, using a three-scenario approach that separates the effect of structural exclusions in standard calculations from the effect of applying project-specific data.

Two main empirical findings emerge from the analysis. First, the comparison between Scenario A and Scenario B suggests that the climate impact of construction activities systematically absent from standard Klimatkalkyl calculations varies considerably between construction types. The activities found to be structurally absent are specialised on-site machinery used to build the temporary constructions, including mobile cranes driving sheet piles, vibratory hammers installing diaphragm wall panels and pile cranes constructing foundations, together with dismantling and transport activities in modules C1 and C2. For the diaphragm wall system, the added contribution from on-site machinery is negligible relative to the material baseline (+0.1%). For the aqueduct, it exceeds the entire standard-calculated total (+137%). The structural exclusion appears to matter most for machine-intensive temporary constructions and least for material-dominated ones, a pattern consistent with broader research on construction-phase emissions.

Second, the comparison between Scenario B and Scenario C suggests that applying project-specific EPDs and confirmed fuel types can reduce calculated emissions substantially relative to generic defaults. For the diaphragm wall, the application of Swerock dotter-EPDs for concrete and the B GROUP STEEL EPD for reinforcement reduces total emissions by approximately 45%. For the canal infill and the aqueduct, the confirmed use of HVO100 across the majority of on-site machinery reduces A5 and C1+C2 contributions substantially relative to a diesel baseline. The two effects operate through different channels and have different implications for procurement design.

From these empirical findings a broader conclusion follows. There is a gap between what is reported through current climate calculations and what actually happens on site, and this gap is structural rather than a matter of data quality or compliance. Trafikverket measures progress toward ambitious reduction targets, including the long-term goal of climate-neutral infrastructure by 2040, against a baseline that systematically excludes a category of emissions which, for the construction types examined here, can be substantial. The current procurement framework may therefore create partial incentive misalignment: contractors who commit to lower-carbon materials and renewable fuels in the construction phase may receive limited formal recognition for these choices because the activities concerned fall outside the calculated reduction mechanism, while temporary works themselves carry no formal reporting obligation at all.

How to address this in practice is genuinely difficult. The baseline calculation is performed before contractors have made the production choices that determine temporary works, and specifying reduction requirements for activities where typical practice varies considerably by site is itself a non-trivial problem. The current approach of excluding construction-phase activities from the reduction mechanism may be a pragmatic interim arrangement, but it sits in tension with the long-term

ambition of climate-neutral infrastructure. The technical capacity to perform more accurate calculations during the construction phase exists; what appears to be missing is a procurement structure that requires this data to be reported and reconciled against the original baseline. Closing the gap, whether through expanded reporting requirements, parallel incentive mechanisms, or integration into the existing framework, is a procurement design question that extends beyond the scope of this study but that the magnitudes observed here suggest is worth examining.

Several limitations should be acknowledged. The study examines a small subset of the temporary works involved in a project of Västlänken's scale, and the findings cannot be directly extrapolated to the project as a whole. The data underlying the machinery calculations consist primarily of operational estimates from production personnel rather than instrumented measurements, and the data context, with some underlying contractual conditions dating from approximately 2018, may not be fully representative of current procurement practice. The TWF 5% significance threshold cannot be directly verified against total project emissions, though the observed magnitudes are consistent with the threshold being exceeded.

These limitations notwithstanding, the study suggests three interim conclusions for further investigation. The first is that the structural treatment of temporary works in Klimatkalkyl-based procurement deserves closer attention, particularly for construction types where on-site machinery and dismantling are likely to represent significant shares of total impact. The second is that the divergence between generic default values and actual project-specific data for concrete and fuel appears substantial enough to affect the relative ranking of construction choices, and this divergence is likely to grow as low-carbon materials and renewable fuels become more widely adopted. The third is that the gap between reported and actual climate impact in current infrastructure procurement is not a marginal measurement issue but a structural feature of how progress toward climate targets is currently assessed, and that addressing it in a manner that is administratively feasible and verifiable is itself an unresolved design problem worth dedicated attention.

Future research extending the methodology to a wider range of constructions, projects and contractors would help establish whether these patterns hold beyond the specific context examined here.

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Appendix A. Machinery Inventory

The following tables present the machinery data provided by Peab's production personnel for each construction studied. Data covers on-site construction activities (module A5) and demolition and transport activities (modules C1 and C2). Operating hours and fuel consumption rates are based on operational estimates from experienced production personnel rather than recorded measurements. All activities have been classified as A5, C1 or C2 respectively.

A.1 Canal Infill (Utfyllnad av kanal)

Equipment	Module	Operating hours	Consumption rate	Total [litres]	Fuel type
Module A5 - On-site construction activities					
Mobilkran	A5	200 h	15 l/h	3 000	HVO100
Frihängande vibro	A5	50 h	25 l/h	1 250	HVO100
Silentpiler	A5	-	-	600	Diesel MK1
Långgrävare	A5	160 h	30 l/h	4 800	HVO100
Lastbilar	A5	267 h	20 l/h	5 340	HVO100
Total - A5				**14 390 l HVO100 600 l Diesel MK1**	
Modules C1+C2 - Dismantling and transport					
Mobilkran	C1+C2	200 h	15 l/h	3 000	HVO100
Frihängande vibro	C1+C2	200 h	25 l/h	5 000	HVO100
Långgrävare	C1+C2	180 h	30 l/h	5 400	HVO100
Lastbil + släp	C1+C2	300 h	20 l/h	6 000	HVO100
Total - C1+C2				**19 400 l HVO100**	

A.2 Crane Foundation (Kranfundament)

Equipment	Module	Operating hours	Consumption rate	Total [litres]	Fuel type
Module A5 - On-site construction activities					
Grävmaskin (30 tons)	A5	148 h	20 l/h	2 960	HVO100
Lastbil tridem	A5	30 h	12 l/h	360	HVO100
Betongpump	A5	12 h	8 l/h	96	Diesel MK1

Equipment	Module	Operating hours	Consumption rate	Total [litres]	Fuel type
Hjullastare[1]	A5	-	-	-	-
Kranbil[1]	A5	-	-	-	-
Total - A5				**3 320 l HVO100 96 l Diesel MK1**	
[1] Present on site but operating hours and fuel consumption could not be attributed; excluded from calculation.					
Modules C1+C2 - Dismantling and transport					
Grävmaskin (30 tons)	C1+C2	80 h	19 l/h	1 520	HVO100
Lastbil + släp	C1+C2	120 h	20 l/h	2 400	HVO100
Total - C1+C2				**3 920 l HVO100**	

A.3 Diaphragm Wall (Slitsmur)

Equipment	Module	Operating hours	Consumption rate	Total [litres]	Fuel type
Module A5 - On-site construction activities					
Betongpumpar	A5	-	-	13 700	Diesel MK1
MC76 schaktmaskin + Hjullastare	A5	35 h	20 l/h	700	HVO100
MC86 schaktmaskin	A5	19 h	20 l/h	380	HVO100
Liebherr LR1400 (kran)	A5	8 h	15 l/h	120	HVO100
Dumprar	A5	36 h	17 l/h	612	HVO100
Hjullastare L50/L70	A5	19 h	12 l/h	228	HVO100
Lastbil + släp (torra massor)	A5	10 h	20 l/h	200	HVO100
Total - A5				**2 240 l HVO100 13 700 l Diesel MK1**	
C1+C2: not applicable - construction remains permanently embedded.					

A.4 Aqueduct (Akvedukt)

Equipment	Module	Operating hours	Consumption rate	Total [litres]	Fuel type
Module A5 - On-site construction activities					
Betongpump	A5	64 h	8 l/h	512	Diesel MK1
Mobilkran (armering/form + spontinstallation)	A5	65 h	15 l/h	975	HVO100
Frihängande vibro	A5	65 h	25 l/h	1 625	HVO100
Grävmaskin*	A5	700 h	19 l/h	13 300	Diesel MK1*
Pålkran*	A5	60 h	35 l/h	2 100	Diesel MK1*
Minidumper*	A5	415 h	10 l/h	4 150	Diesel MK1*
Total - A5				**2 600 l HVO100 20 062 l Diesel MK1**	
* Fuel type unconfirmed; diesel MK1 assumed conservatively. If HVO100 is confirmed for all three machines, Scenario C emissions decrease by approximately 47 tCO_2e.					
Modules C1+C2 - Dismantling and transport					
Frihängande vibro (dra spont)	C1+C2	40 h	25 l/h	1 000	HVO100
Mobilkran (dra spont)	C1+C2	40 h	15 l/h	600	HVO100
Grävmaskin	C1+C2	400 h	19 l/h	7 600	HVO100
Lastbil + släp	C1+C2	600 h	20 l/h	12 000	HVO100
Total - C1+C2				**21 200 l HVO100**	



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