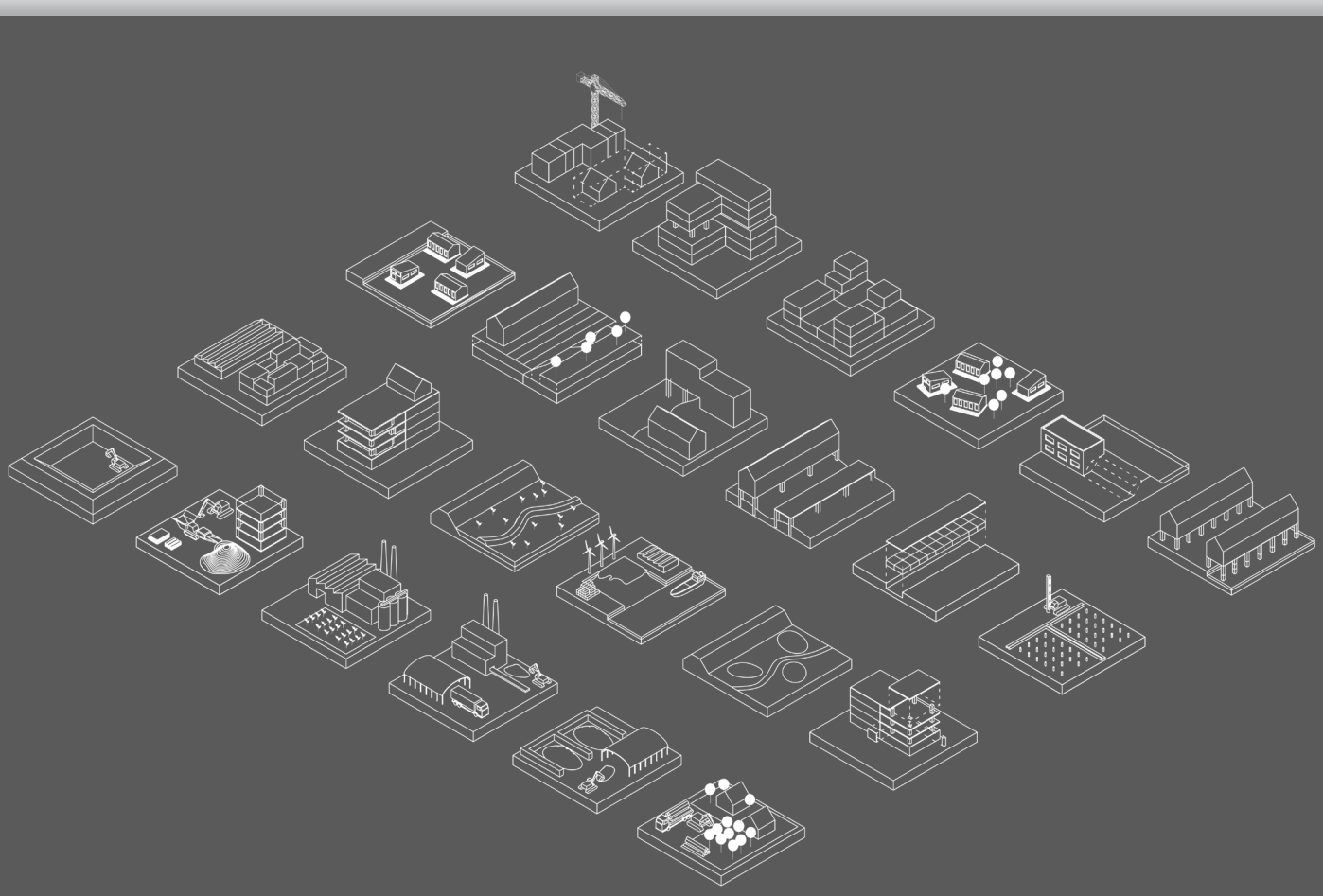
Catalogue of Solutions

Exploration towards sand-senitive solutions

Appendix of the graduation project:
'**City** without **Sand**'



Wouter ter Heijden

TU Delft

Name of solution (template)

Solution #

Description
Description of the solution

Related stock
Building/site/infra
Stock which the solution affects or relates to.

Related LCA module
A-B-C-D
Module/stage which the solution affects or relates to. Corresponding codes are explained in the LCA module legend on the next page.

Applicable on the current stock?
Yes/No
Clarifies if the solution can be applied on current building stock or if it is only applicable in new construction.

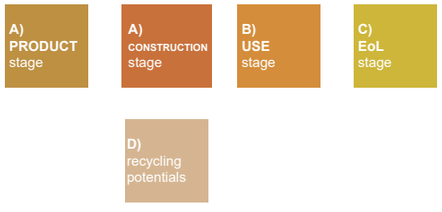
Link with other solutions
Relation to other solutions for essembles

Spatial impact
+ Positive *(e.g. contribution to green)*
- Negative *(e.g. change in accessibility)*
! Requirement *(e.g. stable soil)*
Impact on the spatial environment, both positive and negative quality. The requirements can include elements which are needed for success.

System impact
+ Positive *(e.g. based on waste flow)*
- Negative *(e.g. more transport)*
! Requirement *(e.g. requires biobased facility)*
Reduction or improvement changes the metabolic system of the material or related stock. Sometimes, a specific requirement is needed for success.

Governance impact
Descriptive
Some solutions requires change in policy and strategies in order to succeed,

Environmental impact
A-B-C-D
Based on the related LCA module, a desciption will be given about the impact in the life cycle information. The structured description in the LCA format embraces the transparency for an environmental impact assesment and supported with the diagram below



Source
Related source of solution

Introduction
In order to reduce the consumption of primary sand and gravel in urban construction, new solutions needs to be applied in spatial development. This document collects several solutions related to reduction of primary sand and gravel in urban design, civil engineering and architecture.

The solutions are ordered according to the material efficiency strategy they relate to. Each solutions will include stages they affect and their EOL scenario, according the NEN-EN 15804:2012+A1LCA scheme. The related terms and codes are displayed in the legend on the right. The templete shown on the left page will be used for all solutions.

LCA legend

PRODUCT stage
A1. Raw material supply
A2. Transport
A3. Manufacturing

CONSTRUCTION PROCESS stage
A4. Transport
A5. Construction/ installation process

USE stage
B1. Use
B2. Maintenance
B3. Repair
B4. Refurbishment
B5. Replacement

END OF LIFE stage
C1. De-construction/ demolition
C2. Transport
C3. Waste processing
C4. Disposal

Beyond building life cycle
D. Reuse, recovery & recycling potentials

reduce/prevention

Reduction promotes the decline of net consumption and the demand for material through better design or manufacturing options.

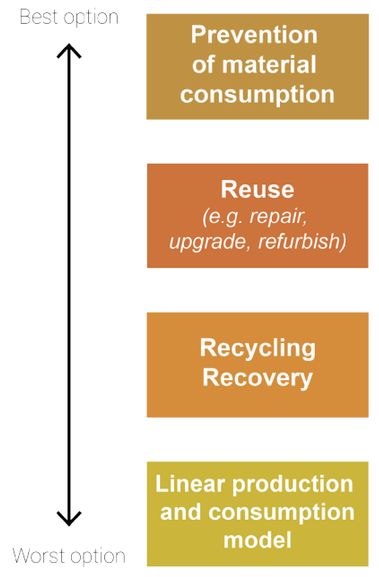
reuse

Reusing aims to make products or components more durable and to facilitate the repair, reuse or upgrade it. Reuse can be done through dissassembly.

recycling

Recycling reduces the consumption of virgin material through the dismanteling of secondary sources.

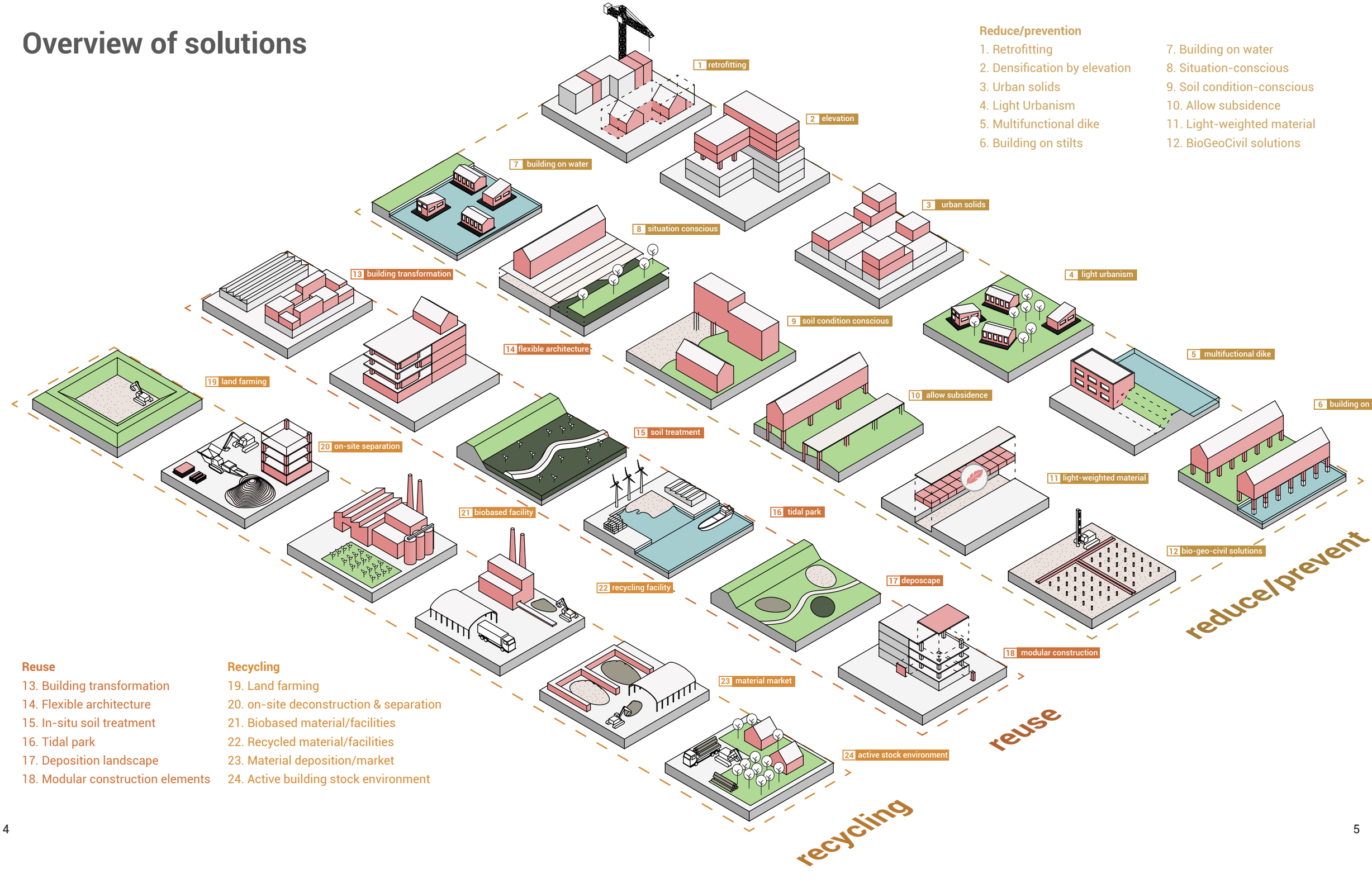
Material Efficiency Hierarchy



Overview of solutions

Reduce/prevention

1. Retrofitting
2. Densification by elevation
3. Urban solids
4. Light Urbanism
5. Multifunctional dike
6. Building on stilts
7. Building on water
8. Situation-conscious
9. Soil condition-conscious
10. Allow subsidence
11. Light-weighted material
12. BioGeoCivil solutions



Reuse

13. Building transformation
14. Flexible architecture
15. In-situ soil treatment
16. Tidal park
17. Deposition landscape
18. Modular construction elements

Recycling

19. Land farming
20. on-site deconstruction & separation
21. Biobased material/facilities
22. Recycled material/facilities
23. Material deposition/market
24. Active building stock environment

reduction / prevention

Overview
1. Retrofitting
2. Densification by elevation
3. Urban solids
4. Light Urbanism
5. Multifunctional dike
6. Building on stilts
7. Building on water
8. Situation-conscious
9. Soil condition-conscious
10. Allow subsidence
11. Light-weighted material
12. BioGeoCivil solutions

Visual impression of reduction of material through the application of building on stilts (solution 6) and situation-conscious (solution 8)
Source: Author

Retrofitting

Solution 1

Description
According to Allwood et al. (2011) long-lasting products are necessary for material efficiency. Long-lasting products in urban environment can be translated in flexible architecture and functions which extend the life span of a building. In urban planning, retrofitting is the strategy where, instead of complete demolishing, changes are made within the urban fabric or building which improve the urban environment. Material conscious planning within retrofitting strategies could reduce material consumption and extend the building's lifespan.

Related stock
Building

Related LCA module
B-C

Applicable on the current stock
Yes

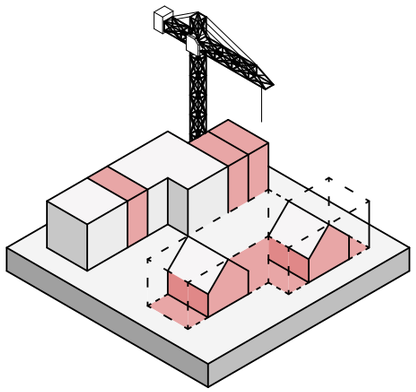
Link with other solutions
#14 Flexible architecture
#18 Modular buildings

Spatial impact
+ Preservation and improvement of current built environment and its quality
- Negative quality resulting from the existing fabric or buildings are harder to improve

System impact
+ Less in- and outflow of construction material in urban development

Governance impact
Retrofitting strategies are already integrated in planning but the material reduction factor should be integrated in the decission model.

Environmental impact
B4 (Refurbishment) is executed on the building stock in order to prevent an End-of-Life of the urban construction with the related in- and outflows.



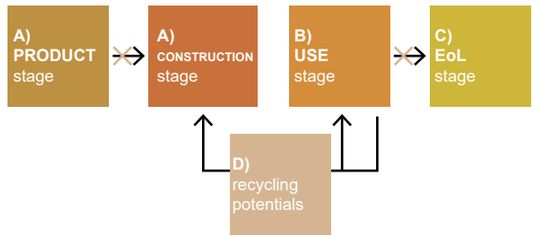


Image 1

Kleiburg, Amsterdam (NL architects)

Image 2

Waterlandplein, Amsterdam

image
1) https://www.blauwekamer.nl/2017/05/22/kleiburg-maakt-bijlmerbelofte-alsnog-waar/
2) https://architectenweb.nl/projecten/project.aspx?ID=28097

reference
Allwood, J. M., Ashby, M. F., Gutowski, T. G., & Worrell, E. (2011). Material efficiency: A white paper. Resources, Conservation and Recycling, 55(3), 362-381.

Densification by elevation

Solution 2

Description
Densification can be done, next to replacement of the current structure, by placing new structures on current ones, densification by elevation. Flat roofs are suitable for elevation which reduces demolition activities. This solution can be introduced as 'light-densification' concept and is suitable in post-war areas (Hazebroek, 2017)

Related stock
Building/site/infra

Related LCA module
B-C

Applicable on the current stock
Yes

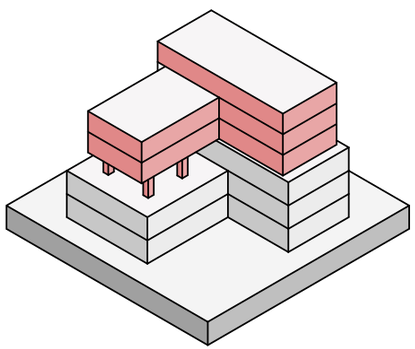
Link with other solutions
#21 Biobased material/facility
#22 Recycling material/facility

Spatial impact
+ Upgrade of low-density areas with no high-rise
- Elevation within the current structure increases the demand for parking space
! Building should technically be feasible for the new construction

System impact
+ No demolition flow
- Negative

Governance impact
Current land owners need to be included in the decision part because these structures are on private proporties.

Environmental impact
Demolition flows (C End of Life stage) from the current buildings are reduced and less primary material (A1: Raw material supply) is required for the same function.



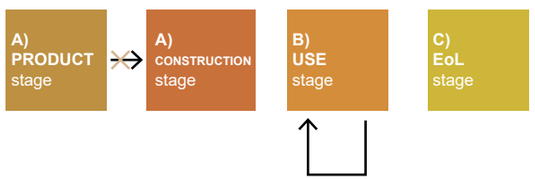


Image 1
De Karel Doorman, Rotterdam (NL architects)

Image 2
Didden Village, Rotterdam (MVRDV)

Image 3
Kantoorgebouw de Brug, Rotterdam (JHK Architecten)

Image 4
Fenixloods, Rotterdam (Mei Architecten)

image
(1) https://www.bna.nl/de-karel-doorman-rotterdam/
(2) https://www.mvrdv.nl/projects/132/didden-village
(3) http://www.jhk.nl/EN/01406-brug.html
(4) https://www.heijmans.nl/nl/projecten/fenixloodsen/

reference
Hazebroek. (2017). *Licht optoppen als recept voor verdichten binnenstad.* Retrieved 21 May 2019, from https://www.gebiedsontwikkeling.nu/artikelen/licht-optoppen-als-recept-voor-verdichten-binnenstad/

Urban solid

Solution 3

Description
Urban solids are construction blocks which can be adapted and transformed in various options (Bergvoet & Tuil, 2016). The solid is the generic structure where different functions and forms can be placed on. These can be demolished and adapted. The new structures on the solids need to be made from fully recycled or biobased construction material.

Related stock
Building

Related LCA module
A5,B1-5,C4

Applicable on the current stock
No

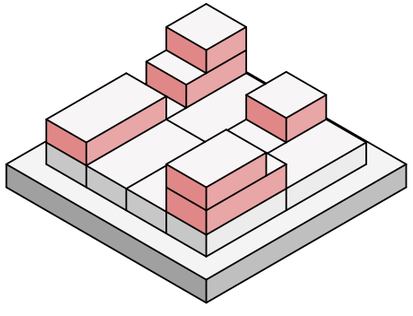
Link with other solutions
#14 Flexible architecture
#18 Modular construction elements
#22 Recycled material/facility

Spatial impact
+ Stable structures in urban environment
+ Flexible
- Monofunctional structure

System impact
+ Promotes changes on functional level by adaptibility
! Requires facility for recycled or biobased material

Governance impact
Urban solid give flexibility and freedom to users to adapt the building to their needs.

Environmental impact
B4-5 (Transport & Construction) and C4 (Disposal) are integrated and reduced in the construction characteristics thanks to its flexible ability.



Source

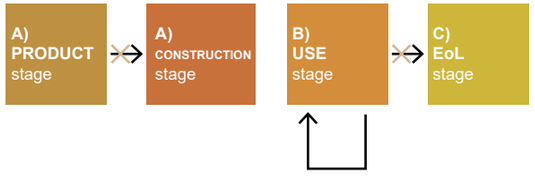


Image 1

Quinta Monroy housing in Iquique, Chile (by Elemental architects (Alejandro Aravena))

Image 2

Urban solid architectural example, Paris (SML-architects)

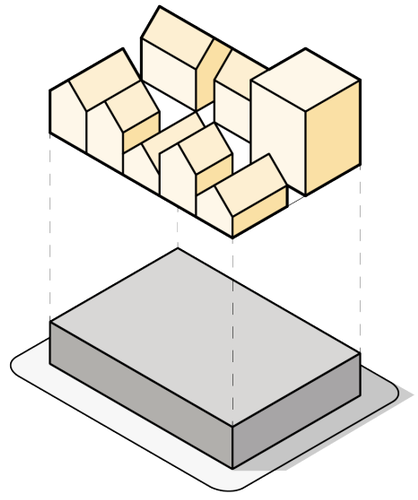


Image 3

Exploded diagram of an urban solid

image
(1) https://www.dezeen.com/2008/11/12/quinta-monroy-by-alejandro-aravena/
(2) http://images.archi/articles/logement-collectif-individuel-0
(3) Author

reference
Bergevoet, T., & Tuijl, M. (2016). *The flexible city : Sustainable solutions for a europe in transition*. Rotterdam: Nai010.

reduce/prevention

Light urbanism

Solution 4

Description
Urban development results in the construction of solid and permanent infrastructure and stocks. Light urbanism ('lichte stedenbouw' in Dutch) is a strategy of flexible construction without the 'heavy' infrastructure for public utility and roads. The building should be light-weighted and without the 'eternal remaining' foundation (Van Timmeren, 2006). Building site preparation is done with minimal improvement and addition of sand. A critical not is the great similarity with a trailer park.

Related stock
Building/site/infra

Related LCA module
A-B-C-D

Applicable on the current stock
No

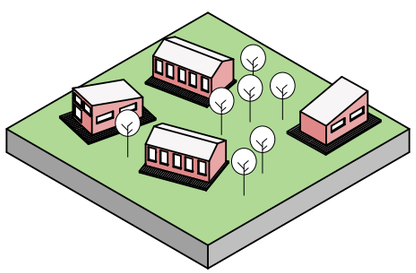
Link with other solutions
#9 Soil-conscious
#18 Modular buildings

Spatial impact
+ Biodiversity and traditional landscape are preserved
- Temporary settlement
! Stable soil and vacant space

System impact
+ Temporal and reduced use of material (dematerialisation)
- Not a long-lasting structure which have a change of quick end-of-life.
- Experimental
! All buildings need to be autarkic

Governance impact
Land should become available for temporary use, which needs corporation of land owners. Flexible planning and housing should be integrated in regional decisions but reduces the influence of government on the final result of the built environment.

Environmental impact
Light Urbanism integrates multiple environmental aspects such as an embeded flexible (B5: Replacement) and temporary potentential (D: Reuse, Recovery and Recycling). Reduction is applicable and affects every LCA stage.



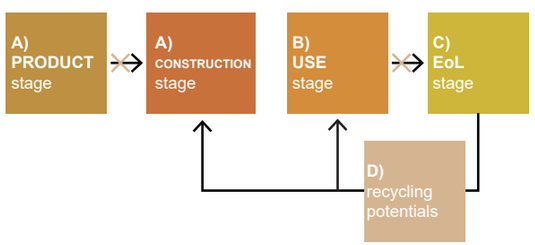


Image 1
Minitopia, Den Bosch

image
1) https://nos.nl/op3/artikel/2181889-ilse-en-wouter-wonen-voor-5000-euro-in-minitopia.html

reference
van Timmeren, A. (2006). Autonomie & heteronomie. Eburon Uitgeverij BV.

reduce/prevention

Multifunctional dike

Solution 5

Description
Flood protection and building construction can be combined in the multifunctional dike.

Related stock
Building/site

Related LCA module
A-B

Applicable on the current stock
Yes

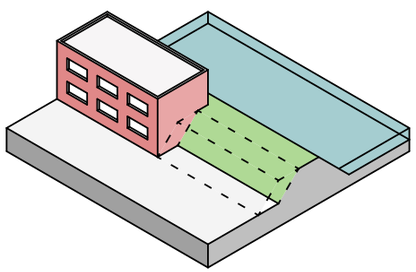
Link with other solutions
-

Spatial impact
+ Interesting typology next to a river
- Change of water nuisance
! Flood protection requirements need to be able to be joined with housing development

System impact
+ Construction adaptation and dike maintenance can be joined

Governance impact
The maintenance and protection of dikes is national security which make dwelling construction within dikes a complex situation for resposibility.

Environmental impact
The maintenance of a dike (B2: Maintenance) is linked with the construction of new buildings (A5: Construction) which can reduce the demand for material (A1: Raw material supply).



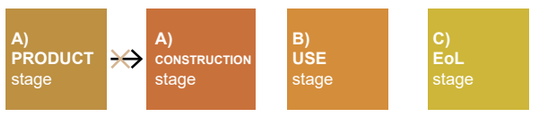


Image 1
Underground parking garage, Katwijk aan Zee (Royal HaskoningDHV)

image
(1) Omroep West (2016) *Ondergrondse parkeergarage Katwijk wint architectuurprijs Beste Gebouw van het Jaar 2016* Retrieved from https://www.omroepwest.nl/nieuws/3156888/Ondergrondse-parkeergarage-Katwijk-wint-architectuurprijs-Beste-Gebouw-van-het-Jaar-2016

reduce/prevention

Building on stilts

Solution 6

Description
Building site preparation is not necessary when buildings are located on stits or on living platforms (Hooimeijer, 2014). The original landscape with weak soil can be preserved while buildings are elevated from the surface level.

Related stock
Building/site/infra

Related LCA module
A-B-C

Applicable on the current stock
No

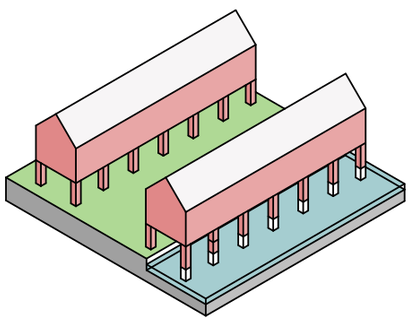
Spatial impact
+ Natural preservation with benefits for water storage and heat reduction
- Accessibility becomes less

System impact
+ Buildings can be modular and flexible

Governance impact
Standard gardens at dwellings are not available.

Environmental impact
A reduction in fill sand is created due to the absence of required building site preperation. This means that less primary material is needed (A1: Raw material supply).

Link with other solutions
#10 Allow subsidence



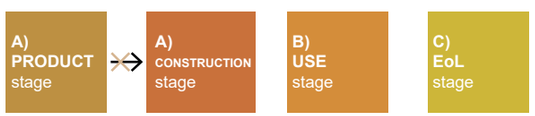


Image 1

The Kasbah, Hengelo (Piet Blom)

image
http://www.architectuur-fotograaf.eu/wordpress/wp-content/uploads/kasbah3.jpg

reference
Hooimeijer, F. (2014). *The making of Polder cities : a fine Dutch tradition*. Retrieved from http://hdl.library.upenn.edu/1017.12/366301

reduce/prevention

Building on water

Solution 7

Description
Building site preparation is not necessary when building are located on water. The construction needs to be light-weighted and the minimum depth under the building needs to be 1 meter (Ven, 2009).

Related stock
Building/site

Related LCA module
A

Applicable on the current stock
No

Link with other solutions
#4 Light Urbanism

Spatial impact
+ Can be combined with climate adaptation goals concerning water storage e.g.
- Impact on natural space
! Available water for construction

System impact
+ Buildings can be modular and flexible

Governance impact
Waterscapes need to be made available for housing development which are currently zoned as natural areas.

Environmental impact
A reduction in fill sand is created due to the absence of required building site preperation. This means that less primary material is needed (A1: Raw material supply).

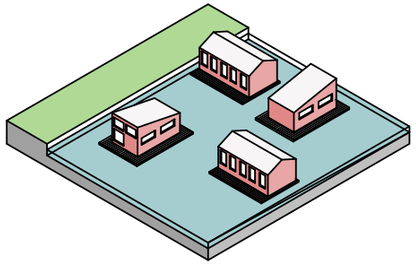


Image 1

Schoonschip, Amsterdam (Space&Matter and Waterloft)

Image 2

Steigereiland, Amsterdam (municipality of Amsterdam)

image
1) http://www.spaceandmatter.nl/schoonschip
2) https://www.arcam.nl/en/waterwoningen-haringbuisdijk/

reference
Ven, F. (2009). *Waterrobuust bouwen : De kracht van kwetsbaarheid in een duurzaam ontwerp*. Rotterdam: Beter Bouw- en Woonrijp Maken/SBR.

Situation-conscious

Solution 8

Description
'Situation-conscious' planning integrates an analysis of the water and soil condition for the building site preparation (de Jong, 2008). With this input, the most suitable location for specific functions, such as housing development, can be choosen in the design part. These decisions prevent future nuisance and maintenance, such as water or subsidence. An example of this type of planning is executed in the design of the Kethel near Schiedam by Bijhouwer. Here, the housing is positioned on the creek ridge while the park is positioned on the peat soil.

Related stock
Building/site/infra

Related LCA module
A-B

Applicable on the current stock
No

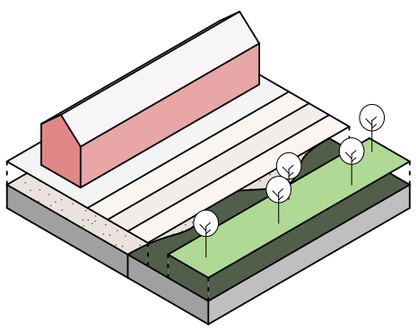
Link with other solutions
#10 Allow subsidence

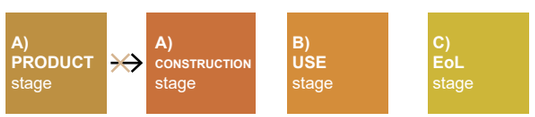
Spatial impact
+ Positive
- No negative environmental nuisance
! Suitable vacant locations

System impact
+ No input for building site preparation and subsidence maintenance
- Development pressure still result in development on weak soil
! All good locations are not available in Randstad region

Governance impact
Current landownership can prevent this type of development to happen. Regional planning decisions about the right development location need to be made based on the most suitable soil location which are quite controversial.

Environmental impact
Material input for building site preparation and subsidence maintance is minimised (A1-5 & B2).





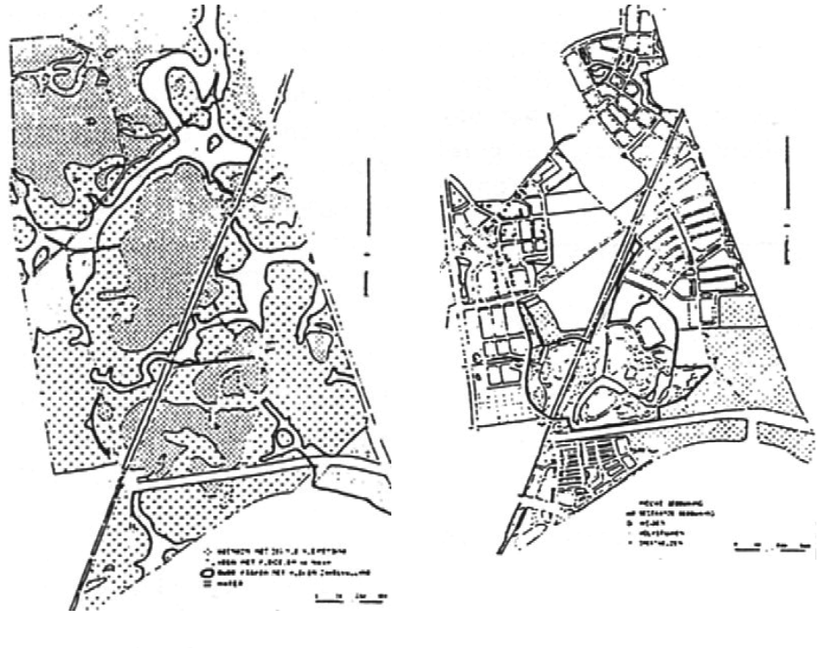


Image 1

Soil map and urban design of the Kethel, Schiedam (Bijhouwer)

image & reference
de Jong., T.M. (2008). *Sun wind water earth life living; legends for design.*

Soil condition-conscious

Solution 9

Description
The condition of the soil needs to meet certain quaility for construction and residential function which requires soil construction works and transfers when a low-soil condition area is transformed into a residential area. This activity is currently not integrated in urban design or planning which could offer creative solution and strategies where consumption and transportation is reduced. A good example is De Ceuvel in Amsterdam where a former industrial site is transformed into a 'Purging park' where contaminated soil is treated (Delva Landscape Architecture, n.d.).

Related stock
Site

Related LCA module
A-C

Applicable on the current stock
Yes

Link with other solutions
#15 In-situ soil treatment

Spatial impact
+ Biodiversity can be improved by combining in-situ treatment
- Less usable space

System impact
+ No sand transport and demand for building site preparation

Governance impact
Health regulations are applicable in contaminated environment which could prevent this type of development. A change within this policy is required for succession.

Environmental impact
For the redevelopment of new sites, C1-4 is reduced due to new construction or planning where contaminated soil outflow is not necessary. This means an inflow of sand in A1 (Raw material supply) is also reduced.

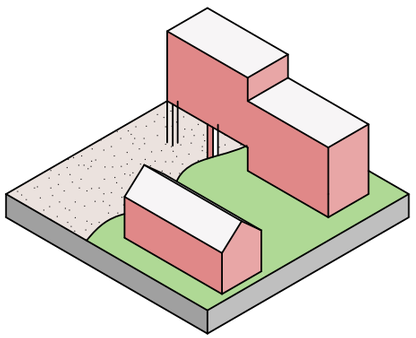


Image 1

Impression of the Ceuvel, Amsterdam (Delva Landscape Architects)

Image 2

Phases of phytoremediation process of the Ceuvel, Amsterdam (Delva Landscape Architects)

image
1) https://architectenweb.nl/projecten/project.aspx?ID=26956
reference
Delva Landscape Architecture (n.d.). De Ceuvel - Amsterdam. Retrieved May 17, 2019, from https://delva.la/projecten/de-ceuvel/

reduce/prevention

Allow subsidence

Solution 10

Description
Instead of maintaining the built environment from the effects of subsidence, a new architecture and environment can be created where the soil is divided from the urban construction and pressure and control are minimised. Neighbourhoods are built on living platforms where the buildings and infrastructure are located on (Hooimeijer, 2014).

Related stock
Building/site/infra

Related LCA module
A-B

Applicable on the current stock
Yes/No (technical feasibility study needed)

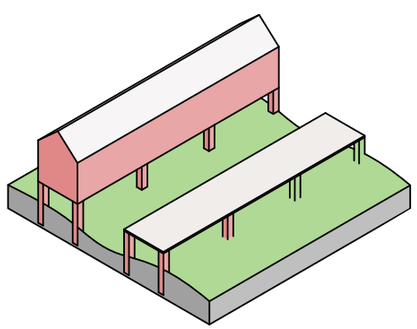
Link with other solutions
#6 Building on stilts

Spatial impact
+ Biodiversity and built environment well interwoven
- Accessibility decreases
- Nuisance from flora and fauna
! Technical feasibility

System impact
+ No sand input for building site preparation or maintenance

Governance impact
If applied in existing built environment, private gardens need to be expropriated. Due to the water management aspect of the natural structure, water boards should be included in the realisation process.

Environmental impact
During the construction, A5 (Construction), and use, B2 (Maintenance), stage, no sand is required (A1: Raw material supply), reducing consumption. Allowing subsidence also reduces CO2 emission from peat oxidation.



A) **PRODUCT** stage → A) **CONSTRUCTION** stage | B) **USE** stage | C) **EoL** stage

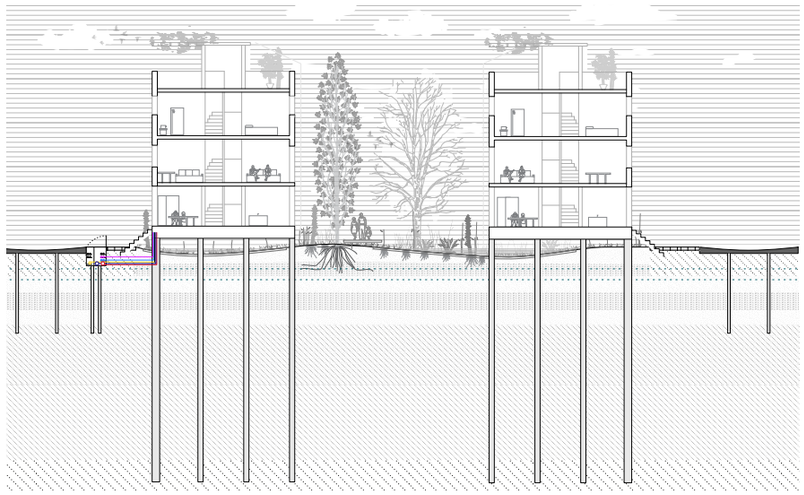


Image 1

Design section of Bloemhof Zuid, Rotterdam (Hooimeijer et al.)

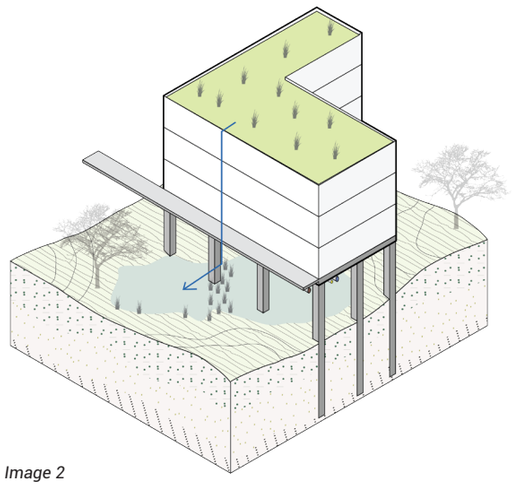


Image 2

Schematic isometry of typology

image
1) Hooimeijer, F., Lafleur, F., Yap, E., Dobbelsteen, J., & Trinh, T-T. (2018). *Intelligent SubSurface Quality 003 Bloemhof-Zuid: Tabula scripta:Structureren, visualiseren enpresenteren (2) author*

reference
Hooimeijer, F. (2014). *The making of Polder cities : a fine Dutch tradition*. Retrieved from http://hdl.library.upenn.edu/1017.12/366301

reduce/prevention

Light-weighted materials

Solution 11

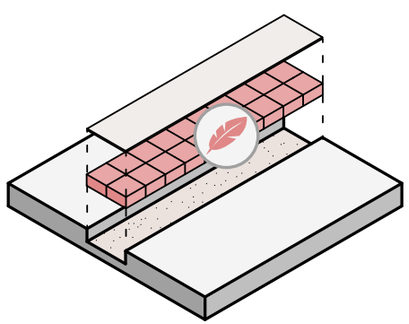
Description
Light-weighted material are suitable for building site preparation in areas with weak soil conditions. These material, suchs as the plastic EPS, Expanded Polysterene, reduces the weight on the soil which reduces the subsidence due to weight compression. This reduction prevents the input of material during the lifespan of the construction. Examples of these materials are a substitute for sand in building site preparation and thus have another environmental impact. Following the NIBE environmental qualification of light-weighted material EPS, it is only an improvement environmentally when the EPS is 100% recycled, otherwise sand would be an environmentally better choise.

Related stock
Site/infra

Related LCA module
A-B

Applicable on the current stock?
Yes

Link with other solutions
#8 Situation-conscious
#22 Recycled material



Spatial impact
+ Less nuisance of subsidence during lifetime

System impact
+ Potential for secondary resources
- Increase in demand for substitute material
! Substitute needs to meet an environmental impact which is lower and more favourable then the current used material.

Governance impact
New material as an alternative can be stimulated by the government to promote the usage as sand substitute.

Environmental impact
During the lifetime of the construction, less to no material is required for the maintenance (B2) of subsided surfaces. However, the material is a new type which have a different production process (A1-3) and end-of-life (C4: Waste processing & C5: Disposal) which means another environmental impact.

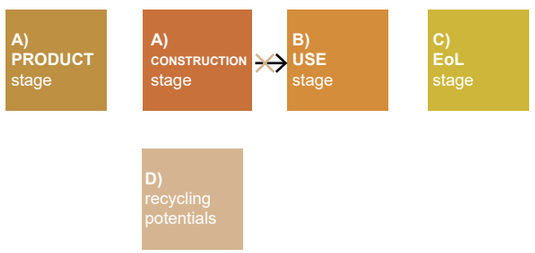


Image 1
Application of EPS in foundation works

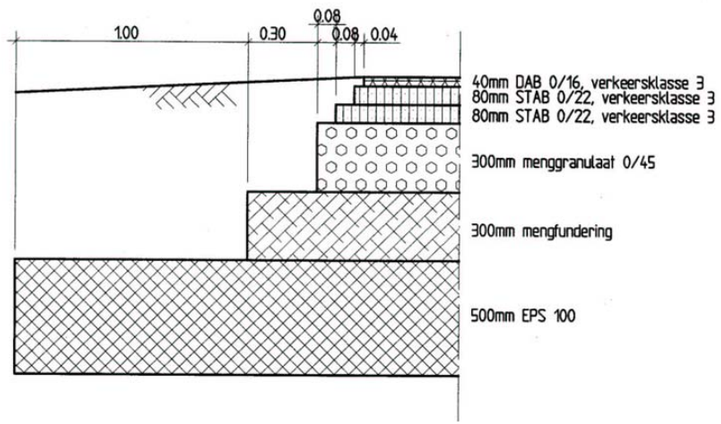


Image 2
Technical section of EPS as foundation material for infrastructure

image
1) https://www.oosterbeek-eps.nl/producten/plus-gww/
2) InfraDelft, 2006. *Casestudie: reconstructie van de N475.* Recieved from https://www.geoblock.nl/wp-content/uploads/2016/10/04-Casestudie-Reconstructie-N475.pdf
reference

BioGeoCivil solutions

Solution 12

Description

Improvement of the material mechanics can be done through BioGeoCivil solutions. These solutions aim to develop 'biology-based material as well as processes which can help to solve engineering challenges addressing sustainability performance while at the same time safegaurding the requires durability aspects such as sufficient strength are functional service lifetime performance' (Jonkers, 2017). The application of these solutions, which relate to biobased material (Solutions 21), expands the lifespan of the material, e.g. self-healing concrete, the strength of the material, e.g. Biogrout (image 1), which reduces the demand for supporting or replacement material during its construction and/or lifespan or by-products as substitute, e.g. bio-cement (image 2).

Related stock

Building/site/infra

Related LCA module

A- B-C-D

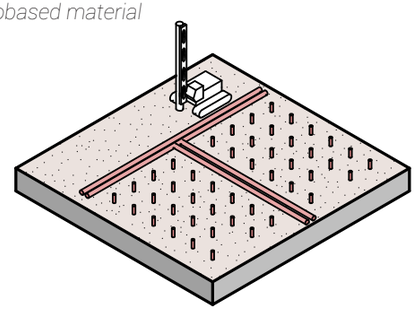
Applicable on the current stock?

No

Link with other solutions

#9 Soil condition-conscious

#21 Biobased material



Spatial impact

+ Same conditions can be achieved

! Application needs to be feasible on the locations

System impact

+ Reuse of residual flows

- Alternative material might by limited in amount

! Availability of alternative material

Governance impact

Sustainable substitute needs to be promoted for its application.

Environmental impact

Sustitute material requires new product (A1: Raw material supply & A3: Manufactering) which can have a new impact in manufacturing or mining but the positive part is its extension of servicelife (B1) and biobased recycling options (C in D) which requires less input of primary material or waste generation.

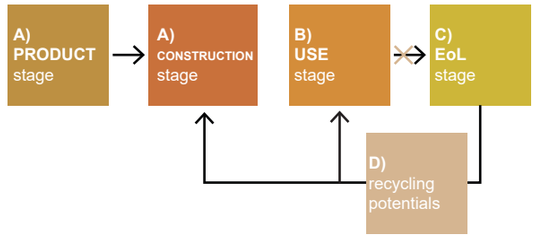


Image 1

Result of Biogrout process

Image 2

Flow chart of Bio-Cement

image

1) https://www.researchgate.net/publication/288624162_Stabilization_of_gravel_deposits_using_microorganisms

image 2) + reference

Jonkers, H. M. (2017). Toward Bio-based geo- & Civil Engineering for a Sustainable Society. *Procedia Engineering*, 171, 168-175. https://doi.org/10.1016/j.proeng.2017.01.323

reuse

Overview
13. Building transformation
14. Flexible architecture
15. In-situ soil treatment
16. Tidal park
17. Deposition landscape
18. Modular construction elements

Visual impression of the reuse of material through the application of in-situ soil treatment (solution 15)
Source: Author

reuse

Building transformation

Solution 13

Description
Current non-residential building can be transformed into residential functions instead of demolishment.

Related stock
Building

Related LCA module
A-B-C

Applicable on the current stock
Yes

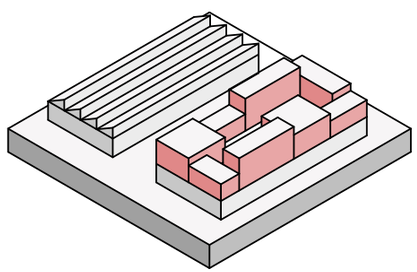
Link with other solutions
#14 Flexible architecture

Spatial impact
+ If there is heritage value, these can be concived
+ No changes needed in the urban fabric
! Construction need to be able to support the new structures

System impact
+ Less outflow of material

Governance impact
Current land owners need to be involved and convinced in the process for the transformation.

Environmental impact
A demolition (C1: deconstruction) is prevented by transformation through refurbishment or replacement (B4-5). However, this activity can still cause inflow of new material (A1).



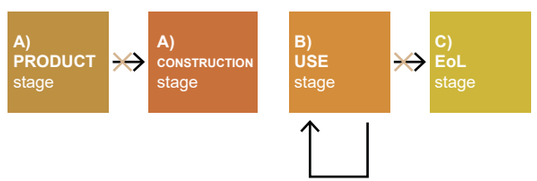


Image 1

Jobsveem, Rotterdam (Mei Architecten)

Image 2

Gebouw Anton, Eindhoven (diederendirrix architecten)

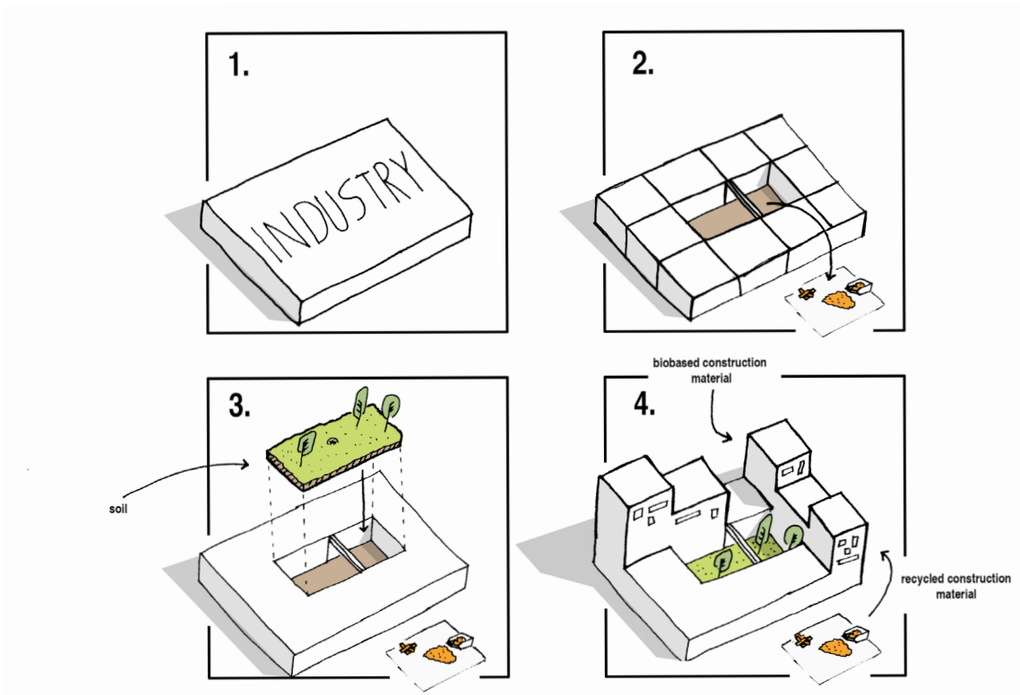


Image 3

Process scheme of transformation

image
(1) https://rotterdamwoont.nl/items/view/168/Jobsveem
(2) https://architectuur.bouwformatie.nl/projecten/Strijp-S%20gebouw%20Anton/?type=Leveranciers

reference
Bergevoet, T., & Tuijl, M. (2016). *The flexible city : Sustainable solutions for a europe in transition*. Rotterdam: Nai010.

reuse

Flexible architecture

Solution 14

Description
Instead of a form folllows function, buildings can become functionally neutral. These buildings are future-proof and can prevent vacancy (Bergvoet & Tuil, 2016). The structure of the building can facilitate different functions.

Related stock
Building

Related LCA module
A-B-C

Applicable on the current stock
Yes/No

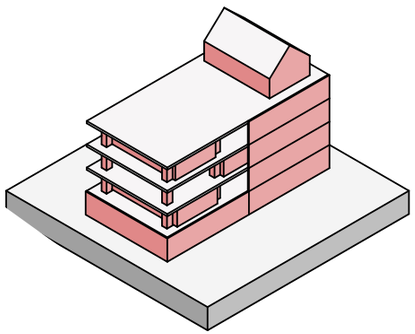
Link with other solutions
#3 Urban Solids

Spatial impact
+ More liveability thanks to flexibiliy
- Less architectural expression or diversity due to neutrality standards

System impact
+ Building longer in system
- Dependency of structure

Governance impact
Adaptation and flexibility of the plot and buildings are restricted and the prevention of demolition needs to be preserved.

Environmental impact
A demolition (C1) is prevented by transformation through repurposing (B4-5).



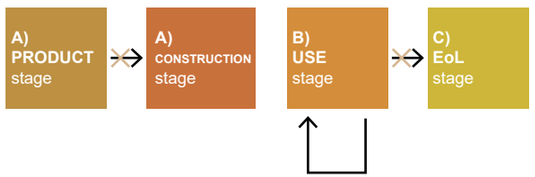


Image 1

Solid 11, Amsterdam (Tony Fretton Architects)

image
https://architectenweb.nl/nieuws/artikel.aspx?ID=29307

reference
Bergevoet, T., & Tuijl, M. (2016). *The flexible city : Sustainable solutions for a europe in transition*. Rotterdam: Nai010.

reuse

In-situ soil treatment

Solution 15

Description
Transportation of contaminated soil for the replacement of clean soil for building site preparation can be reduced when the soil is treated on site. This treatment can be done by phytoremediation

Related stock
Site

Related LCA module
C

Applicable on the current stock
Yes

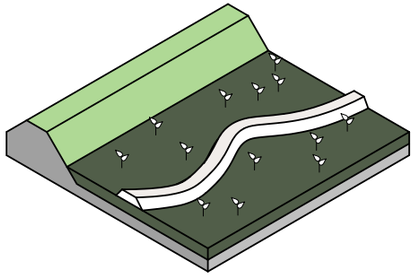
Link with other solutions
#17 Deposition landscape
#21 Biobased material/facility

Spatial impact
+ Opportunity for natural/park creation
- Inaccessable space due to contamination

System impact
+ Natural process
- Process take a lot of time
! Right plant for the right location

Governance impact
Space and time needs to be available for this type of treatment

Environmental impact
The transport and treatment of contaminated soil (C2-3) are reduced by the application of biochemical processes and on site.



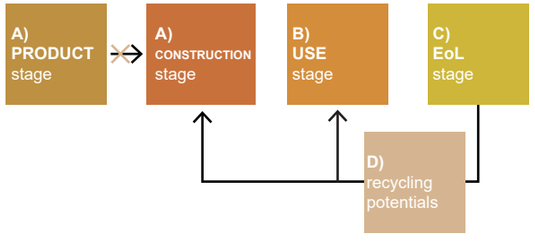


Image 1

Phytoremediation, Quzhou Luming Park (Turenscape)

image
https://land8.com/5-best-plants-for-phytoremediation/

Tidal parks

Solution 16

Description
River shores in urbanised delta areas are transformed into hard, artificial quays. Nature preservation and climate adapation can be managed by transforming these shores back into natural, tidal landscapes. These tidal parks contribute to biodiversity and recreation in the areas. Dredged material can be used in order to construct these landscapes (Van Veelen et al., 2018).

Related stock
Site

Related LCA module
A1-2, B2, C4, D

Applicable on the current stock?
Yes

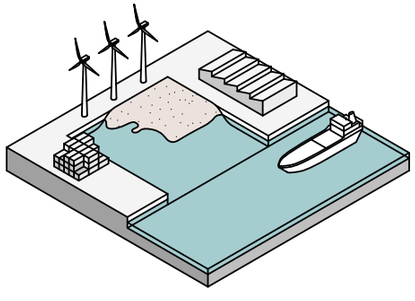
Link with other solutions
#17 Deposition landscape
#19 Landfarming

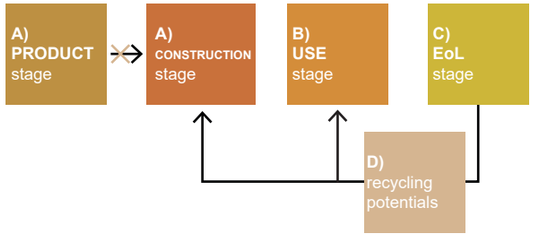
Spatial impact
+ Development of a natural shore park
! Abadonded harbours

System impact
+ New deposit for dredged sediment

Governance impact
Harbour and dredging companies need to agree on the use and placement of sediment in harbour areas.

LCA impact
Dredged sediment is reused (D), to construct land reclamation, which reduces primary material (A1). It also reduces the impact of the maintenance (B2) and impact of disposal (C2 & C4)..





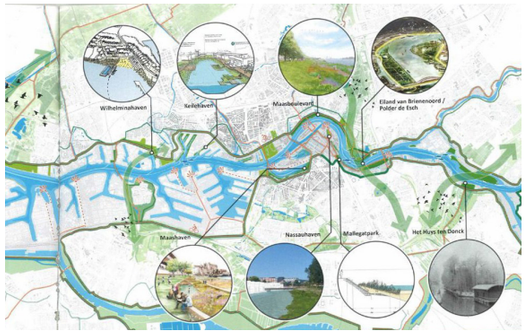


Image 1

Map of potential tidal park sites in Rotterdam (municipality of Rotterdam)

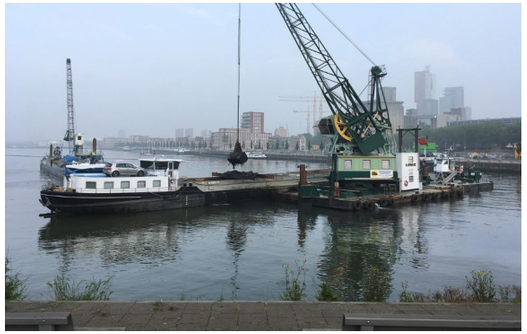


Image 2

Deposition activities in the harbour of Rotterdam

Image 3

Impression of a tidal park (municipality of Rotterdam)

image
1)Gemeente Rotterdam (2018). *De Rivier als een Getijdenpark*. Gemeente Rotterdam
2) Peter van Veelen (n.d.)
3) https://www.rotterdam.nl/wonen-leven/getijdenpark-maashaven/

reference
van Veelen, P., Jansma, J., & Kalogeropoulou, N. (2018). *Designing with Sediment in the Rhine Meuse Delta*. WWF, TUD, Delta Platform.

Deposition landscapes

Solution 17

Description
As a upgrade of the material depositions, landscapes can be transformed with secondary sand into landscape with multifunctional use. Next to storage, treatment can be done at these locations. Examples of multifunctionality are the combination of a BMX park. The landscape is quite dynamic because the material is stored temporary.

Related stock
Building/site/infra

Related LCA module
A-B-C

Applicable on the current stock
Yes

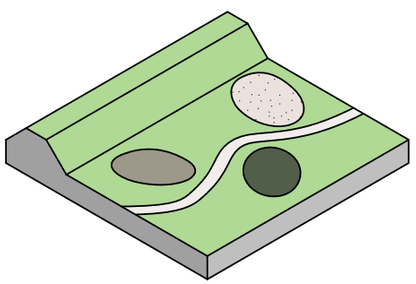
Link with other solutions
#15 In-situ soil treatment
#23 Material market/depot

Spatial impact
+ (temporary) Multifuctional use
- Land competition
! Precautionary measures need to be taken against contamination

System impact
+ Storage capability within system
- Long timespan of storage

Governance impact
Requires land for a long time which might be unbenificial for the landowner or other functions.

Environmental impact
Good opportunity of recycled material (D) for new construction reduces the demand of primary material (A1). However, the storage is competing for available land (A3 or C4D).



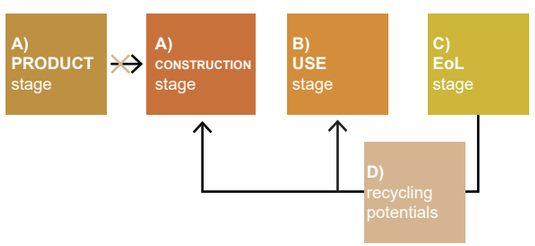


Image 1

Temporary use of brownfield

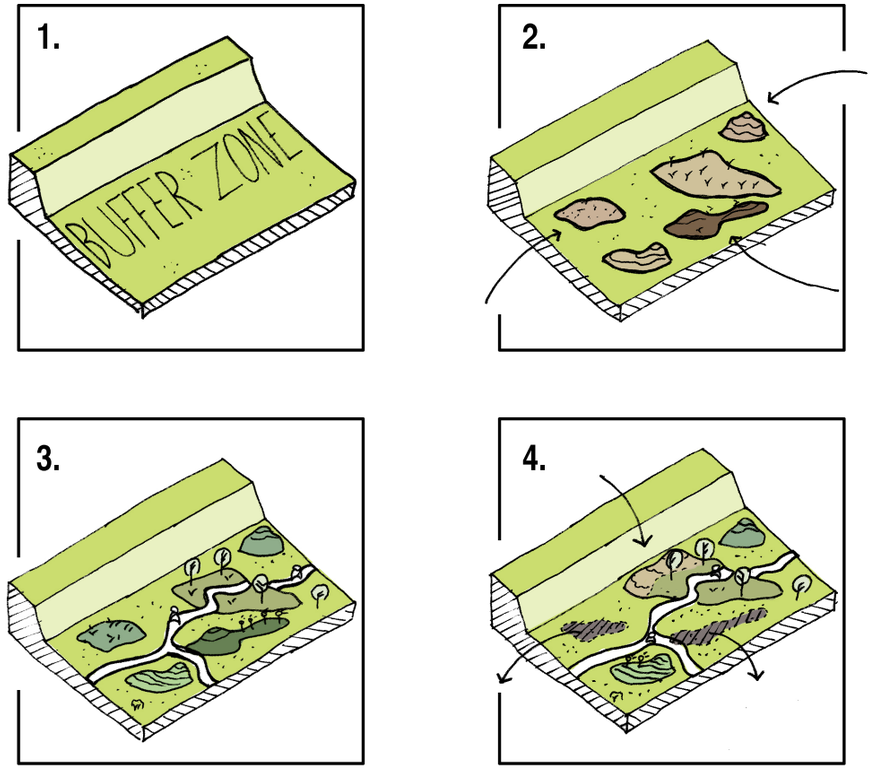


Image 2

Schematic process diagram of a deposcape

image
(1) Green043 Bike park (n.d.) *Green043 Bike park* Retrieved from https://www.green043bikepark.nl/
(2)Author

reuse

Modular construction elements

Solution 18

Description
Buiilding elements can become modular so components can be recycled such as window frames or construction elements. This makes the entire building flexible and deconstructable. Modularity is one of Allwoods et al. (2011) material efficiency strategies.

Related stock
Building

Related LCA module
A-B-C

Applicable on the current stock
No

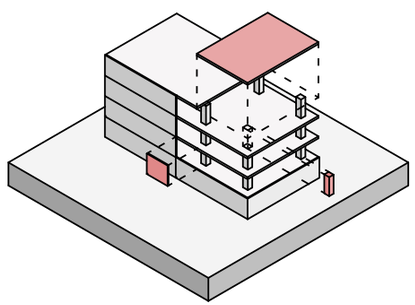
Link with other solutions
#14 Flexible architecture
#22 Recycled material/facility

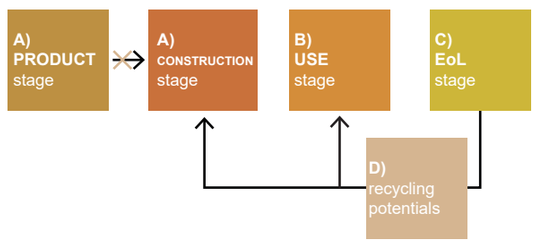
Spatial impact
+ Adaptive built environment

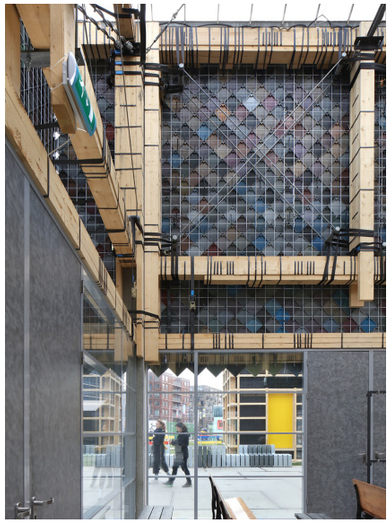
System impact
+ Reuse construction elements
! - New material/elements demand

Governance impact
The quality of the material needs to be garanteed during its lifespan.

Environmental impact
Promotes a EOL-scenariowithin refurbishment (B4) and replacement (B5) or after demolition (C1) where an element of a building(/construction) is reused in the construction (A5) of a new building.







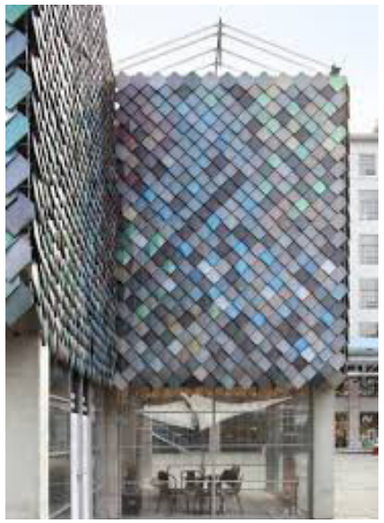


Image 1

Temporary modular building People's Pavilion, Eindhoven (bureau SLA)

Image 2

Impression of a modular building (nArchitects)

image
(1) https://www.bureausla.nl/project/peoples-pavilion/
(2) https://popupcity.net/honey-i-shrunk-the-apartment/

reference
Allwood, J. M., Ashby, M. F., Gutowski, T. G., & Worrell, E. (2011). Material efficiency: A white paper. *Resources, Conservation and Recycling*, 55(3), 362–381. https://doi.org/10.1016/j.resconrec.2010.11.002

recycling

Overview
19. Land farming
20. on-site deconstruction & separation
21. Biobased material/facilities
22. Recycled material/facilities
23. Material deposition/market
24. Active building stock environment

Visual impression of the recycling of material through the application of material deposition market (solution 23) in combination with an active building stock environment (solution 24)
Source: Author

Landfarming

Solution 19

Description
Sediment is a natural transported and abundant material in urbanised delta regions but hinders the economic harbour activities. Landfarming uses dredged sediment for the treatment process which later can be used as fill sand subsitute or other subsitute. Dredged sediment has a high concentration of silt which needs to be removed. A current pilotproject is executed in Delftzijl in the Eems Delta in the north of the Netherlands. Over a period of three years, dredged sediment (mainly clay) is ripen on farmland to eventually be used as dike enforcement or farm soil (Ecoshape, n.d.).

Related stock
Site

Related LCA module
A1-2, B2, C4, D

Applicable on the current stock?
Yes

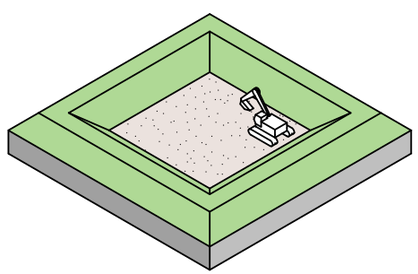
Link with other solutions
#15 In-situ soil treatment
#16 Tidal parks
#17 Deposition landscape

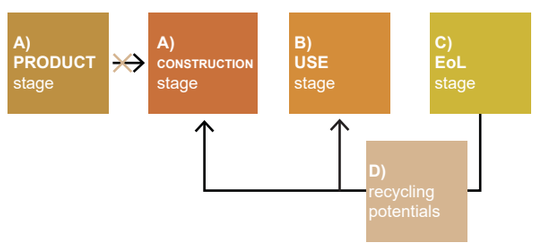
Spatial impact
+ Possibility for natural landscapes
- Requires valuable areas for farming

System impact
+ New deposit for dredged sediment
! Needs to be along waterscapes in order to avoid transfer facilities.
! Technical feasibility of the treatment and application of dredged material for construction material (focus: sand) needs to be investigated

Governance impact
New links and agreements need to be made between dredging companies and surrounded land owners.

Environmental impact
If dredged sediment is used as substitute in other construction, primary material and transport (A1-2) is reduced in the maintenance (B2) phase. Current disposal (C4), of dredged sediment is replaced according to a recycling potential (D).





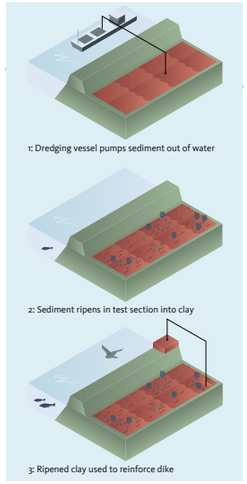


Image 1
Landfarming process scheme

Image 2
Landfarming field

Image 3
Impression of clay ripening production scapes

image
1) Ecoshape. (n.d.). *Living Lab for MUD* [Brochure]. *n.p.*
2) https://www.rtvnoord.nl/nieuws/200148/Eerste-monsters-genomen-uit-kleirijperij-Delfzijl
3)http://www.ee-eemsdelta.nl/nieuws/nieuws/pilot-kleirijperij-langs-eems-dollard-krijgt-vorm

reference
Ecoshape. (n.d.). Pilot Kleirijperij. Retrieved May 17, 2019, from https://www.ecoshape.org/nl/projecten/kleirijperij/

On-site separation

Solution 20

Description
Separation of demolition debris from buildings on-site is essential for the quality and opportunities of recycling. By dismanteling buildings and seperate the material in an early stage, high-quality material can be avoided to be contaminated with other material or to end up as mixed debris (Circle Economy et al., 2016). On-site separation requires space and time for the activity but the material or components can eventually by reused or recycled.

Related stock
Building

Related LCA module
A & C-D

Applicable on the current stock?
Yes

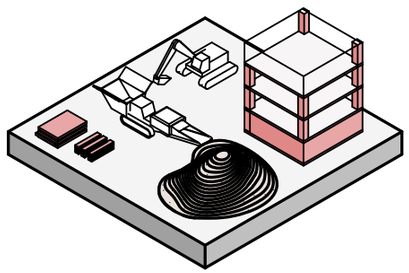
Link with other solutions
#18 Modular construction elements
#22 Recycled material/facility
#23 Material market/depot

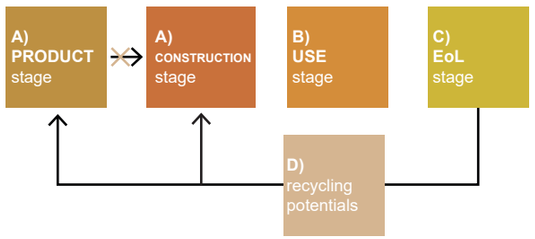
Spatial impact
- Noise nuisance during activity
! Space for separation activities
! External storage for overshoot or supply mismatch

System impact
+ No/less demolition waste
+ Recycling potential in other constructions
! New destination for material application
! Mobile debris crusher and material separation techniques and machines

Governance impact
Flows and storage needs to be monitored and shared.

Environmental impact
Better material separation at demolition phase (C1) increases the opportunity for recycling and reusing (D), depending on disassembly (removal of components, thus modular) or dismantling (removal of material source, thus recycling). These components or materials can be reused in new constructions (A3 or A5).





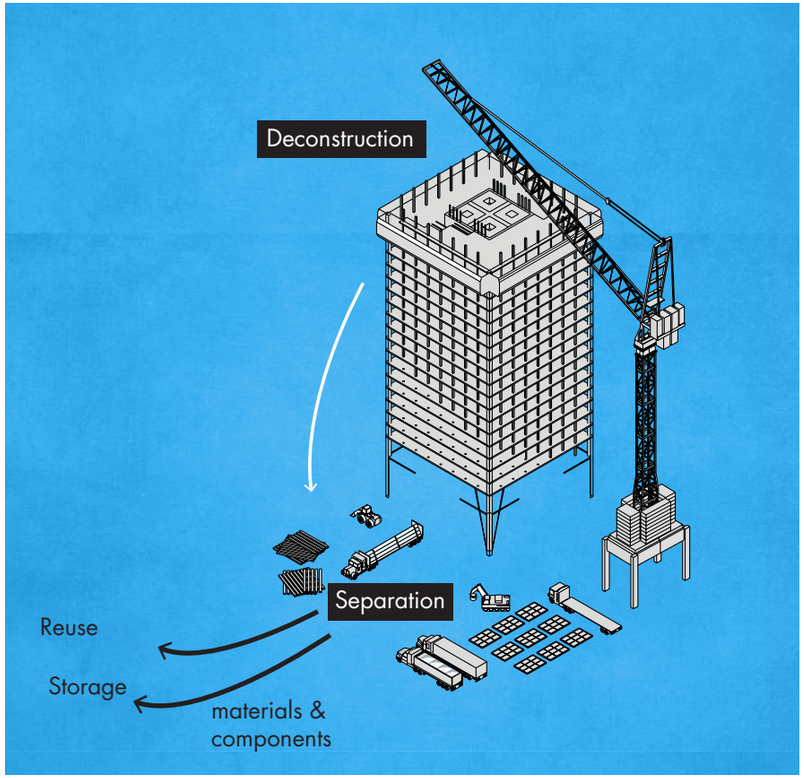


Image 1

Schematic impression of deconstruction and source separation

image + reference
Circle Economy, Fabric, TNO, Gemeente Amsterdam (2016). *Circular Amsterdam*. Retrieved from https://www.amsterdam.nl/bestuur-organisatie/organisatie/ruimte-economie/ruimte-duurzaamheid/circular-economy/report-circular/.

Biobased facility/materials

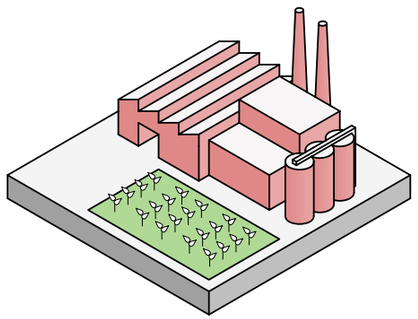
Solution 21

Description
In order to reduce the consumption of primary construction materials, subsitutes need to be used which are renewable. One of the renewable materials are biobased materials. The integration of these type of materials need facilities in order to supply the built environment.). Facilities include production sites, manufacturing sites. Biobased can range from timber material to biochemical solutions such as bacteria, algea or fungi. Examples of application can be found in building construction and infrastructure projects. Some examples, such as the bio-asphalt, can be linked with residual flows within their production, resulting in a win-win situation.

Related stock
Building/infra [materials]

Related LCA module
A to D

Link with other solutions
#18 Modular construction elements
#22 Recycled material/facility
#23 Material market/depot



Spatial impact
+ Manufactering can be integrated in mixed urban environment
- Competition of land for production

System impact
+ Natural product with a biochemical cycle
+ Can be combined with urban organic waste flows

Governance impact
Agreements need to be made on government level to support the use and integration of biobased material. Directing and monitoring the production needs to be done for spatial integration.

Environmental impact
The material is used in every stage but after disposal, C, material can be naturally degredated or reused, D, as raw material, A. However, degredation or incineration lean to CO_2 emission which makes the product balance neutral.
The application of timber has a certain impact on production scape (land competition in A1: Raw material supply). It is assumed that one dwelling requires 20m^2 of CLT, which can be harvest from 0,0328 ha (Bouwtotaal, 2017). With an intensity of 450 kg/m^2 means that one dwelling requires 9 ton of CLT.

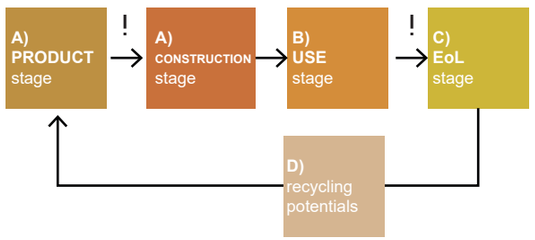
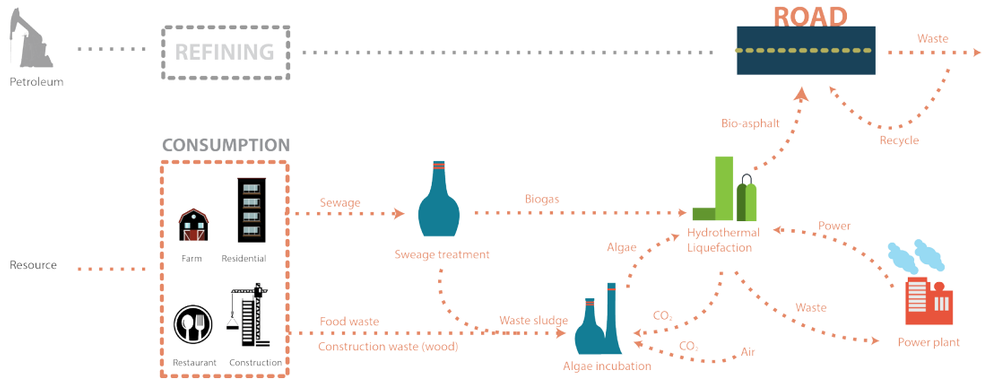


Image 1
Biobased material MycoBoard

Image 2
Fungi production for the MycoBoard



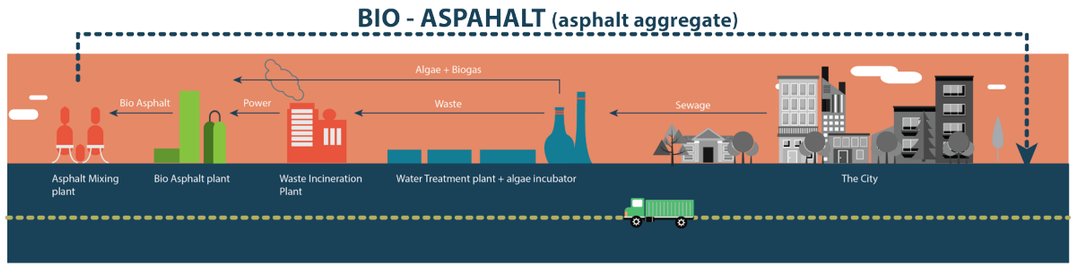


Image 3
Bio-Aphalt production flow

image
(1-2) https://ecovativedesign.com/mycocomposite
(3) KY Oh, A., Tajbakhsh A. & Wai, L. (2017). *Microalgae Bio-Asphalt*. Poster presented at TU Delft: Q4 2016-2017 | AR0071 Geo-design for a Circular Economy in Urban Region. Delft

reference
https://www.blauwekamer.nl/2019/03/14/regio-van-de-toekomst-8-de-toekomst-in-zuid-holland-is-van-hout/
http://www.bouwtotaal.nl/2017/05/hoogbouw-in-hout-met-cross-laminated-timber/

Recycling facility/materials

Solution 22

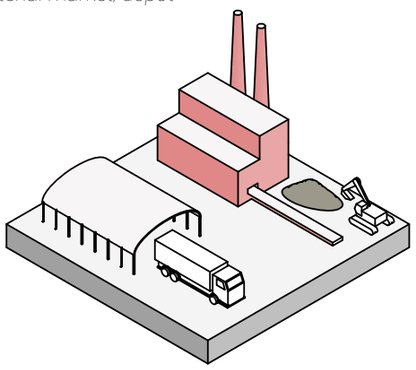
Description
Construction materials which are now downcycled can be better reused by recycling. C&D waste can be a source for new constructions.
As the concept of recycling is quite broad, not all options of recycling are explained here. The solution focuses on the possibilities of recycling within the urban stock (urban mining) and spatial requirements for the implication. An example of the urban mining potential of the plastic EPS is explained on the left page. Tis material is currently used as insulation material in buildings.

Related stock
Building/site/infra [materials]

Related LCA module
A-B-C

Applicable on the current stock
Yes

Link with other solutions
#18 Modular construction elements
#21 Biobased material/facility
#23 Material market/depot



Spatial impact
+ Heritage factor
- Assumed longer deconstruction
! More space for system activities

System impact
+ Minimizing/elimination of demolition waste
- Supply and demand could disbalance
! Spatial requirements for deconstruction, collection, treatment and storage activities.

Governance impact
Stimulation can be made by financial benefits when choosing recycled material. However, materials should be endorsed in order to savegaurd quality but also a platform and material passport need to be made for practical functioning.

Environmental impact
Recycling potentials (D) are fully used by reusing material for new construction (A3-A5). However, the use of secondary material could have a negative impact because of energy demand for recovery or higher requirement of harmful agents. LCA and recycling need to be closely deducted.

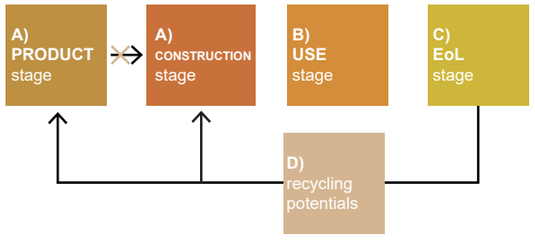


Image 1
Mobile debris crusher

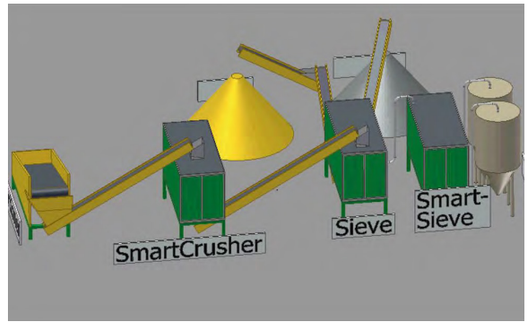


Image 2
Smart crusher instalation for the recovery of 100% recycled concrete

'EPS can be a potential light-weighted substitute for fill sand, but only when it is 100% recycled, otherwise the environmental impact is higher. Recycled material can come from urban mining (assumed 0.01667 ton/dwelling). Per m² 14,2 kg is needed which makes a road of 50x6m depended from 127 urban mining sources.'

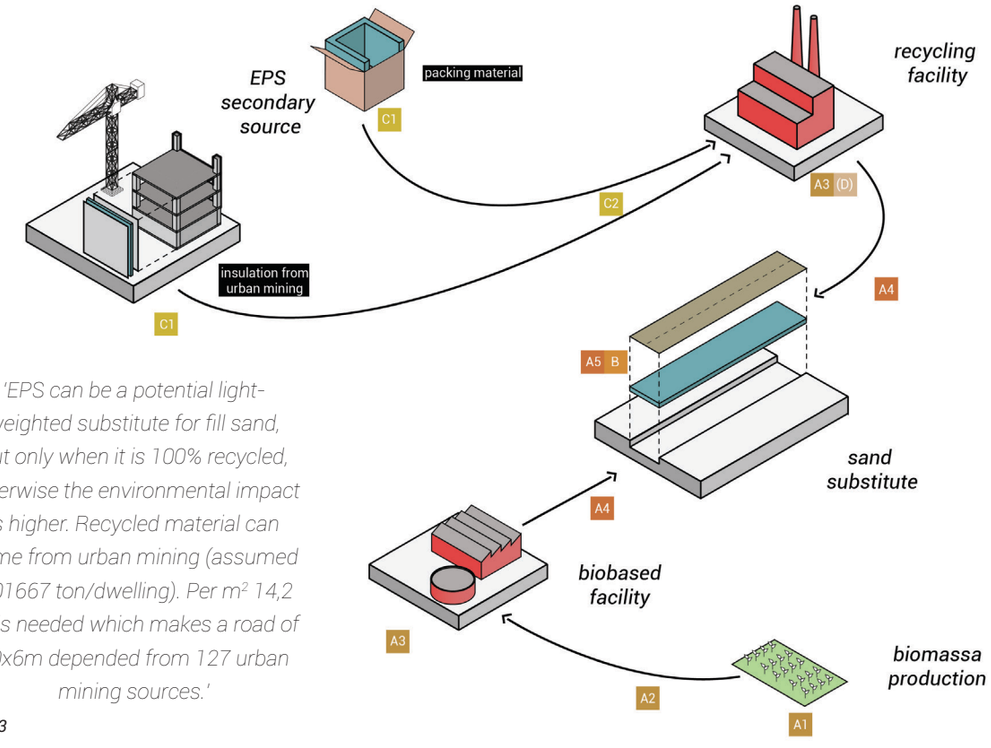


Image 3
Flow chart of EPS recycling potential

image
(1) https://www.boels.nl/huren/grondverzet/specials-1/breekinstallaties
(2) Smart Crusher bv.. (2016). *Slim breken voor beter granulaat*. Retrieved from https://www.vnconstructeurs.nl/wp-content/uploads/2018/06/SmartCrusher-VNconstructeurs-1.5.pdf

recycling

Material market/depot

Solution 23

Description
Recycled material needs to be stored for treatment or future reuse. These markets already exist but more will arise when a circular construction ecosystem is developed.

Related stock
Building/site/infra

Related LCA module
A-C

Applicable on the current stock
Yes

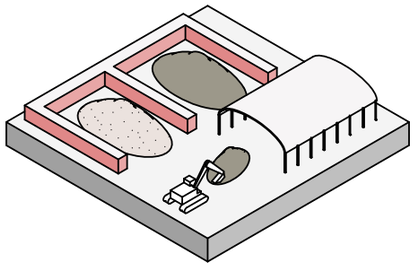
Spatial impact
- Land consumption

System impact
+ Reuse of products
! Monitoring and platform for availability

Governance impact
Flows and storage needs to be monitored and shared.

Environmental impact
Good opportunity of recycled material for new construction (D) reduces the demand of primary material (A1). However, the storage is competing for available land (C3).

Link with other solutions
#17 Deposition landscape
#22 Recycled material/facility



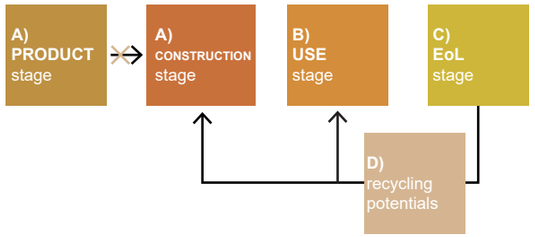


Image 1
Material collection and deposit Cirkelstad

Image 2
Material deposition site

image
(1) https://www.cirkelstad.nl/circulair-inkopen-van-een-afvalbrengstation-speuren-en-puzzelen/
(2)https://gubbels.nl/bedrijfslocaties/

Active building stock environment

Solution 24

Description

In the contemporary built environment, changes in the building stock will occur more often. With trends such as urban mining, integration of construction and demolition can become a core in planning and design. Recent design study by Defacto and Studio Marco Vermeulen are good examples of how these future urban environments will look like, an active building stock environment. The study of Defacto (1) focus on urban mining where the Schie in the Rotterdam-Den Haag region is used as the backbone for recycling. The study of Studio Marco Vermeulen (2) explored the potential of using wood as construction material for the housing demand in the same region.

Related stock

Building

Related LCA module

A-B-C

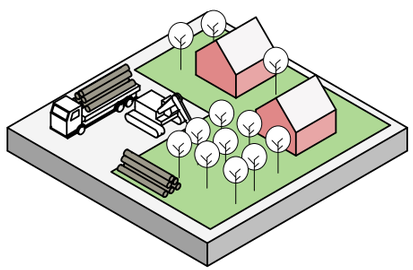
Applicable on the current stock

Yes

Link with other solutions

#21 Biobased material/facility

#22 Recycling material/facility



Spatial impact

+ Flexible built environment

- Nuisance from frequint construction and maintenance

- Causing land competition for production biobased material

System impact

+ Full potential of system optimalisation

- Spatial quality can cover real systematic quality

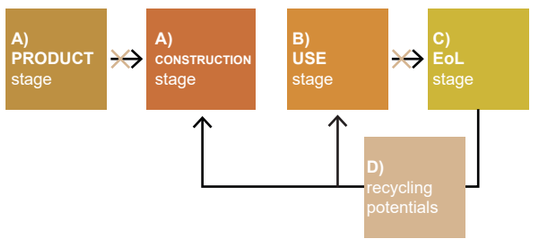
Governance impact

Acceptance and planning on regional scale is necessary for implementation.

Environmental impact

(1) Balance in recycling potential (D) for supply and demand is necessary. (see solution 22 and 23)

(2) Biobased material still causes CO2 emission in the EoL scenario (D) when it is incinerated. (see solution 21)



Research results Defacto

/ Remember: building construction requires space. Especially storage of material which require manufacturing requires ten percent extra space.

/ A market with supply and demand of C&D material is necessary - which is well monitored and combined with social media.

/ In relation to the Environmental and Planning Act (Omgevingswet), circular construction and the manufacturing industry should be given priority.

/ Circular construction meets multiple targets, such as restriction in mobility (less congestion and CO2 emission) and an economic boost for the manufacturing industry.

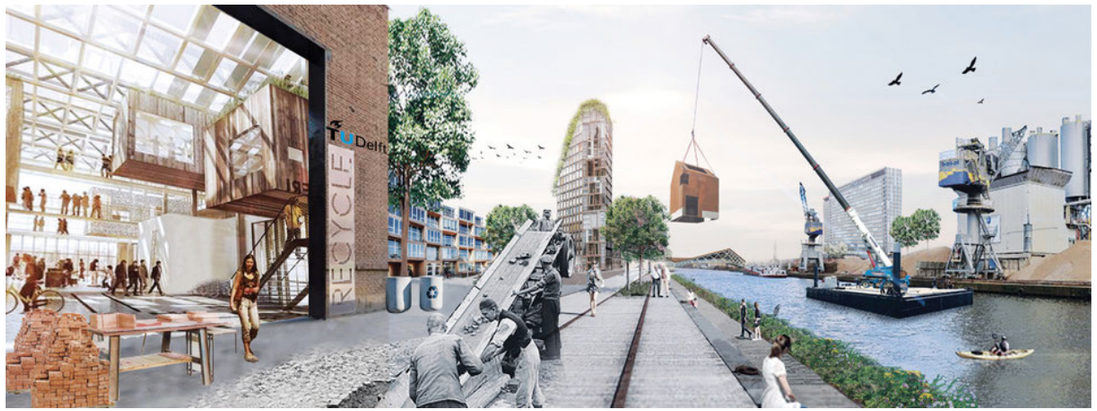


Image 1 & 2

Top: Impression of recycling sites by Defacto. Bottom: Impression of timber production by Studio Marco Vermeulen

/ Solving the housing demand with timber construction is affordable and efficient, and meets societal targets in CO2-emission, biodiversity and spatial quality

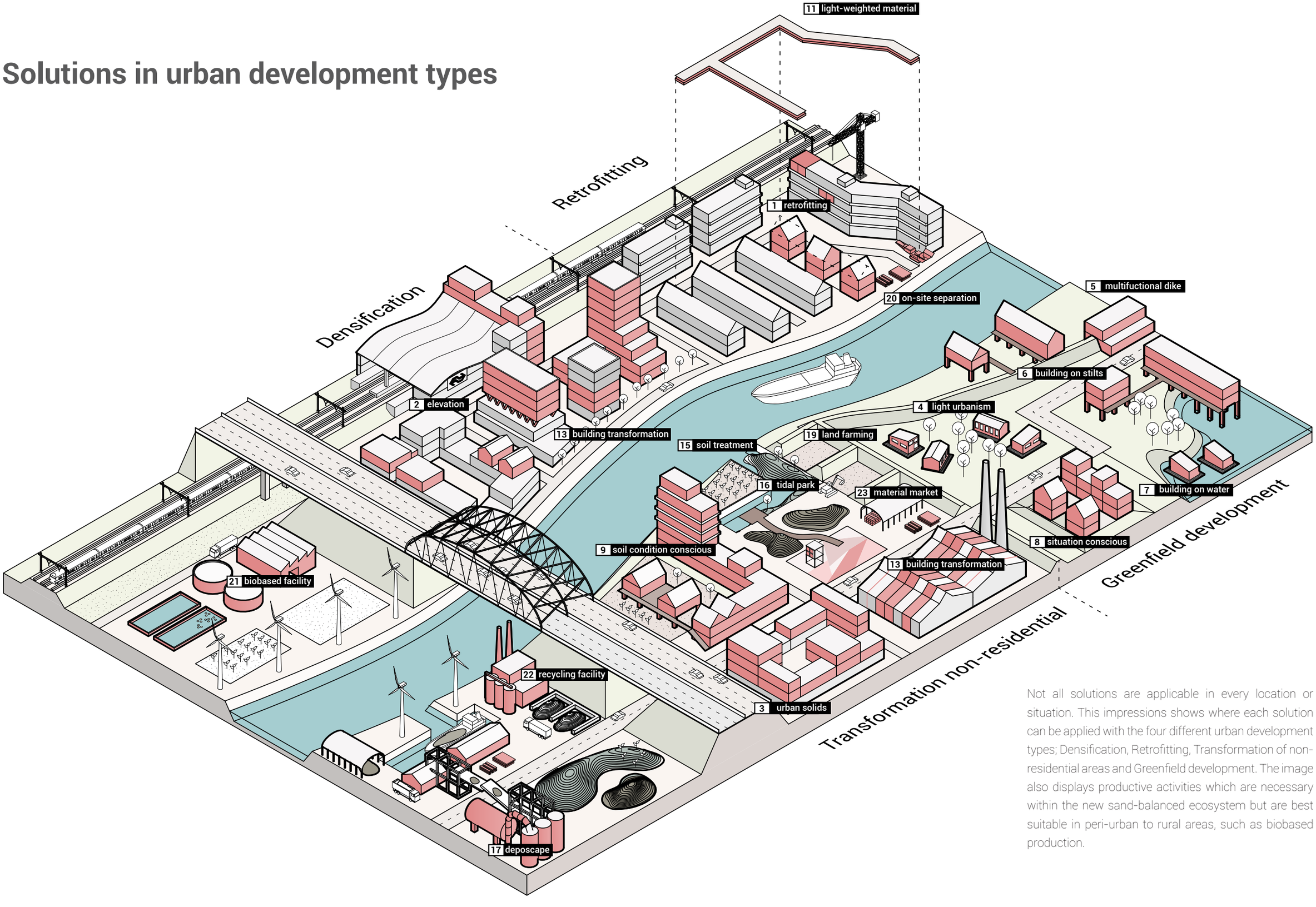
/ Implement the transition from concrete to timber incrementally, so construction companies and goverment agencies can adapt.

/ The State needs to integrate the target to completely realise the dwelling construction sustainable and biobased in 2040 In the Environmental and Planning Act.

reference & image

https://www.blauwekamer.nl/2019/03/14/regio-van-de-toekomst-8-de-toekomst-in-zuid-holland-is-van-hout/

Solutions in urban development types



Not all solutions are applicable in every location or situation. This impressions shows where each solution can be applied with the four different urban development types; Densification, Retrofitting, Transformation of non-residential areas and Greenfield development. The image also displays productive activities which are necessary within the new sand-balanced ecosystem but are best suitable in peri-urban to rural areas, such as biobased production.

Application of the solutions

The previous page shows the abstract application of the solution within the urban environment. This table is more specific about its application with related (GIS) data for regional planning. The table should be read from left to right where the '*Condition*' column states the related conditions for the application of the solutions.

The '*Related geographical data*' refers to the preliminair requirements data for the application of the solution within the specific condition. For example, light urbanism can be applied on only Greenfield development locations,

Reduce/prevention	Condition	Related geographical data
1. Retrofitting	R	Building age (*monofunctional; 1950 until 1980*)
2. Densification by elevation	D	Flat roofs (*for topping*)
3. Urban solids	D, R, T	New construction site (*urban typology*)
4. Light Urbanism	G	Soil condition (*soil strenght*)
5. Multifunctional dike	G, M	Dike improvement (*available*)
6. Building on stilts	T, G	Development areas (*for new construction*)
7. Building on water	T, G	Water areas (*available*)
8. Situation-conscious	G	Soil condition (*soil strenght*)
9. Soil condition-conscious	R, T, G	Soil condition (*contamination level*)
10. Allow subsidence	D, R, T, G, M	Soil condition (*subsidence*)
11. Light-weighted material	D, R, T, G, M	Soil condition (*subsidence, infrastructure*)
12. BioGeoCivil solutions	D, R, T, G, M	VARIOUS (*e.g. soil condition*)
Reuse		
13. Building transformation	D, R, T	Building typology (*vacant, non-residential*)
14. Flexible architecture	D, R, T, G	New construction sites (*urban typology*)
15. In-situ soil treatment	R, T	Soil condition (*contamination level*)
16. Tidal park	M	Harbour sites (*vacant*)
17. Deposition landscape	T, M	Waste landscapes (*available locations*)
18. Modular construction elements	D, R, T, G, M	[NON] (*requirement in architecture*)
Recycling		
19. Land farming	T, G, M	Waste landscapes (*available locations near water*)
20. On-site deconstruction & separation	D, R, T	Demolition sites (*source location*)
21. Biobased material/facilities	D, R, T, G, M	Strategic/logistic location (*for implementation*)
22. Recycled material/facilities	D, R, T, G, M	Strategic/logistic location (*for implementation*)
23. Material deposition/market	M	Strategic/logistic location (*for implementation*)
24. Active building stock environment	D, R, T, G, M	All urban environment (*transformation option*)

D= Densification
R= Retrofitting
T= Transformation
G= Greenfield
M= Maintenance

This issue is part of the appendicies of the TU Delft MSc Urbanism graduation project 'City without Sand' where it is part for the exploration of sand-sensitive solutions for the reduction of material consumption in urban environment.

Colophon
Catalogue of Solutions
Appendix A of 'City without Sand'
MSc Thesis Urbanism
Delft University of Technology

July 2019

Author:
Wouter ter Heijden

First mentor:
Dipl. -Ing. Ulf Hackauf
Second mentor:
Dr. Henk Jonkers

'What are the alternatives for sand consumption in the construction of the urban landscape?'

In order to improve the current construction sand metabolism, new solution needs to be found which can be integrated in the urban development strategy and have a significant impact on the consumption system. The exploration of solutions is based on literature review of innovative projects on circular construction on different scales

June 2019

TU Delft

Urbanism

environmental technology & design