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Investment theme B.

Transformative Bioeconomies: Towards a materials transition that phases out fossil feedstock

1. **Authors**

Harriëtte Bos, Cees Leeuwis
with input from the core team: Harry Bitter, Wouter Post, Sineád O'Keeffe, Barbara van Mierlo, Anne-Charlotte Hoes, Henri Holster, Solen le Clech

2. **State of the art**

This investment theme connects several scientific fields that have so far operated largely separately in WUR and elsewhere. In this description of the '**state of the art**' we discuss them separately, and clearly a key ambition of the investment theme is to connect them meaningfully. In this section we therefore speak of (a) the field of 'sustainability **transition studies**' and (b) the field of '**renewable carbon-based materials**' even though we realize that these are broad umbrella's that cover widely diverging sub-fields.

***Ad. Transition studies*:**

- **a.** *Wat is er gaande op dit thema buiten en binnen WUR*
- **b.** *Wat is er reeds aan kennis op het domein van het investeringsthema*
- **c.** *Wat is de positie van WUR in dit veld en wat is de positie van anderen?*

Transition studies, the science, and also practice, of understanding large scale systems change and pathways towards transformations, has developed rapidly in recent decades (Loorbach et al, 2017; Markard et al., 2012; Köhler et al., 2019; Scoones et al., 2020). It is an approach which deliberatively and normatively focuses on addressing sustainability in innovation at the scale of whole systems. This work has, for example, looked at how emerging networks of innovators, so-called niches, change incumbent systems and how these can be supported through approaches such as strategic niche management. It is also gaining increasing currency in policy cycles, for example the Dutch ministries and the European Union. Different social science disciplines (e.g. innovation studies, political science, science and technology studies, sociology, economics) in WUR and elsewhere have engaged with and contributed to transition studies.

Both understanding and facilitating/supporting transitions towards transformed systems (e.g. in food, non-food, energy) has been a focus of work at WUR for some decades already, at all science groups. WUR does this by developing key transformative technologies, diagnosing wicked problems, understanding effects of transition and transformation on society and its surroundings, and by supporting (and studying) learning among actors involved in sustainability transitions, including public sector, private sector and civil society stakeholders. This has led to key roles of WUR science groups in:

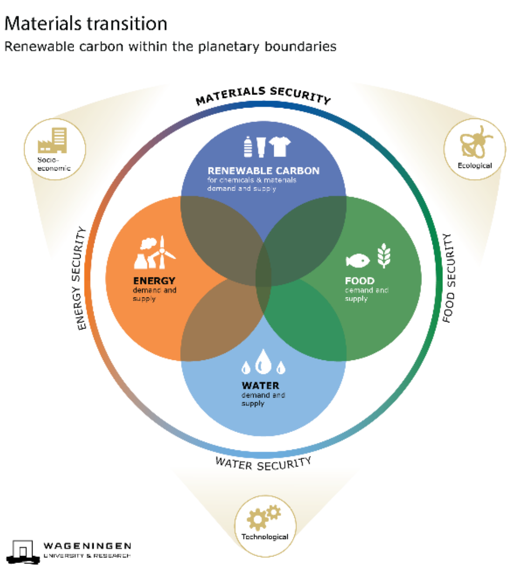
- technology and nature based initiatives and transformative concepts such as: AlgaeParc, AgroParcs, Vertical Farming, Agrifood Robotics, Biobased Economy, Circular Biobased Performance Materials, Circular Agriculture , Regenerative Food Systems and Agriculture , Agroecology and Nature-Based Solutions;
- design programmes and approaches such as Design for System Innovations and Reflexive Interactive Design (Elzen & Bos, 2019)
- transition monitoring approaches such as Reflexive Monitoring in Action (Van Mierlo et al., 2010);
- development of transition theory and approaches such as the small wins approach co-developed in the Connected Circularity strategic investment theme, and approaches such as strategic niche management and the multi-level perspective (Termeer et al., 2019)

We propose to build further on this broad experience, and exploit the specific strength of WUR, which lies in the fact that we combine several areas of knowledge and expertise in one organisation, that are all imperative for the transition towards a bioeconomy. The combination of ecological, socio-economic and technological sciences, plus our hands-on experience in developing new concepts and new technologies that are an integral part of transition makes us stand out. Nevertheless, despite relevant and acknowledged contributions, to some extent and in some aspects WUR can be considered as a follower rather than a leader in the field of transition studies as such. Also given the increasing interest of other research organizations in topics from the WUR domain such as food systems and the bioeconomy, it is of importance to develop a stronger position and thought leadership in this field.

Given the relatively high attention already paid to transitions towards transformed food systems (e.g., in the Protein Transitions strategic investment theme), for this strategic investment theme we propose to zoom in on another field of knowledge development and application in which WUR is active, the bioeconomy, and more specific the transition towards renewable materials. The renewable materials transition includes applications in different fields all related to comfort and shelter, such as building and construction, transport, packaging, furniture, textiles, and many of these materials are presently produced from fossil feedstock. The materials transition is thus intrinsically connected to the transformation of the economy towards a circular economy and is also a central part in the transition towards a fossil free society. Obviously, also bioeconomy has been the subject of transition studies and intervention approaches but this is a field that has a lot of potential to be developed further (Hermans, 2018; Israël-Hoevelaken et al., 2020).

***Ad. Renewable carbon materials*:**

- **a.** *Wat is er gaande op dit thema buiten en binnen WUR*
- **b.** *Wat is er reeds aan kennis op het domein van het investeringsthema*
- **c.** *Wat is de positie van WUR in dit veld en wat is de positie van anderen?*



Carbon based materials are all around us. Materials in textiles, packaging, kitchen appliances, paints, car parts and many building and construction materials are based on the carbon atom, and cannot be made without it, To put it simply 'no carbon no life. Up to 150 years ago these materials came from what nature had to offer ie. biomass from crops, trees or animal origin, including many residuals. Nowadays that is not directly possible anymore due to the increased population on earth, the increased standard of living and the availability of more easily to apply fossil resources. Today many of the desired materials are made from (fossil) oil or gas[1]. The desirable phase out of fossil feedstock thus urges us to find *renewable carbon* based raw materials, which are available on large scale and allow for making the products that provide shelter in our daily life.

Developing and using renewable carbon for materials production involves different products and markets. In addition it connects to different core disciplines (e.g. forestry and forest management, agriculture, plant breeding and agronomy, (bio)chemistry and chemical engineering, mechanical engineering, design, economy, etc. etc.) which each have their own specific development path.

The Challenge Fossil Free (KB 34 project 2020/2021) has developed a vision on the technological possibilities and constraints for renewable carbon feedstock. The central challenge is how to source the feedstock for our future (carbon based) materials needs and how to ensure materials security, next to food, water and energy security, and staying within the planetary boundaries (fig above)).The vision is in line with the recently published EU roadmap 'restoring sustainable carbon cycles'[2] which aims to develop a long-term vision for sustainable carbon cycles (including capture, storage, and use of CO_2) in a climate-neutral EU economy and to kick-start the development of technological and nature-based solutions.

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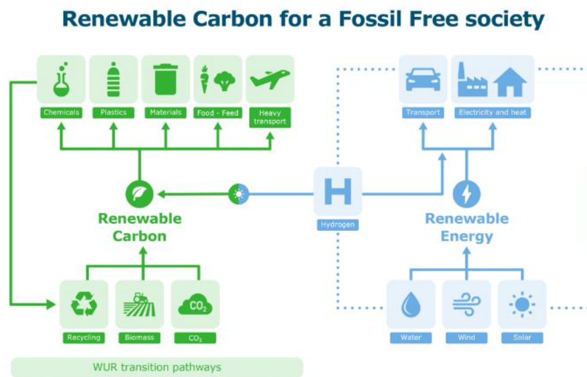
[1] Next to metals and inorganic earth minerals such as concrete
[2] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13066-Climate-change-restoring-sustainable-carbon-cycles_en

Furthermore, the ideas are strongly related to the Renewable Carbon Inititative[3] started by nova Institute and backed up by numerous companies in our domain, many of which are also WUR clients.

These initiatives make clear there are fundamentally only three technological pathways towards renewable carbon based materials available, (1) starting from biomass, (2) applying CO_2 capture and utilization technologies, (3) recycling of discarded carbon based materials. (figure below)

These three pathways focus on three very different approaches, which all are connected to different WUR expertise:
ad 1: producing materials from biomass main and side streams, including the total crop use principle (i.e. producing for food and non-food simultaneously) and based on different components from a plant and animal origin e.g. sugar crops, primary and secondary streams, non-food crops/flax and hemp, algae, manure, etc., including aspects such as breeding, conversion processes, biorefineries
ad 2: producing material through CO_2 capture and utilisation, (including a new role for the agri-food sector turning their CO_2 production into new feedstock and the development of new microbial cell factories/molecular pharming, linking production to larger scale chemical processes…)
ad 3: recycling of carbon based materials (technology development, feasibility/sustainability analysis and including a large role of consumers as suppliers of feedstock)



WUR has been active in all these fields, however, activities have not yet been effectively integrated to strengthen the WUR contribution to the materials transition. Many other players are active in parts of this domain. Nevertheless, because we can cover a multitude of relevant aspects, WUR is ideally equipped to take up a leading role in this transition, if we manage to connect over the full width of our domain.

The materials transition can only be achieved when technological, societal and ecologic aspect are dealt with. The transition is partly a technology agenda, focussing on development of new solutions within ecological boundaries, for instance through the combination of nature based solutions and technological as well as social and institutional innovations. However, to study and implement new concepts and make changes tangible to a wide range of stakeholders, we feel it is imperative to focus our program on two specific areas of application. This gives the added advantage that when applied to a specific field of application (e.g. construction materials) each of the three pathways above can be combined with strategies that reduce the use of carbon-based materials for a particular application or function (e.g. develop building designs that use less materials). We will label this as a fourth pathway that intersects with the other three: the de-materialisation pathway.

The four pathways thus offer interesting challenges but are also an ideal input for studying, developing and modelling an innovative transformative systems approach, since they differ fundamentally in for example, stakeholders involved, state of the art of technology, type and condition of ecosystems, scale and focus. Experiences and learnings from for instance technical, nature based, or institutional oriented projects will thus feed back into the development of the transformative systems approach and vice versa. Furthermore, through the relation with WUR education programmes, such as MBS (Master of Biobased Sciences), relevant results can play an immediate role in student training, and the organisation of the Student Challenge (planned as The Material Challenge) is expected to yield new ideas and approaches to be exploited further.

To develop an innovative angle, which also aligns well with WUR's position as innovation partner of many large organisations in the bioeconomy (e.g. DSM, Cosun, Avantium, Corbion etc..), for this strategic investment theme we will work with new players active in innovative niches as well as with large incumbent organisations that are in materials production (such as polymers/plastics) and their upstream and downstream stakeholders (e.g. customers, prime material producers). Though in transition studies, and also in WUR, focus has often been on innovative niches as relative outsiders of incumbent systems, it is increasingly recognized that transition also comes from within those systems (Turnheim & Sovacool, 2020). That is not to say this is without problems, because lock-ins and path dependencies (i.e. choices from the past make it difficult to be agile and change rapidly) often constrain transformation.

[3] https://renewable-carbon-initiative.com/

3. Vision

a. *Welke kansen en vragen voor het hele investeringsthema komen uit de stand van zaken naar voren?*

The materials transition requires effective integration of knowledge from several fields:

- expertise in technologies for renewable carbon production, re-use, recycling and de-materialization, based in several natural science disciplines;
- expertise in sustainable and fair transitions, incorporating options and insights from several disciplinary perspectives e.g. sociology, ecology and economics;
- expertise and perspectives from societal stakeholders on whom transition in society eventually depends critically;

However, these worlds are currently widely apart. Natural scientists working on new and more technologically focused opportunities often do not see how they can benefit from or link with expertise on sustainability transitions. On the other side of this natural scientist spectrum, ecologically orientated scientist sometimes do not see the need nor the advantages of integrating technological solutions to enhance ecosystem services. Furthermore, social scientists working on sustainability transitions often do not see how they can make their expertise add value to technical disciplines. In many cases, these diverse scientific disciplines often investigating the same topic speak different languages, making communication and understanding somewhat challenging. Meanwhile, societal stakeholders with transformative ambitions often face numerous technical and social challenges in making their alternative options compete successfully with dominant system, and often do not have much contact with relevant scientific expertise. In short, actors who can contribute meaningfully tend to operate in isolation. This arguably leads to sub-optimal learning in transition trajectories, reflected in progress in e.g. the energy transition or the transformation towards sustainable agriculture.

In view of the above, our vision is that this investment theme should strengthen the collaboration and coordination between scientists from widely diverging disciplines as well as between these scientists and societal stakeholders on whom transition depends. We envisage to do this through the development of innovative methodologies, concepts, tools and modes of working that facilitate enhanced mutual understanding and the integration of knowledge across disciplines and bodies of expertise, and work towards coherent action perspectives for all involved.

At an abstract level, such novel forms of collaboration as described above have been proposed in transition studies under various banners, including e.g. action research, systemic thinking, integrated assessment (Loorbach, 2007), reflexive design (Grin et al., 2004) and co-production or co-creation (Chambers et al., 2021). And while there is considerable reflection on the role of research in transition processes (e.g. Loeber, 2004; Turnhout et al, 2013; Loorbach et al, 2017; Bulten et al, 2021) there is still considerable scope for widening the array of operational methodologies, concepts, tools and modes of working that can play a useful role in such approaches. Many of the proposed forms of collaboration remain rather general and offer little specific guidance on how widely diverging disciplines and bodies of expertise can integrate their knowledge and collaborate effectively. Especially the translation towards a perspective of action of individual stakeholders has received little attention so far.

Once developed as part of this investment theme, novel methodologies, concepts, tools and modes of working can also be used in other settings than the materials transition. Thus, they contribute the overall capacity of WUR to work towards transformative change now and in the future.

b. *Aan welke onderwerpen gaat gewerkt worden (en welke niet)?*

As explained in section 2 we propose to focus our efforts to two specific domains: It is imperative that these domains give the opportunity to study the three different pathways and the intersecting de-materialization pathway. In addition, the domain should give possibilities for experimenting with different methodological approaches towards supporting the transition and cross disciplinary collaboration. We defined a set of requirements that the domain should ideally fulfil.

Domains should:

- Comprise the full production, use and after-use aspect of products/materials (i.e. the potential for cascading)
- Comprise recognisable products relating to shelter
- Have a diverse set of stakeholders active
- Have the possibility to study regional, national and international aspects
- Presently (partly) based on fossil feedstock, in future renewable feedstock
- Link to agriculture, forestry, circularity and also possibly CO_2 technologies
- Have meaningful options for dematerialisation
- Have the possibility to involve a wide range of stakeholders: from primary producers, technological parties up till consumers
- Have the possibility to include and apply artistic interpretations and visuals in order to build bridges to non-technological stakeholders

A number of possible domains were discussed and rejected: for instance plastics (too general and too broad), packaging (too narrow), automotive (not appealing), electronics (difficult to recognize the products). Together with the core team the decision was made to start with textiles and building materials (housing and interior) as domains as they fulfil all these requirements. A reconsideration to expand or alter the studied domains may follow after the first year.

Yearly approximately 100 MTon textile fibres are produced. After plastics (over 360 MTon yearly) it is thus the second largest domain of carbon based materials. Textiles are a domain that presently faces a lot of challenges, presently 60% of all textiles are fossil based (mainly polyester). The 40% biobased part is mainly cotton, which has a large ecological footprint. New resources or revisited resources are presently under development. The textiles industry is responsible for circa 20% of global industrial water pollution caused by dyeing and treatment of textiles. On top of that the consumer trend of fast fashion has led to retailers selling clothes that are expected to be disposed of after being worn only a few times. Clothing production has doubled between 2000 and 2015. (Harmsen & Bos, 2019) Altogether these challenges we feel these challenges warrant our choice for textiles as one of our two domains.

Building materials for housing and interior have the possibility for long time carbon sequestration as is presently being exploited for in instance in the KB program circular and climate neutral society.[4] Biobased building is actually one of the focal points for biomass feedstock mentioned in the recent Dutch Coalition agreement.[5] The domain comprises a wide range of different products and applications, many of which are (partly) based on fossil oil and gas resources (paints and coatings, panels, piping and wiring, upholstery, window frames etc). But the domain can also meaningfully connect to regional production of materials and feedstock, such as straw building, hemp for isolation, local construction wood etc. Furthermore the domain gives ample possibilities to include design approaches, as there are many architects active. Furthermore, the domain is easily recognizable for consumers. Therefore we chose this as our second domain.

4. Challenges

- **a.** *Welke uitdagingen/subthema's zijn er te onderscheiden binnen het investeringsthema?*
- **b.** *Inhoudelijke beschrijvingen van de uitdagingen/subthema's.*

As indicated in Section 3, we see a number of challenges and gaps relating to operational methodologies for cross-disciplinary analysis and collaboration in support of the materials transition. Such methods are needed eventually to enhance the maturity and strength of social-institutional, technical and nature-based options that can reduce the dependence of fossil carbon. Below we speak of 'maturity challenges' , 'methodological challenges' and 'imagination challenges'.

Innovative technological, socio-institutional and/or nature-based options and solutions can be seen to have reached a certain level of 'innovation readiness' (see Sartas et al., 2020 and Table 1). 'Maturity challenges' and 'methodological challenges' relate to situations where novel technical, socio-institutional and/or nature based options are being explored and experimented with in society, with or without support from researchers and professional change agents (i.e. innovation readiness levels 4-8, see Table 1).

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[4] https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksprojecten-LNV/Expertisegebieden/kennisonline/Negative-GHG-emissions-and-longtime-sequestration-C-fixation-through-development-of-new-C-based-products.htm

[5] https://www.parlement.com/9291000/d/pdfs/coalitieakkoord-2021-2025.pdf

‘Imagination challenges’ relate to situations where novel ideas have not yet been tested or proven at all, and where practical application is still far away (i.e. readiness levels 0-3, see Table 1).

Innovation readiness score	Innovation readiness level	Description
0	Idea	Genesis of the innovation. Formulating an idea that an innovation can meet specific goal.
1	Hypothesis	Conceptual validation of the idea that an innovation can meet specific goals and development of a hypothesis about the initial idea.
2	Basic Model (unproven)	Researching the hypothesis that the innovation can meet specific goals using existing basic science evidence.
3	Basic Model (proven)	Validation of principles that the innovation can meet specific goals using existing basic science evidence.
4	Application Model (unproven)	Researching the capacity of the innovation to meet specific goals using existing applied-science-evidence.
5	Application Model (proven)	Validation of the capacity of the innovation to meet specific goals using existing applied science evidence.
6	Application (unproven)	Testing of the capacity of the innovation to meet specific goals within a controlled environment that reflects the specific spatial-temporal context in which the innovation is to contribute to achieving impact.
7	Application (proven)	Validation of the capacity of the innovation to meet specific goals within a controlled environment that reflects the specific spatial-temporal context in which the innovation is to contribute to achieving impact.
8	Incubation	Testing the capacity of the innovation to meet specific goals or impact in natural/real/uncontrolled conditions in the specific spatial-temporal context in which the innovation is to contribute to achieving impact with support from an R&D.
9	Ready	Validation of the capacity of the innovation to meet specific goals or impact in natural/real/uncontrolled conditions in the specific spatial-temporal context in which the innovation is to contribute to achieving impact without support from an R&D.

Table 1: Innovation readiness levels as distinguished by Sartas et al, 2020.

Ad. Maturity challenges – phasing in and phasing out:
As discussed in Section 2, there exist several pathways towards a materials transition. In each pathway there can exist a multitude of innovative options that can serve as a starting point for working with societal stakeholders towards a materials transition that effectively replaces fossil carbon by renewable carbon. However, we know from innovation and transition literature as well as from industrial practice that it tends of be extremely difficult for technological, nature-based or social/institutional innovations to break through and scale to a degree that is meaningful. This challenge has several dimensions:

- maturing from a basic model for an innovation (see Table 1) to something that actually works in society at scale requires considerable investment in money and time, and learning from mistakes and failures;
- resistance from the existing socio-technical system and dominant stakeholders will have to be overcome;
- phasing out the pre-existing fossil materials can pose considerable economic and technological challenges;
- technological innovations need to become effectively linked to organizational and institutional innovations and vice versa as well as to changes in mental models and visions (innovation as a coherent package of ‘hardware’, ‘orgware’ and ‘software’). That is: ‘technical readiness’ needs to be combined with ‘societal readiness’;
- there is a need to ensure the ecological compatibility and climate neutrality of technological innovations and their scaling trajectories i.e. that the proposed solution will not generate even greater problems than those that already exist;
- scaling of innovations requires the emergence of support coalitions that are strong enough to overcome the challenges described above.

Ad. Methodological challenges – collaborative analysis, anticipation and decision making:
Overcoming the ‘maturity challenges’ mentioned above, requires ways of working, struggling and co-learning together among stakeholders, as well as conducive interaction between scientists and societal interest groups. In this investment theme we are especially interested in methodologies, concepts, tools and modes of working that can help bridge different disciplinary and/or societal fields of experience, and/or that support decision-making and strategy development towards further investment and scaling. We see several areas that may require attention, including:

- developing cross-disciplinary descriptions and diagnosis of systems that are meaningful to multiple audiences, including objects or visualizations (‘boundary objects’) that enhance the transparency of systems and trade-offs and that help overcome language and communication problems;
- clarifying the interdependencies between technical, nature-based and social-institutional innovations and prioritization of bottlenecks in composite innovation packages;

- anticipation of the likely long term consequences of particular innovations in connection with different values and goals, including assessment of ethics and social justice;
- enhance reflexivity of actors involved, being aware of the need to change their own practices and relationships with others
- creating flexibility and avoid risk-aversion while supporting decision-making regarding the 'opening-up' or ' closing-down' of particular options within pathways;
- enhancing strategy development for out- and upscaling (phasing in) and downscaling (phasing out);
- supporting creative engagement and articulation of supply and demand of knowledge and technology, as well as establishment of initiatives for addressing these.

Ad. Imagination challenges – basic proof of principle for new technical, nature-based and social options
Before it becomes feasible to explore and experiment with technical, nature-based and/or social-institutional options in applied settings, there are challenges involved in imagining new relevant options in the first place, and in validating that ideas or hypotheses can have practical potential for the materials transition. This often poses considerable scientific challenges of a conceptual and methodological nature, and goes along with high risks of 'failure' (or: high potential for learning). In addition, there is the challenge of connecting with societal stakeholders at these early stages of 'innovation readiness', since practical application is still far away. At the same time, engagement with societal stakeholders can be important to assess potential relevance, create interest and/or identify challenges related to ethics and responsibility (Stilgoe et al., 2013). In this investment theme, therefore, we aim to create room for the development of new principles of technical, nature-based or social options/innovations that may have potential to support the transition. We therefore will support proof of principle projects that aim for, for example:

- conceptualizing, designing and proving new concepts and approaches to particular chemical conversions towards carbon based materials, for instance through the application of convergent technologies, or the design of new molecules for materials, using approaches based on biomimicry or translating basic structure properties relations of know materials;
- conceptualizing, designing and proving new approaches of circular (textile and building) material development, safeguarding that four pathways are interlinked (e.g. materials made from biomass can be effectively recycled);
- conceptualizing, designing and proving new technical, nature-based and climate neutral/negative concepts and approaches to supply and apply biomass based materials for specific applications, e.g. multifunctional landscapes with diverse cropping systems, plant breeding with improved properties, biomimicry;
- underpinning or comparing the feasibility of different pathways towards carbon based materials;
- conceptualizing, designing and proving new innovative ways towards product use that can reduce feedstock demand;
- conceptualizing, designing and proving alternative social rules and arrangements that can serve as a leverage for transition by altering the logic of the system;

The proof of principle projects will also connect to one or both domain projects, which will give scientists room for discussing their ideas in an early phase and identify ethical and maturity challenges that may occur at later stages. This simultaneously helps to improve the dialogue among WUR scientists with different background. If the outcomes of proof of principle projects are convincing the investment theme can support further maturing at a later stage.

5. Desired outcomes

a. *Wat zijn de doelen van het investeringsthema t.a.v. onderzoek (zowel fundamenteel als toegepast), onderwijs en waardecreatie?*

Ad. Research goals

- Strengthen the expertise and position of WUR in the academic field of sustainability transitions
- Strengthen the expertise and position of WUR in the academic field of renewable (carbon based) materials for textile and building materials (housing and interior) applications.
- Develop, apply and test methodologies and concepts to enhance inter-disciplinary collaboration and effectively link different scientific disciplines (technical, ecological, social) in transition processes
- Develop, apply and test methodologies and concepts to enhance trans-disciplinary collaboration and effectively link upstream research and societal actors involved in transition

Ad. Education goals

- Strengthening cross-disciplinary knowledge and skills on transition processes through the development of new courses, course materials and/or student challenges for BSc/MSc programs with an interdisciplinary orientation (notably MSc Biobased Sciences, BSc/MSc Communication and Life Sciences, MSc Sustainability Governance)

Ad. Value creation

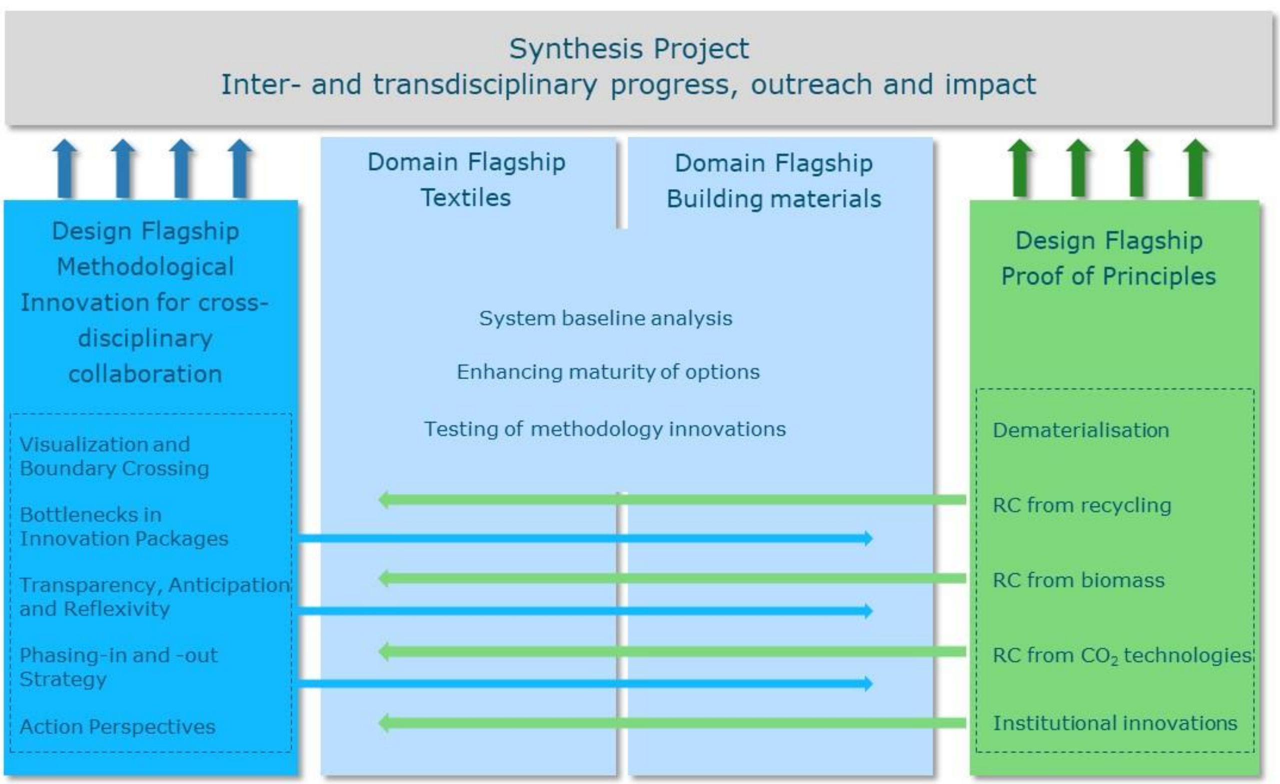
- Increase societal impact (directionality, policy, learning, pathway development) in the direction of a renewable carbon-based materials transition.
- Enhance the technical and societal maturity/readiness of specific options as part of a transition pathway to contribute to a renewable carbon-based materials transition.

6. Plan

a. *Aanpak waarmee doelstellingen en impact kunnen worden gerealiseerd, gespecificeerd naar onderzoek, onderwijs, waardecreatie (incl. markt).*
Specifieke aandachtspunten:
- Hoe wordt gezorgd voor een brede inbedding in de Sciences Groups?
- Hoe wordt gezorgd voor verbinding met en afbakening ten opzichte van aanpalende initiatieven en reeds lopende projecten / vakken (in ieder geval de link leggen met de kennisbasis-thema's).
- inzet van middelen over de verschillende subthema's
- Hoe wordt gezorgd voor aansluiting op externe stakeholders / netwerken (markt en wetenschap); hoe worden marktpartijen geïnteresseerd / betrokken?

Flagship organisation and leadership

The investment theme will be organised in four Flagships and a Synthesis project (see Figure below). The two Domain Flagships work with societal stakeholders on the 'maturity challenges' identified above in connection with specific options that are identified collaboratively. In doing so, they apply and test innovative methodologies, concepts, tools and modes of working that are developed in a dedicated Design Flagship on 'methodological challenges'. A second Design Flagship works on 'imagination challenges' in the form of 'proof of principle' projects that are link to the challenges in one or both Domain Flagships. Some further details are provided below:



Two Domain Flagships – Textiles and Building materials: These Flagships are primarily responsible for organising and coordinating the interaction between WUR staff and societal stakeholders. Each Domain Flagship will first make a baseline system analysis of the sector, including an inventory of existing innovation initiatives that require (and are open to) further analysis and support. They will choose 4 existing innovation initiatives to work on further from early 2022 onwards (1 per transition pathway) and this will later be complemented with promising 'proof of principle' projects where new innovations are introduced. The Flagship projects will implement and document the use of methodological innovations that are developed in the methodological Innovation Flagship. These two Flagships will be lead by two persons from different disciplines; important criteria for selection include having sufficient process expertise and a good network in the sphere of the application domain. We will also establish a linking pin between the team leading the Domain Flagship and people that are active in the Design Flagship Methodological Innovation; this to ensure that Domain Flagships have a good knowledge and understanding of the methodologies available to them.

A Methodological Innovation Design Flagship: This Flagship proposes and develops methodological innovations that can be used in the domain flagships. A call will be developed to which cross-disciplinary teams can respond with methodological and conceptual ideas that have clear potential to support effective bridging across different worlds of expertise, and which are likely to enhance concerted action towards transition. Creative sessions will be organized (starting of February 3rd) to support inspiration and team formation. In order to ensure swift start we can already start work on one specific methodological innovation, which involves identification of interdependent core and complementary innovations (social, technical and nature-based) in an 'innovation package' and an assessment of bottlenecks through assessment of the 'scaling readiness' of elements in a package (Sartas et al.,2020). This Design Flagship will be coordinated by 2 members of the core team, and each funded projects will have its own project leader.

A Proof of Principles Design Flagship: This Flagship proposes and develops novel options (technical, nature-based and/or social-institutional) that have a potential to contribute to the materials transition, as well as a way of testing these in the form of a 'proof of principle' project. A call will be developed to which cross-disciplinary teams can respond with novel proof of principle studies that align with one or more of the 4 transition pathways described in Section 2. The teams will have to make plausible to both a scientific and societal audiences that their idea is relevant to at least one of the Domain Flagships. The proof of principles projects will feed into the Domain Flagships to ensure that implementation of the proof of principle project fosters exchange and learning across different communities of actors. Creative sessions will be organized (starting of March 8th) to support inspiration and team formation. This Flagship will be coordinated by 2 members of the core team, and each funded projects will have its own project leader.

The Synthesis Project: A special project will be created to support the implementation and coordination in the investment theme. Another core task is to synthesize and document the outcomes of the investment theme. The latter will involve comparative analysis across several angles:
- comparing the eventual potential of different transition pathways across the two domains;
- comparing the contribution of methodological innovations in different settings (domains, pathways, options and associated stakeholder networks);
- comparing transition and innovation system dynamics in different domains or pathways;
- etc.

An elaborate proposal will be developed by the core team. One or more postdocs will be employed to work in the synthesis project. We will strive to select people who can work part-time in the synthesis project and another part of their time in another Flagship so that we have full-time capacity available for the investment theme. Furthermore we will give room for WR personnel to work part-time within WU, to build longer time collaborations and strengthen the bond between WR and WU in general.

Composition and role of the core team

The core team is well balanced in WU/WR, Gender, Focus and Seniority

The team is led by Cees Leeuwis SSG WU and Harriëtte Bos AFSG WR
Team members are: Sineád O'Keeffe PSG WR, Solen le Clech ESG WU, Henri Holster ASG WR, Harry Bitter AFSG WU, Wouter Post AFSG WR, Anne-Charlotte Hoes SSG WR, Barbara van Mierlo SSG WU

The core team will have an active role in the program. The synthesis project, the methodology flagship and the Proof of Principle flagship will be coordinated by couples from the core team.
To avoid conflicts of interest the core team members will not be project leaders of the small projects originating from the call for either methodology or proof of principle projects, or the domain flagships.

7. Communication

a. *Communicatie- en kennisverspreidings- en doorstromingsparagraaf over onderzoeksresultaten (hoe, wanneer en aan wie).*

As this project works in a transdisciplinary mode, communication is an integral component in many activities. The Domain Flagships involve close interaction with societal stakeholders, and several methodological innovations that are being developed and tested can in fact be seen as novel communicative tools to enable and enhance effective collaboration between various communities of actors. Thus, communication is not an 'end-of-pipe' consideration, but happens along the entire process.

In addition each project will need to focus part of the budget on preparation of peer reviewed papers.

Furthermore, a theme-wide communication strategy and activities will be set up together with corporate communication..

For daily support, a communication consultant via Team Communication will be invited to the core team meetings if relevant to manage communication output and impact. The communication consultants responsibility for the communication and marketing budget (as stipulated annually in the investment theme program budget) to decide upon, together with the core team, the production of activities and communication means e.g. events, video, website etc..

The connection with LNV and dissemination of results is done in regular meetings with the LNV representative Pauline Buffing (LNV-SKI).

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FASE II

8. **Organisation (see above)**
    - **a.** *Organisatie van het thema: kernteam, samenstelling thematеam, wie doet wat?*
    - **b.** *Wie zijn betrokken en op welke manier?*

9. **Finance/projects**
    - **a.** *Geef aan (in tabelvorm) welke projecten uitgezet worden*
    - **b.** *Geef aan wat de verwachte inzet van middelen is.*
    - **c.** *Geef aan waarom de middelen op deze manier ingezet worden.*
    - **d.** *Welke matchingsmogelijkheden (verwachte multipliers) zijn er?*

Voorbeeld projectentabel

Name Investment theme	Year start	Year end	Project leaders	BAPSCODE	Inzet KB 2022 Ex BTW	Inzet KB 2022 Inc BTW	Inzet WU 2022 ex BTW	Inzet WU 2022 inc BTW	Project/result
Large projects									
Synthesis Project	2022	2024			65		65		
Domain Flagship Textiles	2022	2024			75		75		
Domain Flagship building	2022	2024			75		75		
Methodology flagship	2022	2024			75		75		
Proof of Principle flagship	2022	2024			75		75		
total					**365**	**0**	**365**	**0**	
Small projects									
Methodology project	2022	2022			25		25		
Methodology project	2022	2022			25		25		
Methodology project	2022	2022			25		25		
PoP project	2022	2022			25		25		
PoP project	2022	2022			25		25		
PoP project	2022	2022			25		25		
PoP project	2022	2022			25		25		
total			.		**175**	**0**	**175**	**0**	
Education									
Course tbd									
Student Challenge	2022	2023			30		30		
Total					**30**	**0**	**30**	**0**	
Communication									
Dialogues/community day	2022	2024			25		25		
Communication strategy	2022	2024			25		25		
Conference on the theme	2022	2024			0		0		
Total					**50**	**0**	**50**	**0**	
Coordination									
Coordination + secretarial support	2022	2024			47		47		
Total					**47**	**0**	**47**	**0**	
Overall total					**667**	**0**	**667**	**0**	