Tampere University of Applied Sciences

# The contribution of emission reduction possibilities provided by preconstruction to the climate targets of cities

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**ABSTRACT**

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Preconstruction means actions that are carried out when an area to be constructed is geotechnically too soft or difficult to construct and the area must be for example solidified or mass in the area must be exchanged. As infra construction is very energy intensive, preconstruction provides possibilities for significant emission reductions when the preconstruction alternatives, areal mass balance and alternative materials generated in the vicinity has been mapped early enough in advance.

The objective of this thesis was to study emission reduction potential in preconstruction activities and how considering the preconstruction alternatives can contribute to the climate targets of cities.

Literature review and $CO_2$ emission calculations for actual cases were studied in this thesis. The cases presented in this study are Ramboll Finland's client cases calculated for the cities of Helsinki, Turku and Tampere. The calculation method used in the case examples is developed by Ramboll for $CO_2$ emission calculation purposes in infra projects following the standard CEN/TC 350 Sustainability of construction works.

The results of this thesis will contribute to cities climate target calculations, as well as to national UUMA3 project objectives.

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Key words: preconstruction, climate change, carbon emissions, emission calculation, infra construction, ground improvement

**CONTENTS**

## ABBREVIATIONS AND TERMS

| | |
|---|---|
| Preconstruction | Creating or improving the possibilities of an area to be built, by preconstruction activities which include excavation, blasting and filling, ground improvement and lightening, improving stability, cleaning contaminated soils, dredging of water areas and filling them, demolition of structures and cable transfers. |
| Alternative materials | Refers to all such materials that will replace virgin natural aggregates such as crushed concrete, surplus soils, industrial by-products. Term relates to recycled materials and recovered materials. |
| kt-$CO_2$ eq | Measurement to describe how many tons of carbon emissions are released per unit. Eq refers to equivalent, when also other greenhouse gases are included such as methane and dinitrogen oxide. |
| IOA | Input-output analysis, analytical tool applied for example in life cycle analysis inventory to show what are the inputs and outputs of the system |
| EIA | Environmental impact assessment |
| SEA | Strategic environmental assessment, a tool intended to be used at an earlier stage in the decision-making process on a strategic level and to be used for policies, plans and programmes |
| $m^3$ktr | theoretical absolute volume (abbreviation in Finnish), |
| $m^3$ktd | actual absolute volume (abbreviation in Finnish) |
| $m^3$itd | actual loose volume (abbreviation in Finnish) |
| $m^3$rtd | actual structural volume (abbreviation in Finnish) |
| $m^3$rtr | theoretical structural volume (abbreviation in Finnish) |


where:

y1 = $m^3$ktd/$m^3$ktr / k1 = $m^3$itd/$m^3$ktd / k2 = $m^3$rtd/$m^3$itd / y2 = $m^3$rtr/ $m^3$rtd

# 1 INTRODUCTION

Finland is committed to the EU climate targets and related national targets to reduce greenhouse gas emissions with -40 % by the year 2030 compared to the level in 1990 (Parviainen 2015, 12). The Finnish energy and climate road map for the year 2050, target to decrease the emissions by 80-95 % compared to the 1990 level, is set (Huttunen, 2017, 13).

Cities and municipalities have an important role in accomplishing the climate targets. For example, in cities' own buildings, 5-6 % of the country's heat energy and 3 % of the electricity is consumed. In addition to the direct energy consumption and production, decision of the cities also impacts on the transportation related emissions. To achieve the set climate targets within the emissions trading and its external sectors, cities' own activities are needed (Parviainen, 2015, 12).

Although climate work can be done on a local level without exact emission calculations and based on the experience and indicators, succeeding in the international climate policy, requires emission calculation data. Without homogenous and commensurable emission calculation data, the international commitments are difficult to make, and the fulfilment of previous agreements are hard to monitor in practice (Parviainen, 2015, 13).

Cities have created various strategies to cut the emissions in a certain time frame. Often these climate strategies take into account activities related to improving energy efficiency in the old buildings and estates, the construction of the so called zero-emission buildings and changing the energy forms to renewable energy.

According to the Green Building Council Finland (GBCF), best stage to influence on the infra project emissions, is in the land use planning stage. This is also the stage where most of the project costs are settled (Figure 1).

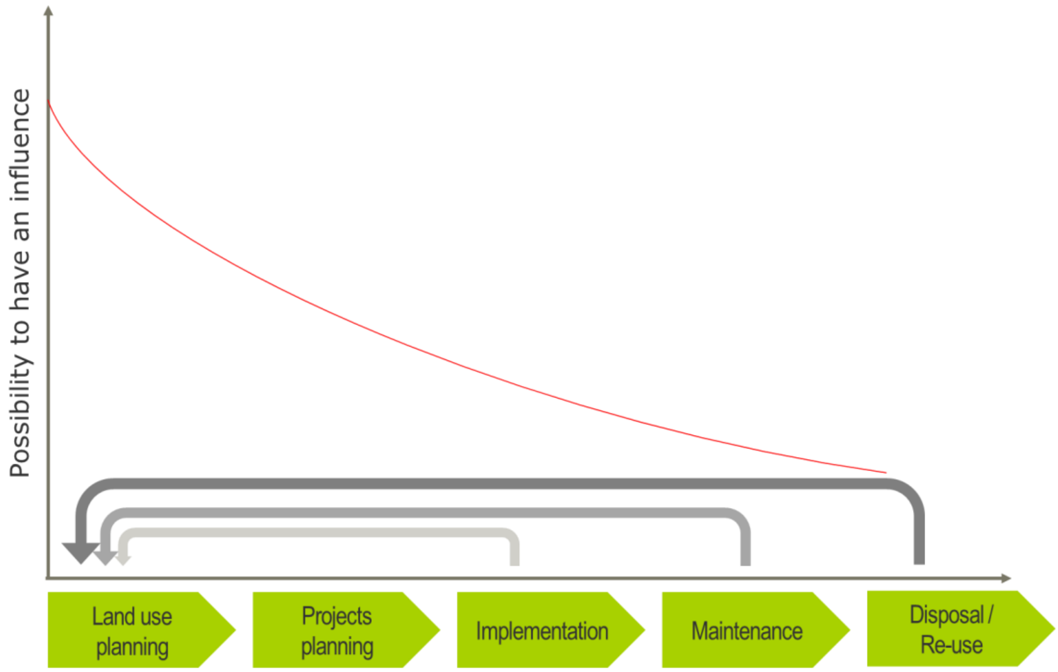


Figure 1. Possibilities to have an influence is significantly bigger in the land use planning stage (Kestävä infra, 2019).

In this thesis, the emission reduction potential provided by the preconstruction activities in the climate targets of cities is studied. The term preconstruction means actions that are carried out when an area to be constructed is geotechnically too soft or difficult to construct and the area must be for example solidified or mass in the area must be exchanged. As the infra construction is very energy intensive, preconstruction provides possibilities for significant emission reductions when the preconstruction alternatives, the areal mass balance and the alternative materials generated in the vicinity has been mapped early enough in advance.

As a background information, the climate strategies of cities of Helsinki, Espoo, Vantaa, Tampere, Turku and Stockholm will be studied for the construction related actions and strategies concerning the mass balance/mass coordination if this has been done.

The objective of this thesis is to analyse the emission reduction potential in preconstruction activities and to give understanding on the magnitude of the emission reduction possibilities. In addition, the calculated cost reductions are also presented although they have not been the focus of the studies.

## 2 METHODOLOGY

The methodology in this study consists of a literature review and $CO_2$ emission calculations case studies. Research field of the literature review is emission calculations in urban development and greenhouse gas emissions temporal allocations, alternative material uses in infra construction and material flows. The literature review is presented in the chapter 3.

The calculation method used in the case examples presented in chapter 6, is MS Office Excel-based program developed in Ramboll for the $CO_2$ emission calculation purposes in the infra projects. Structural components like pile, stabilised column, lightweight aggregate, mass replacement, etc. are specified according to the Finnish Building Information Foundation (RTS) InfraRYL Finnish guideline for construction infrastructure in that specific case and the studied alternatives. All alternatives calculated in the case calculations, are technically comparable with each other.

The $CO_2$ emission calculation follows the standard CEN/TC 350 Sustainability of construction works, and the standard stage A (Figure 2). This stage includes all parts for the product (A1-A3 product stage) and for the construction activities (A4-A5 Construction Process Stage). The calculation does not include the standard stages B (Use stage) and C (End of life stage). It must be noticed, that the decisions made at the stage A, have impact also on the stages B and C as the materials have different characteristics that further impact for example on the structure durability and the use stage.

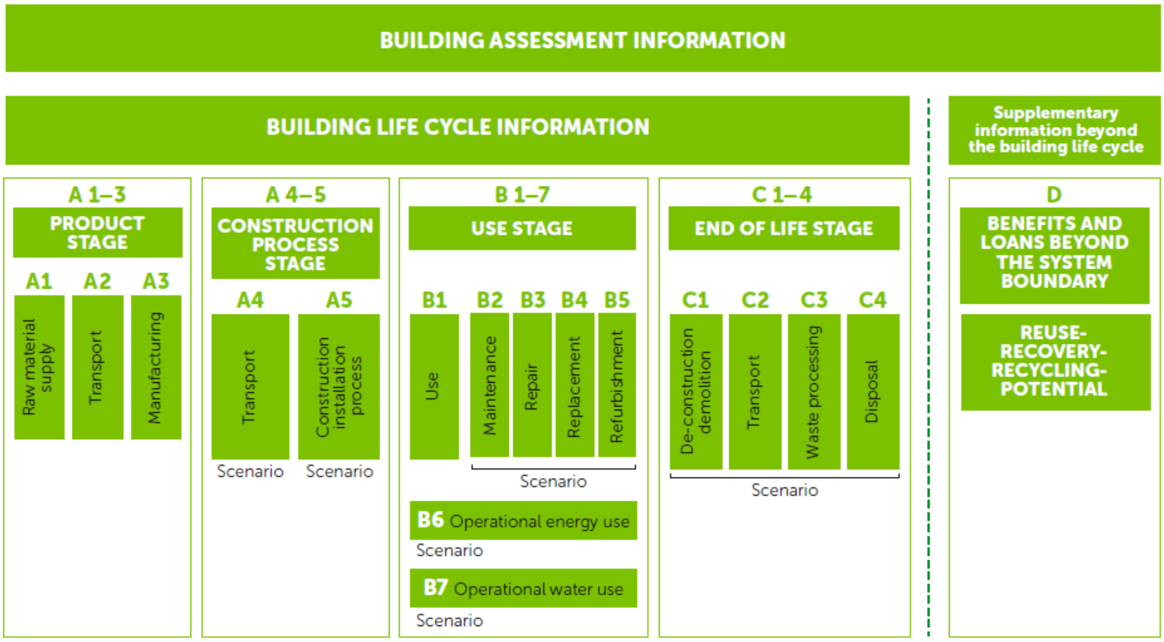


Figure 2. Modules according to the standard CEN/TS 350 (Dettenborn et al, 2018, 3).

As Finnveden and Moberg (2005, 1165-1166) describe in their article “Environmental systems analysis tools – an overview”, environmental impact tools can be considered either a procedural or analytical tool. Procedural tools have focus on the procedure and analytical tools have focus on the analysis’ technical aspects. Further, Finnveden and Moberg (2005, 1166) asks if the tool is used in descriptive or change-orientated studies, and the Ramboll $CO_2$ calculation cases can be considered as change-oriented studies, as they analyses the consequences of a choice – what consequences there are when the preconstruction is done by a method a, b or c.

The used $CO_2$ calculation tool produces input-output (IOA) analysis, where a region (the area to be constructed) is the object of the study. Although it is not an environmental impact assessment (EIA) nor it is not a strategic environmental assessment (SEA), which are used for specific project purposes, the results of these $CO_2$ calculations can (and should) have impact on the decision-making process as the calculations are intended to show where and how the carbon emission reductions can be made without compromising the technical requirements, and simultaneously save the construction costs. In Figure 3 the system boundaries of these calculations are presented.

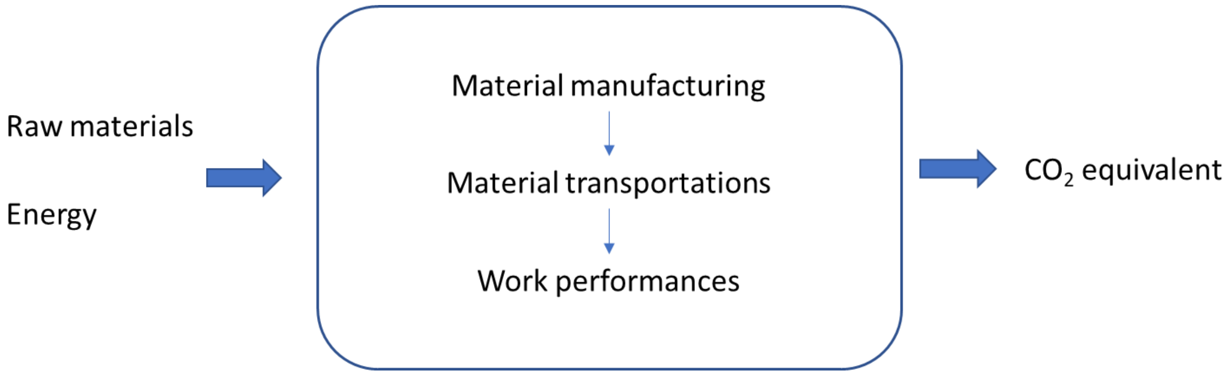


Figure 3. The system boundaries for the case studies presented in this thesis.

In the Ramboll $CO_2$ calculation program, the source information is given into the first sheet. In addition, the information of the transportation distance related to each structural part are given. Additional explanations, such as description of the material or product, soil type, work stages and production plant, are given (Dettenborn et al, 2018, 3). Figure 4 shows an example on the information sheet.

| Vallikatu, Alt 1 | | INFORMATION DATA | | |
|---|---|---|---|---|
| **ID (according to InfraRYL)** | **Structures and structural parts** | **Unit** | **Amounts** | **Transportations km *** |
| 1141 | Removal of top soil | m2tr | 36 456 | 13 |
| 1611A | Earth cut (excavation for quarrying) | m3ktr | 29 753 | 13 |
| 1814 | Leighweight embankments, foamed glass | m3rtr | 19 491 | 90 |
| 2111 | Filter course, sand | m3rtr | 5 895 | 13 |
| 2112 | Geotextile N3 | m2tr | 36 456 | 510 |
| 2121 | Sub-base, crushed rock | m3rtr | 6 622 | 13 |
| 2131 | Unbound base course, crushed rock | m3rtr | 5 724 | 13 |
| 2160 | Ramp filling | m3rtr | 5 965 | 13 |
| 2141,11 | AB 11/100 (40 mm) | m2tr | 9 960 | 13 |
| 2141,3 | AB 16/100 (40 mm) | m2tr | 9 550 | 13 |
| 2141,13 | ABK 32/150 (60 mm) | m2tr | 19 510 | 13 |
| 2211,2 | Kerb, concrete | m2tr | 371 | 165 |
| 2310A | Top soil | m2tr | 8 651 | 20 |
| 2310B | Top soil, bearing | m2tr | 8 295 | 20 |

Figure 4. Example of the $CO_2$ calculation information sheet, case Vallikatu alternative 1.

When the source information is given, a calculation sheet for every structural part is created. In these sheets, the information about the used vehicle and characteristic conversion factors for the soil or material are given, when necessary. With the help of the conversion factors, the right volume unit for the material is determined, as for example, the volume of aggregate can be 2,5-fold depending if it is studied in actual loose volume ($m^3$itd) or in theoretical structural volume ($m^3$rtr). Different materials act differently when they are processed (loosening, compacting) and thus it is important to recognize the material characteristics to ensure the quality of the calculations (Dettenborn et al, 2018, 4).

For every structural part, the emissions from the material production, transportation and work stages is determined. Material production emissions mean the stages A1-3 in the standard CEN/TS 350 (Figure 2). The used emission values for the material production origins from the product manufacturer and in some cases the used values origins to a discussion with the related expert. Transportation and work machine emissions are from the VTT Finnish Technical Research Centre Lipasto-database. The used parameters and their origins are given in Appendix 1.

After all the needed information are given in the Excel sheets, the calculation results are shown in the information sheet (Figure 5). In this thesis, the case calculation result sheets are available in appendices 2-4.

| Vallikatu, Alt 1 | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Trans-portation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1141 | Removal of top soil | m2tr | 36 456 | 13 | 0 | 13 627 | 3 242 | 16 869 | 1,27 | 0,97 % |
| 1611A | Earth cut (excavation for quarrying) | m3ktr | 29 753 | 13 | 0 | 76 946 | 16 925 | 93 871 | 1,25 | 5,41 % |
| 1814 | Leighweight embankments, foamed glass | m3rtr | 19 491 | 90 | 1 135 838 | 7 617 | 14 365 | 1 157 820 | 226,30 | 66,72 % |
| 2111 | Filter course, sand | m3rtr | 5 895 | 13 | 11 960 | 11 015 | 7 144 | 30 118 | 2,81 | 1,74 % |
| 2112 | Geotextile N3 | m2tr | 36 456 | 510 | 7 619 | 1 265 | 0 | 8 884 | 1 282,63 | 0,51 % |
| 2121 | Sub-base, crushed rock | m3rtr | 6 622 | 13 | 25 460 | 14 524 | 11 269 | 51 253 | 3,62 | 2,95 % |
| 2131 | Unbound base course, crushed rock | m3rtr | 5 724 | 13 | 22 008 | 12 555 | 13 693 | 48 255 | 3,95 | 2,78 % |
| 2160 | Ramp filling | m3rtr | 5 965 | 13 | 0 | 13 042 | 1 914 | 14 956 | 1,18 | 0,86 % |
| 2141,11 | AB 11/100 (40 mm) | m2tr | 9 960 | 13 | 34 278 | 1 033 | 3 426 | 38 737 | 38,89 | 2,23 % |
| 2141,3 | AB 16/100 (40 mm) | m2tr | 9 550 | 13 | 32 867 | 994 | 3 285 | 37 146 | 38,90 | 2,14 % |
| 2141,13 | ABK 32/150 (60 mm) | m2tr | 19 510 | 13 | 100 718 | 3 022 | 6 711 | 110 450 | 37,74 | 6,36 % |
| 2211,2 | Kerb, concrete | m2tr | 371 | 165 | 47 254 | 2 968 | 0 | 50 222 | 209,43 | 2,89 % |
| 2310A | Top soil | m2tr | 8 651 | 20 | 1 736 | 3 329 | 555 | 5 620 | 2,67 | 0,32 % |
| 2310B | Top soil, bearing | m2tr | 8 295 | 20 | 28 974 | 28 013 | 14 116 | 71 103 | 4,01 | 4,10 % |
| | | | | | | | Summa | 1 735 304 | | 100,00 % |

Figure 5. Finished $CO_2$ excel calculation, case Vallikatu, alternative 1.

# 3 LITERATURE REVIEW

A number of publications and studies have been explored to find the relevant information connections between the infra construction emission and the LCA calculations, emission reduction possibilities, mass balance coordination and climate targets of cities. There are some studies touching on the subject, but the actual topic of this thesis is yet unexplored thoroughly. In Table 1 the most relevant explored studies and publications are presented.

Although there is a gap in the literature with the exact thesis topic, the reviewed literature yet gave information for this study, and the temporal allocation of the emissions is an important factor as described in three explored studies of Säynäjoki et. al. (2014), Säynäjoki, Heinonen & Junnila (2012) and Schwietzke, Griffin & Matthews (2011).

Coordination of the excavated soils and rocks, and careful designing of the construction activities, can have a significant emission reduction possibility, and in addition, cost savings, as presented by Magnusson, Lundberg, Svedberg and Knutsson (2015) and Magnusson, Johansson, Frosth and Lundberg (2019). Same conclusions have been also found in cities of Helsinki and Espoo as they have created mass coordination programs in order to control the mass flows and related costs in their own infra projects (see chapter 4).

These findings will further encourage to study the emission reduction possibilities within the preconstruction.

Table 1. Studied publications and studies for the literature review in a chronological order.

| | |
|---|---|
| **Source** | **Teittinen, T. 2019. Environmental impact indicators and emission calculations in road construction when using secondary raw materials. Master's Programme in Water and Environmental Engineering. Aalto University.** |
| **Description** | The thesis presents current questions in emission calculation and how they should be developed. |
| **Purpose** | The purpose of the thesis was to provide information how the infra construction related emission calculation should be developed. |
| **Results** | There is a need for national guidance on the emission calculation from infrastructure construction. Guidance is needed at least to help the calculation of life cycle of secondary materials (boundaries), how to take into account the carbon binding capacity of crushed concrete, which data sources should be used and which operations at the construction site should be considered for the emission calculation. |
| **Source** | **Magnusson, S., Lundberg, K., Svedberg, B and Knutsson, S. 2015. Sustainable management of excavated soil and rock in urban areas – A literature review. Journal of Cleaner Production 93 (2015) 18-25.** |
| **Description** | The paper describes the material flow and management practices of urban excavated soil and rock from the perspective of resource efficiency. |
| **Purpose** | The paper is an outcome of the research project "Optimass", which aim was to provide conditions for a more sustainable management of soil and rock in dense city regions. The idea of the paper is to introduce the potential the reduction potential in environmental and economic costs by the mass coordination. |
| **Results** | The literature review showed that there is a gap in the literature related to resource perspective on excavated soil and rock in urban areas. The study identified 8 potential significant mass flows in urban regions related to excavated soil and rock, but the scientific literature deals only with few of these.<br>The paper suggests that the reuse of soil and rock masses can reduce costs and climate impact as the transportation, landfilling and use of quarry materials are reduced and this can be up to 14 kg $CO_2$ per ton. For a single construction project, reusing soil and rock masses can reduce material handling costs with 85 %. |
| **Source** | **Säynäjoki, E. et. al. 2014. Työkaluja vähähiiliseen aluerakentamiseen. MALTTI – matalahiilisen aluekehityksen tukityökalu. Aalto-yliopiston julkaisusarja. Tiede + Teknologia 7/2014. Unigrafia Oy. Helsinki.** |
| **Description** | MALTTI – a support tool for low carbon construction developed in Aalto University in a research project LOCO – Työkaluja vähähiiliseen aluerakentamiseen in 2011-2013 (in English: Tools for low carbon regional building). |
| **Purpose** | MALTTI tool is developed to support low carbon city development in addition to existing tools. It is not intended to use for support town planning nor for exact emission calculations in regional development projects. Instead, the tool brings new approaches when considering the temporal allocation of GHG of new areal construction and usage related to the life cycle of the area. |
| **Results** | Tools like MALTTI reminds designers that all new construction will cause greenhouse gas emissions regardless how efficient the new structures are. These tools can help when observing is it more relevant just to add redevelopment and new buildings and to gather people to growing centres or to maintain current buildings and infra structure. |

| | |
|---|---|
| **Source** | **Säynäjoki, A., Heinonen, J. and Junnila, S. 2012. A scenario analysis of the life cycle greenhouse gas emissions of a new residential area. Environ. Res. Lett. 7 034037.** |
| **Description** | Overall life cycle GHG emissions are assessed of a new residential area and the influence including the temporal allocation of the life cycle GHG emissions are evaluated. |
| **Purpose** | The study suggests the carbon payback time of constructing new residential area is several decades long even when using very energy efficient buildings compared to utilizing the current building stock. |
| **Results** | In the case of new energy efficient housing types, the construction phase accounts for most of the life cycle GHG emissions.<br>Carbon payback time of new construction is several decades long and building new residential areas to mitigate carbon strategies in short-term is not a suitable action. Instead, existing areas should be renovated.<br>But when new residential construction areas are initiated, passive houses should be favoured. |
| **Source** | **Wang, Q., Wu, S. Zeng, Y. and Wu, B. 2016. Exploring the relationship between urbanization, energy consumption, and $CO_2$ emissions in different provinces of China. Renewable and Sustainable Energy Reviews 54 (2016) 1563-1579.** |
| **Description** | The paper empirically investigates the impact of urbanization on energy consumption and $CO_2$ emissions with consideration of provincial differences. |
| **Purpose** | The purpose of the study is to provide an understanding of how the impact of urbanization can differ in terms of energy consumption and $CO_2$ emissions across regions and highlights the establishment of a good foundation for discussion on urban planning, energy consumption and $CO_2$ emission policy. |
| **Results** | The impacts of urbanization differ depending on the region. Cities at a post-industrial stage, such as Beijing and Shanghai, confront a large effect from urbanization due to higher energy consumption in private residential and public service sectors. In eastern China the industrial structures are lighter and rapid urbanization has led to a smaller urbanization impact on energy consumption and $CO_2$ emissions than in western and central parts of the country. |
| **Source** | **Schwietzke, S., Griffin, W.M. and Matthews, H.S. 2011. Relevance of Emissions Timing in Biofuel Greenhouse Gases and Climate Impacts. Environmental Science & Technology. 45, 8197-82013.** |
| **Description** | The study develops the methods to quantify the emissions timing effect in three different ways. |
| **Purpose** | The purpose of the study is to understand if and how the LCA of biofuels can accurately account for the fact that land use change emissions occur early in its life cycle. |
| **Results** | Emissions released early in life cycle cause greater cumulative radiative forcing over the next decades than later emissions. |
| **Source** | **Magnusson, S., Johansson, M., Frosth, S. and Lundberg, K. 2019. Coordinating soil and rock material in urban construction – Scenario analysis of material flows and greenhouse gas emissions. Journal of Cleaner Production 241 (2019).** |
| **Description** | The study described in the article presents a model analysing soil and rock flows in the future in terms of material quality and quantities in urban area. It also analyses the possibility of recycling of excavated soil and rock. |
| **Purpose** | The purpose of the study is to present the mass coordination model Optimass in regional building development project in Södertörn region in Stockholm and to analyse regional self-sufficiency in soil and rock material, and in addition, to analyse changes in material efficiency, transportation demand and corresponding GHG emissions. |
| **Results** | The study showed that excavated materials were enough to cover the quarry materials which would be needed for providing stability and permeability to buildings, streets and highway. The studied scenario analysis also showed that provision of strategically located recycling sites for material coordination could reduce the demand for soil and rock transportation by 23-36 % per studied area, compared to a business as usual scenario. |

In addition to the studies mentioned in the table above, utilisation of the alternative materials and mass balance issues has been surveyed in Finnish national

UUMA programs that has stakeholders from cities, industry, private sector and ministries. UUMA program started in 2006 and currently UUMA3 program is running in 2018-2020. The objective of the UUMA3 program is to implement alternative construction into action in cities and in Finnish Transport Infrastructure Agency (former Finnish Transport Agency) construction projects (UUMA3-ohjelma, 2018).

In a UUMA3 workshop, which was held in 18.9.2019, and in which the author also participated, it was discussed that national, common rules for calculating infra related emission and life cycle calculations should be developed. This thesis and its results will contribute also to the UUMA3 programs objectives.

# 4 BACKGROUND

In the following chapter theory of climate change, resource efficiency and preconstruction methods are briefly studied.

## 4.1 Climate change

As the Intergovernmental Panel on Climate Change (IPCC) has stated in its latest report on 2018, the global warming should be limited to 1.5 ºC compared to previously discussed 2 ºC as it would ensure more sustainable society. The limitation with 0,5 ºC is important as the consequences of 1 ºC warming can be already seen through for example extreme weather conditions, diminishing sea ice in the Arctic area and rising sea levels (IPCC Press release, 2018). Figure 6 shows the amount of $CO_2$ equivalent tons for different climate policies until year 2100. 1.5-2 ºC pathways need very consistent and persevering actions globally.

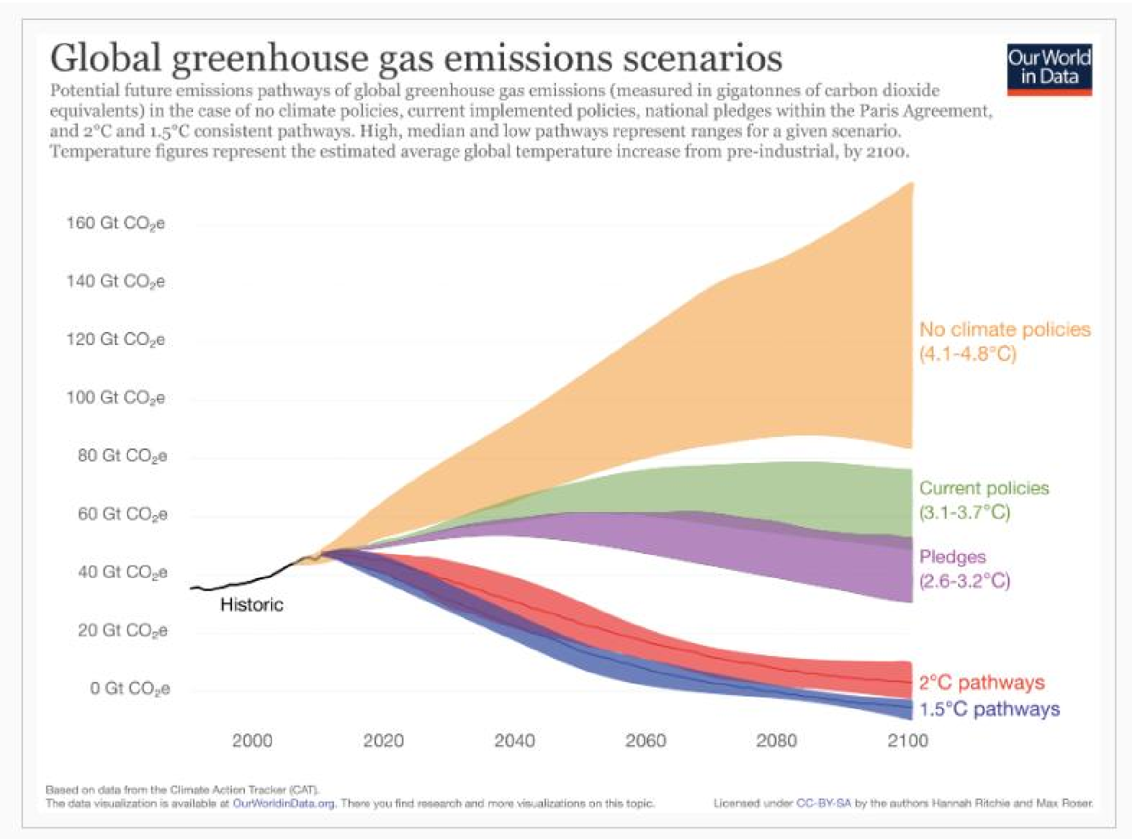


Figure 6. Global greenhouse gas scenarios (Ritchie & Roser, 2017).

According to the IPCC, one pathway to limit the global warming to 1.5 ºC depends on the emissions of greenhouse gases during the next decades. Lower greenhouse gas emissions in 2030 will lead to a better chance of keeping peak warming to 1.5 ºC (Rogeli et. al. 2018, 95).

As already pointed out in chapter 3 and above, the emissions need to be cut now in near future, as $CO_2$ accumulates in the atmosphere and has a certain residence time there. This means the time required for emitted $CO_2$ to be removed from the atmosphere through natural in Earth’s carbon cycle (Ritchie & Roser, 2017). $CO_2$ residence time according to the IPCC varies from 5 to 200 year, depending on the different removal processes (Working Group I: The Scientific Basis. n.d.).

### 4.2 Resource efficiency

Resource efficiency and low carbon are connected to each other in many ways. Resource efficient operations mean that the output is produced with lower emission inputs. When society has set to reach certain climate targets by certain timeframe, the targets will be achieved by effective means and resource efficiency is one of these means (Lehtovuori et al., 2017, 38).

When reaching towards the low carbon society, greenhouse gas emission reductions are needed in all sectors where reductions can be made. The reduction possibilities and related costs are different in different sectors. As most of the current anthropogenic $CO_2$ emissions are related to the energy in one way or another, whether it is the energy industry, other energy consuming industry or transportation or building related energy, all energy issues are in important role to progress low carbon society (Lehtovuori et al., 2017, 38). Three ways to promote low carbon energy use are recognized: 1) to avoid extra consumption, 2) transition of the consumption towards alternatives with lower carbon intensity ($CO_2$ emissions per energy unit) and 3) changes that develop operations or its efficiency (Lehtovuori et al., 2017, 42). In the holistic resource efficient model there should be a general goal to decrease the depletion of natural resources or at least to cut the related depletion growth. The consumption should be focused on a more sustainable way so that the objective would be more often lower in the carbon intensity or would comply the circular economy rules. The output, which is received from the use of resources, should be improved by its resource effectiveness (Lehtovuori et. al., 2017, 47).

Most of the rock aggregate use costs and the environmental impacts are generated in the transportations. The transportation costs are biggest single factor impacting on the aggregate price. Rock aggregate transportations are heavy load transportation, causing noise and airborne emissions, and other harms. If the transportation distances are very long, aggregates cannot be used resource efficiently and the problems are concentrated specially to the growing urban regions (Huhtinen et. al., 2018, 14).

Resource efficiency in the infra construction is not related only in the efficient use of the natural aggregates, but also to the efficient use of the other materials that can be used in the infra structures. These materials are for example fly ashes, waste incineration slag, crushed concrete, slags from metal industry, fibre clay, foamed glass, etc. materials that are usually a by-product from some other process or a new processed material from by-product raw material.

### 4.3 Preconstruction methods

Preconstruction means creating the possibilities to construct on an area that has been unconstructed before due to the poor-quality soil conditions (Nauska and Havukainen, 1998, 2). Preconstruction can also take place when for example an industrial or port area is converted into residential building use, and the requirements for the new purpose are different than in the previous use.

Preconstruction also means improving the quality of soft soils by the means of earth construction methods before the actual construction takes place. To save the costs and emissions, preconstruction should be started as early as possible (Nauska and Havukainen, 1998, 2). Time needed for preloading needs to be taken into account in the construction project schedule. Depending on the ground soil, preloading time is usually 3-12 months, but sometimes the needed time can take even three years. Preloading time depends on the thickness of the settling soil layer and the grain size distribution: the finer the soil is, the slower the pore water can be discharged and the slower the settling takes place (Frimodig, 2014, 34).

In this thesis, preconstruction is considered as part of the regional development and it increases the value of the ground. Preconstruction is not always needed if the ground circumstances are already geotechnically good enough for the needed construction activities.

Most of the regional development projects aggregates are used and produced in the preconstruction operations, when the land is converted applicable for construction. Resource efficient preconstruction has been experienced difficult due to variety of designing and permitting procedures and because legislation [in Finland] does not recognize these processes sufficiently integrated as part of the design phase. The current Land Use and Construction Act (5.2.1999/132) does not require any design of the aggregate use, recycling and storage in the planning stage. The lack of design can lead to impractical use of aggregates, which also impacts on the costs of aggregate transportations and constructing. Virgin rock materials may be used in the regional development although the materials generating in the preconstruction could be utilized if the processing (like storage, crushing and sorting) would be possible at the construction site or its vicinity (Huhtinen et. al. 2018, 9). Land Use and Construction Act is under reform and among other renewals, the planning is expected to be more agile and life cycle issues for construction activities are expected to be considered in the new Act, to be come into effect by the end of 2021.

There are several different preconstruction methods. The available construction time, ground circumstances, the intended use and the loading of the area and construction costs impact on the method to be chosen. Different methods and their requirements are presented in Table 2.

Table 2. Different preconstruction methods (Nauska and Havukainen, 1998, 5).

| **Preconstruction method** | **Impacts/purpose** | **Pohjasuhteet** | **Construction time** | **Environmental considerations** |
|---|---|---|---|---|
| Counter embankment | Improves stability | Clay, silt | Very short | Requires space<br>Grows settelements<br>Is not suitable for city environment |
| Preloading:<br>Loading berm<br>Vertical drainage | Decreases settlements | Loading berm: Clay, silt<br>Shallow soft soil (< 6 m)<br>Vertical drainage:<br>Clay, silt (gyttja) | Long<br>Loading berm: 6…36 months<br>Vertical drainage: 6…24 months | Not very suitable for city environment<br>Vertical drainage is not suitable in the areas where deep-well water is present |
| Lightweight structure | Improves stability<br>Decreases settlements | Clay, silt, gyttja (peat) | Very short | Suitable for city environment<br>When using alternative materials, environmental authority approval is needed |
| Mass exchange<br>by excavating<br>by embankment | Improves stability<br>Almost non-settlement structure | Clay, silt, gyttja, peat<br>Excavation: depth max 6…7 m<br>Embankment: depth mas 12…15 m | Short | Not very suitable for city environment<br>Ground movement around the construction site |
| Deep stabilization/deep mixing<br>Column stabilisation<br>Mass stabilisation | Improves stability<br>Almost non-settlement structure | Clay, silt, gyttja, peat<br>Column stabilization: depth max 15…20 (25 m)<br>Mass stabilization: depth max 6 m | Medium-term 2…6 months | Well suitable for constructed environment |
| Piling | Improves stability<br>Non-settlement structure | Clay, silt, gyttja, peat | Short | Causes some vibration and noise to the environment.<br>Suitable for city environment. |
| Geo-reinforcements | Improves stability | Clay, silt, gyttja, peat | Very short | Makes excavation difficult<br>Settlements can be big |
| Deep compaction | Improves stability<br>Decreases settlements | Silt, sand, gravel, crushed stone | Relatively short | Causes significant vibration to the environment<br>Not applicable to city environment |

## 5 CITY STRATEGIES AND CLIMATE TARGETS

City of Helsinki has been a pioneer in Finland as to mass flow coordination of surplus soils when a development program for utilisation of excavated masses was created already in 2013. Helsinki was forced to take more efficient actions to control the transportation related costs when the city of Vantaa closed their earth landfill area for the surplus soils from city of Helsinki in 2011. City of Vantaa was afraid that their landfill capacity would fill up, and forbid Helsinki to deposit soils to Vantaa landfills. After closing of the landfill there were no clear spot to be pointed for surplus soils which were generated at Helsinki construction sites. Especially the geotechnically poor soils such as clay and silt were forced to be transported long distances to several remote and low capacity landfill and the amount of transported masses quadrupled between 2010-2013 (Helsingin kaivumaiden hyödyntämisen kehittämisohjelma, 2013, 1).

In the Carbon Neutral Helsinki 2035 – action program it has also been recognised that the emissions from work sites can have a significant part of the construction and transport related emission. Foundation circumstances have impact on the infra project carbon footprint during the construction stage. Deep stabilisation, moving soil masses, piling and other earth construction methods increase construction emissions. For example, in the infra construction, foundation engineering activities can cause up to 80 % of the emissions of the whole project. Different earth construction and improvement methods, like loading perm, mass and column stabilisation and mass exchange cover most of the construction project emissions and different methods have emission impacts of a different size (Hiilineutraali Helsinki 2035-toimenpideohjelma, 2018, 63).

In other cities climate strategies preconstruction optimization was not seen as a way to reduce the emission impacts. Resource efficiency and mass coordination was yet considered also in other cities' strategies. In Table 3 'climate and resource efficiency strategies of cities are mapped, and, in the table, it is commented if preconstruction is considered in the strategies.

Table 3. Strategies of cities related to climate change and resource efficiency.

| City | Climate strategy / Climate program | Mass coordination / Resource efficiency program | Other |
|---|---|---|---|
| **Helsinki** | HNH2035-action program (Carbon Neutral Helsinki 2035):<br>Program takes into account, that preconstruction activities can impact on the construction project emissions | Development program for excavated soils in Helsinki:<br>Program takes into account environmental and financial benefits that mass coordination can bring | |
| **Espoo** | Espoo climate strategy 2016-2020:<br>Preconstruction is not considered. Emission savings in construction field concentrates mainly on energy efficient construction and densing the land use. | Action plan for soil and rock aggregate coordination and constructing with alternative materials 2018-2021 | |
| **Vantaa** | Carbon neutral Vantaa 2030-study: Preconstruction is not considered | Roadmap for resource efficiency: Surplus soils and alternative materials are considered in regional development projects<br><br>Action program for soil and rock materials, on preparation stage when writing this thesis | Vantaa environmental policy 2012-2020 (no preconstruction activities mentioned) |
| **Tampere** | Climate strategy 2030 for Tampere urban district:<br>Preconstruction is not considered | Katariina Rauhala: Circular economy in construction (ppt): Comprehensive strategy for mass coordination and utilisation of alternative materials<br>Position for city mass coordinator has been published for recruitment in autumn 2019 | |
| **Turku** | Sustainable climate and energy action plan 2029:<br>Preconstruction is not considered | Smart and Wise project, resource efficiency considered | |
| **Stockholm** | Stockholm action plan for climate and energy 2010-2020 | | Strategy for a fossil-fuel free Stockholm by 2040 (focus in renewable energy modes) |

The report Kiviaineshuoltoraportti 2018 by Huhtinen et. al. describes the current situation in Finland how far aggregate materials need to be transported to the construction sites and where the surplus soil landfills are located. Distances in Stockholm are provided in the article “Coordinating soil and rock material in urban construction – Scenario analysis of material flows and greenhouse gas emissions” by Magnusson et. al. Table 4 shows the distances how far esker and rock materials need to be transported to different city regions.

Table 4. Transportation distances of esker and rock materials to city centres (Huhtinen, et. al., 2018, 15, Magnusson, et. al., 2019, 7).

| **Area** | **Esker material** | **Rock material** |
|---|---|---|
| Metropolitan area of Helsinki (distance to Pasila) | 60-100 km | 15-25 km |
| Tampere region (distance to Tampere station) | 20-30 km | 15-20 km |
| Turku area (distance to Turku station) | approx. 25 km | 8-10 km |
| Oulu region (distance to Oulu station) | 15-18 km | 10-15 km |
| Stockholm | 20 km | 15 km |

Earth landfills are usually located outside of city structure, yet as near the city centre as possible. What it comes to Helsinki metropolitan area, it is not allowed to bring surplus soils excavated in Helsinki, to Espoo and Vantaa cities' earth landfills (Huhtinen, et. al., 2018, 15). In Table 5 the estimates of the distances for soil landfills to the city centres are presented.

Table 5. Earth landfill distances to city centres (Huhtinen, et. al. 2018, 15. Magnusson, et. al., 2019, 7).

| **Area** | **Soil landfill** |
|---|---|
| Metropolitan area of Helsinki (distance to Pasila) | 18-25 km |
| Tampere region (distance to Tampere station) | 14-19 km |
| Turku area (distance to Turku station) | 8 km |
| Oulu region (distance to Oulu station) | 10 km |
| Stockholm (distance to recycling sites) | 0,7-4,7 km |

As the tables above indicates, the transportation distances are long, time-consuming, causing high transportation costs and transportation related emissions to the atmosphere. Transporting materials that long distances as the tables show, is not sustainable and needs to be changed in order to tackle the increasing amount of $CO_2$ emissions in the atmosphere.

In the report "Koldioxidbudget 2020-2040 Stockholms län" the Stockholm province's current $CO_2$ sources has been mapped. According to the report, the four biggest energy related sources are international transportations (4,6 Mt $CO_2$-ekv), national transportations (2,4 Mt $CO_2$), electricity and district heating (0,99 Mt $CO_2$)

and working machines (0,30 Mt $CO_2$). Together these sources are 95 % of the carbon budget that the writers recommend for all Stockholm province (Anderson et al., 2018, 3).

After the above-mentioned report, a second report “A guide for a fair implementation of the Paris agreement within Swedish municipalities and regional governments” suggests e.g. renewable energy sources, investments in carbon dioxide storage of emission in cement and steel production and extensive expansion and investment in public transportation as means to achieve the climate targets (Anderson, Schrage et. al., 2018, 41).

# 6 CASE STUDIES AND CALCULATIONS

In this chapter the results from the different $CO_2$ emission calculations are presented. All the cases are real studies made by Ramboll. Case Karhunkaataja in Helsinki is a $CO_2$ calculation for the future city district. In case Skanssi in Turku, a $CO_2$ calculation was made for three different streets in the area to be constructed. In Tampere, three street cases that were already constructed earlier, were calculated for their $CO_2$ savings potential just to demonstrate to the city policymakers that there are possibilities to save in $CO_2$ emissions and in costs. As an exception, Perhekatu in Turku, was only studied for transportation related savings potential if the masses could be processed nearby locations.

## 6.1 Case Karhunkaataja, Helsinki

Karhunkaataja is part of Myllypuro district in Helsinki, where a new residential area will be built for over 11 000 citizens (see Figure 7 and Figure 8). Also, a new campus of Metropolia University of Applied Sciences is bringing 6 000 students to Myllypuro area. More specifically, Karhunkaataja area will be a district of 3 600 citizens and it is estimated that the construction of the area starts on 2020. Currently the process of alteration of plan is ongoing (Rakentamista 2019-2020, n.d.).


Figure 7. Karhunkaataja area locates in the eastern side of Helsinki (Google Maps).

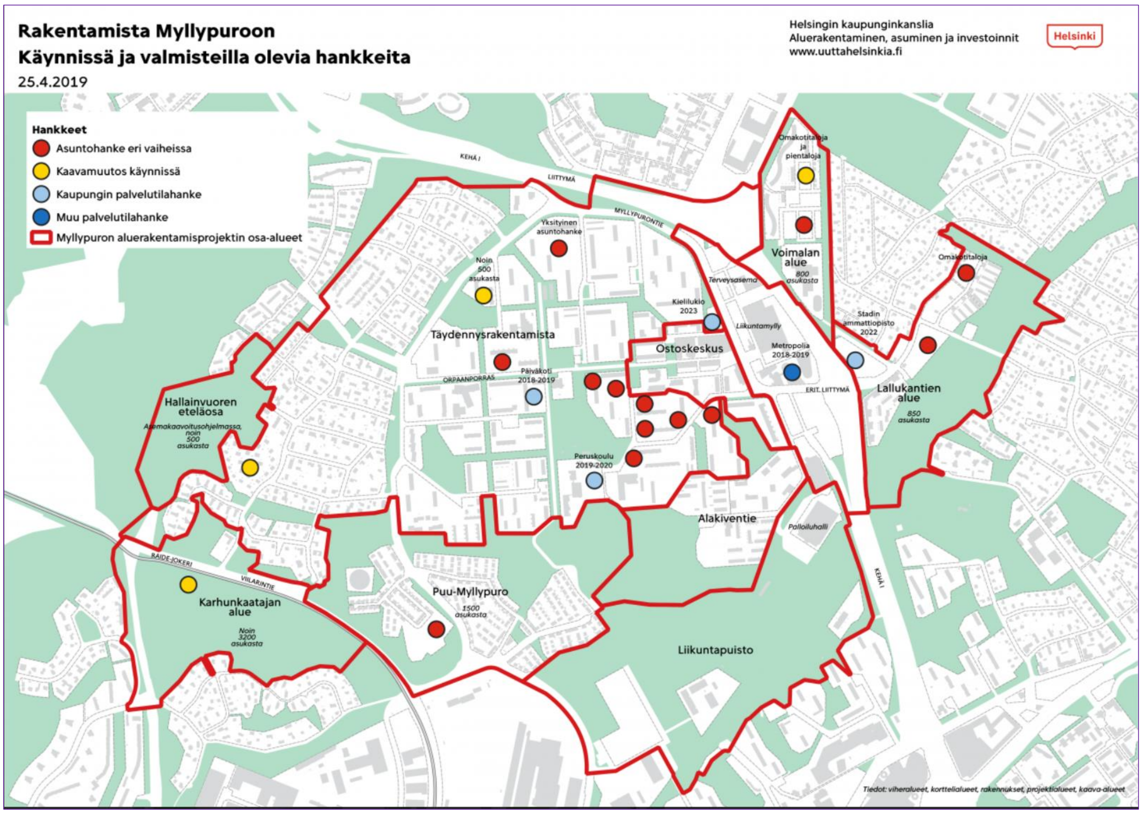


Figure 8. Karhunkaataja area (left bottom corner) in Myllypuro district in Helsinki (Kartat, 2019).

The soil characteristics in Karhunkaataja area is presented in the geotechnical cross-section of Figure 9, where the red area is rock, green is sand/moraine and blue is clay/silt/sand. Lilac shows the filling height, from 0 m to 3 m. The rock will be blasted all the way to grade line in the street areas and it will be removed to the level of -2,5 m from the grade line. In city block areas, the blasting will be done to the level of -1 m from the grade line. In other areas (green and blue), preloading is needed to settle softer areas.

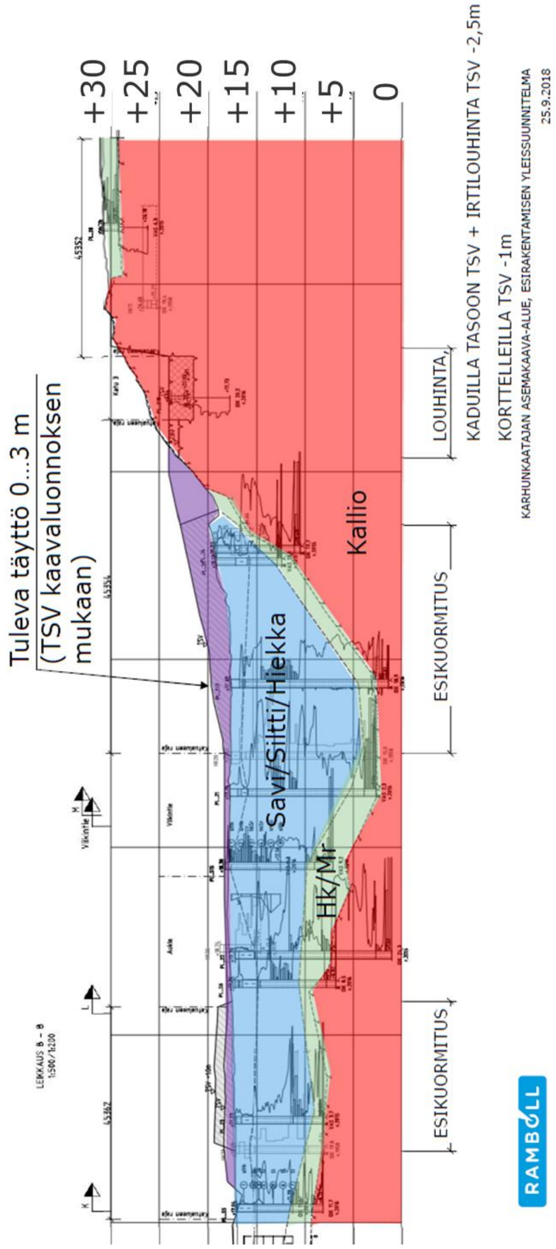


Figure 9. Geotechnical cross-section of Karhunkaataja area (Karhunkaataja, n.d.).

| | |
|---|---|
| Esikuormitus = preloading<br>Louhinta = Blasting of rock | Hk/Mr = Sand/Moraine<br>Savi/Siltti/Hiekka = Clay/Silt/Sand<br>Kallio = Rock |

It was recognized on a very early stage that the regional development and the preload embankment are significant factors for the areal mass balance, $CO_2$ emissions and construction resource efficiency. For the $CO_2$ calculation, three scenarios – technically comparative to each other - were created (see Table 6). Alternatives 2 and 3 also included internal variation between distances and materials. The calculation results are presented in Figure 10.

Table 6. Calculation alternatives for Karhunkaataja case.

| Alternative | Preconstruction method | Other information |
|---|---|---|
| ALT1 | Blasted stones from Viilarintie would be used for the project purposes in preload embankments. | Crushing station in the area is needed. |
| ALT2a | Blasted stones from Viilarintie cannot be utilized in preload embankments and instead material for the embankments are needed 20 000 $m^3$rtr outside the project. | Crushed stone is brought from elsewhere, transportation distance 25 km. |
| ALT2b | | Crushed concrete is transported from 10 km distance. |
| ALT3 | Preloading is compared to some "faster" preconstruction method | |
| ALT3a | Mass stabilisation | Binder material cement, 60 kg/$m^3$, transportation distance 220 km |
| ALT3b | Mass exchange (no loading berm), filling with crushed aggregate or blasted stone. | Excavated soils are transported elsewhere, transportation distance 40 km. |
| ALT3c_1 | Lightweight structure with lightweight aggregate | Transportation distance of lightweight aggregate 126 km |
| ALT3c_2 | Lightweight structure with foamed glass | Transportation distance of foamed glass 126 km |

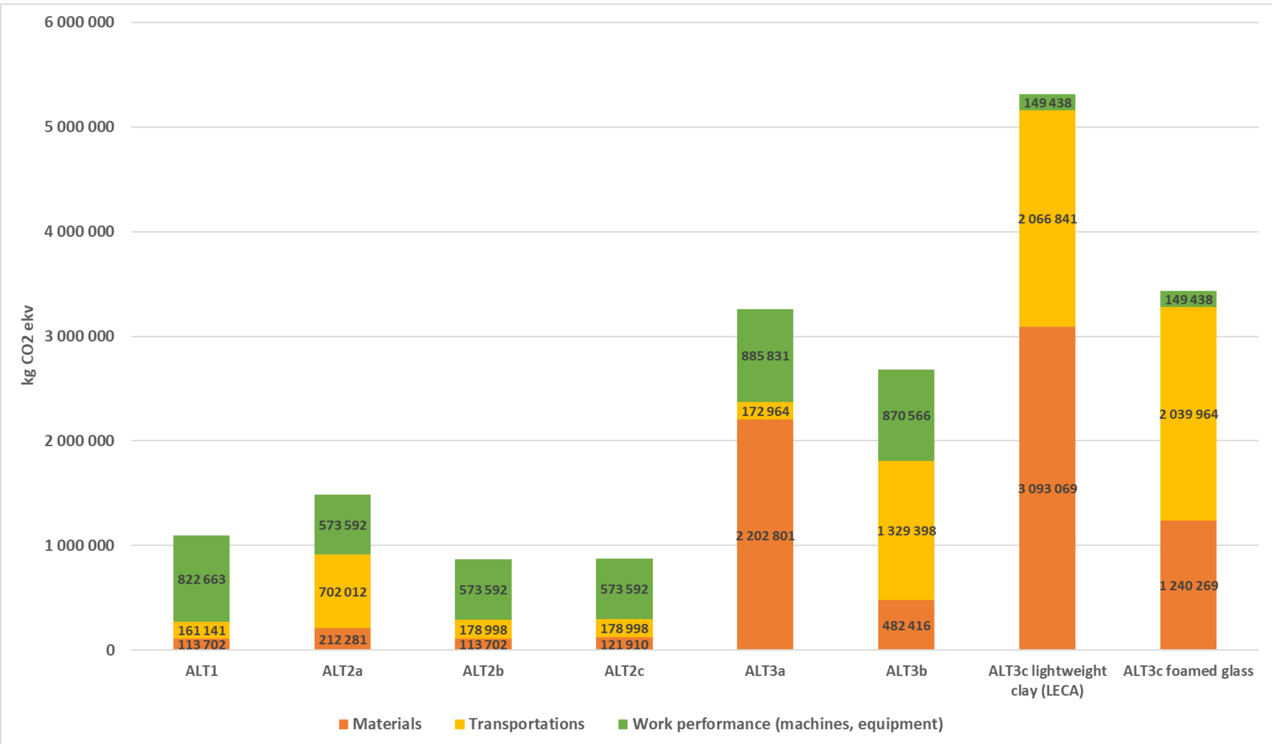


Figure 10. $CO_2$ calculation results for Karhunkaataja area (Karhunkaataja, n.d.).

According to the results, alternative 2b causes less $CO_2$ emissions. In this alternative crushed concrete will be brought from 10 km distance to be used in preload embankments. In alternatives ALT1, ALT2b, ALT2c and ALT3a, the magnitude of transportation related emissions is approximately the same. In these alternatives the main variation comes from work performances and material related emissions. The biggest material emissions are in both ALT3c options and in ALT3a. The biggest transportation related emissions are in ALT3c options, where the lightweight materials have to be transported from 126 kms distance. Alternative 1-2b are preloading alternatives, and it can be clearly seen that if there is time to wait for the preloading impact (1-3 years), it can be significantly lower alternative what it comes to $CO_2$ emissions and most probably to costs, too.

When optimizing the project $CO_2$ emissions, it is important to know, which stages can be optimized, and by which means.

### 6.2 Case Skanssi, Turku

This case is about emission reduction potential in the new residential area Skanssi in Turku, Finland. Skanssi is a piloting district for innovative development and the positive results will be used also in other areas in Turku. This study is part of a bigger objective to decrease the emissions in the built environment in Turku (Dettenborn et al, 2018, 1). In this case, also cover structures were calculated, but in the results the share of preconstruction is described, too. The location of Skanssi district is presented in Figure 11.


Figure 11. Skanssi locates approximately 4 kms from centre of Turku (Google Maps).

Skanssi area is mainly old, uncultivated field meadow. The ground surface descends towards the centrum, thus forming a watery "basin" in the middle of the area. Ground level is approximately on level +18…+26. Esker area in the west line ascends approximately to level +33. Rock hill in the west line is approximately on level +44 at its highest. Skanssi area is mainly clay. Clay in the middle is silty (organic content over 2 %) and there are no dry crust areas. According to the determined grain size analyses, there is also thin and fat clay in the area. Clay depth can be 20 meters in the area. Water contents in disturbed samples were between 60-90 %. Under clay is layered and loose non-cohesive soil before compact and rocky moraine. The soil in the area is frost-susceptible and the groundwater is between level +17…+20 (SM Maanpää Oy, 2013, 2).

In this case the construction of three streets were studied, Skanssinkatu, Vallikatu and Perhekatu. The most cost-effective ways to reduce the emissions in the project, were identified in this study. Emission reduction possibilities were identified by defining less emission intensive solutions for the designed structures and focusing on alternative structures which can be impacted in the design stage (Dettenborn et al, 2018, 1).

### 6.2.1 Skanssinkatu

Skanssinkatu is approximately 300 m long (~2400 paved $m^2$) street (Figure 12). When starting the calculations, construction design level background information was available and the emission calculation was based on the bill of quantities (Dettenborn et al., 2018, 6).

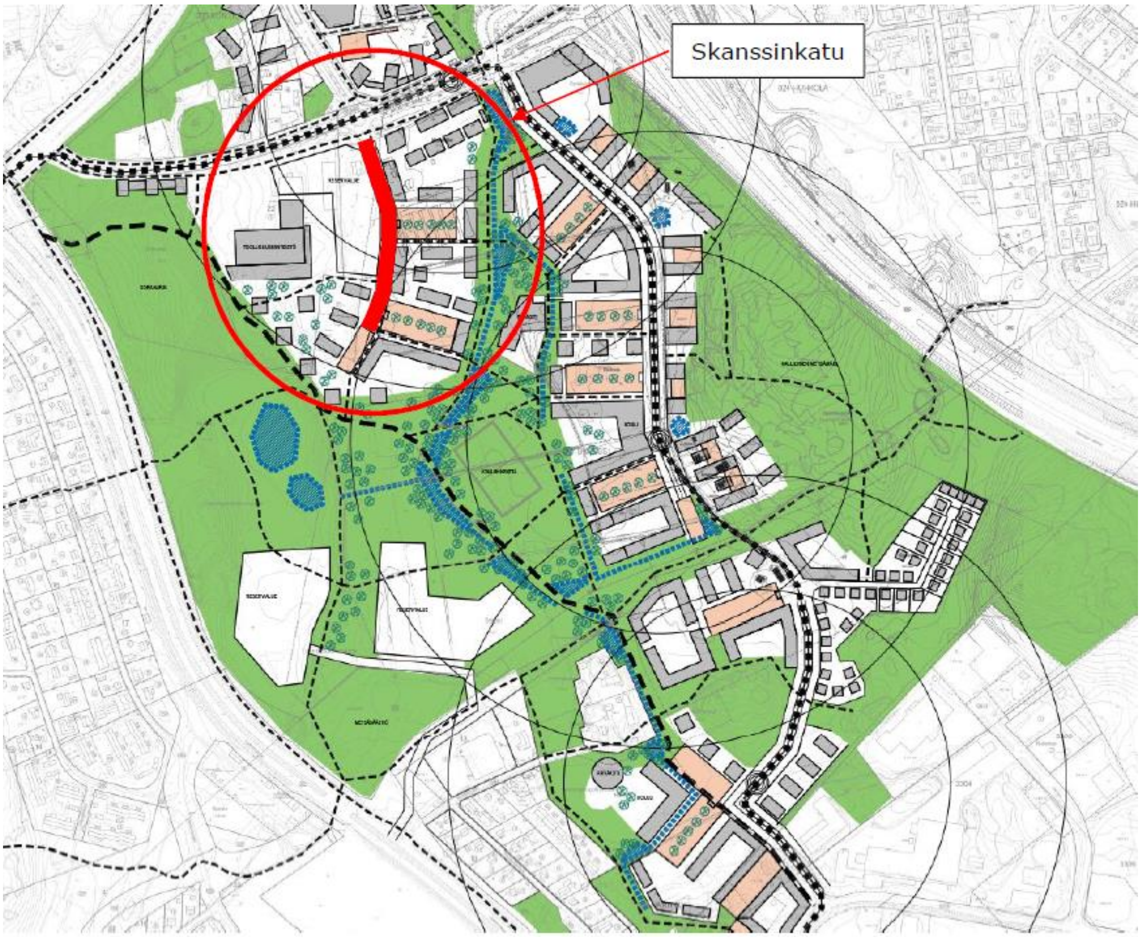


Figure 12. Location of Skanssinkatu in the area (Dettenborn et al., 2018, 6).

According to the calculations, over 80 % of the emissions in Skanssinkatu is generated from the material transportations (Figure 13). Manufacturing of foamed glass is emission intensive process and it is responsible of approximately 70 % of the emissions in Skanssinkatu (Figure 14). In costs, this means 37 % of total costs (Dettenborn et al., 2018, 10).

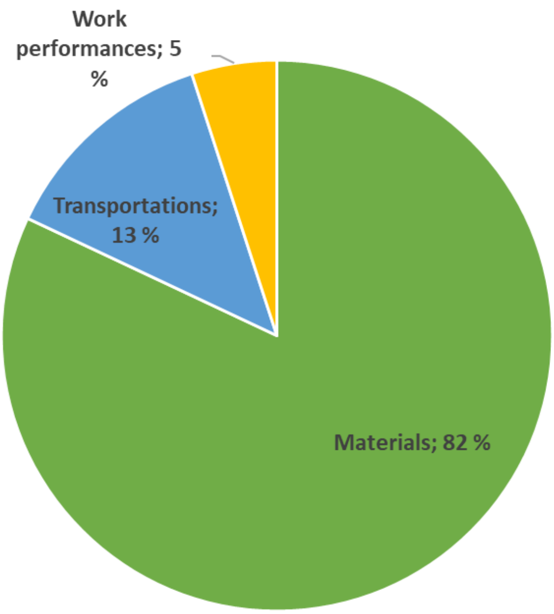


Figure 13. Emission origins and their shares in Skanssinkatu case (Dettenborn et al., 2018, 10).

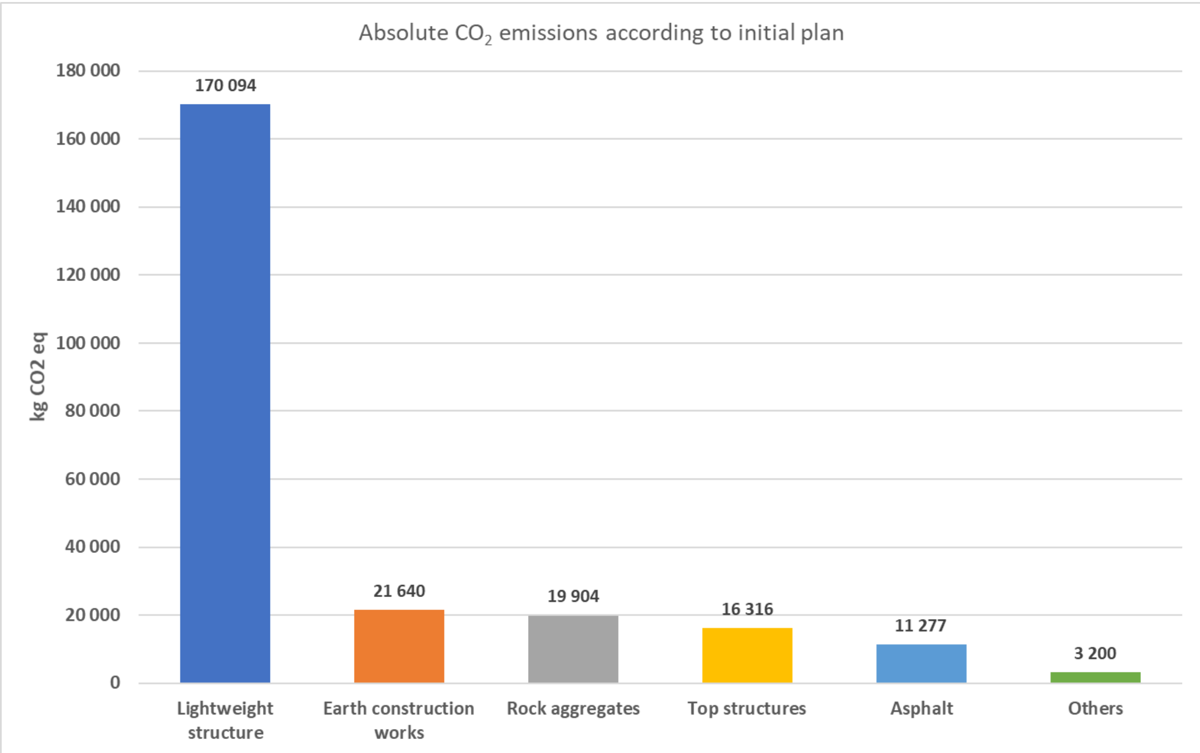


Figure 14. Absolute $CO_2$ emissions in Skanssinkatu according to the initial plan (Dettenborn et. al., 2018, 11).

Where possible, alternative solutions were analysed, and the focus was especially on the materials and work techniques. Following results were achieved (see Figure 15) (Dettenborn et al., 2018, 11-12):

1) Decrease of $CO_2$ eq with 50 %, when rock aggregates in sub-base were replaced with crushed concrete. In addition, crushed concrete is estimated to be approximately 20 % cheaper than rock aggregates.
2) Decrease of $CO_2$ eq with ~80 %, when the masses formed in the area, were utilised in the area. This also cut the mass processing costs with 50 %.
3) Decrease of $CO_2$ eq with 10 % when warm-mix asphalt was used.

Emission reduction activities can be targeted to the most emission intensive parts in Skanssinkatu case. As an exception, the strucure needs lightweight solution and thus emission reductions cannot be made for foamed glass material. With these operations, 10 % reductions in total $CO_2$ emissions can be made for Skanssinkatu. In costs, this means 40 000 euros cost reductions (Dettenborn et al., 2018, 12).

Calculation sheets are presented in appendix 3. The share of total emissions of preconstruction activities in Skanssinkatu alternatives is approximately 90 %.

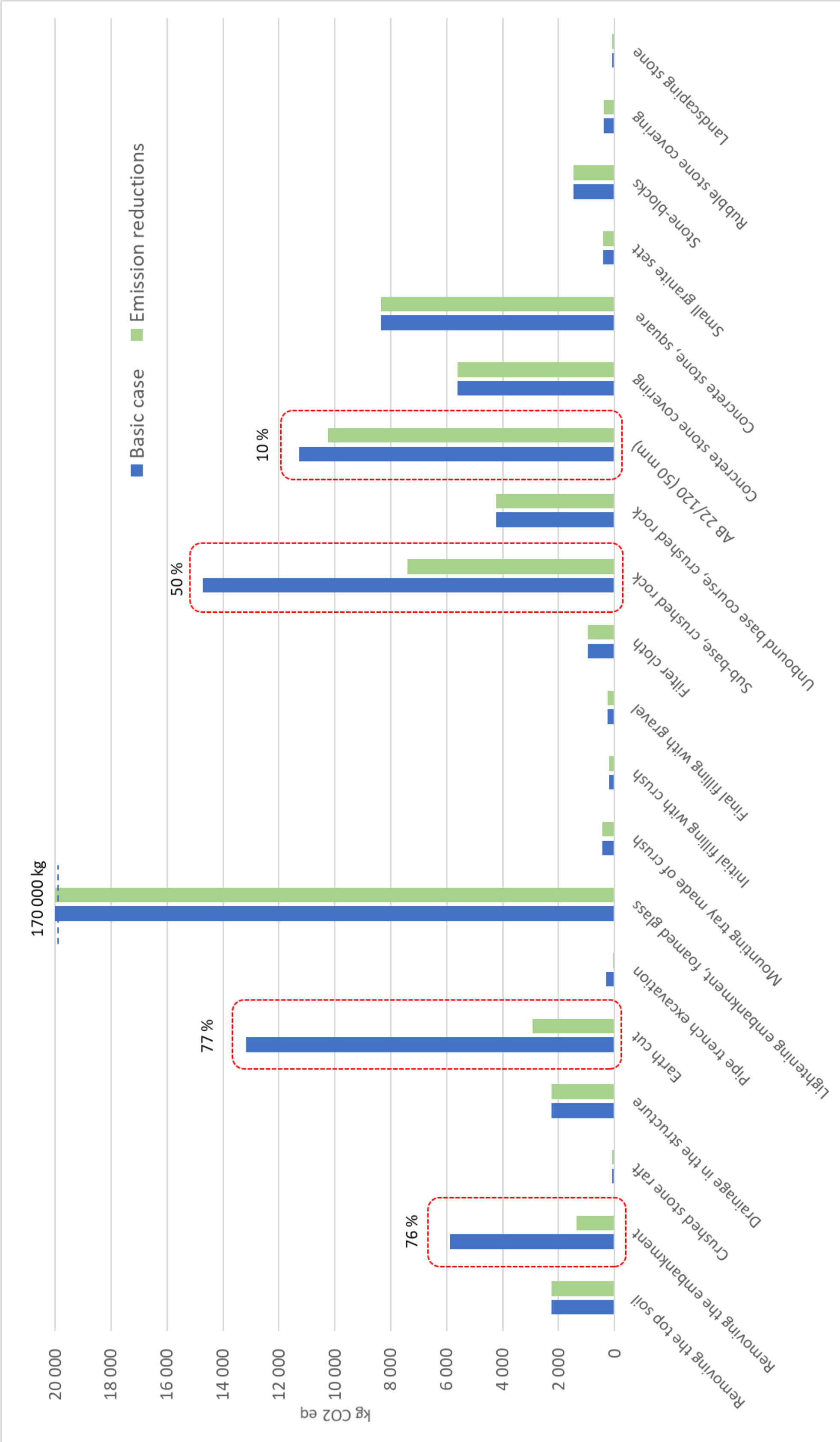


Figure 15. Emission reductions per structural component. Light blue is for the initial situation, green is for emission reductions (Dettenborn et al., 2018, 12).

### 6.2.2 Vallikatu

Vallikatu locates in eastern part of Skanssi area, presented in Figure 16. It is 1200 meters long and there will be 27 500 asphalted square meters (Dettenborn et al., 2018, 6).


Figure 16. Location of Vallikatu in the area (Dettenborn et al., 2018, 7).

Initial data for Vallikatu case was given as “meters/street type”. For $CO_2$ calculation purpose this number information were transformed to match the described structural components according to the general plan. To estimate the street width, the cross-section drawings were used. Alternatives for Vallikatu case $CO_2$ calculations are presented in Table 7 (Dettenborn et al. 2018, 6).

Table 7. Ground improvement alternatives in Vallikatu case (Dettenborn et al. 2018, 15).

| Alternative | Ground improvement method | Other information |
|---|---|---|
| ALT1 | Lightweight structure made with foamed glass | Thickness of lightweight layer = 1 meter |
| ALT1B | Using foamed glass and excavated soils utilised in landscaping/fillings | |
| ALT2 | Column stabilisation by standard binders | -binder lime-cement 1:1 120 kg/$m^3$<br>-column size d600 mm, thickness of clay = 10 meters |
| ALT2B | Column stabilisation | -binder lime-cement-fly ash 1:1:6 200 kg/$m^3$ |

According to the calculation results, depending on the ground improvement method and mass utilisation in the area, the difference in $CO_2$ emission can be even 2.6-fold. In Figure 17 the $CO_2$ emissions between different alternatives are presented, including also the pavement structures. (Dettenborn et al. 2018, 17) The share of preconstruction emissions varies between 81-93 % depending on the alternative. Calculation sheets are presented in appendix 3.

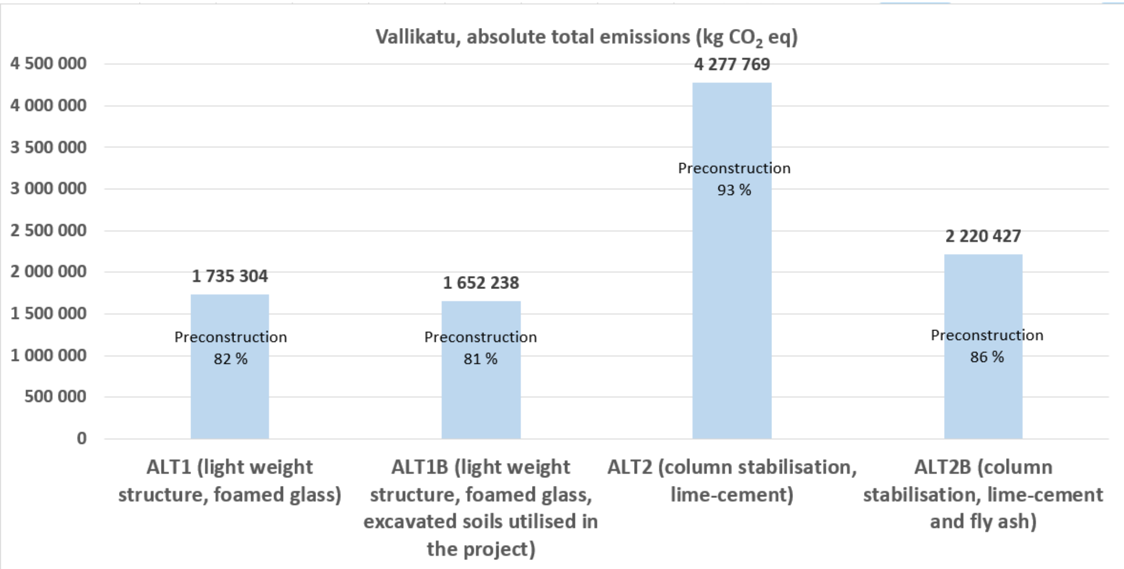


Figure 17. $CO_2$ calculation results for Vallikatu case (Dettenborn et al. 2018, 17).

In Vallikatu case, cost savings were not calculated. In stabilisation works, the binders make the significant part of the costs and especially in column stabilisation, the binder costs are approximately 50-70 % of the total costs. Commercial binders like cement or lime cost 100-12 eur/ton. When the commercial binders can be partly substituted with for example fly ash, the cost of the fly ash can be 0 eur/ton when the ash producing plant wants to get rid of it, instead of landfilling (in 2016 the landfill tax was 70 eur/ton). Column stabilisation and lightweight structure costs cannot be calculated without calculating all the dimensioning design. In general, the lightweight structure is cheaper in areas where the soft clay area is very deep, and the amount of column stabilisation would be big. Either way, the preconstruction method is chosen according to the technical requirements of the area (Dettenborn, et al. 2018, 18).

### 6.2.3 Perhekatu

In the area where the coming Perhekatu is located, are clayey fields. In a town plan there is also a wooded rock ridge. Thickness of the clay in the area is 2.5-8 meters. Calculation of Perhekatu included also 7 700 $m^2$ of street squares (Dettenborn et al. 2018, 8).

The emission calculation for Perhekatu was made according ROLA-quantities (part of Fore cost calculation program provided by Rapal Oy). The initial assumption was that the surplus soils are transported to nearby soil landfill to Hirvensalo, where the transportation distance is approximately three kilometres. Ground improvement method was column stabilisation and binder to be used GTC (mixture of lime, cement and gypsum). Gypsum was assumed to be a by-product, and in the calculation, it was allocated as other recycled materials, too (Dettenborn et al. 2018, 8, 18).

In total, the absolute $CO_2$ emissions for Perhekatu are 1 001 489 kg $CO_2$eq. Per square this is 130 kg $CO_2$ eq per one asphalted street square. Materials generated 91 % of all total emissions, work related emissions were 6 % and transportations 3 %. In Figure 18 the emissions according to structural composition are presented (Dettenborn et al. 2018, 19).

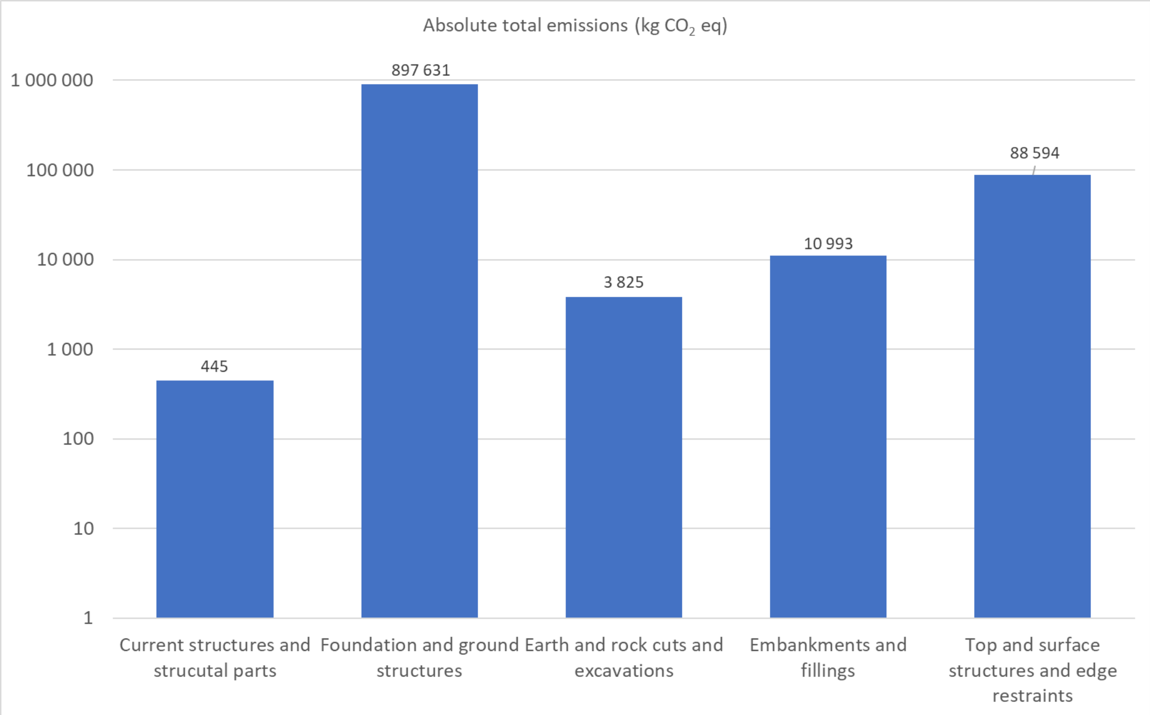


Figure 18. $CO_2$ emission distribution between materials, transportations and work performances in Perhekatu case (logarithmic scale) (Dettenborn et al. 2018, 19).

The biggest emissions are generated from ground improvement structures, and like with Skanssinkatu and Vallikatu cases, ground improvement method determines main part (91 %) of the Perhekatu construction related emissions. Other significant sources of emissions are surface and superstructure and embankment structures.

As an alternative study the emission calculation was made for the situation, where the surplus soils are not transported to landfilling area to Hirvensalo (3 km), but instead to 20 km distance to Piikkiö. In total to absolute emissions were 1 013 421 kg $CO_2$ eq. Compared to the 3 km transportation plan, the difference is 12 058 kg $CO_2$ eq. By optimising the surplus transportation distance, it is possible to achieve 30 % savings in transportation related emissions (Dettenborn et al. 2018, 20).

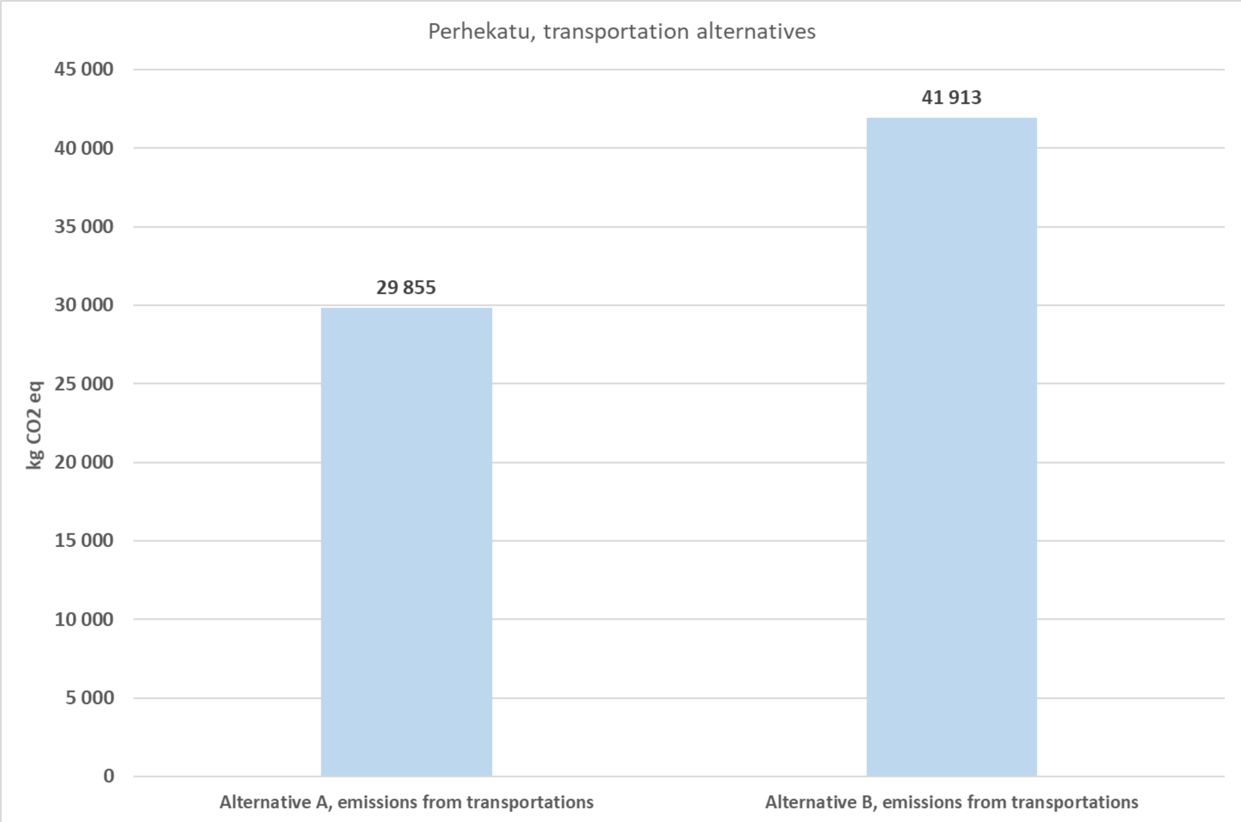


Figure 19. Emissions from transportations for alternative A (3 km) and alternative B (20 km) (Dettenborn et al. 2018, 21).

### 6.3 Case Tampere

Case Tampere is a calculation case where $CO_2$ emission reduction possibilities were calculated years afterwards of actual constructions. The subjects of this study were:

- Kauhakorvenkatu (street)
- Arvo Ylpön katu (street)
- Tesoma school
- Myrskynkatu (street) and Härmälänojanpuisto (park) in Härmälä city area

Figure 20 presents the locations of the cases. Calculations were made for the actual realized construction and for so called resource wise solution according to the method described in chapter 2 (Resurssiviisas infrarakentaminen, 2018, 3).

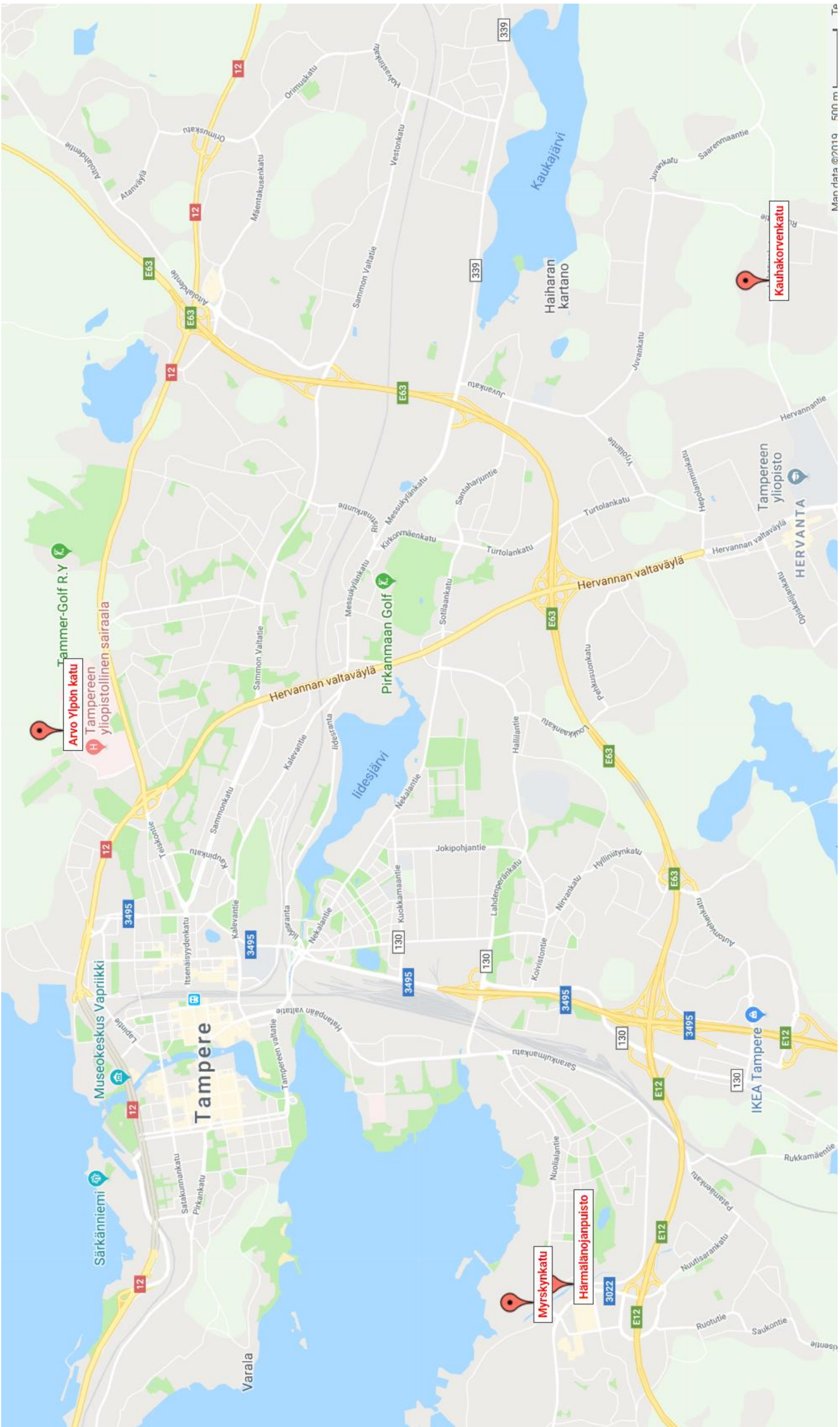


Figure 20. Tampere $CO_2$ calculation case locations in the city area (Google Maps).

### 6.3.1 Kauhakorvenkatu

This street was built in 2013-2014 and its length is 900 meters, of which asphalted pavement 10 500 $m^2$. In addition, 500 meters of water supply management was considered when making the calculations (Resurssiviisas infrarakentaminen, 2018, 5).

In actual construction in 2013-2014 part of the masses were brought to the construction site from 20 km distance from Kangasala and blasted rocks at the site were utilized inside the project. Preconstruction method was pile slab and also a permanent sheet pile wall (Resurssiviisas infrarakentaminen, 2018, 5).

The most significant emissions in the actual construction were (Figure 21) (Resurssiviisas infrarakentaminen, 2018, 11):

- steel piles and permanent sheet pile wall, 41 % of total $CO_2$ emissions
- unbound rock aggregates, 34 % of total $CO_2$ emissions
- asphalt pavements, 16 % of total $CO_2$ emissions
- earth construction works, 6 % of total $CO_2$ emissions

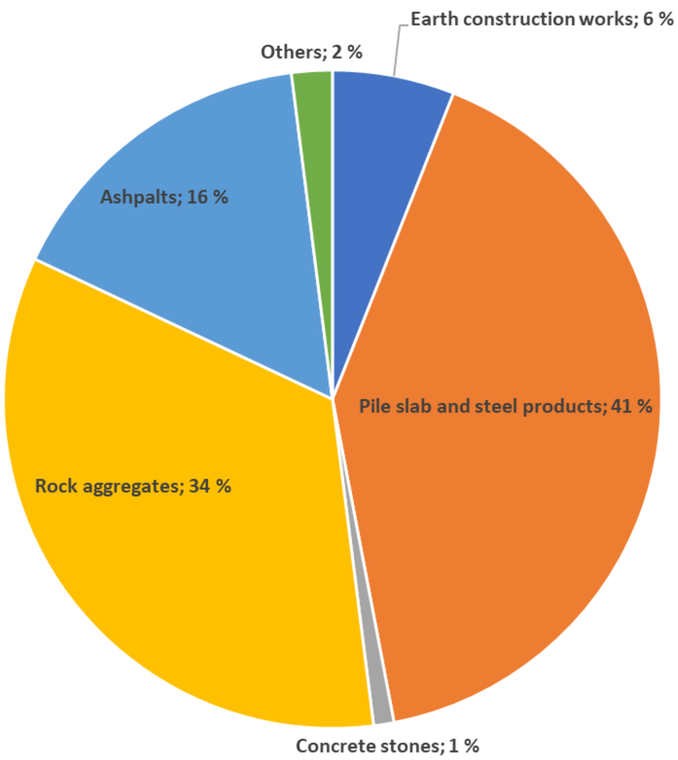


Figure 21. Shares of total emissions in Kauhakorvenkatu case (Resurssiviisas infrarakentaminen, 2018, 12).

Alternative options for Kauhakorvenkatu were:

- asphalt pavements (excluding SMA) made by cold mix asphalt

- fillings: assumption that in 3 km distance would be quarry/another construction site, from where the rock materials are transported to the construction site
- the filling of mass exchange: rock aggregate transported from elsewhere (74 % of the total mass exchange) is replaced with crushed concrete
- filter layer: sand is replaced with bottom ash
- sub-base: 80 % of crushed concrete (transportation distance 20 km) and 20 % of crushed rock (transportation distance 3 km)
- steel piles and permanent sheet pile wall: technical solutions which cannot be impacted

(Resurssiviisas infrarakentaminen, 2018, 13)

Results of alternative options showed that the emissions from rock aggregates decreased with 42 % (64 400 kg $CO_2$-eq) and emissions with different asphalt paving method with 4 % (3 000 kg $CO_2$-eq). All in all, the total absolute emissions decreased with 67 500 kg CO2-eq. When these alternative actions were also calculated for their costs, the cost savings were approximately 110 000 euros. Figure 22 presents the differences between the actual construction and the alternative option (Resurssiviisas infrarakentaminen, 2018, 14-15).

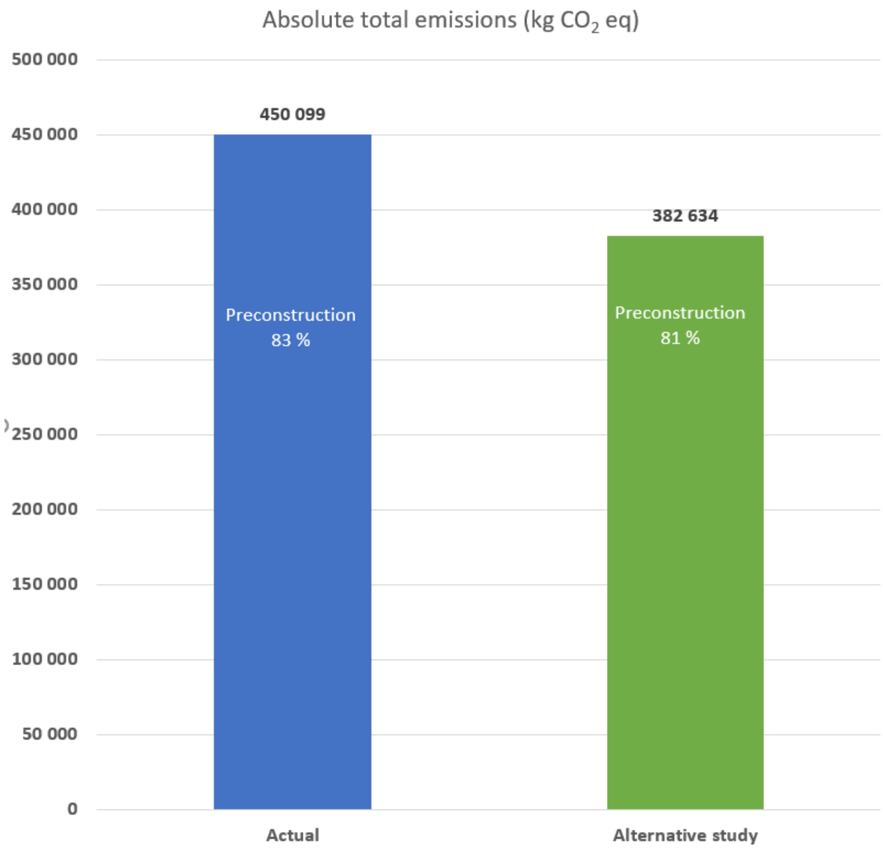


Figure 22. Emission differences between the actual (blue) and alternative option (green) (Resurssiviisas infrarakentaminen, 2018, 14).

### 6.3.2 Arvo Ylpön katu

Arvo Ylpön katu (street) was constructed in 2016-2017. It is 1200 m long of which 14 400 $m^2$ is paved with asphalt. In addition, there is 1000 m outdoor route covered with by-product fines from aggregate production, total area is 3 500 $m^2$. In Figure 23 is presented the structural parts and their $CO_2$ emissions according to the actual case (Alternative 1 in Table 8) (Resurssiviisas infrarakentaminen, 2018, 22).

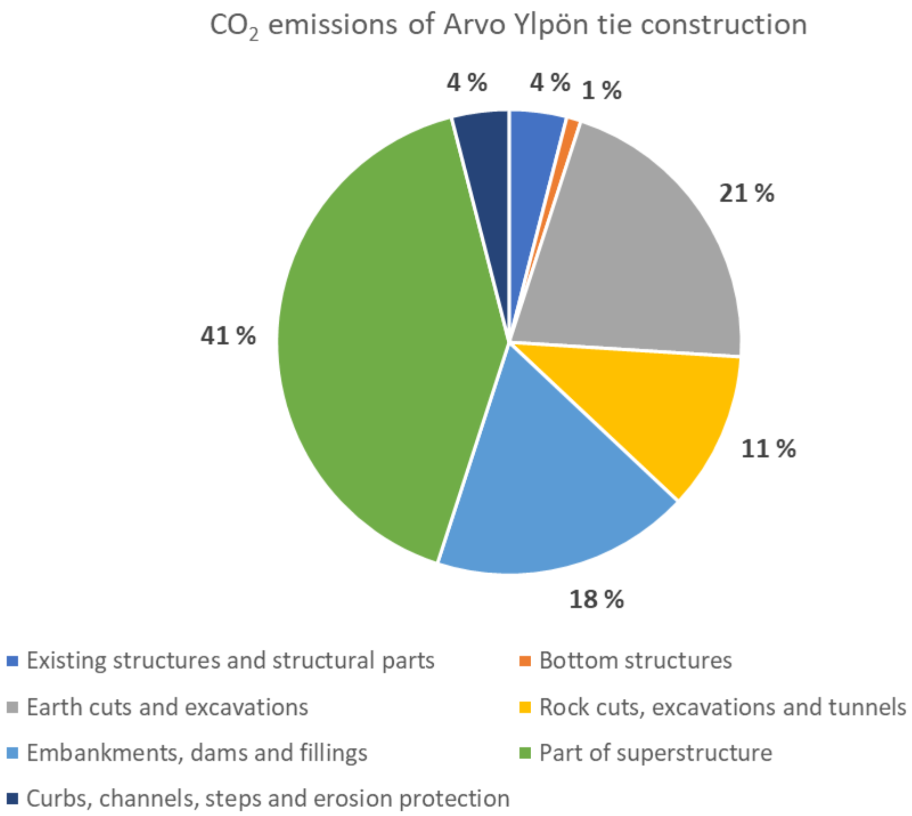


Figure 23. $CO_2$ emissions by structural parts in Arvo Ylpön tie case (Resurssiviisas infrarakentaminen, 2018, 22).

$CO_2$ calculation was made for three different solutions (Resurssiviisas infrarakentaminen, 2018, 17):

1) The actual construction of the street (Figure 23)
2) Assumption that crushed concrete would not be utilised in this site and kerbs would not be recycled
3) Assumption the crushed asphalt would be utilised in fillings and concrete blocks would be replaced with natural stones (+ sensitivity analysis for rocks origin Finland/China)

In Table 8 and in Figure 24 the $CO_2$ calculation results for Arvo Ylpön tie are presented. The most resource wise solution was alternative 3 and according to the study, the emissions would have been approximately 15 % lower than with the actual solution. By utilising crushed concrete, $CO_2$ savings were 22 000 kg (6 % of the total emissions). When the alternative solutions were also calculated for actual costs, the study showed that the cost savings according to alternative 3 were 115 000 euros. All in all, the $CO_2$ savings potential with this case was 62 000 kg $CO_2$ kg eq (Resurssiviisas infrarakentaminen, 2018, 25).

Table 8. Results of Arvo Ylpön tie $CO_2$ calculations.

| kg CO2 eq | Material | Transportations | Work related | Absolute total emissions | Description |
|---|---|---|---|---|---|
| Alt 1 | 166 329 | 93 710 | 106 498 | 366 537 | Actual construction |
| Alt 2 | 178 304 | 104 051 | 106 498 | 388 854 | Crushed concrete was not utilised (instead transported crush/rock), kerb were not recycled |
| Alt 3 | 134 504 | 84 921 | 107 050 | 326 475 | Asphalt crush in sub-base, concrete stones replaced with natural Finnish stones |
| Alt 3 China | 134 504 | 255 112 | 107 050 | 496 666 | Asphalt crush in sub-base, concrete stones replaced with natural Chinese stones |

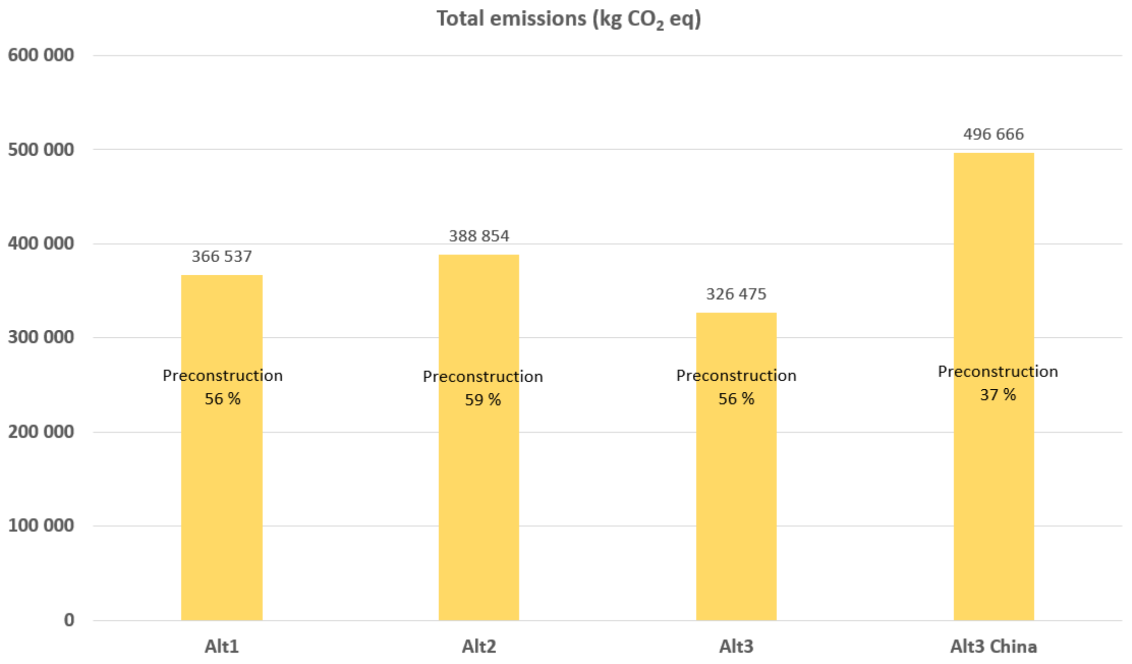


Figure 24. Total emissions of different alternatives of Arvo Ylpön tie calculations.

As it was studied also the impacts on the results between Finnish stones and Chinese stones, the calculations showed that the emissions for concrete stones were 27 100 kg $CO_2$ eq, Finnish stones 8 600 kg $CO_2$ eq and Chinese stones 180 000 kg $CO_2$ eq. Even from the long transportations distance, Chinese stones were approximately 30 % cheaper than Finnish stones (Resurssiviisas infrarakentaminen, 2018, 24). Share of preconstruction varies between 37-56 %. 37 % is exceptionally low share but in this alternative (Alt3 China) total emissions were increased due to the transportation of Chinese stones, which are not part of preconstruction.

### 6.3.3 Myrskynkatu and Härmälänojanpuisto

This case is about street and park in Härmälä area in city of Tampere. In this case the emissions from soil and aggregate transportations from two adjacent areas were calculated. The area of the street Myrskynkatu area is 2 140 $m^2$, total area of the park Härmälänojanpuisto is 3 080 $m^2$ (Resurssiviisas infrarakentaminen, 2018, 33).

Emissions were calculated for three different scenarios accordingly:
Alternative 1: Actual transportation during the construction, where

- contaminated soils and wastes were transported to different waste management sites, transportation distances varied between 21 to 127 kilometres
- peaty soils were transported to be utilised as raw material for soil manufacturing
- soil materials (crushed concrete, bricks, asphalt, crushed rock) that were excavated from the parking area bottom structure were transported to different waste management sites, transportation distances varied between 33-103 kilometres
- crushed concrete was utilised in street area fillings

Alternative 2: optional study, where the assumption is that 70 % of the contaminated soils and park area excavated soils are utilised at the construction site.
Alternative 3: optional study, where the assumption is that concrete crush would not be utilised in street area filling, but instead crushed rock would be transported from 16 km distance. Results of the calculations are presented in Figure 25 (Resurssiviisas infrarakentaminen, 2018, 34).

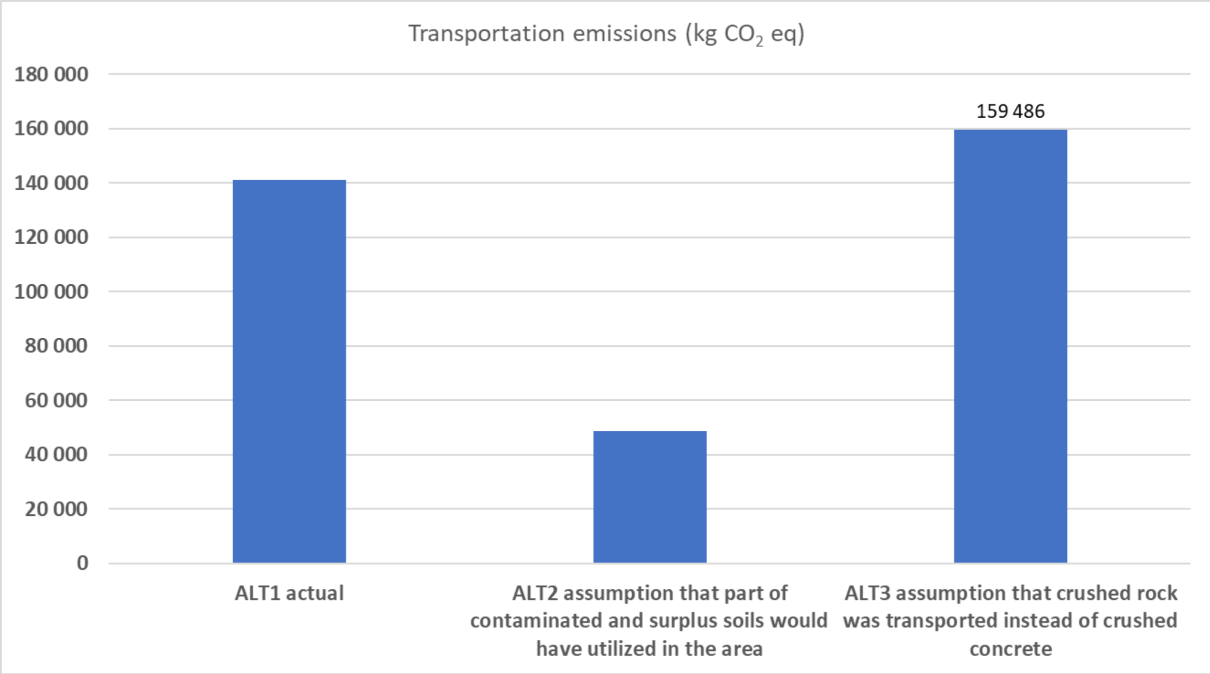


Figure 25. Results of Härmälä area case (Resurssiviisas infrarakentaminen, 2018, 36).

Utilisation of contaminated and surplus soils in alternative 2 decreased emissions from transportations 66 % (92 400 kg $CO_2$ eq). In the actual alternative 1, using crushed concrete instead of crushed rock, savings of transportation related emissions was 18 500 kg $CO_2$ eq. Cost savings that the utilisation of crushed concrete brought was 260 000 euros. In alternative 2 the calculated cost savings were 300 000 euros (Resurssiviisas infrarakentaminen, 2018, 36).

# 7 CASE STUDY SYNTHESIS

In this chapter the resulted $CO_2$ savings and cost savings are synthesised together. Table 9 and Figure 26 presents the absolute emissions and emission savings potential of the calculated cases. These results include also the pavement structures which are not part of preconstruction activities. Street cases Skanssinkatu, Vallikatu, Kauhakorvenkatu and Arvo Ylpön katu are similar cases for comparison purposes.

Table 9. Emissions and emission savings potentials between different alternatives in the studied cases.

| Case | Biggest emission (kg $CO_2$ eq) | Lowest emission (kg $CO_2$ eq) | Emission savings potential (kg $CO_2$ eq) |
|---|---|---|---|
| Skanssinkatu, Turku | 242 866 | 219 106 | 23 760 |
| Vallikatu, Turku | 4 277 769 | 1 652 238 | 2 625 531 |
| Perhekatu, Turku (transportations) | 41 913 | 29 855 | 12 058 |
| Kauhakorvenkatu, Tampere | 450 099 | 382 634 | 67 465 |
| Arvo Ylpön katu, Tampere | 366 537 | 326 475 | 40 062 |
| Karhunkaataja, Helsinki | 5 309 348 | 866 292 | 4 443 056 |
| Myrskynkatu and Härmälänojanpuisto | 159 486 | 48 578 | 110 908 |

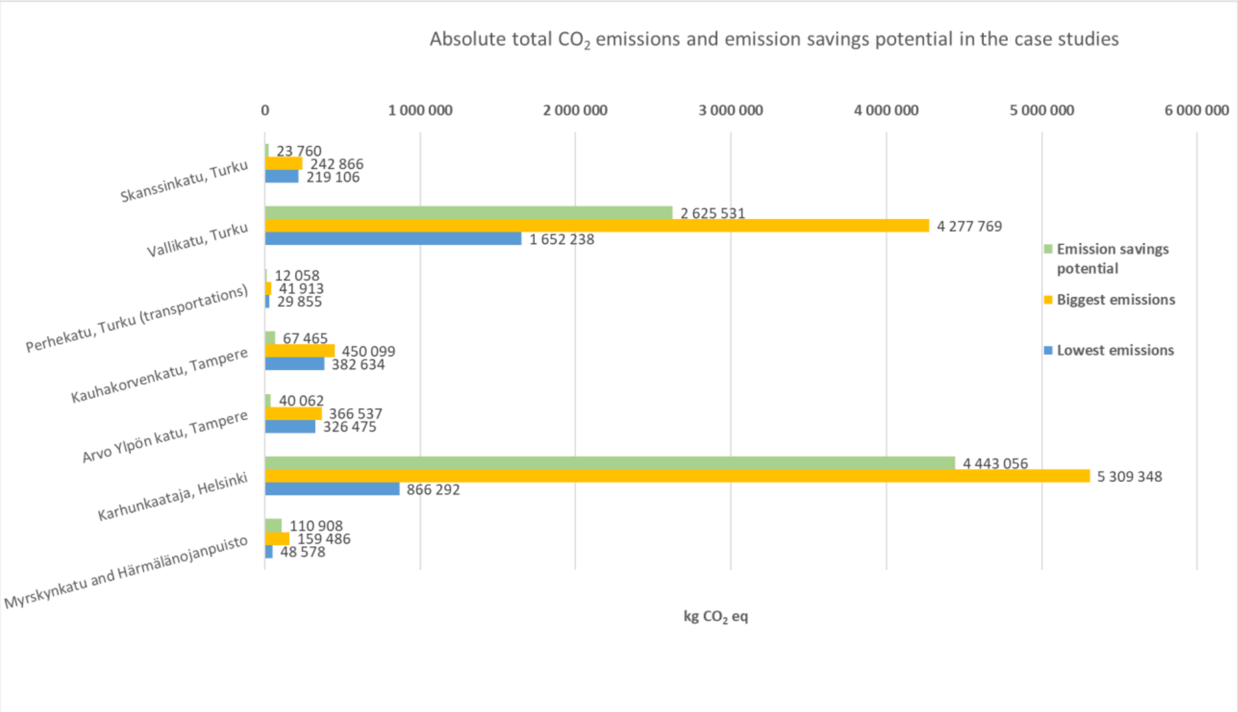


Figure 26. Total emissions and emission savings potential in the studied cases.

In Table 10 the emissions per m$^2$ and per road meter for lowest and highest alternatives are presented.

Table 10. Highest and lowest emissions per m$^2$ and per road meter.

| | Emissions per m2, highest ($CO_2$ eq/m$^2$) | Emissions per m2, lowest ($CO_2$ eq/m$^2$) | Per road meter, highest ($CO_2$ eq/m) | Per road meter, lowest ($CO_2$ eq/m) |
|---|---|---|---|---|
| Skanssinkatu, Turku | 101 | 91,3 | 810 | 730 |
| Vallikatu, Turku | 156 | 60,1 | 3 565 | 1 377 |
| Perhekatu, Turku (transportations) | 5,44 | 3,88 | 107 | 77 |
| Kauhakorvenkatu, Tampere | 42,9 | 36,4 | 500 | 425 |
| Arvo Ylpön katu, Tampere | 25,5 | 22,7 | 305 | 272 |
| Karhunkaataja, Helsinki | 114 | 18,7 | | |
| Myrskynkatu and Härmälänojanpui | 51,8 | 15,8 | | |

In Figure 27 the cost and emissions savings per case m$^2$ are presented. The savings vary between 2,14-57,47 €/saved kg $CO_2$ eq per case square meters, and 1,57-95,8 kg $CO_2$ eq/case square meter. Perhekatu case considers only the transportation optimization. In Vallikatu and Karhunkaataja cases the cost savings were not calculated.

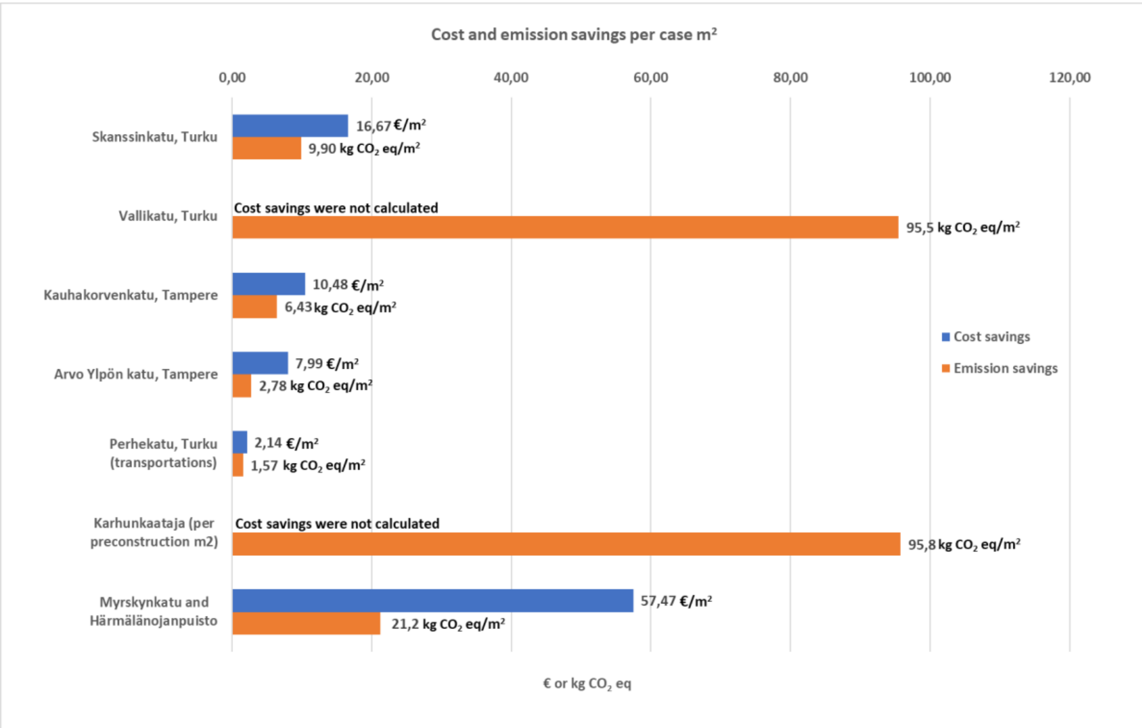


Figure 27. Cost and emission savings compared to case square meters.

In Figure 28 the cost and emissions savings per street length are presented for the street cases. The cost savings vary between 95,83-133,33 eur/saved kg $CO_2$

eq per street meters and emission savings vary between 75-2188 kg $CO_2$ eq/per case street meter. Karhunkaataja and Myrskynkatu and Härmälänoja cases are not included in this figure as they concern the total area, not one specific street. In Vallikatu case the cost savings were not calculated.

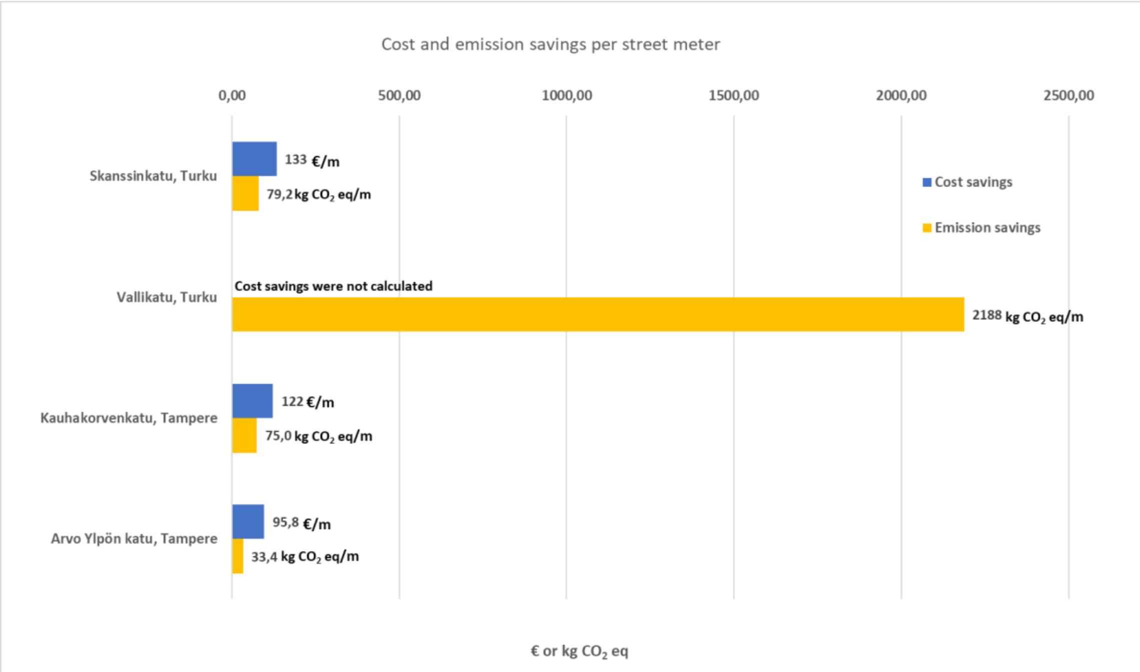


Figure 28. Cost and emission savings compared to road length.

The figures above show that by systematically taking into account different preconstruction possibilities, mass coordination, utilisable alternative materials in the vicinity and transportations, significant $CO_2$ emission and cost savings are possible. This is logical, as when the transportation kilometres can be decreased, also the consumption of diesel fuel is decreased as well as the used working hours for transportations. The share of preconstruction varied in the cases between 37-90 %. The low 37 % share was in the Arvo Ylpön katu case where sensitivity analysis was calculated with the Chinese stones.

# 8 RESULTS

As the case examples show, it is possible to optimize the construction project to save generating $CO_2$ emissions when the mass balance, transportation distances and used materials are studied well in advance. For best results, these should be already considered at the general planning stage – where and how the generating masses can be best utilized. When new area is constructed, there also should be pointed out an area where the needed materials could be stored and processed so that all stages of material logistics can be optimized.

When the results are set in proportion on a local scale, in case Tampere, the annual emission reduction potential can be 360 000 – 530 000 kg $CO_2$ when the results from Kauhakorvenkatu and Arvo Ylpön katu are used for scaling (Resurssiviisas infrarakentaminen, 2018, 3). In Turku, 10 kilometres of roads are constructed every year (Rakentamisessa on runsaasti säästömahdollisuuksia, 2018). In Skanssinkatu case, the emission reduction was 79,2 kg $CO_2$ eq per road meter. If this number is scaled to match the annual 10 km road construction amount, the annual $CO_2$ savings potential could be 792 000 kg $CO_2$ eq. Although the results from the case calculations are case specific, they can be considered to give some direction.

Finland must cut $CO_2$ emissions 80-95 % by the year 2050 compared to the level in year 1990 (71,6 Mtons) (Suomen ilmastopolitiikka, 2015). This means annual reduction by 1 000 000 tons $CO_2$ emissions, and emission cuts need to be made in all those sectors where it is possible. The results of this thesis show that there are emission reduction potentials yet unexplored and not considered in the climate targets of cities.

In Stockholm, large infra construction investments are about to take place in coming year. According to the report “Planned Investments in the Stockholm region 2019-2040” by Tyréns AB, the region of Stockholm shows a volume of 111 billion euros investments until the year 2040 of which infrastructure investments are 9,6 billion euros in railway, subway and light rail. Volume of Stockholm infra projects is massive, so despite of fast urbanization and expanding needs, hopefully the emission reductions and related cost reduction can be taken into account, too.

# 9 DISCUSSION

In this thesis $CO_2$ emission reduction possibilities in different infra projects were studied. The studied calculation alternatives were all technically comparable to each other. It must be remembered that $CO_2$ is one environmental impact parameter and there are other environmental impacts, too, such as depletion of natural aggregates or energy consumption. Energy consumption is not an environmental impact, but it is directly related to airborne emissions. All recycled or upcycled materials might not be the least emission causing materials, but their utilisation should also be considered resource wise when it can substitute for example the need of virgin rock aggregates and the utilisation is possible nearby. Although there are abundant natural rock resources in Finland, they are essential from the ground water protection, landscape and diversity point of view, too, and their utilisation should be on a sustainable level. The metropolitan area of Helsinki is already lacking vicinity of esker materials, so the resource efficiency plays an important role in such areas. $CO_2$ emissions is chosen to be studied in this thesis to show the cities how they can consider emission reduction in their infra projects and how they can contribute to local and national climate commitments.

Ministry of the Environment is preparing a new Decree to ease the utilisation of surplus soils in such a way, that their utilising and temporary storage would not need an environmental permit but instead a registration announcement would be enough. This Decree would also include soil stabilisation with certain waste materials. Registration procedure would streamline administrative procedure. In addition, the Decree would ensure that no harm for the health or for the environment would cause even in a long-term run. It is expected that the Decree comes into effect in 2020 (Jätteiden hyödyntämismahdollisuuksia maarakentamisessa laajennetaan, 2019). From the city point of view, it is important that there are enough temporary storage and material processing sites in the city. These areas will allow to decrease the material transportations and related emissions. Storage and processing sites should be taken into account already in the planning stage, so that when the (pre)construction starts, there is no more need to start mapping where the surplus soils and construction materials should be transported. Also snow handling should be coordinated with mass balance coordination, whenever this is possible.

To create reliable calculations, whether it is a complete life cycle analysis or emission calculation, it is important that the created scenarios are technically realistic and that it is understood what kind of work stages are included in infra construction projects. In transportation calculations, errors in the material volume conversion factors can be significant, especially when the transported mass amounts are big, as it is the case in infra construction projects.

In Arvo Ylpön katu case, the emission impact of Chinese rocks was also calculated. Even the natural resources in Finland are abundant and their transportation kilometres inside Finland are of course much less than transporting them from China, yet the Chinese rocks are cheaper than Finnish ones. The case study showed that the emissions for Chinese rocks are 15 times higher than for domestic rocks. This kind of absurd situations should not take place and the project owner should be aware of the environmental impacts, too, not only financial impacts.

The results of this thesis show the direction that carbon dioxide emission reductions are possible in infra construction, but more calculations are needed to get more specific emission factors for each preconstruction method for future calculations.

## REFERENCES


Anderson, K. et. al. 2018. Koldioxidbudget 2020-2040. Stockholms län. (Carbon dioxide budget 2020-2040. Stockholm province). Project report.

Anderson, K., Schrage, I. et. al. 2018. A guide for a fair implementation of the Paris agreement within Swedish municipalities and regional governments: Part II of the carbon budget reports submitted to Swedish local governing bodies in 2018 project "Koldioxidbudgetar 2020-2040. A report commissioned by Swedish municipalities and regional governments. Climate change leadership node, Uppsala university, Sweden.

Dettenborn, T., Kohonen, R., Känkänen, R. and Niemelin, T. 2018. $CO_2$-päästölaskennan kehittäminen Skanssin alueella ja Turun kaupungin infrarakentamisessa. (Development of $CO_2$ emission calculation in Skanssi area and in infra construction of city of Turku). Ramboll project report. Read 16.9.2019
https://www.turku.fi/sites/default/files/atoms/files//skanssin_alueen_co2-laskenta_loppuraportti.pdf

Finnveden, G. and Moberg, Å. 2005. Environmental systems analysis tools – an overview. Journal of Cleaner Production 13 (2005) 1165-1173.

Frimodig, S. 2014. Tontin pohjarakennuskustannusten laskenta kaavoitusvaiheen suunnittelussa (Estimating site's ground construction costs in land use planning). Master's Degree Programme in Civil Engineering. Tampere University of Technology.

Helsingin kaivumaiden hyödyntämisen kehittämisohjelma (Development program of Helsinki city's excavated soils). 2013.

Hiilineutraali Helsinki 2035-toimenpideohjelma. Pormestarin esitys kaupunginhallitukselle. (Carbon neutral Helsinki 2035 action program). 2018. Helsingin kaupungin keskushallinnon julkaisuja 2018:4.

Huhtinen, T., Palolahti, A., Ehrukainen, E. et. al. 2018. Kiviaineshuollon kehittämishanke (Development project of rock aggregate supply). Ympäristöministeriö.

Huttunen, R. (toim.) 2017. Valtioneuvoston selonteko kansallisesta energia- ja ilmastostrategiasta vuoteen 2030 (Government report on national energy and climate strategy for year 2030). Työ- ja elinkeinoministeriön julkaisuja 4/2017.

InfraRYL. 2018. General Quality Specifications for Infrastructure. Earthworks, foundations and rock structures. Rakennustieto Oy.

IPCC Press release. 2018. Summary for Policymakers of IPCC Special Report on Global Warming of 1.5 °C approved by governments. IPCC Intergovernmental panel on climate change. Read 27.4.2019.
https://www.ipcc.ch/site/assets/uploads/2018/11/pr_181008_P48_spm_en.pdf

J. Rogelj, D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, M. V. Vilariño, 2018, Mitigation pathways compatible with 1.5°C in the context of sustainable development. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press. ((Chapter 2, page 95))

Jätteiden hyödyntämismahdollisuuksia maarakentamisessa laajennetaan, 2019. (The possibilities of utilisation of wastes in earth construction are broaden). Read 30.10.2019 https://www.ym.fi/fi-FI/Ymparisto/Lainsaadanto_ja_ohjeet/Ymparistonsuojelun_valmisteilla_oleva_lainsaadanto/Jatteiden_hyodyntaminen_maanrakentamisessa

Karhunkaataja, n.d. Ramboll project material, not published.

Kartat. 2019. (Maps of Myllypuro city district area). Read 28.9.2019. https://www.uuttahelsinkia.fi/fi/myllypuro/rakentaminen/kartat

Kestävä infra. Määritelmä. (Sustainable infra. Definition.) 2019. Powerpoint-esitys. Green Building Council Finland.

Lehtovuori, P., Vanhatalo, J. Rantanen, A. ja Viri, R (eds). 2017. Kaupunkirakenteen kokonaisvaltainen resurssitehokkuus (Comprehensive resource efficiency of the urban structure). Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 65/2017.

Magnusson, S., Lundberg, K., Svedberg, B and Knutsson, S. 2015. Sustainable management of excavated soil and rock in urban areas – A literature review. Journal of Cleaner Production 93 (2015) 18-25.

Magnusson, S., Johansson, M., Frosth, S. and Lundberg, K. 2019. Coordinating soil and rock material in urban construction – Scenario analysis of material flows and greenhouse gas emissions. Journal of Cleaner Production 241 (2019).

Nauska, J. and Havukainen, J. 1998. Esirakentaminen (Preconstruction). Geotekninen osasto julkaisu 77. Helsingin kaupunki. Kiinteistövirasto.

Parviainen, J. 2015. Kuntien ja maakuntien ilmastotyön tilanne 2015 (The situation of climate work in cities and counties 2015). Strategioista käytäntöön. Kuntaliiton verkkojulkaisu.

Rakentamisessa on runsaasti säästömahdollisuuksia. 2018. (Lot of savings potential in construction activities). Read 5.11.2019. https://www.turku.fi/uutinen/2018-06-20_rakentamisessa-runsaasti-saastomahdollisuuksia

Rakentamista 2019-2020 (Constructioning in 2019-2020). 2019. Read 28.9.2019 https://www.uuttahelsinkia.fi/fi/myllypuro/rakentaminen

Resurssiviisas infrarakentaminen. Tampereen case-kohteiden $CO_2$-päästölaskenta ja resurssiviisaat ratkaisut. (Resource wise infra construction. $CO_2$ emission calculation and resource wise solution for Tampere cases). 2018. Ramboll project report.

Ritchie, H. and Roser, M. 2017. $CO_2$ and other Greenhouse Gas Emissions. Read 3.5.2019. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Schwietzke, S., Griffin, W.M. and Matthews, H.S. 2011. Relevance of Emissions Timing in Biofuel Greenhouse Gases and Climate Impacts. Environmental Science & Technology. 45, 8197-82013.

SM Maanpää Oy. 2013. Rakennettavuusselvitys. Skanssin kaava-alue. (Study of construction circumstances for Skanssi area). Turun kaupunki. Read 4.8.2019 http://www.turku.fi/sites/default/files/atoms/files/skanssi_rakennettavuusselvitys.pdf

Suomen ilmastopolitiikka. Kohti vähähiilistä ja energiatehokasta yhteiskuntaa. 2015. (Finland's climate policy. Toward low carbon and energy efficient society). Ympäristöministeriö, maa- ja metsätalousministeriö ja työ- ja elinkeinoministeriö. Read 17.11.2019 https://ilmasto-opas.fi/ilocms-portlet/article/8a54c390-fed4-42da-a2c2-4bab74993ebd/r/470c0e20-16ce-478f-820a-759f820ceb52/suomen_ilmastopolitiikka_rgb.pdf

Säynäjoki, A., Heinonen, J. and Junnila, S. 2012. A scenario analysis of the life cycle greenhouse gas emissions of a new residential area. Environ. Res. Lett. 7 034037.

Säynäjoki, E. et. al. 2014. Työkaluja vähähiiliseen aluerakentamiseen. MALTTI – matalahiilisen aluekehityksen tukityökalu. Aalto-yliopiston julkaisusarja. Tiede + Teknologia 7/2014. Unigrafia Oy. Helsinki.

Teittinen, T. 2019. Uusiomaarakentamisen ympäristövaikutusindikaattorit ja päästölaskenta tie- ja katurakentamisessa (Environmental impact indicators and emission calculations in road con-struction when using secondary raw materials). Diplomityö. Vesi- ja ympäristötekniikan koulutusohjelma. Aalto-yliopisto.

Tyréns AB. n.d. Planned Investments in the Stockholm region 2019-2040. Read 6.12.2019. https://www.investstockholm.com/globalassets/2.-understartsidor-investment-opportunities/4.-infrastructure/infrastructure_investment_report.pdf

UUMA3-ohjelma (UUMA3-programme). 2018. Read 28.4.2019. www.uusiomaarakentaminen.fi

Wang, Q., Wu, S. Zeng, Y. and Wu, B. 2016. Exploring the relationship between urbanization, energy consumption, and $CO_2$ emissions in different provinces of China. Renewable and Sustainable Energy Reviews 54 (2016) 1563-1579.

Working Group I: The Scientific Basis. n.d. Read 3.5.2019. https://archive.ipcc.ch/ipccreports/tar/wg1/016.htm

# APPENDICES

Appendix 1. Used parameters in the $CO_2$ emission calculations.

| **Material/Performance/Structural part** | **Reference** |
|---|---|
| Characterisation coefficients ($CO_2$, $CH_4$, $N_2O$) | IPCC Fifth Assessment Report (AR5 2013) |
| Lightweight aggregate | E-mail from Leca Finland Ltd |
| Foamed glass | E-mail from Uusioaines Ltd, 14.11.2017 |
| Work performance of column stabilization | Information received by phone from Lemminkäinen Ltd, 3.3.2017 |
| Lime | Nordkalk Ltd, Environment report 2008 and Sustainable Development report 2014 |
| Cement | Finnsementti Ltd, Environment report 2016 |
| Bitumen | Eurobitume, Life Cycle Inventory: Bitumen (2nd Edition – July 2012) |
| Emission figures for vehicles and work machines | Lipasto database by Finnish Technical Research Center VTT |
| Soil volume characteristics and mass coefficients | Infra 2015, Rakennusosa- ja hankenimikkeistö, Määrämittausohje. Rakennustieto Oy, Helsinki. Appendices 1-3. |
| Emission coefficients for materials, products, work machines and work performances | Tien- ja radanpidon hiilijalanjälki, Liikenneviraston tutkimuksia ja selvityksiä 38/2011 (Carbon footprint of construction, operation and maintenance of roads and railways. Research reports of the Finnish Transport Agency 38/2011) |
| | Stripple 2001. Life Cycle Assessment of Road. A pilot study for inventory analysis. IVL Svenska Miljöinstitutet AB. |
| | Panospohjaisen $CO_2$-laskennan pilotointi väylähankkeessa. Liikenneviraston tutkimuksia ja selvityksiä 18/2014. (Pilot study of activity-based $CO_2$ calculation in a transport infrastructure project: improvement of the Ring Road I intersection at the Kivikontie grade separation. Research reports of the Finnish Transport Agency 18/2014) |
| Environment Product Declarations for some products | Rakennustieto RTS EDP-environmental declarations (http://epd.rts.fi/hae-ymparistoselosteita) |

# Appendix 2. Karhunkaataja case results

| KARHUNKAATAJA, Alt 1 | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transpor-tations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq. /ton] | Share of absolute total emissions [%] |
| 11410 | Removal of top soil | m2tr | 51 100 | 1 | 0 | 4 135 | 1 060 | 5 195 | 0,15 | 0,47 % |
| 16110 | Earth cut (excavation for quarrying) | m3ktr | 16 400 | 1 | 0 | 3 657 | 4 650 | 8 307 | 0,27 | 0,76 % |
| 17110_A | Open excavation | m3ktr | 46 700 | 1 | 78 202 | 32 908 | 60 800 | 171 910 | 0,61 | 15,66 % |
| 17110_B | Irtilouhinta | m3ktr | 21 200 | 1 | 35 500 | 14 939 | 27 600 | 78 038 | 0,61 | 7,11 % |
| 17110_C | Crushing of blasted rock | m3ktr | 48 400 | 1 | 0 | 52 393 | 636 146 | 688 539 | 1,54 | 62,74 % |
| 18116A | Preload embankment, masses from the area | m3rtr | 76 600 | 1 | 0 | 19 136 | 88 043 | 107 179 | 0,66 | 9,77 % |
| 18116B | Removal of over embankment | m3rtr | 13 600 | 10 | 0 | 33 974 | 4 364 | 38 338 | 1,32 | 3,49 % |
| | | | | | 113 702 | 161 141 | 822 663 | 1 097 507 | 5,15 | 100 % |

| KARHUNKAATAJA, Alt 2a | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq. /ton] | Share of absolute total emissions [%] |
| 11410 | Removal of top soil | m2tr | 46 400 | 1 | 0 | 4 135 | 1 060 | 5 195 | 0,15 | 0,35 % |
| 16110 | Earth cut (excavation for quarrying) | m3ktr | 10 300 | 1 | 0 | 3 657 | 4 650 | 8 307 | 0,27 | 0,56 % |
| 17110_A | Open excavation | m3ktr | 30 400 | 1 | 78 202 | 32 908 | 60 800 | 171 910 | 0,61 | 11,55 % |
| 17110_B | Irtilouhinta | m3ktr | 13 800 | 1 | 35 500 | 14 939 | 27 600 | 78 038 | 0,61 | 5,24 % |
| 17110_C | Crushing of blasted rock | m3ktr | 31 400 | 1 | 0 | 33 990 | 412 707 | 446 696 | 1,54 | 30,02 % |
| 18116_A | Preload embankment, crush from elsewhere | m3rtr | 20 000 | 25 | 98 578 | 541 279 | 22 988 | 662 845 | 3,58 | 44,55 % |
| 18116_B | Preload embankment, masses from the area | m3rtr | 34 300 | 1 | 0 | 37 130 | 39 424 | 76 554 | 0,24 | 5,15 % |
| 18116_C | Removal of over embankment | m3rtr | 13 600 | 10 | 0 | 33 974 | 4 364 | 38 338 | 1,32 | 2,58 % |
| | | | | | 212 281 | 702 012 | 573 592 | 1 487 884 | 8,32 | 100 |

| KARHUNKAATAJA, Alt 2b | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq. /ton] | Share of absolute total emissions [%] |
| 11410 | Removal of top soil | m2tr | 46 400 | 1 | 0 | 4 135 | 1 060 | 5 195 | 0,15 | 0,60 % |
| 16110 | Earth cut (excavation for | m3ktr | 10 300 | 1 | 0 | 3 657 | 4 650 | 8 307 | 0,27 | 0,96 % |
| 17110_A | Open excavation | m3ktr | 30 400 | 1 | 78 202 | 32 908 | 60 800 | 171 910 | 0,61 | 19,84 % |
| 17110_B | Irtilouhinta | m3ktr | 13 800 | 1 | 35 500 | 14 939 | 27 600 | 78 038 | 0,61 | 9,01 % |
| 17110_C | Crushing of blasted rock | m3ktr | 31 400 | 1 | 0 | 33 990 | 412 707 | 446 696 | 1,54 | 51,56 % |
| 18116_A | Preload embankment crushed concrete, | m3rtr | 20 000 | 10 | 0 | 18 265 | 22 988 | 41 253 | 2,64 | 4,76 % |
| 18116_B | Preload embankment, masses from the area | m3rtr | 34 300 | 1 | 0 | 37 130 | 39 424 | 76 554 | 0,24 | 8,84 % |
| 18116_C | Removal of over embankment | m3rtr | 13 600 | 10 | 0 | 33 974 | 4 364 | 38 338 | 1,32 | 4,43 % |
| | | | | | 113 702 | 178 998 | 573 592 | 866 292 | 7,38 | 100 |

| KARHUNKAATAJA, Alt 2c | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 11410 | Removal of top soil | m2tr | 46 400 | 1 | 0 | 4 135 | 1 060 | 5 195 | 0,15 | 0,37 % |
| 16110 | Earth cut (excavation for quarrying) | m3ktr | 10 300 | 1 | 0 | 3 657 | 4 650 | 8 307 | 0,27 | 0,59 % |
| 17110_A | Open excavation | m3ktr | 30 400 | 1 | 78 202 | 32 908 | 60 800 | 171 910 | 0,61 | 12,30 % |
| 17110_B | Irtilouhinta | m3ktr | 13 800 | 1 | 35 500 | 14 939 | 27 600 | 78 038 | 0,61 | 5,58 % |
| 17110_C | Crushing of blasted rock | m3ktr | 31 400 | 1 | 0 | 33 990 | 412 707 | 446 696 | 1,54 | 31,96 % |
| 18116_A | Sub-base, crushed rock 0-63 | m3rtr | 20 000 | 25 | 8 208 | 18 265 | 22 988 | 49 461 | 3,09 | 40,96 % |
| 18116_B | Preload embankment, masses from the area | m3rtr | 34 300 | 1 | 0 | 37 130 | 39 424 | 76 554 | 0,24 | 5,48 % |
| 18116_C | Removal of over embankment | m3rtr | 13 600 | 10 | 0 | 33 974 | 4 364 | 38 338 | 1,32 | 2,74 % |
| | | | | | 121 910 | 178 998 | 573 592 | 874 500 | 7,82 | 100 |

| KARHUNKAATAJA, Alt 3a | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 11410 | Removal of top soil | m2tr | 51 100 | 1 | 0 | 4 555 | 1 168 | 5 723 | 0,15 | 0,18 % |
| 14132 | Mass stabilised earth structures (cement production and transportation) | t | 3 204 | 220 | 2 028 132 | 26 723 | 59 452 | 2 114 307 | 660 | 64,82 % |
| 16110 | Earth cut (excavation for quarrying) | m3ktr | 16 400 | 1 | 0 | 5 824 | 7 404 | 13 228 | 0,27 | 0,41 % |
| 17110_A | Open excavation | m3ktr | 46 700 | 1 | 120 133 | 50 553 | 93 400 | 264 086 | 0,61 | 8,10 % |
| 17110_B | Irtilouhinta | m3ktr | 21 200 | 1 | 54 536 | 22 949 | 42 400 | 119 885 | 0,61 | 3,68 % |
| 17110_C | Crushing of blasted rock | m3ktr | 48 400 | 1 | 0 | 52 393 | 636 146 | 688 539 | 1,54 | 21,11 % |
| 18111 | Earth embankment (to lower surface of the structural layers, -0,5 m from the grade line) | m3 | 39 900 | 1 | 0 | 9 968 | 45 861 | 55 828 | 0,66 | 1,71 % |
| | | | | | 2 202 801 | 172 964 | 885 831 | 3 261 595 | 663 | 100 |

| KARHUNKAATAJA, Alt 3b | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 11410 | Removal of top soil | m2tr | 51 100 | 1 | 0 | 4 555 | 1 168 | 5 723 | 0,15 | 0,21 % |
| 16110 | Earth cut (excavation for quarrying) | m3ktr | 16 400 | 1 | 0 | 5 824 | 7 404 | 13 228 | 0,27 | 0,49 % |
| 16200 | Excavations for earth exchange | m3 | 63 000 | 40 | 0 | 894 755 | 20 214 | 914 969 | 4,78 | 34,11 % |
| 17110_A | Open excavation | m3ktr | 46 700 | 1 | 120 133 | 50 553 | 93 400 | 264 086 | 0,61 | 9,85 % |
| 17110_B | Irtilouhinta | m3ktr | 21 200 | 1 | 54 536 | 22 949 | 42 400 | 119 885 | 0,61 | 4,47 % |
| 17110_C | Crushing of blasted rock | m3ktr | 48 400 | 1 | 0 | 52 393 | 636 146 | 688 539 | 1,54 | 25,67 % |
| 18111 | Earth embankment (to lower surface of the structural layers, -0,5 m from the grade line) + filling of the earth exchange with masses from the area | m3 | 54 300 | 1 | 0 | 13 565 | 17 422 | 30 988 | 0,27 | 1,16 % |
| 18360 | Filling of mass exchange to current ground level with blasted rock or crush | m3 | 45 600 | 1 | 307 747 | 284 805 | 52 412 | 644 964 | 6,62 | 24,04 % |
| | | | | | 482 416 | 1 329 398 | 870 566 | 2 682 380 | 14,8 | 100 |

| KARHUNKAATAJA, Alt 3C _lightweight clay | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 11410 | Removal of top soil | m2tr | 51 100 | 1 | 0 | 3 074 | 1 168 | 4 242 | 0,11 | 0,08 % |
| 16110 | Earth cut (excavation for quarrying) | m3ktr | 16 400 | 25 | 0 | 145 597 | 7 404 | 153 001 | 3,07 | 2,88 % |
| 17110_A | Open excavation | m3ktr | 46 700 | 25 | 120 133 | 1 263 818 | 93 400 | 1 477 351 | 3,42 | 27,83 % |
| 17110_B | Irtilouhinta | m3ktr | 21 200 | 25 | 54 536 | 573 720 | 42 400 | 670 656 | 3,42 | 12,63 % |
| 18114 | Lightweight embankments (lightweight clay) | m3rtr | 24 000 | 126 | 2 918 400 | 80 632 | 5 066 | 3 004 098 | 417,24 | 56,58 % |
| | | | | | 3 093 069 | 2 066 841 | 149 438 | 5 309 348 | 427 | 100 % |

| KARHUNKAATAJA, Alt 3C _foamed glass | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 11410 | Removal of top soil | m2tr | 51 100 | 1 | 0 | 3 074 | 1 168 | 4 242 | 0,11 | 0,12 % |
| 16110 | Earth cut (excavation for quarrying) | m3ktr | 16 400 | 25 | 0 | 145 597 | 7 404 | 153 001 | 3,07 | 4,47 % |
| 17110_A | Open excavation | m3ktr | 46 700 | 25 | 120 133 | 1 263 818 | 93 400 | 1 477 351 | 3,42 | 43,14 % |
| 17110_B | Irtilouhinta | m3ktr | 21 200 | 25 | 54 536 | 573 720 | 42 400 | 670 656 | 3,42 | 19,58 % |
| 18114 | Lightweight embankments (foamed glass) | m3rtr | 24 000 | 126 | 1 065 600 | 53 755 | 5 066 | 1 119 355 | 233,20 | 32,69 % |
| | | | | | 1 240 269 | 2 039 964 | 149 438 | 3 424 605 | 243 | 100 % |

# Appendix 3. Skanssi case results

| Skanssinkatu, initial case | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Trans-portations km * | Material emissions [kg CO2eq.] | Trans-portation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1141 | Removal of top soil | m2tr | 4 870 | 13 | 0 | 1 833 | 433 | 2 266 | 1,28 | 0,9 % |
| 1142 | Removal of the embankment | m3ktr | 2 080 | 13 | 0 | 4 913 | 982 | 5 894 | 1,23 | 2 % |
| 1331,1 | Crush raft | m3rtr | 10 | 13 | 39 | 39 | 3 | 81 | 3,82 | 0,03 % |
| 1431,2 | Drainage in the construction | mtr | 665 | 250 | 2 231 | 450 | 0 | 2 681 | 9 880,68 | 1,1 % |
| 1613 | Excavation | m3ktr | 4 700 | 13 | 0 | 11 093 | 2 090 | 13 182 | 1,22 | 5 % |
| 1621 | Excavation of the pipe trench | m3ktr | 100 | 13 | 0 | 253 | 44 | 298 | 1,30 | 0,1 % |
| 1814,1 | Lighweight embankments, foamed glass | m3rtr | 2 800 | 85 | 163 170 | 4 861 | 2 064 | 170 094 | 231,42 | 70 % |
| 1831 | Bedrock | m3rtr | 65 | 13 | 250 | 156 | 24 | 430 | 3,10 | 0,2 % |
| 1832 | Initial crush filling | m3rtr | 30 | 13 | 115 | 78 | 10 | 204 | 3,18 | 0,1 % |
| 1833 | Final filling, crush | m3rtr | 45 | 13 | 102 | 136 | 11 | 250 | 2,14 | 0,1 % |
| 2112 | Geotextile N2 | m2tr | 144 | 510 | 33 | 919 | 0 | 952 | 47 203,45 | 0,4 % |
| 2121,2 | Sub-base, crushed rock | m3rtr | 1 900 | 13 | 7 305 | 4 172 | 3 233 | 14 710 | 3,62 | 6 % |
| 2131,2 | Unbound base course, crushed rock | m3rtr | 500 | 13 | 1 922 | 1 111 | 1 196 | 4 230 | 3,96 | 2 % |
| 2141,11 | AB 22/120 (50 mm) | m2tr | 2 360 | 13 | 10 153 | 312 | 813 | 11 277 | 38,23 | 5 % |
| 2143,111 | Concrete stone covering | m2tr | 200 | 165 | 5 014 | 594 | 0 | 5 608 | 200,27 | 2 % |
| 2143,111(2) | Concrete stone covering, squared | m2tr | 180 | 165 | 7 750 | 594 | 0 | 8 344 | 257,54 | 3 % |
| 2143,22 | Granite sett | m2tr | 5 | 200 | 58 | 360 | 0 | 418 | 379,82 | 0,2 % |
| 2143,23 | Granite sett | m2tr | 125 | 200 | 743 | 720 | 0 | 1 462 | 36,33 | 0,6 % |
| 2143,24 | Rubble stone covering | m2tr | 820 | 10 | 200 | 195 | 0 | 395 | 1,72 | 0,2 % |
| 2144 | Landscape stone | kpl | 231 | 10 | 40 | 45 | 5 | 90 | 1,94 | 0,04 % |
| | | | | | 199 125 | 32 831 | 10 909 | 242 866 | 58 256 | 100 % |

| Skanssinkatu, low emission AB, utilisation of excavated soils in the project, sub-base crushed concrete | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Trans-portations km * | Material emissions [kg CO2eq.] | Trans-portation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1141 | Lighweight embankments, foamed glass | m2tr | 4 870 | 13 | 0 | 1 833 | 433 | 2 266 | 1,28 | 1,03 % |
| 1142 | Removal of the embankment | m3ktr | 2 080 | 1 | 0 | 378 | 982 | 1 360 | 0,28 | 0,62 % |
| 1331,1 | Removal of over embankment | m3rtr | 10 | 13 | 39 | 39 | 3 | 81 | 3,82 | 0,04 % |
| 1431,2 | Drainage in the construction | mtr | 665 | 10 | 2 231 | 18 | 0 | 2 249 | 8 289,34 | 1,03 % |
| 1613 | Excavation | m3ktr | 4 700 | 1 | 0 | 853 | 2 090 | 2 943 | 0,27 | 1,34 % |
| 1621 | Excavation of the pipe trench | m3ktr | 100 | 1 | 0 | 19 | 44 | 64 | 0,28 | 0,03 % |
| 1814,1 | Lighweight embankments, foamed glass | m3rtr | 2 800 | 85 | 163 170 | 4 861 | 2 064 | 170 094 | 231,42 | 77,63 % |
| 1831 | Bedrock | m3rtr | 65 | 13 | 250 | 156 | 24 | 430 | 3,10 | 0,20 % |
| 1832 | Initial crush filling | m3rtr | 30 | 13 | 115 | 78 | 10 | 204 | 3,18 | 0,09 % |
| 1833 | Final filling, crush | m3rtr | 45 | 13 | 102 | 136 | 11 | 250 | 2,14 | 0,11 % |
| 2112 | Geotextile N2 | m2tr | 144 | 510 | 33 | 919 | 0 | 952 | 47 203,45 | 0,43 % |
| 2121,2 | Sub-base, crushed concrete | m3rtr | 1 900 | 13 | 0 | 4 172 | 3 233 | 7 405 | 1,82 | 3,38 % |
| 2131,2 | Unbound base course, crushed rock | m3rtr | 500 | 13 | 1 922 | 1 111 | 1 196 | 4 230 | 3,96 | 1,93 % |
| 2141,11 | AB 22/120 (50 mm) | m2tr | 2 360 | 13 | 9 137 | 312 | 813 | 10 262 | 34,79 | 4,68 % |
| 2143,111 | Concrete stone covering | m2tr | 200 | 165 | 5 014 | 594 | 0 | 5 608 | 200,27 | 2,56 % |
| 2143,111(2) | Concrete stone covering, squared | m2tr | 180 | 165 | 7 750 | 594 | 0 | 8 344 | 257,54 | 3,81 % |
| 2143,22 | Granite sett | m2tr | 5 | 200 | 58 | 360 | 0 | 418 | 379,82 | 0,19 % |
| 2143,23 | Granite sett | m2tr | 125 | 200 | 743 | 720 | 0 | 1 462 | 36,33 | 0,67 % |
| 2143,24 | Rubble stone covering | m2tr | 820 | 10 | 200 | 195 | 0 | 395 | 1,72 | 0,18 % |
| 2144 | Landscape stone | kpl | 231 | 10 | 40 | 45 | 5 | 90 | 1,94 | 0,04 % |
| | | | | | 190 805 | 17 391 | 10 909 | 219 106 | 56 657 | 100 % |

| Vallikatu, Alt 1 | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Trans-portation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1141 | Removal of top soil | m2tr | 36 456 | 13 | 0 | 13 627 | 3 242 | 16 869 | 1,27 | 0,97 % |
| 1611A | Earth cut (excavation for quarrying) | m3ktr | 29 753 | 13 | 0 | 76 946 | 16 925 | 93 871 | 1,25 | 5,41 % |
| 1814 | Leighweight embankments, foamed glass | m3rtr | 19 491 | 90 | 1 135 838 | 7 617 | 14 365 | 1 157 820 | 226,30 | 66,72 % |
| 2111 | Filter course, sand | m3rtr | 5 895 | 13 | 11 960 | 11 015 | 7 144 | 30 118 | 2,81 | 1,74 % |
| 2112 | Geotextile N3 | m2tr | 36 456 | 510 | 7 619 | 1 265 | 0 | 8 884 | 1 282,63 | 0,51 % |
| 2121 | Sub-base, crushed rock | m3rtr | 6 622 | 13 | 25 460 | 14 524 | 11 269 | 51 253 | 3,62 | 2,95 % |
| 2131 | Unbound base course, crushed rock | m3rtr | 5 724 | 13 | 22 008 | 12 555 | 13 693 | 48 255 | 3,95 | 2,78 % |
| 2160 | Ramp filling | m3rtr | 5 965 | 13 | 0 | 13 042 | 1 914 | 14 956 | 1,18 | 0,86 % |
| 2141,11 | AB 11/100 (40 mm) | m2tr | 9 960 | 13 | 34 278 | 1 033 | 3 426 | 38 737 | 38,89 | 2,23 % |
| 2141,3 | AB 16/100 (40 mm) | m2tr | 9 550 | 13 | 32 867 | 994 | 3 285 | 37 146 | 38,90 | 2,14 % |
| 2141,13 | ABK 32/150 (60 mm) | m2tr | 19 510 | 13 | 100 718 | 3 022 | 6 711 | 110 450 | 37,74 | 6,36 % |
| 2211,2 | Kerb, concrete | m2tr | 371 | 165 | 47 254 | 2 968 | 0 | 50 222 | 209,43 | 2,89 % |
| 2310A | Top soil | m2tr | 8 651 | 20 | 1 736 | 3 329 | 555 | 5 620 | 2,67 | 0,32 % |
| 2310B | Top soil, bearing | m2tr | 8 295 | 20 | 28 974 | 28 013 | 14 116 | 71 103 | 4,01 | 4,10 % |
| | | | | | 1 448 711 | 189 949 | 96 644 | 1 735 304 | 1 855 | 100,00 % |

| Vallikatu, Alt 1B | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Trans-portations km * | Material emissions [kg CO2eq.] | Trans-portation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1141 | Removal of top soil | m2tr | 36 456 | 13 | 0 | 13 627 | 3 242 | 16 869 | 1,27 | 1,02 % |
| 1611B | Earth cut, soils utilised in the project | m3ktr | 29 753 | 1 | 0 | 5 919 | 16 925 | 22 844 | 0,30 | 1,38 % |
| 1814 | Leighweight embankments, foamed glass | m3rtr | 19 491 | 90 | 1 135 838 | 7 617 | 14 365 | 1 157 820 | 226,30 | 70,08 % |
| 2111 | Filter course, sand | m3rtr | 5 895 | 13 | 11 960 | 11 015 | 7 144 | 30 118 | 2,81 | 1,82 % |
| 2112 | Geotextile N3 | m2tr | 36 456 | 510 | 7 619 | 1 265 | 0 | 8 884 | 1 282,63 | 0,54 % |
| 2121 | Sub-base, crushed rock | m3rtr | 6 622 | 13 | 25 460 | 14 524 | 11 269 | 51 253 | 3,62 | 3,10 % |
| 2131 | Unbound base course, crushed rock | m3rtr | 5 724 | 13 | 22 008 | 12 555 | 13 693 | 48 255 | 3,95 | 2,92 % |
| 2160 | Ramp filling | m3rtr | 5 965 | 1 | 0 | 1 003 | 1 914 | 2 917 | 0,23 | 0,18 % |
| 2141,11 | AB 11/100 (40 mm) | m2tr | 9 960 | 13 | 34 278 | 1 033 | 3 426 | 38 737 | 38,89 | 2,34 % |
| 2141,3 | AB 16/100 (40 mm) | m2tr | 9 550 | 13 | 32 867 | 994 | 3 285 | 37 146 | 38,90 | 2,25 % |
| 2141,13 | ABK 32/150 (60 mm) | m2tr | 19 510 | 13 | 100 718 | 3 022 | 6 711 | 110 450 | 37,74 | 6,68 % |
| 2211,2 | Kerb, concrete | m2tr | 371 | 165 | 47 254 | 2 968 | 0 | 50 222 | 209,43 | 3,04 % |
| 2310A | Top soil | m2tr | 8 651 | 20 | 1 736 | 3 329 | 555 | 5 620 | 2,67 | 0,34 % |
| 2310B | Top soil, bearing | m2tr | 8 295 | 20 | 28 974 | 28 013 | 14 116 | 71 103 | 4,01 | 4,30 % |
| | | | | | 1 448 711 | 106 883 | 96 644 | 1 652 238 | 1 853 | 100,00 % |

| Vallikatu, Alt 2 | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Trans-portations km * | Material emissions [kg CO2eq.] | Trans-portation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1141A | Removal of top soil | m2tr | 36 456 | 13 | 0 | 13 627 | 3 242 | 16 869 | 1,27 | 0,39 % |
| 1611A | Earth cut, soils utilised in the project | m3ktr | 24 067 | 13 | 0 | 62 247 | 13 690 | 75 937 | 1,25 | 1,78 % |
| 14131 | Column stabilisation | mtr | 116 150 | 25 | 3 534 966 | 7 106 | 176 146 | 3 718 219 | 943,50 | 86,92 % |
| 2111 | Filter course, sand | m3rtr | 5 895 | 13 | 11 960 | 11 015 | 7 144 | 30 118 | 2,81 | 0,70 % |
| 2112 | Geotextile N3 | m2tr | 36 456 | 510 | 7 619 | 1 265 | 0 | 8 884 | 1 282,63 | 0,21 % |
| 2121 | Sub-base, crushed rock | m3rtr | 6 622 | 13 | 25 460 | 14 524 | 11 269 | 51 253 | 3,62 | 1,20 % |
| 2131 | Unbound base course, crushed rock | m3rtr | 5 724 | 13 | 22 008 | 12 555 | 13 693 | 48 255 | 3,95 | 1,13 % |
| 2160 | Ramp filling | m3rtr | 5 965 | 13 | 0 | 13 042 | 1 914 | 14 956 | 1,18 | 0,35 % |
| 2141,11 | AB 11/100 (40 mm) | m2tr | 9 960 | 13 | 34 278 | 1 033 | 3 426 | 38 737 | 38,89 | 0,91 % |
| 2141,3 | AB 16/100 (40 mm) | m2tr | 9 550 | 13 | 32 867 | 994 | 3 285 | 37 146 | 38,90 | 0,87 % |
| 2141,13 | ABK 32/150 (60 mm) | m2tr | 19 510 | 13 | 100 718 | 3 022 | 6 711 | 110 450 | 37,74 | 2,58 % |
| 2211,2 | Kerb, concrete | m2tr | 371 | 165 | 47 254 | 2 968 | 0 | 50 222 | 209,43 | 1,17 % |
| 2310A | Top soil | m2tr | 8 651 | 20 | 1 736 | 3 329 | 555 | 5 620 | 2,67 | 0,13 % |
| 2310B | Top soil, bearing | m2tr | 8 295 | 20 | 28 974 | 28 013 | 14 116 | 71 103 | 4,01 | 1,66 % |
| | | | | | 3 847 839 | 174 739 | 255 191 | 4 277 769 | 2 572 | 100,00 % |

| Vallikatu, Alt 2B | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Trans-portations km * | Material emissions [kg CO2eq.] | Trans-portation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1141A | Removal of top soil | m2tr | 36 456 | 13 | 0 | 13 627 | 3 242 | 16 869 | 1,27 | 0,76 % |
| 1611A | Earth cut, soils utilised in the project | m3ktr | 24 067 | 13 | 0 | 62 247 | 13 690 | 75 937 | 1,25 | 3,42 % |
| 14131 | Column stabilisation | mtr | 116 150 | 25 | 1 472 903 | 11 828 | 176 146 | 1 660 877 | 252,87 | 74,80 % |
| 2111 | Filter course, sand | m3rtr | 5 895 | 13 | 11 960 | 11 015 | 7 144 | 30 118 | 2,81 | 1,36 % |
| 2112 | Geotextile N3 | m2tr | 36 456 | 510 | 7 619 | 1 265 | 0 | 8 884 | 1 282,63 | 0,40 % |
| 2121 | Sub-base, crushed rock | m3rtr | 6 622 | 13 | 25 460 | 14 524 | 11 269 | 51 253 | 3,62 | 2,31 % |
| 2131 | Unbound base course, crushed rock | m3rtr | 5 724 | 13 | 22 008 | 12 555 | 13 693 | 48 255 | 3,95 | 2,17 % |
| 2160 | Ramp filling | m3rtr | 5 965 | 13 | 0 | 13 042 | 1 914 | 14 956 | 1,18 | 0,67 % |
| 2141,11 | AB 11/100 (40 mm) | m2tr | 9 960 | 13 | 34 278 | 1 033 | 3 426 | 38 737 | 38,89 | 1,74 % |
| 2141,3 | AB 16/100 (40 mm) | m2tr | 9 550 | 13 | 32 867 | 994 | 3 285 | 37 146 | 38,90 | 1,67 % |
| 2141,13 | ABK 32/150 (60 mm) | m2tr | 19 510 | 13 | 100 718 | 3 022 | 6 711 | 110 450 | 37,74 | 4,97 % |
| 2211,2 | Kerb, concrete | m2tr | 371 | 165 | 47 254 | 2 968 | 0 | 50 222 | 209,43 | 2,26 % |
| 2310A | Top soil | m2tr | 8 651 | 20 | 1 736 | 3 329 | 555 | 5 620 | 2,67 | 0,25 % |
| 2310B | Top soil, bearing | m2tr | 8 295 | 20 | 28 974 | 28 013 | 14 116 | 71 103 | 4,01 | 3,20 % |
| | | | | | 1 785 775 | 179 461 | 255 191 | 2 220 427 | 1 881 | 100,00 % |

| Perhekatu, Alt A | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1112 | Cutting of useful wood | m2tr | 750 | 20 | 0 | 30 | 0 | 30 | 3,39 | 0,00 % |
| 1141 | Removal of top soil | m2tr | 624 | 20 | 0 | 360 | 55 | 415 | 1,83 | 0,04 % |
| 1331 | Crush raft | m3rtr | 179 | 20 | 688 | 630 | 60 | 1 378 | 3,60 | 0,14 % |
| 1413.1A | **Siirtymärakenne (transportation of clay)** | m3ktr | 140 | 3 | 0 | 85 | 80 | 166 | 0,47 | 0,02 % |
| 1413.1B | **Siirtymärakenne (crushed rock)** | m3ktr | 140 | 20 | 538 | 480 | 47 | 1 065 | 3,56 | 0,11 % |
| 1413.1C | Column stabilisation | mtr | 30 500 | 30 | 840 894 | 3 076 | 46 254 | 890 225 | 632,02 | 88,89 % |
| 1422 | EPS frost insulation | m2tr | 303 | 60 | 1 788 | 108 | 0 | 1 896 | 3 128,12 | 0,19 % |
| 1431.22 | Drainage | mtr | 860 | 20 | 2 424 | 36 | 0 | 2 460 | 4 620,41 | 0,25 % |
| 1432 | Drainage well | kpl | 1 | 20 | 155 | 36 | 0 | 191 | 3 824,80 | 0,02 % |
| 1435.32A | Culvert | mtr | 6 | 20 | 43 | 36 | 0 | 79 | 2 621,33 | 0,01 % |
| 1435.32B | Culvert | mtr | 19 | 20 | 135 | 36 | 0 | 171 | 1 710,70 | 0,02 % |
| 1613 | Earth cut (transportation of soil masses for depositing) | m3ktr | 2 139 | 3 | 0 | 1 165 | 966 | 2 131 | 0,43 | 0,21 % |
| 1621 | Excavation of pipe trench, soil masses for depositing | m3ktr | 1 520 | 3 | 0 | 828 | 686 | 1 514 | 0,43 | 0,15 % |
| 1713 | Blasting of rock, rock masses for depositing | m3ktr | 42 | 3 | 0 | 36 | 95 | 131 | 0,87 | 0,01 % |
| 1721 | Pipe and conduit trenches | m3ktr | 16 | 3 | 0 | 13 | 36 | 50 | 0,87 | 0,00 % |
| 1811.19 | Earth embankment, soils from the project | m3rtr | 204 | 1 | 0 | 40 | 260 | 301 | 0,59 | 0,03 % |
| 1812.1 | Ramp filling, masses from the area | m3rtr | 662 | 1 | 0 | 132 | 212 | 344 | 0,21 | 0,03 % |
| 1831 | Bedrock | m3rtr | 136 | 20 | 523 | 480 | 51 | 1 054 | 3,63 | 0,11 % |
| 1832A | Initial crush filling | m3rtr | 712 | 20 | 2 737 | 2 429 | 248 | 5 415 | 3,56 | 0,54 % |
| 1832B | Background filling, crush | m3rtr | 5 | 20 | 19 | 30 | 2 | 51 | 4,77 | 0,01 % |
| 1833 | Final filling, crush | m3rtr | 504 | 20 | 1 938 | 1 710 | 176 | 3 823 | 3,55 | 0,38 % |
| 1837 | **Johtokaivantojen virtaussulut** | kpl | 8 | 1 | 0 | 1 | 3 | 5 | 0,21 | 0,00 % |
| 2112 | Geotextile N3 | m2tr | 8 868 | 510 | 3 015 | 1 002 | 0 | 4 017 | 2 384,18 | 0,40 % |
| 2121.2 | Sub-base, crushed rock 0-63 | m3rtr | 3 762 | 20 | 14 464 | 12 687 | 6 402 | 33 553 | 4,18 | 3,35 % |
| 2131 | Unbound base course, crushed | m3rtr | 774 | 20 | 2 976 | 2 639 | 1 852 | 7 467 | 4,52 | 0,75 % |
| 2141.11 | AB 11/100 | m2tr | 1 314 | 16 | 4 522 | 168 | 452 | **5 142** | 39,13 | 0,51 % |
| 2141.13 | ABK 32/200 | m2tr | 3 227 | 16 | 22 212 | 816 | 1 110 | **24 138** | 37,40 | 2,41 % |
| 2141.3 | SMA 16/100 | m2tr | 3 163 | 16 | 10 881 | 408 | 1 088 | **12 377** | 39,13 | 1,24 % |
| 2161 | **Piennartäyte, crushed rock 0/16** | m3rtr | 13 | 20 | 50 | 60 | 4 | 114 | 4,11 | 0,01 % |
| 2211.22 | Kerb | mtr | 122 | 165 | 1 491 | 297 | 0 | 1 787 | 432,18 | 0,18 % |
| | | | | SUM | 911 493 | 29 855 | 60 141 | 1 001 489 | | 100,00 % |

| Perhekatu, Alt B | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1112 | Cutting of useful wood | m2tr | 750 | 20 | 0 | 30 | 0 | 30 | 3,39 | 0,00 % |
| 1141 | Removal of top soil | m2tr | 624 | 20 | 0 | 234 | 55 | 289 | 1,27 | 0,03 % |
| 1331 | Crush raft | m3rtr | 179 | 20 | 688 | 630 | 60 | 1 378 | 3,60 | 0,14 % |
| 1413.1A | **Siirtymärakenne (transportation of clay)** | m3ktr | 140 | 20 | 0 | 570 | 80 | 650 | 1,84 | 0,06 % |
| 1413.1B | **Siirtymärakenne (crushed rock)** | m3ktr | 140 | 20 | 538 | 480 | 47 | 1 065 | 3,56 | 0,11 % |
| 1413.1C | Column stabilisation | mtr | 30 500 | 30 | 840 894 | 3 076 | 46 254 | 890 225 | 632,02 | 87,84 % |
| 1422 | EPS frost insulation | m2tr | 303 | 60 | 1 788 | 108 | 0 | 1 896 | 3 128,12 | 0,19 % |
| 1431.22 | Drainage | mtr | 860 | 20 | 2 424 | 36 | 0 | 2 460 | 4 620,41 | 0,24 % |
| 1432 | Drainage well | kpl | 1 | 20 | 155 | 36 | 0 | 191 | 3 824,80 | 0,02 % |
| 1435.32A | Culvert | mtr | 6 | 20 | 43 | 36 | 0 | 79 | 2 621,33 | 0,01 % |
| 1435.32B | Culvert | mtr | 19 | 20 | 135 | 36 | 0 | 171 | 1 710,70 | 0,02 % |
| 1613 | Earth cut (transportation of soil masses for depositing) | m3ktr | 2 139 | 20 | 0 | 7 768 | 966 | 8 734 | 1,78 | 0,86 % |
| 1621 | Excavation of pipe trench, soil masses for depositing | m3ktr | 1 520 | 20 | 0 | 5 519 | 686 | 6 205 | 1,77 | 0,61 % |
| 1713 | Blasting of rock, rock masses for depositing | m3ktr | 42 | 20 | 0 | 240 | 95 | 335 | 2,24 | 0,03 % |
| 1721 | Pipe and conduit trenches | m3ktr | 16 | 20 | 0 | 90 | 36 | 126 | 2,21 | 0,01 % |
| 1811.19 | Earth embankment, soils from the project | m3rtr | 204 | 1 | 0 | 40 | 260 | 301 | 0,59 | 0,03 % |
| 1812.1 | Ramp filling, masses from the area | m3rtr | 662 | 1 | 0 | 132 | 212 | 344 | 0,21 | 0,03 % |
| 1831 | Bedrock | m3rtr | 136 | 20 | 523 | 480 | 51 | 1 054 | 3,63 | 0,10 % |
| 1832A | Initial crush filling | m3rtr | 712 | 20 | 2 737 | 2 429 | 248 | 5 415 | 3,56 | 0,53 % |
| 1832B | Background filling, crush | m3rtr | 5 | 20 | 19 | 30 | 2 | 51 | 4,77 | 0,01 % |
| 1833 | Final filling, crush | m3rtr | 504 | 20 | 1 938 | 1 710 | 176 | 3 823 | 3,55 | 0,38 % |
| 1837 | **Johtokaivantojen virtaussulut** | kpl | 8 | 1 | 0 | 1 | 3 | 5 | 0,21 | 0,00 % |
| 2112 | Geotextile N3 | m2tr | 8 868 | 510 | 3 015 | 1 002 | 0 | 4 017 | 2 384,18 | 0,40 % |
| 2121.2 | Sub-base, crushed rock 0-63 | m3rtr | 3 762 | 20 | 14 464 | 12 687 | 6 402 | 33 553 | 4,18 | 3,31 % |
| 2131 | Unbound base course, crushed rock 0-32 | m3rtr | 774 | 20 | 2 976 | 2 639 | 1 852 | 7 467 | 4,52 | 0,74 % |
| 2141.11 | AB 11/100 | m2tr | 1 314 | 16 | 4 522 | 168 | 452 | 5 142 | 39,13 | 0,51 % |
| 2141.13 | ABK 32/200 | m2tr | 3 227 | 16 | 22 212 | 816 | 1 110 | 24 138 | 37,40 | 2,38 % |
| 2141.3 | SMA 16/100 | m2tr | 3 163 | 16 | 10 881 | 408 | 1 088 | 12 377 | 39,13 | 1,22 % |
| 2161 | **Piennartäyte, crushed rock 0/16** | m3rtr | 13 | 20 | 50 | 60 | 4 | 114 | 4,11 | 0,01 % |
| 2211.22 | Kerb | mtr | 122 | 165 | 1 491 | 297 | 0 | 1 787 | 432,18 | 0,18 % |
| | | | | SUMMA | 911 493 | 41 787 | 60 141 | 1 013 421 | | 100,00 % |

# Appendix 4. Tampere case results

| Kauhakorvenkatu, ALT1 | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq. /ton] | Share of absolute total emissions [%] |
| 1112 | Removal of rocks | kpl | 45 | 2 | 0 | 39 | 12 | 51 | 0,21 | 0,01 % |
| 1133 | Demolition of wood columns | kpl | 5 | 2 | 0 | 3 | 1 | 4 | 33,23 | 0,00 % |
| 1141 | Removal of top soil | m2tr | 11 539 | 2 | 0 | 927 | 1 255 | 2 182 | 0,37 | 0,48 % |
| 1151A | Removal of asphalt | m2tr | 85 | 2 | 0 | 9 | 9 | 18 | 0,40 | 0,00 % |
| 1151B | Milling of asphalt | m2tr | 565 | 2 | 0 | 48 | 92 | 140 | 0,46 | 0,03 % |
| 1159 | Kerb removal | mtr | 20 | 1 | 0 | 1 | 0 | 1 | 0,24 | 0,00 % |
| 1321 | Steel pipe column RR170/10 | mtr | 1 166 | 90 | 112 321 | 324 | 2 701 | 115 346 | 2 536,52 | 25,63 % |
| 1326 | Pile slab | erä | 1 | 10 | 15 188 | 72 | 0 | 15 260 | 162,77 | 3,39 % |
| 1327 | Pile cabs | kpl | 132 | 90 | 7 042 | 162 | 0 | 7 204 | 2 526,79 | 1,60 % |
| 1331 | Crush raft | m3rtr | 170 | 20 | 654 | 600 | 57 | 1 311 | 3,61 | 0,29 % |
| 1421A | XPS frost insulation (100 mm) | m2tr | 125 | 160 | 1 435 | 288 | 0 | 1 723 | 137,83 | 0,38 % |
| 1421B | XPS frost insulation for water pipe (100 mm) | m2tr | 285 | 160 | 3 272 | 0 | 0 | 3 272 | 114,80 | 0,73 % |
| 1421C | XPS frost insulation for water pipe (50 mm) | m2tr | 15 | 160 | 86 | 0 | 0 | 86 | 114,80 | 0,02 % |
| 1431 | Drainage in the structure | mtr | 477 | 60 | 1 344 | 108 | 0 | 1 452 | 4 918,39 | 0,32 % |
| 1432 | Drainage inspection wells | kpl | 6 | 60 | 932 | 108 | 0 | 1 040 | | 0,23 % |
| 1434A | Concrete pipe culvert | mtr | 26 | 10 | 1 614 | 18 | 0 | 1 632 | 75,29 | 0,36 % |
| 1434B | Plastic pipe culvert | mtr | 12 | 60 | 85 | 108 | 0 | 193 | 3 179,43 | 0,04 % |
| 1612 | Excavation | m3ktr | 3 575 | 1 | 0 | 649 | 1 614 | 2 263 | 0,28 | 0,50 % |
| 1613 | Excavation | m3ktr | 5 756 | 2 | 0 | 2 291 | 3 307 | 5 599 | 0,39 | 1,24 % |
| 1621A | Installation of cable protection pipe | mtr | 826 | 0 | 925 | 0 | 0 | 925 | | 0,21 % |
| 1621B | Excavation of pipe trench | m3ktr | 1 271 | 2 | 0 | 507 | 713 | 1 219 | 0,38 | 0,27 % |
| 1625 | Excavation for mass exchange | m3ktr | 13 273 | 2 | 0 | 5 282 | 7 441 | 12 723 | 0,38 | 2,83 % |
| 1632 | Permanent steel pile wall | m2tr | 400 | 700 | 41 265 | 4 728 | 258 | 46 251 | 1 050,21 | 10,28 % |
| 1712 | Rock blasting, square blasting h < 1 m | m2tr | 484 | 1 | 0 | 136 | 932 | 1 069 | 0,62 | 0,24 % |
| 1721A | Canal blasting | m3ktr | 190 | 1 | 0 | 54 | 366 | 420 | 0,62 | 0,09 % |
| 1721B | Rock canal, square blasting | m2tr | 44 | 1 | 0 | 13 | 85 | 98 | 0,63 | 0,02 % |
| 1811A | Crush embankment | m3rtr | 2 048 | 20 | 7 874 | 6 928 | 2 354 | 17 156 | 3,92 | 3,81 % |
| 1811B | Moraine embankment | m3rtr | 456 | 1 | 0 | 0 | 524 | 524 | 0,43 | 0,12 % |
| 1816 | Preload embankment, rock crush | m3rtr | 280 | 20 | 1 077 | 960 | 322 | 2 358 | 3,94 | 0,52 % |
| 1817A | Ditch covering with crush | m3rtr | 488 | 20 | 1 876 | 1 650 | 157 | 3 682 | 3,53 | 0,82 % |
| 1817B | Slope filling with excavated masses | m3rtr | 456 | 1 | 0 | 0 | 146 | 146 | 0,12 | 0,03 % |
| 1831A | Levelling course, crush 0/16 | m3rtr | 10 | 20 | 38 | 60 | 4 | 102 | 4,78 | 0,02 % |
| 1831B | Levelling course, crush 0/16 | m3rtr | 101 | 20 | 388 | 360 | 38 | 786 | 3,64 | 0,17 % |
| 1832A | Initial filling, crush 0/16 | m3rtr | 51 | 20 | 196 | 180 | 18 | 394 | 3,62 | 0,09 % |
| 1832B | Initial filling, crush 0/16 | m3rtr | 729 | 20 | 2 803 | 2 459 | 254 | 5 517 | 3,54 | 1,23 % |
| 1833 | Final filling with excavated masses | m3rtr | 466 | 1 | 0 | 99 | 163 | 262 | 0,21 | 0,06 % |
| 1836A | Mass exchange filling (moraine) | m3rtr | 2 663 | 1 | 0 | 561 | 1 403 | 1 963 | 0,28 | 0,44 % |
| 1836B | Mass exchange filling (crush) | m3rtr | 825 | 1 | 0 | 121 | 435 | 556 | 0,36 | 0,12 % |
| 1836C | Mass exchange filling (blasted rock) | m3rtr | 7 735 | 3 | 32 162 | 1 431 | 4 074 | 37 667 | 6,24 | 8,37 % |
| 1836D | Mass exchange filling (crush 0/90) | m3rtr | 2 050 | 3 | 7 882 | 1 039 | 1 080 | 10 001 | 2,28 | 2,22 % |
| 2111 | Drainage course, sand | m3rtr | 1 465 | 20 | 3 496 | 7 888 | 2 088 | 13 472 | 2,70 | 2,99 % |
| 2112 | Geotextile N3 | m2tr | 3 360 | 700 | 1 142 | 1 036 | 0 | 2 178 | 2 818,85 | 0,48 % |
| 2121 | Sub-base, crush 0/90 | m3rtr | 5 275 | 20 | 20 281 | 17 815 | 8 977 | 47 073 | 4,18 | 10,46 % |
| 2131 | Unbound base course, crush 0/32 | m3rtr | 1 039 | 20 | 3 995 | 3 509 | 2 485 | 9 989 | 4,50 | 2,22 % |
| 2141A | AB 11/100 (40 mm) | m2tr | 3 110 | 20 | 10 698 | 510 | 1 071 | 12 279 | 39,48 | 2,73 % |
| 2141B | SMA 22/125 (50 mm) | m2tr | 7 540 | 20 | 32 422 | 1 500 | 2 597 | 36 518 | 38,75 | 8,11 % |
| 2141C | ABK 32/125 (50 mm) | m2tr | 4 550 | 20 | 19 565 | 900 | 1 567 | 22 032 | 38,74 | 4,89 % |
| 2141D | AB 16/125 Kerb joint | jm | 20 | 20 | 26 | 30 | 2 | 58 | 77,14 | 0,01 % |
| 2141E | Cover fastening to the base | m2tr | 2 990 | 20 | 153 | 30 | 0 | 183 | 305,82 | 0,04 % |
| 2143 | Concrete stone covering | m2tr | 155 | 15 | 3 233 | 54 | 51 | 3 338 | 119,65 | 0,74 % |
| 2161 | Bank filling crush 0/16 | m3rtr | 48 | 20 | 185 | 180 | 15 | 380 | 3,71 | 0,08 % |
| | | | | | 335 657 | 65 775 | 48 667 | 450 099 | 18 349 | 100,00 % |

| Kauhakorvenkatu, ALT2 | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq. /ton] | Share of absolute total emissions [%] |
| 1112 | Removal of rocks | kpl | 45 | 2 | 0 | 39 | 12 | 51 | 0,21 | 0,01 % |
| 1133 | Demolition of wood columns | kpl | 5 | 2 | 0 | 3 | 1 | 4 | 33,23 | 0,00 % |
| 1141 | Removal of top soil | m2tr | 11 539 | 2 | 0 | 927 | 1 255 | 2 182 | 0,37 | 0,57 % |
| 1151A | Removal of asphalt | m2tr | 85 | 2 | 0 | 9 | 9 | 18 | 0,40 | 0,00 % |
| 1151B | Milling of asphalt | m2tr | 565 | 2 | 0 | 48 | 92 | 140 | 0,46 | 0,04 % |
| 1159 | Kerb removal | mtr | 20 | 1 | 0 | 1 | 0 | 1 | 0,24 | 0,00 % |
| 1321 | Steel pipe column RR170/10 | mtr | 1 166 | 90 | 112 321 | 324 | 2 701 | 115 346 | 2 536,52 | 30,15 % |
| 1326 | Pile slab | erä | 1 | 10 | 15 188 | 72 | 0 | 15 260 | 162,77 | 3,99 % |
| 1327 | Pile cabs | kpl | 132 | 90 | 7 042 | 162 | 0 | 7 204 | 2 526,79 | 1,88 % |
| 1331 | Crush raft | m3rtr | 170 | 20 | 654 | 600 | 57 | 1 311 | 3,61 | 0,34 % |
| 1421A | XPS frost insulation (100 mm) | m2tr | 125 | 160 | 1 435 | 288 | 0 | 1 723 | 137,83 | 0,45 % |
| 1421B | XPS frost insulation for water pipe (100 mm) | m2tr | 285 | 160 | 3 272 | 0 | 0 | 3 272 | 114,80 | 0,86 % |
| 1421C | XPS frost insulation for water pipe (50 mm) | m2tr | 15 | 160 | 86 | 0 | 0 | 86 | 114,80 | 0,02 % |
| 1431 | Drainage in the structure | mtr | 477 | 60 | 1 344 | 108 | 0 | 1 452 | 4 918,39 | 0,38 % |
| 1432 | Drainage inspection wells | kpl | 6 | 60 | 932 | 108 | 0 | 1 040 | | 0,27 % |
| 1434A | Concrete pipe culvert | mtr | 26 | 10 | 1 614 | 18 | 0 | 1 632 | 75,29 | 0,43 % |
| 1434B | Plastic pipe culvert | mtr | 12 | 60 | 85 | 108 | 0 | 193 | 3 179,43 | 0,05 % |
| 1612 | Excavation | m3ktr | 3 575 | 1 | 0 | 649 | 1 614 | 2 263 | 0,28 | 0,59 % |
| 1613 | Excavation | m3ktr | 5 756 | 2 | 0 | 2 291 | 3 307 | 5 599 | 0,39 | 1,46 % |
| 1621A | Installation of cable protection pipe | mtr | 826 | 0 | 925 | 0 | 0 | 925 | | 0,24 % |
| 1621B | Excavation of pipe trench | m3ktr | 1 271 | 2 | 0 | 507 | 713 | 1 219 | 0,38 | 0,32 % |
| 1625 | Excavation for mass exchange | m3ktr | 13 273 | 2 | 0 | 5 282 | 7 441 | 12 723 | 0,38 | 3,32 % |
| 1632 | Permanent steel pile wall | m2tr | 400 | 700 | 41 265 | 4 728 | 258 | 46 251 | 1 050,21 | 12,09 % |
| 1712 | Canal blasting | m2tr | 484 | 1 | 0 | 136 | 932 | 1 069 | 0,62 | 0,28 % |
| 1721A | Rock canal, square blasting | m3ktr | 190 | 1 | 0 | 54 | 366 | 420 | 0,62 | 0,11 % |
| 1721B | Crush embankment | m2tr | 44 | 1 | 0 | 13 | 85 | 98 | 0,63 | 0,03 % |
| 1811A | Moraine embankment | m3rtr | 2 048 | 3 | 7 874 | 1 039 | 2 354 | 11 267 | 2,58 | 2,94 % |
| 1811B | Preload embankment, rock crush | m3rtr | 456 | 1 | 0 | 0 | 524 | 524 | 0,43 | 0,14 % |
| 1816 | Ditch covering with crush | m3rtr | 280 | 3 | 1 077 | 144 | 322 | 1 542 | 2,58 | 0,40 % |
| 1817A | Slope filling with excavated masses | m3rtr | 488 | 3 | 1 876 | 247 | 157 | 2 280 | 2,19 | 0,60 % |
| 1817B | Levelling course, crush 0/16 | m3rtr | 456 | 1 | 0 | 0 | 146 | 146 | 0,12 | 0,04 % |
| 1831A | Levelling course, crush 0/16 | m3rtr | 10 | 3 | 38 | 9 | 4 | 51 | 2,40 | 0,01 % |
| 1831B | Initial filling, crush 0/16 | m3rtr | 101 | 3 | 388 | 54 | 38 | 480 | 2,23 | 0,13 % |
| 1832A | Initial filling, crush 0/16 | m3rtr | 51 | 3 | 196 | 27 | 18 | 241 | 2,21 | 0,06 % |
| 1832B | Initial filling, crush 0/16 | m3rtr | 729 | 3 | 2 803 | 369 | 254 | 3 426 | 2,20 | 0,90 % |
| 1833 | Final filling with excavated masses | m3rtr | 466 | 1 | 0 | 99 | 163 | 262 | 0,21 | 0,07 % |
| 1836A | Mass exchange filling (moraine) | m3rtr | 2 663 | 1 | 0 | 561 | 1 403 | 1 963 | 0,28 | 0,51 % |
| 1836B | Mass exchange filling (crush) | m3rtr | 825 | 1 | 0 | 121 | 435 | 556 | 0,36 | 0,15 % |
| 1836C | Mass exchange filling (crushed concrete) | m3rtr | 7 735 | 20 | 0 | 9 537 | 4 074 | 13 612 | 2,26 | 3,56 % |
| 1836D | Mass exchange filling (crushed concrete) | m3rtr | 2 050 | 20 | 0 | 6 928 | 1 080 | 8 008 | 1,83 | 2,09 % |
| 2111 | Drainage course, ash | m3rtr | 1 465 | 20 | 0 | 7 888 | 2 088 | 9 976 | 2,00 | 2,61 % |
| 2112 | Geotextile N3 | m2tr | 3 360 | 700 | 1 142 | 1 036 | 0 | 2 178 | 2 818,85 | 0,57 % |
| 2121 | Sub-base, crush 0/90 20 %, crushed concrete 80 % | m3rtr | 5 275 | 17 | 4 056 | 14 787 | 7 181 | 26 024 | 2,89 | 6,80 % |
| 2131 | Unbound base course, crush 0/32 | m3rtr | 1 039 | 3 | 3 995 | 526 | 2 485 | 7 007 | 3,16 | 1,83 % |
| 2141A | AB 11/100 (40 mm) | m2tr | 3 110 | 20 | 9 629 | 510 | 1 071 | 11 210 | 36,04 | 2,93 % |
| 2141B | SMA 22/125 (50 mm) | m2tr | 7 540 | 20 | 32 422 | 1 500 | 2 597 | 36 518 | 38,75 | 9,54 % |
| 2141C | ABK 32/125 (50 mm) | m2tr | 4 550 | 20 | 17 609 | 900 | 1 567 | 20 075 | 35,30 | 5,25 % |
| 2141D | AB 16/125 Kerb joint | jm | 20 | 20 | 23 | 30 | 2 | 55 | 73,70 | 0,01 % |
| 2141E | Cover fastening to the base | m2tr | 2 990 | 20 | 153 | 30 | 0 | 183 | 305,82 | 0,05 % |
| 2143 | Concrete stone covering | m2tr | 155 | 15 | 3 233 | 54 | 51 | 3 338 | 119,65 | 0,87 % |
| 2161 | Bank filling crush 0/16 | m3rtr | 48 | 3 | 185 | 27 | 15 | 227 | 2,21 | 0,06 % |
| | | | | | **272 863** | **62 899** | **46 872** | **382 634** | **18 319** | 100,00 % |

| Arvo Ylpön katu, ALT1 | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1111 | Removal of waste wood, vegetation and top soil | m2tr | 21 270 | 12 | 0 | 7 342 | 1 891 | 9 233 | 1,19 | 2,52 % |
| 1131 | Change of well cover, including pipe valves, renewal of upper well to 1 m depth, demolition of current cover and excavation and filling of new covering | kpl | 7 | 0 | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1151A | Removal of asphalt by milling | m2tr | 170 | 22 | 0 | 132 | 28 | 160 | 2,50 | 0,04 % |
| 1151B | Removal of asphalt by excavation | m2tr | 5 195 | 22 | 0 | 3 398 | 1 076 | 4 474 | 2,30 | 1,22 % |
| 1431.2 | Drainage in the construction | mtr | 1 130 | 60 | 0 | 108 | 0 | 108 | *0,00* | 0,03 % |
| 1432 | Drainage inspection wells | kpl | 10 | 60 | 1 553 | 108 | 0 | 1 661 | *0,00* | 0,45 % |
| 1434.1 | Concrete culvert | m | 21 | 10 | 486 | 15 | 64 | 564 | 322,52 | 0,15 % |
| 1612 | Excavation | m3ktr | 1 711 | 1 | 0 | 246 | 761 | 1 007 | 0,32 | 0,27 % |
| 1613 | Earth cut and excavation of pipe trench | m3ktr | 12 190 | 12 | 0 | 21 018 | 5 420 | 26 438 | 1,19 | 7,21 % |
| 1621A | Pipe trench, excavation of preloading structure | m3ktr | 51 | 1 | 0 | 15 | 32 | 47 | 0,26 | 0,01 % |
| 1621B | Installation of cable protection pipe | mtr | 670 | 60 | 803 | 108 | 9 | 920 | 228,89 | 0,25 % |
| 1621C | Installation of cable protection pipe | mtr | 980 | 60 | 1 175 | 90 | 13 | 1 278 | 217,34 | 0,35 % |
| 1621D | Cable trench | mtr | 1 200 | 16 | 94 | 144 | 1 013 | 1 251 | 11,46 | 0,34 % |
| 1621E | Excavation of pipe trench and transportation | m3ktr | 1 700 | 0 | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1621F | Pipe trench, excavation of blasted rock of preloading structure | m3ktr | 2 340 | 1 | 0 | 658 | 2 474 | 3 132 | 0,38 | 0,85 % |
| 1622 | Culvert trench excvation | mtr | 39 | 12 | 0 | 378 | 90 | 468 | 1,19 | 0,13 % |
| 1625 | Mass exchange excavations | m3ktr | 13 980 | 12 | 0 | 33 381 | 8 033 | 41 414 | 1,18 | 11,30 % |
| 1631 | Trench support | m | 90 | | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1711A | Blasting of rock | m2tr | 475 | 1 | 0 | 133 | 596 | 729 | 0,43 | 0,20 % |
| 1711B | Blasting of rock | m3ktr | 12 730 | 1 | 0 | 3 578 | 28 691 | 32 269 | 0,71 | 8,80 % |
| 1721A | Pipe and cable canals, h<1 m | m2tr | 335 | 1 | 0 | 0 | 884 | 884 | *0,00* | 0,24 % |
| 1721B | Pipe and cable canals, h<1 m | m3ktr | 1 900 | 1 | 0 | 534 | 5 015 | 5 549 | 0,82 | 1,51 % |
| 1762 | Blasted hollows and holes | kpl | 12 | 1 | 0 | 12 | 101 | 113 | 0,78 | 0,03 % |
| 1811.29 | Blasted rock embankment inside the project | m3rtr | 4 790 | 1 | 0 | 922 | 1 603 | 2 526 | 0,22 | 0,69 % |
| 1811.9 | Earth embankment, ramp filling and final filling | m3rtr | 3 320 | 1 | 0 | 727 | 5 051 | 5 778 | 0,63 | 1,58 % |
| 1831 | Crushed rock fillings | m3rtr | 20 388 | 16 | 13 549 | 9 381 | 30 608 | 53 538 | 7,22 | 14,61 % |
| 1834 | Mass exchange share of concrete crush | m3rtr | 4 100 | 2 | 0 | 1 037 | 803 | 1 840 | 0,21 | 0,50 % |
| 1836 | Mass exchange filling to the hard bottom, blasted rock inside the project | m3rtr | 9 880 | 1 | 0 | 1 666 | 1 936 | 3 602 | 0,17 | 0,98 % |
| 2112 | Geotextile N3 | m2tr | 18 770 | 510 | 6 382 | 1 096 | 0 | 7 478 | 2 096,92 | 2,04 % |
| 2132.1 | Kerb stone joint, ABK 32/150 + Ab 16/100 | mtr | 22 | 16 | 38 | 24 | 0 | 62 | 56,23 | 0,02 % |
| 2141 | AB or SMA (40 mm) | m2tr | 14 426 | 22 | 49 648 | 2 507 | 4 968 | 57 124 | 39,60 | 15,58 % |
| 2141.13 | ABK 32 / 150 (60 mm) | m2tr | 9 600 | 22 | 49 559 | 2 507 | 3 306 | 55 372 | 38,45 | 15,11 % |
| 2143.11 | Concrete stone covering | m2tr | 1 247 | 15 | 26 849 | 243 | 0 | 27 092 | 120,70 | 7,39 % |
| 2144.3 | Granite sett covering | m2tr | 33 | 15 | 201 | 27 | 0 | 228 | 21,47 | 0,06 % |
| 2144.4 | Rubble stone covering | kpl | 3 | 15 | 1 | 0 | 0 | 1 | 0,87 | 0,00 % |
| 2145.2 | Crush covering and slope covering | m2tr | 1 620 | 16 | 527 | 384 | 50 | 961 | 3,33 | 0,26 % |
| 2146.2 | Covering, fines from aggregate production | m2tr | 6 270 | 16 | 0 | 744 | 1 937 | 2 681 | 4,70 | 0,73 % |
| 2151 | Transition wedge | m3rtr | 176 | 16 | 767 | 552 | 45 | 1 364 | 3,25 | 0,37 % |
| 2211.1A | Kerb, natural stone | mtr | 787 | 6 | 6 335 | 43 | 0 | 6 379 | 73,68 | 1,74 % |
| 2211.1B | Kerb, natural stone | mtr | 923 | 50 | 8 362 | 450 | 0 | 8 812 | 86,79 | 2,40 % |
| | | | | | **166 329** | **93 710** | **106 498** | **366 537** | **3 348** | 100 % |

| Arvo Ylpön katu, ALT2 (Crushed concrete was not utilised, kerbs were not recycled) | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1111 | Removal of waste wood, vegetation and top soil | m2tr | 21 270 | 12 | 0 | 7 342 | 1 891 | 9 233 | 1,19 | 2,37 % |
| 1131 | Change of well cover, including pipe valves, renewal of upper well to 1 m depth, demolition of current cover and excavation and filling of new covering | kpl | 7 | 0 | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1151A | Removal of asphalt by milling | m2tr | 170 | 22 | 0 | 132 | 28 | 160 | 2,50 | 0,04 % |
| 1151B | Removal of asphalt by excavation | m2tr | 5 195 | 22 | 0 | 3 398 | 1 076 | 4 474 | 2,30 | 1,15 % |
| 1431.2 | Drainage in the construction | mtr | 1 130 | 60 | 0 | 108 | 0 | 108 | *0,00* | 0,03 % |
| 1432 | Drainage inspection wells | kpl | 10 | 60 | 1 553 | 108 | 0 | 1 661 | *0,00* | 0,43 % |
| 1434.1 | Concrete culvert | m | 21 | 10 | 486 | 15 | 64 | 564 | 322,52 | 0,15 % |
| 1612 | Excavation | m3ktr | 1 711 | 1 | 0 | 246 | 761 | 1 007 | 0,32 | 0,26 % |
| 1613 | Earth cut and excavation of pipe trench | m3ktr | 12 190 | 12 | 0 | 21 018 | 5 420 | 26 438 | 1,19 | 6,80 % |
| 1621A | Pipe trench, excavation of preloading structure | m3ktr | 51 | 1 | 0 | 15 | 32 | 47 | 0,26 | 0,01 % |
| 1621B | Installation of cable protection pipe | mtr | 670 | 60 | 803 | 108 | 9 | 920 | 228,89 | 0,24 % |
| 1621C | Installation of cable protection pipe | mtr | 980 | 60 | 1 175 | 90 | 13 | 1 278 | 217,34 | 0,33 % |
| 1621D | Cable trench | mtr | 1 200 | 16 | 94 | 144 | 1 013 | 1 251 | 11,46 | 0,32 % |
| 1621E | Excavation of pipe trench and transportation | m3ktr | 1 700 | 0 | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1621F | Pipe trench, excavation of blasted rock of preloading structure | m3ktr | 2 340 | 1 | 0 | 658 | 2 474 | 3 132 | 0,38 | 0,81 % |
| 1622 | Culvert trench excvation | mtr | 39 | 12 | 0 | 378 | 90 | 468 | 1,19 | 0,12 % |
| 1625 | Mass exchange excavations | m3ktr | 13 980 | 12 | 0 | 33 381 | 8 033 | 41 414 | 1,18 | 10,65 % |
| 1631 | Trench support | m | 90 | | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1711A | Blasting of rock | m2tr | 475 | 1 | 0 | 133 | 596 | 729 | 0,43 | 0,19 % |
| 1711B | Blasting of rock | m3ktr | 12 730 | 1 | 0 | 3 578 | 28 691 | 32 269 | 0,71 | 8,30 % |
| 1721A | Pipe and cable canals, h<1 m | m2tr | 335 | 1 | 0 | 0 | 884 | 884 | *0,00* | 0,23 % |
| 1721B | Pipe and cable canals, h<1 m | m3ktr | 1 900 | 1 | 0 | 534 | 5 015 | 5 549 | 0,82 | 1,43 % |
| 1762 | Blasted hollows and holes | kpl | 12 | 1 | 0 | 12 | 101 | 113 | 0,78 | 0,03 % |
| 1811.29 | Blasted rock embankment inside the project | m3rtr | 4 790 | 1 | 0 | 922 | 1 603 | 2 526 | 0,22 | 0,65 % |
| 1811.9 | Earth embankment, ramp filling and final filling | m3rtr | 3 320 | 1 | 0 | 727 | 5 051 | 5 778 | 0,63 | 1,49 % |
| 1831 | Crushed rock fillings | m3rtr | 20 388 | 16 | 13 549 | 9 381 | 30 608 | 53 538 | 7,22 | 13,77 % |
| 1834 | Mass exchange, blasted rock | m3rtr | 4 100 | 16 | 11 181 | 11 061 | 803 | 23 045 | 2,63 | 5,93 % |
| 1836 | Mass exchange filling to the hard bottom, blasted rock inside the project | m3rtr | 9 880 | 1 | 0 | 1 666 | 1 936 | 3 602 | 0,17 | 0,93 % |
| 2112 | Geotextile N3 | m2tr | 18 770 | 510 | 6 382 | 1 096 | 0 | 7 478 | 2 096,92 | 1,92 % |
| 2132.1 | Kerb stone joint, ABK 32/150 + Ab 16/100 | mtr | 22 | 16 | 38 | 24 | 0 | 62 | 56,23 | 0,02 % |
| 2141 | AB or SMA (40 mm) | m2tr | 14 426 | 22 | 49 648 | 2 507 | 4 968 | 57 124 | 39,60 | 14,69 % |
| 2141.13 | ABK 32 / 150 (60 mm) | m2tr | 9 600 | 22 | 49 559 | 2 507 | 3 306 | 55 372 | 38,45 | 14,24 % |
| 2143.11 | Concrete stone covering | m2tr | 1 247 | 15 | 26 849 | 243 | 0 | 27 092 | 120,70 | 6,97 % |
| 2144.3 | Granite sett covering | m2tr | 33 | 15 | 201 | 27 | 0 | 228 | 21,47 | 0,06 % |
| 2144.4 | Rubble stone covering | kpl | 3 | 15 | 1 | 0 | 0 | 1 | 0,87 | 0,00 % |
| 2145.2 | Crush covering and slope covering | m2tr | 1 620 | 16 | 527 | 384 | 50 | 961 | 3,33 | 0,25 % |
| 2146.2 | Covering, fines from aggregate production | m2tr | 6 270 | 16 | 0 | 744 | 1 937 | 2 681 | 4,70 | 0,69 % |
| 2151 | Treansition wedge | m3rtr | 176 | 16 | 767 | 552 | 45 | 1 364 | 3,25 | 0,35 % |
| 2211.1A | Kerb, natural stone | mtr | 787 | **50** | 7 130 | 360 | 0 | 7 490 | 86,52 | 1,93 % |
| 2211.1B | Kerb, natural stone | mtr | 923 | 50 | 8 362 | 450 | 0 | 8 812 | 86,79 | 2,27 % |
| | | | | | **178 304** | **104 051** | **106 498** | **388 854** | **3 363** | 100 % |

| Arvo Ylpön katu, ALT3 (Crushed asphalt use in sub-base, replacing concrete stones with Finnish natural stones) | | INFORMATION DATA | | | RESULTS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ID (according to InfraRYL) | Structures and structural parts | Unit | Amounts | Transportations km * | Material emissions [kg CO2eq.] | Transportation emissions [kg CO2 eq.] | Work performance emissions [kg CO2eq.] | Absolute total emissions [kg CO2eq.] | Total emissions [kgCO2eq./ton] | Share of absolute total emissions [%] |
| 1111 | Removal of waste wood, vegetation and top soil | m2tr | 21 270 | 12 | 0 | 7 342 | 1 891 | 9 233 | 1,19 | 2,83 % |
| 1131 | Change of well cover, including pipe valves, renewal of upper well to 1 m depth, demolition of current cover and excavation and filling of new covering | kpl | 7 | 0 | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1151A | Removal of asphalt by milling | m2tr | 170 | 1 | 0 | 6 | 42 | 48 | 0,75 | 0,01 % |
| 1151B | Removal of asphalt by excavation | m2tr | 5 195 | 1 | 0 | 154 | 1 613 | 1 768 | 0,91 | 0,54 % |
| 1431.2 | Drainage in the construction | mtr | 1 130 | 60 | 0 | 108 | 0 | 108 | *0,00* | 0,03 % |
| 1432 | Drainage inspection wells | kpl | 10 | 60 | 1 553 | 108 | 0 | 1 661 | *0,00* | 0,51 % |
| 1434.1 | Concrete culvert | m | 21 | 10 | 486 | 15 | 64 | 564 | 322,52 | 0,17 % |
| 1612 | Excavation | m3ktr | 1 711 | 1 | 0 | 246 | 761 | 1 007 | 0,32 | 0,31 % |
| 1613 | Earth cut and excavation of pipe trench | m3ktr | 12 190 | 12 | 0 | 21 018 | 5 420 | 26 438 | 1,19 | 8,10 % |
| 1621A | Pipe trench, excavation of preloading structure | m3ktr | 51 | 1 | 0 | 15 | 32 | 47 | 0,26 | 0,01 % |
| 1621B | Installation of cable protection pipe | mtr | 670 | 60 | 803 | 108 | 9 | 920 | 228,89 | 0,28 % |
| 1621C | Installation of cable protection pipe | mtr | 980 | 60 | 1 175 | 90 | 13 | 1 278 | 217,34 | 0,39 % |
| 1621D | Cable trench | mtr | 1 200 | 16 | 94 | 144 | 1 013 | 1 251 | 11,46 | 0,38 % |
| 1621E | Excavation of pipe trench and transportation | m3ktr | 1 700 | 0 | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1621F | Pipe trench, excavation of blasted rock of preloading structure | m3ktr | 2 340 | 1 | 0 | 658 | 2 474 | 3 132 | 0,38 | 0,96 % |
| 1622 | Culvert trench excvation | mtr | 39 | 12 | 0 | 378 | 90 | 468 | 1,19 | 0,14 % |
| 1625 | Mass exchange excavations | m3ktr | 13 980 | 12 | 0 | 33 381 | 8 033 | 41 414 | 1,18 | 12,69 % |
| 1631 | Trench support | m | 90 | | 0 | 0 | 0 | 0 | 0,00 | 0,00 % |
| 1711A | Blasting of rock | m2tr | 475 | 1 | 0 | 133 | 596 | 729 | 0,43 | 0,22 % |
| 1711B | Blasting of rock | m3ktr | 12 730 | 1 | 0 | 3 578 | 28 691 | 32 269 | 0,71 | 9,88 % |
| 1721A | Pipe and cable canals, h<1 m | m2tr | 335 | 1 | 0 | 0 | 884 | 884 | *0,00* | 0,27 % |
| 1721B | Pipe and cable canals, h<1 m | m3ktr | 1 900 | 1 | 0 | 534 | 5 015 | 5 549 | 0,82 | 1,70 % |
| 1762 | Blasted hollows and holes | kpl | 12 | 1 | 0 | 12 | 101 | 113 | 0,78 | 0,03 % |
| 1811.29 | Blasted rock embankment inside the project | m3rtr | 4 790 | 1 | 0 | 922 | 1 603 | 2 526 | 0,22 | 0,77 % |
| 1811.9 | Earth embankment, ramp filling and final filling | m3rtr | 3 320 | 1 | 0 | 727 | 5 051 | 5 778 | 0,63 | 1,77 % |
| 1831 | Crushed rock fillings | m3rtr | 20 388 | 16 | 971 | 3 215 | 30 608 | 34 794 | 13,68 | 10,66 % |
| 1834 | Mass exchange, blasted rock | m3rtr | 4 100 | 2 | 0 | 1 037 | 803 | 1 840 | 0,21 | 0,56 % |
| 1836 | Mass exchange filling to the hard bottom, blasted rock inside the project | m3rtr | 9 880 | 1 | 0 | 1 666 | 1 936 | 3 602 | 0,17 | 1,10 % |
| 2112 | Geotextile N3 | m2tr | 18 770 | 510 | 6 382 | 1 096 | 0 | 7 478 | 2 096,92 | 2,29 % |
| 2132.1 | Kerb stone joint, ABK 32/150 + Ab 16/100 | mtr | 22 | 16 | 38 | 24 | 0 | 62 | 56,23 | 0,02 % |
| 2141 | AB or SMA (40 mm) | m2tr | 14 426 | 22 | 49 648 | 2 507 | 4 968 | 57 124 | 39,60 | 17,50 % |
| 2141.13 | ABK 32 / 150 (60 mm) | m2tr | 9 600 | 22 | 49 559 | 2 507 | 3 306 | 55 372 | 38,45 | 16,96 % |
| 2143.11 | Concrete stone covering replaced with natural stones | m2tr | 1 247 | 50 | 7 603 | 989 | 0 | 8 592 | 32,75 | 2,63 % |
| 2144.3 | Granite sett covering | m2tr | 33 | 15 | 201 | 27 | 0 | 228 | 21,47 | 0,07 % |
| 2144.4 | Rubble stone covering | kpl | 3 | 15 | 1 | 0 | 0 | 1 | 0,87 | 0,00 % |
| 2145.2 | Crush covering and slope covering | m2tr | 1 620 | 16 | 527 | 384 | 50 | 961 | 3,33 | 0,29 % |
| 2146.2 | Covering, fines from aggregate production | m2tr | 6 270 | 16 | 0 | 744 | 1 937 | 2 681 | 4,70 | 0,82 % |
| 2151 | Treansition wedge | m3rtr | 176 | 16 | 767 | 552 | 45 | 1 364 | 3,25 | 0,42 % |
| 2211.1A | Kerb, natural stone | mtr | 787 | 6 | 6 335 | 43 | 0 | 6 379 | 73,68 | 1,95 % |
| 2211.1B | Kerb, natural stone | mtr | 923 | 50 | 8 362 | 450 | 0 | 8 812 | 86,79 | 2,70 % |
| | | | | | **134 504** | **84 921** | **107 050** | **326 475** | **3 263** | 100 % |

**Härmälänranta, actual**

| Removed masses | Area | Quality | Amount: t | Amount: loads | Destination | Distance (km) | CO2-emissions (t)* | CO2ekv-emissions (t) | % | Muuta |
|---|---|---|---|---|---|---|---|---|---|---|
| Removed contaminated soils and wastes | Myrskynkatu | **waste, contaminated soil** | **5 145** | 124 | Ekokem (Pori/Vkoski), PJH (Tarasten-/Koukkujärvi) | 21...127 | **18,09** | **18,23** | **13 %** | Estimation, on the basis of surface area and thickness of midlayer |
| Removedcontaminated soils and wastes | Konttilukinkatu, southern part | **waste, contaminated soil** | **17 160** | 410 | Ekokem (Pori/Vkoski), PJH (Tarasten-/Koukkujärvi) | 21...127 | **60,13** | **60,62** | **45 %** | Estimation, on the basis of surface area and thickness of midlayer |
| Peatsoil cut | Härmälänojanpuisto | **Peat** | **107** | 3 | Maanrakennus Sulin Oy, transported to Pirkkala to Huovila industrial area | 8 | **0,05** | **0,05** | **0 %** | Cut to improve the filling stability, used as an ingredient in soil manufacturing |
| Removal of bottom structure material from the parking area (utilisation, environmental permit 4.10.2006) | Härmälänojanpuisto | **Crushed concrete, brick, asphalt, crushed rock** | **14 250** | 340 | Suomen Erityisjäte, Forssa/ Ekokem-Palvelu, Valkeakoski | 33...103 | **56,02** | **56,47** | **42 %** | 5670 m2 |
| **Removal, total** | | | **36 663** | | | | **134,3** | **135,4** | | |

| Delivered masses | Area | Quality | t | loads | Destination | Distance (km) | CO2-emissions (t)* | CO2ekv-emissions (t) | % | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| Filling of the street area after the contaminated area has been restored | Myrskynkatu, eastern part | **Sand** | **3 332** | 80 | From Ratina work site, temporary storaging at Ikea | 12 | 1,91 | **1,92** | **34 %** | Estimation of the Cargotec share, calculated from the drawing |
| | Myrskynkatu, western part | **Crushed concrete** | **1 011** | 25 | Internal masses | 0,5 | 0,024813 | **0,03** | **0 %** | Partial filling made by Tampere Infra |
| | Myrskynkatu, in total | **Gravel** | **5 273** | 126 | From Ratina work site, temporary storaging at Ikea | 12 | 3,00 | **3,03** | **54 %** | Partial filling made by Tampere Infra |
| | Konttilukinkatu,southern part | **Crushed concrete** | **12 536** | 299 | Internal masses | 0,5 | 0,296758 | **0,30** | **5 %** | Partial filling, estimate |
| Filling of the park area after the contaminated area has been restored | Härmälänojanpuisto | **Crushed concrete** | **12 536** | 299 | Internal masses | 0,5 | 0,296758 | **0,30** | **5 %** | Partial filling, estimate |
| **Delivered, in total** | | | **34 688** | | | | **4,90692** | **5,6** | | |

*CO2 emissions of an empty car 788 g/km, emissions of full car (load 40 t) 1197 g/km
Corresponding CO2 eq numbers: 796 g/km and 1205 g/km

Reference: http://lipasto.vtt.fi/yksikkopaastot/tavaraliikenne/tieliikenne/kavp60tie.htm

**Härmälänranta, alternative with crushed rock**

| Delivered masses | Area | Quality | t | loads | Destination | Distance (km) | CO2-emissions (t)* | CO2ekv-emissions (t) | Other |
|---|---|---|---|---|---|---|---|---|---|
| Filling of the street area after the contaminated area has been restored | Myrskynkatu, eastern part | **Sand** | 3 332 | 80 | From Ratina work site, temporary storaging at Ikea | 12 | 1,91 | **1,92** | Estimation of the Cargotec share, calculated from the drawing |
| | Myrskynkatu, western part | **Crushed concrete** | 1 011 | 25 | Internal masses | 0,5 | 0,02 | **0,03** | Partial filling made by Tampere Infra |
| | Myrskynkatu, in total | **Gravel** | 5 273 | 126 | From Ratina work site, temporary storaging at Ikea | 12 | 3,00 | **3,03** | Partial filling made by Tampere Infra |
| | Konttilukinkatu,southern part | **Crushed rock** | 12 536 | 299 | Transported from elsewhere | 16 | 9,5 | **9,6** | Partial filling, estimate |
| Filling of the park area after the contaminated area has been restored | Härmälänojanpuisto | **Crushed rock** | 12 536 | 299 | Transported from elsewhere | 16 | 9,5 | **9,6** | Partial filling, estimate |
| **Delivered, in total** | | | **34 688** | | | | **23,9** | **24,1** | |

| Härmälänranta, alternative with contaminated soils | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Delivered masses** | **Area** | **Quality** | **t** | **loads** | **Destination** | **Distance (km)** | **CO2-emissions (t)*** | **CO2ekv-emissions (t)** | **Other** |
| Filling of the street area after the contaminated area has been restored | Myrskynkatu, eastern part | **Sand** | 3 332 | 80 | | 12 | 1,91 | 1,92 | Estimation of the Cargotec share, calculated from the drawing |
| | Myrskynkatu, western part | **Crushed concrete** | 1 011 | 25 | | 0,5 | 0,02 | 0,03 | Partial filling made by Tampere Infra |
| | Myrskynkatu, in total | **Gravel** | 5 273 | 126 | | 12 | 3,00 | 3,03 | Partial filling made by Tampere Infra |
| | Konttilukinkatu,southern part | **Crushed rock** | 12 536 | 299 | | 0,5 | 0,30 | 0,30 | Partial filling, estimate |
| Filling of the park area after the contaminated area has been restored | Härmälänojanpuisto | **Crushed rock** | 12 536 | 299 | | 0,5 | 0,30 | 0,30 | Partial filling, estimate |
| **Delivered, in total** | | | **34 688,05** | | | | **5,5** | **5,6** | |