Sustainable path creation for innovative value chains for organic waste products (SusValueWaste)

1 Introduction

The proposed project will address the potential for value added and improved sustainability in the valorisation of organic waste streams, residual feedstock and by-products (short: OW) – by analysing value chains inside and across different sectors of the bioeconomy. We will analyse a number of industrial cases from different parts of the bioeconomy and collaborate with highly relevant industry actors (e.g. TINE, Cambi, Nortura/Norilia) and technology experts (e.g. Østfold Research, Forestry & Landscape, LTH). The project will help policymakers better govern and regulate the OW industry and the industry actors to identify and exploit new opportunities in the bioeconomy.

Waste and other residual materials from industries and households are of increasing value in today's economy. Substances that have long represented a cost to the economy are becoming a valuable resource, due to changes in technology that enable a greater share of their potential to be extracted. Still, Norway incinerates almost 58 per cent of what is currently defined and registered as wet-organic and wood waste and use, by comparison, less than 3 per cent of these waste resources to produce biogas and fertilizer (Source: Statistics Norway). The manufacturing sector produced approximately 48 per cent of this waste, followed by households with only 25 per cent; and this constituted over 20 per cent of the total waste production Norway. The numbers do not include materials that are at present directly reintroduced into the natural environment, e.g. sludge from fish farms and waste dumped by fishing vessels. This shows that volumes are substantial while valorisation is low and points to the role of industrial sources.

The project has following main objectives:

1. The project will map *industrial capabilities and research & human resources in the OW related industries*, and consider whether and where policy intervention may be needed.
2. The project will help industrial actors to identify possible *pathways to increase their rate of innovation and value added from OW related activities*.
3. The project will carry out *life cycle assessments* and comparative analyses of *environmental performance of OW value chains and selected case studies* to help government and companies to select environmentally beneficial resources, products and production processes.
4. The project will assess how the *regulatory framework* influences the management of organic waste streams in Norway and in the other Scandinavian countries and how the governance systems supports innovation, industrial development and sustainability.

The Bionær call asks for proposals that contribute to the further development of the Norwegian bioeconomy and address value chain development and the circular bioeconomy through interdisciplinary approaches. Our project focusses on innovative and sustainable exploitation of organic waste streams, residual feedstock and by-products. It contributes to the further development of the Norwegian bioeconomy by collaborating with close to ten companies engaged in OW activities. It addresses value chain development and the circular bioeconomy by combining Value chain analysis (Gereffi & Fernandez-Stark, 2011), innovation systems and transition theory and environmental life cycle assessment (Ekman & Borjesson, 2011; Møller et al. 2012). The whole project is based on interdisciplinary *collaboration* between research groups specializing in innovation (NIFU, TIK, Circle, Centre for Innovation Research), environmental research (LTH, Østfold Research, Forrest & Landscape), value chain analysis and relevant technologies (DTU, NIFU, Østfold Research), located in Norway, Denmark and Sweden. The project will integrate multiple disciplines and theoretical approaches and be based on true interdisciplinarity rather than parallel, unrelated research activities.

2 Background and status of knowledge

There exist a number of diverging definitions of 'bioeconomy' (Schmid, Padel, & Levidov, 2012). We define bioeconomy as the set of economic activities related to the sustainable production and use of renewable biological feedstock and processes to generate economic outputs in the form of bio-based food, feed, energy, materials or chemicals while maintaining our environment, and protecting

food quality and biodiversity. A 'circular' bioeconomy means that the existing renewable bio-resources are used in an efficient way, which means that possible organic waste, co-products and by-products are treated as a possible resource for the bioeconomy. Strategies to achieve this circularity include following processes: *reduction* of organic waste streams, finding new highly valued bio-products based on the *re-use* of organic by-products, co-products and waste streams, *recycling* of organic waste, and *recovering of the energy content* of organic waste streams. Especially relevant is crossing existing sectoral borders in the bioeconomy: waste streams and by-products from agriculture might become a resource for aquaculture or biochemical industry or vice versa. However, the term circular bioeconomy is a kind of ideal term: there are always some materials, which will be lost or which will degrade as they pass around the circular loop.

The project seeks to understand pathways to a circular bioeconomy in Norway by identifying and studying innovative value chains for products based on organic waste streams, residual feedstock and by-products. Such pathways emerge as a result of a new, dynamic interplay between i) *technology and sustainability;* ii) *industrial capabilities,* and iii) *regulatory frameworks.* Currently, these three factors tend to be studied in isolation and the result has been fragmented descriptions of the bioeconomy. Our study on the other hand, focuses on the interplay between these three factors and makes use of several theoretical frameworks. These frameworks originate from different scientific disciplines (both natural and social sciences), and deals with different aspects of the bioeconomy. One of the main goals of the project is to integrate these frameworks into a coherent and truly interdisciplinary approach that captures the interplay between technology and sustainability, industrial capabilities and regulatory frameworks. The following theoretical perspectives will be important in the project:

Multi-level perspective (MLP): In recent years, the sustainability transitions has become a popular approach to study transformative systemic changes through a multi-faceted and evolutionary perspective (Markard, Raven, & Truffer, 2012). This work has examined the role that technological niches play in developing transformative systemic change in the face of relatively stable regimes (Schot & Geels, 2008). Existing systems of provision and services tend to be difficult to dislodge because they are stabilised by regimes and lock-in processes that lead to path dependency and 'entrapment', constraining alternatives (Grin, Rotmans, & Schot, 2010). One means via which the governance of transitions is thought to proceed is through strategic niche management (Kemp, Schot, & Hoogma, 1998) – whereby governments, or other actors, deliberately seek to establish conditions under which niches for innovation can grow and 'breakthrough' existing regime conditions. The potential of niches to lead to regime transition is thought to depend on growing the social networks, innovation, and learning that they establish (Szejnwald Brown & Vergragt, 2008). Emphasis has been placed on the role of niches as protective environments that provide space for the development, testing and failure of novel innovations, and where new networks can be supported and sustained (Geels, 2014; Smith & Raven, 2012).

Technological innovation systems (TIS): While the transition approach has proven to be highly resourceful in explaining historical cases of transformative systemic change, its systemic perspective may have come at the expense of a more actor- and agency-oriented analysis (Coenen & Díaz Lopez, 2010). More empirical and theoretical research is needed to understand how strategies, resources and capabilities of individuals, firms and other organisations impact the overall system and trigger transformation processes, and how these changes at the system level feed-back into the observed strategies at the actor level (Farla et al., 2012). A TIS is defined as: "network(s) of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilisation of technology" (Carlsson & Stànkiewicz, 1991:111). The TIS theory has proven highly useful for analysing the industrial dynamics and drivers and constraints of innovation processes that take place in the emergence and formations of new technology-based industries (Bergek, Jacobsson, & Sanden, 2008). Whereas initial studies primarily conducted analyses at the meso-level, there is an increased and explicit interest in the micro-level foundations of technological innovation systems (Bergek et al., 2014). The project

will elaborate on the interplay between micro-level foundations and innovation system dynamics through various inroads.

Global value chains (GVC): The literature on global value chains suggests a focus on 'vertical' relationships between buyers and suppliers and the movement of a product from producer to consumer, also in a local and national context. Many studies have been concerned with how power and rewards are embodied and distributed along GVCs; issues that have been underemphasized in many TIS studies (Bergek et al., 2014). Governance is the process by which so-called 'lead firms' organise activities with the purpose of achieving a certain functional division of labour along a value chain, resulting in specific allocations of resources and distributions of gains. It involves setting of the terms of chain membership, the related incorporation/exclusion of other actors, and the re-allocation of value-adding activities (Gereffi, 1994; Kaplinsky, 2000). Recent literature points out that external actors such as governments, multilateral institutions, and NGOs can significantly influence GVC governance (Ponte, 2007; Riisgaard, 2009), especially in emerging industries, thus creating multipolar chains (Ponte, 2014). In GVC analysis the concept of upgrading is used to identify the possibilities for producers to 'move up the value chain', either by shifting to more rewarding functional positions, or by making products that have more value-added invested in them or that provide higher returns. The upgrading process is examined through the lenses of how knowledge and information flow within value chains (Gereffi, 1999) and displays similarities with innovation system approaches. Upgrading is about acquiring capabilities and accessing new market segments through participation in particular chains.

Life cycle assessment (LCA): The theoretical framework for the environmental systems studies of the OW value chains will be based on the methodology of life cycle assessment (LCA) according to the standard 14044 by the International Organization for Standardisation (ISO, 2006) and further developed into Environmental Product Declarations (EPDs) in ISO 14025. ISO 14044 opens up for further methodological development and adaption in relation to the specific production systems studied. Such methodological development and adaption have been performed in previous research projects, for example, at LTH regarding LCA of bio-based biorefinery systems (see e.g. Tufvesson, Tufvesson, Woodley, & Borjesson, 2013; Törnvall, Börjesson, Tufvesson, & Hatti-Kaul, 2009) and in Ostfold Research for biogas value chains (Lyng et al. 2011, Møller et al. 2012) and for advanced biorefineries (Modahl et al., 2009). Especially emerging production systems based on organic waste feedstock refined to high-value products are complex to assess from an environmental point of view since several different reference systems need to be considered (Ekman & Borjesson, 2011; Ekman et al., 2013, Modahl et al., 2009). Such assessments need to expand the system boundaries and apply a consequential approach and, in addition, utilise dedicated life cycle inventory data taking into account specific local conditions (Tufvesson, Lantz, & Börjesson, 2013).

Multi-level governance: Multi-level governance is a theoretical approach developed in political science. It characterizes the changing relationships between actors situated at different territorial levels. Marks defined multilevel governance as "a system of continuous negotiations among nested governments at several territorial tiers" (Marks, 1993:392). Gupta highlights the differences in driving forces, available instruments and policy mandates in local and national policy, which can lead to contradictory or complimentary policies at different levels of governance (2007). Other studies have concluded that coherence between policies at different levels develops over time and international requirements as well as local conditions can be drivers for it (Monni & Raes, 2008). We can distinguish between vertical and horizontal dimensions of multi-level governance, contributing to policy coordination and policy learning (Kaiser & Prange, 2004).

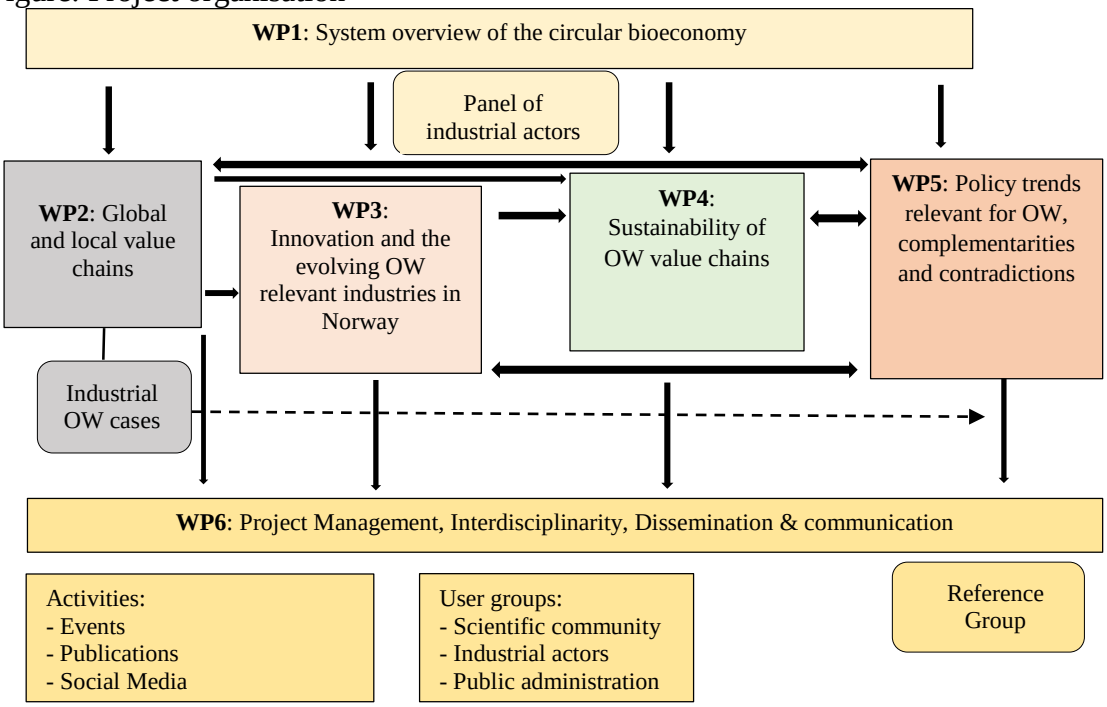
3 Approaches and choice of methods

The project will be organised in five main work packages (WPs). The different WPs will focus on the bioeconomy from different angels. WP2 and WP3 will study industrial capabilities; WP2 and WP4, technology and sustainability; and WP5, policy trends. More specifically the WPs will cover the following subjects and methodologies:

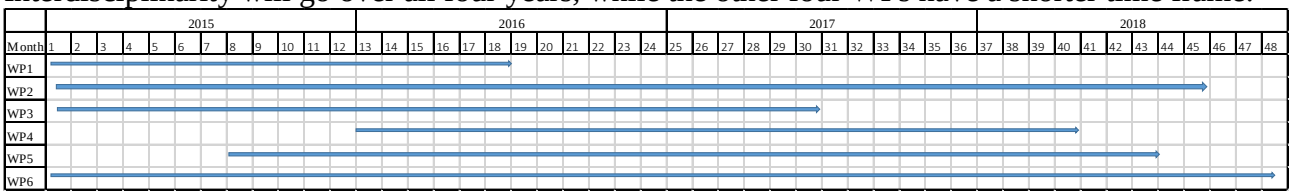
WP1 (System overview of the circular bioeconomy) will provide an overall system overview of the circular bioeconomy, analyse existing visions, setting up and comparing alternative policy scenarios and conduct a foresight study on feasible development scenarios and value chains. WP1 will develop an inventory of existing waste resources and of existing Norwegian actors, a mapping of research and human resources and capabilities in the OW relevant industry, and a foresight study.
WP2 (Global and local value chains) will link localized (i.e. within Norway) capabilities and industrial dynamics to global resources and markets and identify how the existing value chains for bio-based products influence the sustainable value creation from waste streams. WP2 will apply a comparative case study approach.
WP3 (Innovation and the evolving OW relevant industries in Norway) will analyse how diverse technologies and human resources are used by the OW industry and how financial resources and institutional factors specific to the Norwegian economy are influencing, and may in the future come to further influence, the growth of an internationally competitive and thus economically viable OW industry. WP3 will apply statistical analysis on public register and survey data.
WP4 (Sustainability of OW value chains) will evaluate the sustainability implications of present trends and prospected future paths by combining consequential life cycle assessment (LCA) and value chain analysis of OW-based value chains in Norway and Sweden. WP4 will develop a life cycle inventory data set and will apply LCA on the empirical material in WP2, including both conventional LCA and social dimensions (SLCA).
WP5 (Policy trends, complementarities and contradictions) will study the process of policy formulation and implementation for Organic Waste at different levels and sectors of governance. WP5 will carry out document analysis and case studies.
Together the WPs will create a comprehensive and interdisciplinary view of the OW related aspects of the bioeconomy that include the dynamic interplay between technology and sustainability, industrial capabilities and regulatory framework.

4 Project organisation

The WPs are designed to provide an overall system perspective on the circular bio-economy, which enables a systematic and integrated analysis of challenges and opportunities related to exploiting and adding value to OW in Norway in a sustainable way, related environmental issues, value chains, industrial sectors and the relevant regulatory framework.
Figure: Project organisation



A reference group will support the project management.
The project is based on close interactions between the WPs. The system overview (WP1) will give input to WP2–WP5. The foresight study in WP1 will be conducted in collaboration with WP5. The WP2 case studies are informed by insights from WP1 on value chains and the general characteristics and visions of the industry, and draw on WP3 analyses on innovation activities by industry actors. WP2 gives input to WP4 regarding flow of product and inputs along the value chain and to WP5 regarding policy experiences by industry actors in different value chain positions. WP4 will use inputs from other WPs regarding the identification of relevant potential and promising OW value chains (WP1), of value chains related to the identified case studies (WP2) and the influence of the regulatory framework (WP5). WP5 will address the case studies from a policy perspective.
The project goes over four years. WP6 Project management, Communication and dissemination and Interdisciplinarity will go over all four years, while the other four WPs have a shorter time frame:



WP1 – System overview of the circular bioeconomy (month 1–18)

- Number of person months: 28,5+6
- WP leader: Antje Klitkou and Sverre Herstad, NIFU

Participating organisations:	NIFU	TIK	OREEC	NFLI	DTU	CIRCLE	LTH	OR	CIR
Person months	18	7	4	1	1	1	1	1	0,5

Objectives:
WP1 will provide an overall system overview of the circular bioeconomy, analyse existing visions, setting up and comparing alternative policy scenarios and conduct a foresight study on feasible development scenarios and value chains.
Approaches and applied method
We will take stock of Norway's OW resources. In particular, we will compile a current inventory of the different types and sources of this material based on existing data (e.g. SSB), while also exploring how to present the value these composite resources in a standardized way. We provide the basis on which to understand the current extent of OW and to address the question of how to raise the value-extraction from waste resources in Norway.
We will develop an inventory of existing Norwegian actors and their relations regarding OW value chains for realising potentials of a circular bioeconomy and take stock of enterprises and other actors that are active in this area in Norway. We will identify a set of (sub)industries that have grown up in connection with the production / processing of the various by-products /waste feedstock. It will associate industrial classifications (NACE) to these relevant activities both by using information in the national accounts and by consulting a panel of relevant industry experts. Emerging path creation processes, both inside and across the bio-sectors, will be covered in this inventory.
We will focus on the mapping of research and human resources and capabilities in the OW industry, as well as the geographical clustering and mobility of these in Norway. We intend to: i) use linked employer-employee registers to describe the growth of the OW industry in Norway since 2001, ii) map how the internal competence structures firms have evolved during this period, and iii) study their recruitment of various types of expertise (all, highly educated, researchers and managers specifically, from different external sources). This part of the study will build on the extended (cf. Herstad, Sandven, & Ebersberger, 2014) 'industry relatedness framework' of evolutionary economic geography (Boschma, Eriksson, & Lindgren, 2009; Frenken, Oort, & Verburg, 2007), with emphasis on uncovering the domains of the economy with which the recycling industry is 'revealed', by labour

market mobility, to be interdependent (Frank Neffke & Henning, 2013; Timmermans & Boschma, 2014). Based on this, it will iv) describe the geography and institutional dynamics of human resource formation in the industry, and consider whether and where policy intervention may be needed to ensure sufficient diversity in this process.

For studying the visions, trends and expectations of the various actors in the OW value chains we place this work in the context of sustainable transition theory. As has been pointed out above collective visions and expectations play a decisive role for learning processes in emerging technologies. Beside document analysis we will use foresight workshops with different industry actors and experts to discuss identified visions, trends and road maps for the circular bioeconomy.

Description of work and sub-tasks:

1. State-of-the-art study on the contributions of innovation theory to the analysis of the circular bioeconomy and the development of value chains which exploit in a sustainable manner available organic waste streams, residual feedstock and by-products.
2. Inventory of existing waste resources in Norway.
3. Inventory of existing Norwegian actors and their relations regarding OW value chains.
4. Mapping of research and human resources and capabilities in the OW industry.
5. Analysing existing visions, scenarios and road maps for the circular bioeconomy, such as the BioNær programme plan and relevant visions developed in Denmark and Sweden.
6. Foresight study addressing main actors, resources, markets, competencies/ technologies, sustainability, regulative framework, together with industry actors and technical experts, including visioning, trend analyses, road mapping and scenarios of future value chains and involved industrial sectors. This will expand our existing network of industry actors and other experts. We will have sector specific and cross-sectoral working groups.

Deliverables:

D1.1 State-of-the-art paper on circular bioeconomy and valorisation of OW to be presented at international conference (month 5)

D1.2 Report summarizing data challenges, opportunities and preliminary results from sub-task 2 and 3 (month 5)

D1.4 Report on existing visions, scenarios and road maps for the circular bioeconomy in Scandinavia (month 12)

D1.5 Report on Foresight study (month 14)

D1.6 Inventory of existing Norwegian actors and their relations regarding OW value chains (month 14)

D1.7 Scientific article on research and human resources and capabilities in the OW industry in Norway and working paper addressing key aspects of OW industry evolution (month 18)

WP2 – Global and local value chains (month 1–45)

- Number of person months: 57,5+12
- WP leader: Simon Bolwig, DTU

Participating organisations:	NIFU	TIK	OREEC	NFLI	DTU	CIRCLE	LTH	OR	CIR
Person months	20	12		0.5	31	4		1	1

Objectives:

In order to effectively link localized (i.e. within Norway) capabilities and industrial dynamics to global resources and markets, WP2 identifies how the existing value chains for bio-based products influence the sustainable value creation from OW streams in Norway. We then compare different value chains for OW products in a matrix set-up, each value chain case addresses certain aspects, with a synthesis in the end, and draw lessons for bioeconomy development as well as for research.

Description of work and sub-tasks:

Task 2.1 Systematic literature review: Value chain studies exist for the industries covered by SusValueWaste (brewing, dairy, aquaculture etc.), but emphasis has been on the main product (e.g. timber, beer, milk etc.) and few studies have considered associated OW streams or the activities involved in the valorisation of OW. This task will perform a systematic review of value chain studies of the OW-relevant industries, drawing mainly on the GVC and related literature. Based on this review, we:

a. Identify the relevant specific value chains for each industry and summarize their defining characteristics: chain configuration and geographical extent; flow of product, material inputs, and finance along the chain; lead firms and other chain actors and their linkages; the specific roles and positions of Norwegian firms; chain governance; recent chain dynamics and reconfiguration; and key institutional and economic frameworks (drawing on WP3 and WP5).
b. Identify for each industry which characteristics are relevant for the development of innovative value chains for OW products. This information is used in the execution of the case studies (Task 2.2). The hypothesis is that specific characteristics of the products and industries from which the OW originate dictate how the OW value chain develops.

Task 2.2 Case studies of OW value chains: We conduct comparative case studies of OW value chains drawn from across Norway, Denmark and Sweden, drawing on Task 2.1. These studies are centred on the project's case firms and the national, regional or global production networks of which they are part. The studies focus on the configuration, governance, dynamics, and socio-economic performance of the value chains that arise from alternative uses of OW from brewing, dairy, forestry, agriculture, and aquaculture. The value chains include mature and emerging ones, and some combine different sectors of the bioeconomy. We also identify if there are local loops in value chains and whether they compete with or supplement global value chains.

a. The case studies are organised in a matrix, where each value chain case study focuses on certain characteristics and issues, identified based on insights from WP1, Task 2.1, and interviews with the case firms. We do a documentary review followed by interviews with chain actors, starting with the case firms and proceeding to other actors, up- and down-stream from these firms. Sector specialists from the project team contribute to the case studies as appropriate.
b. The analysis of the socio-economic performance of OW value chains focuses on employment effects, quantified and localized through a survey of the firms participating in these value chains (Gereffi & Fernandez-Stark, 2011). This analysis will draw on WP3. Combined with the LCA (WP4), this enables a multi-criteria assessment of OW value chains, and facilitates an analysis of the environmental and economic trade-offs of utilizing OW.
c. A synthesis of the case studies is produced in the end, identifying general trends and patterns as well as strategic lessons for a value-chain approach to bioeconomy development.

Task 2.3 Lessons for value chain research on the bioeconomy: We use Task 2.2 analyses to critically engage with the value chain literature (Task 2.1), discussing how concepts and methods used by value chain scholars can be developed to better account for the characteristics and needs of the bioeconomy.

Deliverables:

D2.1 OW value chain literature review submitted for an international conference (M6)
D2.2 Common case study format developed and shared among project partners (M10)
D2.3 Case study summaries completed (M28)
D2.4 Manuscript on economic and environmental trade-offs in OW utilization submitted to journal (M39)
D2.5 Manuscript on value chain analysis as applied to OW submitted to journal (M45)

WP3 – Innovation and the evolving OW relevant industries in Norway (month 1–30)

- Number of person months: 33,5+12
- WP leader: Fulvio Castellacci (TIK)

Participating organisations:	NIFU	TIK	OREEC	NFLI	DTU	CIRCLE	LTH	OR	CIR

Person months	16	28			1				0,5

Objectives

The objective of this work package is to analyse how human, financial and technological resources interact in the formation of OW-related activities.

Theoretical framework

The work package will build on evolutionary economics and innovation systems. The main idea is that a nascent innovation system will have better prospects of growth if it has actual or potential structural overlaps with existing systems or knowledge bases in the country, and particularly in neighbouring regions. New industries are more often than not dependent on accessing and exploiting competences already developed and applied in other domains of the economy (Boschma & Frenken, 2009; Neffke, Henning, & Boschma, 2011). Understanding current and emerging labour market segments around OW-based industrial activity is therefore of high importance, because it reveals interdependencies and bottlenecks. New firms' entry in the OW business, however, does not only demand the availability of human resources, but also financial capital to make the necessary investments for the purchase of physical capital and machineries embodying state-of-the-art recycling technologies. The role of expectations is very important here (see WP1). Hence, the policy and institutional framework represents an important enabler of new industrial niches' development process, particularly through its effects on agents' set of economic opportunities and incentives. Related to these two dimensions is how RD&I collaboration that facilitate technological development, knowledge transfer and the sharing of high sunk costs in the early stage of the industry life cycle.

Description of work and sub-tasks:

Building on the mapping of OW activity in WP1, WP3 will carry out three related research activities. *First*, we intend to use linked employer-employee data, patent data, R&D/innovation surveys and the Amadeus database on funding/ownership to study firm demographics and innovation patterns in the recycling industry. This and WPs 1, 2 and 5 will, *second*, form the basis for a dedicated survey targeting companies that are part of OW value chains by administering a questionnaire to companies in Norway, Sweden and Denmark. The intention is to provide more in-depth knowledge of inter- and intra-sector linkages, interdependencies and constraints on future development. *Finally*, we will make use of system dynamics modelling to create a stylized model of the Norwegian OW industry. The SD model can be used not only to summarize the status of development of the sector, but also to investigate future scenarios that may be realized depending on different policy developments, and the dynamics of international and domestic markets. This policy scenario analysis will represent a natural bridge to the research that will be carried out in WP5 on the policy conclusions of the project.

Deliverables:

D3.1 Report summarising data challenges, opportunities and preliminary results from Activity 1 and 2 (month 5)

D3.2 Working paper on firms' interactions within the OW value chain (month 10)

D3.3 Working paper on relations between regional and domestic networks and global innovation networks (month 16)

D3.4 Scientific article on interactions within and between different OW value chains in Scandinavia (month 24)

D3.5 Scientific article on system dynamics modelling of the Norwegian OW industry (month 30)

WP4 – Sustainability of OW value chains (month 13–40)

- Number of person months: 38+6
- WP leader: Ole Jørgen Hanssen, Østfold Research & Pål Börjesson, LTH

Participating organisations:	NIFU	TIK	OREEC	NFLI	DTU	CIRCLE	LTH	OR	CIR
Person months	2	6		1	1		20	11,5	

Objectives:
In order to evaluate the sustainability implications of present trends and prospected future paths we will combine life cycle assessment (LCA) and value chain analysis of OW-based value chains in Norway and Sweden. Both potential and promising OW value chains and the value chains in the case studies will be assessed and compared through scenario analyses with current OW handling systems and alternative high-value products.

Theoretical framework
The theoretical framework for the environmental systems studies of the OW value chains will be based on the methodology of life cycle assessment (LCA) according to the standard 14044 by the International Organization for Standardisation (ISO, 2006). The assessments will cover the complete production chain, from raw materials to final end products, and related inputs of energy and resources and outputs of emissions etc., based in a relevant functional unit for comparative analyses. Focus will be on carbon footprint, energy and resource efficiency and other relevant environmental categories. However, the ISO 14044 opens up for further methodological development and adaption in relation to the specific production systems studied. Such methodological development and adaption has been performed in previous research projects, for example, at LTH and Ostfold Research regarding LCA of biobased biorefinery systems (see e.g. Tufvesson, Tufvesson, et al., 2013; Törnvall et al., 2009, Modahl et al. 2009). Especially emerging production systems based on organic waste feedstock refined to high-value products are complex to assess from an environmental point of view since several different reference systems need to be considered (Ekman & Borjesson, 2011; Ekman et al., 2013). Such assessments need to expand the system boundaries and utilise dedicated life cycle inventory data taking into account specific local conditions (Tufvesson, Lantz, et al., 2013). Depending on how the organic wastes and by-products are handled/utilised today, the environmental performance of the emerging OW value chains will differ. The current reference waste handling systems and systems for utilising by-products may change over time due to changes in biomass feedstock volumes, which in turn may lead to changes in the existing markets. Thus, the environmental assessments performed in this WP will include both evaluations of the specific value chains in the project, new potential value chains by scenario analyses and development and adaption of the LCA methodology. Furthermore, the assessments will contain comparisons with existing standardisation systems of biobased products (chemicals, fuels etc.) regarding various sustainability criteria, including Social LCA.

Description of work and sub-tasks:
1. Review of scientific publications, statistical material and existing LCI data bases.
2. Assessment of overall environmental performance and sustainability (focusing on carbon footprint, energy and resource efficiency, and additional environmental categories of special relevance) of potential and promising OW value chains based on a system expansion approach including comparisons with current OW handling systems and alternative production routes of target products (often fossil feedstock based).
3. Development of a life cycle inventory data set regarding OW feedstock and conversion technologies for the case studies studied in WP3.
4. Evaluation of the overall environmental performance and sustainability of the OW value chains case studies in comparison to international sustainability standards for bio-based products, fuels and chemicals.

Deliverables:
D4.1 State-of-the-art study on relevant LCA methods and value chain analysis, including Social LCA (month 16)
D4.2 Review and updating of LCI data from previous studies in Norway and elsewhere (month 16)
D4.3 Scientific article on assessment of overall environmental performance and sustainability of potential and promising OW value chains, including Social LCA (month 22)
D4.4 Life cycle inventory data set regarding OW feedstock and conversion technologies for the case studies (month 30)

D4.5 Scientific article on overall environmental performance and sustainability of the OW value chains in the case studies (month 38)
D4.6 Final report (month 40)

WP5 – Policy trends, complementarities and contradictions (month 8–43)

- Number of person months: 51,5+12
- WP leader: Kyrre Lekve, NIFU

Participating organisations:	NIFU	TIK	OREEC	NFLI	DTU	CIRCLE	LTH	OR	CIR
Person months	30,5	25	2	1	1	3	1		

Objectives:
The objective of this WP is to study the process of policy formulation and implementation for Organic Waste at different levels and sectors of governance. This will include how these levels and sectors interact in determining the overall policy context in which R&D capacity, industrial competences (WP2), new technologies and value chain configurations (WP3) emerge and influence the entry, exit or selection of alternative pathways with different sustainability implications.
Theoretical framework:
Contradictions in policy goals and loose integration of sectoral policies hamper the development of bioeconomy. Important policy areas affecting waste management include industrial policies to preserve agriculture, aquaculture and forestry industries, environmental policy, aimed at mitigating climate change, and biotech policy designed to regulate the introduction of genetically modified organisms. Each of these policy areas are comprised of a diverse set of policy actors and stakeholders that pursue different and occasionally conflicting policy goals, which will be addressed in collaboration with WP1. Better coordination and integration of existing policies is hence wanting. For example, at the European level a number of sectoral policies have been put in place to support the development of a bio-based economy (Horizon2020, Common Agricultural Policy, Lead Market Initiatives and Key Enabling Technologies). However, the lack of integration between policies and initiatives create contradictions in policy goals and perceptions of uncertainties and risks.
Description of work and sub-tasks:
First, we review the scientific literature analysing the role of environmental waste policies in creating an environmentally sustainable and competitive (innovative) OW management industry. This is done mainly through an analysis of policy documents and regulations. Second, we identify the main policies and regulations relevant for OW management in Norway, including relevant EU policies and directives. We then proceed with doing interviews with the case study companies and policymakers, drawing on the industry case studies, the panel of industrial actors and other experts identified in WP1 and WP2. The document analysis and literature review will support the development of the interview questionnaire. Interviews will be framed in cooperation with findings emerging from other WPs.
This WP will contribute to the understanding of how different sectoral policies and levels of governance for OW are working and in what way they give rise to conflicting policy goals and contradictory (or complementary) policy initiatives. The WP will adopt a case study approach to investigate the following questions:

1. What are the main characteristics of the policy framework at different levels of governance (EU, national, local) concerning organic waste management?
2. What are the main contradictions and complementarities of sectoral policies and initiatives and how do they affect the overall policy context for R&D, industrial competences, technology development and value chain configuration?
3. What are the companies' strategies and firms' expectations regarding the policy framework and how do they react on conflicts of interest, changes and constraints?

4. How does the policy framework influence waste management in Norway and in the other Scandinavian countries concerning i) Innovation ii) Industrial development iii) Sustainability?

Deliverables:

D5.1 Report summarizing the findings from the analysis of policy documents and academic literature (month 14)

D5.2 Report presenting results from the interviews with companies and policy makers (month 20)

D5.3 Scientific article about comparison of policy framework at different governance levels in Scandinavia (month 20)

D5.4 Scientific article about companies' strategies and expectations regarding the policy framework (month 30)

D5.5 Scientific article on the influence of the policy framework on innovation, industrial development and sustainability (month 41)

D5.6 Final WP report with policy recommendations, which will feed into the overall conclusions of the project (month 43)

WP6 – Project management (month 1–48)

- Number of person months: 24,5
- WP leader: Antje Klitkou (NIFU)

Participating organisations:	NIFU	TIK	OREEC	NFLI	DTU	CIRCLE	LTH	OR
Person months	17	2	1	0,5	1	1	1	1

Objectives:

This work package focuses (1) on the overall management and coordination of the project, (2) on communication and dissemination of research results and (3) on interdisciplinary and trans-disciplinary collaboration.

Description of work and sub-tasks:

We will introduce the challenges of interdisciplinary and transdisciplinary collaboration in this large project at the kick-off meeting of the project. The concept of "guiding principles" will be introduced and participants will on developing basic guiding principles for information sharing and involvement. These guiding principles will provide a shared platform for the project work and a set of tasks designed to further interdisciplinary collaboration will be developed based on this platform. Developing interdisciplinary tasks in this way is experimental (although not entirely new); we therefore propose monitoring, feedback and adjustment of these tasks as necessary during the project. We suggest that a facilitator working across the different WPs attending meetings assists in identifying relevant issues and arranges appropriate arenas for resolution of issues and takes responsibly for monitoring progress.

1. Establishment of project organisation, monitoring and reporting to the Research Council
2. Establishment of and coordination with Reference group.
3. Further development of communication and dissemination plan.
4. Coordination of partner communication, and organisation and logistics of project meetings, such as annual seminars, open workshops and final conference.
5. Coordination of authors, quality control and manuscript preparation.
6. Organisation, facilitating and coordination of communication with stakeholders, organisation of stakeholder meetings in cooperation with WP1–5.
7. Dissemination of results and outreach to general public in cooperation with WP1–5.
8. Promoting interdisciplinary and transdisciplinary collaboration.
9. Development of policy recommendations based on the results from the project, and involvement in policy processes.

NIFU will have the main responsibility, supported by representatives from the other partner organisations. Representatives from all partners will participate. Antje Klitkou will lead the team,

Kyrre Lekve will be responsible for communication and dissemination and Dorothy S. Olsen for issues related to interdisciplinary and transdisciplinary collaboration.
The project management will coordinate and monitor all the other work packages. Interaction with the Reference group will be the responsibility of the project management. We plan different types of activities addressing different user groups: the scientific community, industrial actors, public administration and the general public. We plan a number of *events*, such as a series of workshops for the foresight study in collaboration with RCN, Bionær. We will organise annual seminars, open workshops with public administration and industry, workshops with panel of firms, presentation at workshops for relevant industrial network organisations, and a final conference.
We will disseminate the results through different *publication channels*, such as reports and working papers, papers at international scientific conferences (ca. 30), scientific articles, including two special issues in recognised international journals (ca. 20), magazine articles and general media dissemination, and a book project synthesising results.
We will different *social media* to inform regularly about our project, such as a project website, accounts at LinkedIn and Twitter.
Deliverables:
D6.1 Detailed communication and dissemination plan (month 2)
D6.2 Agreement with Reference group (month 3)
D6.3 Working paper: Guiding principles for interdisciplinary collaboration in the project (month 4)
D6.4 Annual reports (month 12, 24, 36)
D6.5 Policy recommendations (months 11, 23, 35, 47)
D6.6 Final report (month 48)

5 Collaboration and expertise of applying institutions

5.1 National collaboration

NIFU is the leading Norwegian research institute for studies in innovation, research, and education. The mission of this independent social science research institute is to provide theoretical and practical insight into the dynamics of these activities, while contributing to relevant policy development. NIFU is financed by assignments and receives a core grant from The Research Council of Norway. The institute undertakes research and analysis for a number of Norwegian and international agencies and organisations. NIFU aims to improve our understanding of innovation, research, and education in social systems. The institute is combining theoretical and empirical methods from a variety of research areas and disciplines and is encouraging cooperation across disciplinary frontiers. NIFU has currently some 80 employees, of which 70 are researchers.
TIK Centre for Technology, Innovation and Culture represents ten years of groundbreaking research, education and research communication in Science and Technology Studies and Innovation studies. The Centre consists of approx. 25 staff members and offers postgraduate education (Masters, PhD and PostDocs). TIK participates in a number of international research networks and about 30 per cent of TIK research is funded by The Research Council of Norway and the EU framework programmes.
Østfold Research is a leading research centre in LCA and Environmental Value Chain analyses in Norway, with 20 years of experience in applied research related to waste systems. Østfold Research has developed several models for environmental and economic analyses of organic waste and bio-based products.
The *Norwegian Forest and Landscape Institute* (NFLI) is one of Norway's foremost scientific institutions regarding the use of forest resources, forest ecology and the environment.
OREEC is a network of companies, research institutes, educational institutions and local authorities within clean-tech in the greater Oslo region, Norway.
The Centre for Innovation Research (CIR) is a joint centre between the University of Stavanger (UoS) and International Research Institute of Stavanger (IRIS). It is a multidisciplinary centre with research on innovation processes and their effects at all levels from firms via sectors and regions to countries. Several researchers focus on natural resource based sectors, including environmental and sustainability issues.

5.2 International collaboration

CIRCLE is an interdisciplinary centre of excellence spanning several faculties ay Lund University and one of the largest and most well-known research centres in Innovation Studies in Europe. Research at CIRCLE aims to understand how innovation can help tackling societal challenges, like economic crises, climate change or increased globalization of economic activities. This requires understanding of how knowledge is created and diffused in organizations, networks, regions and countries, how knowledge is turned into innovations, and which conditions promote the diffusion of innovation, as to enhance its impact on society. CIRCLE covers a range of research topics in Innovation Studies which are organized around 5 research platforms: (1) Innovation and Entrepreneurship (2) Innovation, Skills and Strategies (3) Innovation Systems and Innovation Policy; (4) Globalization of Innovation; and (5) Sustainable Transitions. Platforms interact and collaborate, because Innovation Studies is a research field that is inter-disciplinary by nature.

LTH: The Department of Environmental and Energy Systems Studies (EESS), Faculty of Engineering (LTH), Lund University, Sweden, has for three decades been at the forefront of research in the closely interlinked spheres of energy, renewable resources, environment, technology, economy and development. One important research area is the role of biomass in a sustainable bio-based economy and the environmental performance of, for example, organic waste-based value chains from a life cycle perspective. The department has an extensive research collaboration with both national and international universities, institutes and companies.

DTU: The Department of Management Engineering, *Technical University of Denmark* (DTU-MAN), provides industry, private and public organizations, and society at large with cutting edge management knowledge and competences for creating solutions to address grand challenges and improving success based on close interaction of management, engineering, economics, and natural sciences. The Systems Analysis Division at DTU MAN employs about 40 researchers and PhD students, covering several disciplines including economics, engineering, human geography, and natural sciences, organised in two research groups: Energy Systems and Climate Change and Sustainable Development.

5.3 Collaboration with industry

Interaction with industry will be ensured through different arenas: the *panel of industry experts* that will be started already in WP1 and will be used throughout the project, the *industry case studies* that will be started in WP2 and will interact with the other WPs (3–5) as well, and the participation in the reference group. The industry case studies will concentrate on Norwegian cases, but Danish and Swedish cases will be added as well. At the moment, we have signed letters of confirmation to collaborate from following firms, but others will follow if we receive the funding:

- *TINE*, Norway's largest producer of milk, cheese and other dairy products;
- *Norilia*, a subsidiary established by Norway's largest meat producer Nortura to develop new value added from Nortura's rest products;
- *Cambi*, a Norwegian technology provider for the conversion of biodegradable material to biogas, and biosolids/fertilizer, operating a global market;
- *EGE*, the Waste-to-Energy Agency of Oslo City with its biogas plant, which treats organic waste from Oslo and its surroundings and produces biogas and organic fertilizer; and
- *Aquaponics*, a small Norwegian company that is combining agriculture with hydroponics;
- *Carlsberg Group*, one of the largest brewer in the world with its Norwegian subsidiary, Ringnes.
- *Treklyngen*, a Viken Skog subsidiary to develop value added and value chains on forestry products.

Beside these arenas of collaboration, the industry partners will be invited to participate in the annual seminars, co-author magazine articles with our researchers and discuss and disseminate the results in other fora.

5.4 PhD and PostDoc Fellowships – teaching environments

We plan one PhD and two PostDoc positions, and research stays at partner organisations.

TIK has long experience supervising PhD and PostDocs in research projects funded by RCN.

LTH: Environmental and Energy Systems Studies, LTH, plan for research stays at the Østfold Research Institute and NIFU during a period of approximately 2 months in total.

6 Key perspectives and compliance with strategic documents

6.1 Compliance with strategic documents of the applicant institutions

NIFU: This project fits very well with NIFU's strategy for 2010 to 2014. Research within energy and environment is emphasised as one of the scientific priorities for the institute. Furthermore, cooperation with national and international partners is an important priority for NIFU. Especially the collaboration with our Scandinavian partners is adding to the relevance of this project for NIFU
TIK has a strategy of strengthening its research group on resource-based innovation that focusses on the development and deployment of environmental friendly technologies.
OREEC's mission is to stimulate innovation and business development through increased cooperation between members and an array of cluster development activities.
Østfold Research has specialised within environmental protection, with focus on reduction of climate gas emissions, energy consumption and waste as well as minimising other environmental impacts.
NFLI is responsible for a range of national mapping programmes and resource inventories related to land cover, forestry, agriculture, landscape and environment.
The Centre for Innovation Research performs studies of the micro foundations and management of innovation processes in enterprises and the public sector and the proposed research is in line with the strategy of the centre.
CIRCLE: Research at CIRCLE is increasingly concerned with innovation in the context of sustainable transitions. International collaboration and policy impact are important dimensions of CIRCLE's research vision, in addition to scientific excellence.
LTH: Environmental and Energy Systems Studies, LTH, focus on the development and implementation of sustainable biomass-based systems from an environmental, economic and social point of view. This include the fulfillment of sustainability criteria in international standardization systems, which will affect the commercialization of OR-based value chains and high-value products.
DTU: The Systems Analysis Division is a well-renowned and internationally recognized research division, especially regarding research in energy systems, the use of biomass and waste products for energy, sustainability assessments, and climate change mitigation and adaptation.

6.2 Relevance and benefit to society

We address challenges and bottlenecks for innovation and value creation in the relevant value chains (i.e., fertilizer, biomaterials, biogas) with regard to political/regulatory framework, sustainability, technologies, and resources, such as capital, competencies, labour force and market opportunities. The results will be relevant for food and bio-based industrial sectors, covering full value chains. For policymakers, ministries, public agencies and regulatory bodies we will identify main possible conflicts of interests, inconsistencies of the political framework, and regulatory requirements for possible future paths towards a sustainable path creation for innovative OW value chains.

6.3 Environmental impact

Apart from air and car travel in connection with the project implementation, the project is not likely to have any direct positive or negative impact on the environment. Project management meetings will avoid unnecessary travelling by using telephone or video conferences.

6.4 Ethical perspectives

The project will follow the Norwegian legal and ethical guidelines for data collection, analysis and publication. All empirical studies will be reported to and archived at the Norwegian Social Science Data Services (NSD). Research findings will be subjected to scrutiny by national and international peers to secure scientific quality and honesty.

6.5 Gender issues

Several female researchers, including a female project manager are part of the project team. We will attempt to recruit female researchers as Ph.D. or PostDoc for the project.

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