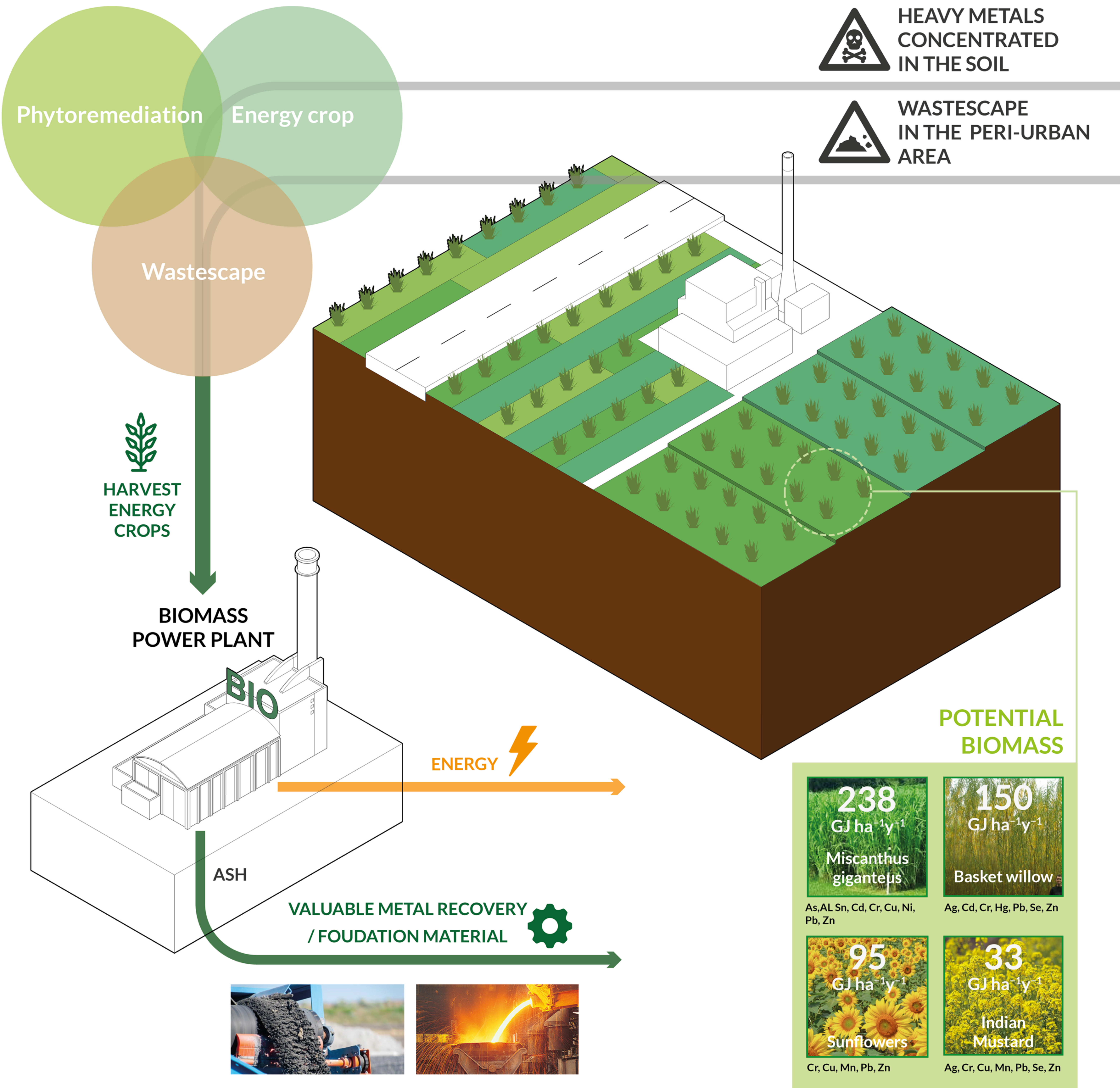
1 | Context Phytoremediation driven energy crops production on wastescapes



Anthropogenic activities have created landscapes with high levels of metal and metalloid element soil contamination. Sites with high levels of contaminants pose a human health risk through direct contact, inhalation, or consumption due to infiltration to groundwater aquifers (Nriagu et al. 1988). Additionally, negative impacts also occur to the local ecosystem, through changes to soil chemistry, eradication of microorganisms, or biomagnification. We will use the term "wastescape" to describe these landscapes that have been contaminated and abandoned.
The ideal solution for dealing with toxic metalliferous soils within wastescapes would be to convert the wastes into useful by-products or energy. Doing so creates the opportunity to provide economic, environmental, and social benefit to the producers and consumers of the waste. Through the valorization of waste, systematic leakage and negative externalities can be minimized. Such actions are crucial when combined with the realities of resource depletion, brought about by the fact that many of the earth's resources are finite. This manner of system operation is often defined as circular, and stands apart from the antiquated linear industrial and economic systems that operate on the idea that there are no boundaries to our ability to extract, consume, and dispose of everything we produce.
Phytoremediation offers a low cost solar energy driven means to extracting the contaminants in soil and water through the use of specialized plants (hyper-accumulators) that naturally extract metals (Ali, et al. 2013)(Wan, et al. 2016). Through the application of phytoremediation, wastescapes can be improved in a way that serves the triple bottom line of people, planet, profit. Fenced off and derelict sites can be landscaped into attractive natural areas. The phytoremediators over time improves the soil and water by removing contaminates. Lastly, the phytoremediators are harvestable for production of sustainable energy and metals or foundational materials, such as concrete reagents(Jiang, et al. 2015)(Pidlisnyuk, et al. 2014). Bio-ore mining is possible when the concentration of metals in the remediating plants is high, the cost for extracting the metal from the plant is low, and the metal's market value is high.

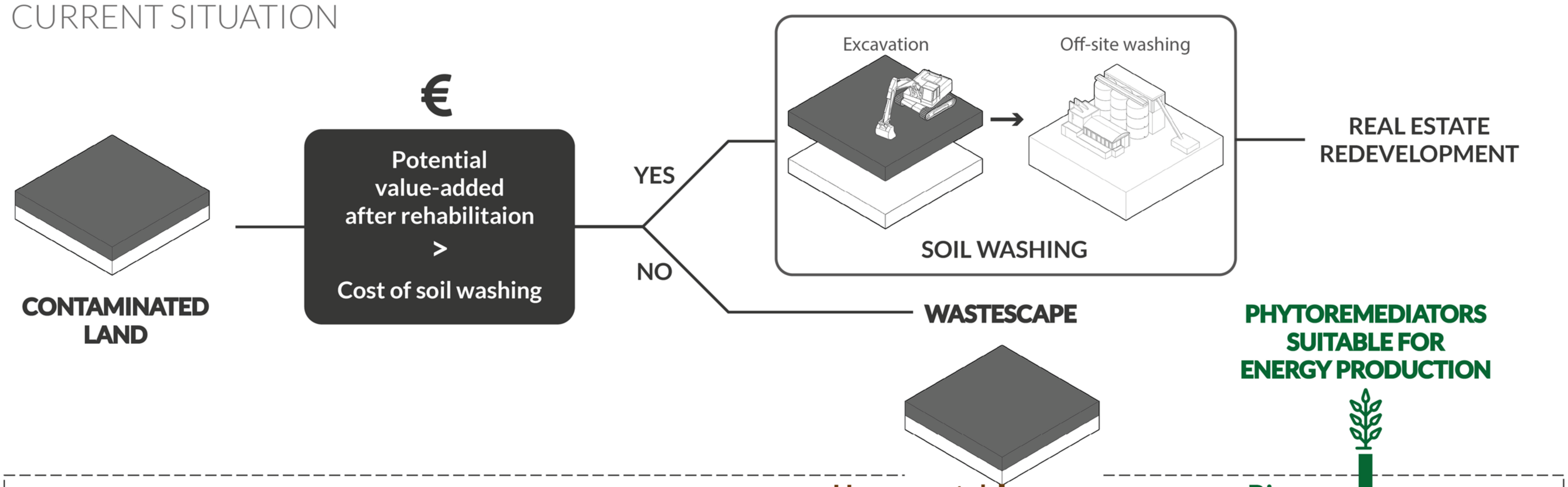
TUDelft

Lars Zwaanenburg | 4641493 | Yi Wang | 4640349
Q4 2016-2017 | AR0071 Geo-design for a Circular Economy in Urban Region
3 May 2017

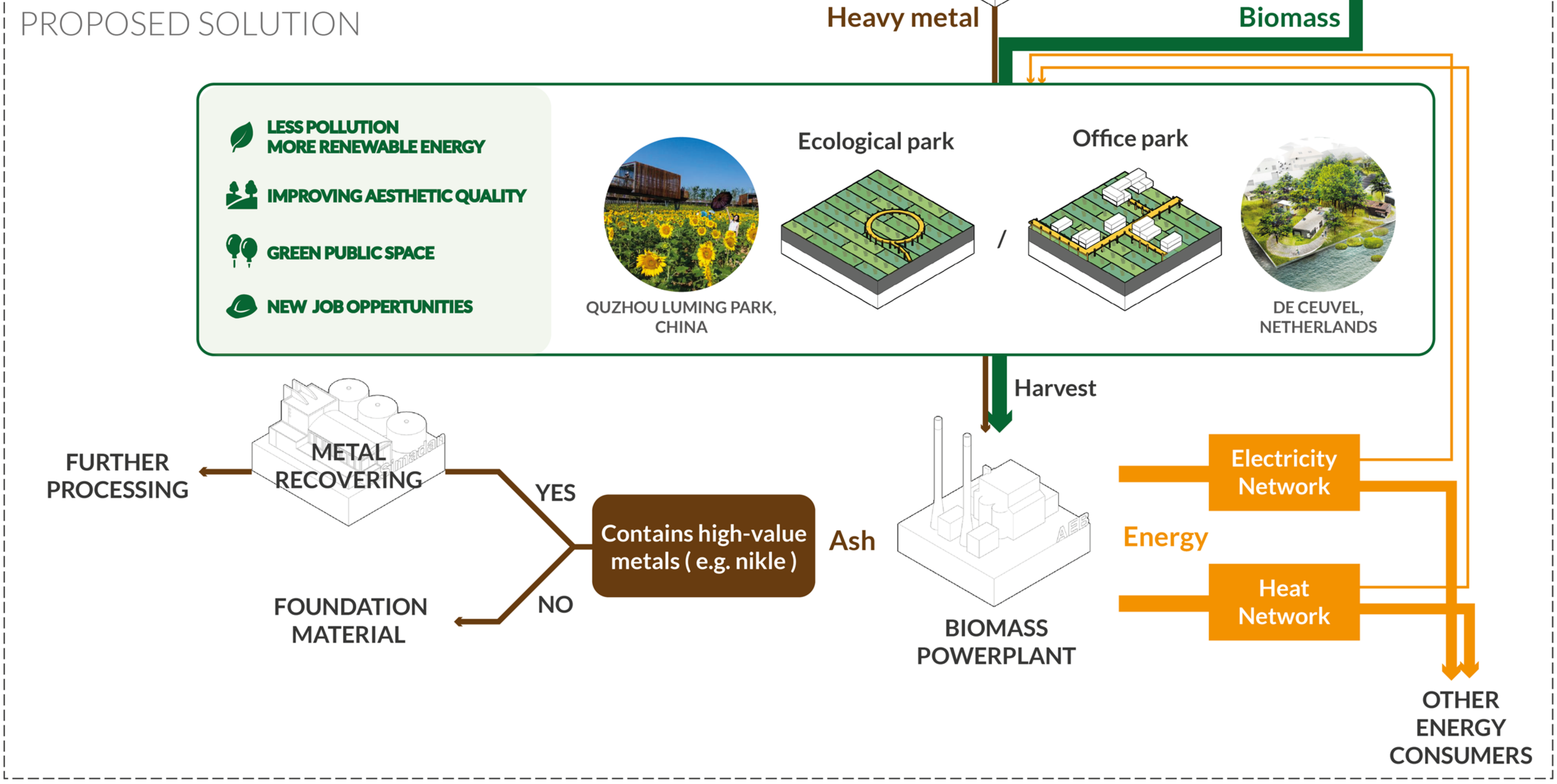
This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 688920

2 | Principle Phytoremediation driven energy crops production on wastescapes

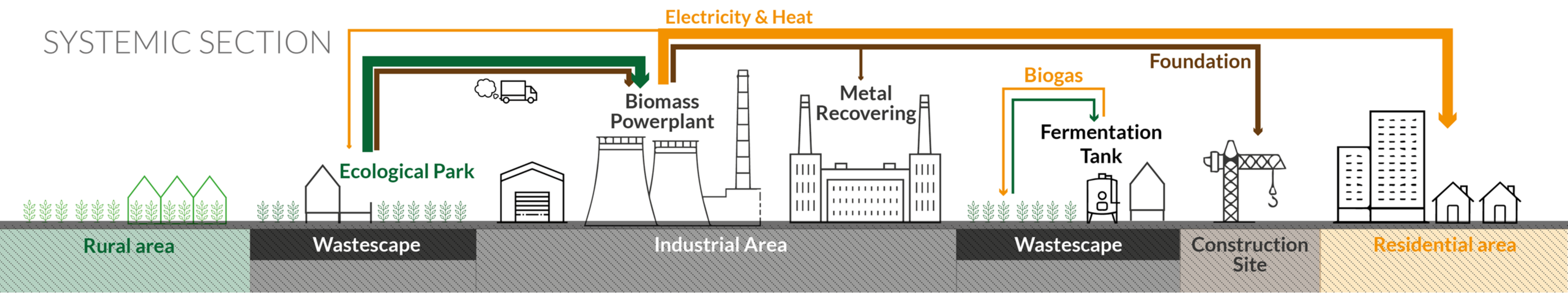
CURRENT SITUATION



PROPOSED SOLUTION



SYSTEMIC SECTION



Wastescapes and the heavy metal contaminates within are the key components to our proposed solution. Due to the high cost of traditional soil remediation processes, like soil washing, contaminated sites become wastescapes. To ignore these wastescapes carries considerable risks to human and environmental health (Nriagu et al. 1988). Therefore, phytoremediation serves as a possible solution. The growth of hyperaccumulating crops atop of wastescapes extracts the contaminates from the soil. By implementing landscape architecture, the process of phytoremediation can also create a green public space. Doing so will increase the social and economic (i.e. increased land values) qualities of the surrounding area. Depending on the levels of contamination at the wastescape, the process of phytoremediation may take many years. Additions of fertilizers, chelates, and minor maintenance will improve the process (Dermont, et al. 2009). Over that time period the phytoremediating plants will be harvested, which in turn creates a number of new flows.

The harvested crops represent the progression of contaminates leaving the wastescape and reducing the ecological and human toxicity within it. Off-site, the crops are processed into biomass. Combustion of biomass produces heat, energy, and bio-ore or foundational materials. Prior to combustion the biomass requires transport and processing. At minimum the biomass must be dried in order to provide higher combustion efficiency. The many flows that are created can be seen as economic opportunities.

The key process changes from our solution are the introduction of biomass, plus its byproducts, and the recreation of useable land. Biomass and its byproducts will be able to combine with the main biomass flows within the Netherlands without causing major disruptions to the supply/demand dynamics or supply chain capacity. Upon completion of the phytoremediation process, the wastescape is transformed into useable land that can be put to productive means. The main actors necessary to engage our proposed solution are mainly the owners of the land, either private businesses or the municipality who acquires it, and the processors and consumers of the biomass.

TU Delft

Lars Zwaanenburg | 4641493 | Yi Wang | 4640349

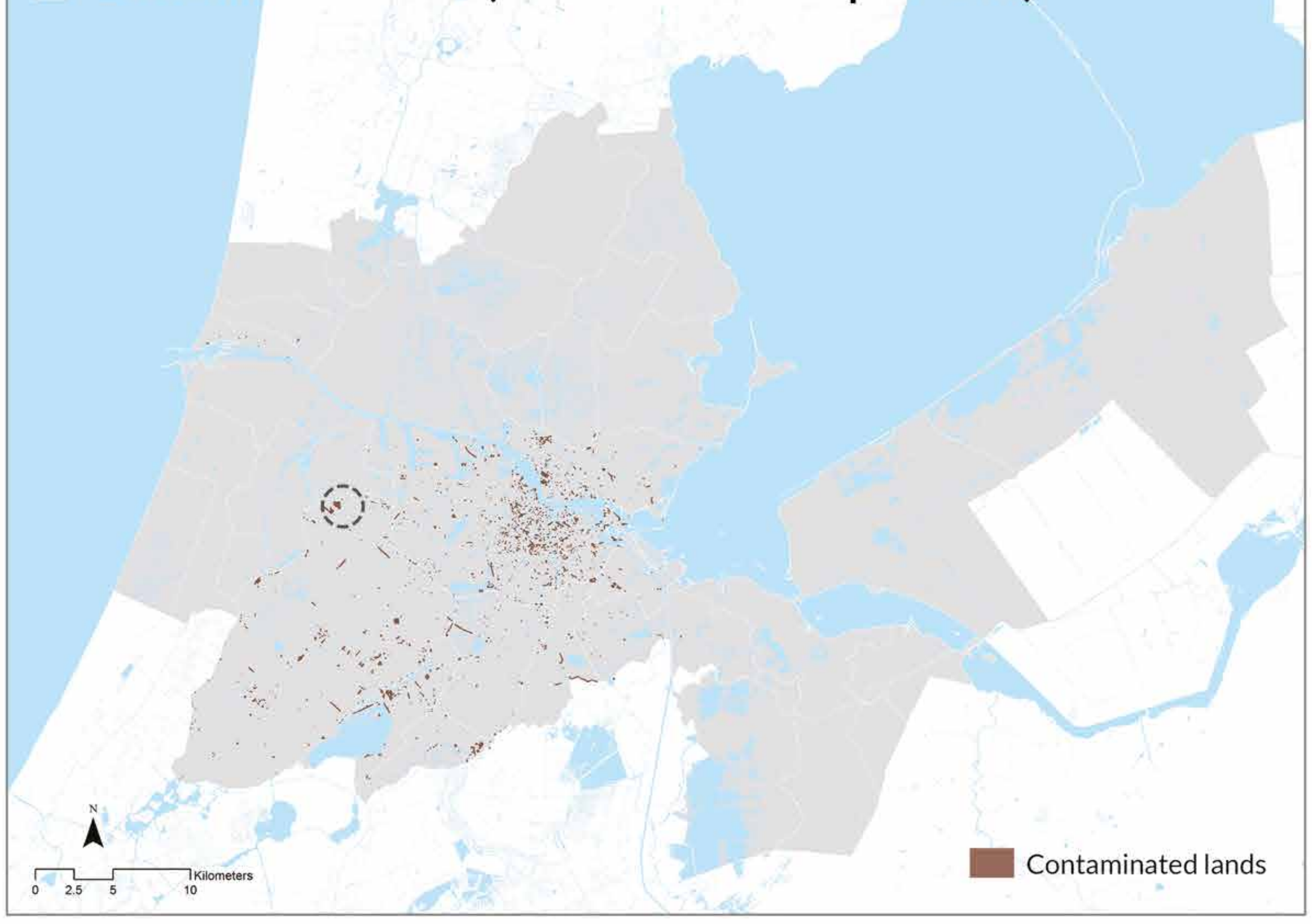
Q4 2016-2017 | AR0071 Geo-design for a Circular Economy in Urban Region
10 May 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 688920

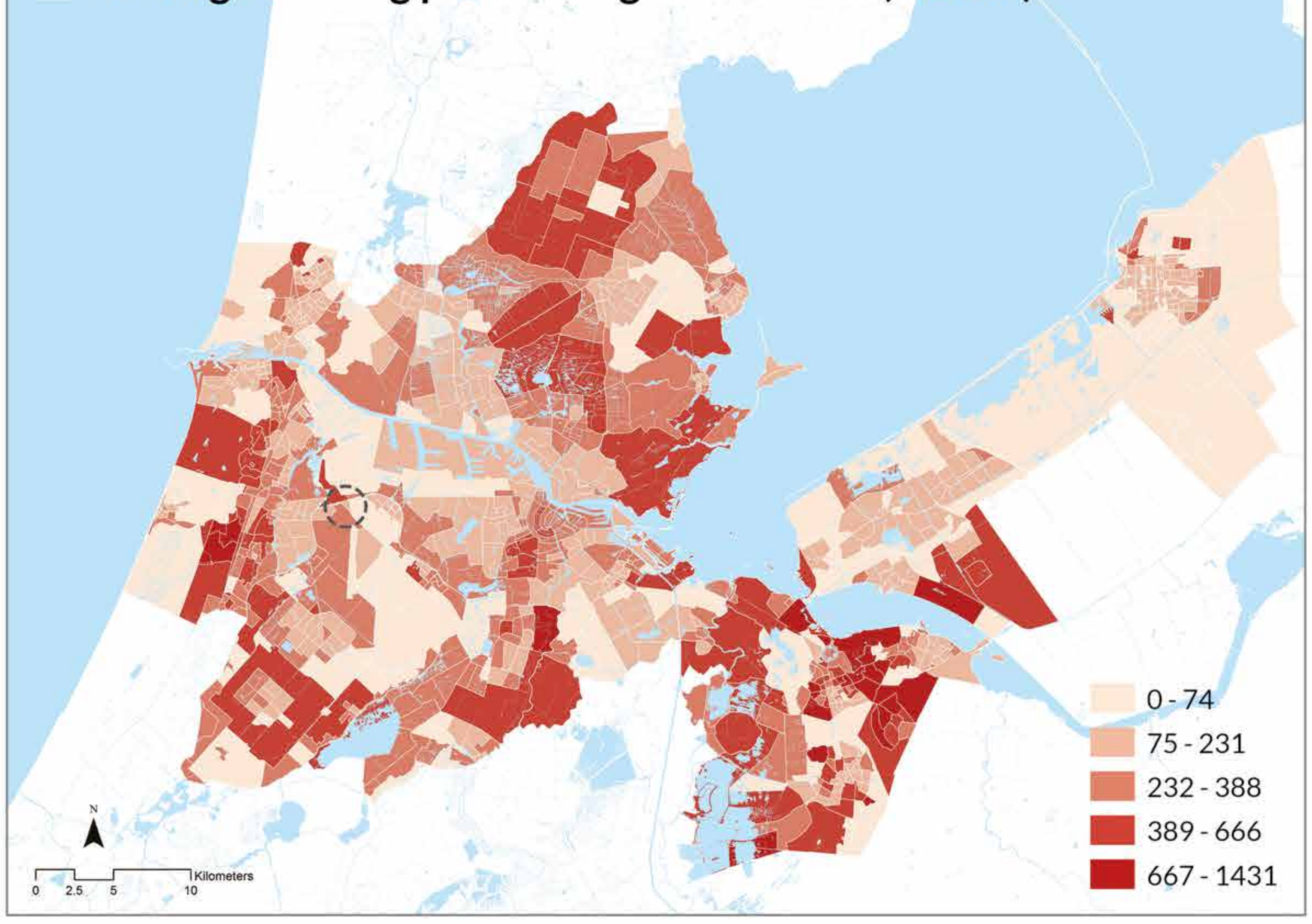
3 | Representation and process model

Phytoremediation driven energy crops production on wastescapes

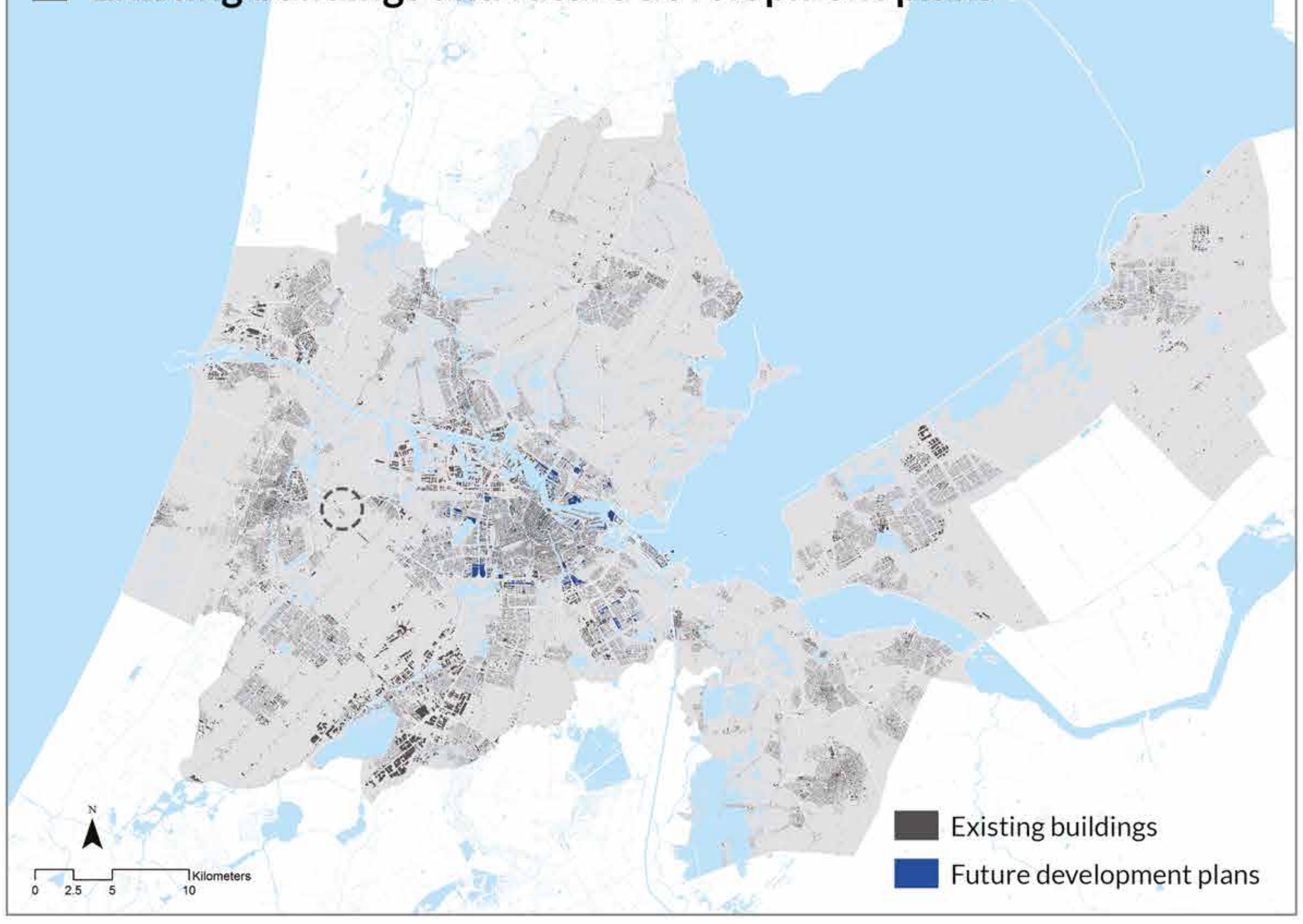
Contaminated lands (Contamination depth <1 m)



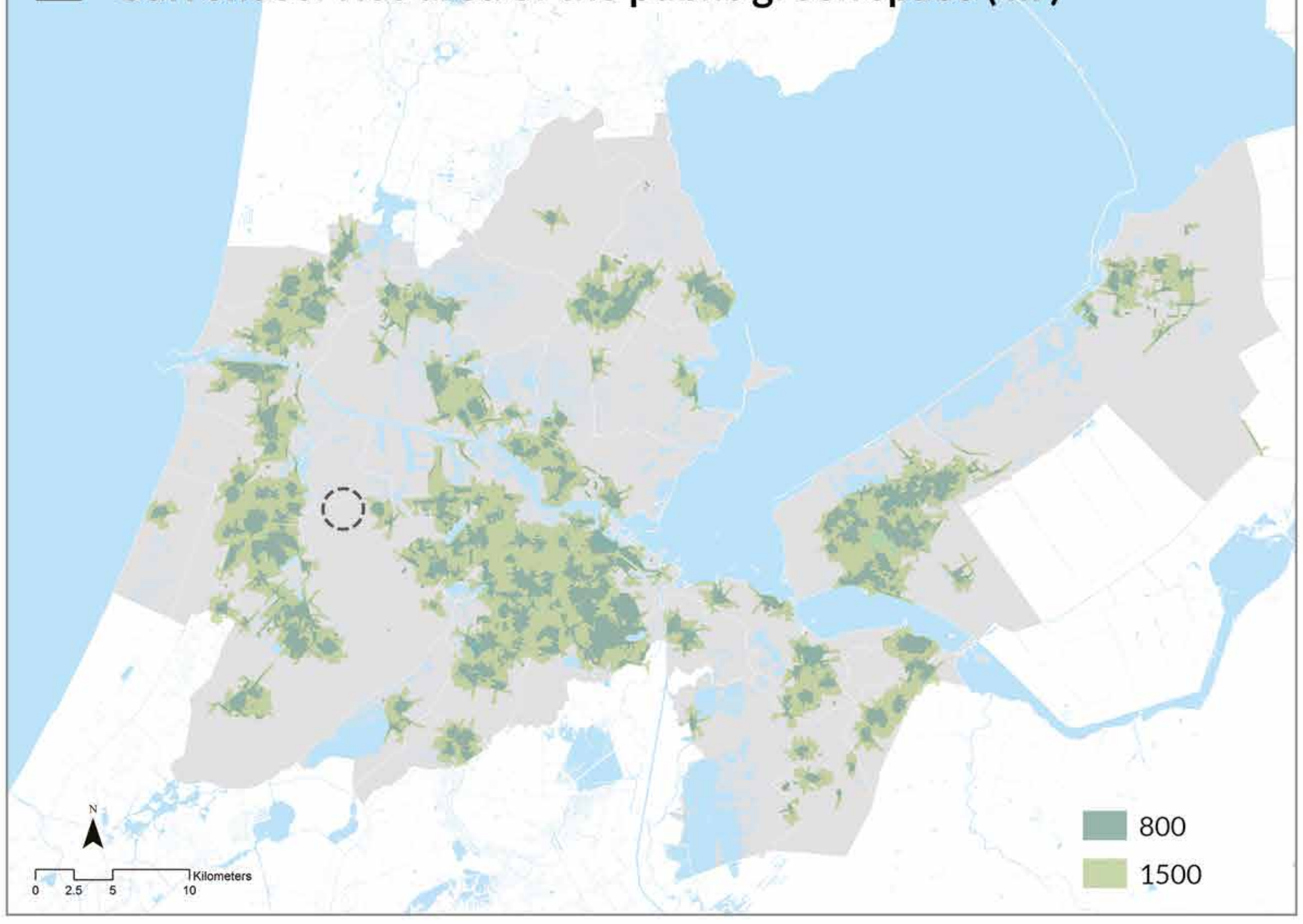
Average housing price of neghbourhoods (KEUR)

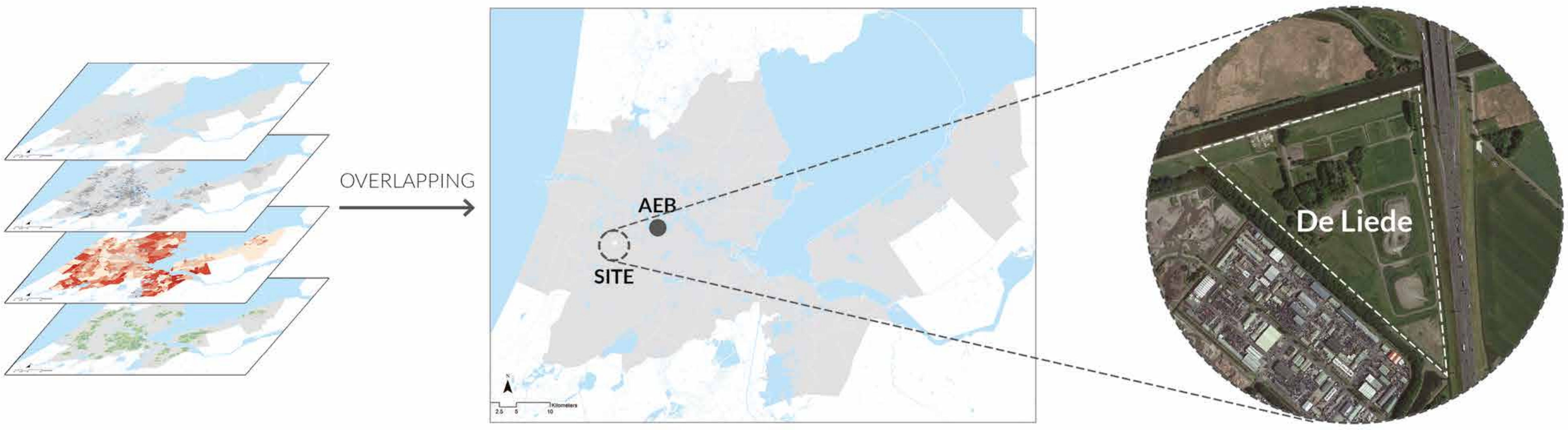


Existing buildings and future development plans



Current service area of the public green space (m)





The map of Amsterdam displays the land value of major sections of the AMA, overlaid by the areas that have soils that require rehabilitation, and future developments. The spatial distribution of rehabilitation sites is mainly along the river which has historically been for industrial use. Many of the areas identified as needing soil rehabilitation within the core of the AMA are still inhabited by operating businesses and houses or have future plans for redevelopment. Due to a lack of accessibility, future development pressures, and land prices the site selected lies in the peri-urban region of AMA. The average land value for the municipality that the site lies within the lower half of the spectrum. The site lies next to an automobile scrapyard zone, which may be the source for the high levels of lead and zinc found on the site. Within the map we have also identified the AEB waste incineration plant that would be able to take biomass for energy production. With the research that we've conducted so far, future plans can be prepared on how to quickly implement phytoremediation in case currently inhabited sites become vacant.

By studying the various morphological, physiological, economic and social geographies of AMA we are able to assess the feasibility of applying phytoremediation upon wastescapes. The first step was to locate landscapes impregnated with contaminates. This data was taken from the Amsterdam municipality and the province of Noord Holland. Areas with a soil contamination depth greater than 1 meter were excluded since the deeper the contamination the longer it will take to remediate the site. Additionally, contamination depths past 5 meters are prohibitive to phytoremediation since plant roots are unable to effectively penetrate and extract metals at such extents (Dermont, et al 2008).

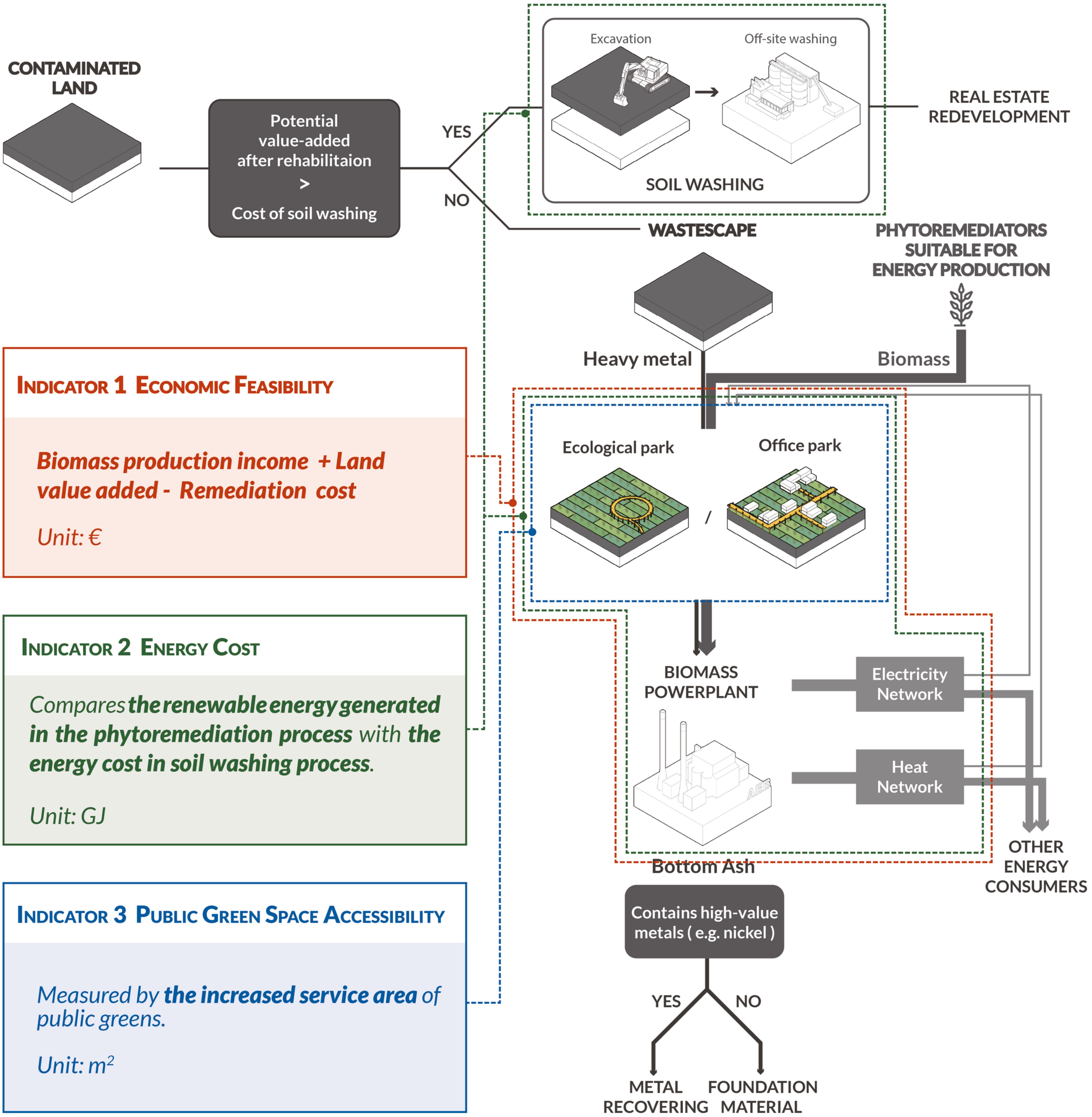
Due to the long time scales of phytoremediation, it was assumed that its application would be more suitable in areas with lower land value prices, since that is an indicator of development pressure and opportunity cost. Using the house values within the Wijk en Buurt Kaart from the Central Bureau of Statistics, we mapped the housing prices of the AMA.

Assuming that the economic output of a phytoremediation site is lower than current and planned future buildings, a morphological map was created with their locations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 688920

4 | Evaluation model

Phytoremediation driven energy crops production on wastescapes



The objective of our study is to assess the viability of using phytoremediation to rehabilitate contaminated wastescapes. To do so, we have identified three impact categories with which to judge the pros and cons of phytoremediation. Assumptions and average numbers are taken, since in reality the sites' individual characteristics can have a considerable range of variation, which will alter the true effectiveness of soil remediation processes.

Economic Feasibility Indicator (€)

We have chosen to assess the impact through a cost versus benefit model. For phytoremediation the initial costs are low, and diminish over the period of remediation (Dermont et al. 2008). The majority of costs will occur during site assessment, design, and preparation. Continuing costs include maintenance, harvesting, processing, etc. The benefits of phytoremediation are two fold. The first is the income generated from biomass production. The second is the increase in the site and surrounding area's property value (Wolch, et al. 2014).

Energy Cost of Phytoremediation Indicator (GJ)

This measures the energy costs of phytoremediation. We will later be comparing phytoremediation to soil washing, the standard method of soil remediation in the Netherlands. In the comparison initial energy costs for setting up each process are assumed to be relatively small and equal. Therefore, only the costs during processing of the soil in soil washing and combustion of biomass are calculated. The significance of measuring energy costs is due to the inherent environmental impacts related to energy consumption.w

Public Green Space Accessibility Indicator (m^2)

An unintended positive byproduct of phytoremediation is the potential improvement of regional accessibility to public green space. The indicator will be measured by quantifying the number of meters squared of added accessibility with 800 and 1500 meters of the site.

TU Delft

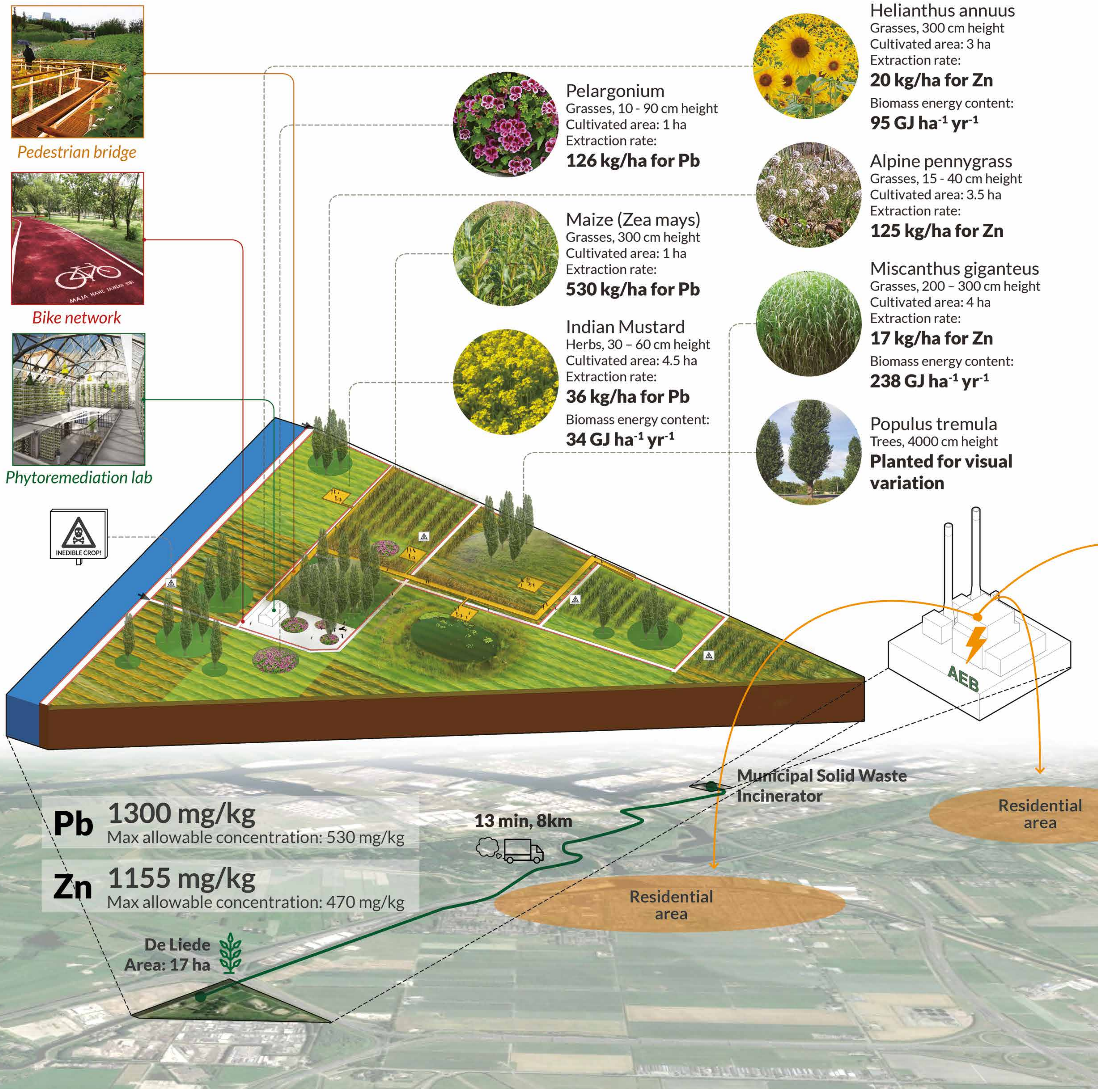
Lars Zwaanenburg | 4641493 | Yi Wang | 4640349

REPAiR

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 688920

5 | Change model

Phytoremediation driven energy crops production on wastescapes



For the change model we apply phytoremediation upon the chosen site De Liede. Located outside of a automobile scrapping industrial zone, the site is contaminated with Zinc (Zn) and Lead (Pb) in concentrations 2 and almost 3 times in excess of the max allowable rates. A selection of hyperaccumulating plants best suited for extraction of Zn and Pb are selected and their rates of extraction and biomass energy content were calculated (CEWEP, 2017). A mock-up of the site is created, in order to give an representation of how the site could also be transformed into a beautiful public green space with various other amenities, including pedestrian bridges, bike network, and academic phytoremediation research lab. A challenge that will still needs to be addressed is the liability created by providing access to the public to plants containing high levels of heavy metals. This problem is particularly poignant since Indian Mustard and Corn will be used for phytoremediation but may be accidentally seen as attractive fresh vegetables for anyone looking to pilfer unguarded food crops (Goldowitz & Goldowitz 2006).

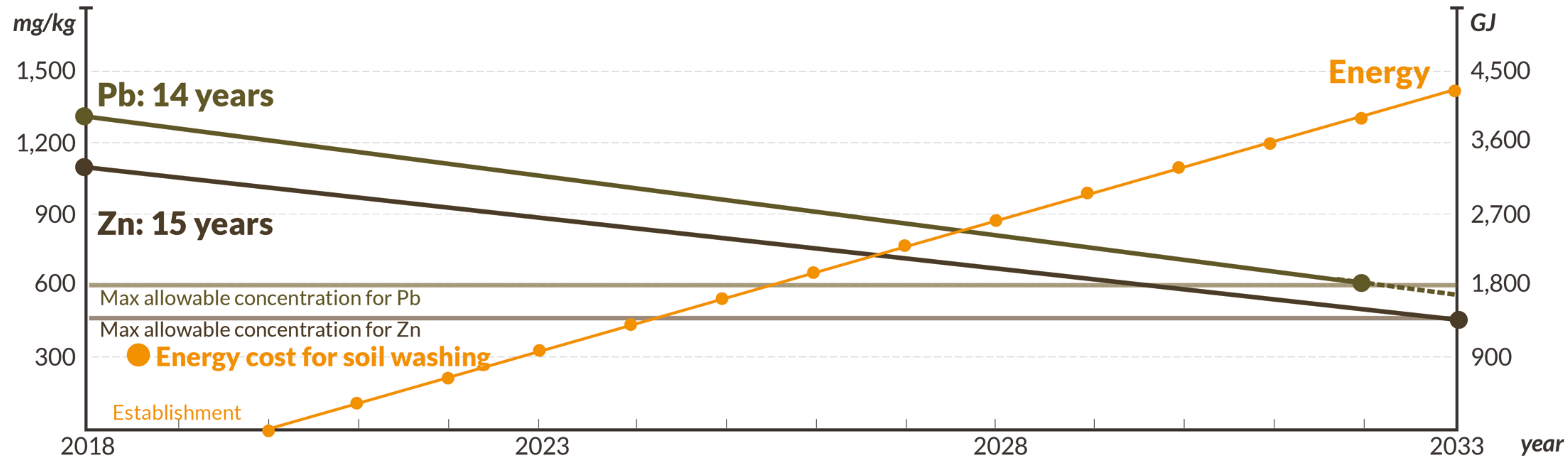
Due to the heterogeneity of contaminates in the soil, and the specialization in metal extraction by the chosen hyperaccumulators, crop rotation will need to be applied to the site. This will ensure the complete coverage of Pb and Zn extraction. Within our change model we also highlight the route and distance to the AEB incineration plant and the proximity of residential areas that could be served by the electricity produced from it using in part the biomass harvested from the site.

Lars Zwaanenburg | 4641493 | Yi Wang | 4640349

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 688920

6 | Impact model

Phytoremediation driven energy crops production on wastescapes



Indicator 1 Economic Feasibility

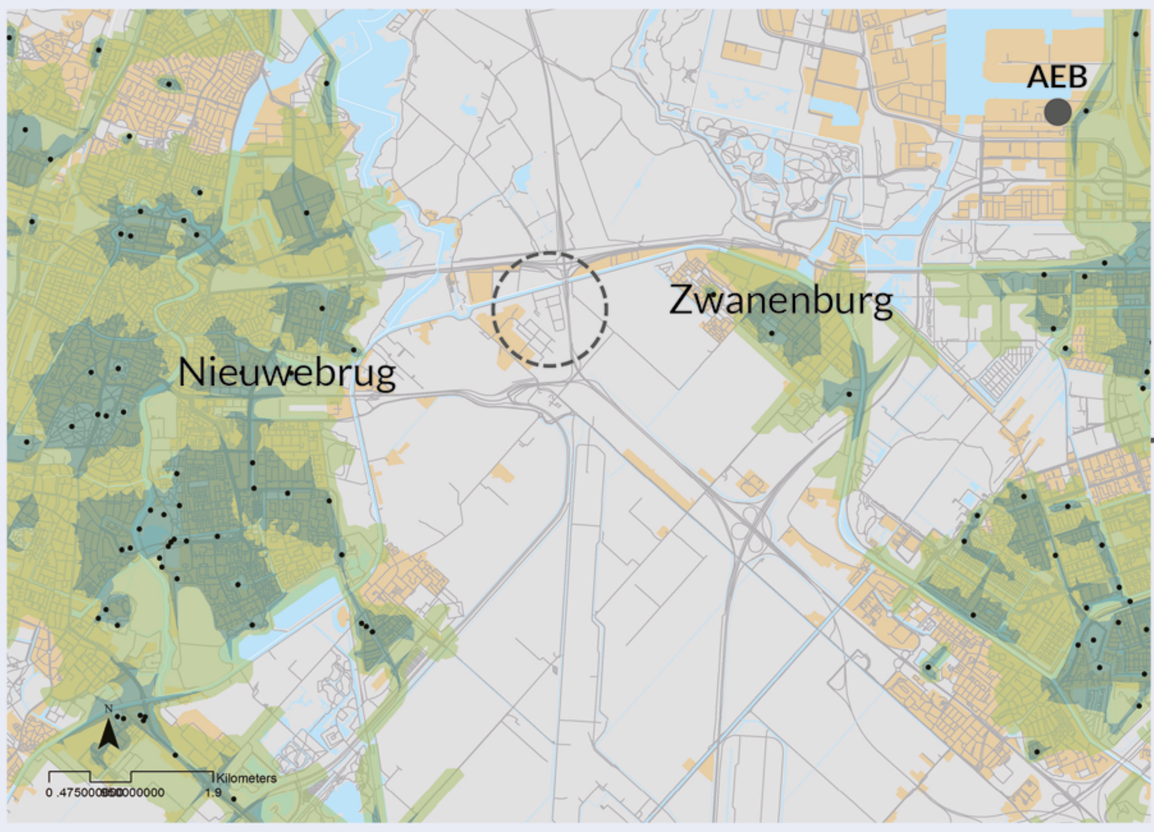
Biomass production income €202,317 - Phytoremediation cost €1,627,504 = -€1,425,187*

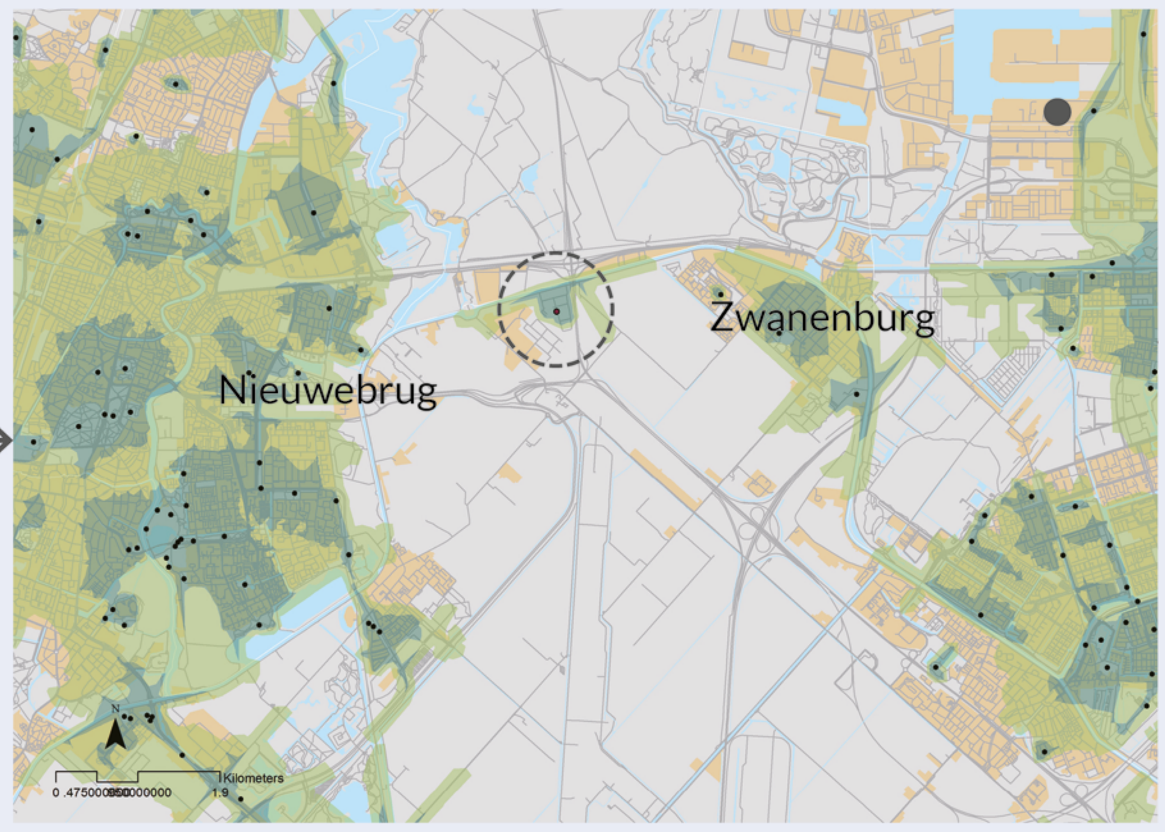
**Land value added not included (no data). Less expensive than Soil washing cost (€30,819,829)*

Indicator 2 Energy Cost

Renewable energy generated 4,335 GJ + the energy cost of washing 8,694 GJ = 13,029 GJ

Indicator 3 Public green space accessibility





The service area (1500m) increased by 80 hactares.

Built-up area
Public greens

Service Area

800 m
1500 m

The final impact model combines the indicators of the evaluation model with the consequences of the change model. The indicator for economic feasibility shows that as time progresses the site produces increased value that helps compensates for the initial costs for remediation in the sale of biomass. This occurs over a time scale of 15 years.

The energy cost of phytoremediation indicator demonstrates that, in comparison to soil washing, a large disparity is observable. Phytoremediation produces negative energy costs due to the combustion of the contaminated biomass, while soil remediation requires substantial energy inputs during the soil processing stage. The divergence of energy use between the two remediation methods gain added significance when viewed in with the lense of environmental impacts associated with nonrenewable energy consumption

Finally, the public greenspace accessibility indicator shows the transformation created by implementing phytoremediation at the site. Due to the close proximity to an arterial road the impact zone is significant. People living in Nieuwebrug and working in the automobile scrapping industrial zone will be the most likely to make use of the new green space.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 688920