Pioneering applications for a zero-waste horticulture

Developed by SIGN and Inagro,
Focusing on closing biomaterial
loops in horticulture.

with support of VLAIO

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RESEARCH & ADVICE IN AGRICULTURE & HORTICULTURE

SIGN
Dutch Foundation for Innovation in Greenhouse Horticulture

RESUME

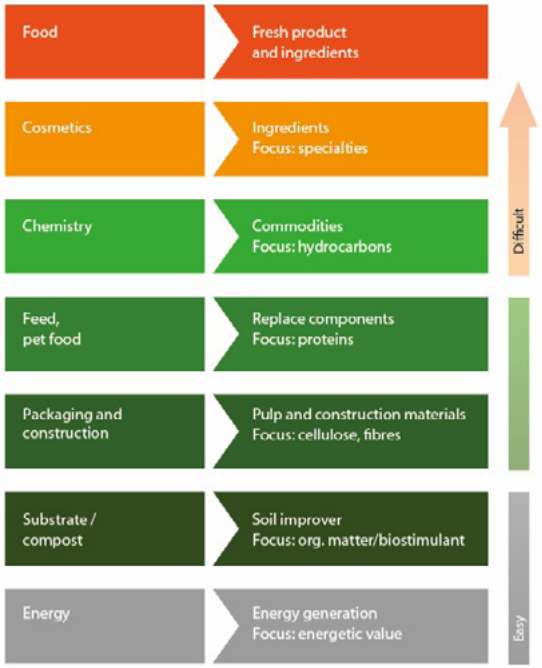
This report provides a comprehensive overview of innovative applications aimed at achieving zero-waste horticulture, focusing on advancements in circular biobased materials. It divides current applications into two main material streams produced during biomass processing: Fiber Materials and Wet Juices.

Fiber materials are primarily used to create physical products across various scales—from large-scale applications in construction to smaller applications in packaging and consumer products. Additionally, these fibers can serve as a feed source for alternative protein production, such as insect-based foods. Lignin and cellulose has applications as binders and flame retardants. Finally, fibres can be used for composting, vermicultures and introducing organic matter to soils for structure and microbiology for plant vitality.

Wet juices, which contain most of the nutrients in biowaste, represent a valuable stream with significant upcycling potential. Approximately three-quarters of plant foliage weight (including branches, leaves, and stems) consists of wet juices, with the remaining quarter being fiber material. Wet juices can be processed into food and drink products, preserving their nutritional value for the industry. Alternatively, essential oils and extracts can be obtained to replace synthetic chemicals, and the juices can be used for natural agricultural and biocontrol solutions, returning nutrients to the growing cycle. When upcycling is not feasible, energy extraction from biomass remains a viable option.

This report showcases various projects in the Netherlands and Belgium, offering both inspiration and insights into the potential of biobased materials in achieving a zero-waste horticulture.

The following picture shows an Lansink ladder for biobased waste valorisation creating a hierchy in waste vlorisation with the most favouritable sector being food and the least being energy.



Picture 1. Lansink Ladder

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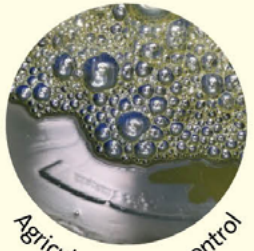


Agricultural & Biocontrol

Packaging & Paper

Combined Energy

Processed Fibers

1.1- Substrate & Feed

Application (Project Name)	**Information**	**Partners** (Link)	**TRL**
Peat substitutes (Substrate growth medium)	Gova BV grows its laurels in a 100% peat-free substrate and can deliver multiyear grown plants. They use fibre from local crops, or residual streams from local production. Varta conducted a study on all possible fibers that could be used in potted plant production.	SIGN, VARTA, Gova link	8
Mushroom Substrate	Repurpose paprika plant biowaste for mushroom cultivation. The biowaste is dried, sterilized, and mixed (30%) with substrates like straw or hemp to balance pH, humidity, and nutrients. The mixture is sterilized, inoculated with mushroom spawn, and used to grow mushrooms.	Eco Consult	6
Champost substrate (Strawberry cultivation)	Use of spent mushroom waste (champost - a byproduct of mushroom cultivation) as a (15%) sustainable alternative to peat in strawberry cultivation.	MBO Lentiz Oostland link	7
Insect feed (Entomoponics Insects fed by greenhouse biowaste)	Mealworms are grown in the greenhouse under the fruit vegetables. The green waste taken from the plants (disformed fruits/prunings) is served to the insects as a wet feed source. The CO2 and temperature produced by the insects is beneficial for the plants and the insects can be used for fish feed or human consumption.	Inagro link	6
Animal feed (Converting harvest waste streams into animal feed supplements)	Explored microbial fermentation of harvest waste, including its conversion into animal feed, uncovering bioactive compounds with potential nutritional benefits and opportunities to optimize the process further.	VITO link	4

Picture 2. Peat free alternative substrate (SIGN)

Picture 3. Insect farming in greenhouse (Inagro)

Picture 4. King Oyster Mushrooms on paprika substrate (Eco Consult)

Picture 5. Strawberry plants on champost (SIGN)

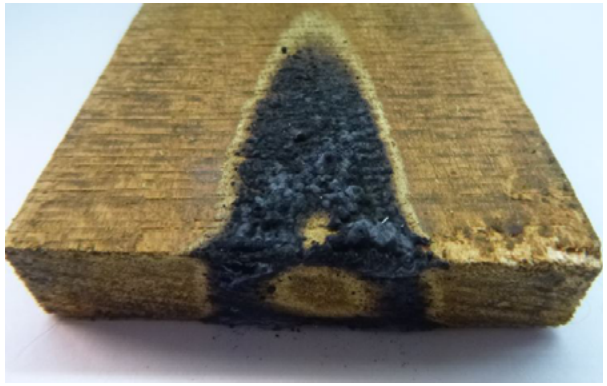
1.2- Construction & Building environment

Application (Project Name)	**Information**	**Partners** (Link)	**TRL**
Building Isolation (BB Block)	Tiny house made from agricultural waste using dried paprika in the hollow walls for isolation purposes.	Floriade link	8
Mycelium Construction & Insulation (Insulation plates in SIGN Sky Garden for Floriade)	Pavilion with isolating roof panels grown with mycelium as binding agent. The mycelium is grown onto paprika fibers and straw.	FAIRM, SIGN link	8
Interior finish panels (Fytopanel)	Decorative, indoor cover panels made from biowaste with natural binders.	Van Hier link	9
Lignin & cellulose (Fire retardants from cellulose)	Cellulose from biomass wastestreams of paprika and tomato processed and used as fire retardant.	Biomimetic Technology, SIGN	6

Picture 6. Tiny house (Floriade)

Picture 7. Mycelium building panel prototype (SIGN)

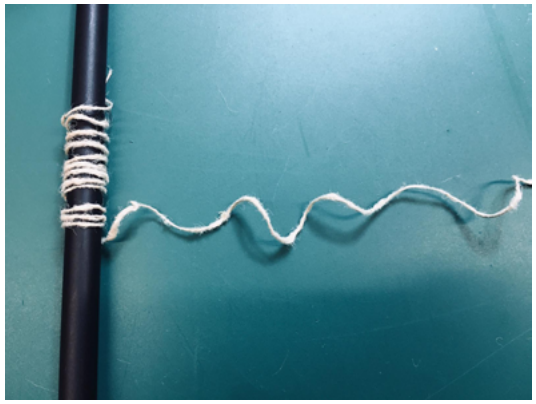
Picture 8. Biowaste panel (Van Hier)



Picture 9. Fire retardant (Biomimetic Technology)

1.3- Products

Application (Project Name)	**Information**	**Partners** (Link)	**TRL**
Textile (T-shirts from tomato fibers)	Textile fibers created from the stems and leaves of tomato plants, inspired by similar efforts using cellulose from cow manure. First extracting filament from plant material, the converting filament into yarn, and finally producing textile from yarn.	Greenport West Holland, Bioboost, Blue City link	4
Leather (Treekind)	A vegan leather made from tomato waste. It repurposes tomato vines from Dutch greenhouse horticulture, transforming a waste stream into carbon-negative, compostable material.	Biophilica, Den Oude Groep, REMOkey link	4
Biobased 3D printing (3D printed furniture)	Using different natural fibers in a large scale 3d printing machine. The pieces are made from sunflower husks, paprika scraps, cellulose, hemp fiber, and even cow manure.	Shellduck co., SIGN link	4
Plate material (Bee Hotel)	Bee hotels made with rose fiber panels and tannin binders utilize agricultural waste and plant-based adhesives to create a biodegradable habitats for pollinators around greenhouses.	Groot Packaging, SIGN link	5
Mycelium Products (Aerospacial chairs and panels)	Mycelium is the roots of the mushrooms, they can be used as binder for natural material. The material grows onto biomaterials like paprika wastestreams into a soft bio-material in the shape af the mold. Applications for airbus are seats and room dividers.	Airbus, SIGN, GISPEN Workbox link	4



Picture 10. Tomato fibers textile (BioBoost)

Picture 11. Tomato leather (Biophilia)

Picture 12. 3d printed sign (Shelduck)

Picture 13. Mycelium airplane seats (SIGN)

Picture 14. Bee Hotel (SIGN)

1.4- Packaging

Application (Project Name)	**Information**	**Partners** (Link)	**TRL**
Cardboard (Circular tomato packaging)	Cardboard made from tomato stems and leaves mixed with raw paper pulp. Developped by Duijvenstijn to package their tomatoes.	Duijvestijn Tomaten link	9
Paper (Chrysanthemum paper)	Paper made from a mix of 50% wet chrysanthemum waste and 50% dry virgin paper pulp is an alternative designed for flower packaging. While more expensive than regular paper, making it well-suited for applications emphasizing natural aesthetics.	SIGN, Beyond Chrysant, Paardekooper, Schut Papier link	9
Biochar Plastic (Plant Pots with biochar plastic)	Using different natural fibers in a large scale 3d printing machine. The pieces are made from sunflower husks, paprika scraps, cellulose, hemp fiber, and even cow manure.	Nettenergy, Delphy link	9

Picture 15. Rose paper (Groot Packaging)

Picture 16. Tomato cardboard packaging (Duijvestijn)

Picture 17. Biochar (nettenergy)

Wet Juices

2.1- Food & Drinks

Application (Project Name)	**Information**	**Partners** (Link)	**TRL**
Protein extraction (Tomato leaves protein extraction)	Tomato leaves, rich in protein, are being tested for extraction at both on-site and biorefinery facilities. The goal is to produce raw protein for animal feed and purified protein for food applications.	Grassa, SIGN link	4
Juice additives (Chicory root juice for bitterness)	The chicory roots juices in replacement for quinine (Bitter additive in food) which comes from the cinchona tree and has to be imported for juices.	Buena ventura, KFS, SIGN	6
Surplus vegetables recovery	Transforms surplus vegetables, such as damaged tomatoes, broccoli, paprika, and courgettes, into high-quality products like soup, ketchup, and sauces.	Verspillingsfabriek link	9

Picture 18. Chicory roots (Keep Food Simple)

Picture 19. Autoclave (Verspillingsfabriek)

Picture 20. Tomato leaf protein extract (SIGN)

2.2- Essential Oils & Extracts

Application (Project Name)	**Information**	**Partners** (Link)	**TRL**
Plant oils & distillation (Essential oils for cosmetic and cleaning products)	Due to the COVID-19 pandemic, surplus plants in greenhouses were repurposed into hand sanitizers. The sanitizer, includes laurel oil for skin softness and celosia extract for a pink color.	Dubbel Doel Flora, SIGN link	9
Plant sterols (Cholesterol-lowering agents from Chrysanthemum)	Vegan alternative made from chrysanthemum for nutritional supplements added to lower cholesterol. (Can be found in margarine or other cholesterol lowering food)	Carbogen Pharma, SIGN	6
Acids & terpenes (Cleaning agents from plant extracts)	Cleaning agents derived from plant extracts, focusing on the use of acids and terpenes. These natural compounds, known for their cleaning and antimicrobial properties, offer an eco-friendly alternative to traditional chemical cleaning agents.	Blankensteyn Reinigingsmiddelen, SIGN	6
PHA (PHA retrieving for bioplastic production from microorganisms)	PHA is a biodegradable polymer produced by certain bacteria, offering a sustainable alternative to traditional plastics. This can be made from wastewaster from the agriculture.	KNN	4
Enzymen	Enzymes belong to the oxidoreductases, which help break down components such as dyes and other chemical compounds. Potential applications seem possible in paper and textile recycling, water purification, animal feed, and food products.	University of Portugal, SIGN, Avans	4

Picture 21. Desinfectant (VARTA)

Picture 22. PHA compost (Ocean cups)

2.3- Agricultural & Biocontrol

Application (Project Name)	**Information**	**Partners** (Link)	**TRL**
Fertilizers	Creating a fully circular solution for organic waste from chrysantum by developing bioinstallations that produces liquid organic fertilizers (potassium, nitrogen, and phosphate) from plant waste streams by fermenting the juices with specific enzymes. The biofertilizers can be added to the existing fertilization recipes.	VARTA, SIGN	5
Biostimulants	Juices of tomato and cucumber plants used for their biostimulant capacities.	Circulair Centrum Zuid, Inagro, Zero-Waste (VLAIO), SIA Raak (HAN, NHOLLAND) link	6
Nematode biocontrol	Research from Ghent University demonstrates that cucumber juice extracted from stems and leaves has a bionematicidal effect, effectively killing nematodes—small worms in plant roots that negatively impact plant health.	Inagro, VLAIO-LA Zero-Waste, Universiteit Gent link	4
Compost & vermiculture	Composting and worm juice for introducing nutrients and microorganisms for soil health in in Rose cultivation farms Kenia.	Bilashaka, Fontana Flowers	9

Picture 23. Juice extraction (SIGN)

Picture 24. Fibers from juice extraction (SIGN)

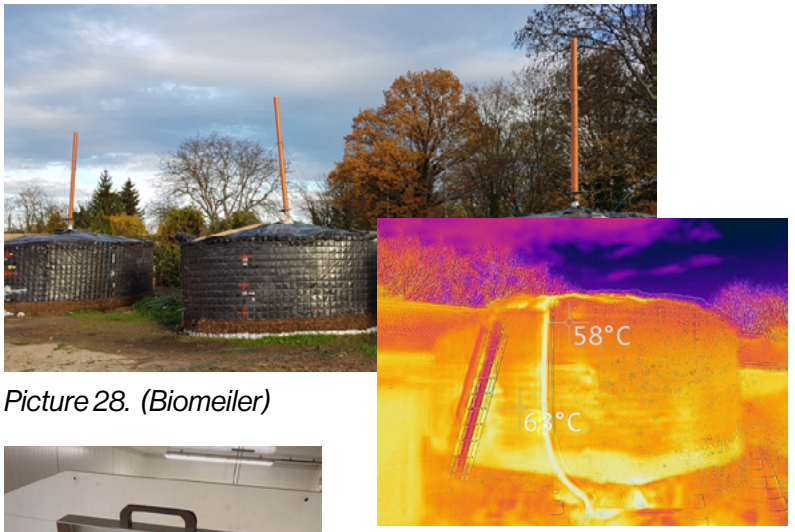
Picture 25. Vermicompost (SIAN Farm)

Picture 26. Spraying biostimulants (Top Crop Manager)

2.4- Combined Energy

Application (Project Name)	**Information**	**Partners** (Link)	**TRL**
Anaerobic digestors	Converting commercial food waste into valuable resources such as biogas, electricity, heat, and natural fertilizer, all through containerized anaerobic digesters placed on-site.	The Waste Transformers link	5
Biomeilers (Bio Compost fermentation extracting Heat and CO2)	Convert the heat from composting into usable warmth for applications like radiant heating or hot water. After the compost is used in food forests or plant cultivation, it is replenished every two years.	Biomeiler link	9
CO2 production (Insect growing on biowast)	Converts organic waste into high-protein feed using black soldier fly larvae (BSFL) and produces frass, a nutrient-rich fertilizer with plant-growth benefits.	Wastech link	4
Biogas Production (Biotransformers)	Compact biodigesters that convert organic waste into biogas for energy and BioWater for soil fertilization. Using anaerobic digestion, they transform 30-600 kg of waste daily.	CIRC link	9

Picture 27. Biowaste digestor (The Waste Transformer)



Picture 28. (Biomeiler)

Picture 28. Thermal scan (Biomeiler)

Picture 29. Insect container (Wastech)

Picture 30. Biotransformer (CIRC)

The examples included in this document are a selection of practices and do not represent all possible approaches. This document was published in 2025 by Stichting Innovatie Glastuinbouw Nederland (SIGN) and Ingaro as part of the Zero-Waste project, funded by VLAIO-LA.

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