A CONCEPTUAL MODEL FOR INNOVATION RESEARCH IN THE BIO-ECONOMY

JONAS VAN LANCKER, EMELY HANSEEUW, LIES KIPS, JARINDA VIAENE AND KOEN MONDELAERS

Institute for agricultural and fisheries research, Belgium

Jonas.vanlancker@ilvo.vlaanderen.be

International Consortium on Applied Bioeconomy Research

ICABR

Paper prepared for presentation at the 17th ICABR Conference

"INNOVATION AND POLICY FOR THE BIOECONOMY"

Ravello (Italy): June 18 - 21, 2013

Abstract

To cope with landscape pressures, such as the increasing resource scarcity, the agrifood-industry is transitioning to a bio-economy. Due to the complexity of the necessary system innovation, supporting research needs to be organized on the interface of different disciplines. Aside from the scientific and technological aspects, biotech researchers have to take into account issues like social norms and legislation, supply chain formation, cost efficiency and logistical challenges to develop marketable innovations. Biotechnological inventions developed based upon the classic science-driven innovation research approach, face a multitude of barriers that prevent end-user adoption, as the research often remains restricted to a single discipline and usually follows a linear process. To identify and circumvent those barriers and the underlying bottlenecks, a methodologically innovative research approach is needed. In this paper we propose an approach which is multi-disciplinary, dynamic, flexible and nonlinear. The resulting conceptual model for bio-technological innovation research, combines sound scientific research with intense multi-stakeholder participation from the initial phase of the research process.

This paper cannot be considered for publication in a special issue of AgBioForum

Key-words: Bio-economy, innovation, stakeholder participation, system innovation, research approach

Introduction

Resources and materials are becoming scarcer due to the increasing production and consumption propelled by demographic changes. Because these trends threaten to undermine welfare worldwide, radical changes towards more sustainability are needed in the material and agri-food system (Paredis, 2011). The agri-food system is mainly organized as a food providing industry, often using wasteful production methods. To cope with the above mentioned landscape pressures, the agri-food industry is making a transition towards becoming a supplier of bio-material for the whole bio-economy. With this transition more of the available biomass will be used in a more efficient way. The bio-economy comprises of those industries that produce renewable biological materials as well as the industries that process those materials into products like food, feed, bio-based products and bio-energy. (OECD, 2013). To realize this transition, incremental innovations alone will not suffice. More radical technological innovations, known as system innovations, are crucial for a successful transition to a more sustainable system (Van Humbeeck, 2003).

Due to its complexity, the applied innovation research providing those innovations will have to be organized on the interface of different disciplines. In order to be called an innovation, an invention has to reach the market (Henry et al., 1991; Ernst, 2001; Van Haverbeke en Cloodt, 2006; Bruns et al., 2008). Biotech researchers and developers therefore have to take into account both techno-scientific aspects as well as the socio-economic aspects such as social norms, legislation, supply chain formation, logistical challenges, cost efficiency, end user adoption and market formation. Classic science-driven innovation research models often focus heavily on the scientific and technological aspects while only briefly examining the socio-economic issues at the end of the research process. This results in a multitude of unrevealed barriers that prevent end-user adoption.

The classic research models, which are often restricted to a single discipline and usually follow a linear process from research over development and demonstration to diffusion, will not suffice to develop innovations that help the agri-food industry's transition. To circumvent the barriers biotechnological inventions face and to identify the underlying bottlenecks, methodologically innovative research approaches are needed. Current literature provides some examples of such new approaches. Bruns et al. (2008) for instance, considers the innovation process to be a dynamic iterative process that involves all relevant stakeholders. Another novel approach is the 'chain linked' innovation model (Gallagher et al., 2012).

In this paper we build on this work and other relevant concepts, such as open innovation and Technological Innovation Systems (TIS), to develop a model for innovation research in the bio-economy. The model is multidisciplinary, dynamic, flexible and nonlinear. The approach takes into account the importance of end-user adoption from the initial phase of the research process. With intense multi-stakeholder participation as the backbone of the model we identified a number of research steps, structural components and research functions needed for biotechnological innovation research. The practical implementation of the model is illustrated by means of three empirical research cases in the bio-economy.

The remainder of this paper is structured as follows: in the next section, the evolution from a linear uni-disciplinary innovation research approach towards a multidisciplinary, flexible and iterative approach is described. Next, the innovation research network, a key element in innovation research, is explored in more detail. All identified key elements for innovation research are then bundled into a conceptual model useful for research in the bio-economy followed by a more detailed explanation of the initial phase of the model, the scope definition phase. Next, three illustrative empirical cases from the bio-economy are described and their use of the scope definition phase is explained. After discussing our findings, this paper ends with formulating some conclusions and avenues for further research.

Innovation Research and Development

To make the transition from agri-food production to a bio-economy, numerous incremental and radical innovations need to be developed. These necessary innovations need to be applicable in the field, wanted by the industry and its supply chains, the end-users, policymakers and special-interest groups. Currently, most agricultural innovation researchers use a linear model of knowledge creation and transfer of technology (Hermans, 2011). This science driven approach is designed to aid in answering a fundamental scientific question, starting from the latest scientific and technological state of the art (SCAR, 2012). These traditionally follow a linear path, assuming that innovation stages follow each other seamlessly (Gallagher et al., 2012). The results are techno-scientifically sound inventions, but are often inapplicable to real world problems. A main reason for the inapplicability are undiscovered bottlenecks which hinder the market adoption. These bottlenecks can originate from different dimensions of the dominant socio-technical regime. Geels (2002, 2005) distinguishes six dimensions that form a socio technical regime: user practices and markets, science, technology, culture, policy and industry. In the bio-economy, examples of potential scientific bottlenecks are characterizing valuable components, stabilizing these components and proving beneficial aspects of components.

Modifying processing machines or harvesting methods are possible technological bottlenecks. Cultural bottlenecks are issues relating to norms and beliefs such as animal welfare or a food (component) from an unconventional source. Possible bottlenecks concerning user practices and markets are the creation of a new market for the innovation or typical user habits which have to be changed. Laws that forbid certain uses of biomass, subsidies that promote certain production methods, abolishment or imposition of quota are examples of policy bottlenecks. Industry bottlenecks are those issues concerning the production and processing of the product. Potential bottlenecks can be lock-ins in organizations, process adjustments that have to be made, logistical challenges or a non-existing supply chain for the possible innovation. In order to identify and develop solutions for the diverse bottlenecks, integrated knowledge of multiple scientific disciplines is required. This human capital needed for biotechnological innovations is far too complex for a single organization (Van Haverbeke and Cloodt, 2006). However, numerous organizations try to generate, develop, build, market, distribute and finance the innovative ideas by themselves (Brocco, 2012). Given that technology is becoming increasingly complex, multidisciplinary and dynamic (Holl and Rama, 2011), the traditional, linear, science driven approach with its uni-disciplinary focus and closed boundaries, is no longer sufficient (Bigliardi et al., 2012).

Innovation is increasingly approached from a systems perspective. One such a system, in addition to national systems of innovation and regional innovation systems is the technological innovation system (TIS), a socio-technical system focused on the development, diffusion and use of a particular technology (Bergek et al., 2008). The system approach views the innovation process as nonlinear and iterative (Bruns et al., 2008; Arnold and Barth, 2012; Gallagher et al., 2012; Pullen et al., 2012). Feedback loops are incorporated in the process to maximize learning and knowledge creation between collaborating partners (Bruns et al., 2008; Gallagher et al., 2012).

The Innovation Network as Key Component for Successful Innovation Research

The participation between different stakeholders is a crucial aspect in innovation research (Bergek et al., 2008; Bruns et al., 2008; Gallagher et al., 2012) because it offers several advantages for the involved parties. Successful stakeholder collaboration requires the researching organization to build an innovation network containing different stakeholder types. Relevant stakeholders for innovation research are members and affiliates of the supply chain: suppliers, intermediate users, end-users, industry associations, financial partners, universities and private research institutions, network organizations, government bodies, NGO's and consultants (Sarkar en Costa, 2008; Huizingh, 2011; Bogers and West, 2012; Chesbrough, 2012). A first important benefit is the access to various types of knowledge from the different stakeholder types. By choosing complementary collaboration partners, an organization can offer its own specific expertise to the project in return for other needed knowledge outside of its core competence (Spithoven and Teirlinck, 2006; Bruns et al., 2008; Voinov and Bousquet, 2010; Kutvonen, 2011; Bigliardi et al., 2012; Gallagher et al., 2012; Holl and Rama, 2012). The present multidisciplinary knowledge increases chances of identifying bottlenecks and formulating solutions to these bottlenecks. A second advantage is the reduced financial cost for the individual company when participating with partners. Although searching for the right partners, convincing them to collaborate and maintaining the relationship will generate additional costs, the cost per partner will be lowered since the costs can be divided among the different partners (Spithoven and Teirlinck, 2006; Sarkar and Costa, 2008; Chesbrough, 2012; Bigliardi et al., 2012). Participation comes with a third advantage: a division of tasks and responsibilities. Correctly dividing tasks leads to the reduction of time needed to complete the research process. This leads to a faster time to market, a fourth benefit of participation (Sarkar and Costa, 2008; Giannopoulou et al., 2011; Chesbrough, 2012 ; Gallagher et al., 2012; Holl and Rama, 2012). A short development time has a positive effect on the probability of market adoption in these volatile times of shorter product life (Drechsler and Natter, 2012) and rapidly changing and evolving problems and needs. This positive effect on probability of market adoption is a fifth benefit of collaboration. In addition to a reduced time to market, there are three other aspects that help increase this probability. First, when consulting stakeholders from an early stage, it becomes possible to gauge which new or improved products, processes or services they are looking for (Von Hippel, 1987; Spithoven and Teirlinck, 2006). Second, involving stakeholders as partners in the research process creates legitimacy, support and credibility for the outcome of the innovation research (Van haverbeke and Cloodt, 2006; Caird et al. 2008; Sarkar and Costa; 2008; Arnold and Barth, 2012). Thirdly, stakeholder involvement means taking their wishes into account, making the formation of the market for the innovation more likely (Von Hippel, 1987; Spithoven and Teirlinck, 2006; Goosen et al., 2007; Sarkar and Costa, 2008; Te Brömmelstroet and Schrijnen, 2010; Voinov and Bousquet, 2010).

Considering these benefits, stakeholder participation is the answer to the multidimensional aspects of innovation research. But how the networks perform at delivering these benefits is influenced by the composition of the network. A high performance innovation network consists of stakeholders that share the same interests and motivations. These interests and motivations result in a mutual vision (SCAR, 2012), which in turn leads to a common final goal for the innovation network (Paredis, 2012). Goal setting offers important guidance and direction to a network. Such a final goal can only be formulated when a certain level of trust is present between the different network players (Wetergren and Holmstrom, 2012). As trust between stakeholders increases, the network cohesion increases (Head, 2008) and the cooperation intensifies (Geels and Raven, 2006). One of the aspects that helps building trust are clear arrangements. For instance, arrangements have to be made about the goals of the different stages of the research, about which stakeholder is going to play what role in the innovation network (SCAR, 2012). The ownership of any intellectual property that is the result of the research effort is another issue that needs to be discussed in an arrangement (Chesbrough, 2012).

A well-structured innovation network can fulfill six functions to facilitate and speed up the innovation research process. These six functions are based on the seven key functions of technical innovation systems and are applied to networks (e.g. Hermans, 2011; Gallagher et al., 2012; Bergek et al., 2008; Hekkert et al., 2007). The first function is adding in knowledge transfers, circulation and development between the different stakeholders. Guiding the direction of the search is a second function of a network. A network of different stakeholders indicates which problems and opportunities they want to see researched and what the solutions should look like. A third function of a network is mobilizing the needed financial and human capital. Facilitating (entrepreneurial) experimentation is a fourth network function. Through providing adequate and complementary resources and because of their insights on industry problems and opportunities, a network can aid in stimulating the necessary experimentation in both the research institutes as well as within the supply chain. The stakeholder network, especially the supply chain partners involved, can aid at identifying potential issues with market formation and help resolve these problems, a fifth function of stakeholder networks. A sixed and last important function of networks is counteracting resistance to change through the creation of legitimacy.

In summary, innovation models have to include stakeholder participation from the beginning of the research. Participation requires the formation of a diverse innovation network that can fulfill its functions. To maximize learning and knowledge creation, the process has to be iterative, flexible and nonlinear. In what follows, the participatory innovation model is developed.

Development of a Conceptual Model Useful for Bio-technological Research

In order to perform innovation research taking into account multiple disciplines, diverse stakeholders, and nonlinear, dynamic aspects, a participatory innovation model is needed. We construct this model based on work from amongst others Bergek et al. (2008), Bruns et al. (2008), Gallagher et al. (2012), Fetterhoff and Voelkel (2006), Wallin and von Krogh (2010), Nambisan et al. (2012) and own insights. The result is a model consisting of eight phases: an innovation impulse, a scope definition and actor identification phase, a stakeholder selection phase, a problem identification and idea generation phase, a project design phase, a research and development phase, real life small scale tests, and the market formation and knowledge diffusion phase.

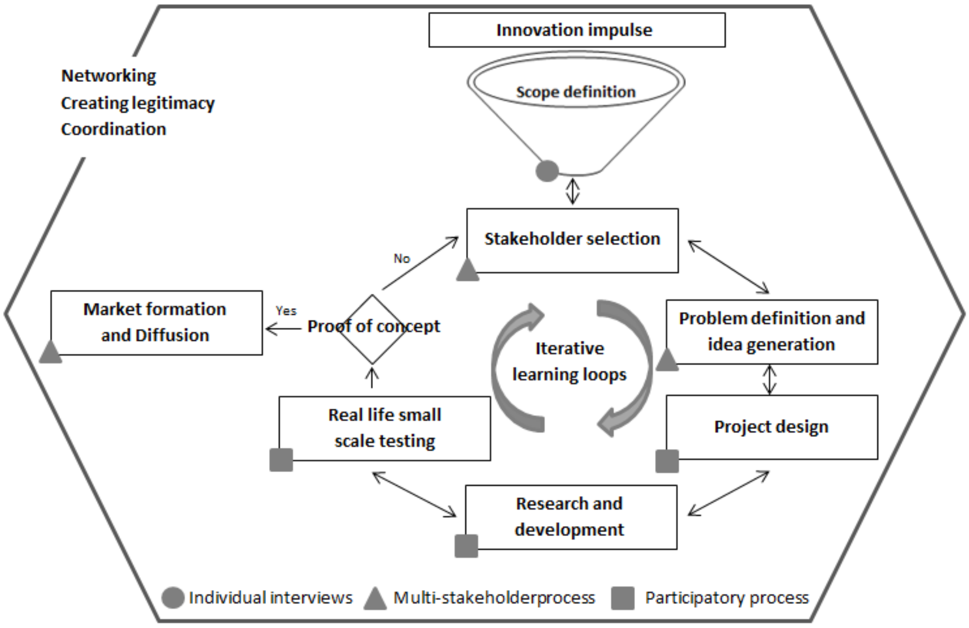
The innovation impulse is the inspiration that starts an innovation research process. It stems from a challenge, opportunity or problem in society, a supply chain, an industry or a single organization. This impulse can thus be diverse in scale and origin. It can originate from a research institution that wants to investigate ways to help remedy a societal pressure such as the increased resource scarcity. Likewise, the impulse can be a logistical problem experienced by a supply chain member.

This impulse leads to the statement of a broad research goal. The broad research goal for the research institute will be 'to develop an innovation that reduces resource use', while the broad goal of the supply chain member will be 'innovate the production process to eliminate the logistical problem'. Whatever the source and scale of the innovation impulse and the resulting broad research goal, it has to be compelling enough for different stakeholders to encourage their participation in the subsequent research and development process.

The broad research goal resulting from the innovation impulse can be met using diverse possible innovation research pathways. Each pathway has its own advantages and disadvantages, depending on the presence or absence of different bottlenecks. Separating the high potential pathways from those with lower probabilities of success, is the first goal of the scope definition phase. This phase identifies and narrows down the number of innovation pathways, using a quick scan of relevant literature and stakeholder consultation. A second goal of this phase is to expand the innovation network with stakeholders that can aid in the research process, starting with narrowing the research scope. This important exploratory phase is explained in more detail in the next section of this paper, including three illustrative cases.

In the scope definition phase a large network of stakeholders is built and consulted. From this innovation network, a number of stakeholders are selected for further investigating the identified high potential research pathways. The selection is based on aspects such as the match between the desired resources (both human and financial) and the resources a stakeholder can offer, the level of trust between stakeholders, the necessary roles in the innovation research process etc. After the stakeholder selection phase, the participating stakeholders enter a problem definition and idea generation phase. In this phase, the group of participating stakeholders reviews the research goal and potential pathways identified during the scope definition phase. As a group they help pinpoint other problems and opportunities that were missed in the scope definition phase. Once the problems and opportunities are clear, the heterogeneous stakeholder group with multidisciplinary knowledge helps to generate ideas that result in integrated win-win solutions for every stakeholder involved. The next step is to translate this in a project design. In this design the necessary research is described and the tasks and corresponding roles are divided. Once the project design is formulated, a research and development phase can start. During this phase, the different ideas that were identified during the idea generation phase are developed and tested for feasibility. The options that yield positive results, are then tested in small scale tests in the real world. With a proof of concept, a phase of diffusion and market formation can begin.

Figure 1: A nonlinear, iterative model for innovation research in the bio-economy



Source: Bergek et al. (2008); Bruns et al. (2008); Gallagher et al. (2012); Fetterhoff and Voelkel (2006); Wallin and von Krogh (2010); Nambisan et al. (2012) and own insights

Although the research process above is described in a linear fashion, the execution is not. Figure one shows the different phases as a flexible, nonlinear, iterative learning process. The nonlinear, flexible use translates in the possibility to swap around different phases or the (partial) integration of different phases to better suit the specific needs of the research. For instance, during the problem definition phase, some basic R&D tests can be conducted to better understand the problems or opportunities. Another example is going back to an actor selection phase during R&D because some essential type of capital is missing. Also in figure one, the different phases are linked with an interaction mode that best suits it. Examples of modes are individual interviews, multi-stakeholder processes and participatory processes. These linkages are another example of the flexibility of this model. Using some multi stakeholder processes in addition to individual interviews during the scope definition phase for instance, can be more efficient to narrow the research scope. The iterative nature of the whole process is another important dynamic feature. To maximize learning effects during the innovation process, the process can be (partially) cycled several times, for instance first as an exploratory cycle to assess the feasibility of several high potential research pathways and then a more profound cycle concentrated on the pathway with the highest potential. Another option is to repeat some smaller partial cycles, such as making a loop of project design, R&D and real life testing until the result is satisfactory or looping the actor selection phase and problem identification phase until all the right stakeholders are selected and every angle of a potential pathway is covered. Aside from the flexibility and iterativety, taking the multidisciplinary aspects of the innovation process into account during the whole process is important. The socio-economic aspects of the innovation have to be considered together with the technical aspects in order to create an innovation that is both technically sound as well as desired by the market. A focus on both is needed in every step and throughout the whole process. Furthermore, while conducting the innovation research, the participating stakeholders are responsible for overlapping activities such as further networking, the creation of legitimacy for the innovation and the coordination of the research efforts.

Because the scope definition phase is a crucial step in determining the followed innovation pathway, it is further explained in the next part of this paper. Doing this phase too hastily or not thorough enough can result in significant, unsolvable bottlenecks later on in the research process which in turn can result in a failed innovation research process.

Detailed Development of the Scope and Actor Identification Phase

The scope definition and actor identification phase is a broad exploratory phase that bridges the innovation impulse with the first innovation phases. In this phase the research field within the scope based on the innovation impulse is briefly explored pursuing two objectives. The first objective is to adjust the scope of the research in order to better delineate what the subject of research is. Depending on what the scale of the innovation impulse is, the scope will need to be widened or narrowed. When the innovation impulse is a rather narrow research goal, like the improvement of a company's production process, the scope will need to be widened to see the bigger picture. Modifying one company's production process can have consequences for the whole supply chain. The scope will thus need to be widened from a fragmented research goal of a single company to a coordinated and integrated research goal with potential gains for every stakeholder involved. With a very broad and general research goal, like increasing sustainability in the bio-economy, the scope will need to be narrowed down to a coordinated and integrated innovation research goal in order to be workable. All research goals originating from the innovation impulse thus have to be viewed from a multi-disciplinary, integrated value- and supply chain perspective, taking bottlenecks and opportunities of all involved stakeholders into account.

To identify which innovation pathways can lead to such an integrated research goal, they have to be analyzed and evaluated. An important criterion that determines the feasibility of an innovation pathways is the presence or absence of bottlenecks that hinder development and implementation. As previously mentioned, such bottlenecks can arise from all six dimensions of the current socio-technical regime: user practices and markets, culture, science, technology, policy and industry (Geels, 2002; 2005). Determining the different bottlenecks can be done by scanning relevant literature and through stakeholder participation.

Identifying stakeholders interested in joining the innovation network around the innovation impulse is the second objective of the scope definition phase. Primary sources to find relevant stakeholders are industry associations, patent analysis and expert interviews (Bergek et al., 2008). Relevant stakeholders are those stakeholders that can help identify bottlenecks or that can provide financial capital or supporting resources. Generally, information about user practices and markets can be obtained from end-users and supply chain partners. Supply chain partners and industry associations are well suited to isolate the industry bottlenecks. Research institutes have expertise to help identify scientific and technological bottlenecks. Policy makers are well suited to pinpoint bottlenecks in policy and laws. Cultural bottlenecks are more general in nature, and can be provided by every stakeholder group. Not only do their areas of expertise differ, different stakeholder groups also have different incentives for participating in innovation research. Industry partners for instance are looking for innovations that will increase their profitability, environmental NGO's seek sustainability, research institutes are after scientific challenges, while policy makers and governments want societal benefits. A valuable research pathway thus offers promising incentives or opportunities for the different involved parties combined with manageable identified or anticipated bottlenecks.

The joint definition of an integrated research goal, as well as the innovation network formation co-develop during this phase. The scope definition process determines which stakeholders are contacted for information and cooperation, but the stakeholder interaction also influences which direction the scope definition process takes. Through this constant interaction, both the scope definition and actor identification objectives can be achieved thoroughly though quickly. In what follows, three empirical cases from the bio-economy are presented as an illustration of the above mentioned aspects of the scope definition phase. We start by giving a short description of the cases using their innovation impulse followed by summarizing the bottlenecks and opportunities identified using the scope definition phase as well as how the phase assisted in building the innovation network.

Description of Empirical Cases

The following three bio-economy cases are all initiated by a public research institute in Flanders that specializes in applied research in the agricultural and fisheries sector. After a brief description of the innovation impulse that led to the startup of the projects, we illustrate how the different researchers made use of the scope definition and actor identification phase in the next section. All three cases are using the model presented in this paper.

Despite continuous efforts to increase the efficiency of agricultural production and industry processing methods, large quantities of by-products are still generated. A large part of those plant-based by-products are currently treated as waste and thus not or only partially valorized. In the light of pressures like the increasing resource scarcity, this suboptimal usage of by-products is a waste of potentially valuable resources. An increasing number of research is being done on diverse streams of by-products from the agricultural sector to valorize them in some way, showing promising results. This is the innovation impulse for the first case, resulting in a research project with the broad starting goal: the high-value valorization of vegetable and fruit by-products from the agri-food industry. Which by-products and which valorization methods will be researched should be determined during the start of the innovation research process.

The innovation impulse for this first case is in part responsible for the innovation impulse for the second case. The intense use of farmland puts pressure on the fertility of the soils. With the valorization of by-products being a hot topic, an increasing number of by-products that normally remain on the field are now removed. This results in a gradual decrease organic matter content and in nutrient leaching, important factors in soil fertility. By composting by-products from the bio-economy, nutrient cycles can be closed. Compost is a slow working fertilizer that is a source of stable organic matter with large quantities of stable carbon. Compost also increases soil biota, thereby increasing disease resistance and decreasing the need for pesticides. Despite these benefits, compost is hardly ever used by farmers, indicating that there are different bottlenecks hindering this. This led to a research project with the innovation impulse: the valorization of by-products from agriculture and horticulture through composting. Here, in contrast to case one, the type of valorization is already determined, composting. The main challenge at the start of this case is identifying the bottlenecks and selecting which bottlenecks will be the focus of the project.

The innovation impulse that motivated the third case originates from the controversial discard ban measure to reform the fisheries industry into a sustainable industry that only fishes at maximum sustainable yield level. With this ban, discarding damaged, undersized, quota restricted or low value fish will no longer be allowed. This means these economically less interesting fish will take up a considerable part of the available hold space, since avoiding unwanted fish in the nets is impossible with the current fishing technology. Currently, for undersized or underutilized fish landed, only relatively low value pathways of animal feed and energy production exists. Without more profitable ways to valorize these discards, the profitability of this already highly competitive business is further pressured. This resulted in a research project with the innovation impulse: a valuable use for discards, valorizing unwanted and underutilized fish.

Application of the Model to the Cases

In case one (fruit and vegetable by-products), the first goal in the scope definition was to determine which by-product will become the focus of the innovation research process. After listing all cultivated crops in Flanders, the first step was to evaluate them on four criteria: by-product availability (crop production volume, number of volume by-products per crop, seasonality), geographical spread, current application of the by-products and the necessity to adjust harvesting techniques. Based on these criteria, five crops were further scanned for potential. One of these crops, is Belgian endive, as it has four streams of by-products, a year round availability, a geographically concentrated cultivation and no major adjustments have to made to the harvesting technique. Scanning the literature and current research projects revealed that little research is performed on Belgian endive, indicating a lack of knowledge about the biochemical components in endive. To get a better idea of the composition of Belgian endive, the literature on chicory, a vegetable from the same botanical family as endive, was explored and revealed the potential presence of several high value components. More research into the current applications of Belgian endive by-products revealed a valorization as feed for animals or as input material for compost, while the potential for higher valorization is present. Since food processing companies feel that food by-products should be used in food applications as much as possible, the possibility of a food application was investigated. More specifically, to circumvent the novel food regulations, the possibility of extracting food additives was explored. Inulin is such an additive that is currently extracted out of chicory. Inulin is thus an interesting pathway for valorization of Belgian endive by-products since there is a market for it and an industrial scale extraction process exists.

This information was collected by scanning relevant literature and by consulting multiple different stakeholders such as farmer advisors, the industry association representing the fruit and vegetable processing companies, fruit and vegetable processers, farmers, several organizations with expertise in the cultivation of Belgian endive and the national federation of food processing companies. These consultations form the basis for the innovation network, the second goal of the scope definition phase. This because many of these stakeholders can play a role later in the research process. Furthermore, the consulted stakeholders provided contact information of several potentially interesting other stakeholders.

The second case, concerning composting, used the scope definition phase to identify all bottlenecks and opportunities concerning on-farm composting. A first identified issue are the subsidies that are given for the generation of green energy out of biomass. This results in considerable amounts of biomass used as a green energy source, which in turn leads to a shortage of woody material. This important fiber rich component gives structure to compost. Several possibilities for solving this shortage of wooden materials were identified: lab tests show that by-products from nature conservation can be used as fiber rich material, clippings from road sides show potential, tree breeders have green and brown waste that can serve as a substitute and fruit cultivators have fiber rich pruning waste. A second consequence of the subsidies is that composting by-products is economically less attractive than using by-products as an energy source. Another bottleneck is the very complex regional legislation concerning composting resulting in required permits, as many by-products are currently considered waste products. The need for compost and willingness to use it on farms was also investigated. The fruit sector and biological farmers are looking for a general soil improver with high water retaining capacity and high organic matter content that is uncontaminated with pathogens and weed seeds. Additionally, the time of nitrogen-release should match with the needs of the crops, something which is currently impossible. Tree breeders are also looking for a general soil improver to maintain the organic matter content of the soil. A general reoccurring concern from the farmers is that the compost quality is inconsistent, making it unreliable. There thus is a need for clear compost parameters and adjustment of the process in such a way that the compost consistently meets those parameters. Companies that use potting media are looking for a substitute for peat, an unsustainable input material in potting media. Using compost as a substitute could be a possible research pathway. A qualitative compost requires several diverse by-products, which are often unavailable at the individual company. Getting the by-products all in the same place forms a logistical challenge. This means getting the material from someplace else, creating an additional (transport) cost. A last identified bottleneck is that composting requires a significant investment in machinery and manpower.

Intense stakeholder interaction was used to collect this information. Several compost researchers, farmers from different agricultural activities, tree breeders, small businesses specialized in composting, nature conservators, as well as the national farmer association, the Flemish composting organization, national federation for potting media, a research institute specialized in fruit cultivation, a producer of grass sods and an industrial composter were contacted to acquire a multi-dimensional view. These stakeholders, especially the industry associations, like in case one, also offered contact information of other potentially interesting stakeholders. This case also used the scope definition phase to start building an innovation network consisting of stakeholders from diverse stakeholder groups.

The discard ban case faces a significant policy bottleneck as it remains unclear what the final policy on the discard ban will look like. It could be that the European Union decides that the obligated landings or processed products can't be sold with a profit. Another possibility is that some valorization options will be prohibited, like applications for human consumption. This could be a possible issue when pursuing high valorization options. Another issue is the uncertain availability since the amounts of fish being discarded on vessels depends on a multitude of variables like time of fishing, fishing ground, fishing technique, weather, etc. This makes estimating the total volume of bycatch that will have to be landed very difficult and estimating the bycatch of a single fish species nearly impossible at this time. To overcome this difficulty and to compensate for seasonal differences, the chosen valorization pathway has to be applicable to a whole group of fish (flatfish in Flanders) and not only to one specific species. Fish silage is a product that offers a lot of opportunities to meet those requirements. Furthermore, this relatively simple technology requires lower investment costs compared to the production of its competitor, fish meal. The process is also very flexible because the size of the containers can be adjusted to the supply of fish. As long as the silage is kept in sealed containers it can keep for up to two years without loss of quality. A research opportunity presents itself in trying to reduce the water content (currently 80%) of the silage to reduce transport costs. Another challenge is increasing the protein content of silage, which is currently only 15%. Fish silage can be marketed as a fertilizer or as animal feed. However, the agricultural industry has prejudices towards the use of fish products in animal feed due to fish odor and/or taste in the meat, milk and eggs. But fish silage has the benefit of having a malty smell and not leaving a taste in animal products. However, because Flemish pig farmers do not use mash diets, there is currently no market for fish silage as an input material for pig feed.

Stakeholder consultation and network formation remains limited in this case. Aside from consulting fisheries and animal feed researchers and a government official, not much contact with stakeholders has been made. The most important reason for this is the uncertainty about the way the discard ban will be implemented, as it significantly influences which stakeholders will be relevant for the innovation research.

Discussion

Table 1 gives an overview of the different bottlenecks and opportunities presented in the three cases. It clearly shows that opportunities and bottlenecks concerning innovation arise in all regime dimensions. To identify these diverse opportunities and bottlenecks and to be able to generate solutions for them, a multi-dimensional perspective and research approach is thus needed.

The flexibility and iterative nature of the research process is also illustrated in the cases. Case one and three used the scope definition phase mainly to narrow down the different possible innovation pathways, while case two used it to broaden the view and to identify all potential bottlenecks and opportunities that different stakeholders experience. Furthermore, in case one, a focus group was used to check correctness of gathered data and to receive information, while the other cases relied more on individual interviews. Another example of the flexible and iterative use of the model is the preliminary research conducted in case two. This created a learning loop, giving information about the feasibility of different nature management by-products. The cases further show how important stakeholder participation is to quickly expand the knowledge of the individual organization. For instance, thanks to stakeholder interaction in case one, an additional potentially valuable by-product of endive was discovered. The importance of the scope definition phase as a networking phase, is also illustrated. Both in case one and two the innovation network expanded during the scope definition phase due to acquired contact information from other stakeholders. The co-development of the integrated research goal and the innovation network is demonstrated as well. For instance, in case one, based on interviews, the harvesting technique becomes a criterion for selection, indicating the importance of consulting stakeholders with this technical knowledge. Another example is how, in case three, the prejudice towards fish products by farmers influences the direction of search towards pathways with limited odor problems.

Table 1: Overview of identified bottlenecks and opportunities in bio-technological cases

	By-products of Belgian endive	Composting by-products	Silage from fisheries by-products
	Bottlenecks and opportunities	**Bottlenecks and opportunities**	**Bottlenecks and opportunities**
User practices and markets	Current low value applications Existing market for chicory-inulin	Compost has product properties several agricultural subsectors are looking	No market for products from bycatch Possible markets for fish silage
Culture	Food by-products should be used in food applications		Agricultural sector fears a fishy odor in their products Silage does not have a fish odor
Science	Little knowledge about biochemical components	Substitute for peat needed Optimize composting process	Improving protein content Reducing water content
Technology	No major adjustment needed in harvesting technique Little adjustments to inulin extraction process		Fairly simple and flexible technology
Policy	Novel food regulation	Subsidies for green energy from biomass Complex regional regulations Many by-products are considered waste products	Uncertain implementation of the discard ban No recognition of food safety organization needed
Industry	Adequate by-product availability Year round availability Geographically concentrated	Shortage of woody materials Woody material available in some sectors but no established supply chain Collection of by-products in one place Investments in composting machinery and manpower	Uncertain available bycatch Lower production cost compared to fish meal Long shelf life

Although the three cases offer an illustration of how the innovation process can be approached using this model, they all show several limitations. Two important limitations are the number of cases and their diversity. More cases originating from different innovation impulses can confirm the validity of our model. Furthermore, in this paper we especially focus on the first phases of the innovation model.

In addition, important aspects such as arrangements about roles, responsibilities and division of outcomes, important issues in collaborative innovation research projects, are not treated here. Stakeholder selection criteria, evaluation tools and process measurements and how to evolve from an innovation network towards a supply chain are other examples of important issues.

Conclusion and Avenues for Future Research

Due to the multidisciplinary nature of bottlenecks that hinder innovation adoption, a nonlinear, flexible, iterative research approach with intense stakeholder interaction is required. In this paper we propose such a model. An innovation research model is needed to provide a rationale to evolve from an innovation impulse to a technologically sound and supported innovation. Such a rationale helps to structure the complex process of innovation research and can give guidance and support to every stakeholder involved.

As illustrated in three cases, a scope definition phase is needed to either broaden or narrow the starting innovation impulse towards a workable, integrated research goal and to identify the most promising valorization pathways. Furthermore, in the scope definition phase, by identifying and interacting with diverse stakeholders, the innovation stakeholder network is constructed which will support the remainder of the innovation research. As well as further validation of the innovation research cycle, more research on best modes of stakeholder interaction, network arrangements and evaluation tools is needed.

References

Arnold, M. and Barth, V. (2012). Open innovation in urban energy systems. *Energy efficiency, 5,* 351-364.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A. (2008). Analyzing the functional dynamics of technological innovation system: A scheme of analysis. *Research Policy, 37,* 407-429.

Bigliardi, B., Dormio, A., Galati, F. (2012). The adoption of open innovation within the telecommunication industry. *European Journal of Innovation Management, 15,* 27-54.

Bogers, M. and West, J. (2012) Managing distributed innovation: strategic utilization of open and user innovation. *Creativity and innovation management, 21,* 61-75.

Brocco, M., (2012). A Meta Model for Team Recommendations in Open Innovation Networks. *PhD-thesis, Technische Universität München, Germany*.

Bruns, M., Trienekens, J.H., Omta, S.W.F., Hamer, M., Petersen, B. (2010). Demand of the meat industry for management support in R&D cooperation projects. *In: Proceedings of the 9th Wageningen International Conference on Chain and Network Management (WICaNeM), Wageningen, The Netherlands, 26-28* May 2010.

Caird, S., Roy, R., Herring, H. (2008). Improving the energy performance of UK households: Results from surveys of consumer adoption and use of low- and zero-carbontechnologies. *Energy Efficiency, 1,* 149-166.

Chesbrough, H. (2012). Open innovation: Where we've been and where we're going. *Research-technology management, 55,* 20-27.

Drechsler, W. and Natter, M. (2012). Understanding a firm's openness decisions in innovation. *Journal of business research, 65,* 438-445.

Ernst, H. (2001). Patent applications and subsequent changes of performance: evidence from time-series cross-section analyses on the firm level. *Research Policy, 30,* 143-157.

EU SCAR (2012). Agricultural knowledge and innovation systems in transition - *a reflection paper, Brussels.*

Fetterhoff, TJ. and Voelkel, D. (2006). Managing open innovation in biotechnology. *Research-technology management, 49,* 14-18.

Head, B. (2008). Assessing network-based collaborations. *Public Management Review, 10,* 733-749.

Hermans, F. (2011). Social Learning in Innovation Networks: How multisectoral collaborations shape discourses of sustainable agriculture. *PhD-thesis, Wageningen University, The Netherlands*.

Gallagher, K.S., Grübler, A., Kuhl, L., Nemet, G., Wilson, C. (2012). The Energy Technology Innovation System. *Annual Review of Environment and Resources, 37*, 137-162.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy 31,* 1257-1274.

Geels, F.W. (2005). Technological transitions and system innovations: A co-evolutionary and socio-technical analysis. *Cheltenham: Edward Elgar.*

Geels, F.W. and Raven, R. (2006). Non-linearity and Expectations in Niche- Development Trajectories: Ups and Downs in Dutch Biogas Development (1973-2003). *Technology Analysis & Strategic Management, 18,* 375-392.

Goosen, H., Janssen, R., Vermaat, J. (2007). Decision support for participatory wetland decision-making. *Ecological engineering, 30,* 187-199.

Giannopoulou, E., Ystroumlm, A., Ollila, S. (2011). Turning open innovation into practice: open innovation research through the lens of managers, *International journal of innovation management, 15,* 505-524.

Henry, J., Walker, D. (1991). Managing Innovation. *London, Sage Publications*.

Holl, A. and Rama, R. (2012) Technology sourcing: are biotechnology firms different? An exploratory study of the Spanish case. *Science and public policy, 39,* 304-317.

OECD. (2013) The Bioeconomy to 2030: designing a policy agenda, *http://www.oecd.org/futures/long-termtechnologicalsocietalchallenges/thebioeconomyto2030designingapolicyagenda.htm*

Kutvonen, A. (2011). Strategic application of outbound open innovation, *European journal of innovation management, 14,* 460-474.

Nambisan S., Bacon, J., Throckmorton, J. (2012). The Role of the innovation capitalist in open innovation: A case study and key lessons learned. *Research-Technology Management, 55,* 49-57.

Paredis, E. (2011). Transition management as a form of policy innovation. A case study of Plan C, a process in sustainable materials management in Flanders. *Working paper.*

Pullen, A., de Weerd-Nederhof P., Groen, A., Fisscher, O. (2012). Open Innovation in Practice: Goal Complementarity and Closed NPD Networks to Explain Differences in Innovation Performance for SMEs in the Medical Devices Sector. *Journal of product innovation managament*, *29*, 917-934.

Sarkar, S. and Costa, A. (2008). Dynamics of open innovation in the food industry. *Trends in food science & techonology, 19,* 274-580.

Spithoven A. and Teirlinck P. (2006). De appreciatie van netwerkvorming in innovatiestrategieën. *Tijdschrift voor economy en management, LI,* 269-307.

Te Brömmelstroet, M. and Schrijnen, P., (2010). From planning support systems to mediated planning support: A structured dialogue to overcome the implementation gap. *Environment and planning B: Planning and design, 37*, 3-20.

Van Haverbeke, W. and Cloodt, M. (2006). Open innovation in value networks. In Open innovation: researching a new paradigm, *Oxford University Press*.

Van Humbeeck, P. (2003). Naar een industrieel beleid voor het milieu. Technologie en innovatie als sleutel voor een duurzame welvaart, *SERV, Brussel*.

Voinov, A. and Bousquet, F. (2010). Modelling with stakeholders. *Environmental modeling & software, 25,* 1268-1281.

Von Hippel, E. (1987). Cooperation between Rivals: Informal Know-How Trading. *Research Policy, 16,* 291-302.

Wallin, M.W. and von Krogh, G. (2010). Organizing for Open Innovation: Focus on the Integration of Knowledge. *Organizational Dynamics, 39,* 145-154.

Westergren, U. and Holmström, J. (2012). Exploring preconditions for open innovation: *Value networks in industrial firms. Information and organization*, *22*, 209-226.

Tables

Page 18:

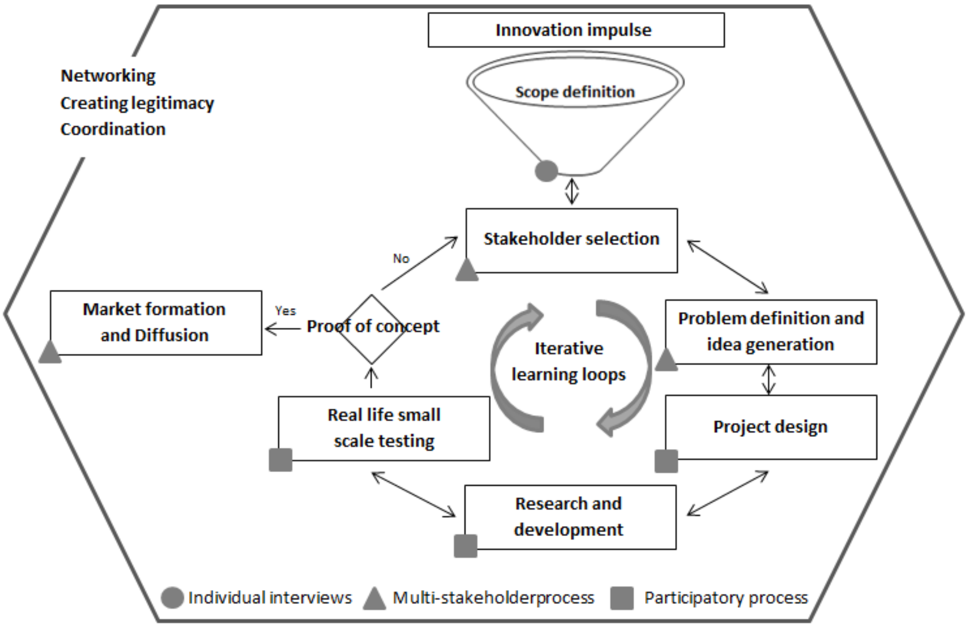
Table 1: Overview of identified bottlenecks and opportunities in bio-technological cases

	By-products of Belgian endive	**Composting by-products**	**Silage from fisheries by-products**
	Bottlenecks and opportunities	**Bottlenecks and opportunities**	**Bottlenecks and opportunities**
User practices and markets	Current low value applications Existing market for chicory-inulin	Compost has product properties several agricultural subsectors are looking	No market for products from bycatch Possible markets for fish silage
Culture	Food by-products should be used in food applications		Agricultural sector fears a fishy odor in their products Silage does not have a fish odor
Science	Little knowledge about biochemical components	Substitute for peat needed Optimize composting process	Improving protein content Reducing water content
Technology	No major adjustment needed in harvesting technique Little adjustments to inulin extraction process		Fairly simple and flexible technology
Policy	Novel food regulation	Subsidies for green energy from biomass Complex regional regulations Many by-products are considered waste products	Uncertain implementation of the discard ban No recognition of food safety organization needed
Industry	Adequate by-product availability Year round availability Geographically concentrated	Shortage of woody materials Woody material available in some sectors but no established supply chain Collection of by-products in one place Investments in composting machinery and manpower	Uncertain available bycatch Lower production cost compared to fish meal Long shelf life

Figures

On page 9:

Figure 1: A nonlinear, iterative model for innovation research in the bio-economy



Source: Bergek et al. (2008), Bruns et al. (2008), Gallagher et al. (2012), Fetterhoff and Voelkel (2006), Wallin and von Krogh (2010), Nambisan et al. (2012) and own insights