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CIRCULAR Bio-waste in Apeldoorn

Demonstration Report

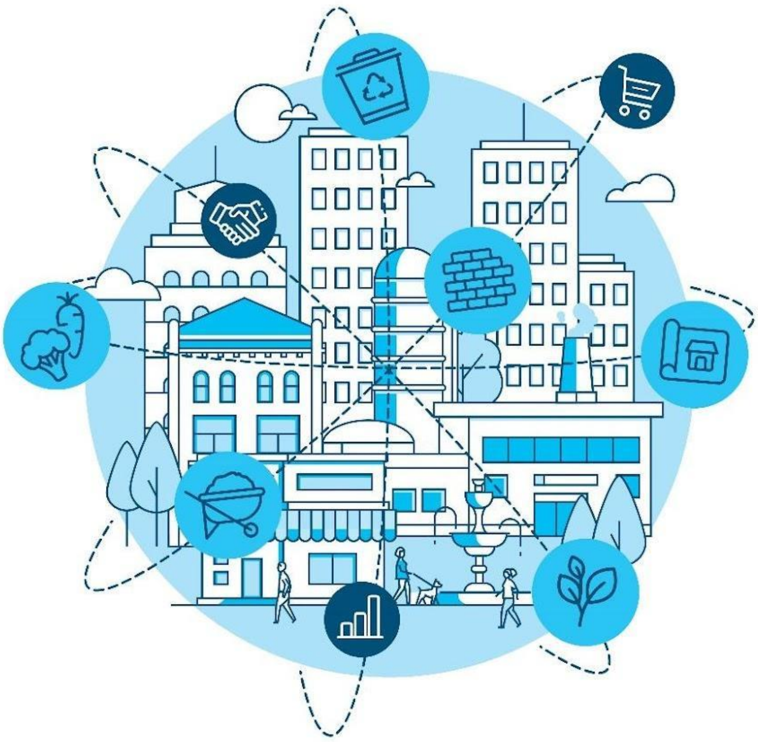
Demo 1: Bokashi from leaves

Demo 2: Biochar from pruning

Demo 3: Fibre-based products from grass

Demo 4: 3D printing with organic fibres

Municipality of Apeldoorn



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Abstract	Circular economy of bio-waste sector was demonstrated in Apeldoorn with four demonstration actions: 1. Bokashi from leaves, 2. Biochar from pruning, 3. Fibre-based products (grass-paper) and 4. 3D printing with organic fibres (Japanese Knotweed) This report describes the implementation, results, and conclusions of these demonstration actions.
Keywords	Circularity, Bokashi, Biochar, Grass fibres, 3D printing
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1 Executive summary

The CityLoops project brought together seven European cities – Apeldoorn, Bodø, Mikkeli, Porto, Seville, Høje-Taastrup and Roskilde - to pilot a series of demonstration actions to close the loop of two of the most important waste streams in Europe: Construction and Demolition Waste, and Bio-waste. The aim was to become a circular city in which no resource goes to waste, driving the transition to the circular economy. The project started 1.10.2019 and ended 30.9.2023. ICLEI- Local Government for Sustainability - coordinated the project and it received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 821033. Wageningen Research and the Municipality of Apeldoorn were responsible for the project implementation in Apeldoorn. This report presents Apeldoorn's demonstration actions on bio-waste (bio-waste from green spaces) – their implementation, results and lessons learned, as well as replicability and future perspectives. During the project Apeldoorn developed 4 demonstrations:

Demo 1 Bokashi. Bokashi is a fermentation process that converts organic waste (in Apeldoorn leaves) into a soil amendment which adds nutrients and improves soil texture. In this video the demonstration of bokashi in in Apeldoorn is shown: https://youtu.be/siuDVO6wAaE

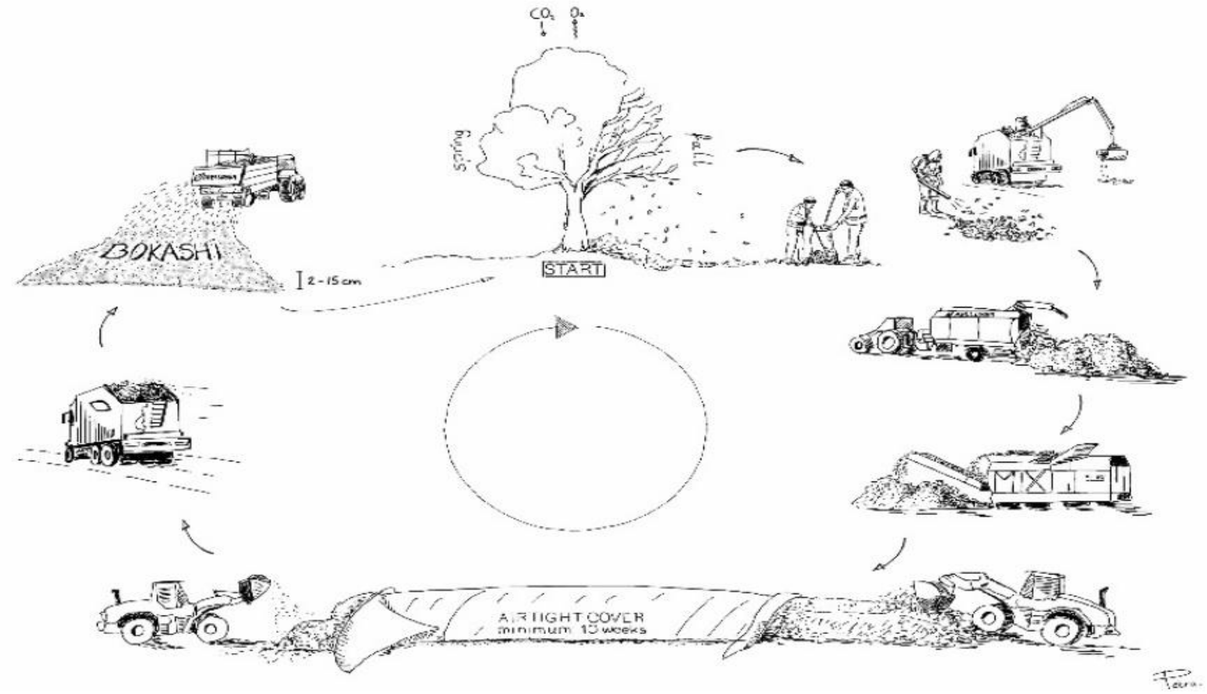


Figure 1: Bokashi process

Demo 2 Biochar. Biochar is a charcoal-like substance that is made by burning biomass in a controlled process called pyrolysis. During pyrolysis organic materials, such as wood chips, leaf litter or dead plants, are burned in a container in the absence of oxygen. As the materials burns, they release little to no contaminating fumes. During the pyrolysis process, the organic material is converted into biochar, a stable form of carbon that cannot easily escape into the atmosphere. The energy or heat created during pyrolysis can be captured and used as a form of clean energy. In Apeldoorn a desktop study was performed on Biochar production and some test with biochar. Apeldoonr did not produce biochar. The pyrolyze installation is quite expensive. This demo showed the possibilities to use biochar. In a video these opportunities are shown: https://youtu.be/nliVtXz1q-Y

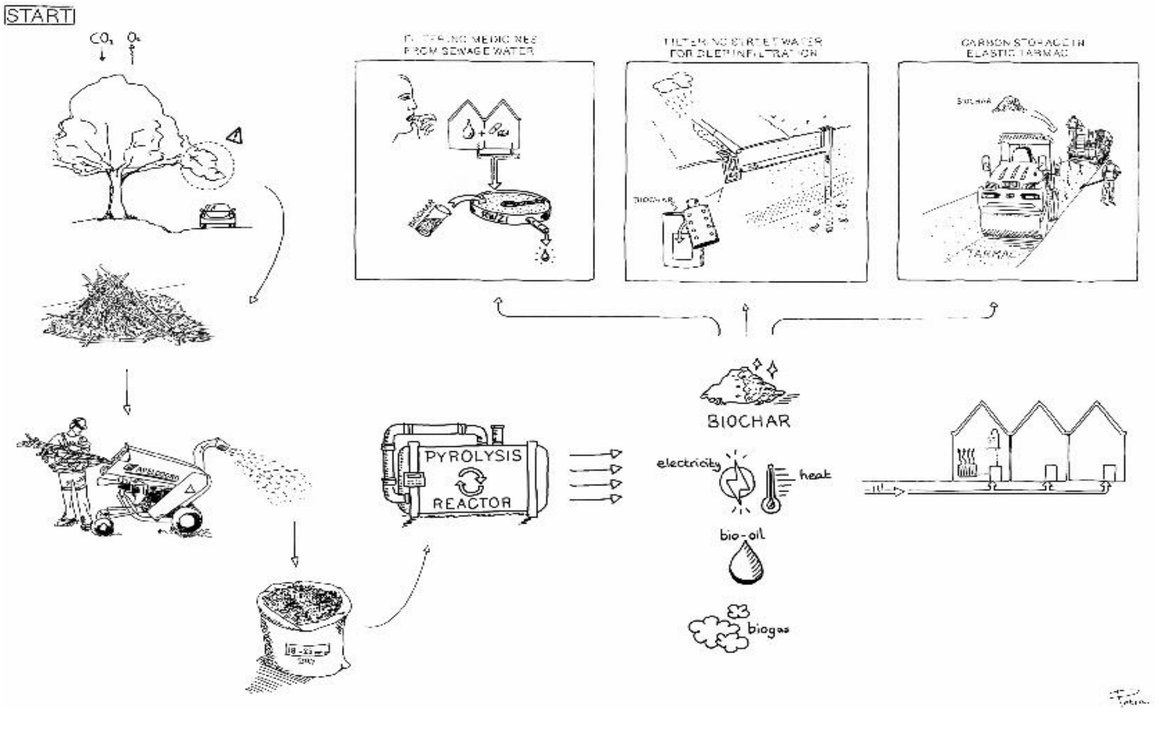


Figure 2: Biochar process

Demo 3 Fibre-based products from grass. It is possible to make paper with grass. These days grass will be cut every year and composted or brought to a biodigester. Apeldoorn is home to several paper factories, in the demo the option to produce paper with grass on city scale is shown. The demonstration is presented in the video: https://youtu.be/ZFHqWcvqCdU

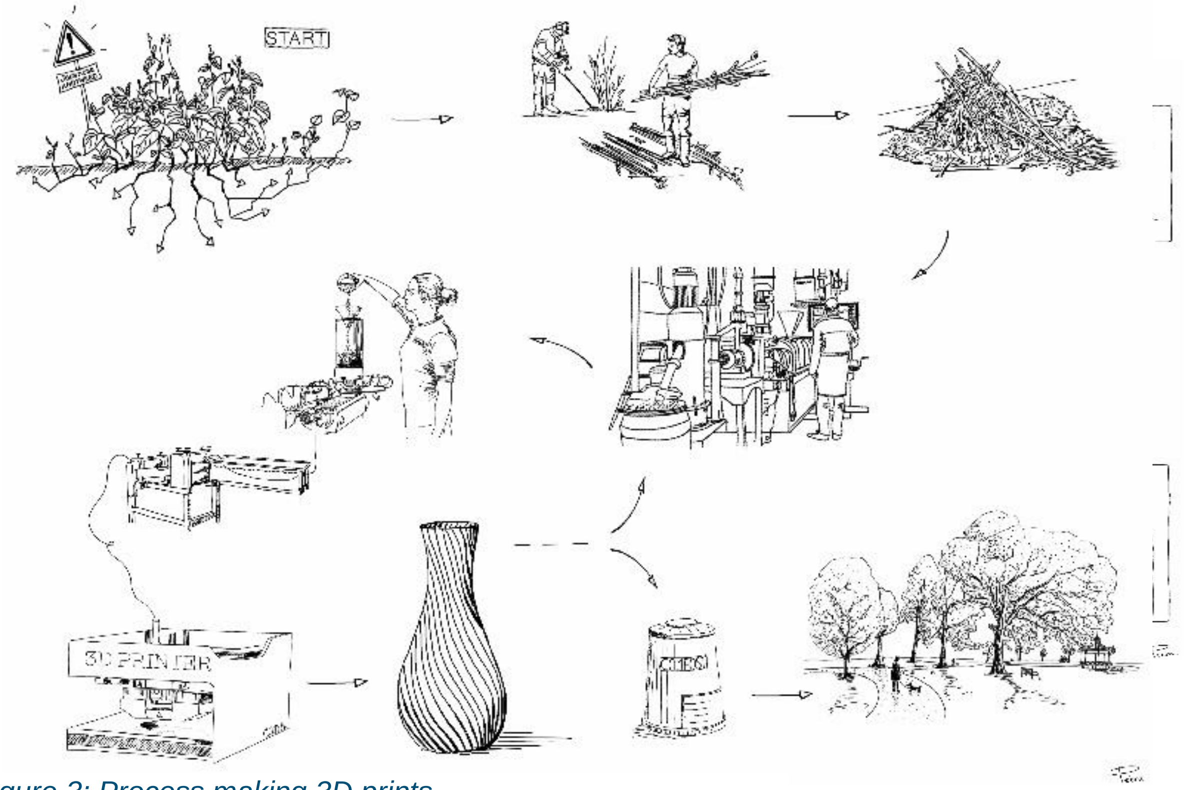


Figure 3: Process making 3D prints

Demo 4 3D printing of Japanese knotweed. Japanese knotweed is a plague in the city. The growth of plant is strong and can demolish buildings. Every year Apeldoorn either mows the Japanese Knotweed or uses pesticides to remove these invasive plants. The plant can also be used as a resource to make filament for 3D printing. In Apeldoorn experiments to make filament of Japanese knotweed and to make 3D prints were performed. In this video the process is shown: https://youtu.be/ZFHqWcvqCdU

Lessons learned

Apeldoorn has learned valuable lessons during the demonstrations, the added value of describing the circularity of new valorisation options (e.g. by the circularsquare) and collecting data concerning circular solutions are recognized and will be used in the future. Circular procurement will be incorporated into the procurement of Apeldoorn.

In CityLoops Apeldoorn decided to explore the possibilities of circular processes for bio-waste from green spaces inside the city and on city level. Currently the treatment of bio-waste is performed on regional scale by Circulus. This novel approach resulted in new responsibilities for departments inside Apeldoorn. Main responsibility is located at the department of Management and Maintenance of public spaces. The interest of this department is on improving the quality of the public spaces rather than on producing products or raw materials from the collected bio-waste. Focus of this department was therefore the demonstration of bokashi.

The overall policy of the municipality is focussing on the energy transition and not on circularity. This resulted in a limited uptake of the demonstrations towards biochar, paper, and 3D-products inside the city departments.

The stakeholders involved in 3D-printing and paper are focussing on showing bio-based solutions to the public/inhabitants, rather than starting a production facility. Industrial interest for Biochar was found on regional level. CityLoops showed that to upscale the new initiatives more interest and dedication from departments and the city council is necessary.

Wageningen Research functioned as expert and pilot scale producer in the demonstrations towards grass paper and 3D printing filament from Japanese Knotweed. This enabled to showcase these applications without preliminary influence from competing industries. Wageningen Research will assess the interest of industrial partners in producing the paper and filament inside, but also outside of Apeldoorn.

The restrictions on personal contacts during the Covid period did influence the effectiveness of communication between stakeholders. The options to showcase the demonstrations to inhabitants and other stakeholders were limited. It is expected that increased interest will be gathered based on the produced videos and dissemination of the results of the demonstrations.

The transition towards a more circular city by producing products from bio-waste from public spaces is part of the overall transition towards more bio-based products. For this transition to occur the economical feasibility of the valoristion options must improve. Existing woodbased and fossil fuel-based alternatives dominate the market, new bio-based options will need economical incentives to get ahead.

Future perspective

Apeldoorn will continue with production and research towards the effect on the quality of the soil from the application of Bokashi until the end of 2026. The process is improved continuously. The focus is on researching the optimal time for spreading and improving the quality of the Bokashi. Alternatively the effect of mulching leaves and directly spreading will be considered.

Biochar is just at the beginning of its development. European wide pop-ups of biochar installations and initiatives are seen. Apeldoorn has been approached several times to join new initiatives. Currently this is out of scope for the municipality. This can change when energy transition becomes more important than nowadays.

In Fibre-based products from grass the interest of the paper industry and large users of paper in the grasspaper product is very limited. Apeldoorn will not be active in promoting this option. Paper industry in the Netherlands is struggeling, among others because of the high energy price and the large CO_2 output of the industry. The paper industry focusses on these large issues rather than changing to an alternative feedstock, grass.

In 3D printing enough interest from possible users of the filament was found. Currently the market for 3D filament containing fibres is small. Next step is to interest industrial partners in producing commercial batches of 3D filament containing Japanese Knotweed. Apeldoorn does not intend to produce its own 3D filament.

2 Introduction

Between 2019 and 2023 the municipality of Apeldoorn and Wageningen Research as part of the CityLoops project aimed to make impact with regards to the circularity of bio-waste from green public spaces. The impact claim is and was *to improve human well-being, quality of life (people), environment (planet) in line with the SDGs and circular business models (profit)*.

Apeldoorn used the Theory of Change (TOC) (described in circularsquare©) is part of the transition from a linear to a circular city. To make impact, the actions to be taken need to be described, together with an overview of current and intended output and outcome, and how the change contributes to the impact claim. Results need to be measured (monitoring and evaluation) and it should be describer how the actions can lead to the goal to become a circular city.

Apeldoorn focussed on creating circular solutions for the bio-waste generated in green public spaces, in particular grass, leaves, pruning and a weed, Japanese Knotweed. In the optimised implementation plan (OIP) (CityLoops deliverable 3.3) five different demonstration actions were defined, during the demonstration phase it was decided to join the fifth demonstration (municipal cleaning of grass by volunteers in cooperation with the city) with the other demonstrations as a method to improve the purity of the collected bio-waste. The four remaining demonstrations are:

Demo 1: Bokashi from leaves

Leaves are collected in the autumn and processed into Bokashi. The bokashi is used to improve the quality of the public spaces.

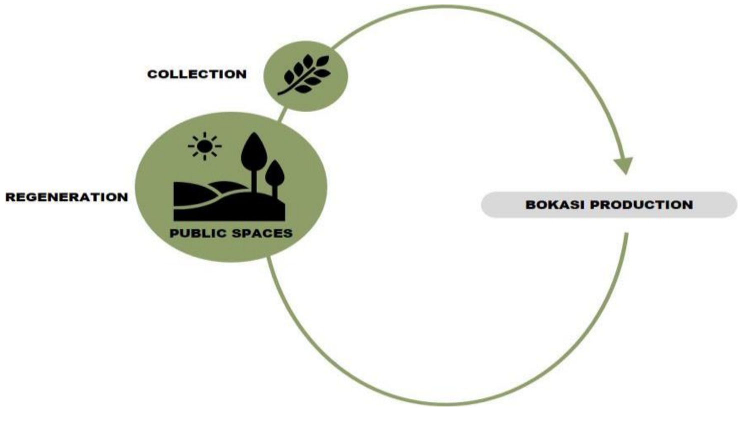


Figure 5: Circular representation of Bokashi from leaves

The demonstration aims to show that by producing bokashi, the treatment of collected leaves can be performed inside the city, by the department Management and Maintenance of public spaces. Bokashi can be spread in Apeldoorn. Before this demonstration leaves were exported outside of the city and composted regionally. Compost originating from the region was bought and imported to improve the soil in Apeldoorn.

Demo 2: Biochar from pruning

Pruning is collected and processed into biochar. Biochar can be used for improving soil quality, purifying water or as component in asphalt. Depending on the chosen use of the biochar, after the use phase the biochar can be returned to nature.

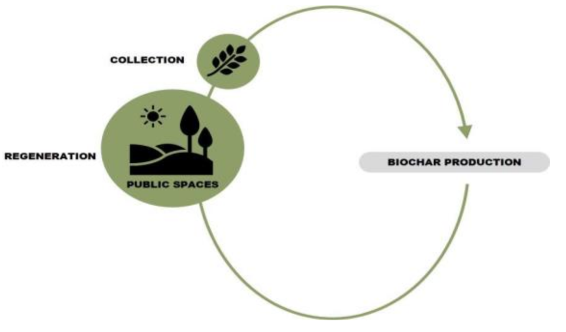


Figure 6: Circular representation of Biochar from pruning

Currently collected pruning is exported outside Apeldoorn to be used in e.g. composting. Biochar is currently not used to improve the quality of the soil. Biochar is imported to be used in purification of water. The demonstration aims to show the possibilities of producing and applying biochar in Apeldoorn.

Demo 3: Fibre-based products from grass

Grass is collected and processed into pulp suited for paper making. The pulp is used in a papermill to produce paper. Grass based paper can be recycled or composted to be returned to nature.

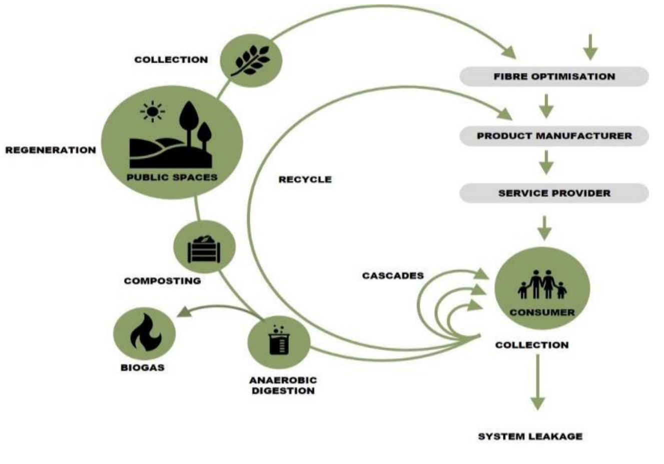


Figure 7: Circular representation of Fibre-based products from grass

Alternative fibres for the paper-industry have been studied in the Netherlands for at least 20 years. Apeldoorn has four paper factories inside the municipality. Currently this paper industry uses recycled paper and virgin pulp imported from outside the Netherlands as resource. The demonstration aims to show that grass collected from Apeldoorn can be used to produce paper, reducing the import of wood-based pulps. Currently collected grass is exported outside of Apeldoorn to be composted or used in the production of biogas. The production of grass-paper was demonstrated in a paper museum “De Middelste Molen”, located in Apeldoorn. The museum hosts the oldest working paper machine in the Netherlands.

Demo 4: 3D printing with organic fibres

Japanese Knotweed is collected and in combination with a biobased, biodegradable plastic Polylactic Acid (PLA) converted into filament suitable for 3D printing. Products printed from this filament can be recycled or composted under industrial composting conditions. The compost can be returned to nature.

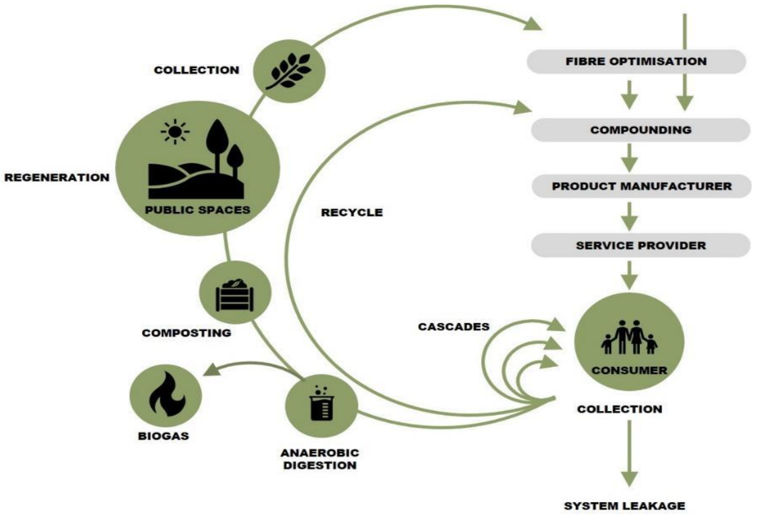


Figure 8: Circular representations of 3D printing with organic fibres

The demonstration aims to show that it is possible to produce filament from Japanese Knotweed and use this filament to produce 3D printed objects in Apeldoorn. Currently all filament used in Apeldoorn is imported. Collected Japanese Knotweed is burned to prevent spread. Using Japanese Knotweed as a fibre source in filament will reduce the amount of filament that is imported into Apeldoorn. The production of 3D products from the filament was demonstrated in the makerspace of the experience lab of Apeldoorn's Museum CODA, a space where inhabitants can use 3D-printers.

2.1 Set up of this document

This document consists of five chapters:

- Introduction
- Description of the city context of Apeldoorn

  Providing insight into the city of Apeldoorn and its bio-waste flows

- Description of the three tools that were developed to support the demonstration actions:
  - Bio-waste valorisation decision support tool
    A tool that was used to select the four demonstration actions and can be of help to other cities aiming to find circular valorisation options of bio-waste from green spaces.
  - List of innovative sorting and treatment options for bio-waste from Green Spaces
    A list of options to sort and treat bio-waste from green spaces to enable circular valorisation
  - Business plan development tool
    A tool describing different elements of circular business cases.
- Implementation activities

  In this chapter the four demonstrations are described consecutively. For each demonstration action procurement, stakeholder activities, results, evaluation, lessons learned, and future perspective is presented.

- Conclusions

3 City context

Basic characteristics - physical, sociocultural, geographic, economic

Apeldoorn is a city of 165.611 inhabitants. It is the main city of ‘the Veluwe’; a forest-rich ridge of hills that is considered as the Netherlands finest area of natural scenic beauty. Its surface of 339.96 km^2, the 11th city of the Netherlands. The inhabitants make up 77,970 households, which use on average 1,200 m^3 of natural gas and 2,830 kWh of electricity. Apeldoorn holds 15,310 companies offering 104,000 employees a job. The most important economical activities are trade, technology, and healthcare.

Governance

The democratic structure is comparable to other municipalities in the Netherlands. A board of one mayor and five council members executes the policy guidelines set by the local council, which holds 39 seats. Within the municipal organization a board of directors, consisting of one municipal secretary and four theme managers, manages around 1,300 civil servants. The strategy of Apeldoorn has been laid down in a vision called ‘Woest aantrekkelijk Apeldoorn’; in English ‘Wildly Attractive Apeldoorn’, referring to the wildlife that is present in abundance. It mentions the following forecasts and targets towards 2040 (Apeldoorn, 2022):

- An expected increase of 180,000 inhabitants, so 12,500 houses are needed.
- Increase of 80 ha business parks
- Increase of spatial green and blue areas, including an increase of biodiversity and a decrease of nitrogen
- Increase of shared and sustainable mobility
- Decrease intensive agricultural areas.

Governance related to bio-waste management

Apeldoorn cooperates with 7 other municipalities in the region of ‘the Stedendriehoek’. These are shareholder of Circulus. Circulus is the waste company of the region and collects the household waste. The table shows the amount of collected household waste in the years 2021 and 2022 in Apeldoorn.

Table 1: Household waste collected in Apeldoorn

	2021	2022
Inhabitants	164770	165586
Unseparated [kg/year/citizen]		
Residual waste	62.1	62.8
Bulky waste	24.8	24.8
Separated [kg/year/citizen]		
Garden, vegetables & fruit waste	155.1	156.0
Paper & Cardboard	56.3	56.6
Packaging glass	25.0	25.3
Plastic, metal & drink cartons	50.5	49.4
Textile & clothes	4.8	4.9
Diapers	4.8	4.3
Electronic waste	5.6	5.6
Organic waste	5.9	5.8
Others	41.0	42.0

Because every municipality is a shareholder of Circulus, there is no need for a tender of waste management collection. Every year policy makers of each of the 8 municipalities have contract and supply meetings with Circulus. For the next year an ambition web will be part of the contract meeting (Figure 9). The ambition web is parted of the circular procurement guidelines used by Apeldoorn in cooperation with Rijkswaterstaat in CityLoops. The topics of the ambition web are shown.

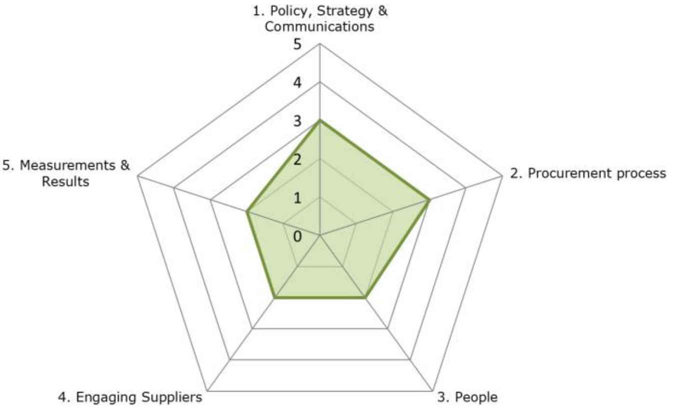


Figure 9: Ambition web used during contract meetings between Apeldoorn and Circulus

Bio-waste collection in Apeldoorn is divided between different actors.

1) Bio-waste from households is collected by Circulus. (Circulus-Berkelhas recently changed its name to Circulus) This includes GFT (Vegetable, Fruit, and Garden waste) and pruning from private gardens. After collection Circulus transports these waste stream to Attero, which treat the waste into compost or digestion.
2) Bio-waste from green spaces is collected by the department of Management and Maintenance (Beheer en onderhoud) of Apeldoorn. This department is responsible for managing open spaces and collects small organic waste, mixed organic waste, woody biomass, leaf litter, grass clipping, and Japanese Knotweed. The decision on how these biomass streams are treated depends on a single contractor who is responsible for most of the treatments. Department activities are tendered. The collected bio-waste is for the largest part directly transported to a company called Rettera. Short intermediate storage at facilities of the department of Management and Maintenance is possible. Rettera processes the bio-waste to compost, except for bio-waste consisting of Japanese Knotweed and polluted leaf litter, these streams are incinerated.

A visualization of the bio-waste flows in Apeldoorn, focussing on household and green spaces bio-waste is presented in Figure 10.

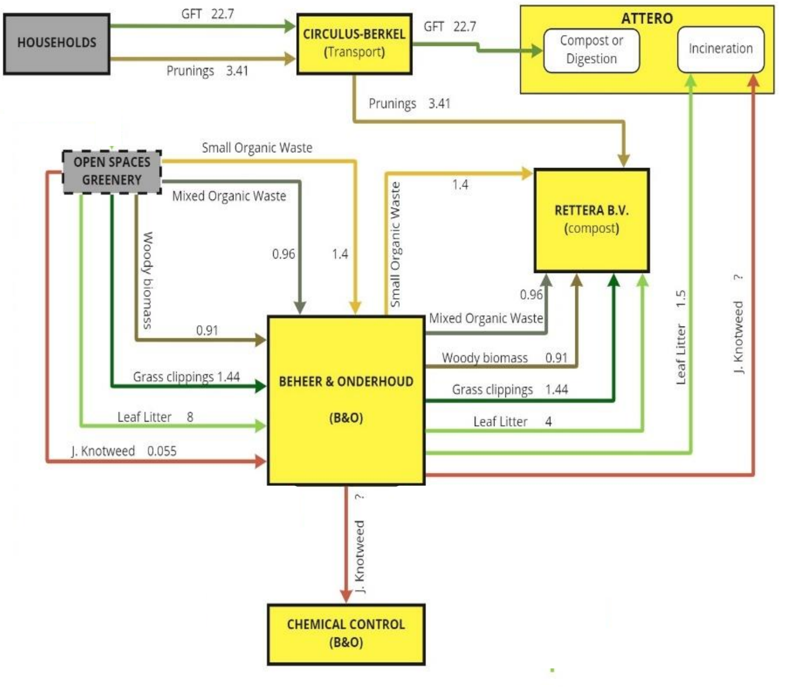


Figure 10: Overview of actors and quantities of the yearly bio- waste flows in kiloton present in Apeldoorn's biological waste system based on the final weighted mass and estimated mass for J. knotweed in 2019. Partially adapted from (Korte, 2020).

4 Tools

In the preparation phase prior to the demonstration phase three tools were developed. These tools are described in this chapter. During the demonstration phase the tools have been adapted to reflect the changing insights during the demonstrations.

4.1 Bio-waste valorisation decision support tool

This tool aims to help cities to choose between all kind of possible valorisation options for bio-waste prior to deep diving into all the details of a circular valorisation option.

During the preparation phase of CityLoops a selection of four different valorisation options was made to demonstrate in Apeldoorn. The selection process was based on a set of parameters, ideas, and dreams of a future circular city regarding bio-waste and public spaces. Link to the bio-waste valorisation decision support tool: https://cityloops.eu/fileadmin/user_upload/Materials/Tools/bio-waste_valorisation/Bio-waste_valorisation_decision_tool_%E2%80%93_Apeldoorn.pdf

The input for the tool consists of four distinct factors:

- Factor I: Policy goals of the city
- Factor II: Circular economy principles
- Factor III: Parameters of the bio-waste
- Factor IV: Parameters of possible converting processes.

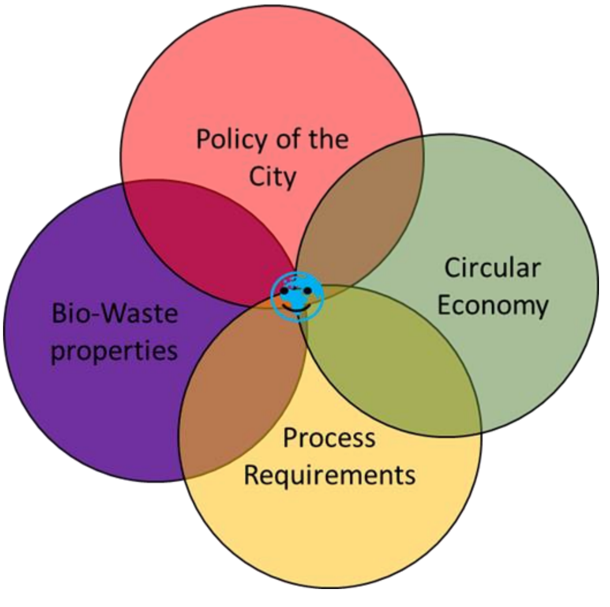


Figure 11 Combination of the different groups will result in a choice for valorisation options

Factor I: Policy goals of the city

The overall goal of CityLoops is "To better understand how local governments can best promote the transition to a circular economy (CE) in their city. Closing urban material and resource loops, and thereby reducing the environmental footprint, increasing regenerative capacities, and stimulating new business opportunities." CityLoops decided on a definition of circular cities and connected the progress towards becoming a circular city with the global development goals. [CityLoops D6.1] Specific cities however will have their own policies towards circularity and may focus on other topics. In e.g., Apeldoorn the focus of the city was for the last years on the Energy Transition rather than circularity, but as with all municipalities focus is subject to political and private sector influences over time.

Decisions on the management of bio-waste from public spaces, are made by the cities department of "Management and Maintenance of public Spaces". Priorities centre on maintaining and improving the quality of the public spaces. BW Collection times can be out of synch with industry timings for their raw material needs (e.g., the times grass is mown is controlled by the times different flowers are present).

Creating an overview of the policies and practices of a city regarding the circular economy and bio-waste will help to decide which valorisation options to select.

Factor II: Circular economy principles

Circular economy is an umbrella term used to convey and promote improved activities which at the practical level may refer to many different processes. Such as reuse of materials, returning nutrients to the environment, preventing plastic waste, moving away from a fossil oil-based society are all possible achievements that are referred to as part of the circular economy. Three different models were used in the decision tool to describe (parts of) the circular economy:

- The butterfly model of Ellen MacArthur
- Waste hierarchy, ladder of Lansink
- The biobased value pyramid

The butterfly model of Ellen MacArthur

The butterfly model describes the circular economy as consisting of two circles, one focussing on finite materials (blue) and one on renewables (green). Bio-waste is part of the green cycle.

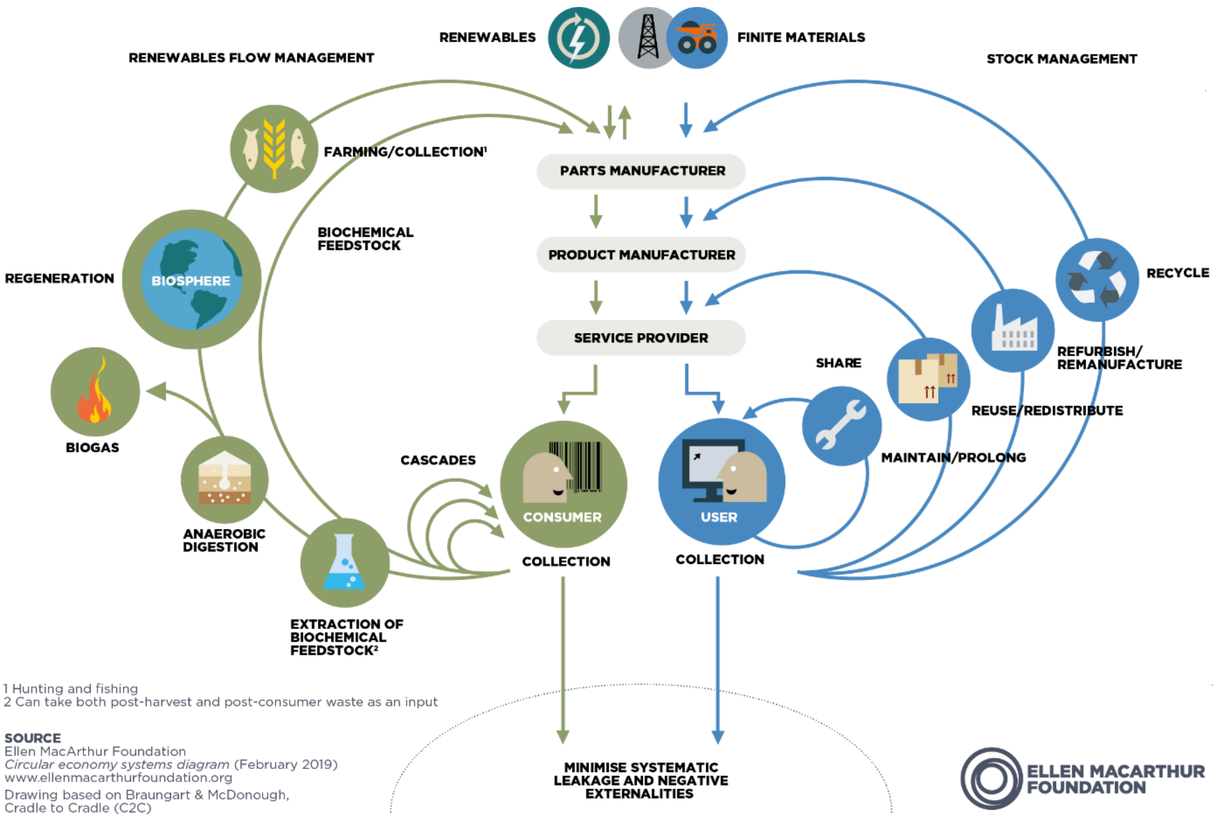


Figure 12 Butterfly model, Ellen MacArthur circular economy systems diagram

All parts of the circles should be considered, the model shows that products made from biomass after use by consumers can be reused several times by consumers directly (cascades) or after a second manufacturing step. This “reuse” of products is thereby used in a separate way of the “reuse” of finite materials, where the terms share, maintain, prolong, reuse, redistribute, refurbish, remanufacture, and recycle are used. Most importantly for used products from renewables as bio-waste there is the option to regenerate the biomass by returning the nutrients and CO_2. to the biosphere. Here additionally the options to create bio – energy and extracting bio-chemicals are positioned.

The butterfly model does not specifically describe bio-waste from green spaces as a resource, and without creating products or materials from the bio-waste, the processes used to maintain or improve the quality of the green spaces are part of the regeneration. The butterfly model focusses on the production of materials to be used by consumers. Leaves, pruning, grasses that are collected and used to maintain the green spaces (even after composting or the bokashi process) do not add any product, chemical or bio-chemical to the circular economy. However, it is part of the circular economy and should be part of a circular city.

Valorisation options for bio-waste from green spaces will validate how current practices in Apeldoorn can be illustrative of a move towards more circular practices through public-private partnerships or develop practices that are reflective of the butterfly model.

Waste hierarchy, ladder of Lansink

The Dutch politician Ad Lansink designed a waste hierarchy that is used often when discussing possible options for handling waste. It was not specifically made with bio-waste in mind. It combines (but pre-dates) valorisation options from both the blue and green cycles from MacArthur.

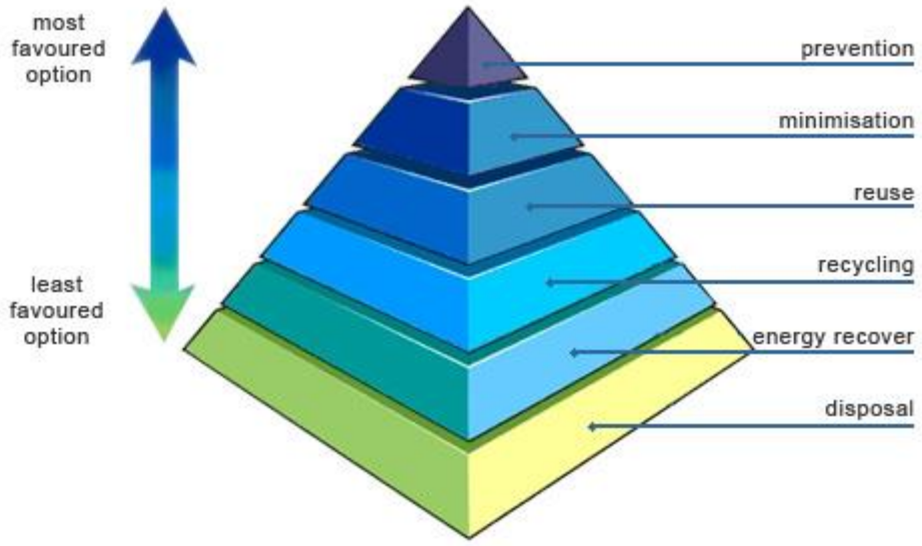


Figure 13 Waste Hierarchy [www.adlansink.nl]

On the top end, for bio-waste from green spaces both prevention and minimisation are an option. It is possible to select plants and design green spaces in such a way that less bio-waste is generated. Direct return of the generated bio-waste during pruning or removal of leaves from the streets into the biosphere for example after chipping or mulching could be used. This may be cost-effective and even improve the quality of the green spaces, but will not help in creating a circular, biobased economy. On the bottom end, disposal in landfills (e.g., because of contaminations), should be avoided at all costs. For bio-waste reuse could be thought of as creating products or chemicals from the bio-waste, as described by the green circle in the butterfly model of MacArthur. Recycling can be done directly by e.g., digestion, but ideally should be performed after the reuse stage. Recycling includes the option to recover nutrients to regenerate the biosphere. Energy recovery refers to incineration with energy recovery.

The biobased value pyramid

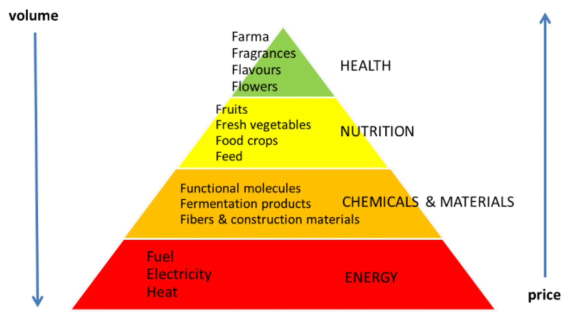


Figure 14 Biobased value pyramid [www.wikiwijs.nl]

The volume and price of biobased products are often presented as a pyramid. Most biomass is used to produce energy at low costs, most expensive products are pharma and fragrances, but volumes are low.

The biobased value pyramid can differ based on e.g., location and technical developments.

In the decision tool, the three models are used to characterise the different valorisation options. Options can be rated based on their position inside the three models. In Apeldoorn valorisation options were graded high if they fit into the MacArthur green circle, if they focus on reuse and recycle options in the waste hierarchy by Lansink and if they are high in the biobased value pyramid.

Factor III: Parameters of the bio-waste

Properties of the bio-waste collected in a city determine to a substantial extent the possible valorisation options. A good overview of bio-waste should contain the following parameters:

- The amount of bio-waste collected on e.g. a yearly basis
    - Amount in tonnes wet
    - Amount in tonnes dry
- The type of bio-waste collected
    - What (part of) plants are present in the bio-waste?
    - What is the state of the bio-waste (dried out/fresh/old etc.)?
- The availability of the bio-waste throughout the year
    - When is the bio-waste collected?
    - Can the bio-waste be stored (and how does that change the quality)?
- The composition of the bio-waste
    - What are the chemical components in the bio-waste?
    - What are the larger components in the bio-waste (e.g. fibres, protein)?
- The quality of the bio-waste
    - What impurities are present in the bio-waste (e.g. sand, plastic)?
    - How stable is the bio-waste?

The gathered information can be used to match converting processes with the bio-waste, e.g. on scale, desired components, and purity. City policies may also influence the bio-waste parameters: Apeldoorn has reduced the space for storage of bio-waste in the past years. Increasing storage space would increase costs, but also increase valorisation options.

The work done by Metabolism of Cities, partner in CityLoops, to visualise the locations inside the cities where biomass is produced, stored, discarded, and reused as bio-waste would also be a valuable addition to the overview of parameters of bio-waste [Metabolism of Cities, 2023]. A simplified version [Figure 10] created by Apeldoorn was used in the selection of valorisation options for Apeldoorn.

Factor IV: Parameters of possible converting processes

Different parameters have been used to characterise possible converting processes. An overview contains:

- Categorisation of a valorisation process based on the type of converting
  Valorisation options can be e.g. fit into handicraft, agricultural, mechanical, and chemical categories. Distinct categories are more suited into the environment of a circular city.
- Scale of the process
    - Scale relates to the amount of biomass per year that is needed to run the process. General rules are used to estimate the optimal scale of valorisation options, partly based on the scale of existing processes and partly on design rules for small scale biorefineries [Bruins, 2015].

- Flexibility of the process
    - Is it possible to use multiple feedstocks in the process, thereby reducing the amount of bio-waste necessary?
    - Is year-round production necessary to create economic viability of the valorisation process?
- What is the technology readiness level (TRL) of the proposed valorisation option?
  The TRL defines how much technological research is still needed prior to implementation. It can also be used to estimate the required time necessary before a valorisation option can be implemented in the city.

Table 2: Technology Readiness level [Definition used by Horizon 2020]

Technology Readiness level	
TRL 1	basic principles observed
TRL 2	technology concept formulated
TRL 3	experimental proof of concept
TRL 4	technology validated in lab
TRL 5	technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	system prototype demonstration in operational environment
TRL 8	system complete and qualified
TRL 9	actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

For Apeldoorn it was chosen to only consider valorisation options that were estimated to be above TRL 4 to be able to demonstrate the options in CityLoops.

The parameters of the different converting processes were used to enable the decisions between the different valorisation options. Processes should fit the policy of the City; processes could be graded on circularity principles and the parameters of the bio-waste were compared with the different processes.

Two other key factors for a circular bio-waste process are kept out of the selection. The economic viability of the process and the interest of industrial partners in developing a business.

- Economic viability

The reason for disregarding the economical viability in the tool is partly based on the overall goal of CityLoops. It is envisaged that the shift to a circular city may result in higher costs in processing of bio-waste, but will result in other (e.g., environmental, and social) benefits for the city. Disregarding the economical viability is also motivated by the "inconvenient truth" that without e.g., a CO_2 tax or a subsidiary contribution there are few biobased processes for non-food and feed applications besides the existing large-scale industries that are economical viable. Some economical factors are considered in Group IV, parameters of possible converting processes, mainly in considering the economy of scale for different processes.

Of course, after the demonstration upon deciding to continue with the valorisation option, economic viability will have to be considered.

- Interest of industrial partners

The interest of existing or upcoming industrial partners in setting up a process on bio-waste was kept out of the selection tool because it is desirable that a city decides on routes towards a circular city/economy based on “neutral” data instead of being led by industry. A city should consider the values of all stakeholders rather than focussing only on industrial entrepreneurship. However, the selection tool and the distinct groups in the tool would be very useful in evaluating the ideas of interested industries.

The demonstrations are used to interest industrial partners into the chosen valorisation options.

4.2 List of innovative sorting and treatment options for bio-waste from Green Spaces

Bio-waste that is collected from households, industry or in this case green spaces will contain impurities: Components that are undesired or hamper the use of bio-waste in the circular economy. Removing these impurities is crucial to enable the correct processing of this material stream. One of the options envisaged to create value from bio-waste rather than having to pay to discard bio-waste is the cleaning of bio-waste by the city.

Whether a component is considered an impurity depends on the requirements of the envisaged valorisation strategy. Impurities can be divided into two groups. The first group consists of materials that are biologically not considered to be part of biomass: e.g. Sand, Plastic, Metal, Glass, Paper packaging (boxes, cups, bags, drinking cartons). These impurities are undesired in almost all recycling processes. The second group consists of components that are biological, but not the desired material for a selected circular process. Examples are bark, when wood is desired, twigs when leaves are desired, moss when grass is desired, or leaves when the stalks of Japanese Knotweed are desired.

A list of technologies was created that describes different sorting and treating methods which can be applied to make bio-waste from public spaces suitable as feedstock to produce bio-based products. The technologies were physically assessed in the facilities of Wageningen Food and Biobased Research. For each of the demonstration cases methods were selected and used either on side in Apeldoorn (Bokashi) or in Wageningen (suggest annex refs go here). Treatment options assessed and presented include selectively removing components and/or drying the material, optimising the bio-waste by mechanical or biological pre-treatment, or tailoring the fibre properties. The technologies listed are suitable to be performed at small scale and minimal impact. It is envisaged that they could be performed in a city/agricultural like environment rather than e.g. at a chemical site:

- Washing (active)
- Washing (passive)
- Filtration
- Electrostatic separation
- IR cleaning
- Cutting

- Sink-float separation
- Hydrocyclone
- Wind sifting
- Fluidised moving bed separation
- Inclined vibration screening
- Grinding
- Drying (active)
- Drying (passive)
- Pressing
- Municipal cleaning

Link to the list of sorting and treating options: https://cityloops.eu/fileadmin/user_upload/Materials/Tools/bio-waste_valorisation/Sorting_tool_Apeldoorn.pdf

4.3 Business plan development tool

Apeldoorn developed a canvas to provide insight into the costs and benefits of a circular bio-waste project. This canvas is referred to as CircularSquare-plan and can be used to describe a business plan.

Link to Business plan development tool: https://cityloops.eu/fileadmin/user_upload/Materials/Tools/Enablers/CircularSquare.pdf

Apeldoorn intends to use the CircularSquare-plan in discussing new circular bio-waste projects with interested stakeholders, as a starting point to work together.

CircularSquare-plan offers a complete overview of how to establish a business plan for a circular economic based cost-benefit analysis for your project. The business case in this plan is a supply chain description, including People, Planet, Profit and will help to set up the total business plan for the idea in bio-waste. The circularsquare is presented as a canvas. (Figure 15).

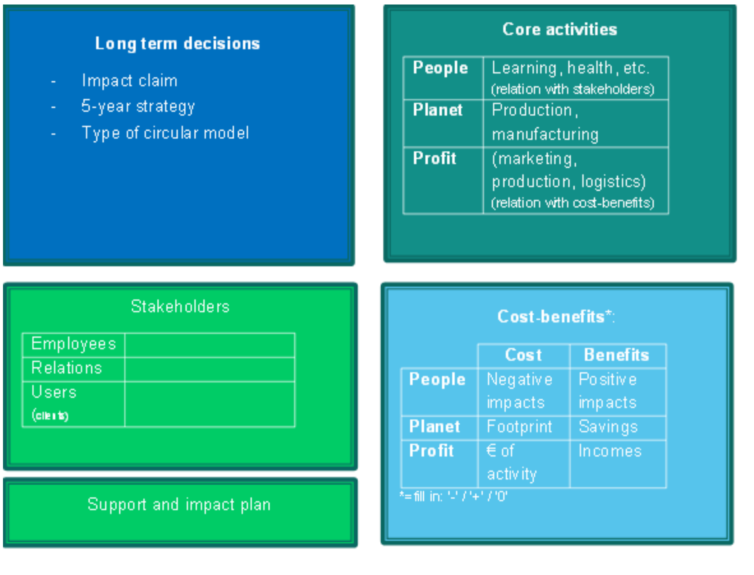


Figure 15: Canvas of the CircularSquare-plan as developed by Apeldoorn

- In the long-term decisions box (dark blue) the long-term strategy is described. It shows the impact claim, the 5-year strategy and the type of circular model.

- In the core activities box (dark green) the main activities of the business case are described. Some of these are future activities.
- In the stakeholder box (light green) the most important persons/organisations are shown who are involved in this business case.
- In the Costs-benefits box (light blue) people, profit and planet are distinguished.

A business case is part of a business plan. While the plan is the total overview the idea, the business case describes meticulously the most important activity whether the activity is interesting to invest in; Invest in profit, people, or planet. This circularsquare can inspire the first steps of circular procurement: In the circularsquare the ambitions of a new project are set. By setting ambitions beforehand and clearly prioritising certain circular strategies a starting point for the interaction with stakeholders is established. The gathered information can be used in the tendering process.

5 Implementation activities

5.1 Stakeholder participation

In the demonstrations Apeldoorn and WR have worked with several stakeholders. Three stakeholder groups can be distinguished:

- Internal stakeholders. Colleagues working at the municipality of Apeldoorn.
- External stakeholders:
    - Experts. Those who are involved as an expert in the project.
    - Similar partners, like other municipalities
    - Social organisations
    - Contractors
- Inhabitants. Those who live in Apeldoorn

In the demonstrations of Apeldoorn one of the consortium partners is Wageningen Research. In the table WR is not considered as a stakeholder, but as a consortium partner. In the matrix below the stakeholders who participated in the different demonstrations are shown:

Table 3: Stakeholder participation in the demonstrations

	Colleagues	Inhabitants	Experts	Similar partners	Social organisations	Contractors
Bokashi	X	X	X			
Biochar	X	X		X		X
Fibre-based products	X		X		X	X
3D printing	X		X		X	

Bokashi

In this demo Apeldoorn worked mainly with internal stakeholders from different departments. Collection, cleaning up the roads, driving in tractors was done by colleagues. Driving at the heap, add minerals, operating machines and driving with shovels was done by Bij de Oorsprong (external stakeholder). When the Bokashi was ‘ready to spread in the city’ internal stakeholders spread the bokashi in the neighbourhoods. Approximately 2 months before spreading the bokashi, the communication department (internal stakeholder) starts with informing inhabitants. During spreading the bokashi inhabitants can ask for information about the process, the product, etc. The municipality of Apeldoorn has different social media to express their information.

Biochar

In the demo Apeldoorn collaborated with similar partner the Municipality of Enschede and 2 contractors. One contractor was involved in setting up a business case. This organisation is a waste management company who was interested to build a plant. The other organisation uses biochar in asphalt and made Ecofalt. In the experiment of using biochar in cleaning up the water, Apeldoorn collaborated with internal stakeholders.

Fibre-based products from grass

WR has been involved in most of the pilot and demonstration projects on paper products from grass in the last 25 years, collaborating with the owners and collectors of grass, the converters of grass into fibre and the paper producers. Apeldoorn participated in a project to produce paper from grass on national scale “Van berm tot bladzijde” (From roadside to page). Partners included Rijkswaterstaat and paper factory Parenco in Renkum.

In this city scale project the department of management and maintenance and the paper museum “De Middelste Molen” were involved. Combining the knowledge of the volunteers of the museum (Most volunteers are former employees of the nearby paper industries) and the experts on grass collection. The background knowledge of WR was used to optimise the converting process.

3D printing of Japanese Knotweed

WR has been involved in projects on fibre composites consisting of natural fibres and thermoplastic matrix materials for the last 25 years, collaborating with suppliers of natural fibres, new thermoplastic materials, compounding companies and producers of composite products. The last 15 years the focus shifted from oil-based plastics to biobased and biodegradable plastics, with special emphasize on PLA. For the experiments WR included an intern from the group of Prof. Dr.-Ing. Joerg Muessig within the City University of Applied Sciences - Hochschule Bremen, Germany. This group has a long track record in Research on fibre composite materials. Apeldoorn collaborated with a contractor to mow the Japanese Knotweed. The filament has been used by the experience lab located in the CODA museum in Apeldoorn. Inhabitants using filament for 3D printing have been contacted to comment on the properties of the filament.

Lesson learned

In the demonstration Bokashi all three groups of stakeholders were involved, mainly because of the large scale of this demonstrations and the advanced level of this technology. In the three other demonstrations the scale was smaller, and level of technology readiness was lower. In the demonstration Biochar industrial parties were involved in a later stage during the demonstration. In the demonstrations on fibre-based products and 3D printing it was decided to postpone the influence of external industrial partners until after the demonstration was finished. This was possible because of the market knowledge of WR on these topics.

What Apeldoorn learned is that huge steps can be made by involving stakeholders in an earlier stage. This stage Apeldoorn calls ‘conceptual thoughts. Upon having conceptual thoughts Apeldoorn should send a message to other organisation who are or will be interested to join a demonstration. The reasons therefore are manifold and include:

- When involving stakeholders earlier, a larger group can discuss the supply chain, the circular route, and the possible solutions.
- When involving stakeholders earlier, a richer amount of knowledge is available
- When involving stakeholders earlier, there will be a broader range of replication opportunities.

5.2 Circular Procurement

During CityLoops new methods for circular procurement were developed. These rules have not been demonstrated during the bio-waste demonstrations in Apeldoorn.

Bokashi

The production of bokashi is performed by a contractor "Bij de Oorsprong". Contacts between this contractor and Apeldoorn were established years prior to CityLoops. No circular procurement was performed for this demonstration.

Biochar

No circular procurement was performed in this demonstration. The stage of development of this demonstration was too immature to perform procurement.

Fibre-based products from grass

Circular procurement was no part of this demonstration. The partners of the project performed the demonstration. Paper production was performed by the Paper Museum "De Middelste Molen" in Apeldoorn.

3D printing of Japanese Knotweed

Circular procurement was not a part of this demonstration. Apeldoorn performed all experiments in collaboration with WR and the CODA Experience lab of Apeldoorn.

5.3 Demonstration Bokashi

5.3.1 Introduction

Bokashi is a fermentation process that converts organic matter into a soil amendment which adds nutrients to the soil and improves soil texture. In Apeldoorn bokashi is produced from leaves and used to improve the soil of public green spaces. Bokashi is also used to refer to the product of the Bokashi process.

Bokashi is one of the business cases that was started before CityLoops. In Figure 16 the timeline of bokashi in Apeldoorn is shown.

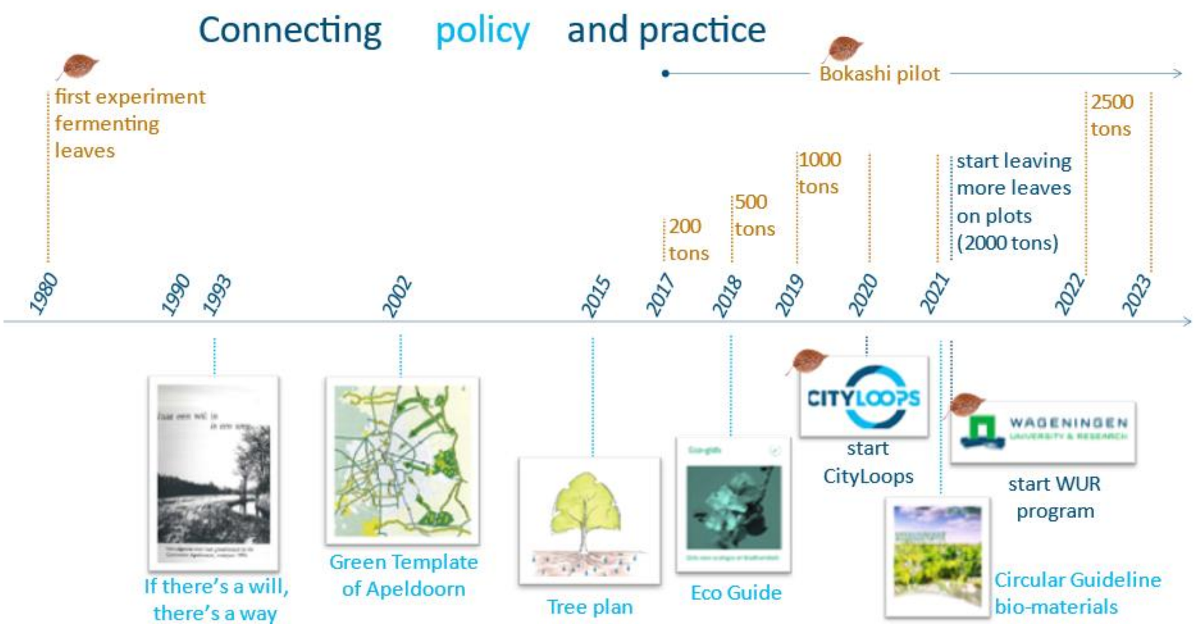


Figure 16: Timeline on bokashi in Apeldoorn

The bokashi process was selected to be demonstrated because it fits perfectly to the goal of the city to enhance the quality of the soil. Current soil quality in Apeldoorn is poor. It is also a good example of a circular city project. The collected leaves used to be transported outside of the city and converted into compost. Compost was bought from outside the city to improve the soil. The bokashi process is performed inside the city, reducing import and export. From the scope of circular economy, the bokashi process does bring back the nutrients that are lost with the bio-waste to the green spaces.

To better understand the value of Bokashi in improving the quality of the soil, during CityLoops Apeldoorn joined a WR project (Knowledge programm, part of basic financing of WR by the Ministry of LNV) on Circular Terrain Managment comparing Bokashi and compost (see frame). Additional measurements on soil quality and bokashi composition were done in cooperation with this knowledge programm

Knowledge program Circular Terrain management

From 2021 untill 2025 WR researches the quality and effectiveness of produced soil improvers, specifically Bokashi and compost. This is done in cooperation with 60 participants, coordinated by the Centre of Soil Ecology. The WR program aims to collect content and evidence to stimulate circular use of biomass and biomass-based fertilizers. To expend knowledge, to increase cooperation and to incorporate circular use of biomass in National policy and legislation. Main goal is to determine:

- The composition of the fertilizers:
  - composition (nutrients and contaminators) by analysing 80 Bokashi- and compost samples from the pilots.
- The effect of Bokashi and compost in a field lab and on pilot plots, considering agricultural effects, soil biodiversity and environmental effects by:
  - studying the effect on 3 soil types
  - determining potential soil structure by incubation tests
  - evaluating the experiences of participants.

Next to the possible benefits to the soil, the WUR also researches possible risks to soil quality when products of grass or leaves are used as soil improver. This is done by measuring and analysing the composition of these products as well as monitoring the long-term effects of periodically using these products.

5.3.2 Implementation

5.3.2.1 Sourcing

In Apeldoorn each year about 7000-8000 tons of leaves are collected from public grounds like public roads, footpaths and lawns. These leaves are transported to a local processor, to be used as a base product in the creation of compost. Compost is then transported back to the city, to fertilize public green plots. Over the past decades, the interest in enhancing the quality of soil has grown. With the effects of climate change on soil and biodiversity, the importance of creating and managing healthy and resilient green places is becoming more evident. By starting the experimental use of Bokashi, Apeldoorn tries to find answers to these challenges.

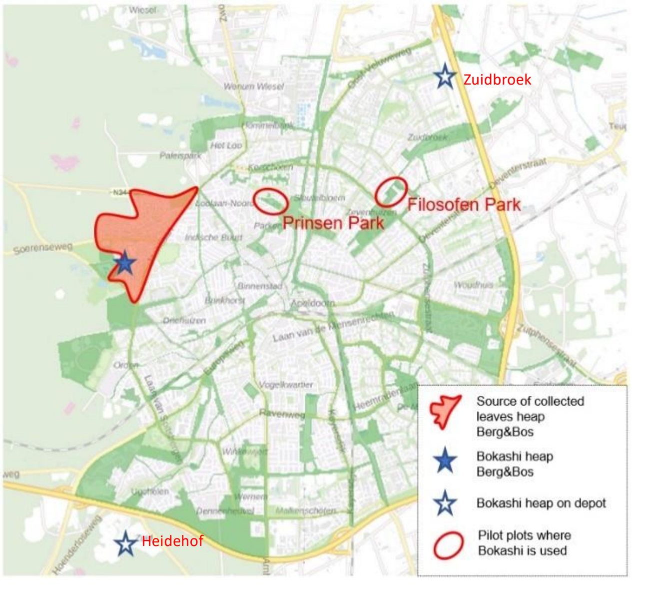


Figure 17: Map of Bokashi-pilot locations In Apeldoorn.

To shorten, simplify and upcycle this circle of nutrients, Apeldoorn started the first experiment in 2017 by fermenting its own leaves by using the Bokashi process, in the area Berg&Bos. It started with a small amount of two hundred tons. Main target was to find out more about the production process. What does collecting leaves, creating, and distributing Bokashi on a local scale include? In 2018 the production was increased to 500 tons of leaves, in 2019 to nearly 1000 tons.

In 2020 Apeldoorn joined the CityLoops project. Two pilot areas: the Filosofen park and the Prinsen park (Figure 17) where chosen to test the effects of using Bokashi on the soil. In 2022 Apeldoorn scaled up to processing 2500 tons of leaves, divided over three locations: the original Berg&Bos-location, a depot in the area Zuidbroek and a depot on the cemetery Heidehof. Most bokashi was spread in the spring. The Bokashi of Zuidbroek was spread in September 2022 to observe the differences between a spring gift and an autumn gift. In 2023 the Bokashi production was continued at the same scale and locations.

5.3.2.2 Sorting and treating

Three methods were used to obtain the right purity of leaves to be used in the bokashi process.
Firstly, the location for the collection of the leaves during the demonstration was chosen based on the amount of litter that was to be expected. Although this resulted in a visibly small number of impurities in the leaves, upon upscaling leaves had to be sourced from more polluted areas, decreasing the effectiveness of this method.
Secondly, municipal cleaning, during collection volunteers selectively removed larger pieces of litter from the streets.

Thirdly, a magnetic separator was used inside the bokashi processing unit to remove pieces of metal, this is established technology to prevent damaging the cutting blades.

5.3.2.3 Processing

Making and using Bokashi is a circular process of local leaves to which micro-organisms are added to start and support fermentation. The following picture shows this annual process in 6 steps, starting in the autumn.

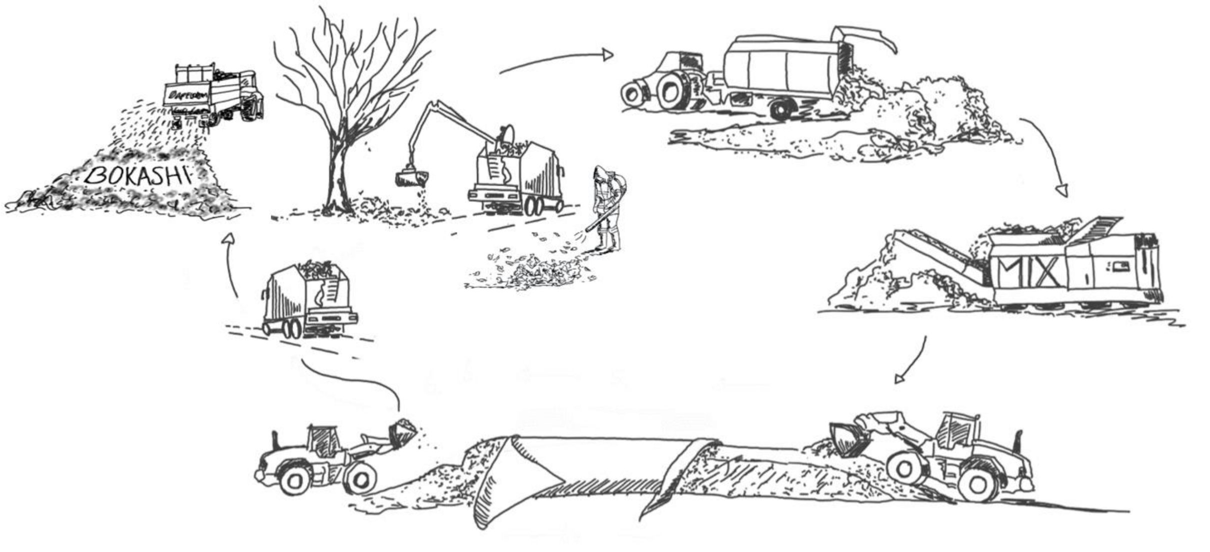


Figure 18:Visualtization of the process of making Bokashi from leaves (P.Bennink©)

The video showing the process: https://youtu.be/siuDVO6wAaE

5.3.2.4 Use of Bokashi

The produced bokashi is spread on public green spaces. Two locations have been chosen to monitor the effect. In those locations 3 plots are made on which different ways of soil improvement are used and tested: compost, Bokashi and nothing used (reference plot).

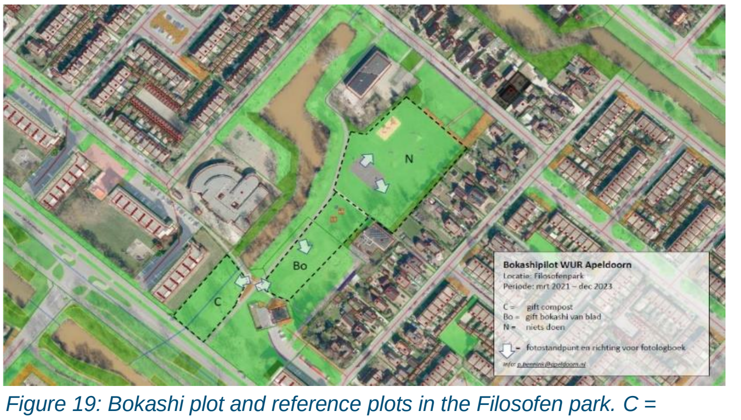


Figure 19: Bokashi plot and reference plots in the Filosofen park. C = compost used. Bo = Bokashi used. N = Nothing used (reference plot).

The Filosofen park is a relatively young park, created in the late ninety sixties. Before that, the grounds were used for agricultural purposes. The plots consist of poor sandy soil, mostly managed as short grass land with a few young trees spread. The park is used for recreation and sport activities (low intensive use).

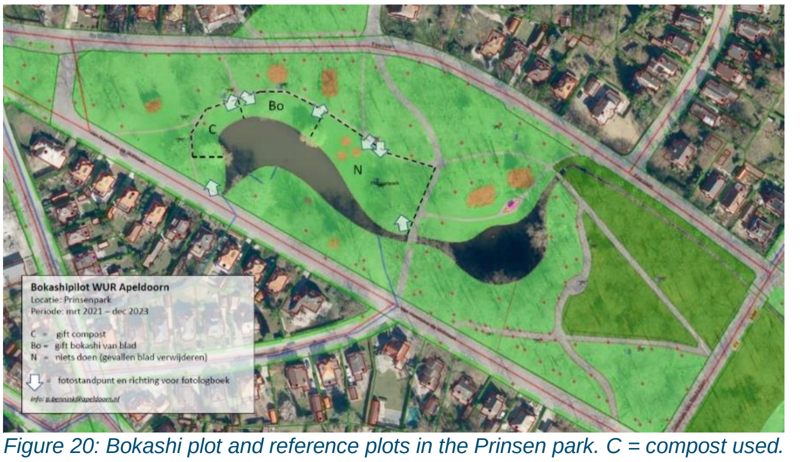


Figure 20: Bokashi plot and reference plots in the Prinsen park. C = compost used. Bo = Bokashi used. N = Nothing used. (reference plot)

The Prinsen park is built in 1909 and one of Apeldoorn's National monuments. This romantic park is a more mature and used for recreation and fishing in the pond. The soil is sandy and moderately humus rich, mostly managed as short grass land with old trees spread.

The original idea of Apeldoorn was to add a plot of 'leaving leaves year-round' to the WR-research, on our own account. In practice it was hard to maintain the leaves on these plots all year round. The recreational use of the parks conflicted with leaving an almost permanent layer of leaves on the fields and the leaves caused bald spots in the grass. The leaves were kept in place as long as possible, till the start of the new year and were then collected and removed. Too short to be of representative value to the research. Therefore, after the first year, these plots were removed from the research.

Figure 21 From top to bottom: Compost-, Bokashi- and non-fertilizer plot in the Filosofen park on the 15th of July 2022 during a long period of drought and heat.

Figure 22: From top to bottom: Compost-, Bokashi- and non-fertilizer plot in the Prinsen

Quality of the soil improvers

- Bokashi from leaves on average contains more organic material (45wt%), than locally produced compost (32%) and certified produced compost (26%). In addition, Bokashi contains a larger share of ‘unstable’ organic material compared to compost. After spreading the Bokashi on the plot, soil life profits from this unstable part of organic material which is then decomposed.
- The soil improvers contain comparable amounts of macro nutrients (N, P, K) compared to certified produced compost.
- Almost all samples of the soil improvers met the amounts of heavy metals and arsenic that are legally determined for certified produced compost.
- The amounts of organic micro pollutions (PAK’s, mineral oil and PFAS) were low and in most soil improver samples not detectable.
- In most samples no residues of pesticides were found (or in very low amounts, around detection level)
- Considering weed pressure, 70% of the samples did not contain germinating seeds of weeds, which proves there is enough reduction of weed pressure.
- Considering the amount non-organic pollutions of soil strange pollutions, most of the samples met the requirements of certified produced compost. The bokashi contains too many stones.

Effects on soil of pilot plots

In 2021 the soil of all 60 pilots of the Circular Terrain Management study has been analyzed three times: once before adding the soil improvers (reference measurement in March) and each autumn at the end of growing season (in October). The spring analyses showed huge differences between the pilots considering: soil type (sandy to heavy clay), amount of organic material, water-retaining capacity, soil life (fungi and bacteria), cultivation system and management. The Autumn analyses need more data from coming years to show results.

In the Prinsen park the differences are not distinctive, also not in 2022. The plots react similar on the weather extremes. The more humidious soil, the nearby presence of the pond and shadow of old trees might temper the Bokashi-effect. In both parks, no differences were seen in biodiversity as far as vegetation is concerned.

5.3.3 Business case

Long term decisions

- Impact claim: *Bokashi is the best natural soil improver*
- 5-year strategy:
  - *Delete: artificial fertilizer within 5 years*
  - *Strength: a combination of compost and bokashi*
  - *Reduce: the use of gasoline machines*
  - *Create: more bokashi at the local scale and increase*
- Type of circular model: *Life cycle model*

Core activities

People	Pick up leaves by people, truck driving, mix machines steering Improve circular learning, driving carefully
Planet	Use of (less) fertilizers, increase use of natural soil improvers (by leaves), driving tractors, machines, leave blowers, sweepers, slider, truck with crane, shovels, mixed machine.
Profit	Cost reduction and effectiveness are the main goals to realize the impact claim.

Stakeholders

Employees	- *20 people from the municipality of Apeldoorn* - *15 people from Circulus (waste company)* - *15 people with a distance to the labour market* - *5 volunteers (Although there are more volunteer in total, the activate participants are 5 individuals).* *Timeline: 4-5 days a week. 9 weeks effectively "*
Relations	*5 employees from the contractors*
Users (clients)	*The municipality of Apeldoorn use their own product*

Cost-benefits:

	Cost	**Benefits**
People	- *In 9 weeks 50 people clean up the roads and make them safe.* - *Job creation: volunteers and people with a distance to the labour market work*	*People have work* *The environment of inhabitants of Apeldoorn increases by having greener spaces*
Planet	*115.82 ton CO2*	*Increase in wellbeing living*
Profit (*Per 2.500 tonnes of leaves:*)	- *€ 30.000 external costs* - *€ 17.500 for minerals and additional products* - *€ 280.000,00 (employees),*	*No buying of artificial fertilizers; Compost, Additional chalk*

ACTIVITIES	OUTPUTS	EFFECTS	HIGHER EFFECTS
Pick up leaves	Clean roads	People happy with clean roads	Enhancement of well-being
Make bokashi	Natural fertilizer	High quality of green spaces	City become a greener city
Inform inhabitants	News, letters	People get informed by making bokashi	People understand the need of making a natural soil improver

5.3.4 Monitoring and evaluation

The demonstration of production and use of Bokashi was successful. On the envisaged large-scale leaves were collected, cleaned, processed into Bokashi, and spread in public spaces.

Impurities (e.g. plastic and metal parts) that are present in the collected leaves will show up in the produced bokashi, except for the metal parts that are removed during the process. During spread of the bokashi the impurities are also spread. During upscaling of the process from 200 to 2500 ton more the leaves had to be sourced from places that were more polluted, e.g. because of heavy traffic. This resulted visibly in a higher number of impurities in the leaves. Municipal cleaning by volunteers and civil servants prior to collecting the leaves, helped in reducing the number of impurities.

Upon spreading the bokashi an odour can be observed in the near vicinity. Some complaints from the inhabitants were obtained during the demonstration. The odour can be described as a mossy, forest odour, but some people find it less pleasant.

The production of bokashi from leaves results in a more circular city. A comparison between the new and old situations is presented in Figure 23 and Figure 24

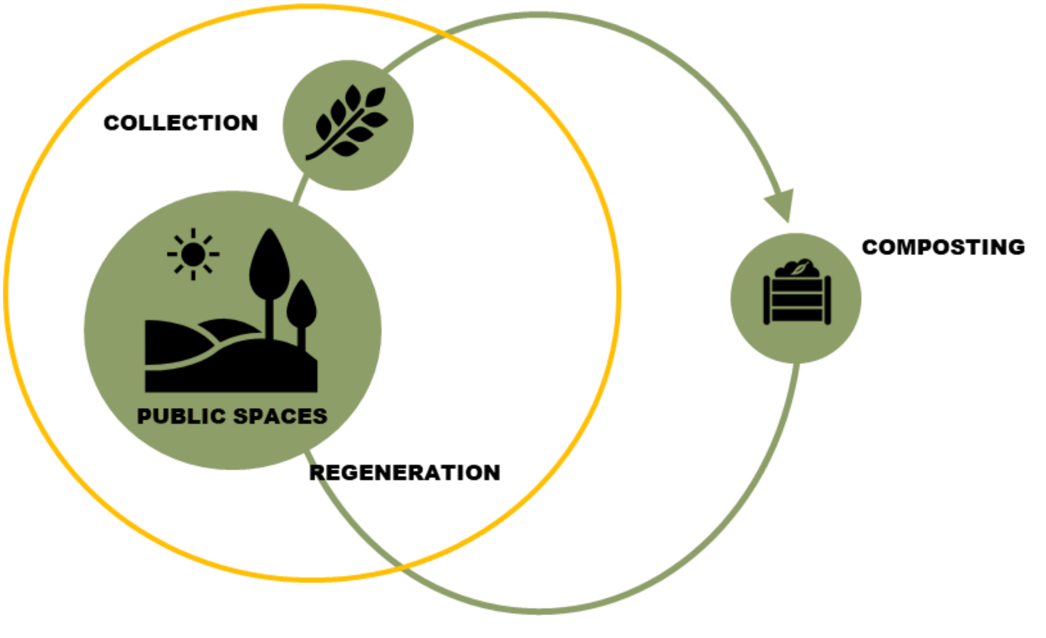


Figure 23 Base case, leaves are composted outside the city (Yellow line: City boundaries)

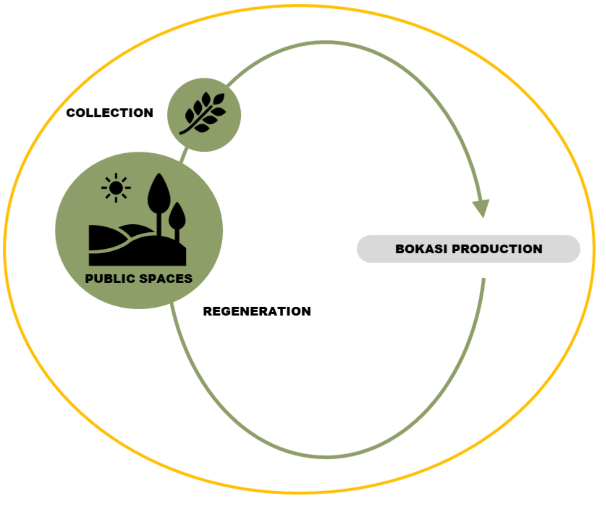


Figure 24: Bokashi production, bokashi production with leaves inside the city (Yellow line: City boundaries)

There are three main differences between the base case and the bokashi scenario.

Firstly composting is performed outside of the city and bokashi inside. Although the leaves are transported over shorter distances in the Bokashi production, the reduction of transportation distances was not established during the demonstration. More focus on reducing the amount of impurities in the leaves and matching the collection of the leaves with the days of bokashi production also influenced the transportation.

Secondly the emission of CO_2 during the production and use phase of compost and bokashi differ. Initial research results from WR show that while composting has a larger CO_2 emission during the production, Bokashi may have a larger CO_2 emission during use. In the CityLoops project these differences were not measured.

5.3.5 Lessons Learned

The production of bokashi had started on smaller scale prior to CityLoops. The demonstration has shown internal stakeholders in Apeldoorn that is important to describe in more detail how chosen solutions for treatment of bio-waste add to circularity. This description, represented by the circularsquare, can be used to activate more people within the organization (more integral, than sectoral). The increased knowledge on the production and use of bokashi can be used to be more specific in circular procurement. Main objective of the department of Management and Maintenance of public spaces continues to be to optimise the quality of the public space, within the available budget.

Main driver for continuation of bokashi production will be proof that the increase in soil quality is better compared to other options (composting/mulching). A longer evaluation period of the effect of bokashi on the quality of the soil is necessary to show the benefits of the process compared to composting. Results are anticipated from the Knowledge program Circular Terrain management in the coming years.

Apeldoorn also experiments with mulching -a major part of- the fallen leaves on the plot. By leaving the mulch on site, the nutrients stay where they are produced. Aim is to create the smallest circle of nutrients, originated and adapted to its own environment. This method is applied where possible, considering safety (clean ways versus the slippery leaves) and recreational use. Plots with forest on it or perennials or shrubs are very suitable for this low extensive form of green management. Mulching seems to cause less nuisance compared to leaving whole leaves. Mulch does not easily blow away – for example to roads- and neither suffocates underlying lawns too much.

5.4 Demonstration Biochar

5.4.1 Introduction

Biochar is a product produced by pyrolysis of biomass residues. During pyrolysis, the biomass residues degrade because of the elevated temperature of the process and the absence of oxygen into a carbon-rich solid, resembling charcoal.

Apeldoorn has investigated the possibilities of producing biochar from pruning. Originally a small demonstration pyrolysis plant would be used to produce biochar in Apeldoorn, during the demonstration it was decided to defer from this plan and focus on investigating production on larger scale. In cooperation with other municipalities biochar was assessed in several applications.

Pruning is currently returned to green spaces as addition to the soil after chipping. Using the pruning as resource for the circular economy, by creating biochar, would be higher in the waste hierarchy. Biochar could be used to capture CO_2 in the soil, to improve the soil and to capture water in the soil. Other uses of biochar include the use in water treatments plants to capture chemicals.

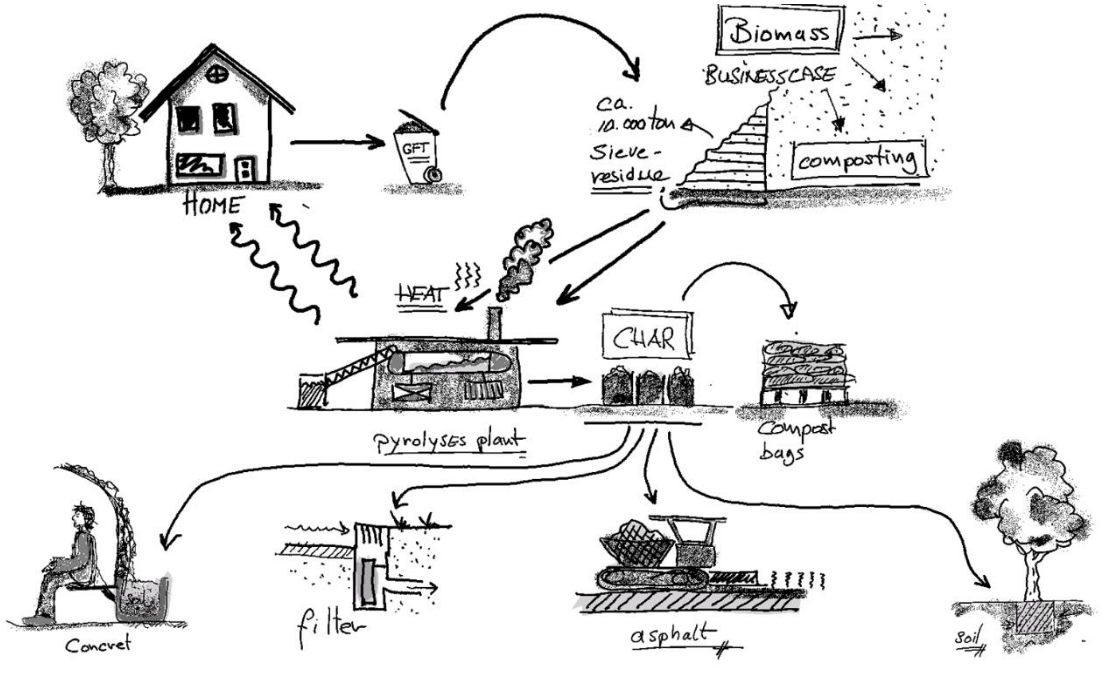


Figure 25: Overview of the possibilities of producing and applying biochar in Apeldoorn

5.4.2 Implementation

5.4.2.1 Sourcing

Pruning was selected as source to produce biochar. Apeldoorn possesses forest plantations, forests, avenue trees and bush areas.

- The total amount of forest plantation is 168 ha. They are maintained because of safety reasons for inhabitants, because of diseases and to keep the path accesible.
- The total amount of forest in Apeldoorn is 942 ha. Only 40 ha is owned by the Municipality of Apeldoorn. All the other areas are owned by the Kroondomeinen and Natuurmonumenten. The forest owned by Apeldoorn are maintained because of safety reasons for inhabitants, because of diseases and to keep the path accessible.
- The total amount of avenue trees is 70.000. They are pruned because of safety reasons or diseases.
- The total area of bushes is 60 ha. They contain shrubs and ornamental shrubs. The shrubs are pruned every year to keep them healthy. Therefore they can reach an age of 25-30 years. Without pruning, their lifespan would only be between 5-10 years.

Main goal of pruning is to improve biodiversity and make the forest, avenue lanes and bushes climate adaptive. In all situations (forest plantation, forest area and bushes) the main reason to prune and cut them is because of safety reasons, diseases of the plants or because the branches are hanging over de pathways, so no one can walk there anymore.

The total process of harvesting trees, shrubs, bushes includes:

- A visual inspection of all trees and bushes is made to identify their quality, vitality, and environmental situation The result is a yearly report. The report describes the quality, liveability, and environmental situation of the trees/bushes.
- When pruning, the nature management code must be followed up. This code of conduct contains a protocol to be actively alert to flora and fauna and gives us the scope to do our work without permits. Inspection in the work corridor based on this code of conduct guarantees that account of the living environment is taken. When animals or special plants are encountered in the work corridor, the protocol contains an action perspective to act appropriately. For example, in the case of a hedgehog, release the hedgehog in the correct place in the vicinity of the find spot. Incidentally, this does not only apply to flora and fauna but also if, for example, loose dirt or debris is found. Then another protocol comes into effect to carefully remove the dirt.
- After control of the flora and fauna situation the team will cut or prune the trees or bushes. Almost 800 trees/bushes are cut/prune every year. (This is approximately 0,92 kton of woody biomass)
- The trees are used for other products, like bird houses, benches or 'street furniture'.
- The branches and twigs are cut into wood chips. These wood chips can be used as input for the biochar process, by reducing the size further. To produce biochar, the small pieces must be between 8-22 mm each (Attero, 2022)

5.4.2.2 Sorting and treating

The processes used to clean the pruning prior to using it in the biochar production process is a sieving process. At WFBR chipped pruning from Apeldoorn was sorted using a vibrating screen, the smallest fraction sorted of < 5 mm contains most of the sand. The largest fraction > 15 mm contains the larger pieces of wood and leaves. The desired middle fraction could be used to produce biochar.

A second chipping could be applied to the large fraction and returned to the vibrating screen in a second sorting.

Of 70 kg (dry weight) of chipped pruning 18wt % was smaller than 5 mm, 24 wt% was larger than 15 mm. The desired fraction contained 48 wt% of the initial material.

Figure 26 Vibration screening at WFBR (Left, chipped pruning, middle vibration screen, right, desired fraction)

5.4.2.3 Processing

Biochar can be made from several biomass ‘products’, like grass, leaves, branches, trees when it has a dimension between 8 – 22 mm. 1 ton biochar may adopt 3,3 ton CO2. In Figure 27 the pyrolysis process to make biochar is shown. In **Error! Reference source not found.** a possible production plant is shown.

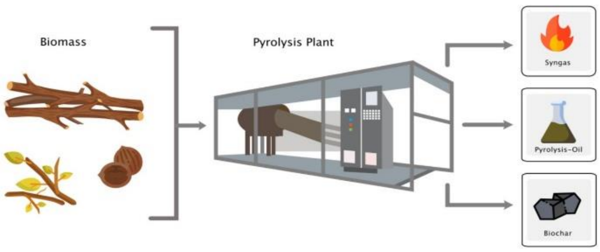


Figure 27: Overview of pyrolysis process

	Liquid (bio-oil)	Solid (biochar)	Gas (process gas)
FAST PYROLYSIS Moderate temperature (> 500 °C) Short vapour residence time (<2s)	75% (25% water)	12%	13%
INTERMEDIATE PYROLYSIS Low-moderate temperature (< 500 °C) Moderate hot vapour residence time	50% (50% water)	25%	25%
SLOW PYROLYSIS (< 500 °C) Low-moderate temperature, Long residence time	30% (70% water)	35%	35%
GASIFICATION high temperature (>800 °C) Long vapour residence time	5% (5% water)	10%	85%

Figure 28: The mass distribution of the products of pyrolysis at different processing conditions

According to the University of Roskilde (Tobias Pape Thomsen) a pyrolysis installation of 20 Mwatt will cost approximately € 1.5000.000.

The temperature of making biochar lays between 500-700 º C (depends on the use of biochar after).
The amount of biochar produced depends on the processing conditions.
In principle, everything of organic material can be pyrolyzed. Attero, a commercial waste company says that the most interesting fraction is the part from 8-22 mm.
The smaller and larger fractions can be used for different processes:

- 0-8 mm bio-waste has the most value to make compost
- 8-22/25 mm for biochar
- >25 mm to make biogas.

Currently also the fraction 8-25 mm goes to biogas. To add more value to bio-waste, you should use this fraction to make biochar.

5.4.3 Implementation

Because Biochar can made of at least 75 products, you can use biochar for multiple applications. The illustration shows just a small of markets you can use biochar. In Apeldoorn a few of these applications were tested. Some of the tests are ongoing.

Figure 29: Different markets for biochar application

In asphalt and concrete as an alternative filler:

Figure 30: Application of biochar in asphalt and concrete

In green spaces, where biochar provides water retention. These pictures comes from a webinar with Kekkilä BVB. The picture left was in 2018; it was the dryest season in Stockholm. The picture at the right was in 2020. 2 years after adding Biochar in the green spaces.

Figure 31: Application of biochar as water retention aid

In this photo you see a WADI (location for water drainage and infiltration). The left photo shows the WADI in 2019. The middle photo is the WADI in 2020 with heavy rain fall. The photo at the right is the WADI 1 month after heavy rainfall. The soil in the WADI has a mixture of soil and biochar.

Figure 32: Application of biochar in a WADI

In the photo's below you see some urban WADI's. The most important benefit of adding biochar in urban WADI's is that they store more water in the plant WADI's. Both photos are from the same location (but another view).

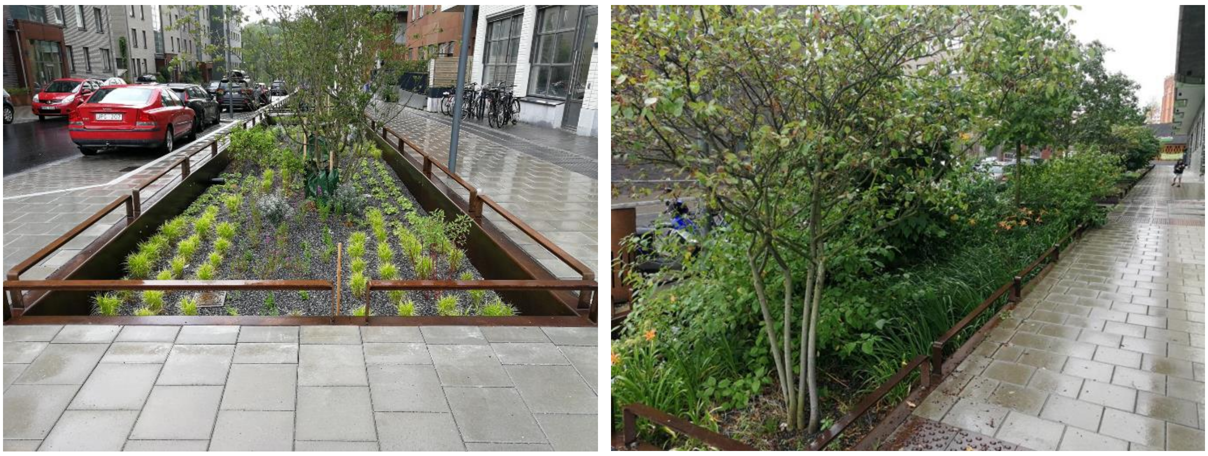


Figure 33: Application of biochar in an urban WADI

Applying Biochar in a planting bill helps to retain water. 800 litres of water were added, after waiting several hours still 150 litre of water remain in the bin.

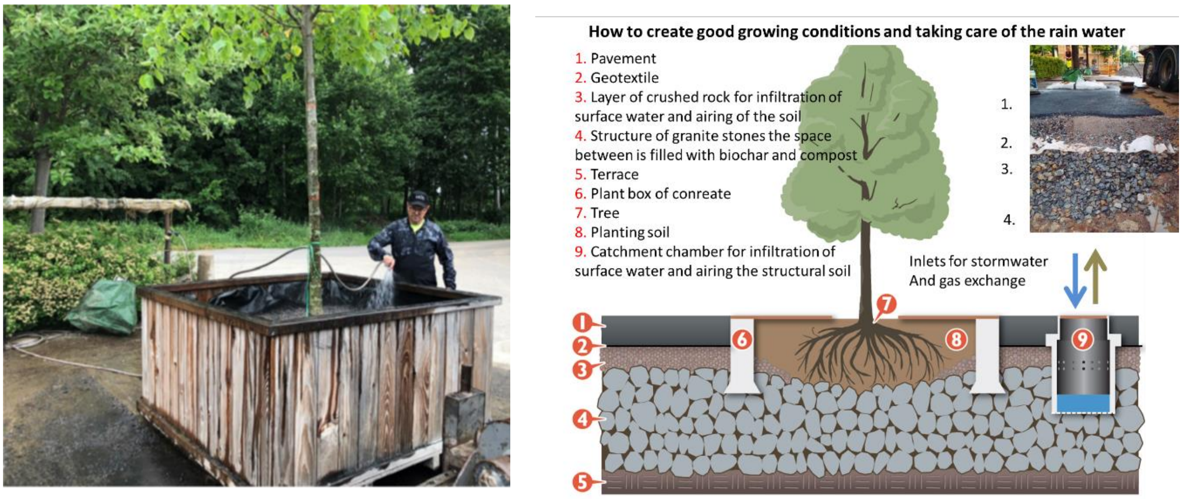


Figure 34: Application of biochar in a planting bin

Demonstration in Apeldoorn

In Apeldoorn a demonstration to use biochar as a rainwater treatment plant was started. At the top the current situation has been shown (red cross). At the bottom the new situation is shown. (green check mark)

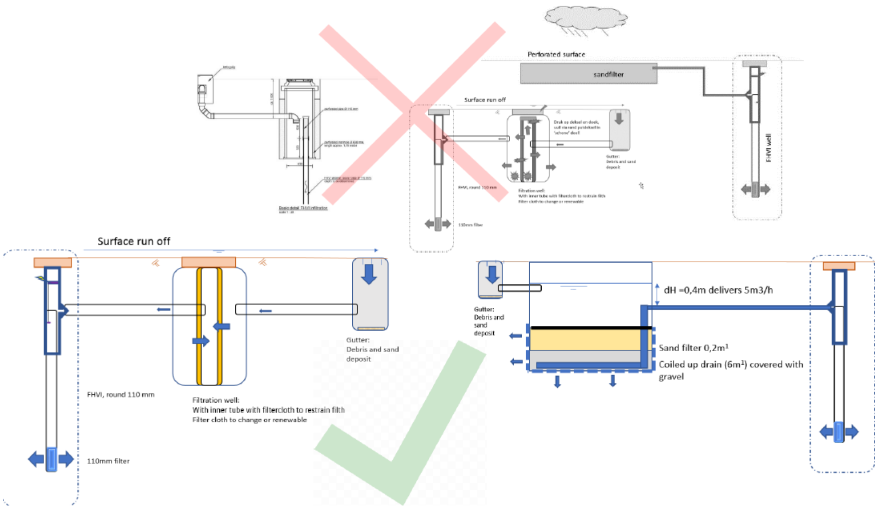


Figure 35: Application of biochar in treatment of rainwater (situation before and after implementation

Below the current situation outside. The WADI is used to collect water. The water is directly flooding below the soil/ground. The main reason to use biochar in the rainwater treatment system is to clean the water before it is adopted in the soil (as an infiltration method). When installing the rainwater treatment system as a pre-filter, the system will keep its infiltration capacity with cleaner water.

Figure 36: Demonstration of the use of biochar in rainwater treatment

The demonstration is still 'under construction'. In February 2023 the first stage was started. It was not possible to do this earlier because no rainwater treatment system was available. This year (2023) the first results are collected, hopefully there will be difference with traditional cleaning of the water.

5.4.4 Business case

In the 'Canvas below', an abstract of the business case is presented.

Long term decisions

- Impact claim: *Biochar reduces CO2 on earth*
- 5-year strategy:
  - *Delete: bio-waste stream to incinerator*
  - *Strength: separation of bio-waste streams*
  - *Reduce: use of bio-waste to compost*
  - *Create: a pyrolyse installation and a warm net system*
- Type of circular model: Life cycle model

Core activities

People	Collect pruning, wood chips Learning, set up production,
Planet	- Harvest wood, branches; - Use of pyrolyse installation to make biochar and use heat for warm-net-system - Use biochar in several products and reduce CO2.
Profit	Logistics, cost of contractor, PR, production of biochar, use of heat in warm-net.

Stakeholders

Employees	- *20 people from the municipality of Apeldoorn; 14 of them are employees, 5 of them have distance to labour market.*
Relations	*Contractor*
Users (clients)	*The municipality of Apeldoorn use its own products*

Cost-benefits:

	Cost	**Benefits**
People	- *€10.000,00 per year* - *Cost of pyrolysing installation and cost of the use of biochar in products can not be made*	- *20 people have work and social network* - *People in pyrolyse installation and people who use biochar can not be given*
Planet	- *44.524,2 kg CO2. Total use of 44.524,2 kg CO2 can be reduced by using electric machines.* - *Using pyrolyse installation can reduce 20.000 tonnes of CO2 per year.* - *1 tonnes of Biochar can adopt 3,67 tonnes of CO2.*	
Profit	- *€15.000.000* - *Costs of pyrolyser unknown*	- *Sell of heat* - *Sell of biochar*

ACTIVITIES	OUTPUTS	EFFECTS	HIGHER EFFECTS
Cutting/ pruning trees and bushes	Safe path, less change of incidents	Happy living near or in the city	Enhancement of well-being
Pyrolyze trees/ bushes	Biochar and heat	Adoption of CO2, and warm houses/buildings	Reduction of CO2 in the air and use of heat in houses
Inform inhabitants	News, letters	Spatial area become greener, air more healthy	Happy living for the next generation

5.4.5 Monitoring and evaluation

The demonstration has shown different possibilities to produce biochar and the use of biochar in different applications. Economical calculations on biochar from experts outside of the project have shown that biochar production is only viable when the produced heat/energy during the process is applied inside the city or in a different industry. This implies that setting up a biochar production facility in Apeldoorn should be joined with initiatives for district heating. The scope of such a processing plant is well outside the scope of the department of Management and Maintenance of public spaces. The interest of other departments is limited, mainly because the biochar production facility will emit nitrogen containing gasses. Nitrogen emission needs to be reduced in the coming years by all industries and farmers in the Netherlands, therefore introducing a new industry is not preferred.

Production on regional scale rather than city scale is assessed by Attero, a waste processing company. Because of the large-scale solution pruning can be separated based on size, different processes can be used for distinct size fractions. Attero will assess biochar production in relation to other outlets for the desired fraction.

The introduction of biochar production of pruning in Apeldoorn would make Apeldoorn more circular, as depicted in Figure 37 and Figure 38. In these two figures the use of biochar in purification of wastewater is shown.

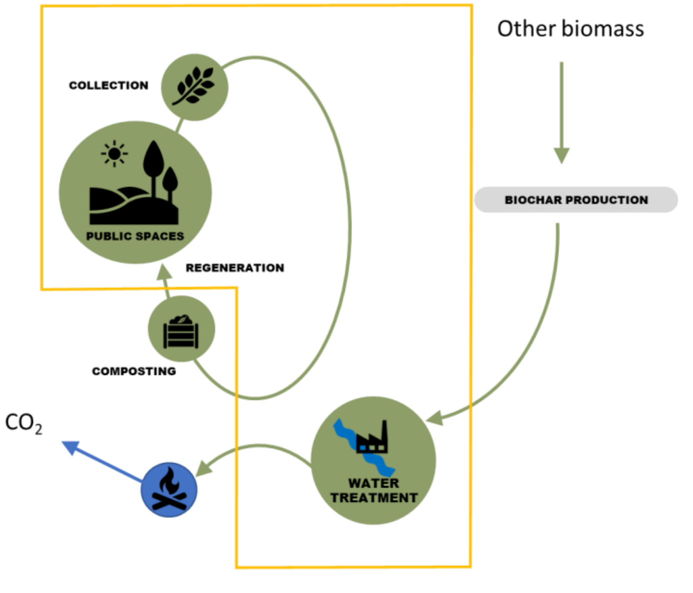


Figure 37: Base case, pruning are used in composting, biochar is obtained from outside the city (Yellow line: City boundaries)

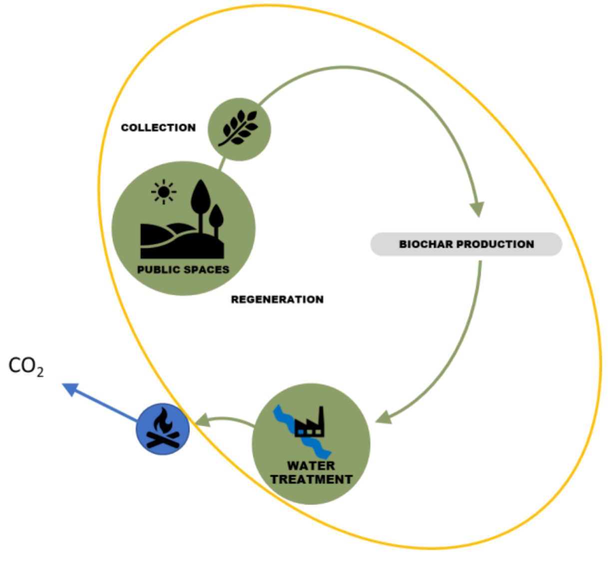


Figure 38: Proposed biochar production inside the city from pruning (Yellow line: City boundaries)

Although the base case and the proposed new scenario seem different, the effect of this change on the GHG emissions per year will be limited. The reason being that the produced biochar, after usage in the water treatment plant, will need to be burned. In the base case the biochar can be produced from e.g. pruning from outside the city, in the proposed scenario the biochar is produced from pruning inside the city. This may result in slightly reduced transport distances for pruning and biochar, the effect will be small, especially because the improvement of soil in Apeldoorn is a goal of the city. The reduced amount of compost from the pruning may have to be compensated by obtaining compost/pruning from outside the city.

5.4.6 Lessons learned

Biochar is and was completely new for the Municipality of Apeldoorn. At the start of CityLoops Apeldoorn was part of a project to produce biochar on small/city scale, driven by the energy transition. The role of Apeldoorn in this project moved towards the city Enschede, together with the responsible person on this topic. During CityLoops the implications of producing biochar on city scale became clearer, including that Biochar production within Apeldoorn will result in nitrogen emission. An increase in nitrogen emission is currently not an option because of lack of nitrogen space. Therefore research into local biochar production is terminated.

Discussions on the use of biochar in Apeldoorn and the production on regional scale will continue, as regional scale nitrogen emissions may be allowed. By using the circularsquare canvas in a circular procurement market consultation Apeldoorn can start the meeting with e.g. a waste company and discuss what is needed to set up a biochar installation. A biochar installation can be part of a municipal heat organisation or in a joint venture with the market. Hopefully CityLoops inspired internal stakeholders to make the next step.

5.5 Demonstration Fibre-based products from grass

5.5.1 Introduction

Grass in public spaces and roadsides is mown once or two times every year. The grass is transported to a waste company and almost all the grass is treated in a biogas installation. In this demonstration the option to use grass as an alternative fibre source in paper products on city scale was tested.

In the last 25 years grass has been used in the Netherlands to produce paper in several commercial batch productions. In the last 8 years moulded fibre products, egg boxes containing up to 50% of grass, have been produced continuously on commercial scale. In a circular city the amount of grass from public spaces is not enough to fit the capacity of most paper factories. However in Apeldoorn a very small paper factory exists. At the east side of Apeldoorn (In conjunction with the city Loenen) several paper industries are concentrated, combining an industrial wastewater treatment plant. The paper museum in this area owns the oldest working paper machine in the Netherlands and produces paper on a regular basis (1-2 days per month).

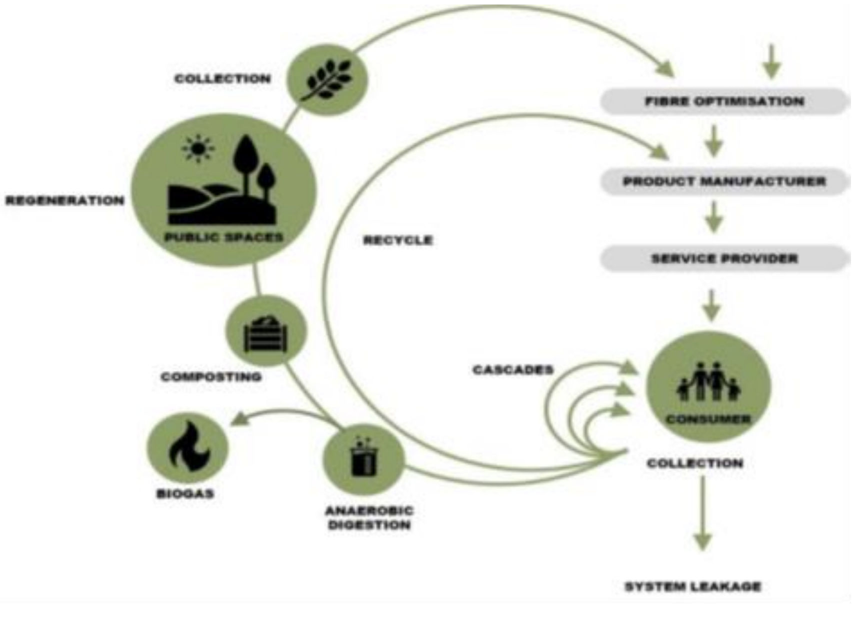


Figure 39 Circular production of paper from grass

On the ladder of Lansink, using grass as resource of fibres will surpass the current use for biogas production. Meadow grass can be used as feed source for cattle; however this application is not allowed for grass from public spaces and roadsides because of the risk of harmful contaminants. Although the amount of grass in Apeldoorn is not enough to use as a resource for the paper industry throughout the year specialised paper production batches can be produced at different commercial paper industries in Apeldoorn or elsewhere in the Netherlands, (e.g. at The Middelste molen in Apeldoorn, Papier Fabriek Schut in Heelsum or Huthamaki in Franeker.)

5.5.2 Implementation

5.5.2.1 Sourcing

In Apeldoorn the area of the public spaces where grass is mown covers about 70 ha.

Table 4: Overview of grass collected from public spaces in Apeldoorn

District	Type	Main stream	[Total m^2]
North	Functional	Every year in June cut roadside grass is cut	32043
		Transport clippings to depot in one pass the municipality of Apeldoorn	
North	Functional	Every year in June and September/October roadside and embankment is mowed	15775
		Transport clippings to depot in one pass the municipality of Apeldoorn	
North	Ecological	every year in September/October roadside and embankment is mowed	304527
		Leave clippings for a minimum of 5 and a maximum of 8 days, after 'transport to depot of municipality of Apeldoorn	
South	Functional	Every year in June and September roadside grass and embankment is mowed	123584
		Transport clippings to depot in one pass the municipality of Apeldoorn	
South	Ecological	every year in September/October roadside and embankment is mowed	315111
		Leave clippings for a minimum of 5 and a maximum of 8 days, after 'transport to depot of municipality of Apeldoorn'	

The process of collecting grass and the reasons for the current practice is given below:

- Main goal of grass maintenance: increase biodiversity at spatial area. As much as possible ecological maintenance.
- The nature management code of conduct is implemented at every step in the public outdoor space. This code of conduct contains a protocol to be actively alert to flora and fauna and gives us the scope to do our work without permits. Inspection in the work corridor based on this code of conduct guarantees that the living environment is taken into account. When animals or special plants are encountered in the work corridor, the protocol contains an action perspective to act appropriately. For example, in the case of a hedgehog, release the hedgehog in the correct place in the vicinity of the find spot. Incidentally, this does not only apply to flora and fauna but also if, for example, loose dirt or debris is found. Then another protocol comes into effect to carefully remove the dirt.
- During the year a contractor cut the grass functional or ecological. This depends on location in district (north/south). Functional means the grass must be cut because of street view. Ecological means the grass will be used for flora and fauna to increase the biodiversity of the roadside grass.
- During the year 2 specialist collect the seeds for own use from the grass areas. When the flowers 'shoot' the seeds, they collect the seeds. Over 60 seeds are collected and stored in Apeldoorns seed shelter. This is done to increase the native flora. The other reason is to increase knowledge about native flora.
- This grass will be collected by a tractor with loading wagon. 2 in total.
- All grass will be transported to the composter, 10 km away. Ecological grass will be transported 5-8 days later than non-ecological grass. Transport to composter has a distance of (average) 10 km single track.

5.5.2.2 Sorting and treating

Mowed grass typically contains large sized impurities and sand. Larger particles in the grass can be removed prior to mowing by volunteers in municipal cleaning. Different strategies can be applied to remove the amount of sand present in the collected grass. After collection washing combined with flotation is the easiest way to separate the sand from the grass, specifically because water will be added during the pulping and paper making process anyway. Tests on grass harvested in Apeldoorn showed a sand percentage of 20 wt%. In other projects on collected roadside grass sand amounts of up to 40wt% were found.

5.5.2.3 Processing

- **Background**

The use of grass as a raw material in the biobased/circular economy has a long history. A general description of the processing options is normally referred to as a green biorefinery: Distinct types of grass (meadow, verge) and other green biomass can be processed using different techniques into fibres, proteins, acids, and minerals, each of which can be used in materials, feed, fertilisers and other products. WFBR has been studying various processing options for grass together with industry for the last 25 years. [Keijsers, 2010]. Small scale processing units working on fresh grass have a capacity starting at 10kton of grass/year, processing units working on silage grass have a capacity of 40 kton/year, capacities significantly larger than the available amount of grass from public spaces in Apeldoorn. This means it is not economical viable to set up a processing unit only for Apeldoorn.
Therefore, WFBR chose an uncomplicated process to mechanically pulp grass for paper production that could be performed on even smaller scale. Recently the attention of start-ups and initiatives working on green biorefineries has moved away from paper production into insulation products and feed options (meadow grass).

The use of alternative fibres for the paper industry (outside the normal wood pulps and some use of cotton, hemp, and flax for specialty papers) is still not flourishing. The reason is twofold, firstly most paper companies are owned by companies who also control wood production. Finding an alternative to wood is out of their scope of business. Secondly countries like the Netherlands with limited amount of forest plantations do not have pulping industries. New companies producing pulp from alternative fibres will have to build up knowledge on the novel resources and on the pulping industry.

Some initiatives have been successful in producing paper from grass on an industrial scale. Demo runs were performed in the papermills of Parenco (Renkum), Schut Papier (Heelsum) and Smart packaging solutions (Loenen). Huhtamaki performed long time production of moulded fibre products (egg boxes). In the past Apeldoorn cooperated in an initiative “Van berm tot bladzijde” (From roadside to page) this initiative ended when the ownership of the designated papermill (Parenco, Renkum) changed.

- **Practical work**

The practical work at WFBR focussed on the production of a pulp from grass suitable to be used at the oldest working mill in the Netherlands, De Middelste Molen. This mill has specific requirements for a pulp, mostly because it has not incorporated the usual improvements in the paper industry of the last 50 years.

Mechanical pulps from alternative fibre crops e.g. grass combine low mechanical properties with poor drain ability. Drain ability refers to the amount of water that can be removed in the first part of the paper machine, the sieve section. Chemical pulps have better mechanical properties and better drain ability. The paper machine of De Middelste Molen is suited for pulps with good drainability, as the capacity to remove water in the sieve section is limited. It was decided on using a mild mechanical pulping process using low intensity refining.

The process used to mechanically pulp collected grass from Apeldoorn was simple. The grass was cut using a guillotine cutter, washed, and mechanically refined using a disk refiner. Then the pulp was concentrated on a belt press and kept frozen until use.

5.5.3 Implementation

Two batches of grass pulp were produced, the first time a smaller batch (about 5 kg) to be used at De Middelste Molen for demonstration purposes. The paper was produced by hand. The second batch was larger (about 30 kg) and used to produce paper industrially. Twenty percent of the normal pulp used in the paper production process was replaced with the grass pulp. Twenty percent seems a minor amount, however most demo-production processes towards grass paper only use 10% replacement. At De Middelste Molen the grass pulp was mixed with the other pulps in a Valley Beater. The pulp was then brought onto the wet section of the paper machine: a sieve section followed by a press section. The paper was transported by hand to the dryer section, where the paper was dried using steam.



Figure 40 Paper making from grass pulp by hand during the CityLoops study visit

Figure 41: Paper production at De Middelste molen (a. part of the grass pulp, b. Valley beater, c. sieve section of wet end, d. press section of wet end, e. transfer by hand to drying section, f. dried paper coming from the drying section)

5.5.4 Business case

In the canvas below an abstract of the business case is Presented.

Long term decisions

- Impact claim: *Use the strengths of JK in new products*
- 5-year strategy:
  - *Delete: the use of chemical pesticides*
  - *Strength: awareness to make products of biomass*
  - *Reduce: areas of JK*
  - *Create: Short (value)chain to make 3D printings at regional scale*
- Type of circular model: *Extended life time*

Core activities

People	- Making plan to reduce JK - Set up data portal. - 1 person control locations - 2 persons to reduce JK on small locations, 1 person drive tractor on large location. - 1 person check large location. - Compounding factory - Filament production factory
Planet	- Use of pesticides - Use of car to drive to location. - Use of tractor to mow locations. - Computers to do work for locations
Profit	With less money large impact. Cost reduction and effectiveness

Stakeholders

Employees	- *1 policy maker making policy plan and management.* - *1 data policy maker*
Relations	- *2-3 people from contractor (all year) for small locations* - *1-2 people from contractor (all year) for large locations)* - *Compounding & filament production facility*
Users (clients)	*Inhabitants can report locations of Japanese knotweed via a website.* *Compounding & filament producing industry* *Societal organisations use filament of JK to make 3D prints*

Cost-benefits:

	Cost	**Benefits**
People	- 2 policymakers - 2-3 people from contractors for small locations - 1-2 people contractor (small locations)	*People can make new products of JK filament into 3D prints.* *Inhabitants has les problems with JK in garden and neighbourhoods*
Planet	*4.495 kg CO2 per year.*	*Instead of use of pesticides filament can be made for use of 3D printing*
Profit	€ 7.657 (employees) € 55.000 small locations € 15.000 large locations	*Sell of JK to compouning industry* *(at 400 euro/ton)*

ACTIVITIES	OUTPUTS	EFFECTS	HIGHER EFFECTS
Set up plan, digital control	Real time project management	Inhabitants experience little discomfort	City with no JK
Remove JK in spatial area	Area with no JK	High quality of green spaces	City become a good living city
Make filament for 3D use	Biobased filament	People can make 3D products with biobased materials	Happy feeling of contribution to a better life

5.5.5 Monitoring and evaluation

The demonstration has shown that also on small city scale grass can be used as a fibre source for producing paper. The grass can partly replace used paper or virgin pulp. The demonstration focussed on producing paper in a paper museum, but previous projects have shown that using grass in paper can also be done on large scale.

The value of collected grass for its use in paper is estimated to be higher than the value of grass for digesting of composting. The value for digesting of composting is normally zero, or even less. The value of collected grass for use in paper is estimated at the value of recycled paper. Currently about 150 Euro per dry ton.

There is no economical businesscase for the production of paper from grass. Mainly because of lack of demand for this paper. There is also little intent from the paper industry to start using novel sources of fibre. Some of the reasons for the lack of intent are:

- Most pulp and paperindustries are owned by very big companies, who have their own wood plantations. Changing to grass would reduce their influence on the raw material sourcing
- Most papertypes are produced not in one, but in several paperfactories. This creates flexibility in matching supply and demand. (A paperfactory near Apeldoorn will most likely be closed because the overarching company owns five factories producing the same type of paper, demand has decreased, one factory can be closed to reduce costs). Introducing grass paper at a selected location will decrease the flexibility.
- Especially in the first years of using grass, the costs will be higher than the costs of regular paper pulp. The market (e.g. food packaging) has no intention to pay more for the grass paper. (The opposite was true for the egg-boxes containing 50% of grass, both the moulded fibre factory and the people buying eggs were willing to pay extra.)
- On small scale grass can be obtained from one supplier, on larger scale grass should be sourced from a large amount of suppliers, which may also lead to inconsistencies in cleanliness of the grass. A novel source of fibre that has become more present in the paperindustry is sugar cane bagasse. Sugar cane plantations are big enough to supply this residue to the pulping industry on large scale.

The group of volunteers at “De Middelste Molen” consist of retired workers from the paperindustry. They reflect the attitude towards grasspaper that can be found thoughout the industry. It is a nice idea, it is good to show it as a possibility, but it is to far fetched to use it in the actual paperindustry.

A study on the ideas of the inhabitants on Apeldoorn was not performed, previous studies from WR have shown that people like the idea, but the influence of the people on the type of paper used in e.g. packaging is limited.

Using grass as input for the production of paper in Apeldoorn instead of composting will results in a more circular Apeldoorn. In Figure 42and Figure 43the differences between the current and proposed situation is presented.

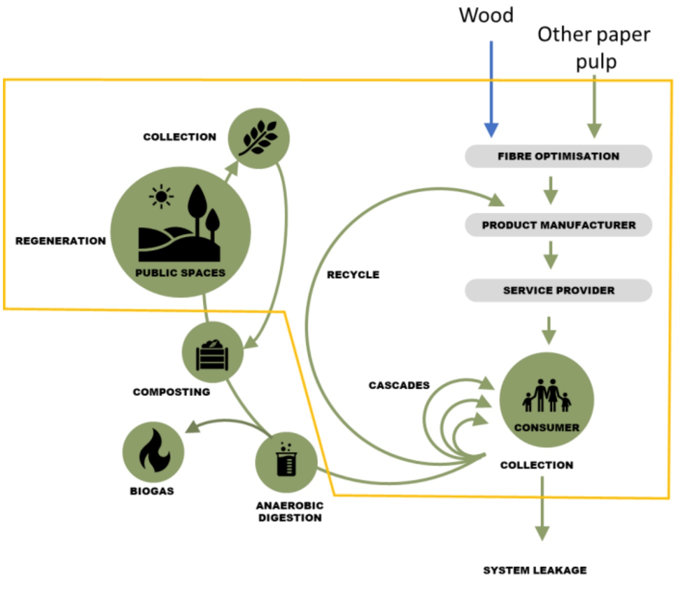


Figure 42: Base case Wood based paper production (Yellow line: City boundaries)

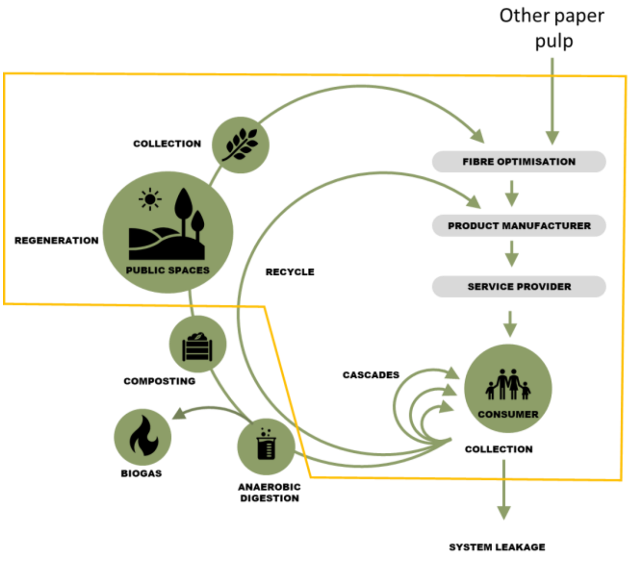


Figure 43: Use of grass in paper production (Yellow line: City boundaries)

The main difference between the proposed scenario and the base case is the replacement of part of the pulps used in paper production with pulp produced from grass. This results in less CO_2 emission during the pulping process and a reduced import of wood(or wood pulp). The paper produced in CityLoops is not directly comparable with 100% wood based papers. The produced grass paper stands out, because it visibly contains grassfibres.

- GHG emissions during the pulping process: The demonstration in Apeldoorn was not a good representation on how much CO_2 could be reduced on larger scale for use in a larger papermill. The grass paper was produced in a very old paper mill, and therefore the grass pulp production could be kept relatively simple compared to pulping for more modern and larger paper mill. The company Creapaper (Grass Paper EU project H2020-EU-2.3 Industrial leadership) has shown that a 95% reduction in CO_2 emissions for paper pulp from grass compared to wood pulp is possible. (The average GHG emmision of european short fibre kraft pulp mills was 0.111 ton CO2eq/ADT pulp, EU benchmark values 2016/17). Changing from wood pulp production to grass pulp production will reduce the CO_2 emissions during the production with less than 0.1 CO_2 kg/kg grass.

- Reduction of wood use. The yield of kraft wood pulping of hard wood (short fibres) is about 50%, The yield of mechanical grass pulping is about 70%. Therefore 1 kg of grass can replace about 1.4 kg of wood. The reduction of wood use will reduce the amount of CO_2 used from outside the city with 2.6 (1.4 * 1.83) kg CO_2/kg grass.

5.5.6 Lessons learned

The demonstration has shown that it is possible to produce paper from grass in Apeldoorn on small scale. The properties of this paper and the appearance are different from paper based solely on wood. Other projects have shown that it can be used in moulded fibre products, packaging material, and copy and graphic paper. The lack of interest of the paperindustry in producing grass-paper on commercial scale, and the lack of demand from e.g. the packaging industry are the two main reasons that prevent upscaling. Both de Middelste Molen in Apeldoorn (about 100kg batches) and papierfabriek Schut in Heelsum (upwards of 1000 kg) can produce small batches of grass paper on demand.

Previously Apeldoorn was involved in a country wide project on producing paper from grass on large scale. This pilot stopped one year after the start of CityLoops. The main reasons for stopping the pilot were the financial business case, and the change of ownership from the intended paper factory. The new owner is not interested in alternative fibre sources.

Apeldoorn will not be the driving force in the business case from grass to paper. The role of Apeldoorn and the department of Management and Maintenance of public space would solely be to deliver clean grass to a pulping facility.

5.6 Demonstration 3D printing

5.6.1 Introduction

Japanese Knotweed (JK) is an invasive species regarded as a pest that needs to be destroyed. In this demonstration Apeldoorn shows that the plant can be used as a fiber source to produce composite materials, in particular filament for 3D printing. The bioplastic chosen as matrix material in the composite is polylactic acid (PLA) a biobased plastic produced from e.g., sugarcane residues, which is compostable in industrial processes. This enables the circular economy scheme as presented in Figure *44*.

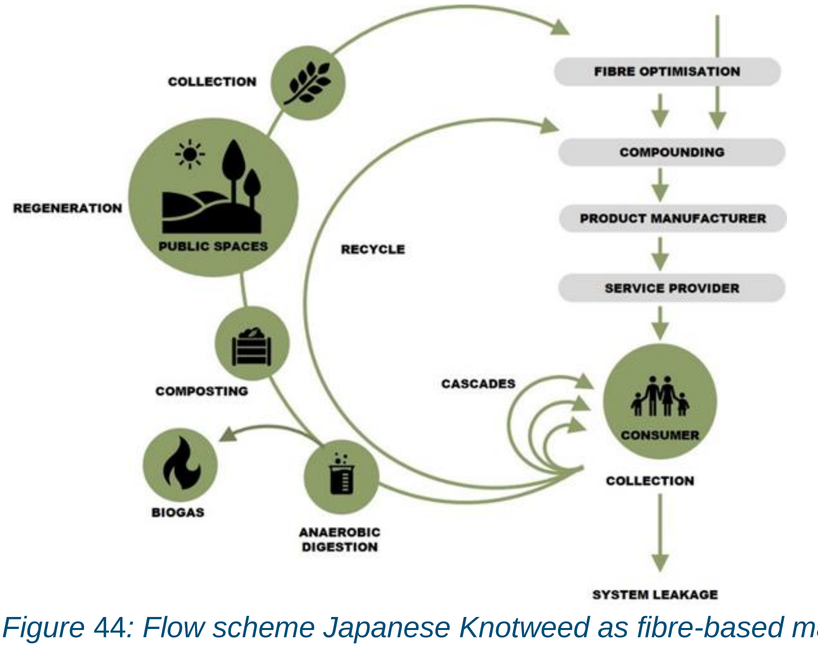


Figure 44: Flow scheme Japanese Knotweed as fibre-based material for 3D-printing

The policy of the city is currently to remove JK completely from the city, however in practice besides plants being destroyed, plants are also controlled by mowing. Resulting in an amount of biomass that could be used in the circular economy. Japanese Knotweed is currently destroyed with chemicals on the spot or the parts above ground are removed yearly by mowing. The mowed parts are transported and burned. Using the transported materials in products instead of burning is a good example of climbing the waste hierarchy. The long fibres in the stalks are interesting to produce fibre composites. Using Polylactic Acid (PLA) as biobased plastic in the composite enables the return of the produced products to the biosphere after the consumer phase. The amount of Japanese Knotweed that is collected yearly is small, but the processes to mix (compound) fibres and bioplastic and the production process towards 3D printing filament are well suited to process smaller batches of material. The rest of the year the installations to compound and produce filament can be used for other materials.

The main reasons to destroy JK are the decrease of biodiversity and the damage roots cause to streets and underground cables and sewer tubes. Apeldoorn has not received claims because of personal accidents involving JK (e.g. tripping over damaged parts of pavement)

5.6.2 Implementation

5.6.2.1 Sourcing

Japanese Knotweed is present in hundreds of spots in Apeldoorn, the identified locations and spread in recent years is shown in Figure 45. The city of Apeldoorn created a webpage where citizens can report new locations: https://www.apeldoorn.nl/home/bb-melding-onkruid’

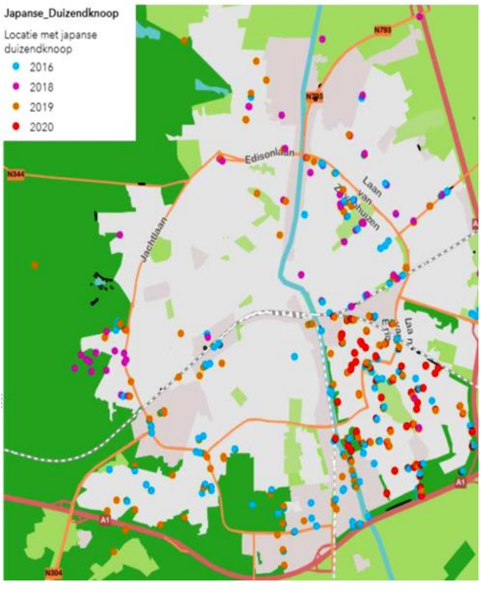


Figure 45: The spread of the Japanese Knotweed from 2016 to 2020 (Bouchier, 2020)

The maintenance department estimated the number of spots at 260 locations infested with the invasive species in 2019. As of 2022, 350 locations have been identified with the invasive species (interview with Sievert Glazenburg, 2022). According to Sievert Glazenburg (2022) each year the Japanese knotweed population expands with 10%.

Most of the locations (about 250) are small, around 1,5 m^2 per locations. The larger locations (about 20) have an average area of 200 m^2 each. In the next years, the small locations will be removed by chemical pesticides. The large locations will be mowed, and therefore will not be removed.

For optimal removal of JK by chemical pesticides, the treatment should be after the 21st of June. This is based on the growing system of the plant and the storage of the nutrients throughout the year.

Table 5: Current treatment method of small and large areas of JK and the persons involved.

Small areas Chemical destruction with glyphosate	Larger areas Mowing
In the beginning of each year a policy maker is making a Japanese knotweed treatment plan. All spots from last year are checked. The use of glyphosate is checked with the responsible politicians. On rejection mowing is used instead of the chemical pesticide.	In the beginning of each year a policy maker is making a Japanese knotweed treatment plan.
A data analyst keeps constant track of the spots where the presence of Japanese Knotweed is reported. At the beginning of the year the policy maker and the data analyst check the new spots.	A data analyst keeps constant track of the spots where the presence of Japanese Knotweed is reported. At the beginning of the year the policy maker and the data analyst check the new spots.
The destruction of Japanese Knotweed by injection with glyphosate takes on average 2,5 hours per location. Work is performed by a single person. Actual time may change on the difficulty of the location. Costs are €45 per hour.	A tractor with a closed loading/collector and mowing machine is used. Care is taken during collection and transport to prevent spread. After the mowing process the combination is cleaned.

5.6.2.2 Sorting and treating

Japanese knotweed is a dominant plant, preventing most other plants from growing in the same spot. Larger waste objects that are accessible and visible from the streets/pavements are removed by volunteers (municipal cleaning) throughout the year. JK is mowed and collected in a very selective way, separately from other bio-waste. This results in a relatively clean and uniform resource for further processing. To obtain the best results in 3D printing the leaves can be removed from the stalks. During the demonstration materials from the stalks with and without leaves included were produced.

5.6.2.3 Processing

- Background

Composite materials from bio-based fibres and a (bio-) plastic have been developed and produced for a long time. The processing and material properties necessary for filament for 3D printing relate closely to those for injection molding and profile extrusion. Both latter technologies are used on a much larger scale and products from these technologies are used all around us. (e.g., Decking and garden fences, car parts and containers for household applications). Milled wood is the mostly used bio-based fibre, but e.g., miscanthus is also used as a resource. The use of longer fibres, e.g., from flax, hemp, and jute results in better properties, but because of the higher price they are only applied in specific cases [Bos, 2004]. WFBR has been involved in numerous projects to produce bio-based fibre composites, aiming at improving properties, assessing the applicability of new fibre resources and new bio-based plastics. 3D printing of larger and smaller objects with fibre composites is currently performed on small scale. Some demo-projects show the possibilities to produce large objects e.g., street furniture. The production of small objects focusses on prototyping, or decorative applications.

- Practical work

WFBR performed two series of tests to assess and optimise the properties of JK composites in 3D printing. In the first series WFBR compared the properties of composites from JK with those from grass, leaves and pruning from Apeldoorn. WFBR produced test samples using injection moulding and 3D printing and compared the mechanical properties.

In the second series WFBR compared different processes to produce fibre composites from JK and made a comparison with milled wood and miscanthus.

The process from JK to filament consists of three stages [*Figure 46*]:

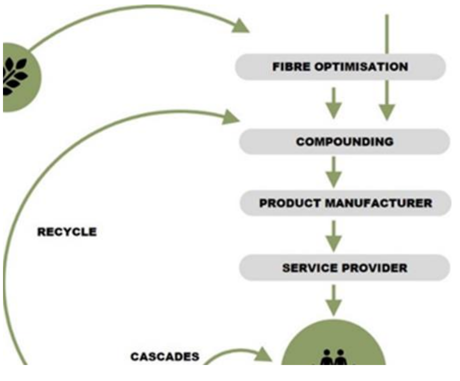


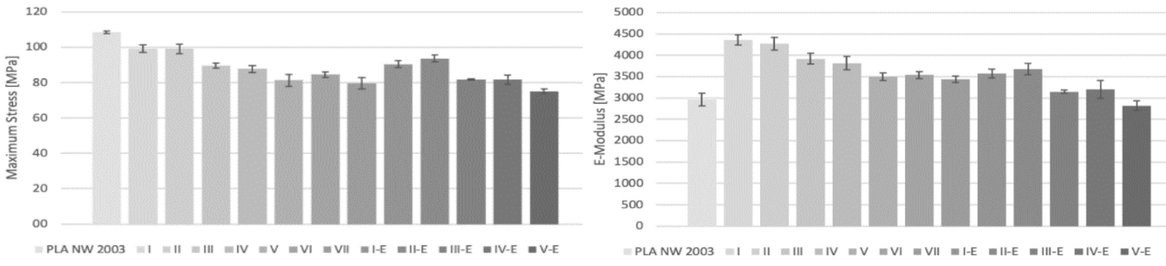
Figure 46 Filament production process (part of figure 8)

After the sourcing, additional treatments are necessary to prepare the fibres.

- The fibre optimisation consists of cutting, cleaning, fibre extraction, neutralisation and drying. Fibre optimisation was performed using a disk refiner, aiming at optimally using the long fibres in the knotweed, and as comparison by simple milling with a cutting mill. Neutralisation and drying of the fibres are necessary, because after harvest plants tend to acidify. PLA will deteriorate rapidly when in contact with water or acid at higher temperatures.
- Compounding was performed using a co-rotating twin screw extruder in combination with an underwater pelletiser.
- Filament production was performed using a single screw extruder and a water bath to cool the filament.

Figure 47: The demo-processing of JK to filament (a. Cutting the JK to reduce stalk length, b. Mechanical extraction of fibres using a disk refiner, c. Compounding and pelletising PLA and JK, d. Drying of the pellets, e. Filament production, f. dried filament.

In the first series the leaves were separated from the stalks, only the stalks were used in the processing. The mechanical properties of produced compounds were assessed using a three-point bending test on test bars produced with injection moulding. (The injection moulding process is more suited to test material properties as 3D printing).



Compound	Code
80% PLA + 20%JK-r	I
80% PLA + 20%PR-r	II
80% PLA + 20%GR-c	III
80% PLA + 20%GR-hm	IV
80% PLA + 20%LE$_R$-hm	V
80% PLA + 20%LE-r	VI
80% PLA + 20%LE$_R$-r	VII
90% I + 10% Ecoflex	I-E
90% II + 10% Ecoflex	II-E
90% III + 10% Ecoflex	III-E
90% IV + 10% Ecoflex	IV-E
90% V + 10% Ecoflex	V-E

Figure 48. Bending Stiffness (E-modulus) and Strength (Maximum stress) properties of Fibre-PLA composites in three point bending test. (Pure PLA, I. PLA + JK, II. PLA + pruning, III&IV, PLA + Grass, V, VI, VII PLA + leaves, E, ecoflex added to improve flexibility)

The results show that the addition of JK increase the stiffness of PLA and slightly reduces the strength. JK gives superior properties compared to the other bio- wastes from Apeldoorn.

In the second series the dimensions of the filament were adjusted to improve the processing in a 3D printer. (Thickness of the filament can change during production, thickness was too thick in parts of the produced filament) In the second series leaves were not separated from the JK and an alternative extraction process (simple milling) was introduced as alternative to the mechanical extraction using a disk refiner.

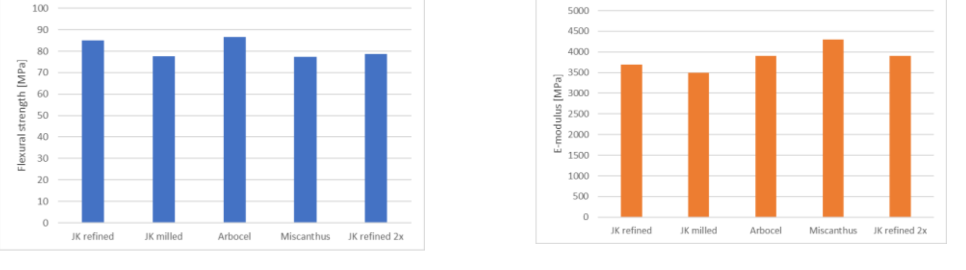


Figure 49: Bending stiffness and strength of injection moulded composites (JK refined and milled compare the two different extraction processes, Arbocell is a commercially available milled wood, Miscanthus is milled miscanthus, JK refined 2 is a more intensively refined JK sample)*

The results show that the JK composites are comparable in strength and stiffness with the wood and miscanthus composites. The more intensive extraction method using disk refiner rather than simple milling does result in slightly better properties. Specifically in bending stiffness the effect of the longer fibres of JK is not seen, this may be because the wood and miscanthus samples are more homogeneous, the JK samples consists of long fibres and smaller particles from among others the leaves.

5.6.2.4 Implementation

The produced filament containing 20% of JK was evaluated at the experience lab of CODA, a museum in Apeldoorn. Some decorative objects were produced to have products to discuss the possibilities of the filament.

Figure 50 Demonstration of 3D printing with JK-PLA composite at CODA


Figure 51: Test bars JK-PLA produced at WFBR


Figure 52 Products produced at WFBR, green: PLA (a PLA-filament with average mechanical properties; brown, JK-PLA (The filament produced in this demonstrations); black, Tough PLA (a commercial PLA filament with improved mechanical properties).

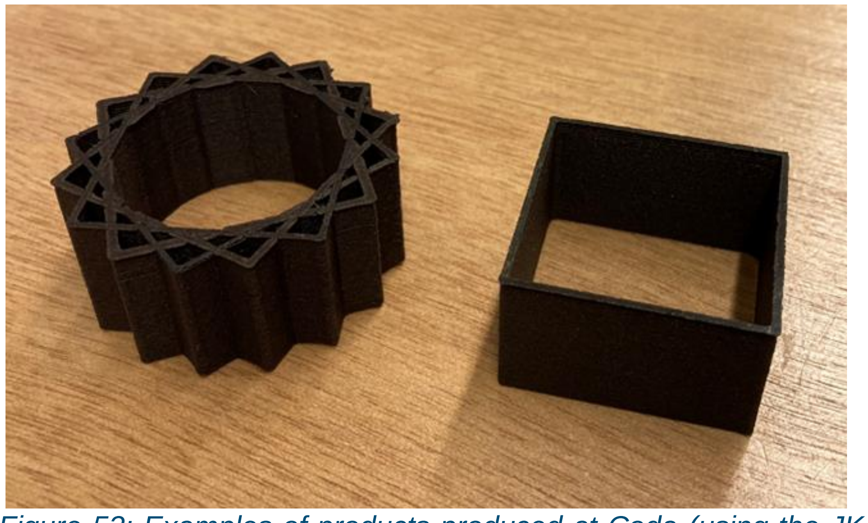


Figure 53: Examples of products produced at Coda (using the JK-PLA filament produced in this demonstration)

Additional tests were performed at WFBR to understand the mechanical properties of 3D JK-PLA printed products compared with injection moulded products. A reduction of properties is found, depending on e.g. the filling degree of the objects.

Discussion with the repair café at Foeniks, Apeldoorn, has been the start for using the produced JK-PLA filaments as resource for selected parts of objects to be repaired.

5.6.3 Business case

In the ‘canvas below’ an abstract of the business case is presented.

5.6.4 Monitoring and evaluation

The demonstration has shown that Japanese Knotweed can be used as a fibre in PLA filament. The filament can be used in 3D printers. Two different processes were tested to extract the fibre from the Japanese Knotweed stems. The more elaborate process using a disk refiner did result in the best filament properties, reflecting the presence of long fibres in JK. The simple milling process, which is also used to produce fibres from wood and miscanthus for use in fibre composites did also result in good filament properties. This shows that Japanese Knotweed is a suitable raw material for use in fibrecomposites, without need for large alterations to the currently used processes.

The current sourcing system of JK is optimal for the use as fibre. Only JK is collected and everything is brought to a central place. Main attention point will be preventing the spread of JK during the transportation from the central spot to the processing plant.

3D printing is an upcoming industry, 3D printing from filament is a part of this industry. Filament containing fibre is only used by a minor part of the current industry. This implies that demand for fibre-PLA filament is limited. However several versions are already on the market e.g. with wood, miscanthus and hemp. The next step for Apeldoorn and WR will be to assess the interest of industry in producing JK-PLA filament. One hurdle in this assesment is that the initiative in promoting filament containing hemp and miscanthus is coming from companies growing hemp and miscanthus. These companies may not be interested in promoting or producing an alternative fibre source.

The value of fibres for use in composites is estimated at about 400 euro per dry ton, the value of JK for burning is limited. Milled wood fibres can be obtained at about 200 euro per dry ton, but hemp and miscanthus have a higher value.

Filament for 3D printing is commercially sold at 20-30 Euro/kg. Commercial production runs from Jk to PLA filament are expected to be economically viable. The market for this type of filament is unknown, but is likely to grow.

Inhabitants from Apeldoorn that are used with 3D printing have been assasing the filament. Reactions were mixed. At CODA and at the repaircafe of Apeldoorn people were enthousiastic because of the circularity of using JK in 3D printing. Experienced hobbyists in 3D printing were critical. The fibres present in fibre containing filament (including JK) result in different properties and appearance of the printed objects. Most hobbyists match the filament with the desired appearance of the object. Filament containing fibres is not often used.

Producing 3D filament from Japanese Knotweed instead of wood will increase the circularity of Apeldoorn. In Figure 54 and Figure 55 both scenarios are depicted. It should be noted that currently there is no production of filament in Apeldoorn, it is expected that the use of filament will increase in the coming decennia.

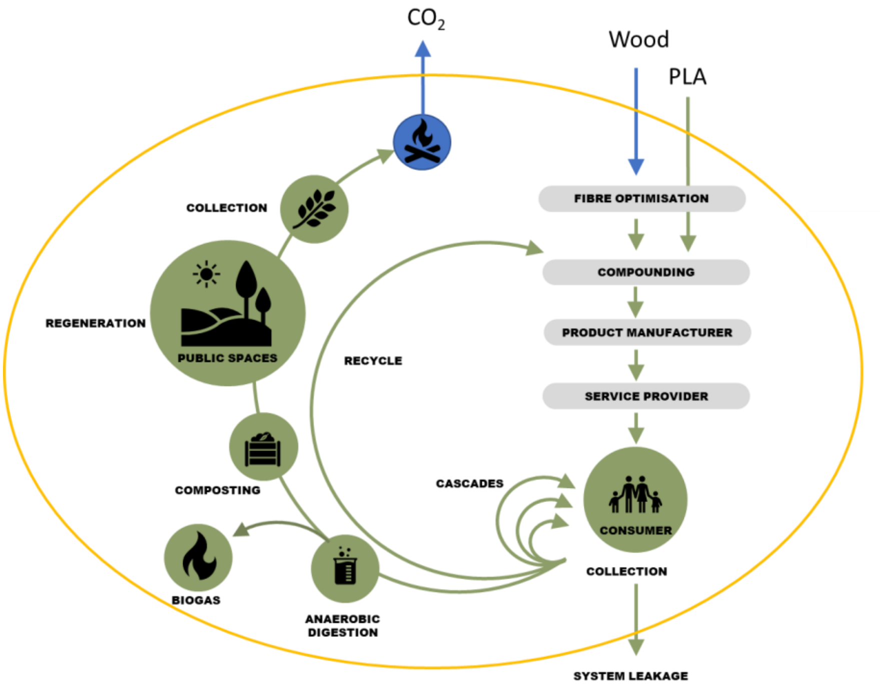


Figure 54: Base case 3D printing with wood filled PLA obtained from outside the city (Yellow line: City boundaries)

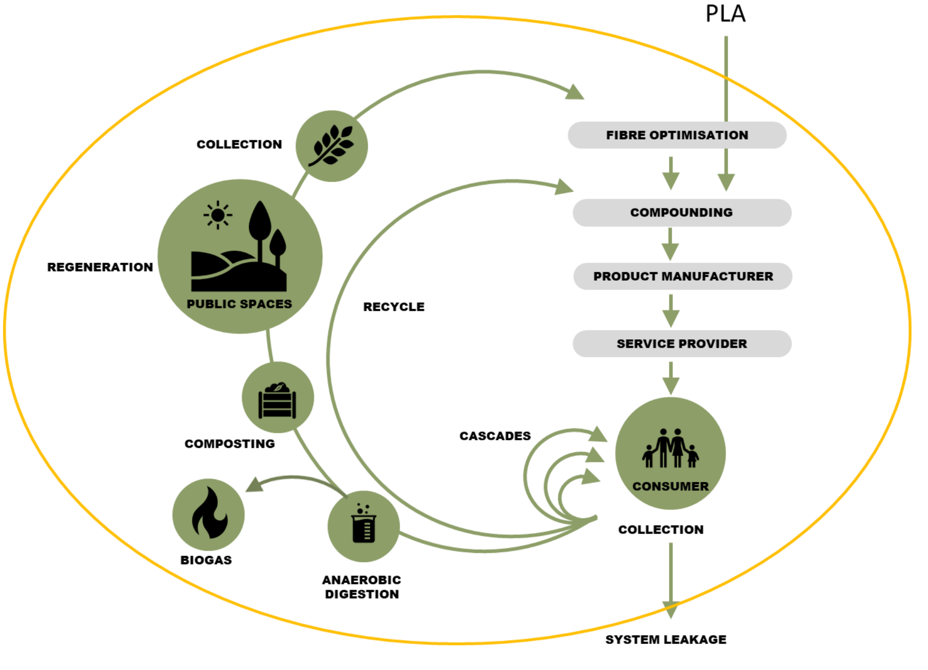


Figure 55: Production of 3D filament containing Japanese Knotweed (Yellow line: City boundaries)

The demonstration has shown that the processes to incorporate Japanese Knotweed into 3D printing filament are highly like the processes that are used to incorporate wood (and e.g. hemp and miscanthus). The main difference for the GHG emissions per year of the proposed scenario compared to the base case are the reduced use of wood from outside the city and the prevention of burning of the Japanese Knotweed. The carbon content of wood can be estimated at 50% (EN 16449). The related CO_2 can be calculated from the atomic weights of carbon (12) and carbon dioxide (44). (Amount CO_2= 44/12 * Amount C). The carbon content of knotweed stems is 46% [Q Cheok *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.*

991 012104]. The prevention of burning will reduce the amount of CO_2 emission with 1.69 kg CO_2/Kg Knotweed (0.46*44/12). The reduction of wood use will reduce the amount of CO_2 used from outside the city with 1.83 kg CO_2/Kg Knotweed.

5.6.5 Lessons learned

The demonstration has shown that it is possible to produce 3D printing filament from Japanese Knotweed and PLA, and that there is interest from stakeholders in using this type of filament in 3D printing. The mechanical properties of the filament are comparable with filaments produced from commercially available fibre sources, milled wood and miscanthus. It is possible to produce filament with superior mechanical properties using the long fibres present in JK, however, this requires more intensive pre-processing of the fibres.

Next step in the developing the demonstration towards a commercial process is to acquire interest from industrial partners into producing filament from Japanese Knotweed. Apeldoorn decided that setting up their own production unit is outside the scope of the municipality.

6 Conclusions

Apeldoorn has learned valuable lessons during the demonstrations, the added value of describing the circularity of new valorisation options (e.g. by the circularsquare) and collecting data concerning circular solutions are recognized and will be used in the future. Circular procurement will be incorporated into the procurement of Apeldoorn.

In CityLoops Apeldoorn decided to explore the possibilities of circular processes for bio-waste from green spaces inside the city and on city level. Currently the treatment of bio-waste is performed on regional scale by Circulus. This novel approach resulted in new responsibilities for departments inside Apeldoorn. Main responsibility is located at the department of Management and Maintenance of public spaces. The interest of this department is on improving the quality of the public spaces rather than on producing products or raw materials from the collected bio-waste. Focus of this department was therefore the demonstration of bokashi.

The overall policy of the municipality is focussing on the energy transition and not on circularity. This resulted in a limited uptake of the demonstrations towards biochar, paper, and 3D-products inside the city departments.

The stakeholders involved in 3D-printing and paper are focussing on showing bio-based solutions to the public/inhabitants, rather than starting a production facility. Industrial interest for Biochar was found on regional level. CityLoops showed that to upscale the new initiatives more interest and dedication from departments and the city council is necessary.

Wageningen Research functioned as expert and pilot scale producer in the demonstrations towards grass paper and 3D printing filament from Japanese Knotweed. This enabled to showcase these applications without preliminary influence from competing industries. Wageningen Research will assess the interest of industrial partners in producing the paper and filament inside, but also outside of Apeldoorn.

The restrictions on personal contacts during the Covid period did influence the effectiveness of communication between stakeholders. The options to showcase the demonstrations to inhabitants and other stakeholders were limited. It is expected that increased interest will be gathered based on the produced videos and dissemination of the results of the demonstrations.

The transition towards a more circular city by producing products from bio-waste from public spaces is part of the overall transition towards more bio-based products. For this transition to occur the economical feasibility of the valoristion options must improve. Existing woodbased and fossil fuel-based alternatives dominate the market, new bio-based options will need economical incentives to get ahead.

6.1 Future perspectives

In the demonstration Bokashi Apeldoorn will continue with production and research towards the effect on the quality of the soil until the end of 2026. The process is improved continuously. The focus is on researching the optimal time for spreading and improving the quality of the Bokashi. Alternatively the effect of mulching leaves and directly spreading will be considered.

Biochar is just at the beginning of its development. European wide pop-ups of biochar installations and initiatives are seen. Apeldoorn has been approached several times to join new initiatives. Currently this is out of scope for the municipality. This can change when energy transition becomes more important than nowadays.

In Fibre-based products from grass the interest of the paper industry and large users of paper in the grasspaper product is very limited. Apeldoorn will not be active in promoting this option. Paper industry in the Netherlands is struggeling, among others because of the high energy price and the large CO_2 output of the industry. The paper industry focusses on these large issues rather than changing to an alternative feedstock, grass.

In 3D printing enough interest from possible users of the filament was found. Currently the market for 3D filament containing fibres is small. Next step is to interest industrial partners in producing commercial batches of 3D filament containing Japanese Knotweed. Apeldoorn does not intend to produce its own 3D filament.

6.2 Replication

The options to replicate the demonstrations from Apeldoorn in other cities or regions differ per demonstration.

The production of bokashi from leaves is already considered in different cities in the Netherlands and tested in the replication city of Apeldoorn within Cityloops: Espoo. Bokashi production technology can be copied and performed on large scale. A replicating city will need to look at the permits to produce and apply bokashi in their country.

The production of biochar from pruning is more suited for replication on regional scale. Investment in a biochar production plant is capital intensive. A combination with district heating to optimize the economy of the process is necessary. The use of biochar from different sources is widespread. In the Netherlands no full-scale commercial biochar production facilities are running. Replication in a region with existing biochar production is an option.

The production of paper from grass shows that this bio-waste can be used as a valuable resource. Replication of this demonstration or another use of grass fibre on city or regional scale depends on economical demand for the grass fibre containing product. Current economical situation of the paper industry is poor and investing in alternative fibres is not on the agenda.

The production of PLA-fibre composite materials from Japanese knotweed or other bio-waste towards 3D printing filament or injection moulding can be replicated in other cities. Existing fibre extraction and compounding companies should be able to produce these materials with interesting properties. Driving force of the replication can be the possibility to replace fossil -based plastics with a circular alternative.

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Annex 1: Impacts

This section summarizes the impacts achieved by Apeldoorn as measured by the expected outcomes and indicators given in the city's bio-waste Evaluation Plan (D6.2). Intermediate-stage results of the demo actions have previously been discussed in the CityLoops Interim Evaluation Report (D6.3). Final, updated results will be presented in the CityLoops Final Evaluation Report (D6.4).

Demonstration action 1: Bokashi

Planned outcome: Increased awareness and knowledge among stakeholders of the business case of the demo action

Indicator	Baseline result	Final result
4. CE-related knowledge building campaigns: Qualitative description	Dissemination of knowledge and learnings is completely new, therefore the baseline is 0.	3 CE related knowledge campaigns were initated and targeted to three main groups (inhabitants, external stakeholders and internal stakeholders) Each knowledge campaign was charactered by usage of diffent cmmunication channels (workshop, social media, CLN meetings, site visits)
5. CE-related knowledge building campaigns: Impact	Dissemination of knowledge and learnings is completely new, therefore the baseline is 0.	3 CE related knowledge campaigns, one overarhcing video campaign
6. Circularity-related stakeholder activities	Baseline 0.	The circularity related stakeholder activities can be rougly devided into three main categories 1 CLN network (2) internal stakeholder activities (3) site visits and peering for replication

Planned outcome: Network(s) established in the field of biowaste activities to disseminate and promote the business case of the demo action

Indicator	Baseline result	Final result
9. New formal CE-based collaboration platforms/networks	0, as there is currently no CE-based collaboration platform/network	4 networks
10. Stakeholder contribution to improved circularity	Baseline 0.	4 stakeholders (bij de oorsprong, WUR, internal stakeholders within the municipality and the consortium circulair terreinbeheer
11. Communication measures on circular transformations and waste prevention	Baseline 0.	14 communication measures (press realeases, websites, events, social media, mediaarticles) Total people reached 2777

Planned outcome: The results of the validation of the business case of the demo action have provided information to be used in the adoption of circular procurement practices in MoA

Indicator	Baseline result	Final result
12. Circularity requirements in procurement beyond existing levels	Baseline is 0	We've been working with RWS on the procurement guidelines. However in the DA's of BW no prcourement was necessary andt herefore the guidelines have not been tested as such.

Planned outcome: The business case of the demo action has been tested and validated based on environmental, social, and economic considerations

Indicator	Baseline result	Final result
23. Eco-innovation: Qualitative description	Baseline is 0. Currently no work processes are designed in accordance with a business case.	In the business case, called circularsquare we adopt ‘people’, profit’ planet. Attached we have business case biowaste description in Excel. Here you can find numbers/information about the 3P’s.
24. Eco-innovation: Impact	Baseline is 0. Currently no work processes are designed in accordance with a business case.	The business case is just the start of a description in how you can make the world even better. In the template we adopt a Impact strategy, which can help you to ‘delete’, ‘create’, ‘strength’ and ‘create’ activities to become even more circular. A suggestion of a circular business model is also done. By making a Theory of Change approach, you will or can describe your impact claim.

Planned outcome: Through the demo action, the GHG emissions (tCo2 eq. / tBW) of the associated business case have been clarified.

Indicator	Baseline result	Final result
85. GHG emissions per year (with changed methodology, not per year, but per mass - see outcome)	Baseline is 0	115,82 ton Co2

Demonstration action 2: Biochar

Planned outcome: Increased awareness and knowledge among stakeholders of the business case of the demo action

Indicator	Baseline result	Final result
4. CE-related knowledge building campaigns: Qualitative description	Dissemination of knowledge and learnings is completely new, therefore the baseline is 0.	3 CE related knowledge campaigns were initiated and targeted to three main groups (inhabitants, external stakeholders and internal stakeholders) Each knowledge campaign was charactered by usage of different communication channels (workshop, social media, CLN meetings, site visits)
5. CE-related knowledge building campaigns: Impact	Dissemination of knowledge and learnings is completely new, therefore the baseline is 0.	3 CE related knowledge campaigns, one overarching video campaign
6. Circularity-related stakeholder activities	Baseline 0.	The circularity related stakeholder activities can be roughly divided into three main categories 1 CLN network (2) internal stakeholder activities (3) site visits and peering for replication

Planned outcome: Network(s) established in the field of biowaste activities to disseminate and promote the business case of the demo action

Indicator	Baseline result	Final result
9. New formal CE-based collaboration platforms/networks	0, as there is currently no CE-based collaboration platform/network	4 networks
10. Stakeholder contribution to improved circularity	Baseline 0.	4 stakeholders (company from Germany), Municipality of Enschede, Alterra, Peter Pannekoek
11. Communication measures on circular transformations and waste prevention	Baseline 0.	14 communication measures (press releases, websites, events, social media, media articles) Total people reached 2777

Planned outcome: The results of the validation of the business case of the demo action have provided information to be used in the adoption of circular procurement practices in MoA

Indicator	Baseline result	Final result
12. Circularity requirements in procurement beyond existing levels	Baseline is 0	We've been working with RWS on the procurement guidelines. However, in the DA's of BW no procurement was necessary and therefore the guidelines have not been tested as such.

Planned outcome: The business case of the demo action has been tested and validated based on environmental, social, and economic considerations

Indicator	Baseline result	Final result
23. Eco-innovation: Qualitative description	Baseline is zero. Currently no work processes are designed in accordance with a business case.	In the business case, called circularsquare we adopt 'people', profit' planet. Attached we have business case biowaste description in Excel. Here you can find numbers/information about the 3P's.
24. Eco-innovation: Impact	Baseline is zero. Currently no work processes are designed in accordance with a business case.	The costs for the municpality to obtain the raw material for biochar is 15 million a year. At current stage, the dependency on biochar is completely with the market. As ther is no prodcution side for the municaplity of Apeldoorn, the turnover number is not applicable to this case. The number of the materials impacted is 800 trees per year

Planned outcome: Through the demo action, the GHG emissions (tCo2 eq. / tBW) of the associated business case have been clarified

Indicator	Baseline result	Final result
85. GHG emissions per year (with changed methodology, not per year, but per mass - see outcome)	Baseline is zero	- 4 people cutting/ pruning 800 trees per year. - Pruning/ cutting a tree will cost 4 hours, with one chainsaw. - 1 hour of chainsaw use costs 11,345 kg/CO2. - 3.200 hours x 11,345 kg/CO2 = 36.3 ton/CO2

Demonstration action 3: Fibre-based products

Planned outcome: Increased awareness and knowledge among stakeholders of the business case of the demo action

Indicator	Baseline result	Final result
4. CE-related knowledge building campaigns: Qualitative description	Dissemination of knowledge and learnings is completely new, therefore the baseline is 0.	3 CE related knowledge campaigns were initiated and targeted to three main groups (inhabitants, external stakeholders and internal stakeholders) Each knowledge campaign was charactered by usage of different communication channels (workshop, social media, CLN meetings, site visits)
5. CE-related knowledge building campaigns: Impact	Dissemination of knowledge and learnings is completely new, therefore the baseline is 0.	3 CE related knowledge campaigns, one overarching video campaign
6. Circularity-related stakeholder activities	Baseline 0.	The circularity related stakeholder activities can be roughly divided into three main categories 1 CLN network (2) internal stakeholder activities (3) site visits and peering for replication
Outcome review: •		

Planned outcome: Network(s) established in the field of biowaste activities to disseminate and promote the business case of the demo action

Indicator	Baseline result	Final result
9. New formal CE-based collaboration platforms/networks	0, as there is currently no CE-based collaboration platform/network	4 networks
10. Stakeholder contribution to improved circularity	Baseline 0.	
11. Communication measures on circular transformations and waste prevention	Baseline 0.	14 communication measures (press releases, websites, events, social media, media articles) Total people reached 2777. In order to explain the DA's to a wider audience (colleagues from other departments, inhabitants etc) A video has been developed and released

Planned outcome: The results of the validation of the business case of the demo action have provided information to be used in the adoption of circular procurement practices in MoA

Indicator	Baseline result	Final result
12. Circularity requirements in procurement beyond existing levels	Baseline is 0	0 in the DA there have not been circularity requirements in procurement beyond existing levels. However, the expectation is that with the next phase of upscaling, this will be the case

Planned outcome: The business case of the demo action has been tested and validated based on environmental, social, and economic considerations

Indicator	Baseline result	Final result
23. Eco-innovation: Qualitative description	Baseline is zero. Currently no work processes are designed in accordance with a business case.	In the business case, called circularsquare we adopt 'people', profit' planet. Attached we have business case biowaste description in Excel. Here you can find numbers/information about the 3P's.
24. Eco-innovation: Impact	Baseline is zero. Currently no work processes are designed in accordance with a business case.	costs approximately 280.000 EUR a year. / 667,8 hectares impacted

Planned outcome: Through the demo action, the GHG emissions (tCo2 eq. / tBW) of the associated business case have been clarified

Indicator	Baseline result	Final result
85. GHG emissions per year (with changed methodology, not per year, but per mass - see outcome)	Baseline is zero	5 tonnes of grass per hectare (ww.agrimatie.nl). 668,7 x 15 tonnes of grass = 10.031 tonnes of grass per year. 1 tractor with a loading wagon may transport 48 tons of grass. This combination uses 17,04 kg/CO2 per hour. Pick up a full combination took: 4 hours. Transport to location is 2 hours (retour). 6 hours per load. 10.031/48 tons of grass = 209 runs. 1 run took 6 hours. 209 x 6 hours = 1.254 hours x 17,04 CO2 per hour = 21.366 kg CO2. this is 21,36 tonnes CO2. Safe only transport to composter? it is: 209 x 2 x 17,04 CO2 = 7,12 tonnes of CO2.

Demonstration action 4: 3D printing

Planned outcome: Increased awareness and knowledge among stakeholders of the business case of the demo action

Indicator	Baseline result	Final result
4. CE-related knowledge building campaigns: Qualitative description	Dissemination of knowledge and learnings is completely new, therefore the baseline is 0.	3 CE related knowledge campaigns, one overarching video campaign
5. CE-related knowledge building campaigns: Impact	Dissemination of knowledge and learnings is completely new, therefore the baseline is 0.	3
6. Circularity-related stakeholder activities	Baseline 0.	WUR testing the filament / CODA and New Tech Park pilots 3D printing

Planned outcome: Network(s) established in the field of biowaste activities to disseminate and promote the business case of the demo action

Indicator	Baseline result	Final result
9. New formal CE-based collaboration platforms/networks	0, as there is currently no CE-based collaboration platform/network	4 networks
10. Stakeholder contribution to improved circularity	Baseline 0.	4 networks
11. Communication measures on circular transformations and waste prevention	Baseline 0.	14 communication measures (press releases, websites, events, social media, media articles) Total people reached 2777

Planned outcome: The results of the validation of the business case of the demo action have provided information to be used in the adoption of circular procurement practices in MoA

Indicator	Baseline result	Final result
12. Circularity requirements in procurement beyond existing levels	Baseline is 0	At current stage this is in experimental phase, WUR is conducting the experiments on making the Japanese fibres into a filament. Both stakeholders are engaged to the experimental nature of this pilot. With the aim to learn, rather than sell. The experimental nature makes procurement at this stage redundant. This however would be the case once this would be scaled and brought to the as such.

Planned outcome: The business case of the demo action has been tested and validated based on environmental, social, and economic considerations

Indicator	Baseline result	Final result
23. Eco-innovation: Qualitative description	Baseline is zero. Currently no work processes are designed in accordance with a business case.	In the business case, called circularsquare we adopt ‘people’, profit’ planet. Attached we have business case biowaste description in Excel. Here you can find numbers/information about the 3P’s.
24. Eco-innovation: Impact	Baseline is zero. Currently no work processes are designed in accordance with a business case.	4333,7 m2 materials impacted / 55.000 EUR for larger locations

Planned outcome: Through the demo action, the GHG emissions (tCo2 eq. / tBW) of the associated business case have been clarified

Indicator	Baseline result	Final result
85. GHG emissions per year (with changed methodology, not per year, but per mass - see outcome)	Baseline is zero	4499 kg Co2

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and bio-waste, where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and soil, and bio-waste, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspects of CityLoops are stakeholder engagement and circular procurement.

CityLoops started in October 2019 and will run until September 2023.

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