

From waste to source of income!

Better use of horticultural residual flows

Guidance for stakeholders

Recommendations from the
Interreg 2 Seas project BioBoost



BioBoost

Accelerating biobased horticulture

BioBoost

The Interreg 2 Seas project BioBoost began early in 2017; it was set up to explore and improve sustainability in horticulture by stimulating innovation in biobased circular economy developments, using as exemplars the Flanders region around Roeselare (Belgium) Westland region (Netherlands) and Lee Valley/East of England (UK). The project focuses on feedstocks mainly from the first part of the supply chain, aiming to utilise crop 'waste streams' and compounds for economically higher valorisation. New products for use as biopesticides, food & feed, cosmetics & health and for the construction and paper & cardboard industry are being piloted and tested.

To this end, activities have been carried out in the project to examine essential conversion factors and to test possible applications. During the project, partners from the United Kingdom, Belgium and the Netherlands have been working together to develop and test production of various higher value solutions. The primary aims of the BioBoost project was to contribute to reducing waste in the horticulture production supply chain, whilst also strengthen the economic outcomes for stakeholders.

For more information see: <https://www.bioboosteurope.com/>

Aim of this brochure

The purpose of this brochure is to inform government and stakeholders about key elements of a strategy that was developed by BioBoost project partners to identify and reduce wasteful practices and to develop economically viable alternatives. This is particularly relevant to 2 Seas Interreg regions, which produces significant amounts of horticultural co-products and residues, but is also relevant to other regions. These key elements are informed by work undertaken by partners during the four-year life of the project and their interactions with stakeholders in the industry.

Colofon

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Contents

Converting horticultural 'waste' to new sources of income!	4
Circular and biobased horticulture.....	6
Approach.....	8
Clever communication and cooperation.....	10
Breaking down the barriers.....	12
Creating examples by facilitating entrepreneurs with innovations.....	14
Improving the accessibility of knowledge and information.....	16
From strategy to action.....	17
The future starts now, for everyone.....	18



Converting horticultural 'waste' to new sources of income!

Enormous potential for maximising economic returns by clever use of green by-products

Horticulture produces large quantities of 'green co-products', such as stems and leaves, but also unsellable fruit and vegetables. This is often thrown away as waste at present, or used for making low value compost or the production of green biogas, but there are higher-value outcomes possible. We are at the beginning of a new green revolution, whereby companies can utilise by-products to produce higher value products.

Great potential

A third of the food produced in the world is currently wasted, which amounts to about 1.3 billion tons per year. About half of this waste occurs during the initial cultivation of the crops, before they are even harvested. Fruits and vegetables are thrown away due to overproduction/surplus often associated with growers commitments to retail customers, or due to failure to reach minimum specification (size, shape, colour etc). In addition, there are significant quantities of co-products such as leaves and stems that do not form part of the normal crop harvested. Much more is now being done to prevent waste, but the residual flow from horticulture will always be significant due to the short life-expectancy of many crops allied to unknown factors such as weather and customer buying behaviour. Therefore it is likely that fresh produce will continue to generate waste, co-products and surplus even if production can be better matched to retail demands and contracts. This presents an exciting challenge for innovative utilisation of these feedstocks.

Win-win

The use of green horticultural by-products for new applications is potentially beneficial for the environment and combating climate change by, for example, reducing methane and ammonia release from landfill. Furthermore, high-quality use of these residual by-products can lead to additional income for the horticultural sector, providing economic return to both growers and innovators working with them to utilise waste feedstocks.

Much to be done

There is a mounting feeling of urgency to devise a more sustainable economy, as illustrated by the Sustainable development Goals, the Paris Agreement and the recent European Green Deal, but that will not happen automatically. We must all take action and responsibility for our part in this, whether as a consumer or a producer.

Much work to be done!

2019 Circularity Gap Report reveals that the world is only 9% circular and the trend is negative

The Global Circularity Gap Report is an annual report measuring the state of circularity. It's goal is to inspire action and realise a global circular economy. The Circularity Gap Report is launched annually during the World Economic Forum's Annual Meeting in Davos: <https://www.weforum.org/events/world-economic-forum-annual-meeting-2020>

Guidance and recommendations

In the following chapters, we highlight several ways that we could design a more circular, biobased horticultural economy in the future. We want to stimulate your curiosity and excite your imagination, with the intention that you will be able to see the advantages of a less wasteful and more innovative horticulture. We hope that you will become inspired to play your part in the necessary transition. This document and others

published on the BioBoost website, aims to provide some guidance and recommendations how this may be achieved; and to help inspire you to see how it might apply in your own situation. This brochure is a very short summary of work and strategies that the group has devised; much more detail can be found in our publications and through our WebPages. Its primary aim is to reach a wide audience and share our ideas to trigger further development.

Using Insects to Valorise Horticultural Residues

Food waste conversion engines

Insects represent a natural 'food waste conversion engine', and can cheaply and efficiently transform organic waste into complex proteins and fats in their bodies. Black Soldier Fly larvae can reduce food waste volume by up to 95% over a rapid two week growing cycle. The larvae are an ideal feed source for farmed salmon and poultry and a potential substitute for meat proteins.

BioBoost research

Three BioBoost project partners established dedicated insect facilities to conduct research about how to rear insect species on an industrial scale, their nutritional needs or how to process residues with them. Working co-operatively, Inagro, VIVES and NIAB have been optimising hatcheries and growth of selected insect species using various waste feedstocks. The results are very promising.

Test protocol plant residues reveals optimal diet composition

A protocol was developed to test plant residues, paying attention to the performance and composition of the larvae, and also to the nutritional composition of the residues. In order to select interesting residues and mixtures, experiments assessing the nutritional requirements of the larvae were conducted. The research showed that a diet with 30 % dry matter of which 15 % protein, 40 % non-fibre carbohydrates and 2 % fats, should be sufficient.

Aquaculture

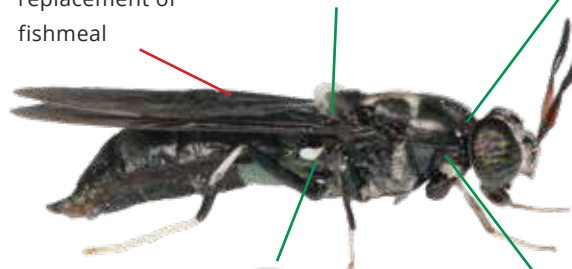
- Protein source
- (Partial) replacement of fishmeal

Petfood and hobby

- Fishing bait
- Bird food
- Reptile food
- Hypoallergenic dog and cat food

Farmaceuticals

- Chitin
- Lotions
- Antibiotics



Other applications

- Biofuel
- Bioplastics
- Coatings
- ...

Human consumption

- Sustainable protein
- Source of Vitamin B12
- Source of Iron

A full report on the insect research can be found in the publications section of the BioBoost website: www.bioboosteurope.com/en

Circular and biobased horticulture

Sustainable exploitation of natural resources

Horticultural co-product and waste streams can be used for new purposes, which contribute to the development of a bioeconomy. This development leads to a win-win situation for both the environment and the economy.

Bioeconomy

In a bioeconomy, or bio-based economy, the production and use of biological resources to provide products, processes and services are sustainable; inputs and resources are renewable and waste is cycled back into the system approximating to a 'closed loop'. Currently, we use significant quantities of non-renewable resources such as fuel and inputs from petrochemicals. The challenge is to replace non-renewable inputs with renewable feedstocks such as biomass. The biomass on which a bioeconomy is based can come from primary terrestrial or marine production, whether wild-harvested or farmed, and from the surpluses, secondary materials, side-streams, by-products and wastes that accrue during the processing of primary inputs.

The bioeconomy provides a useful approach, because it encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products such as food, feed, biobased products and bioenergy. The shift to a more circular bioeconomy is necessary to address climate change and offers the potential to reduce dependency on non-renewable fossil resources.

When applying these principals to horticulture, the trick is to extract maximum value from crop plant materials, and to use them as smartly as possible in a wide range of biobased, renewable and recyclable products.

Circular economy

A circular economy is based on three principles, aiming to:

Reduce resource use: consuming less, increasing resource-use efficiency, sharing goods and substitution of scarce resources;

Retain value: the value of goods and materials in use should be kept as high as possible, for as long as possible;

Recycle: useful resources or energy of disposed products or by-products should be recovered to reduce waste and resource extraction.

Circularity for biobased horticulture therefore aims to:

- Ensure that the earth's regenerative capacity is not exceeded;
- Substitute fossil sources with biobased renewables;
- Increase production efficiency;
- Limit residual flows and optimise the value of by-products and residues to maximise economic outcomes.



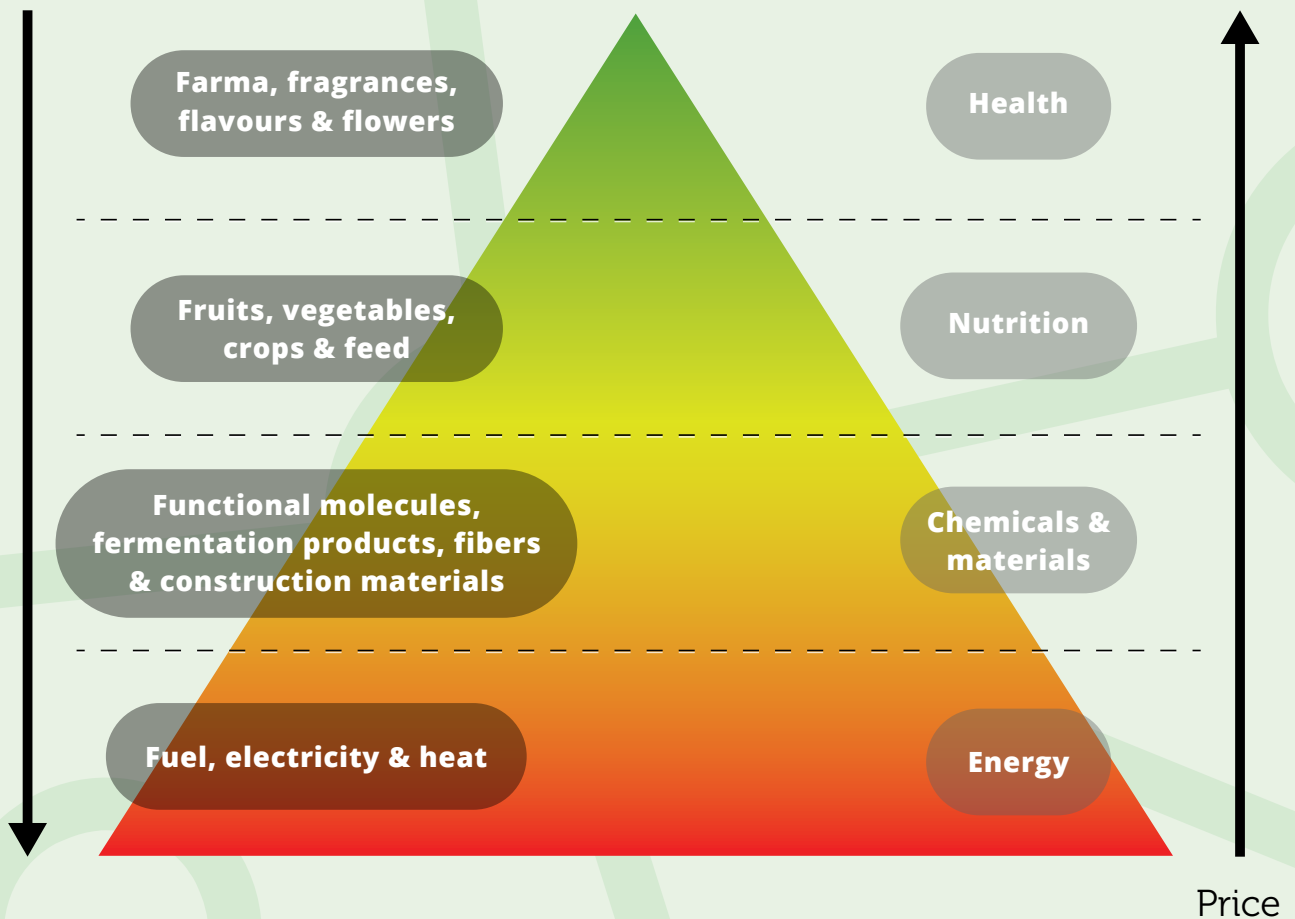
Valorisation of biomass: Residual flows are worth money

The valorisation of biomass can be illustrated by the bio-cascading principle, also known as the value pyramid. Pharmaceutical products add much value per unit of product but in a small volume, whereas energy carriers add little value per unit of product but in large quantities

Agriculture, horticulture and stock farming produce feedstock and products for the entire value pyramid. Each layer in the pyramid hosts its own number of bio based innovations.

Following harvest, a significant quantity of plant material remains in the field, such as stems and leaves, and sometimes fruit and vegetables that cannot be marketed, due to it failing minimum specifications of retail customers (e.g. too ripe/large/small fails to find a customer at the auction). These vegetable waste streams can be used to make materials, provide a source of useful molecules (e.g. for, pharmaceuticals or cosmetics), or used as a feed for another process such as insect farming). This can generate additional income for the horticulture.

Volume



Approach

Key success factors for accelerating a biobased and circular horticulture



Wastage in horticulture is often unnecessary and leads to extra costs; such as removal to landfill. This also destroys potential valuable plant material that could be used in new applications. Processing of these under-utilised feedstocks offers good opportunities, but restructuring the present system is a major challenge. Fossil based products are cheap due to a robust supply system and many decades of optimisation by the petrochemical industry.

However, the follow-up costs (as for the environment) are not included in that economic model and the appalling economic and environmental consequences of climate-change. Bio-based products don't have follow-up costs. Unfortunately, like other alternatives to petrochemical use, they are currently slightly more expensive. What can be done to change this situation?

The key elements of an approach; a strategy to identify and reduce wasteful practices and ways to develop economically viable new practices to reproduce and valorise horticultural co-products and residues are being considered. Based on the work done in the project, and interactions with industry stakeholders, the BioBoost partnership has identified the following four key elements, and these are then considered in the following chapters in more detail.

Clever communication and cooperation

The bioeconomy cannot be applied from the supplier side into society unless society knows what constitutes a bioeconomy and can both understand its role and welcome its products and services. Vice versa, suppliers within the value chain need to see the advantages and the perspectives. You could say a push and pull approach is necessary: push from supplier side, pull from consumer side.

A true change can only be made through the participation of all players in the production and value chain and by creating the right conditions for involvement of all stakeholders, including public authorities. Added value should be equally divided along value chain so that economic feasibility is assured for all actors involved.

Breaking down the barriers

Currently, there are numerous obstacles to embracing a more circular bioeconomy; such as in legislation, technology, social perception and financing. These must be tackled to enable biobased circular within horticulture so that handicaps, such as cost will help to facilitate moves from present use of fossil reserves and wastage-based practices. It is of the utmost importance to put removal of these obstacles at the top of the agenda and to find solutions.

Creating examples by facilitating entrepreneurs with innovations

To change existing practices and to substantiate the advantages of a biobased and circular horticulture (in the long run) good examples are crucial to demonstrate possible routes to valorisation and sustainable practices; and to inspire to development of ideas into action. Targeted financial and knowledge support of entrepreneurial companies is necessary to create these examples and to increase the range of options.

Improving the accessibility of knowledge and information

Many good examples already exist, including valuable information, but it is often hard to find; when “we can’t see the wood for the trees”. Improving the potential to find and share information and to provide it in a more bespoke form for the industry is crucial to accelerate the necessary transition.

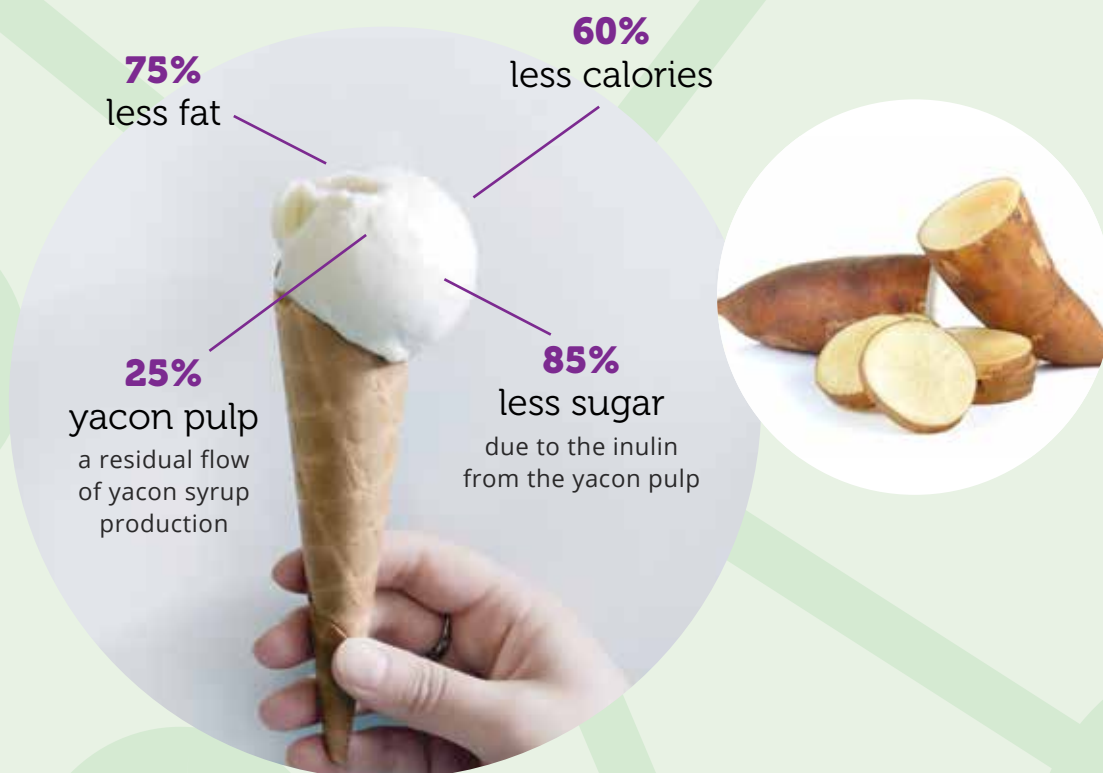
Healthy Yacon Ice Cream

New root vegetable

Yacon is a new emerging root vegetable, with the advantage that it is rich in inulin, a prebiotic with health-giving properties (e.g. against diarrhoea). Inulin is a carbohydrate, a collective name for sugar chains that are not metabolized by humans and so exhibit a low calorific value, what is interesting to people with diabetics or obesity.

Valuable yacon residues

For the moment, yacon is mainly used to make syrup from the juice. The pulp, which is 40% of the complete yacon is normally not recovered. The pulp consist of 85% of moisture and 10% of fibres and has a sweet taste. In BioBoost partner VIVES used the pulp to make ice cream that contains less sugar than the normal dietary ice cream.



More information can be found in the report 'Pretreatment methods and techniques' in the publications section of the BioBoost website: www.bioboosteurope.com/en

Clever communication and cooperation

Storytelling, key messages for all stakeholders, partnerships for action

Making the horticulture industry more circular by utilising by-products and waste streams is a complex task. Only by participation and cooperation of all stakeholders, we can make this possible. Targeted communication is necessary so that industry and users can perceive the benefits of a biobased and circular horticulture. Stories are illustrative and can inspire to action.

BioBoost campaign

In the second half of 2019 BioBoost held the campaign 'More profit, less waste' to increase awareness that much more is possible with green residuals from the horticultural industry. Various activities were organised in Belgium, the Netherlands and in the UK. The main target group of the campaign were horticulturists and the general public. Project partners developed a number of information posters to demonstrate this and created a short information film (<https://youtu.be/Vw4lvQbQMIw>). There was considerable interest in these resources and participants were eager to learn more.

Key messages per target group

Depending on the target group, basic messages need to be developed suitable for specific situations. In our campaign we worked with the following basic message:

'Horticultural waste streams can be used for new purposes; which contribute to the development of a bioeconomy. Such a development leads to a win-win situation for the environment and the economy.'

Furthermore, additional tailor made messages per target group are necessary. In our campaign we formulated the following for growers and other SMEs:

- New (additional) revenue models are possible in the horticulture (in near future):
 - » rejected crops and horticultural waste are (potentially) worth money
 - » growing of new crops for the bioeconomy
- Residual streams can contribute to the bioeconomy:
 - » can be used as alternative for fossil materials
 - » customers could prefer products from residual streams in future

- The situation is changing rapidly,:
 - » new legislation (banning use of plastics, CO2 taxes, etc)
 - » growing number of new applications of horticultural 'waste' and plant compounds
- Not acting now is not an option:
 - » the changing process is unstoppable, this is not something for future generations
 - » waiting for fully proved revenue models puts you at a disadvantage
 - » participation and investment is necessary in order not to miss the boat (entrepreneurship is taking certain risks)

Cooperation

Innovation cannot be done alone. For success of new initiatives collaboration and cooperation is essential. Bio-economy needs a multidisciplinary approach. Therefore our additional message to those who want to take action was:

- Find help from colleagues, researcher's expertise and join forces.
- Involve value chain parties. They play an important role, it's not only a question of supply. Build value chains simultaneously with new initiatives, so that new products have a ready market.
- Establish triple-helix cooperation of authorities, industry and research.



Climate game 'Save our planet'

BioBoost developed a board game to make the pupils aware of our influence on the climate and tests their knowledge on the basis of multiple choice questions. These are, for example, about food waste. The better the pupils pay attention during the 2 hour education module, the better they can play the game 'Save Our Planet'. In a playful manner, they can acquire knowledge about biomass used for bio-economy with the game. The game is made in both Dutch and English for young people over the age of 16. An online version is available in Dutch: <https://canvas.instructure.com/enroll/G738DE> and English: <https://canvas.instructure.com/enroll/FLFWFN>



Breaking down the barriers

Identifying and overcoming obstacles

Once sources of by-products and other residual flows have been identified, finding and realising potential successful alternative uses is often frustrated by limiting factors. These factors are of different kind and require a tailored approach and solution.

#1

Market failures in economy

Market failures are considered the main reason that circular economy principles are being embraced too slowly.

- a. The negative environmental effects are not reflected in market prices. Therefore the positive impact of biobased/circular products compared with fossil-based, non circular products cannot be 'cashed' and this puts those products at a competitive disadvantage to the current linear economy.
- b. Transaction and operational costs are generally higher in a circular economy, partly explained by higher labour intensity and recycling strategies.
- c. Also volumes are currently too low because of poor consumer demand.

#2

Reluctance among financiers

Even as positive business cases seem realistic, the financial market is reluctant:

- a. the innovative nature of circular/biobased products makes investing riskier than in conventional business,
- b. overlooking the risks in the linear economy works against the circular economy,
- c. financiers perceive circular business models as riskier in general.

#3

Legislation is lagging behind developments

The legislative and political environment should be as supportive as possible for uses of horticultural 'waste'. There's a strong need to institute mechanisms for revision of legal categorisations of wastes and enforcement of waste management rules that currently still limit the potential for re-use of biomass and used materials; we need mechanisms for rapid review of these as innovations arise.

#4

Knowledge and technology gaps

It is necessary to define and categorise horticultural waste streams and to determine material flow volumes. This is not always systematically done on regional or national level, which complicates the need to increase the sense of urgency and to investigate practical solutions at the right scale. Although a start has been made, there are still numerous questions about how to optimally 'harvest' the green waste and purify it, stabilisation techniques of residues, extraction methods of valuable components and application possibilities. Further development is needed of flexible, versatile technologies, that can process a wide diversity of biomass fractions.

#5

Social/cultural situation

Norms, ideas, customs and social context of people determine their attitude towards biobased and circular products. This is a complex system. Research shows that consumers are less inclined to reuse when their income rises. Growers in general don't feel responsible for their 'green waste' and what happens with it. Consequently, there is a major challenge to positive image-building for both the consumer and the supplier.

The way forward

Overcoming these obstacles is not easy and there is no general solution. However, ignoring them is not an option if we want to make the biobased/ circular horticulture a success. Therefore, relevant stakeholders do need to take action to diminish or take away these obstacles (see chapter 'From strategy to action').

Creating examples by facilitating entrepreneurs with innovations

Inspiration to idea development and action

Inspiring examples are crucial to change existing practices and to substantiate the advantages of a biobased and circular horticulture; demonstrating potential for action. Targeted financial and knowledge-support of entrepreneurial companies is necessary to create these examples and to increase the range of options.

Experimentation necessary for innovation

It is commonly accepted that new knowledge is a primary driver for economic growth, however it is not clear which mechanisms are best at converting new knowledge into economic activity and growth. Diffusion of new knowledge is important (see next chapter) but also, system-wide entrepreneurial experimentation that creates, selects, and scales up new technology and innovations is needed. Entrepreneurial experimentation is crucial in the innovation process itself (“technical experimentation”) as well as in translating innovations into economic activity. “Living labs” have good potential as support vehicles to enhance entrepreneurial biobased and circular.

Facilitating front runners

Individuals, organisations and institutions interact in the exploration, creation, discovery, and exploitation of opportunities and new ideas. An individual entrepreneur might very well experiment with and exploit knowledge, technology, or ideas created by someone else in the system. However, help is needed to make it a success:

- **Technical and knowledge support:**
The creation of opportunities through technical experimentation is an important and indispensable part of the innovation process. Cooperation with

and support of knowledge parties is necessary to ensure required know-how and consultancy.

- **Financial support**
Existing companies and start-ups have limited financial resources for experimentation, especially SMEs. Incentive structures in the form of, e.g., tax relief, (easily accessible) grants, vouchers and loans are necessary to stimulate innovation and experimentation.
- **Business advise**
There is limited knowledge of new circular/biobased markets and marketing concepts for new circular/ biobased products. Advice and mentoring are necessary to detect viable opportunities and to develop potential successful new business models, business cases and marketing strategies. The circular economy concept is necessary in all sectors and should not only focus on niche markets.

Good examples result in good followers

The more examples applications from horticultural by-products come available, the better suppliers and consumers will understand the opportunities of a circular horticulture and how valorising ‘green waste’ can contribute to a better environment and to potential extra income for growers and suppliers. And better understanding will inspire to own ideas and action.



T-shirt from Tomato Stems?

Alternative raw material for textile

The clothing industry - especially the cotton industry - has a poor reputation in terms of environmental damage and resource use. Therefore a project has started to investigate the utilisation of the fibres of tomato stems to manufacture textiles for t-shirts and other clothing. These stems are currently collected and composted, then used as soil amendments in public gardens. If successful, we realise that large industries as the horticulture and textile work together using circular bioeconomy principles. That is the dot on the far horizon, but this project is an initial exploration.

BlueCityLab Rotterdam

BioBoost partner assigned BlueCityLab in Rotterdam to do the actual work. The production route is the following: Plant -> Pulp -> Polymer -> Filament -> Yarn -> Textile.

The work is divided into three main phases:

- 1) Conversion of tomato fibres to textile fibre
- 2) Attempt to turn this textile fibre into a fabric
- 3) Pilot production of a t-shirt or blouse from the fabric

In all these phases there is a lot of research and testing. These were recorded on film and - where possible - shared via Instagram @tomatentextiel.

Many challenges

The project is still in the development phase. After making a polymer from the pulp, using chemical processing, the production method is being investigated. The challenges for the making of the natural synthetic fibre were the following:

- Facilities for local pulp production are not currently available.
- A constant supply of pure and clean amount of stems.
- Defining quality requirements with a view to scalability of the production process.
- Finding the best breakdown basic route of the tomato plant into cellulose.
- Finding out which sustainable technology is best suited to produce "large" amounts of cellulose polymer.
- Finding a spinning mill for production of prototype T-shirts from the manufactured 'lyocell' was the final challenge; and is ongoing.



Improving the accessibility of knowledge and information

Sharing knowledge and information

Transferring latest research results on horticultural by-products, best practice approaches and improved methodologies, including biotechnical advances, to the farming community is the key to advancing biobased/circular horticulture. We need to give good examples of applying this knowledge and information in new applications.

Sharing good examples

We should revalue all types of horticultural materials so that we can ultimately make the best use of them. The circular biobased society also offers many business opportunities. However, before we can take these opportunities, we need to become aware of them. There are already an increasing number of examples, but they are often difficult to find. Therefore, it is necessary to provide centralised points of information and knowledge exchange.

BioBoost Platform

In order to share knowledge and ideas in the field of biobased horticulture in a better way, BioBoost developed such an information point in the form of a digital platform. The interactive platform aims to stimulate and inspire and connect biobased initiatives in horticulture by facilitating the sharing of good examples online, including background information.

The more examples we gather on the platform the better we can stimulate circularity and a biobased development. Have a look at the platform website <https://www.bioboost-platform.com/> and check it out!

Knowledge parties

Knowledge institutes and circular knowledge partners can offer much added-value through sharing knowledge gained in projects and other activities; and from both a scientific and practical point of view. There is a rich variety in knowledge institutions that already provide this scientific and practical knowledge, however the accessibility and reach needs to be improved. Cross sectoral approaches are necessary to bridge the gap from theory to practice.

Education

In order to create a circular horticulture, we need new kinds of skills, co-operation between different domains, and a general change in attitudes and operating methods. Professionals, experts and decision-makers, both now and in the future, will play a decisive role in building a new circular future. Education plays an important role in developing and adopting these new skills.

BioBoost developed a lesson pack consisting of a ready-to-use learning module with a board game to support learning about the circular economy (see page 11). This teaching package is intended for pupils in secondary education. In total 500 games have been distributed among schools.

From strategy to action

Who shall take action?

Strategic intentions for shaping a circular and biobased horticulture need to be translated decisively into practical and effective ground-level supportive policies and actions from all stakeholders. This will require cooperation across all sections of society and an integrated view to prevent too firm separation into research and innovation, investment, social, political and regulatory

Public authorities..

...must set the proper conditions, create a level playing field, stimulate innovation and experimentation and need to be realistic in short term expectations:

- ✓ Increase awareness for the relevance and urgency of a circular and biobased horticulture
- ✓ Support cross-value chain collaboration
- ✓ Implement standards and norms for circular and biobased products to facilitate consumer behaviour
- ✓ Promote fair prices for biobased products: tax polluting activities instead of subsidising 'green alternatives'
- ✓ Continue to mobilise financial support to foster bottom-up innovation
- ✓ Revise and actualise the legal framework, e.g. regulations on (re)use of 'waste' and physical planning

Horticultural industry..

...needs to make a mental-shift from thinking in traditional production of 'perfect' fruits (taking into account unsold products and a lot of green waste) to becoming a supplier of raw materials and utilisation of all plant compounds for a broader base of consumer industries:

- ✓ Acquire relevant circular and biobased knowledge and develop practical corporate visions
- ✓ Dare to be creative and to experiment even if this involves financial investment

- ✓ Collaborate with knowledge and value chain partners to identify opportunities, implement pilot projects and devise new business models and to share knowledge and experience (open innovation)

Financial sector..

... should focus more on the long-term horizons and take into account possible future tightening of environmental regulations and fallibility of linear businesses; helping to scale up circular business:

- ✓ Help to establish the collaborations needed for developing circular value chains
- ✓ Create new expertise and tools to assess the risks of innovative circular technologies
- ✓ Establish risk-sharing instruments for investments in circular/biobased horticultural products

Researchers..

...must be able to provide knowledge and expertise for complete valorisation of whole plants:

- ✓ Further invest in basic R&D regarding the composition of plant compounds and application possibilities
- ✓ Establish technical advisory services to the horticultural industry to support biobased and circular innovation
- ✓ Develop standards and benchmarks for the circular and biobased aspects of horticultural products

Consumers..

...need to be empowered to be able to make responsible choices about products and consumption patterns and life style:

- ✓ Favour biobased and circular products
- ✓ Must be willing to pay a fair price for all their products
- ✓ Demand reliable labels and brands for biobased and circular products



The future starts now, for everyone

Imagine what a circular economy within horticultural value-chains might look; and how you could get involved

Although there are many challenges in realising a circular biobased horticultural industry, there is no reason to delay your participation. On the contrary, you cannot afford to wait; the transition will become an unavoidable, unstoppable process. There are great economic and marketing opportunities to be taken by producing new and higher value products from food by-products; we invite you to step up to the challenge and contribute. Being part of the circular economy will be your future license to produce.

Horticulture in the future – how will it look?

The future horticultural company will not only be a direct producer of food and ornamental crops, but will also supply raw materials for several other industries. This could include biomass for the paper and cardboard industries, ingredients such as antioxidants or colourants for the food industry; fine chemicals for crop protection, pharma and cosmetics; biomass, pigments and processing for textiles; food and feed for humans livestock and pets etc... All outgoing streams will be produced on industrial specifications and will be used in other agricultural or industrial processes.

The production process is (re)organised to be efficient and circular wherever possible. All wastewater cleaned,

reused and nutrients are recovered. Glasshouses are independent from the national grid and with zero emission. Crop protection follows the Integrated Pest Management principles; including biological, using natural enemies and green biopesticides. Potting compost is sourced from biomass that is either a product of recycling, or primary production; which can itself be recycled following cultivation. Through precision fertigation, the use of nutrients, and resultant diffuse pollution is minimised. Use of plastic in horticulture is replaced by recoverable or rapidly degradable biobased products, so that all plant parts can be used. This includes plastic rope and supports in glasshouses and fleece in the field.

Crop varieties, growing conditions and harvesting methods are adapted to maximise optimal full utilisation or valorisation of the whole plant: fruits, flowers, stems, leaves and roots. This may require a genetic redesign for several crop species. The concept of crop 'waste' thus ceases to be a meaningful concept; replaced by a list of outputs according to species and growing conditions.

Innovative total valorisation of tomatoes as an exemplar of potential

Tomato is an exemplar in the efficient cultivation of a high value crop; it could provide a model for potential in other crops. How could the optimal sustainable cultivation and valorisation of co-products look in the future using *Solanum lycopersicum* 'optimal' varieties?

The primary cultivation is integrally linked to demand, so that supply fulfils that demand as it changes; informed via 'big data' analysis of weather and consumer behaviour. Undesired overproduction of fruits is thus prevented as much as possible. The inevitable production of some surplus is fed into primary processing on site or in a biomass processing hub close by; such as for production of dried, juice, soup or paste products, allied to more sophisticated storage of the fresh tomatoes.

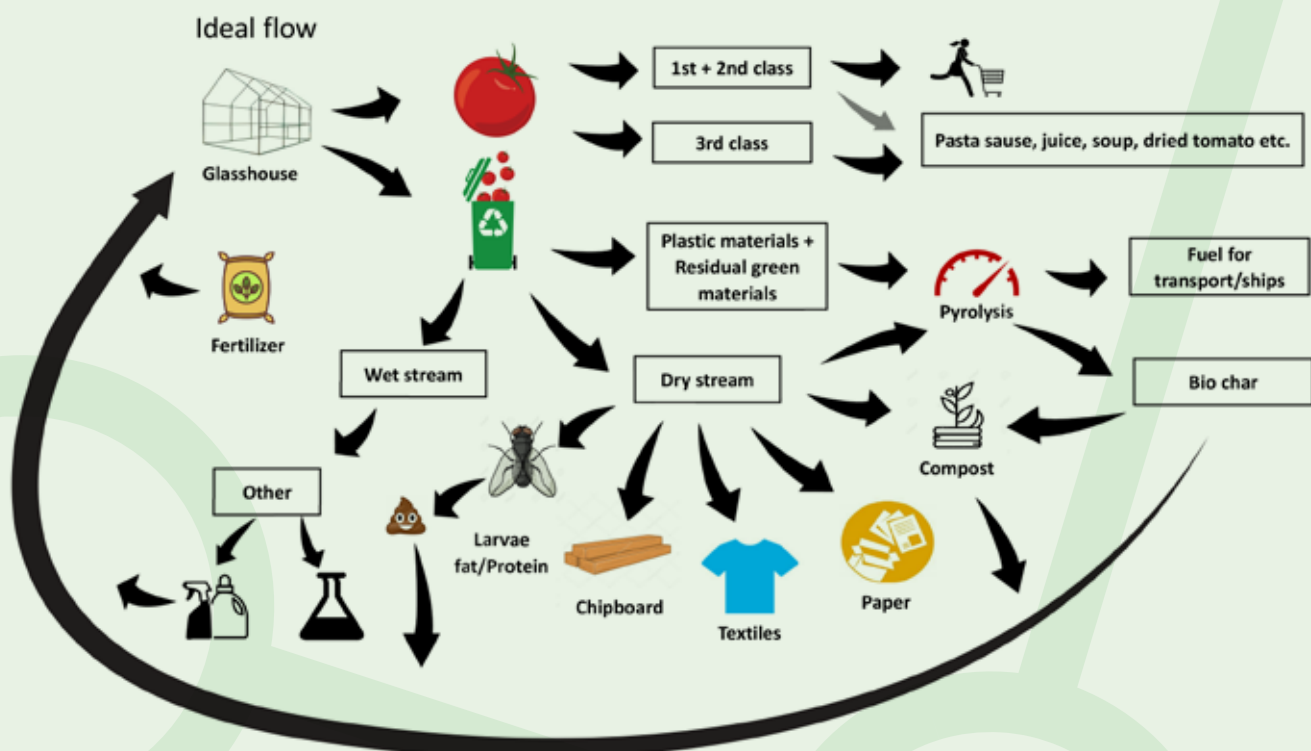
The unusable green fruits, leaves and stem material is separated in a dry and a wet fraction via tailor-made separation methods. The wet fraction is processed for use as fertilizer (liquid or solid) or for extraction of various valuable components (e.g. antioxidants, lycopene, vitamins) for food, feed, pharma or cosmetic industries. The dry fraction can be used in a range of applications; for example, as a component of livestock bedding material; in the insect larvae cultivation process, or as a soil conditioner directly if unsuitable in feed or bedding. The harvested larvae, which will require additional food from other valorisation sources, provide high quality clean food or feed; especially fats and protein. The dry fraction can also be used to make paper, cardboard or can be mixed with woody parts in the production of hardboard and chipboard, or the lignin can be converted to polymers to produce fabrics.

Using circular bioeconomy principles there may be a tertiary or further use of material. The insect cultivation, for example, yields insect waste and inedible components of their feed. This can then be used through further processing, such as the chitin for pharma/ crop protection, or directly as an active soil improver and fertilizer. Any remaining parts and residues can be composted or used for energy production; but this is a relatively low value valorisation and only considered once other high value components have been used or extracted.

Chain relation – chain reaction

This ideal tomato scenario illustrates that the components of an optimal bioeconomy are highly interlinked. An ideal bioeconomy in the horticultural industry needs participation by many players across the whole value chain and associated networks. Changing a part of the chain can lead to changes elsewhere and eventually the whole chain network. This means that a single change in the chain could impact both negatively or positively on other components; any changes in feedstock utilisation need to consider this. If a complex network of industry has grown to use many different components, then new initiatives should consider impact before making changes. This co-operative decision process will form an important part of the transition to a biobased circular economy in horticultural industries.

Chain reaction of horticulture:





Partners



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