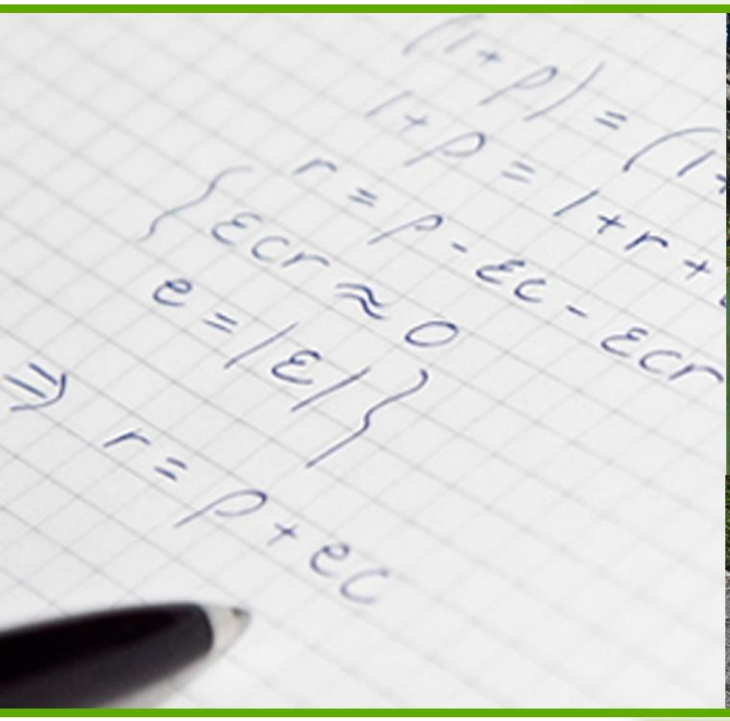
enveco
Environmental Economics Consultancy

Mapping of Eco-System Services in the Fixfabriken area

Method development and case study application



The Balance 4P project of the SNOWMAN Network Coordinated Call IV

Mapping of Eco-System Services in the Fixfabriken area

Method development and case study application

The Balance 4P project of the SNOWMAN Network Coordinated Call IV

MATS IVARSSON

2015

Rapport 2015:6

www.enveco.se

CONTENTS

SUMMARY

This report is part of the project BALANCE4P - *Balancing decisions for urban brownfield redevelopment*. The overall aim of the BALANCE 4P project has been to develop a holistic approach that supports redevelopment of brownfields by integrating technical, economic and social aspects, and provide means for clearly communicating challenges and opportunities of site-specific subsurface qualities. The main findings of the BALANCE 4P project are reported in Norrman et al. (2015a).

One important method in the BALANCE 4P project has been to use real case studies as a mean of applying and testing the outcomes of different activities and instruments. In the Fixfabriken case study (for details see Norrman et al., 2015b), the sustainability of alternative redevelopment strategies actions is assessed by means of three different methods:

- the SCORE tool (Garção, 2015),
- mapping of Ecosystem services (ESS), and
- social impact analysis (SIA) (Norrman et al., 2015b).

The basic idea of all three approaches is to analyse the change brought about by different redevelopment alternatives in comparison with the reference scenario. This report gives an in depth description of the ESS-mapping approach, both the methodology itself and its application to the Fixfabriken case study.

The objective of the analysis has been to investigate the potential of ESS-mapping in adding useful information to the sustainability appraisal of identified redevelopment alternatives. The method applied (COWI 2014) follows the principles outlined in a guidance for implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC), the guide follows three steps:

1) Identification of relevant ecosystem services and their status on the remediation site given present land use (reference scenario).
2) Quantification of changes in quality and quantity of ecosystem services affected in the identified redevelopment alternatives.
3) Monetary valuation of the welfare effects from identified changes.

The third step of the methodology, *Monetary valuation*, has not been applied in the Fixfabriken application. The analysis was delimited to *a semi quantitative comparison* between the reference scenario and the resulting changes in the provision of ecosystem services in five different redevelopment scenarios, see Garção (2015).

A few specific features of the redevelopment alternatives turned out to have a profound impact on the resulting ranking of studied alternatives. These features are characterized by their impact on the supply of both urban- and soil ESS. On the positive side; the creation, or preservation, of green space will have a positive impact

on several urban ESS, e.g. *Air quality regulation, Climate regulation local (urban climate), Noise reduction, Aesthetic values* and *Recreation and ecotourism*. The same feature does in addition imply positive effects on a number of soil ESS, e.g. *Fresh water, Climate regulation (global), Flood regulation* and *Water purification and waste treatment*. On the negative side; while having a positive effect at the redevelopment site on both urban and soil ESS, excavation and transportation of polluted soil to off-site landfills might lower the desirability of several redevelopment alternatives due to the risk of local adverse effects on the land-fill site. Whether or not these negative effects materialize depends on the conditions at the land fill site prior to the deposition. If the land fill site is new, or if the level of pollution in the masses is higher than previously deposited material, then negative effects might be expected in the supply of both urban ESS (i.e. *Recreation and ecotourism*) and soil ESS (e.g. *Fresh water* and *Water purification and waste treatment*).

Due to this, one of the redevelopment alternatives appears as the most desirable from an ecosystem services perspective. This alternative implies excavation of contaminated materials to be transported off-site to final disposal, possibly with some treatment at the disposal site. The southern part of the redevelopment area becomes a green area to preserve and emphasize the historical importance of the site. The upper soil layers are remediated through soft techniques (e.g. phytoremediation), i.e. no excavation unless any extreme hot-spots are found in the coming investigations. This allows a lower disturbance of the underneath layers, thus lower probability of affecting the known archaeological remains from the Early stone age and Neolithic age at the site.

The two least attractive alternatives implies increased excavation and deposition of polluted soil. These alternatives would potentially have large negative effects on ecosystem services at off-site landfills.

The method is promising as a means to prioritize between development alternatives. However, there are a number of methodological challenges to address in future applications:

- Further attention should be paid to alternative scales, e.g. are the effects in terms of changes in the status of ecosystem services linear?
- The effect from changes in the provision of different ecosystem services might differ greatly in importance but still have the same score in the analysis.
- Summing the effects on all affected ecosystem services at individual parts of the site will inherently hide details regarding changes that might be of great local importance.
- Knowledge about the local conditions in areas affected by remediation actions is of great importance, not only at the actual site but also at off-site landfills and along the transport routes to the landfills.

SAMMANFATTNING

Denna rapport är en del av projektet BALANCE4P som har det övergripande syftet att utveckla en helhetssyn till stöd vid förnyelse genom efterbehandling och byggnation av underutnyttjade industriområden (*brown fields*) genom en integrering av tekniska, ekonomiska och sociala aspekter. Metoden ska också tillhandahålla verktyg för att tydligt kommunicera platsspecifika utmaningar och möjligheter med avseende på undermarksförhållanden. Huvudresultaten från BALANCE4P-projektet redovisas i Norrman et al. (2015a).

En viktig utgångspunkt i arbetet inom BALANCE4P-projektet har varit att använda fallstudier från verkligheten som ett sätt att tillämpa och testa utfallet av olika aktiviteter och instrument. I fallstudien för Fixfabriken (se Norrman et al., 2015b) har tre olika metoder tillämpats för hållbarhetsutvärderingar av alternativa metoder för förnyelse genom efterbehandling byggnation:

- SCORE-modellen (Garção, 2015),
- Ekosystemtjänstanalys (ESS), och
- Social analys (SISA) (Norrman et al., 2015b).

Målsättningen för samtliga ansatser är att analysera förändringar som förväntas uppstå till följd av olika alternativ för efterbehandling och nybyggnation och att jämföra dessa med ett referensscenario. I den här rapporten ges en fördjupas beskrivning av ekosystemtjänstanalysen, både med avseende på metoden som sådan och på hur den tillämpats på Fixfabrikens fallstudie.

Målsättningen med analysen har varit att undersöka potentialen hos ekosystemtjänstanalysen när det gäller att tillföra ny information i hållbarhetsutvärderingar av föreslagna alternativ för efterbehandling och byggnation. Metoden som tillämpas i rapporten följer den vägledning som utvecklats av COWI (2014) för genomförandet av EUs ramdirektiv för vatten (2000/60/EG) och översvämningsdirektiv (2007/60/EG), vägledningen baseras på tre steg:

1) Identifiering av relevanta ekosystemtjänster och deras status i det utvärderade området givet pågående markanvändning (referensscenariot).
2) Kvantifiering av förändringar i ekosystemtjänsternas kvalitet och kvantitet till följd av aktuella alternativ för sanering och utveckling.
3) Monetär värdering av förändringar av välbefinnande/välfärd till följd av förutsedda förändringar.

Det tredje steget i metoden, *Monetär värdering,* har inte tillämpats i Fixfabrikens fallstudie. Analysen har avgränsats till en semi-kvantitativ jämförelse mellan referensscenariot och de förändringar i tillgången till ekosystemtjänster som bedöms resultera till följd av olika scenarier för efterbehandling och byggnation, se Garção (2015).

Vissa åtgärder inom efterbehandlings- och byggnationsalternativ medför positiv påverkan på båda typerna av ekosystemtjänster har därför visat sig ha stor betydelse för den slutliga rangordningen av alternativ. Ett exempel är tillskapande och/eller bevarande av gröna ytor, detta bedöms exempelvis stärka de urbana ekosystemtjänsterna *Reglering av luftkvalitet, Klimatreglering lokalt (stadsklimat), Bullerminskning, Estetiska värden* samt *Rekreation och ekoturism*. De ekosystemtjänster med jordanknytning som bedöms påverkas positivt är exempelvis *Tillgång till rent vatten, Klimatreglering (globalt), Översvämningsreglering* samt *Vattenrening och nedbrytning av föroreningar*. Åtgärden med störst sammantagen negativ påverkan är schaktning och bortförsel av förorenade jordmassor för placering på deponi. Om, och i så fall i vilken omfattning, negativa effekter uppstår på deponier avgörs av de lokala förhållandena. Om en ny deponi måste tas i anspråk, eller om föroreningsgraden i de befintliga massorna är lägre än de i de massor som ska deponeras, då kan de negativa effekterna förväntas bli stora på både urbana- (exempelvis *Rekreation och ekoturism*) och jordrelaterade ekosystemtjänster (exempelvis *Vattenrening och nedbrytning av föroreningar).*

I analysen framstår ett alternativ som det mest hållbara ur ett ekosystemtjänst-perspektiv. Alternativet innebär utgrävning av förorenade massor för slutlig deponering, eventuellt med viss bearbetning på platsen för deponering. Den södra delen av området blir grön-område för att bevara och understryka platsens historiska betydelse. Det översta jordlagret saneras med ”soft techniques” (t.ex. phytoremed-iation), I området planeras ingen schaktning av förorenade massor om inga extremt ”hot-spots” påträffas. Metoden innebär en lägre risk för negativ påverkan på de arkeologiska lämningarna från tidig- och sen stenålder som finns på platsen.

De två minst attraktiva alternativen kännetecknas av schaktning och deponering av förorenade massor i en större omfattning och en minskning av befintliga gröna ytor i den södra delen av området.

Metoden är lovande för prioritering mellan olika efterbehandlings- och byggnationsalternativ, framtida applikationer innebär emellertid ett antal metodologiska utmaningar

- Alternativa bedömningsskalor behöver undersökas. Exempelvis, är effekterna med avseende på förändrad tillgång till ekosystemtjänster linjär?
- Betydelsen av förändrad tillgång till olika ekosystemtjänster kan variera betydligt men fortfarande ha samma ”score” i analysen.
- Summering av effekter från alla berörda ekosystemtjänster inom ett område kan innebära att detaljer av stor betydelse ”göms” i analysresultatet.
- Kunskap om lokala förhållanden i det område som påverkas av sanering och utveckling är av stor betydelse, inte bara på själva platsen för projektet men också längs vägarna till och på den eller de platser som planeras tas i anspråk för deponering av förorenade massor.

1 INTRODUCTION

1.1 Background

Land take as a result of urbanization is one of the major soil threats in Europe. One of the key measures to prevent further urban sprawl and additional land take, is redevelopment of urban brownfields: underused urban areas with, in many cases, soil and groundwater pollution, which can be a bottleneck for redevelopment of brownfields instead of green fields. A difficulty for brownfield redevelopments is that in urban projects the responsibilities, tools and knowledge of subsurface engineering and urban planning and design are not integrated; they depend heavily on each other but work in different sectors. The urban designer usually deals with opportunities for socio-economic benefits while the subsoil engineer deals with the technical challenges of the site.

In the remediation sector, there is a broad on-going work to develop methods and tools that supports sustainable remediation. Remediation was earlier viewed as a sustainable action in itself, but today negative impacts of remediation are acknowledged, e.g. transport emissions and fatality risks, health risks during remediation, consumption of energy and materials as well as being costly (Vegter et al., 2003; SuRF-UK, 2010). There is today an increasing demand for assessing remedial activities with regard to all three of the commonly mentioned sustainability dimensions: environment, economy and society. The International Standard Organization (ISO) currently works on a standard for sustainability evaluation of remedial actions and there are several SuRF (Sustainable Remediation Forum) organizations worldwide (USA, UK, Australia & New Zealand, Canada, Italy, the Netherlands, Taiwan and Brazil) that support this development. SuRF-UK suggested a general framework for assessing the sustainability of soil and groundwater remediation, broad enough to apply across different timescales, site sizes, and project types (Bardos et al., 2011). In accordance with Bardos et al. (2011), there are several attempts to incorporate sustainability in early phases of projects, as there is a general idea that the largest (sustainability) gains are achieved early in projects when they are still flexible.

1.2 Balance 4P project

The background to the Balance 4P project is the idea that a better cooperation between urban developers and sub-surface specialists in early phases of the redevelopment process can accelerate brownfield redevelopment and potentially identify more sustainable redevelopment strategies.

The overall aim of the BALANCE 4P project has been to develop a holistic approach that supports redevelopment of brownfields by integrating technical, economic and social aspects, and provide means for clearly communicating challenges and

opportunities of site-specific subsurface qualities. The main findings of the BALANCE 4P project are reported in Norrman et al. (2015a). One of the technical work packages of the project aimed to apply and assess sustainability assessment methods of alternative land redevelopment strategies to evaluate and compare the ecological, economic and social impacts of land use change and remedial technologies (WP4) . One important method in the BALANCE 4P project has been to use real case studies as a mean of applying and testing the outcomes of different activities and instruments. In the Fixfabriken case study (for details see Norrman et al., 2015b), the sustainability of alternative redevelopment strategies actions is assessed by means of three different methods:

1) **SCORE** (Sustainable Choice of REmediation). SCORE is a multi-criteria decision analysis (MCDA) method which allows for transparent assessment of the sustainability of remediation alternatives at contaminated sites (Rosén et al., 2015). SCORE evaluates the performance of alternatives relative to a reference scenario in the economic, environmental and social sustainability domains, following the view of sustainable development given by, for example, the United Nations (2012). The analysis for the Fixfabriken site is reported in Garção (2015).
2) **Social Impact Analysis** (here SIA). The methodology applied here was developed by the City of Gothenburg to support planners for identifying and evaluating social needs and impacts in relation to plans (Göteborgs stad, 2015). The analysis is reported in Norrman et al. (2015)
3) **ESS-mapping** (Ecosystem services mapping). The sustainability of different remediation actions is assessed by mapping changes in the supply of ecosystem services at relevant temporal and spatial scales associated with different alternatives.

1.3 Aim and scope of the report

This report describes the methodology of the ESS mapping and how the method is applied to the Fixfabriken case study area.

The ESS-mapping follows the methodology put forward in COWI (2014) for ecosystem services analysis;

1) **Identification**: which ecosystem services are of importance given local conditions as well as temporal and spatial considerations? The identification forms the reference scenario to which changes in supply of ESS from different redevelopment alternatives are evaluated.
2) **Quantification**: changes in the supply of ESS imposed by different redevelopment alternatives are quantified by means of biophysical indicators.
3) **Valuation**: the changes in welfare brought about by different redevelopment alternatives are valuated.

The analysis is limited to step 1-2. Instead of valuation of changes in welfare, the different remediation alternatives are ranked by means of a semi-quantitative scale reflecting changes in the supply of ESS from associated redevelopment alternatives. The objective is to arrive at a ranking that can be compared to the corresponding rankings of redevelopment alternatives developed in the SCORE and SIA approaches.

2 THE FIXFABRIKEN SITE IN GÖTEBORG

The Fixfabriken site, a former industrial area, is found in the western part of Gothenburg on the south side of the harbour inlet. The site is being redeveloped into a mix-use area consisting of residential housing, commercial buildings and public spaces. The redevelopment is complicated by the occurrence of contaminated soil caused by previous activities in the area. Due to this fact, and to the fact that the Urban Planning office in the municipality of Gothenburg was in the phase of compiling information for a detailed plan over the area, the Fixfabriken site was considered to be a suitable case study area in the Balance 4P project. The area is owned by the private developer (consisting of two large companies; *HSB* who builds, develops and manage housing for over 0, 5 million resident in Sweden and *Balder*, with a large property portfolio represented in many Swedish towns and cities), the municipality and a number of smaller parties, a situation that was considered advantageous for the purpose of involving stakeholders in the planning process.

A thorough description of the Fixfabriken site, as well as the activities e.g. workshops and stakeholder analysis that have been carried out in order to apply and assess different methods and tools that can provide input to and support the decision on a detailed plan is given in Garção (2015).

2.1 Site description

The site can be divided into four main areas: The Fixfabriken factory, the bus garage, the tram hall and the Karl Johansgatan area. The following site descriptions are collected from Garção (2015).

The Fixfabriken factory has had industrial activities since the 1940s. The soil at the Fixfabriken factory is contaminated to some extent by trichloroethylene, a chlorinated solvent. The present spreading conditions of the contaminants are to a large extent unknown. Archaeological remains are known in the area, although its boundaries are not defined.

The Bus garage property is owned by the municipality and is probably contaminated to some degree.

The Tram hall is operated by Göteborgs Spårvägar, which has a permit to be operating in the upcoming years. The municipality owns the property. Recently the company showed to the municipality its interest to keep operating the tram hall further after this deadline.

The Karl Johansgatan area includes the area in between the Karl Johansgatan, Boulevard which is the main road serving the local neighbourhood, and the highway E45. It also includes the Karl Johansgatan Boulevard itself. Road infrastructures and traffic generate adverse effects, namely noise, air pollution and visual intrusion. Land

use at the area includes two petrol stations, a residential area, parking lots, crossings and small green areas in between.

2.2 Generation of redevelopment alternative(s)

For identifying and designing sustainable redevelopment strategies, a number of activities have been carried out within the Balance 4P project. Several student and stakeholder workshops have been arranged in addition to interviews with stakeholders to elicit preferences with regard to land-use and compilation of data with regard to soil contamination and other local preconditions for planning and development, e.g. archaeological findings, Garção (2015), Norrman et al. (2015b).

The activities resulted in the following five redevelopment scenarios as described in the Balance 4P main technical report, Norrman et al. (2015b).

2.2.1 Reference scenario

The reference scenario corresponds to the present situation, keeping a relatively underused area within an attractive part of Gothenburg.

2.2.2 Alternative 1

The Fixfabriken factory is demolished. The existent filling material beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use with some commercial areas in the ground floors are then constructed, starting 5 years from now. Redevelopment occurs during 2 years. Housing heights are 4-7 floors, with a mix of rental and condominium apartments. The excavated contaminated materials are not further treated but are transported off-site to final disposal, possibly with some treatment at the disposal site.

The Bus garage is demolished and the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use, with commerce/offices/services at the ground floor, are then constructed, starting 8 years from now. It is assumed that the development occurs in two stages. The total redevelopment period is 3 years. Housing heights are 4-7 floors, with a mix of rental and condominium apartments. The excavated contaminated materials are not further treated but are transported off-site to final disposal, possibly with some treatment at the disposal site.

The Tram hall is kept as it is. No remediation action is taken, unless any extreme hot-spots are found in the coming investigations.

The existing petrol stations at the street Karl Johansgatan are demolished, and the present residential area is kept. New buildings for industrial and office use are then constructed, starting 10 years from now. It is assumed that the redevelopment occurs in several stages, during 8 years. No action is taken in the remaining area along the street Karl Johansgatan. Regarding remediation action, the filling materials beneath

the places to be reconstructed are dug out. The excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site.

2.2.3 Alternative 2

The Fixfabriken factory is demolished. In the northern part the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. New buildings for residential use are then constructed in the northern part, starting 5 years from now, and during 2 years. Housing heights are 4-7 floors, with a mix of rental and condominium apartments. The excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site. The southern part becomes a green area to preserve and emphasize the historical importance of the site. The upper soil layers are remediated through soft techniques (e.g. phytoremediation), i.e. no excavation unless any extreme hot-spots are found in the coming investigations. This allows a lower disturbance of the underneath layers, thus lower probability of affecting the known archaeological remains from the Early stone age culture ”Sandarna settlement” (6000 B.C.) and prehistoric settlements from Neolithic age (late stone age), and eventual remains of an ancient military camp (1500s-1600s A.C.).

The Bus garage is developed in the same way as described in Alternative 1. The Tram hall is treated as described in Alternative 1. The Karl Johansgatan area is handled in the same way as described in Alternative 1.

2.2.4 Alternative 3

The future land uses in this alternative are developed quite differently from alternatives 1 & 2 and also the remediation strategy is different. Whereas Alternatives 1 & 2 emphasize excavation, this alternative focuses on no excavation, but instead using surface cover, hot-spot in-situ remediation and active ventilation of new constructions to prevent vapors in-door to manage contamination.

Consequently, when the Fixfabriken factory is demolished, foundations and sub-surface structures are left untouched to disturb the sub-soil as little as possible. These structures are instead ventilated to manage contamination. Around buildings, in-situ and soft techniques (e.g. phytoremediation) are potentially applied in combination with surface cover. New buildings are constructed on top of existing sub-soil structures. Ground floor is ventilated to manage contamination and used as commercial space. 2 floors of apartments are built on top of these for residential use, with a mix of rental and condominium apartments. In addition, 20% of the apartments are subsidized for low-income families. Development starts 5 years from now, and is carried out during 2 years.

The Bus garage is demolished without digging out the existent filling materials beneath the buildings. New buildings are constructed on top of the surface with piling

where needed, to disturb the sub-soil as little as possible. New buildings are constructed on top of existing sub-soil structures. Ground floor is ventilated to manage contamination and used as commercial space. 3-4 floors of apartments are built on top of these for residential use, with a mix of rental and condominium apartments. In addition, 20% of the apartments are subsidized for low-income families. Around buildings, in-situ and soft techniques (e.g. phytoremediation) are potentially applied in combination with surface cover. Development starts 4 years from now, and is carried out during 2 years.

The Tram hall is kept as it is. No remediation action is taken, unless any extreme hot-spots are found in the coming investigations.

The Karl Johansgatan area is developed in the same way as described in Alternative 1.

2.2.5 Alternative 4

Fixfabriken factory is handled in the same way as described in Alternative 1.

The Bus garage is demolished and the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. A new tram hall is constructed, starting 8 years from now, and during 2 years. The excavated soil is handled in the same way as described in Alternative 1. Different future land uses are thus the main difference between Alternative 1 and 4.

The Tram hall is demolished and the existent filling materials beneath and eventually the superficial part of the underneath layer is dug out. New buildings for residential use (a mix of rental and condominium apartments), with commerce/offices/services at the ground floor, are then constructed, starting 10 years from now. It is assumed that the redevelopment occurs in 2 different stages, in a total of 3 years. The excavated contaminated materials are not adequate to be used on-site and are transported off-site to final disposal, possibly with some treatment at the disposal site.

The Karl Johansgatan area is handled in the same way as described in Alternative 1.

2.2.6 Alternative 5

This alternative keeps the existing constructions at the area to a highest extent, namely Fixfabriken and the tram hall.

Buildings and uses (industrial and offices) at Fixfabriken factory are kept as they are. Buildings are renovated to assure an adequate indoor air quality, namely through active ventilation. The space is used as incubator for new businesses and social entrepreneurs. Depending on further investigation of the soil contamination in the area, in-situ remediation might be carried out if there are any hot-spots / left source areas. This is assumed to occur 2 years from now.

The Bus garage is developed in the same way as described in Alternative 1, but with housing heights of 7-15 floors, with a mix of rental and condominium apartments. In addition, 20% of the apartments are subsidized for low-income families.

The Tram hall is treated as described in Alternative 1. The Karl Johansgatan area is handled in the same way as described in Alternative 1.

The essential remediation- and land use features in the redevelopment alternatives area concluded in figure 1 and table 1 - 2 below.

Figure a Overview of redevelopment strategies at the Fixfabriken site. From Garção (2015).

Table 1 Planned future land use in the five redevelopment scenarios in different parts of the Fixfabriken case study area.

Area	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Fixfabriken	New buildings for residential use with some commercial areas in the ground floors are constructed. Housing heights are 4-7 floors, with a mix of rental and condominium apartments.	New buildings for residential use are constructed in the northern part. Housing heights are 4-7 floors, with a mix of rental and condominium apartments. The southern part becomes a green area to preserve and emphasize the historical importance of the site.	New buildings are constructed on top of existing sub-soil structures. 2 floors of apartments are built on top of these for residential use, with a mix of rental and condominium apartments. 20% of the apartments are subsidized for low-income families.	As alternative 1.	Buildings and uses (industrial and offices) at Fixfabriken factory are kept as they are.
Bus garage	New buildings for residential use, with commerce/offices /services at the ground floor Housing heights are 4-7 floors, with a mix of rental and condominium apartments.	As alternative 1.	New buildings are constructed on top of the surface with piling where needed, to disturb the sub-soil as little as possible. Ground floor is ventilated to manage contamination and used as commercial space. 3-4 floors of apartments are built on top of these for residential use, with a mix of rental and condominium apartments. 20% of the apartments are subsidized for low-income families.	A new tram hall is constructed.	The Bus garage is developed in the same way as described in Alternative 1, but with housing heights of 7-15 floors, with a mix of rental and condominium apartments. In addition, 20% of the apartments are subsidized for low-income families.
Tram hall	The Tram hall is kept as it is.	As alternative 1.	As alternative 1	New buildings for residential use (a mix of rental and condominium apartments), with commerce/offices /services at the ground floor, are constructed.	As alternative 1
Karl Johansgatan area	The present residential area is kept. New buildings for industrial and office use are constructed, no action is taken in the remaining area along the Karl Johansgatan Blvd.	As alternative 1.	As alternative 1	As alternative 1	As alternative 1

Table 2 Remediation actions in the five different redevelopment scenarios in different parts of the Fixfabriken case study area.

Area	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Fixfabriken	Demolished, existent filling material beneath the buildings and the superficial part of the underneath layer are dug out. The excavated contaminated materials are not further treated but are transported off-site to final disposal, possibly with some treatment at the disposal site.	Demolished. In the northern part the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. The excavated soil is handled in the same way as described in Alternative 1.The upper soil layers are remediated through soft techniques i.e. no excavation unless any extreme hot-spots are found in the coming investigations.	Demolished, foundations and sub-surface structures are left untouched to disturb the sub-soil as little as possible. These structures are instead ventilated to manage contamination. Around buildings, in-situ and soft techniques (e.g. phytoremediation) are potentially applied in combination with surface cover.	As alternative 1.	Buildings and uses (industrial and offices) at Fixfabriken factory are kept as they are.
Bus garage	Demolished, existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. The excavated contaminated materials are not further treated but are transported off-site to final disposal, possibly with some treatment at the disposal site.	As alternative 1.	The Bus garage is demolished without digging out the existent filling materials beneath the buildings. Around buildings, in-situ and soft techniques (e.g. phytoremediation) are potentially applied in combination with surface cover.	The Bus garage is demolished and the existent filling materials beneath the buildings and the superficial part of the underneath layer are dug out. The excavated soil is handled in the same way as described in Alternative 1.	The Bus garage is developed in the same way as described in Alternative 1.
Tram hall	The Tram hall is kept as it is. No remediation action is taken, unless any extreme hot-spots are found in the coming investigations.	As alternative 1.	As alternative 1	The Tram hall is demolished and the existent filling materials beneath and eventually the superficial part of the underneath layer is dug out.	As alternative 1
Karl Johansgatan area	Petrol stations demolished, excavation and disposal of contaminated soil.	As alternative 1.	As alternative 1	As alternative 1	As alternative 1

2.3 Assessments of project redevelopment alternatives

The sustainability assessment of redevelopment alternatives developed during the project was done with three different approaches: the SCORE tool (Garcao, 2015), mapping of Ecosystem services (ESS), and social impact analysis (SIA) (Norrman et al., 2015b). The basic idea of all three approaches is to analyse the change brought about by different redevelopment alternatives in comparison with the reference scenario. This report gives an in depth description of the ESS-mapping approach, both the methodology itself and its application to the Fixfabriken case study.

3 MAPPING OF ECOSYSTEM SERVICES

Mapping of ecosystem services, or ecosystem services analysis, has been applied on the Fixfabriken case study in Gothenburg as one of three methods for evaluating sustainability in redevelopment projects. The objective of the analysis has been to investigate the potential of this method in adding useful information to the sustainability appraisal of identified redevelopment alternatives. The outcome of the three methods applied, and a comparative discussion is given Norrman et al. (2015b).

3.1 Method

The ESS-mapping applied follows the principles outlined in a guidance for implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC); Development for Integration of Ecosystem Service Assessment into WFD and FD Implementation (COWI 2014);

1) Identification of relevant ecosystem services and their status on the remediation site given present land use (reference scenario).
2) Quantification of changes in quality and quantity of ecosystem services affected in the identified redevelopment alternatives.
3) Monetary valuation of the welfare effects from identified changes.

The third step of the methodology, *Monetary valuation*, has not been applied in the Fixfabriken application. The analysis was delimited to *a semi quantitative comparison* between the reference scenario (business as usual) and the resulting changes in the provision of ecosystem services in five different redevelopment scenarios, see Garção (2015) for a detailed description of the alternatives.

The steps described above following COWI (2014) is also in accordance with the 6-step approach to ecosystem services analysis put forward in a World Resource Institute guidance document; *Weaving Ecosystem Services into Impact Assessment (WRI 2013)*. A similar approach to COWI (2014) and WRI (2013) is further presented in the guide for valuation of ecosystem services published by the Swedish EPA in 2015; *Guide för värdering av ekosystemtjänster* (Naturvårdsverket 2015).

3.1.1 Identification of relevant ecosystem services

Identifying the ecosystem services relevant for the case study site is the starting point in establishing an ESS base line description. By mapping the relevant ESS and assessing their present supply, as well as their potential future supply, the reference scenario forms the boundary condition for the evaluation of all proposed redevelopment scenarios.

3.1.1.1 A classification system

The identification process starts with choosing a relevant classification system of ecosystem services. The most renowned and used overarching classification systems are:

- MEA - Millenium Ecosystem services Assessment (2005)
- TEEB -The Economy of Ecology and Biodiversity (2008)
- CICES - The Common International Classification of Ecosystem Services (2010)

The Fixfabriken application takes its point of departure in the CICES classification adapted to urban (Baggethun et al., 2013) and soil (Finvers, 2008) contexts, see tables 3 and 4 below.

Table 3 Urban ecosystem services as presented by Baggethun et al. (2013)

Ecosystem service		Urban context
Provisioning	Food	Vegetables produced by urban allotments and peri-urban areas.
	Fresh water	Ecosystems provide cities with fresh water for drinking and other human uses and by securing storage and controlled release of water flows. Vegetation cover and forests in the city catchment influences the quantity of available water.
Regulation & Maintenance	Air quality regulation	Vegetation in urban systems can improve air quality by removing pollutants from the atmosphere, including ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter less than 10 µm (PM10).
	Climate regulation global	Carbon sequestration and storage by biomass of urban shrubs and threes.
	Climate regulation local (urban climate)	Water areas buffer temperature extremes by absorbing heat in summertime and by releasing it in wintertime trees. Urban vegetation provide shade, create humidity and block wind, water from the plants absorbs heat as it evaporates, thus cooling the air in the process.
	Water regulation	Soil and vegetation percolate water during heavy and/or prolonged precipitation events. Vegetation reduces surface runoff following precipitation events by intercepting water through the leaves and stems. The underlying soil also reduces infiltration rates by acting as a sponge by storing water in the pore spaces until it percolates as through-flow and base-flow.
	Noise reduction	Urban soil and plants can attenuate noise pollution through absorption, deviation, reflection, and refraction of sound. In row plantings of trees, sound waves are reflected and refracted, dispersing the sound energy through the branches and trees.
	Water purification and waste treatment	Wetlands and other aquatic systems, for example, filter wastes from human activities; this process reduces the level of nutrients and pollution in urban wastewater. Likewise, plant communities in urban soils can play an important role in the decomposition of many labile and recalcitrant litter types.
	Pollination and seed dispersal	Urban ecosystems provide habitat for birds, insect and pollinators. Pollination, pest regulation and seed dispersal are important processes in the functional diversity of urban ecosystems and can play a critical role in their long term durability.
	Maintaining nursery populations and habitats	Urban systems can play a significant role as refuge for many species of birds, amphibians, bees, and butterflies
	Natural hazard regulation	Storm, flood and wave buffering by vegetation buffers, wetland areas; heat absorption during heat waves.
Cultural	Knowledge systems	Allotment gardening as preservation of socio-ecological knowledge.
	Aesthetic values	Urban parks, sea view, urban scenic view in sight from houses.
	Cultural heritage values	E.g. Neolithic settlement
	Recreation and ecotourism	Urban green areas provide opportunities for recreation, mediation and relaxation.

Table 4 Soil ecosystem services as presented by Finvers (2008).

Ecosystem service		Soil context	Functional process
Provisioning	Food	Nutrient cycling to support plant growth (primary production) including food and fiber production	Soil biota recycle dead organic matter into mineralized for usable by plants and required for vegetative cell information and growth.
	Biomass	Basis of all terrestrial ecosystems –life support	Soil (horizon) development and disturbance regime controls ecosystem development.
Regulation & Maintenance	Fresh water	Water purification and soil contaminant reduction	Atmospheric deposits, applied fertilizers, pesticides or other contaminants are adsorbed into soil aggregates, by clay particles and organic matter, and degraded (chemically altered) by soil biota.
	Climate regulation global	Carbon Sequestration	Carbon in short-lived to more stable forms of soil organic matter are (SOM) is stored (and recycled). SOM is approximately 58% organic carbon.
		Regulation of greenhouse gasses	Soil biota affect fluxes of CO_2, CH_4 and N_2O.
	Water regulation	Flood regulation	Rainfall infiltration and storage in soil reduces the rates of surface runoff, reducing and delaying peak flows, and reducing flood risk. Decreased surface runoff also result in lower rates of erosion, reducing sediment load in flood water (reducing their volume).
	Erosion regulation		
	Water purification and waste treatment	Remediation of soil contaminated by diffuse airborne pollution.	Soil biota metabolize contaminants through oxidative or reductive processes.

3.1.1.2 The ESS reference scenario description

The reference scenario description is compiled from information on the importance/relevance of specific ecosystem services at the site before any actions have been deployed, consequently it corresponds to the reference scenario of business as usual, i.e. no action (chapter 2.2.1). The identification is preferably based on as many sources of information as possible, including e.g. maps (GIS, photos etc.), monitoring data, personal visits to the site and interviews with experts regarding local conditions. In the assessment it is also important to consider the spatial scale (the size of the site in relation to the relevant scale of the ecosystem service) and temporal scale (e.g. does the ecosystem service exist under limited parts of the year).

In the Fixfabriken case, aerial images complemented with information on future land use, geological and archaeological investigations on the site, as well as planned remediation actions, are used to make qualitative assessments of the present supply

of relevant ESS for the reference scenario, as well as changes due to remediation and planned future land use, see example in figure 2.

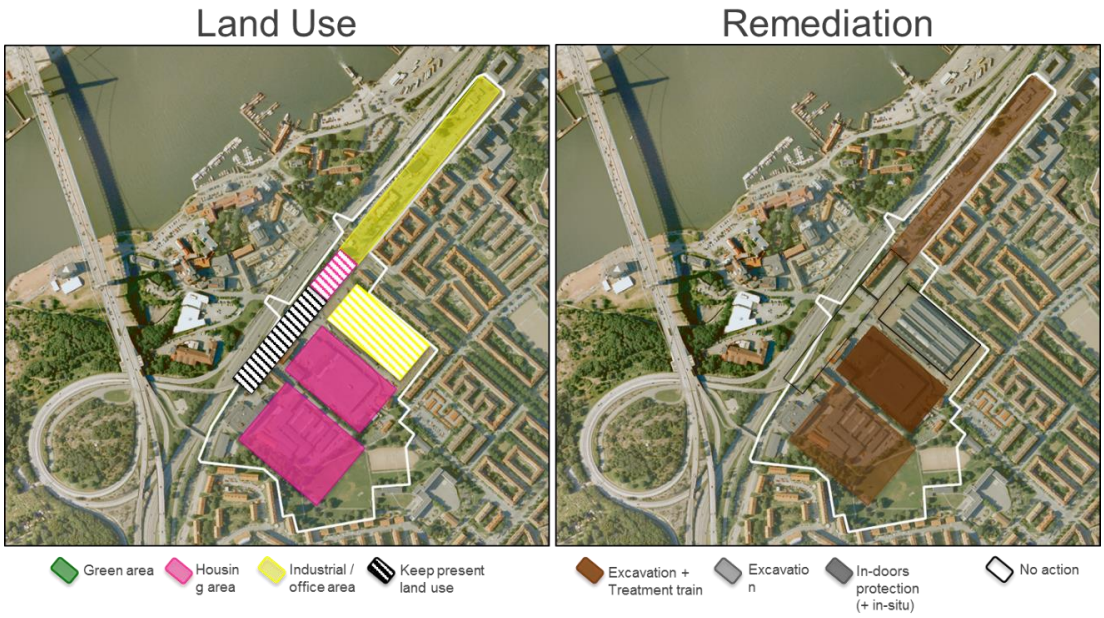


Figure 1 Aerial image of the Fixfabriken area. The image reveals information on both the present and future land use as well as planned remediation actions.

3.1.1.3 Criteria for selecting ESS

Following COWI (2014) each of the "candidate" ecosystem services identified as relevant in tables 3 and 4 for the urban- and soil contexts are assessed by means of a simple semi-quantitative scale, see table 5.

Table 5 The semi-quantitative scale used to assess the relevance of ecosystem services at the Fixfabriken redevelopment site.

Ecosystem service	Current importance	Future potential importance
Food	0	+
Air quality regulation	+	+++
Flood regulation	+	++
…	…	…

0	Not relevant due to local conditions, context, temporal or spatial considerations
+	Existent but of marginal importance due to local conditions, temporal or spatial considerations
++	Important but with a limited supply due to local conditions, temporal or spatial considerations
+++	Important, at or close to its maximum supply with regards to local conditions

The criteria for selecting an ecosystem services for continued analysis is fulfilled when the score (++) or higher is appointed, either with regards to current importance

(which implies a need to conserve and protect the supply of the ESS) or with regards to future potential importance (which implies potential future societal benefits).

3.1.2 Quantification

The quantification step implies continued analysis of the identified ESS by:

1) Identification of suitable indicators to describe changes in relation to the reference scenario, and
2) Identification of sources of information and/or data with regard to the indicators.

The indicators for the urban and soil ESS (tables 6 and 7) that have been collected from different literature sources serve as physical interpretations, or proxies, of the impacts on ecosystem services that can be expected from the remediation process itself and the future land use at the site. The indicators may also be used as a basis for performing monetary assessments of the changes in provision of ecosystem services that follows from redevelopment projects, but this has not been done in this study.

Table 6 Indicators for quantifying changes in provision of urban ecosystem services.

Ecosystem service		Indicator	Reference
Provisioning	Food	1) Production/Harvest (ton/year), 2) Areas available suitable for production (m^2)	Hauser et al. 2011, Mazza L., et al. 2011, Baggethun et al. 2013, Egoh et al 2012
	Fresh water	Groundwater generated (m^3/ha/year;m^3/year)	Hauser et al. 2011, Baggethun et al. 2013
Regulation & Maintenance	Air quality regulation	Leaf area index (Area of vegetation (ha))*	Burkhard, B. et al. 2012, Egoh, B et al 2012
	Climate regulation global	1) Carbon bound in ecosystems = C sequestration (ton C/year; ton C/ha/year), 2)O_2-CO_2 balance (+/- kg C /year) Production or reduction of other GHG (kg/yr; kg/ha/year)*	Mazza L., et al. 2011
	Climate regulation local (urban climate)	Area of vegetation (ha)	Nowak et al 2012
	Water regulation	1) Area of vegetation (ha), 2) water storage capacity (m^3/ha/year)	1)Egoh, B et al 2012 2)Maes J. et al 2011
	Noise reduction	1) Leaf area (m^2) and distance to roads (m): [dB(A)]/vegetation unit (m)* 2) Area of vegetation (ha)	1) Baggethun et al. 2013 2)Maes J. et al 2013
	Water purification and waste treatment	Volumes of soil available for filtration (m^3/ha)	Baggethun et al. 2013
	Pollination and seed dispersal	1) Species diversity and abundance of birds and bumble bees* 2) Area of vegetation (ha)	1)Baggethun et al. 2013 2) Egoh, B et al 2012
	Maintaining nursery populations and habitats	Conservation status of habitats and species; number of species for which the GI element provides habitat*.	Mazza L., et al. 2011
	Natural hazard regulation	Natural water retention capacities (m^3)*	COWI 2014
Cultural	Knowledge systems	Participation, reification and external source of social-ecological memory.*	Baggethun et al. 2013
	Aesthetic values	Scenic landscape (ha) (e.g. revealed through prices on real estate)	COWI 2014
	Cultural heritage values	Number of visitors/tourists	
	Recreation and ecotourism	1) Area of green public space (ha)/inhabitant (or every 1000 inhabitant) 2) Number of visitors/tourists	Baggethun et al. 2013

*Area of vegetation (ha) is used as proxy for the suggested indicator.

Table 7 Indicators for quantifying changes in the provision of soil ecosystem services.

Ecosystem service		Soil context	Indicator	Reference
Provisioning	Food	Nutrient cycling to support plant growth (primary production) including food and fiber production	1) Production/Harvest (ton/year), 2)Areas available suitable for production (m^2)	Hauser et al. 2011, Mazza L., et al. 2011, Baggethun et al. 2013, Egoh et al 2012
	Biomass	Basis of all terrestrial ecosystems –life support	Soil (horizon) development and disturbance regime controls ecosystem development.*	Finvers 2008
Regulation & Maintenance	Fresh water	Water purification and soil contaminant reduction. Contaminants are adsorbed into soil aggregates, by clay particles and organic matter, and degraded, (chemically altered) by soil biota	Volumes of soil available for filtration (m^3/ha)*	Finvers 2008
	Climate regulation global	Carbon sequestration and Regulation of greenhouse gasses	1) Carbon bound in ecosystems = C sequestration (ton C/year; ton C/ha/year)*, 2) O2-CO2 balance (+/- kg C /year) Production or reduction of other GHG (kg/yr; kg/ha/year)	Mazza L., et al. 2011
	Water regulation	Flood regulation	Natural water retention capacity (m^3)*	COWI 2014
	Erosion regulation			
	Water purification and waste treatment	Remediation of soil contaminated by diffuse airborne pollution. Soil biota metabolize contaminants through oxidative or reductive processes.	1) Nutrients levels (C,N,P), moisture (40-60 % of field capacity), appropriate pH (~7) and T (15°-45° C), oxygen for oxidative process*. 2) Removed/immobilized pollutants (kg N, P, C, heavy metals, pesticides, and other pollutants (y^{-1})	1)Finvers 2008 2)COWI 2014

*Area of vegetation (ha) is used as proxy for the suggested indicator.

3.1.3 Evaluation of redevelopment alternatives by analysis of changes in the supply of ESS

The changes in provision of ESS resulting from different redevelopment alternatives are assessed qualitatively, quantitatively and semi-quantitatively by use of information on remedial activities such as excavation of soil, on site/off-site remediation actions and the future land use as represented by the indicators in table 6 and 7.

The ecosystem services at the site are initially given semi-quantitative scores in the range 0 – 3 (table 8) reflecting their status in the present day land use (reference scenario) at the site

The changes in supply of ESS resulting from different remediation actions and future land use are consequently compared to the reference scenario and scores are appointed to the resulting state at the site based on the scale presented in table 8.

The final step is the ranking of redevelopment alternatives according to the outcome of the scoring.

Table 8 Semi-quantitative scores used to describe the status of ecosystem services in the reference scenario.

Score		Explanation
0	Present land use hinders the supply of ESS	Used in situation when the supply of the ESS is hindered by the present land use. One example is found in the ESS *Food*; there are no vegetables produced in urban allotments in the Bus garage area due to the ongoing land use.
1	Present land use has a severely negative effect on the supply of ESS but allows for some supply of ESS	Used in situations when the supply of the ESS exists but is impaired by the present land use, e.g.; there is some vegetation along the Karl Johansgatan Boulevard (trees and bushes) with a positive *noise* reducing effect in relation to the road passing just north of the area. This effect could be enhanced if the present land use, in terms of buildings, roads, infrastructure etc. allowed for more vegetation.
2	Present land has a somewhat negative effect on the supply of ESS	Used in situations when the supply of the ESS is somewhat negatively affected by the present land use, e.g.; fields of lawn and vegetation are found in the areas surrounding the future redevelopment sites. These areas have positive effects on the ESS *Air purification* and *Local climate*. The supply of these ESS is however impaired by buildings and roads which implies that the full potential is not achieved.
3	Present land use is not affecting the supply of ESS negatively	Used in situations when the ESS can be considered to be unaffected by the present land use. An example is given by the high *cultural values* represented by the Neolithic remaining south of the Fixfabriken factory area.

3.1.4 Monetary valuation of the welfare effects from identified changes

The third step of the methodology concerns the valuation of changes in supply of ecosystem services. Since actual monetary valuation is not done in this report, the following is a short walk through of the steps required for a practical valuation of the changes in the supply of ecosystem services resulting from the different redevelopment alternatives in the Fixfabriken case study.

The value of ecosystem services, and changes in their supply, is to a large extent determined by how they are used in society. Practical valuation therefore takes its point of departure in identifying the causal chain between ecosystem components (biophysical structure e.g. vegetation or function), the services provided by the ecosystems, and lastly, the benefits from the services accruing to society in terms of human wellbeing through different uses, and in some cases; non-uses (Olander et al. 2015).

This chain is often described in terms of stock and flow (Barbier, 2009; Mäler et al. 2009). The quality of the ecosystem being the stock regulating the available flow of services that is turned into benefits in terms of contributions to human wellbeing by different uses in society.

The economic valuation of ecosystem services is thus based on people's own perception of wellbeing, and the contribution to wellbeing by benefits from ecosystem services. In addition, economic values accruing to businesses benefiting from ecosystem services is also an important feature of the valuation.

3.1.4.1 What is valued?

In the Fixfabriken case study, a first step is to relate the relevant ecosystem services to human uses that may be affected by the redevelopment alternatives. Tables 6 and 7 gives examples of biophysical indicators that can be used in the matching between services and uses.

An example could be made of the soil ecosystem service Flood regulation which has been matched to the biophysical indicator Natural water retention capacity (m^3), see table 7. The human use, and potential benefit, from this service is determined by the required capacity to deal with storm water in the future developed area. A good capacity for natural water retention implies a lower need for man-made structures to deal with excess storm water. Changes made to the local retentions capacity, e.g. by excavation of soils, may thus increase the need for expensive technical solutions in the future.

3.1.4.2 How is valuation done in practice?

After establishing links between ecosystem services and human uses, the next step is to determine suitable ways for valuation. There are different methods available for valuing different types of ecosystem services. In the case of provisioning services,

when the benefit from the service is traded on a market e.g. food or biomass, then valuation is possible trough analysis of market prices.

In cases of regulating and maintenance services, valuation can be more complicated. Regulating and maintenance services often function as intermediate services to the final services represented by provisioning services. In such cases, valuation should be restricted to final ecosystem services in order to avoid double counting.

In other cases the Regulating and maintenance services are themselves final services and the valuation may be done by e.g. means of market prices. In the example above, regarding the ecosystem service *Flood regulation*, the valuation can be done by assessing the cost for technical solutions to compensate for decreased natural water retention due to i.e. excavation of soils.

In yet other examples, e.g. *Climate regulation global*, there are catalogue values available from several international sources that can be put to use after due consideration of suitability, e.g. The White House (2015) or Trafikverket (2015).

Cultural ecosystem services represent a third category comprising e.g. recreational opportunities, aesthetic and cultural values. The valuation of these services requiring additional methods. Recreational values can be captured by travel cost methods and aesthetic values can be analyzed by hedonic pricing methods investigating the impact of scenic views on local real estate prices. Cultural values can also be assessed by stated preference methods, e.g. contingent valuation or choice experiments. A thorough review of available valuation techniques is given in chapter 5 of The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. (TEEB 2010).

3.2 Results

3.2.1 Identification and present state assessment of relevant ESS (reference scenario)

After analyzing the sources of information regarding the physical conditions and present land use at the site (e.g. aerial images of the Fixfabriken site, project information on planned future land use, geological surveys and archaeological surveys presented in Garção (2015), a number of urban- and soil ESS where selected (Appendix A, tables A1 and A2) as relevant for further analysis in the Fixfabriken case study, tables 9 and 10. The scale presented in table 5 was used for the selection.

The present state of each ESS is assessed using the scores described in table 8 above.

Figure 2 Aerial image of the Fixfabriken showing the different areas. The area referred to as "Adjacent area" in the analysis is the green space just south of the yellow colored Fixfabriken factory area (from Garção, 2015).

The present land use with large areas of hardened surfaces and factory buildings implies low status in many urban and soil ESS in the reference scenario. The Adjacent area just south of the Fixfabriken factory area (see figure 3) but within the remediation site, is however given higher scores due to existing vegetation with positive effects on e.g. *Air quality*, *Noise reduction*, and geological conditions suitable for infiltration of ground water with positive effects on e.g. *Flood regulation* and *Water purification*. A part of the Adjacent area also contains the remains of a Neolithic settlement which implies high *Cultural heritage values*, the settlement also protrudes under the Fixfabriken factory area.

Table 9 Status of urban ESS identified as relevant at the Fixfabriken site.

Ecosystem service	Parts of the Fixfabriken site				
	Fixfab.[1]	Bus garage	Tram hall	K-J Blvd[2]	Adj. areas[3]
Air quality regulation	1	0	0	1	2
Climate regulation local	1	0	0	1	2
Noise reduction	1	0	0	1	2
Aesthetic values	0	0	0	1	2
Cultural heritage values	2	0	0	0	3
Recreation and ecotourism	0	0	0	0	2

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions.

Table 10 Status of soil ESS identified as relevant at the Fixfabriken site.

Ecosystem service	Parts of the Fixfabriken site				
	Fixfab.[1]	Bus garage	Tram hall	K-J Blvd[2]	Adj. areas[3]
Fresh water	0	0	0	1	3
Climate regulation global	1	0	0	1	2
Flood regulation	1	0	0	1	2
Water purification and waste treatment[4]	0	0	0	1	2

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4] Refers to remediation of soil contaminated by diffuse airborne pollution.

3.2.2 Quantification of effects from redevelopment scenario compared to the reference scenario

For evaluation of the effects on urban- and soil ESS from the remediation actions and the planned future land use at the site, the changes in identified ESS indicators are quantified. The results are presented in appendix B, tables B1 – B10. In addition to the different parts of the actual site, some concern is also given to “areas off-site” (AOS). Areas off site refers to non-specified landfills, this is of particular importance when polluted soil from the site is transported off-site for deposition on landfills or further treatment. The potentially negative effects on local ecosystem services at landfills or disposal sites need to be considered in order for the analysis to be complete.

In the final step, scores are appointed to the estimated changes in supply of ecosystem services in the different redevelopment alternatives based on the estimated changes in quantified indicators.

All redevelopment alternatives are described in detail in Garção (2015).

3.2.2.1 How to interpret the tables

In the tables below, presenting the changes in supply of ecosystem services associated with different redevelopment alternatives, green color indicates an improvement in comparison to the reference scenario and red color indicates a deterioration. The figure in the upper left part of each divided cell indicates the score of the ecosystem service in the reference scenario as described in tables 9 and 10, the score in the lower right part indicates the expected score after redevelopment. A single score without the diagonal line indicates a change in the supply of an ecosystem service relative to an unknown prevailing status, i.e. at landfill sites.

3.2.2.2 Alternative 1.

Details regarding quantified changes in the indicators representing soil- and urban ecosystem services are described in appendix B, tables B1 – B2, the consequent scores appointed to changes in the supply of ecosystem services are presented in tables 11 and 12. See section 3.2.2.1 for interpretation of the table content.

Effects on urban ecosystem services (1):

Air quality regulation, Climate regulation local (urban climate) and Noise reduction. A decrease in the provision of the ESS above is foreseen as a result of the removal of 0.5 ha of vegetation, trees and lawn.

Aesthetic value. The provision of this ESS is considered to increase considerably due to the scenic view offered from the planned residential areas.

Cultural heritage values. Excavation of parts of the Neolithic settlement is considered to have a negative impact on the ESS. However, the negative effect could be turned into a positive effect if a thorough archaeological investigation is performed previous to the excavation.

Recreation. The future planned land use will offer improvements in terms of recreation at the site compared to the present land use. There is however a risk that this positive effect might be cancelled out by negative effects in areas off-site used as disposal sites for polluted soil.

Table 11 Summary of assessments regarding changes in urban ESS as a consequence of redevelopment alternative 1. (See section 3.2.2.1 for interpretation of the table content.).

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Air quality regulation	1 / 0								
Climate regulation local (urban climate)	1 / 0								
Noise reduction	1 / 0								
Aesthetic values	0 / 2		0 / 2						
Cultural heritage values	2 / 1								3 / 2
Recreation and ecotourism	0 / 1	-1	0 / 1	-1	0 / 1			-1	
Total change in provision	-1	-1	+3	-1	+1			-1	-1

1 Fixfabriken factory area, 2 Karl Johansgatan Boulevard, 3 Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. 4 Areas Off-site

Effects on soil ecosystem services (alt. 1):

A decrease in the provision of the ESSs *Fresh water, Climate regulation global, Flood regulation* and *Water and Purification and waste treatment* is foreseen as a result of the removal of 0.5 ha vegetation, trees and lawn in the adjacent area.

An increase is on the other hand expected for the ESS *Fresh water* in the parts of the Fixfabriken where the soil at present is heavily polluted, this positive effect might be cancelled out by negative effects in areas off-site used as disposal sites for polluted soil.

An increase in the provision of the ESS *Fresh water* and *Water purification and waste treatment* can be foreseen in K-J Blvd as a result of excavation of polluted masses, it is however questionable if the positive effect is great enough to motivate a higher score than that of the base line.

The disposal of polluted soil off-site might bring about a negative effect that could be considerable given the conditions on the landfill site prior to the deposition.

Table 12 Summary of assessments regarding changes in soil ESS as a consequence of redevelopment alternative 1 and future land use. (See section 3.2.2.1 for interpretation of the table content.)

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Fresh water	0 / 1	-1	0 / 1	-1	0 / 1			-1	3 / 2
Climate regulation global									2 / 1
Flood regulation									2 / 1
Water purification and waste treatment[4]		-1		-1				-1	2 / 1
Total change in provision	+1	-2	+1	-2	+2			-2	-4

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

3.2.2.3 Alternative 2

Details concerning quantified changes in the indicators representing soil- and urban ecosystem services are described in appendix B, tables B3 and B4. The effects regarding strengthened or diminished supply of ecosystem services from redevelopment alternative 2 compared to the reference scenario are presented in tables 13 and 14. See section 3.2.2.1 for interpretation of the table content.

Effects on urban ecosystem services (alt. 2)

Air quality regulation, Climate regulation local (urban climate) and *Noise reduction*. An increase in the provision of the ESS above is foreseen as a result of the creation of 0.4 ha green space.

Aesthetic value. The provision of this ESS is expected to increase considerably due to the scenic view offered from the planned residential areas.

Cultural heritage values. Excavation of parts of the Neolithic settlement is expected to have a negative impact on the ESS. However, the negative effect could be turned into a positive effect if a thorough archaeological investigation is performed previous to the excavation.

Recreation. The future planned land use will offer improvements in terms of recreation at the site compared to the present land use. There is however a risk that this positive effect might be cancelled out by negative effects in areas off-site used as disposal sites for polluted soil.

Table 13 Summary of assessments regarding changes in urban ESS as a consequence of redevelopment alternative 2. (See section 3.2.2.1 for interpretation of the table content.)

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Air quality regulation	1 / 2								
Climate regulation local (urban climate)	1 / 2								
Noise reduction	1 / 2								
Aesthetic values	0 / 2		0 / 2						
Cultural heritage values	2 / 1								
Recreation and ecotourism	0 / 1	-1	0 / 1	-1	0 / 1			-1	
Total change in provision	+5	-1	+3	-1	+1			-1	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

Effects on soil ecosystem services (alt. 2)

Fresh water, Climate regulation global, Flood regulation. An increase in the provision of the ESS *Fresh water, Climate regulation global* and *Flood regulation* is foreseen as a result of the creation of 0.4 ha of green space. There is an additional positive local effect on the ESS *Fresh water* due to the fact that the polluted soil is transported off-site. The anticipated positive effect might however be countered by negative effects in the landfill areas used for disposal of the polluted soil.

An increase in the provision of the ESS *Water purification and waste treatment* is foreseen as a result of the creation of 0.4 ha green space. An increase can be foreseen in K-J Blvd as a result of excavation of polluted masses. It is unclear if this positive effect will be large enough to motivate a higher score than that of the reference scenario, it is therefore left unchanged. The disposal of polluted masses off-site might however bring about a negative effect that could be considerable given the conditions on the landfill site prior to the deposition.

Table 14 Summary of assessments regarding changes in soil ESS as a consequence of redevelopment alternative 2.

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Fresh water	0 / 2	-1	0 / 1	-1				-1	
Climate regulation global	1 / 2								
Flood regulation	1 / 2								
Water purification and waste treatment[4]	1 / 2	-1		-1				-1	
Total change in provision	+5	-2	+1	-2				-2	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

3.2.2.4 Alternative 3

Details concerning the quantified changes in the indicators representing soil and urban ecosystem services are described in appendix B, tables B5 and B6, The effects in terms of strengthened or diminished supply of urban and soil ecosystem services from redevelopment alternative 3 compared to the reference scenario are presented in tables 15 and 16. See section 3.2.2.1 for interpretation of the table content.

Effects on urban ecosystem services (alt. 3):

Aesthetic value. The provision of this ESS is expected to increase considerably due to the scenic view offered from the planned residential areas.

Recreation. The planned future land use will offer improvements in terms of recreation at the site compared to the present land use. Alternative 3 does however also include deposition of polluted soil from K-J Blvd which potentially may impose negative effects at off-site landfills with regards to the ESS *Recreation*.

Table 15 Summary of assessments regarding changes in urban ESS as a consequence of redevelopment alternative 3.

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Air quality regulation									
Climate regulation local (urban climate)									
Noise reduction									
Aesthetic values	0 / 2								
Cultural heritage values									
Recreation and ecotourism	0 / 1				0 / 1			-1	
Total change in provision	+3				+1			-1	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

Effects on soil ecosystem services (alt. 3):

An increase in the provision of the ESSs *Fresh water* in the parts of the Fixfabriken where soft remediation techniques are applied (phytoremediation).

An increase in the provision of the ESS *Fresh water* and *Water purification and waste treatment* can be foreseen in K-J Blvd as a result of excavation of polluted masses, it is however questionable if the positive effect is great enough to motivate a higher score than that of the base line. The disposal of polluted masses off-site might however bring about a negative effect that could be considerable given the conditions on the site prior to the deposition.

Table 16 Summary of assessments regarding changes in soil ESS as a consequence of redevelopment alternative 3 and future land use.

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Fresh water	0 / 1		0 / 1					-1	
Climate regulation global									
Flood regulation									
Water purification and waste treatment[4]								-1	
Total change in provision	+1		+1					-2	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

3.2.2.5 Alternative 4

Details concerning the quantified changes in the indicators representing soil and urban ecosystem services are described in appendix B, tables B7 and B8, the consequent scores appointed to changes in ecosystem services area presented in tables 17 and 18. See section 3.2.2.1 for interpretation of the table content.

Effects on urban ecosystem services (alt. 4):

Alternative 4 implies excavation in all four areas of the site. Since no on-site remediation of polluted soil is included, this is the remediation strategy among the five alternatives that leads to the largest amounts of polluted soil being deposited at off-site landfills. This is reflected in negative scores on AOS for the supply of the ESS *Recreation*.

In the same way as for alternative 1, the partial excavation of the Neolithic settlement is considered to have a negative impact on *Cultural heritage values*. However, the negative effect could be turned into a positive effect if a thorough archaeological investigation is performed previous to the excavation.

Table 17 Summary of assessments regarding changes in urban ESS as a consequence of redevelopment alternative 4.

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Air quality regulation	1 / 0								
Climate regulation local (urban climate)	1 / 0								
Noise reduction	1 / 0								
Cultural heritage values	2 / 1								3 / 2
Aesthetic values	0 / 2								
Recreation and ecotourism	0 / 1	-1		-1	0 / 1	-1		-1	
Total change in provision	+1	-1		-1	+1	-1		-1	-1

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

Effects on soil ecosystem services (alt. 4):

Since excavation without on-site remediation of polluted soil is planned in all four areas within the site, potentially large negative effects can be anticipated in off-site landfills after deposition. This is reflected in negative scores at AOS for the ESS *Fresh water* and *Water purification and waste treatment*.

Alternative 4 also implies removal of ca 0.5 ha of vegetation in the adjacent area, this results in negative scores for the ESS *Freshwater, Climate regulation global, Flood regulation* and *Water purification and waste treatment*.

Table 18 Summary of assessments regarding changes in soil ESS as a consequence of redevelopment alternative 4.

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Fresh water	0 / 1	-1	0 / 1	-1		-1		-1	3 / 2
Climate regulation global									2 / 1
Flood regulation									2 / 1
Water purification and waste treatment[4]		-1		-1		-1		-1	2 / 1
Total change in provision	+1	-2	+1	-2		-2		-2	-4

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

3.2.2.6 Alternative 5

Details concerning the quantified changes in the indicators representing soil and urban ecosystem services are described in appendix B, tables B9 and B10, the consequent scores appointed to changes ecosystem services area presented in tables 19 and 20. See section 3.2.2.1 for interpretation of the table content.

Effects on urban ecosystem services (alt. 5):

In alternative 5, both Fixfabriken and the tram hall are kept intact which is reflected in relatively small changes in supply of ecosystem services compared to the reference scenario. Some positive effects are anticipated in the Bus garage area where new buildings for residential use with commercial/offices/services at the ground floor implies increased *Aesthetic values* in addition to increased possibilities for *Recreation* compared to the reference scenario.

The remediation actions in this alternative implies excavation and deposition of polluted soils at off-site landfills which is reflected in potentially decreased possibilities for *Recreational* activities at landfill sites. The planned change of activities in the tram hall is expected to increase the opportunity for *Recreation*.

Table 19 Summary of assessments regarding changes in urban ESS as a consequence of redevelopment alternative 5.

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Air quality regulation									
Climate regulation local (urban climate)									
Noise reduction									
Aesthetic values			0 / 2						
Cultural heritage values									
Recreation and ecotourism			0 / 1	-1	0 / 1			-1	
Total change in provision			+3	-1	+1			-1	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

Effects on soil ecosystem services (alt. 5)

The effects on soil ecosystem services from alternative 5 is limited to the positive impact on the ESS *Fresh Water* in the Bus garage area from excavating and removing polluted soil. Consequently there might be a negative effect on the ESS *Fresh Water* from the deposited soil at landfill sites. The same is valid for the landfill site used to deposit polluted soil from Karl Johansgatan Boulevard.

Table 20 Summary of assessments regarding changes in soil ESS as a consequence of redevelopment alternative 5 and future land use.

Ecosystem service	Effects in parts of the Fixfabriken site and areas off-site (AOS)								
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Fresh water			0 / 1	-1				-1	
Climate regulation global									
Flood regulation									
Water purification and waste treatment[4]				-1				-1	
Total change in provision			+1	-2				-2	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

3.2.3 Summary

The result from the summary of the analysis (table 21) shows that redevelopment alternative 2 appears to be the most desirable from an ecosystem services perspective. This alternative is identical in terms of remediation actions and future land use to alternative 1 with the exception of a green space which is planned in the south part of the Fixfabriken area. The creation of the green space has a strong impact on the final score due to its strengthening of the provision of both urban and soil ecosystem services while the corresponding negative effects in the adjacent area foreseen in alternative 1 are avoided. Alternative 1 is ranked as the fourth most attractive option in the analysis.

The second best alternative is represented by 3 which is the alternative that involves the least deposition of polluted soil at off-site landfills. In addition, this alternative impose no negative impact on the adjacent area or on cultural heritage values on the site. The only potentially negative impact in comparison to the reference scenario is attributed to the deposition of polluted soil from the Karl Johansgatan Boulevard area on off-site landfills.

The third best score is attributed to alternative 5. This alternative makes the most use of existing buildings and structures leaving both the Fixfabriken and the tram hall intact. It does however imply excavation and deposition of polluted soil from both the bus garage and Karl Johansgatan areas which renders negative scores from potentially negative effects at off-site landfills.

The two least attractive alternatives are 4 and 1, which is mainly explained by two common features: both alternatives implies excavation and deposition of polluted soil with potentially negative effects on ecosystem services at off-site landfills, both alternatives also implies negative effects on the adjacent area just south of the Fixfabriken as a part of the existing green space is claimed by the planned land use.

A major part of the negative effects that are expected in the redevelopment alternatives are associated with excavation and removal of polluted soil for deposition at off-site landfills. Whether or not these negative effects will materialize depends on the conditions at the landfill sites prior to the deposition. If the landfills have been previously used for similar purposes, then the new addition of polluted soil will not result in additional local negative effect on the supply of ecosystem services. If a new site is required for the deposits, or if the soil in question has a higher degree of pollution compared to the existing soils at the landfill site, then the negative effects might be of relevance for the analysis.

Another important part of both positive and negative impacts come from changes in the so called *adjacent area*. The redevelopment alternatives 1 and 4 implies that some 0.5 ha of this area will be claimed by the new land use causing negative effects on several ecosystem services, e.g. *Air quality regulation, Climate regulation local (urban climate)* and *Noise reduction*. In addition, the future land use also implies excavation of parts of a Neolithic settlement in the redevelopment area. The excavation is expected to have a negative impact on the ESS *Cultural heritage values*, this however depends on whether or not the excavation is preceded by an archaeological investigation that may turn the negative effect into a positive one by means of e.g. exhibitions of the findings.

Table 21 Summary of effects on urban and soil ecosystem services from different redevelopment alternatives in the Fixfabriken case study.

Redevelopment alternatives/ Ecosystem service	Effects in parts of the Fixfabriken **site** and areas off-site (AOS)									Summary			
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]	Pos. impact	Neg. impact	Total score	Rank
Alternative 1													
Urban ESS	-1	-1	+3	-1	+1			-1	-1				
Soil ESS	+1	-2	+1	-2	+1			-2	-4				
Summary	±0	-3	+4	-3	+2			-3	-5	+6	-14	-8	4
Alternative 2													
Urban ESS	+5	-1	+3	-1	+1			-1					
Soil ESS	+5	-2	+1	-2				-2					
Summary	+10	-3	+4	-3	+1			-3		+15	-9	+6	1
Alternative 3													
Urban ESS	+3				+1			-1					
Soil ESS	+1		+1					-2					
Summary	+4		+1		+1			-3		+6	-3	+3	2
Alternative 4													
Urban ESS	+1	-1		-1	+1	-1		-1	-1				
Soil ESS	+1	-2	+1	-2		-2		-2	-4				
Summary	+2	-3	+1	-3	+1	-3		-3	-5	+4	-17	-13	5
Alternative 5													
Urban ESS			+3	-1	+1			-1					
Soil ESS			+1	-2				-2					
Summary			+4	-3	+1			-3		+5	-6	-1	3

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

3.3 Sensitivity reflections

It is clear from the analysis that local conditions at landfill sites might play an important role for the final result in the Fixfabriken case study. Assume for example that no additional negative effects on ecosystem services would occur in landfill sites used for deposition of polluted soil from the site; the summation in table 21 would then turn out as shown below in table 22 after removal of negative effects on the ESSs *Recreation and ecotourism* and *Water purification and waste treatment*.

Table 22 Ranking of the redevelopment alternatives under the assumption of "no negative effects" from deposition of polluted soil on the supply of ecosystem services at off-site landfills.

Redevelopment alternatives	Effects in parts of the Fixfabriken area and areas off-site (AOS)									Summary			
	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]	Pos. impact	Neg. impact	Total score	Rank
1	±0		+4		+2				-5	+6	-5	+1	4
2	+10		+4		+1					+15	-	+15	1
3	+4		+1		+1					+6	-	+6	2
4	+2		+1		+1				-5	+4	-5	-1	5
5			+4		+1					+5	-	+5	3

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

The rank between the different options remains the same after removing the potentially negative effects on landfill sites. The most attractive alternative (2) appears even more favorable while the differences between the other alternatives decreases, leaving alternative 5 only marginally better than alternative 1.

The latter result indicates that the final ranking in table 21 is sensitive to the representation of the negative effects on off-site landfills. Due to lack of information, a uniform score of -1 was applied to describe all negative effects from deposition of polluted soils at off-site landfills. In order to increase the precision in the analysis, a differentiated approach could be applied where variability in terms of negative effects (e.g. level of pollution of the soil from different parts of the site, amounts of those soils, impact at individual landfill sites) is reflected in the score.

4 DISCUSSION AND CONCLUDING REMARKS

This analysis indicates that a semi-quantitative approach to map the changes in provision of ecosystem services that will follow from different redevelopment alternatives will potentially add important decision support regarding the economic and social desirability of available options. The principal strength of the method is its ability to map and quantify changes in wellbeing that in many cases are neglected in applications of cost-benefit analysis to redevelopment projects, despite the relevance of those changes in such analysis.

The optimal contribution to the cost-benefit analysis would be to arrive at monetized valuations of changes in wellbeing attributed to different redevelopment alternatives. This would offer a more comprehensive and accurate assessment of all the changes in wellbeing brought about by specific redevelopment options. Even though this report doesn't go that far, the methodology describes the links in the causal chain between ecosystem features or functions on one end, and effects on human wellbeing on the other end. These links being e.g. a compilation of suitable biophysical indicators to represent ecosystem services, facilitating the assessment of the relation between those biophysical indicators and related human uses. In doing this, it paves the way for monetized valuations of benefits accruing to different redevelopment alternatives. In cases where monetary valuation is not possible, or suitable, the result of the analysis can be used together with traditional assessment of costs and benefits in multi criteria analysis (MCA) allowing for both qualitative, quantitative as well as monetized data in the assessment.

In the Fixfabriken case study, a semi-quantitative assessment was at this stage suitable. The Fixfabriken site was in the process of developing a detailed plan of the area (see also Norrman et al., 2015b), a stage in which a lot of detailed data is not available and a lot of the knowledge is qualitative. The assessments of the reference scenario and the outcome of different redevelopment alternatives with regard to ecosystem services, have been based solely on desk top studies including readily available information regarding present and planned future land use (e.g. GIS-maps), results from geological as well as archaeological investigations and proposed remediation measures and techniques presented in the Fixfabriken case study (Garção, 2015 and Norrman et al., 2015b). In order to generate a better background material to underpin the analysis, this information could be complemented by means of focus groups and interviews with stakeholders. This would generate more precise information on perceived spatial importance and relevance of ecosystem services in the area. It would also generate a deeper understanding of the temporal aspects of the ecosystem services and benefits in the reference scenario and redevelopment alternatives.

Another aspect that would benefit from a stakeholder oriented elicitation method concerns the relation between "man-made" ecosystem services (e.g. green roofs, permeable pavements) and "in-situ" ecosystem services (e.g. tree canopies serving as

cooling elements in the summer in addition to a positive effect on air quality). If there is a measurable difference in the stakeholder group regarding preferences between ecosystem services already in place and those that need to be constructed, this need to be reflected in the assessment.

4.1 Caveats

The result from the analysis can be used to give an indication on changes in the provision of ecosystem services that can be expected from different redevelopment strategies. Summing the scores of effects on different ecosystem services poses however a number of problems that need to be considered

- The semi-quantitative scores chosen to describe the status of ecosystem services in the reference scenario and in changes due to remediation actions ranges from 0-3. It should be emphasized that the choice of scale is this study is arbitrary and only a suggestion. Further attention should be paid to alternative scales, e.g. are the effects in terms of changes in the status of ecosystem services linear?
- The effect from changes in the provision of different ecosystem services might differ greatly in importance but still have the same score in the analysis. There is for example probably a great difference between the negative effect on wellbeing from increased noise from traffic that might be expected from the removal of a tree line in the adjacent area, compared to the negative effect on wellbeing that might occur at a disposal site used for depositing 26 000 m^3 of polluted soil. A way to deal with this would be to assign weights to the scores used to describe changes in the provision of ecosystem services in a way that would reflect their relative importance at the local scale.
- Summing the effects on all affected ecosystem services at individual parts of the site will inherently hide details regarding changes that might be of great local importance. This problem will to some extent be remedied by the use of weights as discussed above to highlight the relative importance of different changes in the supply of ecosystem services. This must nevertheless be kept in mind when the resulting scores are evaluated.
- Knowledge about the local conditions in areas affected by remediation actions is of great importance, not only at the actual site but also at off-site landfills and along the transport routes to the landfills. The negative effect from disposal of polluted soil at a landfill is determined by the initial conditions at the landfill site as well as the degree of pollution (and amount) of the soil being deposited.

REFERENCES

Baggethun et al. 2013, Urban Ecosystem Services. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities 2013, pp 175-251 Cranfield University, UK

Barbier, E.B. 2009, Ecosystems as Natural Assets, Foundations and Trends in Microeconomics, 4(8): 611-681.

Bardos, R.P., Bakker, L.M.M., Slenders H.L.A., Nathanail, C.P., 2011. Sustainability and remediation. In: Swartjes, F.A. (Ed.) Dealing with contaminated sites. Springer, 889-948.

Burkhard, B. et al. 2012, Mapping ecosystem service supply, demand and budgets, Ecological Indicators 21, 17-19.

COWI 2014, Support Policy Development for Integration of Ecosystem Service Assessments into WFD and FD Implementation, Resource document, January 2014

Egoh, B et al 2012, Indicators for mapping ecosystem services; a review. JRC scientific and policy reports. European Commission.

Finvers, M.A., 2008, Application of DPSIR for analysis of soil protection issues and an assessment of British Columbia's soil protection legislation. M.Sc. Thesis.

Garção, R., 2015. Assessment of alternatives of urban brownfield redevelopment. Application of the SCORE tool in early planning stages. Master Thesis 2015:15. Chalmers University of Technology, Gothenburg, Sweden

Haines-Young and Potschin 2013, Common Internatioinal Classification of Ecosystem Services (CICES) Consultation version 4.

Hauser et al. 2011, Linking the ecosystem accounting framework with country-specific indicators, Swiss Federal Office for the Environment FOEN.

Maes, J. et al 2011. A European assessment of the provision of ecosystem services. JRC European Commission 2011.

Maes et al 2013. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessment under action 5 of the biodiversity strategy to 2020. Publications office of the European Union, Luxembourg.

Mazza L., et al. 2011, Green Infrastructure Implementation and Efficiency. Final report for the European Commission, DG Environment on Contract ENV.B.2/SER/2010/0059. Institute for European Environmental Policy, Brussels and London.

Millenium Ecosystem Assessment 2005, Ecosystem and human wellbeing: Synthesis. Island Press, Washington DC.

Mäler, K.-G., Aniyar, S. and Jansson, Å. (2009) Accounting for Ecosystems, Environmental and Resource Economics, 42: 39-51.

Norrman 2015a; Norrman J, Volchkco Y, Maring L, Hooimeijer F, Broekx S, Garção R, Beames A, Kain J-H, Ivarsson M, Touchant K. 2015, BALANCE 4P: Balancing decisions for urban brownfield redevelopment. Technical report of the BALANCE 4P project of the SNOWMAN Network coordinated call IV. Report 2015:11. Chalmers University of Technology, Gothenburg, Sweden.

Norrman 2015b; Norrman J, Maring L, Hooimeijer F, Broekx S, Garção R, Volchkco Y, Kain J-H, Ivarsson M, Touchant K, Beames A. 2015, BALANCE 4P: Balancing decisions for urban brownfield redevelopment – case studies. Case study report of the BALANCE 4P project of the SNOWMAN Network coordinated call IV. Report 2015:12, Chalmers University of Technology, Gothenburg, Sweden.

Nowak J. et al 2006, Air pollution removal by urban trees and shrubs in the United States,

Lydia Olander, Robert J. Johnston, Heather Tallis, Jimmy Kagan, Lynn Maguire, Steve Polasky, Dean Urban, James Boyd, Lisa Wainger, and Margaret Palmer. 2015. "Best Practices for Integrating Ecosystem Services into Federal Decision Making." Durham: National Ecosystem Services Partnership, Duke University. doi:10.13016/M2CH07

Naturvårdsverket 2015, Guide för värdering av ekosystemtjänster. Rapport 6690, Augusti 2015.

Rosén, L., Back, P-E., Söderqvist, T., Norrman, J., Brinkhoff, P., Norberg, T., Volchko, Y., Norin, M., Bergknut, M., Döberl, G. 2015. SCORE: A novel multi-criteria decision analysis approach to assess the sustainability of contaminated land remediation. Science of the Total Environment 511, 621-638.

SuRF-UK, 2010. A Framework for Assessing the Sustainability of Soil and Groundwater Remediation. Contaminated Land: Applications In Real Environments (CL:AIRE). London, United Kingdom.

TEEB 2010, The Economics of Ecosystem Services and Biodiversity – Ecological and Economic Foundations.

Trafikverket 2015, Samhällsekonomiska principer och kalkylvärden för transportsektorn: ASEK 5.2 - Kapitel 12 Kostnad för klimateffekter.

UN 2012, The future we want. Resolution adopted by the General Assembly 27 July 2012. A/RES/66/288. United Nations, New York.

Vegter, J., Lowe, J., Kasamas, H., 2003. Risk-based land management – a concept for the sustainable management of contaminated land. Land Contamination & Reclamation 11 (1), 31-36.

Weaving Ecosystem Services into Impact Assessment. World Resource Institute (WRI) 2013.

Digital sources

White house 2013

https://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

APPENDICES

A. Selection of ecosystem services

The selection of relevant ecosystem services from the "candidate lists" (see section 3.1.1.1) is based on assessments of present and potential future importance making use of a simple semi-quantitative scale according to:

- 0 Not relevant due to local conditions, context, temporal or spatial considerations
- \+ Existent but of marginal importance due to local conditions, temporal or spatial considerations
- ++ Important but with a limited supply due to local conditions, temporal or spatial considerations
- +++ Important, at or close to its maximum supply with regards to local conditions

The Fixfabriken case study site is divided into several sub-areas. The assessment of relevance/importance as well as selection of individual ESS is however done for the entire site and not for each sub-area.

The motivation for the selection of urban ESS is given in table A1 below, and for soil ESS in table A2.

Table A1. Assessment of relevance/importance and selection of Urban ESS (Baggethun et al. (2013)) for mapping in the Fixfabriken case study site.

Ecosystem service		Urban context	Present importance	Potential future importance	Selected (Y/N)	Comment
Provisioning	Food	Vegetables produced by urban allotments and peri-urban areas.	0	+	N	No present urban allotment, might be possible in the future but only marginally
	Fresh water	Ecosystems provide cities with fresh water for drinking and other human uses and by securing storage and controlled release of water flows. Vegetation cover and forests in the city catchment influences the quantity of available water.	0	+	N	No extraction of water for the purpose of producing drinking water at resent, none is planned in the future.
Regulation & Maintenance	Air quality regulation	Vegetation in urban systems can improve air quality by removing pollutants from the atmosphere, including ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter less than 10 µm (PM10).	++	+++	Y	Present vegetation offers supply of the ESS with relevance to local residents, the planned future land use (housing) increases the importance of the ESS.

Cont. table A1

Ecosystem service		Urban context	Present importance	Potential future importance	Selected (Y/N)	Comment
Regulation & Maintenance	Climate regulation global	Carbon sequestration and storage by biomass of urban shrubs and threes.	-	-	N	This ESS is selected among the soil ESS, see table A2.
	Climate regulation local (urban climate)	Water areas buffer temperature extremes by absorbing heat in summertime and by releasing it in wintertime trees. Urban vegetation provide shade, create humidity and block wind, water from the plants absorbs heat as it evaporates, thus cooling the air in the process.	++	+++	Y	Present vegetation offers supply of the ESS with relevance to local residents, the planned future land use (housing) increases the importance of the ESS.
	Water regulation	Soil and vegetation percolate water during heavy and/or prolonged precipitation events. Vegetation reduces surface runoff following precipitation events by intercepting water through the leaves and stems. The underlying soil also reduces infiltration rates by acting as a sponge by storing water in the pore spaces until it percolates as through-flow and base-flow.	-	-	N	This ESS is selected among the soil ESS, see table A2.
	Noise reduction	Urban soil and plants can attenuate noise pollution through absorption, deviation, reflection, and refraction of sound. In row plantings of trees, sound waves are reflected and refracted, dispersing the sound energy through the branches and trees.	++	+++	Y	Present vegetation offers supply of the ESS with relevance to local residents, the planned future land use (housing) increases the importance of the ESS.

Cont. table A1

Ecosystem service		Urban context	Present importance	Potential future importance	Selected (Y/N)	Comment
Regulation & Maintenance	Water purification and waste treatment	Wetlands and other aquatic systems, for example, filter wastes from human activities; this process reduces the level of nutrients and pollution in urban wastewater. Likewise, plant communities in urban soils can play an important role in the decomposition of many labile and recalcitrant litter types.	0	+	N	Not relevant at Fixfabriken at present, might be of limited importance depending on local storm water strategies planned for the future.
	Pollination and seed dispersal	Urban ecosystems provide habitat for birds, insect and pollinators. Pollination, pest regulation and seed dispersal are important processes in the functional diversity of urban ecosystems and can play a critical role in their long term durability.	+	+	N	Existing but of low importance for the site.
	Maintaining nursery populations and habitats	Urban systems can play a significant role as refuge for many species of birds, amphibians, bees, and butterflies	+	+	N	Existing but of low importance for the site.
	Natural hazard regulation	Storm, flood and wave buffering by vegetation buffers, wetland areas; heat absorption during heat waves.	0	+	N	Not relevant at Fixfabriken at present, might be of limited importance depending on future local storm water strategies.

Cont. table A1

Ecosystem service		Urban context	Present importance	Potential future importance	Selected (Y/N)	Comment
Cultural	Knowledge systems	Allotment gardening as preservation of socio-ecological knowledge.	0	+	N	No present urban allotment, might be a possible land use in the future but only of marginal importance
	Aesthetic values	Urban parks, sea view, urban scenic view in sight from houses.	+	+++	Y	At present the esthetic values are limited due to a low number residents on the site, the planned future land use (housing) will however increases the importance of the ESS.
	Cultural heritage values	E.g. Neolithic settlement	+++	+++	Y	The Neolithic settlement at the case study area represents high cultural values both on local and national scale, it will continue to do so after redevelopment.
	Recreation and ecotourism	Urban green areas provide opportunities for recreation, mediation and relaxation.	++	++	Y	The park area in connection to the actual site represents high recreational values to nearby residents, its importance will increase further due to the planned land use (housing).

Table A2. Assessment of relevance/importance and selection of Soil ESS (Finvers (2008)) for mapping in the Fixfabriken case study site.

Ecosystem service		Soil context	Present importance	Potential future importance	Selected (Y/N)	Comment
Provisioning	Food	Nutrient cycling to support plant growth (primary production) including food and fiber production	+	+	N	No present urban allotment, might be a possible land use in the future but only of marginal importance
	Biomass	Basis of all terrestrial ecosystems –life support	+	+	N	The scale of the changes in the supply of biomass due to different redevelopment alternatives is of marginal local importance
Regulation & Maintenance	Fresh water	Water purification and soil contaminant reduction	++	++	Y	An important ESS due to local soil contaminations, will continue to be of importance also after redevelopment. (functional process: adsorption of contaminants into soil aggregates).
	Climate regulation global	Carbon sequestration and regulation of greenhouse gasses	++	++	Y	Carbon sequestration and regulation of greenhouse gases is increasingly important, both locally and globally.
	Water regulation	Flood regulation	+	++	Y	Local flood regulation will be of growing importance in a future climate where precipitation is expected to increase in the region of interest.
	Erosion regulation					
	Water purification and waste treatment	Remediation of soil contaminated by diffuse airborne pollution.	++	++	Y	An important ESS due to local soil contaminations, will continue to be of importance also after redevelopment (functional process: Soil biota metabolism.)

B. Changes in indicators representing urban ESS as a result of redevelopment alternative

Details concerning the quantified changes in the indicators representing soil and urban ecosystem services as a result of redevelopment alternatives 1 - 5 are described in table B1 – B10 below.

Green color indicates an improvement in provision of ecosystem services brought about by the redevelopment alternative in comparison to the reference scenario, red color indicates a deterioration.

Table B1. Changes in indicators representing urban ESS as a result of redevelopment alternative 1 and in comparison to the reference scenario.

Ecosystem service	**Fixfab.[1]**	**AOS[4]**	**Bus garage**	**AOS**	**Tram hall**	**AOS**	**K-J Blvd[2]**	**AOS**	**Adj. areas[3]**
Air quality regulation	- 0.5 ha vegetation, trees and lawn								
Climate regulation local (urban climate)	- 0.5 ha vegetation, trees and lawn								
Noise reduction	- 0.5 ha vegetation, trees and lawn								
Aesthetic values	Urban park and urban scenic view in sight from houses.(no. of apartments)		Urban park and urban scenic view in sight from houses (no. of apartments)						
Cultural heritage values	Parts of the Neolithic settlement is excavated								Parts of the Neolithic settlement is excavated
Recreation and ecotourism	Removal of the buildings creates opportunities for recreation, mediation and relaxation.	Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	Removal of the Garage creates opportunities for recreation, mediation and relaxation	Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	Change of activities in the tram hall creates opportunities for recreation, mediation and relaxation			Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

Table B2. Changes in indicators representing soil ESS as a result of redevelopment alternative 1 and in comparison to the reference scenario.

Ecosystem service	**Fixfab.[1]**	**AOS[5]**	**Bus garage**	**AOS**	**Tram hall**	**AOS**	**K-J Blvd[2]**	**AOS**	**Adj. areas[3]**
Fresh water	-54 000 m^3 contaminated soil	+27 000 m^3 contaminated soil	-70 000 m^3 contaminated soil	+35 000 m^3 contaminated soil				+26 000 m^3 contaminated soil	Approximately 0.5 ha of vegetated land is removed
Climate regulation global									Approximately 0.5 ha of vegetated land is removed
Flood regulation									Approximately 0.5 ha of vegetated land is removed
Water purification and waste treatment[4]		+27 000 m^3 contaminated soil		+35 000 m^3 contaminated soil				+26 000 m^3 contaminated soil	Approximately 0.5 ha of vegetated land is removed

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4] Refers to remediation of soil contaminated by diffuse airborne pollution, [5]Areas Off-site

Table B3. Changes in indicators representing urban ESS as a result of the redevelopment alternative 2 and in comparison to the reference scenario.

Ecosystem service	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Air quality regulation	+ 0.4 ha green area								
Climate regulation local (urban climate)	+ 0.4 ha green area								
Noise reduction	+ 0.4 ha green area								
Aesthetic values	Urban park and urban scenic view in sight from houses.(no. of apartments)		Urban park and urban scenic view in sight from houses (no. of apartments)						
Cultural heritage values	Parts of the Neolithic settlement is excavated								
Recreation and ecotourism	Removal of the buildings creates opportunities for recreation, mediation and relaxation.	Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	Removal of the Garage creates opportunities for recreation, mediation and relaxation	Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	Change of activities in the tram hall creates opportunities for recreation, mediation and relaxation			Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site.

Table B4. Changes in indicators representing soil ESS as a result of the redevelopment alternative 2 and in comparison to the reference scenario.

Ecosystem service	**Fixfab.[1]**	**AOS[5]**	**Bus garage**	**AOS**	**Tram hall**	**AOS**	**K-J Blvd[2]**	**AOS**	**Adj. areas[3]**
Fresh water	-54 000 m^3 contaminated soil	+27 000 m^3 contaminated soil	- 70 000 m^3 contaminated soil	+35 000 m^3 contaminated soil				+26 000 m^3 contaminated soil	
	+ 0.4 ha green area leads to increased infiltration to groundwater								
Climate regulation global	+ 0.4 ha green area leads to increased carbon sequestration								
Flood regulation	+ 0.4 ha green area leads to increased infiltration to groundwater								
Water purification and waste treatment[4]	+ 0.4 ha green area leads to increased purification of diffuse airborne pollution	+27 000 m^3 contaminated soil		+35 000 m^3 contaminated soil				+26 000 m^3 contaminated soil	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4] Refers to remediation of soil contaminated by diffuse airborne pollution, [5]Areas Off-site.

Table B5. Changes in indicators representing urban ESS as a result of the redevelopment alternative 3 and in comparison to the reference scenario.

Ecosystem service	**Fixfab.[1]**	**AOS[4]**	**Bus garage**	**AOS**	**Tram hall**	**AOS**	**K-J Blvd[2]**	**AOS**	**Adj. areas[3]**
Air quality regulation									
Climate regulation local (urban climate)									
Noise reduction									
Aesthetic values	Urban park and urban scenic view in sight from houses.(no. of apartments)								
Cultural heritage values									
Recreation and ecotourism	Removal of the buildings creates opportunities for recreation, mediation and relaxation.				Removal of the tram hall creates opportunities for recreation, mediation and relaxation			Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

Table B6. Changes in indicators representing soil ESS as a result of the redevelopment alternative 3 and in comparison to the reference scenario.

Ecosystem service	**Fixfab.[1]**	**AOS[5]**	**Bus garage**	**AOS**	**Tram hall**	**AOS**	**K-J Blvd[2]**	**AOS**	**Adj. areas[3]**
Fresh water	Soft technique remediation of contaminated soil (phytoremediation) around buildings.		Soft technique remediation of contaminated soil (phyto-remediation) around buildings.					+ 26 000 m^3 contaminated soil	
Climate regulation global									
Flood regulation									
Water purification and waste treatment[4]								+ 26 0000 m^3 contaminated soil	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4] Refers to remediation of soil contaminated by diffuse airborne pollution, [5]Areas Off-site

Table B7. Changes in indicators representing urban ESS as a result of the redevelopment alternative 4 and in comparison to the reference scenario.

Ecosystem service	**Fixfab.[1]**	**AOS[4]**	**Bus garage**	**AOS**	**Tram hall**	**AOS**	**K-J Blvd[2]**	**AOS**	**Adj. areas[3]**
Air quality regulation	- 0.5 ha vegetation, trees and lawn								
Climate regulation local (urban climate)	- 0.5 ha vegetation, trees and lawn								
Noise reduction	- 0.5 ha vegetation, trees and lawn								
Aesthetic values	Urban park and urban scenic view in sight from houses.(no. of apartments)								
Cultural heritage values	Parts of the Neolithic settlement is excavated								Parts of the Neolithic settlement is excavated
Recreation and ecotourism	Removal of the buildings creates opportunities for recreation, mediation and relaxation.	Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.		Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	Removal of the tram hall creates opportunities for recreation, mediation and relaxation	Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.		Deposit of polluted soil potentially counters opportunities for recreation, mediation and relaxation at landfill sites.	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

Table B8. Changes in indicators representing soil ESS as a result of the redevelopment alternative 4 and in comparison to the reference scenario.

Ecosystem service	**Fixfab.[1]**	**AOS[5]**	**Bus garage**	**AOS**	**Tram hall**	**AOS**	**K-J Blvd[2]**	**AOS**	**Adj. areas[3]**
Fresh water	-54 000 m^3 contaminated soil	+27 000 m^3 contaminated soil	- 70 000 m^3 contaminated soil	+35 000 m^3 contaminated soil	- 58 000 m^3 contaminated soil	+ 29 000 m^3 contaminated soil		+ 26 000 m^3 contaminated soil	Approximately 0.5 ha of vegetated land is removed
Climate regulation global									Approximately 0.5 ha of vegetated land is removed
Flood regulation									Approximately 0.5 ha of vegetated land is removed
Water purification and waste treatment[4]		+27 000 m^3 contaminated soil		+35 000 m^3 contaminated soil		+ 29 000 m^3 contaminated soil		+ 26 0000 m^3 contaminated soil	Approximately 0.5 ha of vegetated land is removed

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4] Refers to remediation of soil contaminated by diffuse airborne pollution, [5]Areas Off-site

Table B9. Changes in indicators representing urban ESS as a result of development alternative 5 and in comparison to the reference scenario.

Ecosystem service	Fixfab.[1]	AOS[4]	Bus garage	AOS	Tram hall	AOS	K-J Blvd[2]	AOS	Adj. areas[3]
Air quality regulation									
Climate regulation local (urban climate)									
Noise reduction									
Aesthetic values			Urban park and urban scenic view in sight from houses (no. of apartments)						
Cultural heritage values									
Recreation and ecotourism			Removal of the Garage creates opportunities for recreation, mediation and relaxation	Deposit of polluted soil counters opportunities for recreation, mediation and relaxation.	Change of activities in the tram hall creates opportunities for recreation, mediation and relaxation.			Deposit of polluted soil counters opportunities for recreation, mediation and relaxation.	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas - area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4]Areas Off-site

Table B10. Changes in indicators representing soil ESS as a result of development alternative 5 and in comparison to the reference scenario.

Ecosystem service	**Fixfab.[1]**	**AOS[5]**	**Bus garage**	**AOS**	**Tram hall**	**AOS**	**K-J Blvd[2]**	**AOS**	**Adj. areas[3]**
Fresh water			-70 000 m^3 contaminated soil	+35 000 m^3 contaminated soil				+26 000 m^3 contaminated soil	
Climate regulation global									
Flood regulation									
Water purification and waste treatment[4]				+35 000 m^3 contaminated soil				+26 000 m^3 contaminated soil	

[1] Fixfabriken factory area, [2] Karl Johansgatan Boulevard, [3]Adjacent areas – area within the redevelopment site but separated from the actual buildings affected by the remediation actions. [4] Refers to remediation of soil contaminated by diffuse airborne pollution, [5]Areas Off-site

Research, consulting and teaching for a sustainable future

Enveco Environmental Economics Consultancy is well-established in the environmental economics research community. We offer analysis, research, education and training in environmental economics and ecological economics. Our clients are in the private, non-profit and public sectors. We are located in Stockholm and Göteborg but work nationwide as well as internationally.

Enveco Miljöekonomi AB
Måsholmstorget 3, SE-127 48 Skärholmen
Kyrkogatan 30, SE-411 15 Göteborg

www.enveco.se
E-mail: info@enveco.se