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Sustainable Bio-economy:

Potential, Challenges and Opportunities in Finland

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Contents

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Preface

Can economic growth comply with sustainable development? There are strong signals indicating that the demand for renewable, bio-based raw materials is increasing substantially.

In Finland, the bioeconomy is linked to the countryside. In addition to the developing bioeconomy sector, our approach towards the countryside is changing. Could these two lines of development be interlinked for mutual benefits? The fact that the bioeconomy and the local solutions of the green economy are becoming more popular is not only of local significance – they have positive social and financial impacts both at the national and global level.

Sitra's Landmarks programme develops a versatile local bioeconomy where different raw materials originating from the forests, fields and waste are upgraded to energy, fuel, nutrients and fractions of a high added value to global destinations, while improving the efficiency of the local material cycle.

What we need now are medium bioeconomy mediator companies and a favourable operating environment for them. This report is our first step towards the development of commercially viable bioeconomy concepts and making them available on the global market.

Eero Kokkonen

Senior Lead, Bioeconomy
Landmarks Programme
Sitra, the Finnish Innovation Fund

Sitra, the Finnish Innovation Fund´s Landmarks Programme (2010–2014) seeks new views on what kind of role the countryside could have in the future good life of Finns and the solutions of sustainable development. The Programme accelerates profitable business based on the local solutions of the green economy. For example, the programme develops and pilots new business models for local food, service solutions of local energy, and operating models of local bioeconomy.

www.sitra.fi/maamerkit

Esipuhe

Voiko kasvava talous olla kestävän kehityksen mukaista? Vahvat signaalit kertovat uusiutuvien biopohjaisten raaka-aineiden kysynnän olevan merkittävässä kasvussa.

Suomessa biotalous kytkeytyy maaseutumme. Kehittyvän biotaloussektorin ohella suhtautumisemme maaseutuun on muuttumassa. Voitaisiinko nämä kaksi kehityslinjaa kytkeä siten, että ne hyödyttäisivät toisiaan? Biotalouden tai vihreän talouden lähiratkaisujen yleistymisellä ei ole vain paikallista merkitystä – niillä on positiivisia sosiaalisia ja taloudellisia vaikutuksia sekä kansallisesti että globaalisti.

Sitran Maamerkit-ohjelma kehittää monimuotoista paikallista biotaloutta, jossa metsistä, pelloilta ja jätteistä tulevista eri raaka-aineista jalostetaan energiaa, polttoaineita, ravinteita ja korkean lisäarvon fraktioita maailmalle, paikallista ainekiertoa samalla tehostamalla.

Nyt tarvitsemme keskisuuria biotalouden välittäjäyrityksiä sekä toimintaympäristöä, jossa niiden on suotuisaa toimia. Kädessäsi oleva selvitys on avauksemme sekä liiketaloudellisesti toimivien biotalouskonseptien kehittämisestä että niiden viemisestä maailmalle.

Eero Kokkonen

Johtava asiantuntija, biotalous
Maamerkit-ohjelma
Sitra

Sitran Maamerkit-ohjelmassa (2010–2014) etsitään uusia näkökulmia siihen, millainen rooli maaseudulla voi olla tulevaisuuden suomalaisten hyvässä elämässä ja kestävän kehityksen ratkaisuissa. Ohjelma vauhdittaa vihreän talouden lähiratkaisuihin perustuvaa kannattavaa liiketoimintaa. Ohjelma kehittää ja kokeilee esimerkiksi uusia lähiruoan liiketoimintamalleja, lähienergian palveluratkaisuja sekä paikallisen biotalouden toimintamalleja.

www.sitra.fi/maamerkit

Executive summary

The field of bio-economy is developing rapidly. Today there is a variety of related technologies and raw materials on offer, and many more are not yet utilised. These technologies interconnect and work in symbiosis supporting each other – waste from one process is a fuel for another. Many technologies also operate on the side-flows or waste from other processes and provide side benefits such as reduced nutrient emissions. Bio-economic solutions use raw materials that have significant side-benefits and provide local jobs while reducing waste amounts and waste management costs. This forms an industry complex in a technical, commercial and social sense.

The bio-economy is the key means to replace fossil fuels while ensuring a sustainable food production. However, the energy content in renewable fuels is quite low which leads to a limited transportation radius and the need for small installations. The energy production capacity of fuels and energy sources vary significantly, while the availability of fuels and energy sources is also very local.

Bio-economic solutions involve companies from different industries that are not accustomed to working together. To create a functioning bio-economic solution the different forms of earning logic must be fitted together and the local value chain must be integrated and operated in order for the technical solution to function. In addition all the positive side-effects such as reduced greenhouse gas and nutrient emissions need to be capitalised and priced.

Fortunately, the market for small-scale solutions is large, which provides a basis for mass-production of bio-economic solutions. The side benefits can be identified, measured and productified into services. A fully integrated solution creates a hybrid where different systems complement each other, thereby increasing the profitability of the investment. In addition, a system consisting of many small production plants is highly reliable.

Though local conditions and needs vary, the need for customisation is limited. The alternatives can be identified and turned into interchangeable modules. Functional modularisation provides economies of scale and adaptability which can be turned into a business-driven offering.

Last but not least, the capability to develop, design, deliver and operate bio-economic solutions can be exported – sustainable food and renewable energy production are needed worldwide.

Yhteenveto

Biotalous kehittyy nopeasti. Nykyään on tarjolla monenlaista teknologiaa ja useita raaka-aineita, joita ei hyödynnetä. Nämä teknologiat ovat kytköksissä toisiinsa ja tukevat toisiaan – yhden prosessin jätteet toimivat polttoaineena toiselle prosessille. Monet teknologiat toimivat myös muiden prosessien sivutuotteilla tai jätteillä ja samalla tuottavat lisähyötyä, kuten vähentyneitä ravinnepäästöjä. Biotaloudelliset ratkaisut käyttävät raaka-aineita, joiden lisähyödyt ovat merkittäviä, ja edistävät paikallista työllisyyttä samalla kun vähentävät jätteiden määrää ja jätteenkäsittelykustannuksia.

Biotalous on avainkeino fossiilisten polttoaineiden korvaamiseen ja kestävän ruuantuotannon varmistamiseen. Uusiutuvien polttoaineiden energiasisältö on kuitenkin matala, minkä vuoksi kuljetusmahdollisuudet ovat rajalliset ja pienille tuotantolaitoksille on tarvetta. Polttoaineiden ja energianlähteiden energiantuotantokapasiteetti vaihtelee merkittävästi ja niiden saatavuus on pitkälti paikasta riippuvainen.

Biotaloudelliset ratkaisut koskettavat yrityksiä useilta toimialoilta, jotka eivät ole tottuneet työskentelemään yhdessä. Toimivan biotaloudellisen ratkaisun luomiseksi ansaintalogiikan eri muodot on sovitettava yhteen, ja tekninen ratkaisu on integroitava ja sulautettava paikalliseen arvoketjuun jotta se toimisi. Tämän lisäksi kaikki positiiviset sivuvaikutukset, kuten pienentyneet kasvihuonekaasu- ja ravinnepäästöt, pitää kapitalisoida ja hinnoitella.

Onneksi pienen mittakaavan ratkaisun markkinat ovat laajat, mikä antaa lähtökohdan biotaloudellisten ratkaisujen massatuotannolle. Lisähyödyt voidaan tunnistaa, mitata ja tuotteistaa palveluiksi. Täysin integroitu ratkaisu luo hybridin, jossa eri systeemit täydentävät toisiaan lisäten investoinnin kannattavuutta. Lisäksi monista pienistä tuotantolaitoksista koostuva systeemi on erittäin luotettava.

Vaikka paikalliset olosuhteet ja tarpeet vaihtelevat, mukauttamisen tarve on rajallinen. Vaihtoehdot voidaan tunnistaa ja muuntaa keskenään vaihdettaviksi moduuleiksi. Toimiva modulointi tarjoaa mittakaavaetuja ja sopeutuvuutta, jotka voidaan muuttaa bisneslähtöiseksi tarjoukseksi.

Viimeisimpänä mutta ei vähäisimpänä, kykyä kehittyä, suunnitella, toimittaa ja operoida biotaloudellisia ratkaisuja voidaan hyödyntää vientituotteena – kestävää ruuan ja uusiutuvan energian tuotantoa tarvitaan maailmanlaajuisesti.

1 Introduction

This report is the outcome of a project carried out by the PBI Research Institute for the Finnish Innovation Fund Sitra, the aim of which was to explore the potential of a distributed bio-economy in Finland. The project was completed in February of 2011, and its results are reflected in this report.

A bio-economy is perceived as an economy based on sustainable production and conversion of biomass to be used as a major resource in a wide variety of industries. The locality of biomass production and low sustainability of its transportation over long distances calls for a distributed bio-economy consisting of a variety of small-scale solutions. This report gives an overview of the current bio-economic solutions introduced in Finland, as well as the tendencies in their development in other countries. The aim of the report is to give the reader a good overview of the current situation in Finland regarding the bio-economy and current efforts in building it by covering the following issues:

- The potential for a bio-economy in Finland
- The potential impact of bio-economic solutions on the environment, investments, country exports, supply security, and sustainability
- The main hurdles hindering the development of a bio-economy in Finland
- The recommendations on the services, processes or resources required for building a strong, sustainable bio-economy industry in Finland.

The content of this report is based both on public information as well as on information retrieved during in-depth interviews with actors and authorities involved in a number of bio-economic solutions developed in Finland at present. Therefore the report also summarises concrete key issues that need to be addressed by companies and authorities.

The ultimate goal of the report is to increase awareness of the bio-economy, its role in the transformation towards a sustainable society and the effect on the country’s wealth and competitiveness. The challenges brought up in the report are intended to stimulate the dialogue and cooperation between the actors, which is a crucial part of a sustainable bio-economy.

2 Background

2.1 Methods

The pre-study on distributed bio-economies was carried out by exploring the background of the bio-economy in Finland, benchmarking other leading countries and assessing concrete bio-economic solutions implemented in Finland. Four cases were chosen for the latter aim, including sustainable production of biofuels, integrated with waste management and fertiliser production, sustainable farming and transportation. The cases are only examples of concrete developments in the Finnish bio-economy and are chosen to illustrate the real directions of the development and obstacles in its way. The sustainability of the focal solutions and potential for the development of the bio-economy in Finland were assessed by considering their environmental, economic and social impacts. The credibility of the solutions was also addressed, since it constitutes the basis for developing the knowledge and expertise that can be exported by Finland abroad. To this end, the maturity, potential and challenges for each bio-economic solution were analysed. The bottom-up approach allowed us to assess what real efforts towards the bio-economy exist in Finland and what challenges they face.

In order to gain insight into the focal bio-economic solutions, the representatives of the companies involved were interviewed. The exploration was carried out through creating a discussion about each bio-economic solution and challenges in its implementing by focusing on the business idea of the solution, feasibility, sustainability of the solution, the interplay of actors involved in the solution and the potential of its replication in other locations.

The interviews were carried out during the period December 2010 – January 2011.

Derived from these interviews, a list of critical actors affecting and being affected by the solutions was created. The most important stakeholders, including, for instance, authorities, were interviewed, focusing on the following issues:

- Possibilities for various incentives for companies developing sustainable bio-economic solutions
- The development of a regulatory basis for promoting or not obstructing the bio-economy
- The potential of solid country-level policy for a bio-economy in Finland.

The second round of interviews allowed gaining a more objective outlook on the challenges in implementing bio-economic solutions by establishing not only the benefits of such solutions, but also the prerequisites for complying with the regulations.

2.2 Global Challenges and the Bio-economy

Climate change and diminishing resources, such as oil, phosphate and other commodities, are driving a need to change the ways of production. The need to be more energy- and material efficient is not so much dictated by environmental concerns, but rather by the threat to the supplies of these basic resources. According to the New Policies Scenario introduced in the World Energy Outlook 2010 (International Energy Agency, 2010), the world energy demand will increase by 36% between 2008 and 2035 mainly due to demand from the fast developing non-OECD countries, and China in particular. At the same time oil is expected to remain the dominant fuel in the primary energy mix during this period. Though the production of natural gas liquids and unconventional oil may grow over the focal period, the growth will not be enough to cover the energy demand (see Figure 1), and the development of new crude oil fields will be required. The obvious scarcity of crude oil and expected price rise therefore require a simultaneous improvement in the efficiency of its use and its active replacement by renewable energy sources. Thus 'green' fuels are not only a question of mitigating climate change, but also of securing the energy supplies of the world and each country separately.

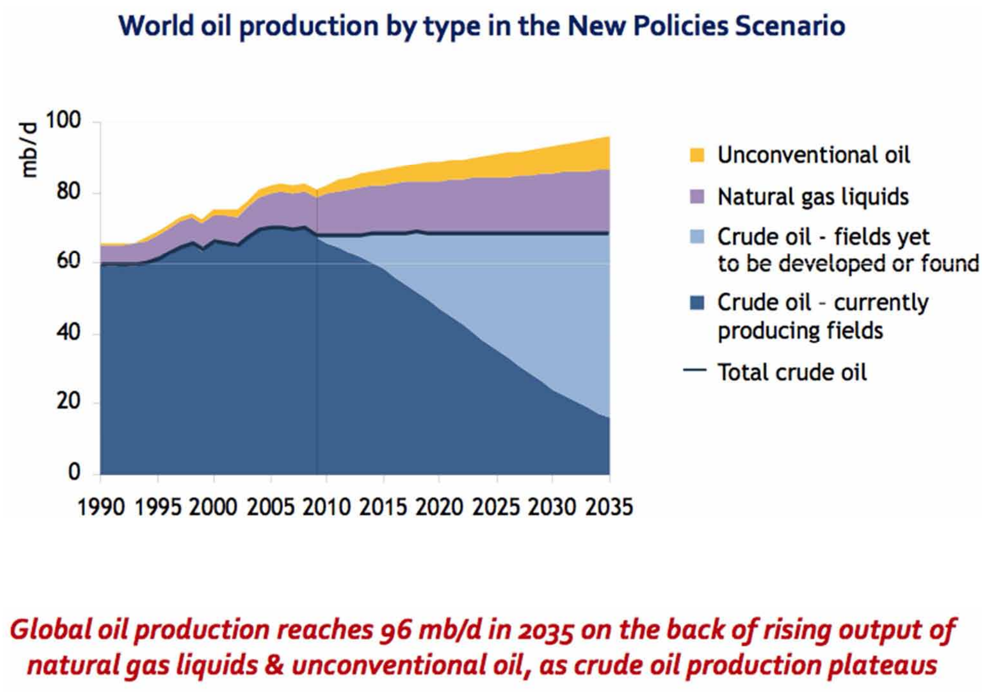

Figure 1. World oil production by type in the New Policies Scenario (source: International Energy Agency, 2010).

Though unconventional oil is more abundant than conventional oil, the cost of its extraction is much higher, and the upfront capital investments are larger and have a very long payback period. At the same time the greenhouse gas emissions during the production phase are higher for unconventional oil compared to conventional oil (International Energy Agency, 2010). The development of extraction technology might improve in the coming years; however the environmental impact and economic costs of oil still require the switch to renewable energy as soon as possible. Biomass is considered to be one of the options to replace the non-renewable resource, since it is renewable and basically present in any location. Though renewable energy is most often associated with solar, wind, water and geothermal energy, the role of biomass should not be underestimated. In certain applications bioenergy is the only sustainable alternative or is needed to power the development of zero-emission technologies.

Climate change is another important driver for sustainability. Concerns about the environment define international agreements and country-level goals for reducing the impact caused by growing production and consumption. Bans on certain harmful substances causing the depletion of the ozone layer, such as chlorofluorocarbons, allowed reducing the environmental impact of global production on climate change. However, the main share of the impact still belongs to carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), which come mainly from energy, transport and agriculture. Moreover, the emissions of these gases, especially CO_2, continue to increase at a regular rate. Figure 2 illustrates how the Radiative Forcing of these greenhouse gases, which contributes to the warming of the atmosphere, grows over time.

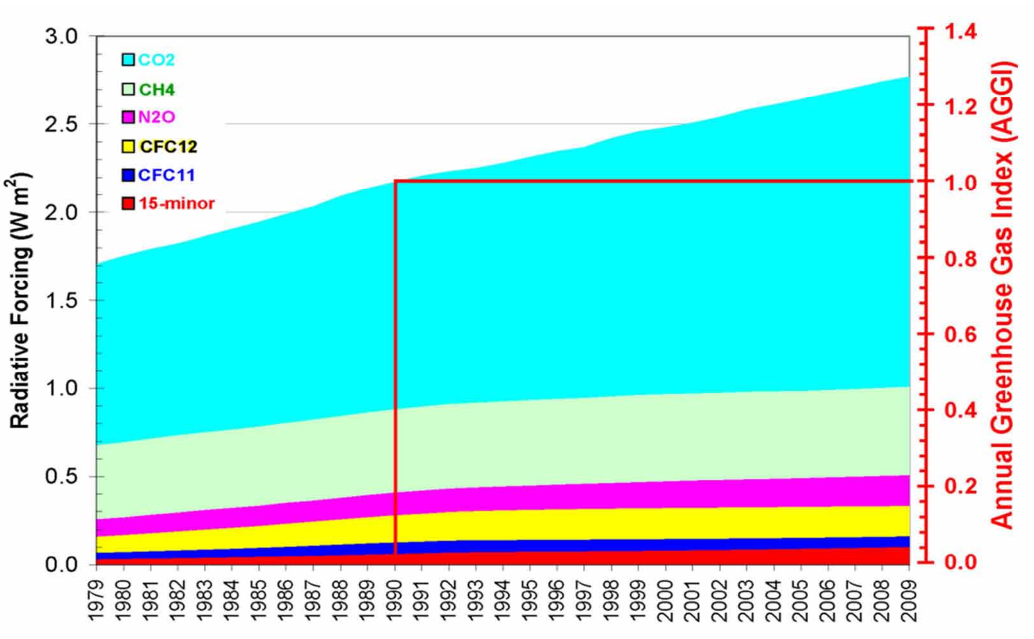

Figure 2. Radiative forcing, relative to 1750, of all the long-lived greenhouse gases (source: NOAA, 2009).

The causes for this growth are the unprecedented exploitation of non-renewable resources and nutrient run-off. Therefore a more efficient and sustainable mode of resource use is required globally. This requirement brings one back to the need for renewable non-fossil energy, but also brings up the idea of effective and natural-like nutrient cycling to prevent nutrient run-off. An example of the problem and its potential solution is the farming sector. A sustainable way of recycling biomass within the ecosystem, i.e. the use of manure or biowaste for fertilisation, was abandoned due to the cheapness and higher efficiency of phosphorous fertilisers, mined from the Earth's crust. This caused the extensive mining of a scarce resource, just as in the case of fossil fuels, while at the same time allowing the biomass produced in large quantities to degrade by its own means and generate nutrient run-off. Figure 3 illustrates the dynamics of the use of various substances for fertilisation globally over the past 200 years.

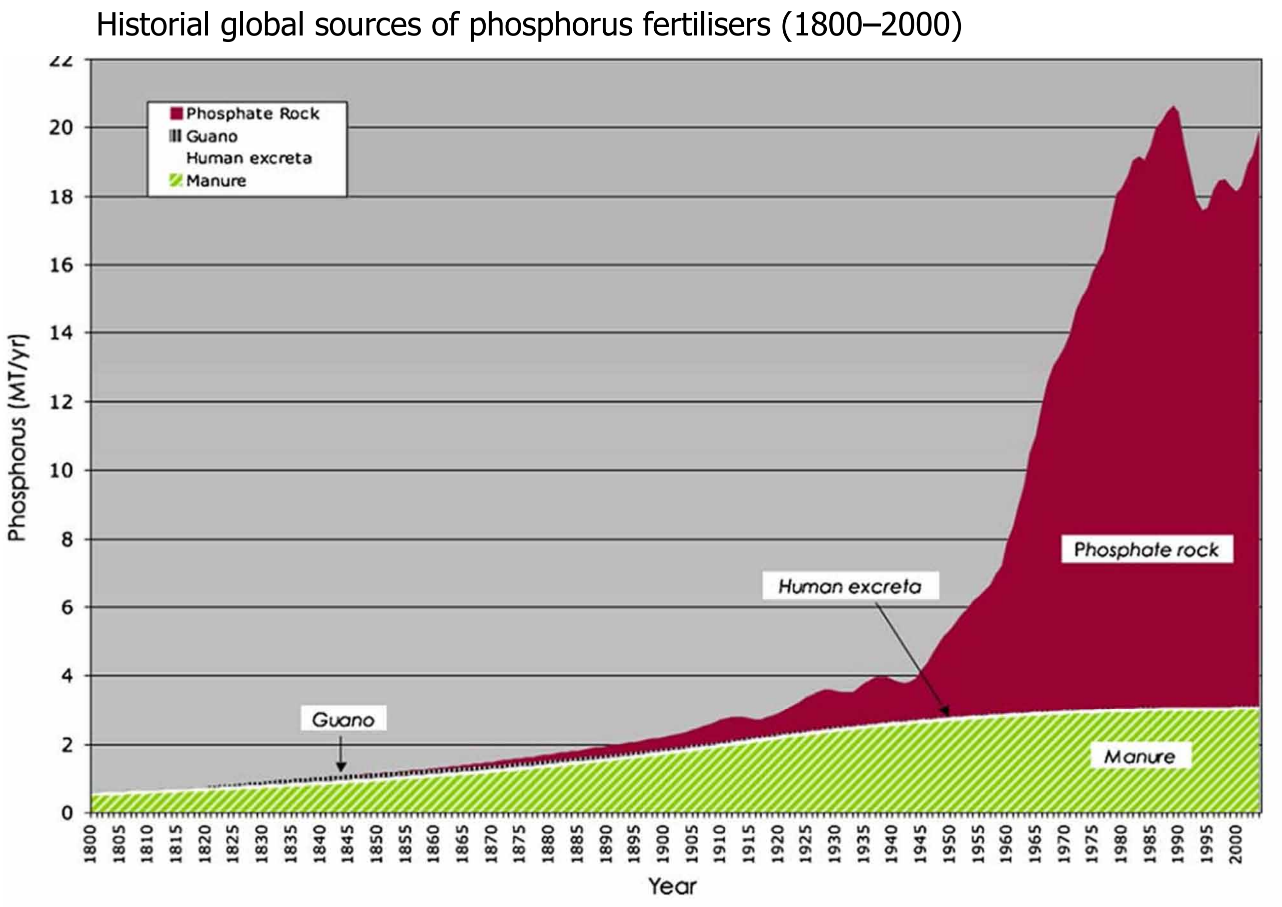

Figure 3. Historical sources of phosphorus for use as fertilisers (1800–2000) (source: Cordell et al., 2009).

It can be seen in Figure 3 that the mining of phosphate rock has increased drastically in the past 50 years, which has recently caused an upswing in the prices for synthetic phosphorous fertilisers. Since global phosphate production has stagnated, the cost of synthetic fertilisers is undermining the stability of the world's food production. At the same time the biomass that can be used for the production of natural fertilisers is underexploited, and ley farming, which contributes to the natural "recovery" and fertilisation of land, is considered to be no longer economically feasible for farmers.

The bio-economy strives to integrate the biomass flows of different industries in such a way that one industry's waste or emissions become another industry's raw material. This approach is a means to create effective material loops and fight the problems of climate change and resource depletion (OECD, 2009; EuropaBio, 2010b). A number of such bio-economic solutions already exist, integrating power production with plasterboard manufacturing and greenhouses (Kalundborg, Denmark) or sewage treatment with public transport (Borås, Sweden). Studies have shown that bio-economies are highly beneficial in a financial way as well, since emissions together with waste management and raw material costs are reduced. On a social sustainability level, a bio-economy increases the efficiency of local production and thereby strengthens local business with all its side-benefits.

Since biomass has characteristics that differentiates it from fossil resources, for instance, regarding energy content, availability and distribution (as illustrated in Figure 4), an economy based on biomass requires different ways of working, cooperation and structure of the industrial sector. Since biomass has a lower energy density than fossil fuels, it limits the transport distance so that the refining or unit of consumption needs to be close to the source. The production facility also needs to be small because the amount of biomass within a transport radius is limited. However, the number of biomass sources is much higher. Biomass is available practically everywhere. This means a distributed structure of several standardised production facilities can be applied. The industry structure of a bio-economy is fundamentally different from a fossil-based industry.

There are also many forms of biomass that would be suitable for usage but which simply have not been considered crops thus far, such as for example the water hyacinth. Much of the bio-economy has so far focused on traditional solutions such as corn-based ethanol.

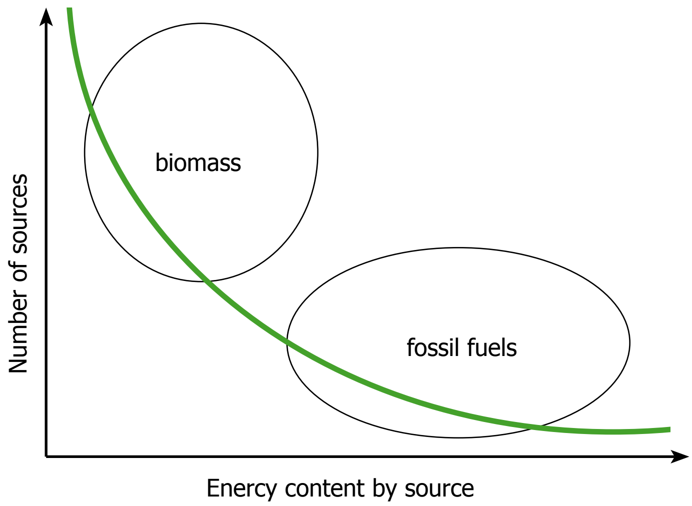

Figure 4. The relation between the energy content of various energy sources and their availability.

However, although certain bio-economic solutions have proven to be beneficial they have not become an established concept. Bio-economic solutions arise organically out of local driving actors with a common interest. There are today no suppliers able to systematically supply modular, reproducible bio-economic concepts, partly because a bio-economy is a highly complex system that requires both advanced technologies and services throughout the life cycle.

In Finland a number of companies from energy, transportation, biofuel, farming and other sectors are developing new concepts for delivering the entire bio-economy and bio-economic solutions as part of it. If successful, these concepts could potentially provide a significant benefit for Finland both in terms of emissions, production and exports. However, this will require a set of skills and capabilities in identifying, establishing and operating the networks that form the solutions and in managing the authorities that influence the systems. A number of chosen bio-economic solutions developed in Finland are reviewed later in this report as the potential elements of a Finnish bio-economy.

2.3 Desktop Study of the Sustainable Bio-economy

2.3.1 Introduction Theory

Bio-economy

As at present the major resources powering the world's economy are of non-renewable origin, there will arise a need to find and exploit new resources at some point in time. Even before this point rising prices for the limited resources will draw attention to other alternatives, such as renewable materials. Biofuels may become increasingly competitive with the currently preferred fuels (Bio-economy, 2011). Fossil fuels are also extensively used for producing chemicals, plastics, etc. If replacing them in these applications, biomass, such as straw or starch, can be fermented and converted with the help of specially developed micro-organisms or enzymes, becoming an appropriate raw material for production (Bio-economy, 2011). The replacement of non-renewable resources by renewable bio-resources is the basic idea behind the bio-economy, which is gaining popularity in the developed world at present.

The bio-economy was defined in the report "The Knowledge Based Bio-Economy in Europe: Achievements and Challenges" (KBBE, 2010) as follows:

> *The bio-economy is the sustainable production and conversion of biomass, for a range of food, health, fibre and industrial products and energy, where renewable biomass encompasses any biological material to be used as raw material.*

The bio-economy generally includes agriculture, forestry, the food industry, fish farming, chemical, pharmaceutical, cosmetic and textile industries, as well as energy production based on using biomass as the main raw material (Bio-economy Research and Technology Council, 2011). Biotechnology may be defined as the technological basis for the bio-economy, as it focuses on the research and development of biological science for the variety of applications mentioned above. It is emphasised by the European Commission that the bio-economy in Europe needs to be knowledge-based, just as the European manufacturing industry has become so. It means extensive research in terms of new biotechnology and its applications in order to improve the efficiency of production in any industrial sector, rather than straightforward replacement of non-renewable resources with bio-based resources (KBBE, 2010). Biotechnology is divided into four main subfields:

- Red biotechnology focusing on medical applications
- Blue biotechnology focusing on aquatic applications
- Green biotechnology focusing on agricultural applications
- White biotechnology focusing on industrial applications.

Thus the main impact of the bio-economy includes replacement of non-renewable resources by bio-based ones, e.g. in production of energy, plastics, and medicines. At the same time the aim is to increase the material efficiency, so that the most possible high-value products are produced from biomass.

The shift towards the bio-economy is expected to help solve the following issues:

- Dependency on limited fossil resources
- Increases in energy use, especially in the transport sector
- Climate change and global warming (as biofuels are proven to have improved combustion characteristics and to reduce air pollution on the life cycle scale)
- Contamination of the environment by unnatural and non-degradable materials
- Need for social and demographic development
- Decline in European agriculture
- Food supply security.

The emphasis in bio-economic policies has been mainly placed on research and development, introduction of new materials, search for new applications of biomaterials, and other technological developments. However, though a certain technological base for e.g. production of biofuels already exists, in many cases it proves to be unfeasible economically, despite all the environmental and social benefits the technology brings. Another issue is that the approach of promoting replacement of fossil fuels with biofuels may lead to displacement of environmental burden from one problem to another. In particular, the exploitation of bio-resources in an unsustainable and poorly planned way may lead to competition for resources and risk of underproduction of food for the sake of energy and technical plants on arable land. Thus, a strict cleantech focus is not enough. It is necessary to take a systemic perspective.

It was noted in reports on the future of the bio-economy in Europe (KBBE, 2010; EuropaBio, 2010a; OECD, 2009) that the main prerequisites for its successful implementation are favourable economic and regulatory conditions. Though a bio-economy develops in different ways in various countries (Stuart and Sorenson, 2003; Tödtling and Trippl, 2005; Ahn et al., 2010), public support and coordination is a common need during the first stage of industry development (Furman et al., 2002; Ahn et al., 2010).

Therefore the management and strategic perspective of the bio-economy should play an important role in establishing the concept and what needs attention. This question was addressed in the report "Industrial or White Biotechnology" (EuropaBio, 2010a), where it was stated that the removal of technical, economic, regulatory and implementation barriers is one of the major parts in the action plan for moving towards a bio-economy.

Despite extensive discussions about the bio-economy even at the highest governmental levels, the main challenge of industry restructuring is still to be solved. It is acknowledged that a new economy type is required for solving environmental problems and developing a successful bio-economy (Birnie et al., 2009; Patermann, 2010), employing efficient value chains that combine the food, feed, fibre, fuel and biomaterials value chains. There is a need for a new organisation to conduct, fund and organise biotechnological research, and to produce, design, and market products. This change is then to facilitate the cooperation between farmers, forest-owners, producers, and engineers in brand new alliances (Patermann, 2010).

This challenge at the same time constitutes an opportunity to create new knowledge and expertise in integrating the new value chains, especially for Finland with its abundance and variety of biomass and the strategy of being a knowledge-driven state.

Sustainability

When talking about the bio-economy sustainability is one of the key issues. A bio-economy can be considered sustainable if it is ensured that resources are spent reasonably and in a strategic manner, and that they are used in the most efficient way by producing as many high-value products as possible, in other words, those with a small or nonexistent negative impact. Such a bio-economy is able to improve the supply security of the country in terms of major resources, such as food, fuels and materials, as well as to create an opportunity for a new knowledge-intensive industry.

In order to ensure that the approach to implementing bio-economic solutions is truly sustainable, it is necessary, instead of focusing only on the technological part, to take a broader look and consider the interconnections between industries and the whole life cycles of bio-based goods produced. This is a need also emphasised by the Organisation for Economic Co-operation and Development in their report "The Bioeconomy to 2030: designing a policy agenda" (OECD, 2009).

In the scope of this report sustainability is understood as defined by the Brundtland Commission:

> *Sustainability is "meeting the needs of the present without compromising the ability of future generations to meet their own needs".*
>
> (World Commission on Environment and Development, 1987).

This definition addresses the contradiction between the environmental threats caused by contemporary economic growth and the need for this growth to mitigate poverty. This dilemma has led to the idea of three dimensions of sustainability: environmental, social and economic, which are mutually dependent and need to be better integrated (Adams, 2006). It also proposed that if one of the dimensions, or 'pillars', collapses, society cannot be regarded as a sustainable one. Discussions about the interconnection between the three dimensions led to the idea of 'strong' and 'weak' sustainability. 'Weak' sustainability cannot eliminate the trade-offs between the social, economic and environmental dimensions, and they are offsetting each other. The opposite case, 'strong' sustainability, is able to maximise the benefits in each dimension, and they are no longer competing (see Figure 5).

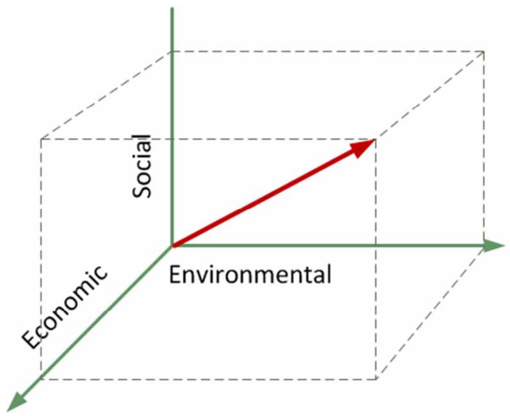

Figure 5. The interdependency of the three dimensions of 'strong' sustainability.

A bio-economy, if properly defined, implemented and managed, has great potential to help in building a strong sustainable society by giving the opportunity to substitute scarce resources with renewable ones. Sustainable bio-economic solutions need to be evaluated taking a broad system perspective and by assessing the impacts of the whole product life cycles in all the three dimensions of sustainability.

The potential for renewable energy provided by the bio-economy is an important contribution to sustainability. Biomass is considered to be a renewable resource because it receives energy from the sun, but only as long as the nutrients used for growth are returned back to the land.

Though the production of renewable energy has positive ecological and economical effects, it might contradict the social dimension of sustainability. An example is the production of the first generation of biofuels, and bioethanol particularly. The first generation of ethanol is produced from the biomass that is easily fermentable, i.e. sugar cane, sugar beet and cereals. It is questionable if replacing of fossil fuels with such biofuels is really sustainable, since the usage of highly nutritious food crops for production of fuel to be exported in large quantities, appears to cause unsustainable usage of country resources and land. Such approach will not secure the food supply and self-sufficiency of a country. Jeopardising meeting the citizens' need for food thus jeopardises social sustainability.

However it is possible to produce ethanol by fermenting cellulose, which is a more abundant and non-food biomass derived from grass, straw or paper waste. The production of the first generation of biofuels may lead to increased food prices and possible pollution increase through the whole life cycle of ethanol production. Production of the second generation of bioethanol, in contrast, brings the social, economic and environmental value of not using arable land specially for energy crops, improving waste management and using the materials more efficiently. This example shows that a systemic view on the effects of each bio-economic solution is necessary in order to reveal the sustainable ones.

Credibility

As a significant number of new biotechnology and cleantech solutions, which are the elements and basis for the bio-economy, are now being proposed, it makes it difficult to choose the direction of development on the country level and for financing institutions to make investment decisions. Moreover the management and business part of the solutions has become as critical as the technical feasibility of the solutions for their successful implementation.

Therefore in the scope of this study the credibility of the bio-economy and its concrete elements, or solutions, is addressed. By credibility we mean the technological feasibility of the solutions, the viability of the business idea behind them, the capabilities of the involved organisations to implement the solution, and the support of the business and social environment for the solution. Thus, a bio-economic solution is credible if it has a well-grounded potential to be implemented and is sustainable according to all three dimensions of sustainability.

This approach towards assessing the maturity of the concepts or the credibility of the solutions is intended to draw attention to the ability to realise the solutions in practice. A poorly thought-out business idea or supply management are factors that drastically affect the credibility of the whole sustainable solution. However there are certain factors that are not dependent on the solution implementer, such as the legislative or business environment. It is necessary, nonetheless, to take the related obstacles into account, try to affect the situation and find the necessary support. Addressing all the challenges and obstacles is a special capability that takes a central position in the maturity of a biotechnological solution.

During the desktop study it was explored what the main hurdles are that the bio-economy faces at present and what efforts are believed to be the prerequisites for its successful development. The following supporting factors were commonly identified in the policies and reports on the bio-economy:

- High-level political commitment
- Broad R&D support
- Promotion of market pull by financial incentives and standard setting
- Targets for government purchase of bio-based products
- Knowledge sharing.

Coming to the implementers' level, they face certain cooperation and coordination problems, which have not yet been studied thoroughly in the light of the bio-economy. However research on industrial symbiosis and eco-industrial parks is an interesting benchmark, as the idea of cycling the material flows in industrial settings is closely connected to the improvement of material efficiency and in many cases implies the refining and reusing of biomass-derived materials. In organising industrial symbiosis it is important to ensure knowledge flow and benefit sharing between the stakeholders. It is assumed that these prerequisites for successful symbiosis are equally true for a new type of industry where agriculture, waste management, material production, energy production and other industries become a part of the bio-economy and are no longer disconnected.

Prerequisites for successful organising of industrial symbiosis that are regarded critical in the literature on industrial ecology (Chertow, 2007) include:

- The commercial nature of the material exchanges
- Trust between the involved parties
- Sufficient information exchange
- Technical integration
- A coordinative function helpful in organising more substance exchanges and moving them forward.

It is important to underline that the research on industrial symbiosis shows that though a regulating force is needed to organise the waste and by-product exchanges between various companies, the major driving force is always the business interest. The role of trust should not be underestimated.

2.3.2 Benchmark with Other Countries

As has been acknowledged, the bio-economy develops differently in various countries (Stuart and Sorenson, 2003; Tödtling and Trippl, 2005). This happens because the biomass resources, the technologies required, the political situation, existing expertise and businesses all vary locally. Therefore it is believed that there is no universal idea of a sustainable bio-economy, but rather there are certain bio-economic solutions that can be suitable and applicable in different locations. There is also the expertise of developing such bio-economic solutions and a bio-economy in general that can be transferred across boundaries.

A number of country-specific experiences in developing a bio-economy are discussed in this section to understand what improvements, challenges and concrete solutions exist in other countries. The especial focus is put on the issues that are also important for a Finnish bio-economy and focal bio-economic solutions that are analysed later in this report.

The following examples of bio-economic development in various countries show that the major effort is directed to biotechnological research and its financing. At the same time in a number of the leading countries the policy in favour of the bio-economy is developed on the country level and support from authorities is ensured. However, though the cooperation between various actors in the biotech industry is promoted, often the industry structure remains the same, focusing on single products' development rather than bio-economic joint business models.

Sweden

An example of a successful bio-economic solution is the case of the City of Linköping in Sweden. This medium-sized city with a population of 140 000 people made the decision to reduce the local pollution from diesel buses by converting the bus fleet to an alternative fuel. Natural gas seemed to be the best option; however the plans to expand the gas grid from the south of Sweden to the city were never implemented. Locally produced biogas was then chosen as the alternative to diesel.

The city government took the lead in implementing the solution by creating a joint company Linköping Biogas AB together with the local slaughterhouse Swedish Meats AB and the farmers' association Lantbrukets Ekonomi AB to build the biogas plant and establish the infrastructure for a biogas-fuelled fleet. At present the biogas plant is owned and operated by Svensk Biogas, which is a subsidiary of the City of Linköping.

The biomass used for the production of biogas is manure and waste mainly from the food industry, such as waste fat, vegetable fat, slaughter waste and so on. The waste coming from the slaughterhouse is transported through a 1.7 km-long pipeline to the biogas plant. The same underground trench is used for the gas pipeline that transports upgraded biogas to the fuel stations for the buses, allowing savings in transportation and infrastructure costs.

Organic fertiliser, which is a by-product of biogas production, is certified according to the Swedish certification system SPCR120 and thereby can be used in farming.

The local transportation system includes around 60 biogas buses, which completely replaced the diesel ones. The refilling system is based on a slow filling system, meaning overnight refuelling of the buses, which allows saving on the capacity needed for gas storage and gas compression. A unique transport solution is the first biogas train in the world, launched between Linköping and Västervik. The solution is claimed to be sustainable as biogas replaces the diesel that was previously used for fuelling the train, and the greenhouse emissions are brought to zero. Another option would be to electrify the railroad, which would bring financial and environmental costs, much higher than the conversion of the train required.

The biogas-based solution has made it possible for the municipality to decrease the CO_2 emissions from urban transport by 9,000 tonnes per year and to decrease the local emissions of dust, sulphur and nitrogen oxides. Other benefits include the replacement of artificial fertiliser by a locally-produced, organic one and improvement in the treatment of the organic waste in the region. The biogas from the plant annually replaces 5.5 million litres of petrol and diesel thereby decreasing the dependency on imported fossil fuels.

Later, Svensk Biogas AB and the City of Linköping launched Swedish Biogas International, a company that builds and operates biogas plants and provides expertise in creating this kind of biogas solution. The focus is still on the technical side of the systems, i.e. development of the technical solution, which is customised according to the biomass to be utilised and application of biogas so that the process fits the customer needs and opportunities. The market for this offering is mainly Sweden, the USA and South Korea (Swedish Biogas, 2011).

Germany

The bio-economy in Germany is rapidly developing. The main focus in this industry is on the medical or 'red' biotechnology, which is being developed by 83% of around five hundred biotech companies (Bio-economy, 2011). Animal health feed and other agricultural products and applications are developed within 29% of those 500 companies, whereas the industrial applications focus accounts for only 13%. It can be seen from these statistics that some companies focus on several areas and thus are assigned to more than one application area. The economic sectors related to the bio-economy provide around 14% of the country's GDP and 13% of all jobs (Bio-economy, 2011).

The development of the bio-economy in Germany is supported by the Bio-economy Research and Technology Council, which advises the government of Germany on how to promote the bio-economy in the country and develops the strategy for it. It is important to highlight that the Council comprises representatives of various research and authority institutions and aims at improving the cooperation between them in order to create objective goals and research agendas (Bio-economy Research and Technology Council, 2011).

However, Germany also provides an example of the problems that might occur if the bio-economy is not managed thoroughly and responsibly. At the beginning of 2011 a scandal regarding dioxin that was found in animal feed emerged. The oils intended for biodiesel production were by mistake or machinations mixed with the animal feed (BBC, 2011). This caused a long chain of food contamination with dioxin, resulting in threats to people's health and the country's welfare in general, since a significant number of animal breeding farms were shut down for a certain period of time. The example shows how tightly the food industry is connected to the fuel industry in a bio-economy, and what stringent control needs to be taken. Another issue that is raised by the accident is the trust between the businesses and trustworthiness of suppliers. In this case, the company recycling the fats and oils was not able to provide the required level of maturity and responsibility to act as a crucial element of the bio-economy. The case should not, however, discourage people from implementing the bio-economy. It rather serves as a reminder of the importance of responsibility and quality in such solutions.

Denmark

Denmark with its case of a successful eco-industrial park in Kalundborg has been inspiring industrial ecologists for several decades. Though the exchanges in the region involve inorganic substances and energy, the example of the successful organisation of a closed material and energy loop is a good benchmark. It is crucial to note that the incentive for starting the exchanges was purely economic, when certain enterprises started to lack resources, such as water, and had to improve their material and energy efficiency and substitute materials with wastes from other production.

Despite the spontaneous emergence of this industrial symbiosis, later the coordination problems required the establishment of a joint company, which was founded by the stakeholders. The mission of this company is to promote further symbiosis between the industries in the area and support information sharing (Chertow, 2007).

Denmark also has a municipality that claims to be completely energy self-sufficient and carbon neutral due to the use of renewable energy sources, including biomass. This is the oft-discussed example of Samsø Island, with a population of around 4,000 people. The island has four district heating plants that use solar panels, locally grown straw or wood pellets, to produce hot water and distribute it through underground pipes to heat area residences. As the straw comes from crops that remove atmospheric CO_2, the heating in this way is considered to be carbon neutral (Fields, 2009). Eleven inland wind turbines produce electricity, which covers the local demand. As the island did not solve the transportation fuel problem and fossil fuels are still used, the decision was made to build 11 more wind turbines offshore to compensate the carbon footprint created by transportation by selling the green energy to Denmark's grid.

The United States of America

The development of biotechnology is already one of the key strategic objectives in the USA. The targets for the year 2030 have been set, stating the share of biomass-derived products in total production for power generation, transport fuels and other products. The supporting acts have been issued, which contain the guidelines for companies on how to gain societal approval and how to remove the barriers to the development of bio-economic solutions (EuropaBio, 2010a). The financial support for implementing the solutions is made in the form of direct investments, joint research programmes and other incentives.

The development of a bio-economy in the USA is tightly connected to developments in biotechnology, such as the development of genetically modified species and bio-based pharmaceuticals. Certain technical developments are facing public unacceptability and are banned in Europe (KBBE, 2010). At the same time the USA is one of the leaders together with Brazil in the world production of biofuels. The industry has developed quickly in the past five years regarding regulations on the mandatory use of the biofuels in the country and tax incentives. Currently the US biofuel production not only covers the national demand, but also allows export of the fuel to other countries. However the sustainability of this fuel in the life cycle of its production and distribution still remains questionable.

China

China's agricultural infrastructure appears to be appropriate for a bio-economy and is developing rapidly. Thus presumably the country has great potential for a bio-economy in the future, once it develops the technological base (EuropaBio, 2010a).

In the biofuel industry developments are large scale. Currently a number of ethanol plants have been built in China. The ethanol produced is mixed with car gasoline to reduce its environmental impact and increase the car fuel availability. It is notable that these plants are large-scale, such as the Jilin plant with a capacity of 600 000 tons per year. However, the size of the market in China can accommodate consumption of the amount of biofuel produced.

In China, a significant number of projects for biofuels and bio-based products are funded by a national high-tech R&D programme. Another feature of the planned economy in China is the opportunity to regulate feedstock prices to ensure their availability. The government supports the development of bio-based chemicals by various incentives for producers and a preferential tax treatment for selected firms in emerging biochemical industries. In terms of controlled demand, there is a specific programme that promotes production and consumption of biodegradable plastics in the country (KBBE, 2010).

Belgium

A remarkable example of an industrial eco-park combining energy production and farming exists in Belgium. In 2009 a 9 MW combined heat and power (CHP) plant was built in the agricultural area near Merksplas by Finnish company Wärtsilä. The plant can be fuelled by various liquid biofuels. The heat produced at the plant is used for agricultural operations in the nearby greenhouses. The plant also generates electricity, which is sold to the local grid and then distributed to the nearby households (Wärtsilä, 2011).

The efficiency of the whole solution is more than 85% as the recovered heat is effectively used for agriculture, which allows sequestering more than 36 000 tons of CO_2 per year (Wärtsilä, 2011).

The solution is interesting also because it was financed mainly by the private sector: local agricultural companies and the energy company Thenergo, with the active participation of a special company for the development of sustainable energy projects.

2.4 A Vision for Finland

Finland has all the prerequisites to become a leading country in a decentralised bio-economy due to its knowledge orientation and high availability of biomass. However the current management of and business approach to the production and consumption of bio-based products is a serious barrier (Sitra, 2011). Taking biofuel plants as an example, the currently preferred scale and structure of the plants leave no chance for Finnish biofuel production to be competitive, since the transportation of biomass over long distances is not feasible. Therefore there is a need for local medium-sized biofuel plants, collecting the local biomass and producing value-added main and by-products, such as biofuels, fertilisers, medical products, etc.

A bio-economy that is distributed has greater viability and is generally more sustainable, as there are less transportation costs involved. Another main characteristic that, according to Sitra (2011), should belong to the Finnish bio-economy is a tight connection to waste management, ensuring that there is a "double" benefit coming from utilising waste for value-added applications.

This type of decentralised bio-economy, comprising production, waste management, energy generation and agriculture, strives for new types of business logic on the country level and new supporting legislation.

Biofuels appear to be the most attractive alternative in the transportation sector, especially when the next generation biofuel technology develops further. This will allow producing biofuel from lignocellulosic biomaterials, which are more abundant and economically suitable for fuel production compared to food crops (International Energy Agency, 2010). For Finland this means that the decline in paper industry might become an opportunity for high-value biofuel production. In addition the waste-like biomass, such as straw or reed, may be processed into fuel, covering the energy demand and reducing the nutrient run-off at the same time.

The knowledge intensity of the bio-economy, as envisioned in the report "The Knowledge Based Bio-Economy in Europe: Achievements and Challenges" (KBBE, 2010), brings to mind Finland's brand report (Country Brand Delegation, 2010). The latter sets the aim of turning the country into the solver of "the world's most wicked problems", to which the energy, waste management, food security and agriculture problems may be rightfully ascribed. It is proposed in the report that Finland should attain the image of a knowledge-developing country and provide problem-solving solutions to the whole world with the help of that knowledge.

As discussed in the brand report, the economy of Finland is based on added value derived from natural resources, abundant forest biomass in particular. While the annual production of traditional crops is about 6 million tons per year, the annual growth of the biomass derived from forest in Finland is equivalent to about 56 million tons of dry biomass. It means that the forest biomass is abundant in Finland at present. At the same time a significant amount of other biomass, such as manure or grass from fallow lands, is not fully utilised. This opens up the potential for improving the biomass utilisation rate, development of new high-value products derived from the biomass and creation of marketable expertise in implementing bio-economic solutions (see Figure 6).

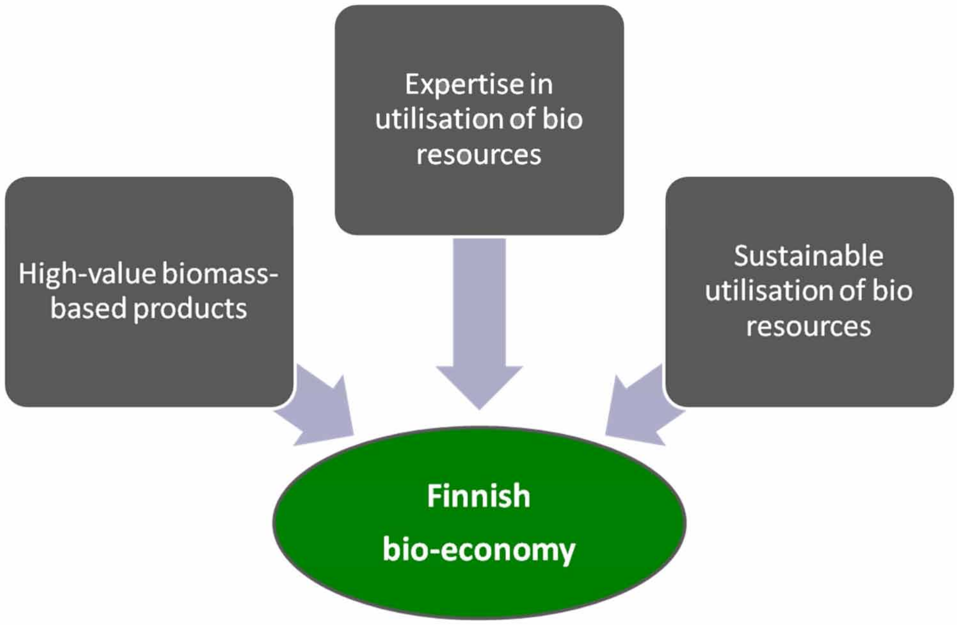

Figure 6. Prerequisites for a sustainable bio-economy in Finland.

The expertise in implementing such bio-economic solutions in other locations, especially outside Finland, is a high-value product that can be exported. However, initially the replication of the solutions needs to be "tested" within the country to achieve a high level of credibility and trustworthiness. The country needs to become the 'national lead user' for the bio-economic solutions to prove their sustainability and the credibility of Finnish businesses to deliver it abroad. For Finland to become the solver of the world's problems including energy and food-related ones, it is reasonable to first solve her own problems and improve the country's energy and food supply towards being sustainable.

3 The Analysis of Bio-economic Solutions

3.1 Conditions for Bio-economic Development in Finland

A great number of factors influence the development of a bio-economy in a country. Since a bio-economy is not an individual industry, but rather the underlying structure of the production in a wide range of essential industries such as energy, food and material production, there is currently not one legislative body or ministry that can be assigned to create and control a bio-economy. Moreover, the factors that affect all these involved industries and their interrelations constitute a complex environment for the bio-economy in the country.

Therefore, to assess the potential for a bio-economy in the country, it is necessary to take a broad look and see what favourable and obstructing conditions there are and what is to be improved in order to build a sustainable and competitive bio-economy in Finland. These conditions include the market situation, legislative environment, research and development, financing opportunities and many other factors that support or to the contrary obstruct the development of a bio-economy in the country.

The commitment to the creation of a bio-economy in Finland is present at different levels of authorities and among businesses. However, there is still no solid long-term strategy on how to achieve it. To ensure a common understanding of the way the bio-economy should be developed in the country thus requiring well-coordinated cooperation, such a policy is crucial. It does not mean binding regulations, but rather a common vision of Finland's future and industrial development in the scope of the bio-economy and concrete supportive measures that will be taken.

In the national long-term climate and energy strategy, Finland is committed to reducing the carbon dioxide emissions from road vehicles by 15% from their 2005 level by the year 2020. This means that Finland strives to achieve a reduction of four million tonnes in its carbon dioxide emissions, one-fourth of this reduction being achieved by increasing the share of renewable energies in transport, in other words by increasing the use of biofuels. This is a prerequisite and acknowledgement of the need to develop the bio-economy. However the concrete measures taken may turn out to be unsupportive for this.

A new feed-in tariff scheme introduced in Finland starting from 2011 supports wind, biogas and wood-based power generation (Energy-Enviro, 2011). As pure wood burning still constitutes the major part of the country's renewable energy production, the renewable energy package is sometimes called a "Package of sticks" (Risupaketti). The package supports biogas production, however, only for electricity and heat production purposes. The support for biogas as a traffic fuel is not realised, meaning that the opportunities for renewable fuels in transport may be limited due to the lack of high-level commitment. At the same time, the need for renewable transportation fuels is addressed by the act promoting the distribution obligation for traffic biofuels that can be mixed with conventional gasoline or diesel fuel. The target is 20% of renewable fuels in the total mix can be met faster due to the "double counting", which can be applied if a biofuel is derived from waste materials or inedible cellulose or lignocellulose. The promotion of such fuels is to support the production of biodiesel from wood materials and waste-to-ethanol production. It is also important to use the raw material and fuel where the highest value can be achieved. For example, fuels that are suitable for transportation should not be used for heating when other options, such as pellets that cannot be used in transportation, are available (see Table 1).

Table 1. Bio-resources and potential.

			Usage		
Raw material	**Refinement method**	**Product**	**Heat Generation**	**Electricity Generation**	**Transport**
Biowaste	Collection	Biogas	X	X	X
Biowaste*	Distillation*	Ethanol*	X	X	X
Green mass*					
Community sludge	Anaerobic digestion	Biogas	X	X	X
Manure					
Wood/ Waste	Gasification	Wood gas	X	X	
Wood	Chipping	Chip	X	X	
Wood	Pelletising	Pellet	X	X	
Wood	Chopping	Firewood	X		

* Biowaste and green mass can be used for ethanol production.

At the same time the Natural Resource Strategy for Finland (Sitra, 2009) is acknowledging that Finland has significant amounts of biomass and the base for developing expertise in its efficient and high-value application. This strategy proposes that this is to be realised through four key strategic goals:

1. Finland has a thriving bio-economy generating high added value.
2. Finland utilises and recycles material flows effectively.
3. Regional resources generate both national added value and local wellbeing.
4. Finland takes initiatives and leads the way on natural resource issues.

These strategic goals set the requirement for a Finnish bio-economy to use the resources efficiently and to create high-value products. The idea of knowledge export is also repeated in the Natural Resource Strategy, showing that intangible value in the bio-economy is the key goal for Finland in order to stay competitive.

The commitment to a bio-economy can be also seen in terms of financing research and development, since research in biotechnology has become one of the priorities set by the government in Finland. Currently there are a number of research programmes acknowledged as contributing to biotechnology research, such as SymBio - Industrial Biotechnology and BioRefine supported by Tekes. The pilot and demonstration facilities related to bio-economic research are mainly built for refining of biomaterials, i.e. separation, filtration, grinding processes, and conversion to biofuels, such as bioethanol, biogas, biodiesel and syngas. The major financing sources are the government of Finland and private companies. It must be noted however that the initiative generally comes from the research organisations that seek financing for the pilot and demonstration plants and biotechnological research in general in cooperation with the private sector (Bio-economy, 2011).

However it was noted in the interviews with the companies involved in the focal bio-economic solutions that although funding for developing biotechnology is available, the need for research of business concepts and their integration in such solutions is underestimated and therefore poorly financed.

The legislative environment for the bio-economy still remains rather unstable. This is partly connected to the fuel taxation legislation, which does not take into account all the possibilities of renewable biofuels in the country. The current support for renewable energy may be disruptive for certain biofuels as discussed above. Another example is the promised support for ethanol production from food plants, which does not contribute to the development of a resource-efficient bio-economy in Finland. The acceptance of biogas transportation is also struggling due to the unfavourable legislative conditions that the natural gas market is suffering from.

However certain positive developments in legislation are taking place. One example is the redevelopment of the legislation related to fertilisation and feed production to take into account the opportunity to utilise biofuel by-products. Inapplicable regulations or ones that are lacking are preventing the industry from rapid development, but the current trend of authority and business cooperation is a positive sign that the environment is changing to support a bio-economy.

To sum up, Finland possesses significant biomass resources, expertise in technology, a range of supporting research and pilot cases. There remains a need for coordination and an overall country-level strategy that would take an overall systemic perspective on the impact of the bio-economy and strive to develop it, not only to reduce emissions, but also to strengthen business.

3.2 Examples of Bio-economic Solutions in Finland

3.2.1 Sustainable Food and Energy Production

Background

The starting point for this analysed case is very interesting. There was a need to eliminate the residues from a local fishery. It was concluded that the fish waste could be utilised in a more beneficial way and turned into fish-oil. It was also noticed that the remaining biomass after the fish oil production was rich in proteins and could be used as raw material for e.g. the feed industry.

In the same area where the fishery is located, there is a landfill where biowaste was earlier dumped. The biowaste could be more efficiently utilised if it was treated in a biogas plant. Therefore, a biogas plant was built close to the landfill. The biogas plant will also treat other kinds of biomass, however taking into consideration the further usage of the humus from the biogas production.

In order to ensure efficient usage of the biogas, a power plant running both on biogas and bio-oil was designed. The emissions (CO_2) from the power plant will be used in a nearby greenhouse. Moreover, there will also be wind power built in the area, which requires balancing power. This will be ensured by the power plant located in the same area. The heat from the power plant will be used in the fish farm, which requires much energy. The fish farm was earlier struggling with wastewater treatment, but this will be solved by using some of the wastewater in the greenhouse.

The greenhouse will provide, besides sustainably produced vegetables, an important source of biomass for biogas production. Briefly it can be said that the solution combines food production, energy production, biogas production and waste management in one local eco-industrial park (see Figure 7). The close proximity of the businesses involved allows an efficient exchange of biomass, nutrient, energy and other material flows for mutually beneficial production.

The Value Chain and Earning Logic

The factors that ensure the feasibility of the solution are the reduction of costs due to effective material cycling inside the eco-industrial park and revenues for the products that are sold to the outside consumers. These products include renewable fertiliser, sustainably farmed fish (no nutrient emissions), vegetables, sustainable electricity that can be dispatched according to need and bio-oil for fuel. In addition the solution provides waste processing and nutrient removal and mitigation in the waterways and the sea. The eco-industrial park also produces fish-oil (or bio-oil) for the market utilising a technology developed within the park. The technology itself has been commercialised and can thereby be considered as another product from the eco-industrial park.

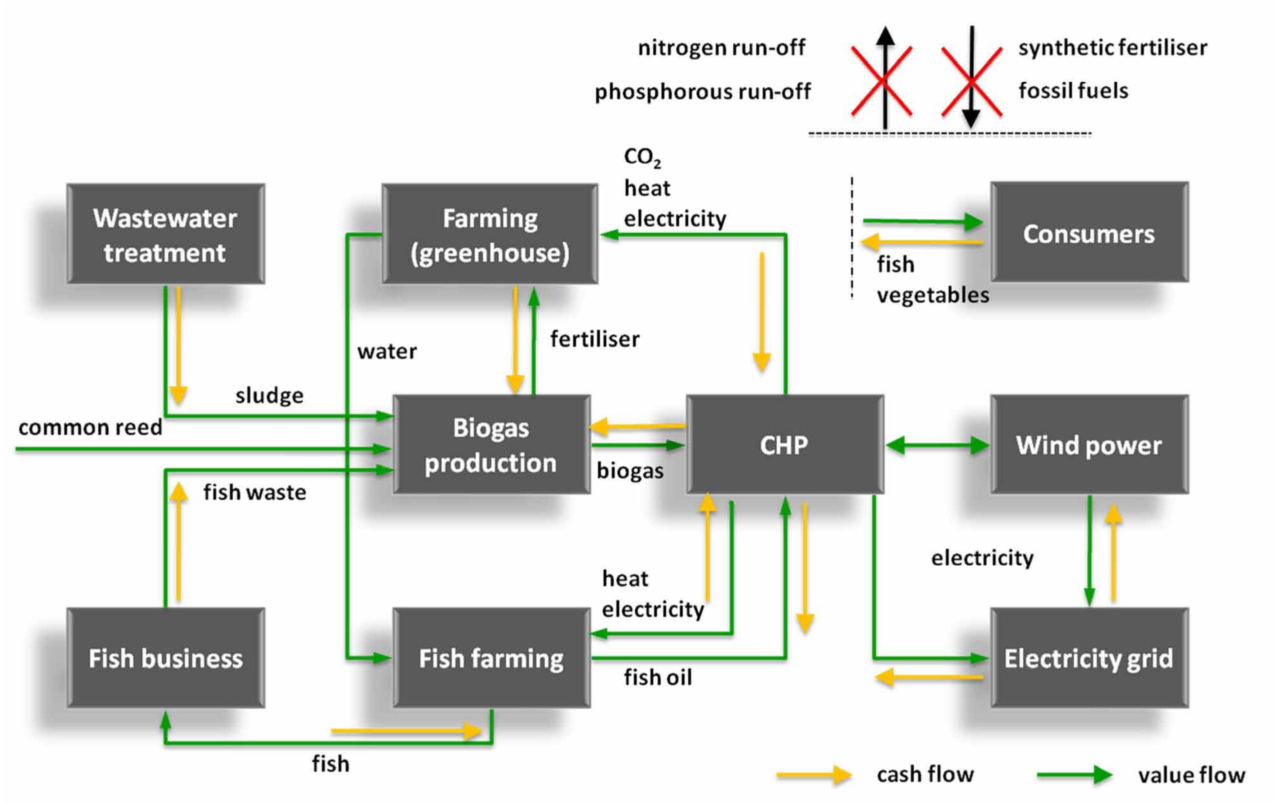

Figure 7. Value network in a sustainable food and energy production solution.

The production costs are reduced due to water reuse, renewable energy production in the form of biogas and the possibility to effectively cycle heat and CO_2 in the premises. The material used for biogas production, i.e. fish residues, dead fish collected in the sea, sludge from the wastewater treatment facility and common reed, are waste or low-value materials at present. This makes the biogas production feasible and contributing to sustainability. Farming becomes more profitable compared to traditional practices due to the use of locally produced organic fertiliser and CO_2 coming from the CHP in the greenhouses. The locally produced energy is renewable due to the balancing use of wind power and biogas. The excess power is sold to the local grid, which is another source of income for the solution.

Actors and Stakeholders

The main actors can be seen in Figure 7. The requirement for the businesses involved, in case the solution is replicated in other locations, is that they need to be professional operators in their area – farming, fish production or power generation. This is crucial since the solution is combined of a number of industries and the operators need to have enough expertise to set it up and operate properly together.

There are also stakeholders that affect the solution, though they are not directly involved in it. These are authorities and investment funds. For the solution to be replicated in other locations, the support from the authorities is required, e.g. in the form of adjusted and new regulations. Investment funds are still reluctant to invest in distributed renewable energy, since the often-changing legislative environment makes it challenging to predict the feasibility and payback period of the investment.

Potential, Challenges and Benefits

The main potential is seen in replicating the solution in other places, in and outside Finland. This would bring the economy of scale to certain companies, while some businesses may be local. There seems to be an interest in the domestic market for corresponding solutions, but the investment decisions are not made for several reasons, e.g. lack of a clear strategy for biofuels on the national level and a lack of legislation.

As already mentioned, one of the highlighted challenges is the legislation. The biofuel power plants are not regulated by any special regulation, as the concept is quite new. This poses a number of problems in the operating phase such as the control of emissions, which varies as the biomass quality is not homogeneous as in the case of fossil fuels. Thus the traditional emission measurement according to the output is not feasible for biogas-fuelled power plants. The technical problems related to the emission control system can be solved; however the legislation also needs to be adjusted to the use of renewable fuel if it is to support it. There is a similar problem with the regulations on using fish oil in power production, which simply do not exist yet.

A key challenge lies in integrating the different businesses. Conceptually the solution can work based on many different streams, not only, for example, fish but also slaughterhouse waste. The solution thereby fits most medium-sized and smaller municipalities which have municipal and industry waste as well as agriculture. However, replicating the solution requires identifying the key stakeholders and potential stakeholders that are needed to create a local solution. To fully realise this solution the capability to identify potential stakeholders and mobilise, organise and coordinate them has to be created.

The benefit of this solution is that it allows utilisation of waste in a way that is beneficial for the environment and the businesses involved. The solution also provides new local jobs, local energy and local food production at lower environmental and financial costs.

3.2.2 Sustainable Transportation System

Background

The focal transportation system is based on the integration of traffic, waste management, biogas production industries, and agriculture. The tight interconnection of these industries is aimed at ensuring the supply of the feed for biofuel production and the demand for the fuel produced. The city authorities play the integrative and coordination role, as the bio-economic solution is designed for a municipality.

The Value Chain and Earning Logic

The value chain is comprised of a number of value chains, so it can be referred to as a value network. Its composition is presented in Figure 8. The value chains of sustainable food production in agriculture, biogas production and distribution, gas vehicle distribution and waste management are in such connection that they form an example of industrial symbiosis, where one industry benefits from another and is sustainable as long as other industries are.

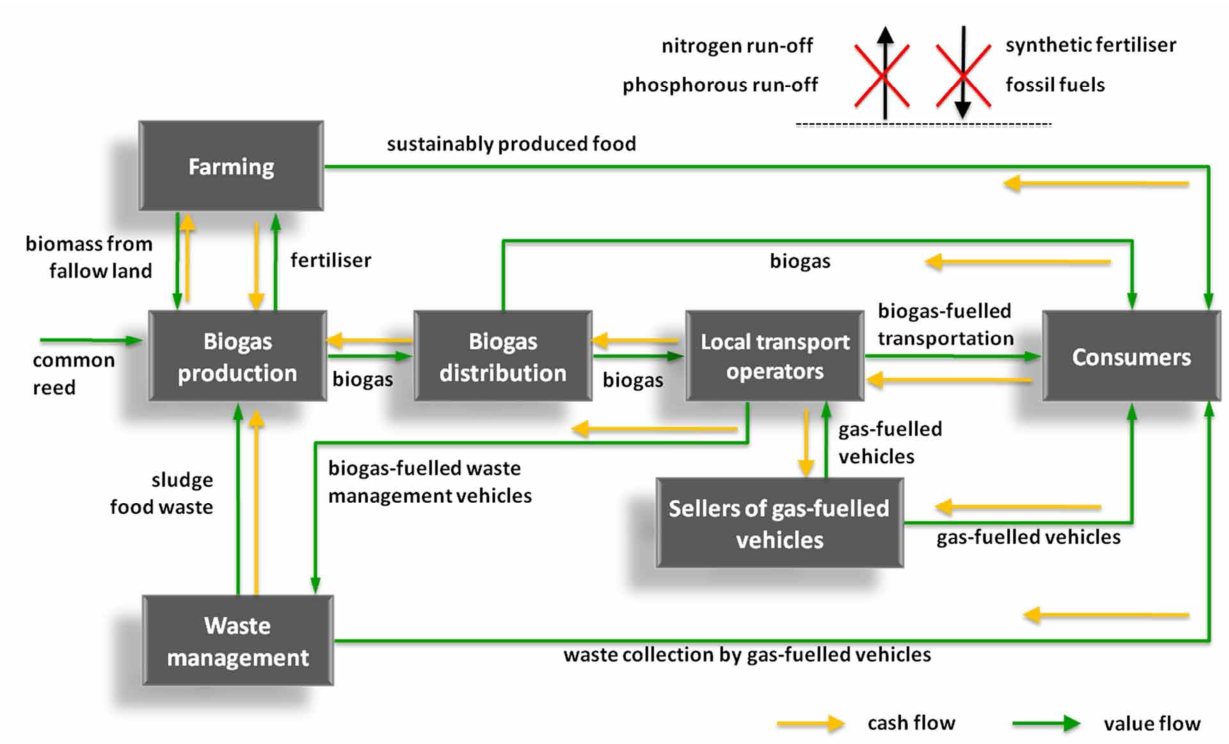

Figure 8. Value network in a sustainable transportation solution based on biogas.

The biogas production chain usually struggles with being profitable. In this case profitability is ensured by a number of reasons:

- the biogas production business has a secondary cash flow for utilising waste as long as it is producing and selling biogas;
- the biogas production has a secondary cash flow for selling fertilisers to farms;
- using biomass from fallow lands makes ley farming profitable, which in turn reduces the fertiliser cost and fuel cost from cultivation while improving crop yield;
- the production of biogas from local biomass and local distribution within municipality limits allows setting a lower price for the biofuel, ensuring demand and creating a local cash flow from transport fuel;
- the demand for biogas is also ensured by providing it as a clean alternative for public transport and waste transport.

The biomass supply for biogas production is compiled of a number of material flows, such as sludge from the local wastewater treatment plant, municipal waste, grass from fallow lands and reed from sea- and lakeshores.

The benefits for agriculture include land improvements by ley farming, which becomes more feasible as non-food crops have value in biogas production. Moreover such an approach to fertilisation combined with the use of organic fertiliser produced at the biogas plant reduces costs for fertilisation as such, since the need for synthetic fertiliser is reduced or even eliminated, and the price for the organic fertiliser is very competitive.

Waste management improves due to the usage of locally produced greener fuel and decreased noise and emission levels compared to the currently used gasoline.

Actors and Stakeholders

The main actors in this bio-economic solution are presented in Figure 8. However it needs to be noted that the city government has a very important role of coordinator of the whole system and purchaser of the majority of the "green" services produced by the businesses involved, such as waste management with the help of biogas-fuelled trucks and sustainable municipal transport. The individual purchasers of biogas cars are required for further development of the system. However their traditional preferences and certain caution about the promised gas price increase in Finland were acknowledged in the interviews with the business actors as the main obstacles in this line of development.

Potential, Challenges and Benefits

The major environmental benefits brought by such systems are the decrease in CO_2 emissions, nitrogen emissions and noise. Moreover, particle emissions are non-existent. The decrease in synthetic fertiliser use in agriculture and the effective utilisation of waste for energy production reduce the overall system environmental impact. Therefore promotion of biogas use in such local transportation systems is able to mitigate global warming, as it allows decreases in emissions from traffic, minimising the emissions from decomposition of organic waste, and minimising the nutrient releases from the production of artificial fertilisers.

Some challenges concerning the biogas production chain are grounded in the legislative constraints. The quality of the output fertiliser falls under the same legislation as manure fertilisation, so for the earning model to work the fertiliser needs to be of proper quality.

The central role of the municipality forms a particular challenge in this solution. The municipality is a key stakeholder that stands to receive many of the benefits of the solution and is also the one that manages public transport, traffic, sewage and waste collection. However, the municipality is not the one that will actively strive to replicate the solution in other locations, and other municipalities may balk at developing the integration capabilities required. Companies therefore need to establish the capability to integrate with different municipalities in such a way that the municipality, with little effort, can enable the solution implementation.

To ensure the success of the solution new service concepts and clear roles and responsibilities between the different companies involved in the unity need to be established. The pricing of any by-products also needs to be carefully developed in order to ensure a cash flow that can be directed to the correct source.

3.2.3 Sustainable Farming and Biogas Production

Background

This solution follows the idea of an eco-industrial park, in which a number of industrial enterprises are closely located and exchange energy and material flow. The solution includes biogas production, power and heat production, waste management, farming and a number of industrial plants that act as consumers of the produced energy. The initiating businesses are an engineering company for biogas plants and a company operating the biogas plant.

The Value Chain and Earning Logic

The earning logic of the engineering company is providing knowledge on biogas plants' construction and related environmental issues. It offers pre-design, help in receiving the necessary permits, feasibility studies and construction of biogas plants, which means the offering goes beyond traditional engineering and the revenue is generated mainly by services.

The operating company has a number of dimensions in its business: production of biogas and fertilisers, heat and power production, and waste management (see Figure 9). The "multi-stream" income flow for the products and services ensures the feasibility of the business. However, there exists a problem with selling the fertiliser produced alongside the biogas production, which is a challenge and opportunity at the same time, as the cash flow still needs to be established. At present the fertiliser is given away for free to the farmers, and the operating company has to pay for its transportation. The potential solution to the fertiliser problem is to cooperate with a company that can turn the material into a product with higher value.

The remarkable element of the earning logic in the solution is the fact that by combining the supply of raw material for biogas production with the service providing e.g. waste management by the biogas plant operator, it increases the revenue while securing the supply. This is a good example of changing the traditional business model of a biogas producer into one with a wider scope. Location, however, has a crucial role in this solution, since the proximity of pig farms and other biomass producers to the biogas production plant allows drastic savings on biomass transportation costs by transporting it through a pipeline. At the same time it is possible and feasible to transfer the heat produced at the CHP plant back to the farms and to the nearby industrial and municipal areas.

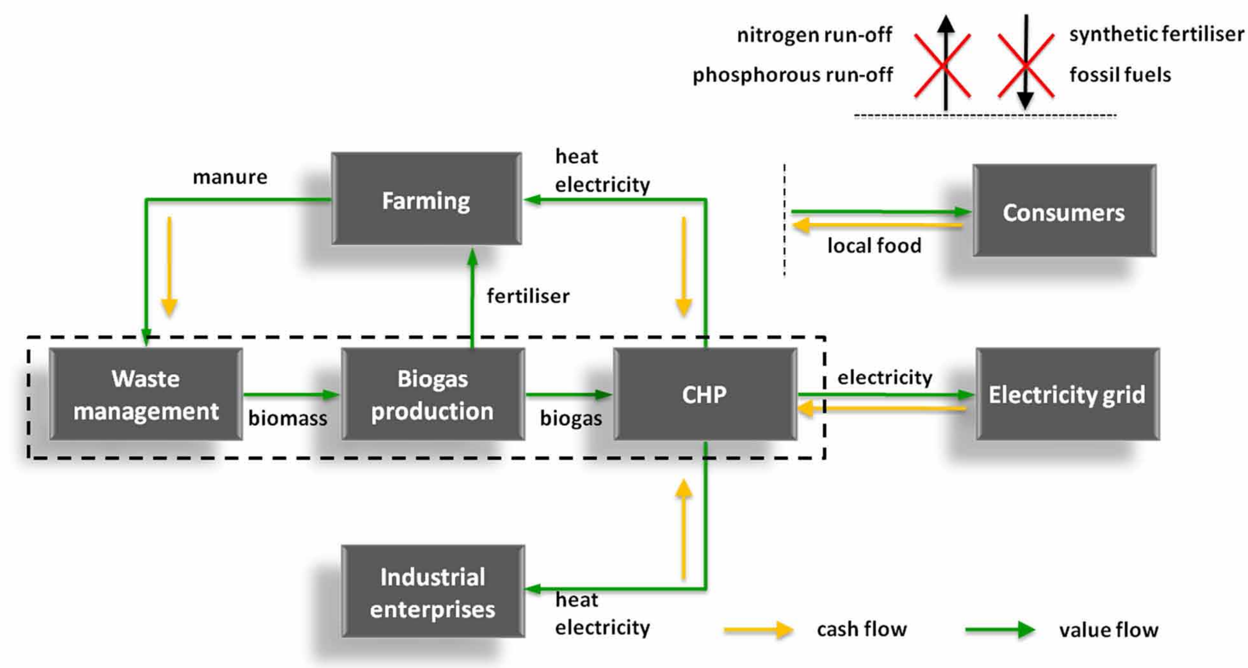

Figure 9. Value network in a sustainable biogas production and farming solution.

Actors and Stakeholders

The major role belongs to the company that operates the biogas plant, which provides a wide range of products and services needed for the solution to function. The farms and industrial plants act as both the producers of biomass necessary for biogas production and the consumers of the produced energy and other products. The authorities play an important role, especially at the investment and construction phase.

Potential, Challenges and Benefits

The potential is there to export the knowledge of implementing similar solutions in other locations. The technological part of the solution is quite easy to export, whereas the challenge is to export the expertise in exploring local conditions, finding local partners in a routine way, etc. Usually it takes years. However this service is more promising, since there is already an established market for biogas plant engineering companies.

Resource-wise, there is the potential for 300 biogas plants similar to the focal solution in Finland that can be built in the rural areas, which have enough biomass and the relevant demand for fertilisers, heat and energy.

The idea of local sustainable food and energy production proved to work so well that the Finnish government plans to create an eco-industrial park around it. Since the operating company owns the area, it shows how a successful concept is able to attract more investments.

One of the challenges that the solution faces is the lack of governmental support, as the latter focuses now mainly on big companies and solutions in the energy sector, but not the small-scale distributed ones. The infrastructure for distributed energy is not as easy to be established, which is another challenge. Since the solution involves a number of other industries, the legislation also sometimes poses a problem. The legislation on animal by-products, fertilisers, and soil improvements change often and unpredictably. As these industries form the inseparable parts of the solution's value chain and business idea, this legislative instability affects the potential for long-term investments and stability of the whole solution.

Local authorities may also pose problems; however the operating company regards it as routine work to communicate and arrange the solution implementation. The level of education of the authorities plays a big role here. It often happens that certain measures or requirements do not apply to the business, but since there is no special regulation for the new business, the companies need to follow formalities and spend extra resources on doing so.

The solution has a positive impact on the local actors, i.e. farmers and businesses, as new job opportunities are created and local sustainably produced fuel and fertiliser are available. As a consequence, the food in the area is sustainably produced without consuming fossil fuel for energy and heat, nor synthetic fertilisers. Biogas production is generally more sustainable, as it focuses on waste management rather than energy itself, as is the case in Germany, for example. In the latter case the energy is cheaper, but its production may not be optimally sustainable, as the side-flows are not taken care of.

3.2.4 Sustainable Ethanol Production and Distribution

Background

The idea behind sustainable ethanol production is to build a number of small-scale (1000 m^3 of ethanol per year) plants near feedstock such as starch- and sugar-containing waste and side streams. This would minimise the transportation costs. The feed for bioethanol should be waste biomaterials or non-food crops that are grown regardless, e.g. for the purpose of ley farming. This makes ethanol production sustainable, as it implies not only biofuel produced at any cost, but a solution that solves waste management and certain agricultural challenges, such as land and water contamination by synthetic fertilisers.

Value chain and earning logics

The value network for ethanol production and distribution is presented in Figure 10. The major income comes from ethanol. Certain biomass used as raw material for ethanol production is generally perceived as waste, so the waste producers pay for it to be taken for biofuel production. In this case the earning logic for the ethanol producer is such that up to half of the money comes from a waste management gate fee and the other half comes from selling ethanol and other energy by-products. Certain materials however are not yet considered as waste, e.g. straw, and the ethanol producer might need to pay for collecting them.

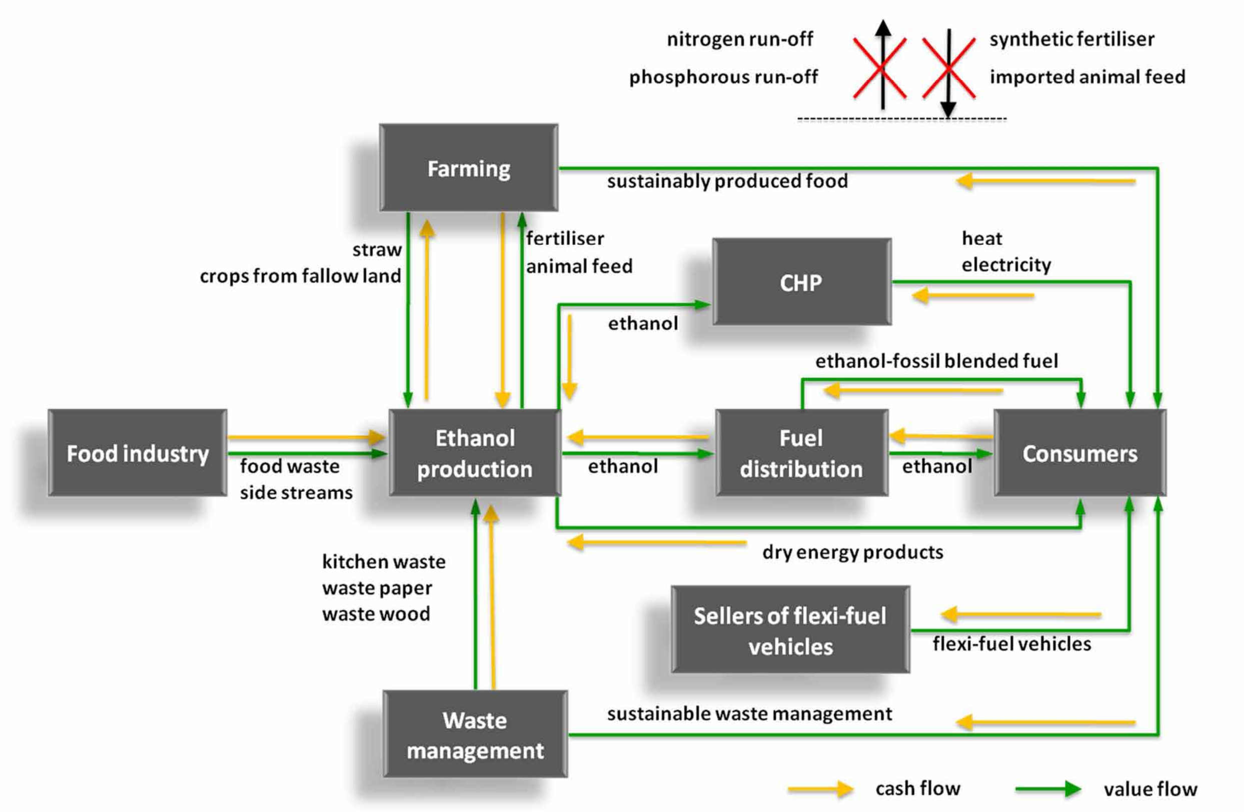

Figure 10. Value network in a sustainable ethanol production solution.

Actors and Stakeholders

The main challenge in such system is the organisation of the raw material supply and ownership of the ethanol plants. The ethanol producer, as well as biomass suppliers, is reluctant to own the biofuel plants. For the former it is more attractive to buy the ethanol from the plants and possibly operate them. At the same time the biomass suppliers, i.e. food producers or farmers, do not want to enter the alien (for them) energy market, as it is not their core business.

In addition the support from other fuel distributors might be needed to distribute the biofuel across a larger area.

Potential, Challenges and Benefits

The major potential for ethanol utilisation is the 2011 increase in ethanol demand in Finland, grounded in new regulation setting the content of ethanol in car gasoline up to 10% in order to comply with the EU Renewable Energy Directive and EU Fuel Quality Directive. Currently in Finland there is the need to blend 100 million litres of ethanol per year. It is estimated that by 2020 the blending requirement will be 300 million litres. At present the demand is covered mainly by ethanol imported from abroad, e.g. Brazil. As the purpose of blending ethanol with gasoline is the reduction of the fuel's environmental impact, the use of locally produced and waste-derived ethanol would be a more effective alternative to the imported one. Distributed production would even further lessen the environmental impact, as the raw material transportation costs are minimised. Other benefits of such an ethanol production are the improvement of waste management, biomass refining efficiency and agriculture due to the utilisation of the ethanol production by-products instead of synthetic fertilisers. Therefore, if a broader system view is taken on distributed local ethanol production, it is obvious that the environmental impact is much lowered compared to common centralised ethanol production from food crops.

This solution is however facing a number of challenges. One of them lies in the fact that the raw material used for ethanol production defines the applicability of the produced by-product to animal feed. For instance, if ethanol is produced from kitchen waste, the generated by-product may be used only for fertilising, provided that it complies with the corresponding regulations, or for making dry fuel for CHP. This means that the ethanol production facilities need to be separated in case of a multi-feed process in one location according to the raw material properties.

The potential is to find more raw materials for the biofuel production, such as starch liquid remaining from enzyme production, which is currently used in the paper industry. If the paper industry undergoes a downturn, the starch liquid, as well as the sawdust currently used for pulp production, will become 'unassigned' biomaterials, applicable for ethanol production. The cellulose derived from waste paper, waste wood, and straw is also a potential raw material that can be used in ethanol production.

Support for green energy currently promised by the Finnish government is actually money reserved for ethanol facilities using malt or wheat for biofuel production. However such an approach to ethanol production is much less sustainable than the case solution's described here.

4 Generic Value Chains

The analysis of the value chains (VCs) in the focal bio-economic solutions showed that the earning logic and value generated is common to certain cases. However there are differences in the value chains that are dictated by the proximity of the businesses in focus (see Figure 11).

The first type of value chain, 'Local Bio-economy', is similar to eco-industrial parks in terms of earning logic and organisation of the flow exchanges. The businesses involved in the value chain are located in one industrial area, small enough to improve energy efficiency by circulating heat, water and other substances. The biomass flow is also cycled to make its use as efficient as possible by reusing, recycling and producing green energy out of it. The close proximity of industrial enterprises allows savings in the biomass and energy transportation costs, thus reducing the price for the internal products. This in turn allows reductions in financial and environmental costs for the parties involved.

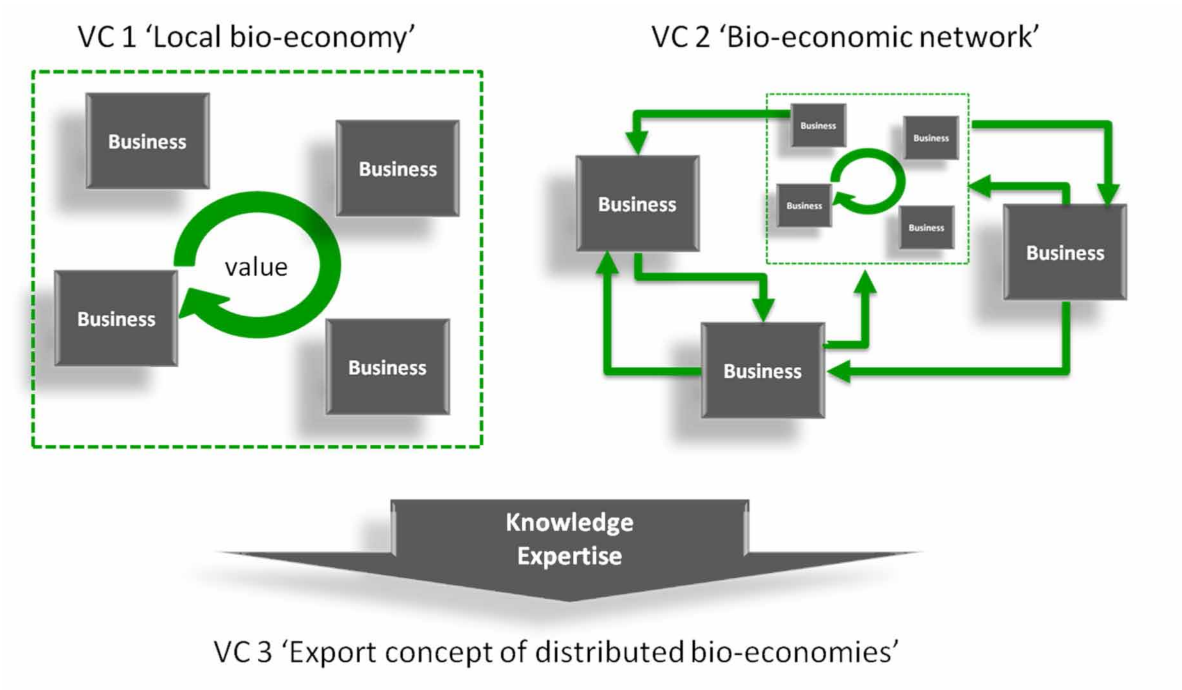

Figure 11. The value chains (VC) in a distributed bio-economy.

The value chain of the second type, the bio-economic network, involves industries rather than concrete enterprises and thus means cooperation across a broader region. The relative locality of the solution still remains important as it ensures reduced environmental impact of the bio-based products produced inside the 'bio-economic network'. However the main outputs of solutions with such a value chain are the effective utilisation of biomass and production of high-value bio-based products.

The third type of value chain, 'An Export Concept of Distributed Bio-Economies', implies a business that offers expertise in organising the value chains of the first and the second type. We stress that this includes not only development of the technical part of the solutions, but the capability to organise the cooperation between the companies, stakeholders and other actors, taking into account the local conditions. Development of this value chain is crucial since the investments made by companies to create local bio-economic solutions can be recouped when a certain economy of scale is achieved, i.e. replication of these solutions is not only environmentally but also economically sustainable.

4.1 Value Chain 1 – Local Bio-economy

The core of this value chain is the energy and biomass exchange in the premises, as it allows reducing financial and environmental costs (Figure 12). The proximity of the involved enterprises makes certain exchanges possible, e.g. direct use of CO_2 produced by one process in greenhouse farming. The major value received by the actors is the substitution of certain supplies with locally produced and often cheaper options. For example, the fertiliser produced in the eco-industrial park replaces synthetic fertilisers, and the efficient energy cycling and production of biofuel reduce or eliminate the need for fossil fuels.

Biomass production is an important part of the value chain, as it affects the opportunities for 'green' energy production: the volume, quality and type of energy. This, in turn, defines the technologies applicable in such a solution and actors that need to be involved in the system. The mixture of biomass sources is very local, and its mapping for each area is one of the potential services that may accompany the bio-economic or energy solution development offering. Biomass mapping and assessment may also be a service provided by a waste management company for industrial enterprises, as it is sometimes done in the scope of waste management services at present.

Energy production is included into the value chain, because it is considered to be a crucial step in biomass refinement: the most value can be derived from biomass, especially waste biomass, if it is first used for transport biofuel and energy production and then for other purposes, such as fertiliser or feed production.

Waste management inside such a system changes its traditional role, as more materials become a valuable raw material instead of waste. The fees for collecting waste biomass still need to be collected, as otherwise the incentive for reducing waste output will diminish, threatening environmental sustainability. However the fees need to be lower compared to average waste management options, so that the biomass producers would still be interested in cooperating. Waste management can be established as a separate business in such a solution, but generally it is simply another service that the energy producing business provides. In any case the close location of the businesses involved makes it a question of only tens of kilometres' transportation, often by pipe.

The consumers here are generally the industries involved in the eco-industrial park. The closed character of the solution secures demand for the renewable energy and the supply of biomass for its production. As the energy and biomass are cycled in a limited small area, this provides a high efficiency of their use.

The output of this value chain are the normal products of the industries involved, such as food and energy, going to the outside customers, but they can be rightfully considered to be produced in a sustainable manner and having a lowered environmental impact.

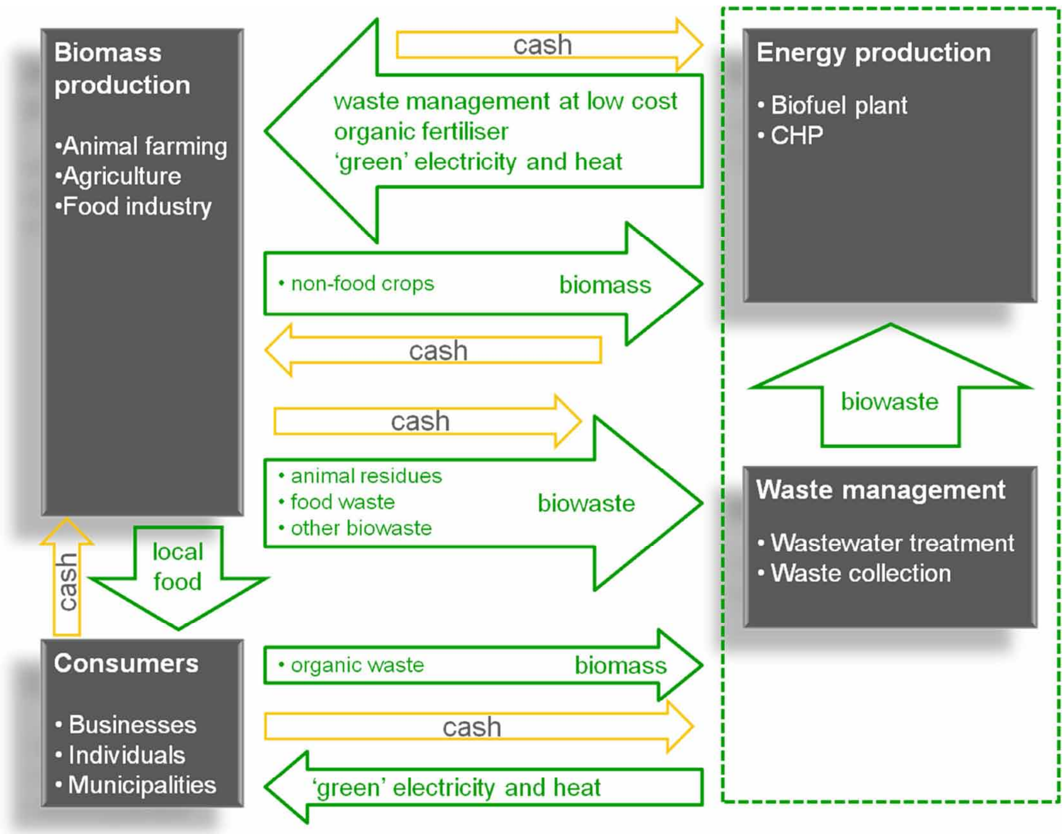

Figure 12. Value chain "Local bio-economy".

4.2 Value Chain 2 – Bio-economic Network

This value chain is appropriate for more large-scale solutions, covering a bigger area, but still quite local. Therefore there is a need for high-value products to be produced from biomass, so that their transportation would be financially and environmentally feasible.

The value chain includes biomass production, biomass refining or production of high-value bio-based products, waste management, various supporting businesses and consumers (Figure 13).

Biomass production does not mean, for instance, determined growing of energy crops for biofuel production, but instead averagely functioning industries that have significant amounts of biomass as their by-product or waste. These industries include food production, animal and plant farming, and slaughterhouses. Municipal and commercial waste is also a potential source of biomass. To ensure a smooth and high-quality supply of this raw material for refining, a tight cooperation with the waste management business is required. This is especially important as the quality and composition of the input materials define the properties and application of the output bio-based products.

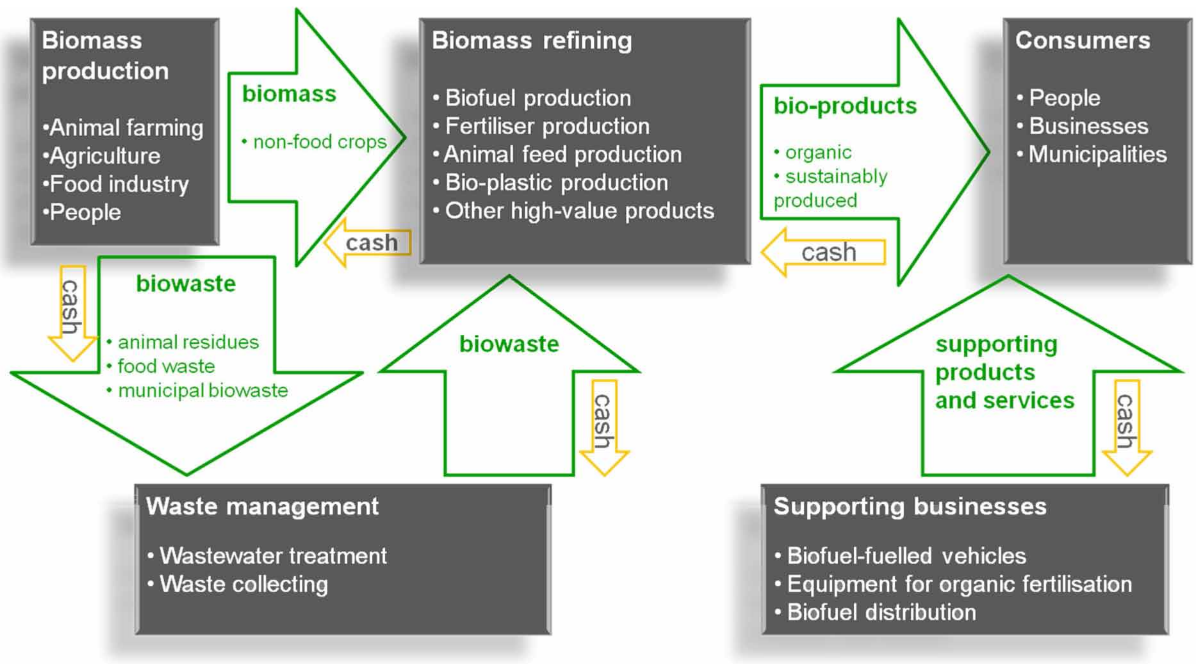

Figure 13. Value chain "Bio-economic network".

The products produced at the refinement stage include biofuels, fertilisers, animal feed, bio-plastics, and any other bio-based products.

The consumers here are actually anyone who finds the products valuable. This also includes the businesses involved in the bio-product production value chain. For example, agriculture is providing biomass, but at the same time it consumes the organic fertiliser. The biofuels produced in the network may be used by local citizens, by municipalities in power plants or by waste management companies to fuel their waste collection vehicles. This way the biomass is used effectively and the nutrients are 'cascaded' to gain as much value from the local biomass as possible.

4.3 Value Chain 3 – An Export Concept of Distributed Bio-economies

As it proves to be challenging to establish these kinds of value chains in practice, the knowledge and expertise in doing it is itself a valuable product. The companies in the focal solutions are willing but not yet able to establish the 'Knowledge export' value chain and export the solution to other locations. One identified reason for this is that a 'reference case' in Finland needs to be implemented first, so that the knowledge could be successfully marketed. Certain companies are already able to provide knowledge of building, for instance, biogas plants and consultancy in terms of improving industries' environmental impact. This example belongs to the first value chain 'Eco-industrial park', but the knowledge export for the second value chain still remains unrealised, as it requires not only expertise in technical integration, but also the strong capability of business integration in new business, social and political settings.

Because bio-economic solutions mainly focus on integrating and establishing business operations in a symbiotic way, the key focus in exporting the solutions must be on establishing the stakeholder network required for locating, building and operating the solution. This will require a strong local presence which can be provided by key companies in the solution. This must then be backed up with a network of capabilities such as cultivation, forestry, traffic planning or similar functions that can be drawn upon to ensure the functioning and credibility of the different parts of the bio-economic solution.

Exports of bio-economic solutions will mostly be in the form of knowledge, i.e. services. Finland has a track record in knowledge intensive exports. Exporting bio-economic solutions would largely consist of exporting whole business models which are then applied locally.

4.4 Map of Actors

4.4.1 Actors and Their Roles and Responsibilities

In a bio-economic system there are several actors involved, all more or less interconnected and with separate roles and responsibilities. In order to ensure successful operation of the bio-economy, the actors involved and their responsibilities need to be clearly defined. An example of the different actors and their responsibilities in each part of the value chain is presented in the table below, Table 2.

Table 2. Key actors and their responsibilities in the value chain.

	Value Chain	Examples of Key Actors	Responsibilities
Raw Material	Biomass producers	Farmers	Sustainable farming, livestock breeding, production of biomass from fields
		Food Companies	Providing raw material for the eco-industrial system
		Biomass companies	Common reed harvest, algae production etc.
	Waste management	Wastewater treatment facilities	Supply of sludge for biofuel production
		Waste collection companies	Supply of biowaste
Refinements	Producers	Biogas producers	Biogas production, fertilisers, other products
		Ethanol producers	Ethanol production, feed stock, fertilisers, other products
		CHP	Heat & electricity production
End Products	Customers/Users	Farmers	Usage of bio-fertilisers
		Transport companies	Utilisation of biofuels
		Bus companies	Utilisation of biofuels
		Private persons	Utilisation of biofuels, "sustainable food", heat & electricity
		Other	Electricity, heat, CO_2 etc.
Enablers	Supporting actors	Vehicle distributors	Providing biofuel-fuelled vehicles
		Financiers	Providing needed financing for actors
		Engineering Companies	Providing standard solutions for the bio-economy
		Ely-keskus	Practical support in terms of advice
		Consultants/Research institutes	Enhancing & improving the system benefits
		Media	Information about aim, target and available solutions
	Municipalities/ Local Authorities	Decision-makers	Commitment & incentives Leading & coordinating Ensuring commitment from inhabitants
		Local authorities	Understanding of system concept, ensuring all regulations are followed
		Evira	Clear directives and governance
		Ministries	Clear directives

Some of these actors are presented more in detail in this section of the report.

Investment Institutions

Investment institutions play a large role in the development of bio-economic solutions. However the challenge is that current projects for creating such solutions often lack the credibility necessary for being financed. Normally investment funds, banks, and various foundations have a set of criteria to assess the potential and feasibility of such projects. The criteria for assessing the financial feasibility of projects are quite traditional: the forecasted cash flow, ability of the project to pay back the loans, and ability of the companies involved in the project to handle the uncertainty and challenges that may arise during the project. For complex bio-economic solutions, which involve a significant number of partners and are affected by a variety of legislative and political factors, the uncertainty reaches very high levels and makes it extremely difficult to predict the market development and feasibility of the solution. Taking the biogas-based transportation system as an example, it is affected by the market and the political and legislative situation in the gas, fertiliser, and transportation sectors, which has proven to change often and unpredictably in the past years.

The credibility of the actors involved in bio-economic solutions is also rather difficult to evaluate, since often the solution implementation requires new capabilities not necessary previously for the core business of the actors. In this respect, the awareness of this need and the will of companies to develop these capabilities may be the decisive factor in assessing their competence for a bio-economic solution project.

The projects for developing sustainable bio-economic solutions have the potential for certain environmental problems, as discussed earlier. This strength can serve as a means to draw additional financing from the investment institutions that put environmental problem solving as their priority. In order to access this financing opportunity, the bio-economic solutions need to have clear positive environmental impact and assessment of their contribution to fighting environmental problems. In general, this may refer to positive effects on the environmental situation, e.g. reduction of the nutrient run-off, decrease in use of fossil fuels, or reduction of harmful emissions from the system perspective. The improved environmental impact needs, however, to be visible through calculations, such as amount of reduced CO_2 or volume of fossil fuel that is replaced with renewable energy. At the same time careful consideration of the environmental impact of a bio-economic solution is able to increase the credibility and public acceptance of the solution. The life cycle perspective of the whole solution needs, however, to be taken into account, and life cycle impact calculations may pose a challenge.

4.4.2 Missing Actors

At present there are two key elements missing in the field of bio-economic solutions in Finland: a bio-economic development and integration company and outward-oriented business-models in the leading bio-economic companies.

Bio-economic Development and Integration Company

Although there are many well-established companies that can supply the technologies and engineering companies that can provide the technical configuration of bio-economic solutions, there are no companies that have the capability to create working bio-economic solutions. The situation is comparable to complex production plants where no single supplier has the overall knowledge. In the case of bio-economic solutions the question is not only about achieving a technical integration (engineering) but also economic and environmental (and to a certain degree social) integration.

In order to get the bio-economy started a company that focuses on developing and delivering bio-economic solutions would be needed. The role of the company would be to continuously identify needs in the market while at the same time scouting for solutions to these and other needs in order to develop standard modular bio-economic solutions. Thus the company would provide an integrating service to the field of bio-economy.

The earning logic of the company needs to be based on the actual value of the solution. This way there will be an incentive to reduce investment costs through standardisation and modularisation. Suppliers are encouraged to present part solutions or technologies and thereby influence the bio-economic solution to their own advantage.

In establishing such a company it is important to ensure that the business model and earning logic of the company is outward oriented, i.e. driven by the benefit of the key stakeholders (Wikström et al., 2010). The key capability of the company would lie in integrating the business models of different industries through technical solutions proposed by technology suppliers. The company would strive to continuously develop the solutions by following both the development of needs, technologies and scientific and legal developments, thus leveraging the uncertainty of cleantech and bio-economy to its advantage.

Developing Capabilities of Key Bio-economy Companies

The companies that are striving to be key actors in driving the bio-economy need to develop business models that are outward-oriented. Rather than simply developing a technology or process and expecting other stakeholders to adapt, companies should develop services which will lower the threshold for other stakeholders to join bio-economic solutions. By combining the services with the company's products or technology the company can provide added value, for example, in the form of waste management (biogas and ethanol) or fertilisation (biogas).

Companies aiming for a key role in the bio-economy should also develop capabilities to integrate local companies, be they local entrepreneurs or local representatives of larger chains. Being able to integrate locally in an efficient manner is a key element in developing distributed operations and exporting the solution.

Just as with products and technology, services can also be standardised and mass-customised, thereby driving down the service cost. Companies should strive to develop mass-customised modular product-service solutions.

4.4.3 Potential Actors

Local energy companies and the food industry are potential industries with which to connect on a larger scale. There is a lack of small-scale (under 10 MW) renewable solutions whereas there are many energy and district heating grids in that range. This provides a basis for developing standardised modular solutions.

The food industry starting from agriculture all the way to consumer sales includes high amounts of organic side flows and waste. Bio-economic solutions provide the food industry the possibility to defer waste management costs and increase sustainability and thereby brand value.

In addition to the above, municipalities are key actors in developing the bio-economy. As noted earlier, municipalities have a key role in enabling bio-economic solutions. They also have an interest in developing local business, improving the environment and reducing costs from waste management and are well connected with the local businesses to do so.

4.4.4 Authorities, Stakeholders and Other Actors

Ministries

Based on the case studies, the following ministries can be considered to be in a key position to ensure a successful bio-economy in Finland.

- Ministry of Finance
  - Expertise in tax policy matters
  - In charge of legislative and financial requirements of local government functions

- Ministry of Agriculture and Forestry (MMM)
  - Sustainable usage of natural resources
  - Agriculture
  - Development of the countryside
  - Food & food safety
  - Water

- Ministry of Employment and the Economy (TEM)
  - Employment
  - Regional development
  - Energy and climate politics
  - Innovation and technology politics
  - Market regulation

- Ministry of the Environment
  - Ensurance of a good and safe living environment
  - Biological diversity
  - Environmental damage prevention
  - Improved housing conditions

These ministries have different areas of responsibilities, which will affect a bio-economic solution in different ways. The decisions made by the Ministry of Finance affects the taxation and thereby the profitability related to bio-economic solutions, while the Ministry of Agriculture and Forestry affects the bio-economic solutions with decisions related to e.g. sustainable usage of natural resources. The Ministry of Employment and the Economy makes decisions on regional development and, perhaps the most important area, energy and climate politics. The Ministry of the Environment also has an influence on bio-economic solutions from an environmental point of view.

There are indications that entrepreneurs with the intention to build up new bio-economic solutions face troubles when dealing with the authorities due to unclear roles and responsibilities. There seems to be a missing common understanding on how bio-economic solutions should be handled. Moreover, there also seems to be missing a clear strategy for bio-economic solutions within and between the ministries.

There are many reasons why entrepreneurs feel that a common strategy and understanding of bio-economic solutions are missing. Sometimes the advice and directives given to the entrepreneurs are contradicting; in other cases the needed documents or permits are not fit for the bio-economic solution. Moreover, the legislation and directives given by the authorities can be applied differently in different regions. This contributes to the increased uncertainty the entrepreneurs are experiencing.

An improved understanding of the bio-economy on a higher level, both in the ministries and by the entrepreneurs, could improve the prerequisites for the development of bio-economic solutions in Finland. In order to achieve this, proven solutions are needed as evidence to show the sustainability and credibility of the business.

Local Authorities

Variance in how laws and regulations are interpreted and implemented by local authorities can cause significant hurdles when developing a local bio-economic solution. This should therefore be taken into account when mapping the potential for bio-economic solutions.

Evira

Evira is the Finnish Food Safety Authority, whose aim is to control food safety, animal health and welfare, plant health and develop the requirements for plant and animal production (Evira, 2011). The organisation is an important actor, especially for the biofuel production part of bio-economic solutions and sustainable agriculture. Regarding, for instance, biogas production, the limitations on the use of the animal feed produced (in ethanol production) or fertilisers (in biogas or ethanol production) are controlled by the authority.

The Department of Food and Health of the Ministry of Agriculture and Forestry is responsible for legislation and general guidance of control, while Evira is the controlling body (Evira, 2011); thus the latter has a limited impact on the legislation related to food safety, including animal feed and soil improvement regulations. It is important to note that although there are a number of country-level laws regulating food safety, the major regulating legislation is accepted at the European Union level, meaning that it is common to all the EU countries.

The authority recognises the importance and future of the bio-economy in Finland, but as the organisation controlling food safety, it warns companies to be responsible in cycling the biomass. According to Evira, the companies should pay attention to the produced fertilisers and animal feed safety. There is pressure to use more bio-economic solutions and recycling back into nature. But there is the risk that if biowaste is used for fertilisers, it may cause fertiliser contamination with harmful substances or plant pathogens – various diseases and harmful pests.

Since a biofuel producer needs to be approved or registered by Evira as a feed producer, this means that it indeed becomes part of the biofuel production business. The influence of this widening of the operation scope results in the adjustment of the production process, raw material requirements, hygiene in the production premises, control systems, etc. The control of raw material becomes a crucial issue, since it directly affects the quality of the by-product of biofuel production and whether it can be used for animal feed or fertilisation. The supplier of the raw material may also need to change certain processes of handling the biomass used for biofuel, animal feed and fertiliser production.

The above generally means that a biofuel producer needs to take control of the by-products' quality, not only the biofuel, and this control is to be established over the whole supply chain. Besides this, understanding of the feed or fertilisation business is crucial for a biofuel producer in a bio-economic solution.

Since it is not feasible nor reasonable to control every biofuel plant that produces animal feed or soil improvement material, and only occasional visits to the production sites may be made, the major responsibility should be taken by the businesses. An example of severe problems related to the interconnected biofuel and food production in Germany discussed earlier is a warning to follow the regulations on food safety strictly, even if it is not the core business of the companies. Otherwise the whole idea of the bio-economy might be questioned. Therefore Evira underlines that the ability of an operator to handle the feed production alongside the biofuel production properly is one of the main issues when developing bio-economic solutions.

Cooperation with companies in developing the regulations and control of food-related products in biofuel production is already established in Finland. The cooperation is done generally through joint research projects and collaborations with Evira at the stage of developing the plans for biofuel plants. This shows that there is the potential of a common effort towards a bio-economy in Finland.

SYKE

The Finnish Environment Institute (SYKE) is both a research institute and a centre for environmental expertise (SYKE, 2011). The authority conducts research on environmental changes and the ways to control them. SYKE promotes a broad and long-term perspective on environmental sustainability and conducts multi-disciplinary research to this end.

Possessing significant expertise in environmental issues, the authority sees the future of the bio-economy as a part of the "green economy", which also includes other 'clean' technologies, such as wind power or ground heat power. However the limited amount of biomass in Finland needs to be taken into account. This implies the need for the efficient use of the biomass and the production of high-value products out of it. Moreover, this could become Finland's 'competitive advantage', since there is no potential for producing 'bulk' biomass-derived products in Finland.

One of the challenges is the structure of the current wood and paper industry, which could play the major role in the bio-economy. At present the products of this industry are of too low value and soon will not be able to compete, for instance, with Chinese products. The renewable energy currently produced also needs to be questioned in terms of how sustainable its production is. For this, a life cycle perspective of the fuel production needs to be taken. Though currently EU legislation requires a 35% improvement of the environmental impact for biofuels compared to fossil fuels, it is still a challenging task to assess all the impacts. One of SYKE's priorities is to contribute to the related research and make these assessments more precise and useful.

The challenge for Finland is to find the most promising and competitive technologies and areas of application and invest in their development. In this respect, SYKE's role is to produce sustainability dimensions, to map the potential biomass resources and explore what the most sustainable and competitive ways to utilise it are. The strength of the authority and Finland in general is the availability of the required environmental data and research.

5 Potential, Challenges and Benefits of the Bio-economy in Finland

5.1 Potential

The development of a bio-economy has a promising future in Finland. This is due to the variety and high availability of biomass resources, substantial technological base for its refinement and the commitment to build a sustainable society in the country. After the sustainable bio-economy is established and tested inside the country, export of the knowledge can become one of the high-value products that Finland can offer to the world's community. Besides improving the country's competitiveness, this would promote sustainability in other countries and make the current efforts to fight environmental problems more effective and advantageous for the industry.

However due to the innovative and complex nature of the bio-economy its development faces a number of challenges.

5.2 Challenges

Lack of Standardisation

There is a clear lack of standardisation in the current bio-economies, which has a severe impact on the feasibility of the solutions. Through modularisation of certain parts of the value chain, both in terms of technical modularisation and business concept modularisation, a better feasibility can be achieved through e.g. economies-of-scale (Hellström and Wikström, 2005). This will also ensure better reliability in the operation of the installations.

Inward-Oriented Business Models

Many of the actors involved in the bio-economy business lack an outward-oriented business model, which is needed in order for bio-economies to succeed. By outward-oriented business model we mean a business model that takes into account not only the particular company and its earning logic, but also the other actors in the network (Wikström et al., 2010).

Challenges Related to Authorities

There are several challenges with bio-economic solutions that can either directly or indirectly be addressed by the authorities. They are as follows:

- Solid requirements on materials that can be used for biofuel production
- Limitations on usage of biofuel production by-products (for example, for animal feed or fertilising)
- Need for country-level quotas for biofuels
- Tax breaks and other incentives
- Life-cycle thinking in decision-making
- Legislation changes and the related uncertainty
- Missing permits and regulation, e.g. for new types of production in the scope of the bio-economy.

Challenges Related to Knowledge and Information Flows

The producers of biomass that can be used as the material for biofuel production generally come from other industries that are not energy-related. Often they do not possess the necessary information on the character of the biomass flow they have, such as peak loads, volumes, seasonal changes in the flow, quality and content of the biomass, etc., as they do not need this information for their core business or even waste management. This means that in order to be integrated into a bio-economic solution the suppliers of biomass will have to invest in new processes and assets that will help to monitor the required information. Taking a step ahead, they might need to improve the quality and other biomass flow characteristics in order to fit into or to improve the functioning of the whole solution.

Related to Investments

Certain bio-economic solutions appear to be attractive from the sustainability point of view, but do not bring immediate and significant profits. This is why investments in such solutions have a number of features:

- They secure the business if the environmental legislation is toughened in the future for the sake of moving towards sustainability.
- At the same time, it is hard to predict the changes in energy, environmental and other related legislation and policy, which may make certain elements of the solution impossible or unfeasible.
- The profit from operating bio-economic solutions may be quite small but steady. It is thus not so appealing for big companies or investment institutions to invest into such solutions and put too much effort into them.

It was proposed by the companies interviewed that in order to gather the funding, an operating or production company needs to be created that will have a number of companies and institutions as the shareholders. This would also address the problem of benefit and risk sharing and the core business problem discussed further.

Benefit and Risk Sharing

In the case one company attempts to organise the whole bio-economic solution, it has to bear all the risks alone. This fact prevents many of them from taking the risk, as the bio-economy related business is too innovative and it is not too urgent in an economic sense to switch to it.

At the same time certain actors inside a bio-economic solution may receive benefits for being sustainable in the form of tax reductions and other incentives. Such benefits need to be fairly distributed between the companies involved in the solution, as do the losses and risks related to operation of the whole system.

Industry Restructuring and Core Business

The study showed that biomass producers are reluctant to enter the biofuel production business as it is not their core business. At the same time, biofuel producers are not eager and able to manage the whole supply chain or enter the waste treatment business, as their core business is only biofuel production. The missing interfaces between the companies involved in a bio-economic solution are a challenge but at the same time an opportunity to deliver new services.

Commitment from Other Actors Involved

Understanding of such big systems and the benefits they bring is sometimes difficult for companies as the concept is new and uncertain. To gain the commitment from the required actors, such as municipalities, companies, and farmers, the idea of the bio-economy and responsibilities of each party need to be explicitly explained and communicated.

Education and Awareness

It appears that education in terms of sustainability and life cycle thinking is required for companies, authorities and the public. Sustainable and beneficial solutions proposed face misunderstanding because this arrangement of industry is new and its benefits are not yet measurable by common means. It takes time and monetary resources therefore to communicate the benefits and the need for bio-economic solutions to authorities that may not have an interest in them and to people that are often against anything new.

Locality and Small Scale

Certain bio-economic solutions need to be decentralised and small-sized, but still may be replicated in many locations. This is the opposite of the huge, centralised industrial formations dominating at present.

As an example, hybrid trucks, which are apparently more 'green' than diesel trucks, cannot drive long distances, as there is no fuel saving at high speeds. However, inside the city where there are many stops, the environmental benefits of driving a hybrid truck are undeniable. Here the question is whether to make the effort and develop the technology further so that the hybrid engine would be beneficial in any circumstances and distances or whether to focus on the proper application for the technology and apply it there for the sake of sustainability.

In a similar way, many bio-economic solutions require local use, which means close biomass and demand allocation. This saves the environmental and financial costs related to logistics, while providing the social benefits of local employment and infrastructure development.

5.3 Benefits and Impacts of the Bio-economy

The development of a bio-economy is able to affect a number of critical environmental, social and economic problems and create new opportunities in these domains. Major industries will be influenced by the bio-economy in the form of new possibilities for development, but certain challenges still need to be overcome in order to take these opportunities.

The effect of the bio-economy on the energy sector is positive in the sense that the need to make the switch from fossil fuels to a more sustainable option can be partly met by producing renewable energy from biomass. The promotion of bioenergy is able to decrease the levels of harmful emissions and depletion of non-renewable resources, thus reducing the harmful environmental impacts of industry. At the same time the relative independence from fossil fuels in the country has a positive effect on supply security.

The reduced environmental impact of biofuels is caused partly by the improved combustion characteristics compared to certain fossil fuels. But what is more important, the biofuels produced in a well-managed bio-economy have significantly lower impact in the life cycle scale. If a biofuel is produced from local waste material and is used locally, the emissions are reduced in the raw material production, transportation and distribution phases.

Agriculture inside a bio-economy can revive as an industry. The downfall of agriculture has been a serious problem in a number of countries, including Finland. The increased value of bio-resources is able to promote the development of agriculture into a profitable business. This would mean a more effective use of the natural resources of the country and development in the rural areas. For Finland, whose territory is constituted mainly of rural areas and forests, rural areas' development is particularly important. The environmental impacts of agriculture are also potentially reduced if it becomes part of the bio-economy. The sector would become more sustainable with the extensive use of local organic fertilisers instead of synthetic ones. These organic fertilisers, the by-product of biofuel production, have a number of benefits compared to synthetic fertilisers. In terms of the environment, the use of organic fertilisers not only brings nutrients to the soil, but also ensures their retention in the soil and recreation of the humus layer. The inability of synthetic fertilisers to provide these qualities has led to the problems of nutrient run-off and thin humus layer. This is especially affecting the Nordic countries and the eutrophication of the Baltic Sea.

The effective exploitation of ley farming is another potential benefit of the bio-economy. The fields that are left fallow for certain periods can be used for growing energy crops, such as clover, which do not require fertilisation of the land. This would improve the efficiency of natural resource use while not harming the environment and biodiversity.

Waste management is another sphere influenced by the bio-economy. The industry changes from a purely waste collecting service to a biomass production industry. This brings not only business opportunities, but also important environmental benefits: a significant amount of biowaste is not simply left to degrade, but is refined into a number of high-value products. Thus the nutrient run-off from waste is partly solved. Another opportunity to address this problem in the scope of the bio-economy is the exploitation of common reed for biofuel production as a means to reduce eutrophication of the Baltic Sea.

At the social level the bio-economy is also an opportunity for development. The job-creating role of local sustainable solutions is often underestimated. As it was discussed earlier, economic development in rural areas is made possible in a sustainable bio-economy. The question of unemployment is very problematic now for developed countries, since many 'bulk' jobs are outsourced to other countries in the search for a cheaper labour force. This has been a challenge for a number of major industries in Finland, such as shipbuilding or communication technologies. Generally the solution to this problem is a focus on high-value services and export of knowledge rather than physical goods. Along similar lines, a bio-economy would create a number of jobs in solutions during its development and knowledge in doing so would become a valuable export product.

The local character of bio-economic solutions creates the opportunity for producing local products: fuels, food, materials, etc., the safety and quality of which is a benefit for Finnish society. The economic implication is the support of local producers by promoting the bio-economy.

On the country level, the economic situation may be stabilised and improved for a number of reasons: energy efficiency in the whole country is a good opportunity to be money efficient, and the export of the concept and expertise in developing bio-economic solutions may become a new high-value product, improving the GDP and country image in the world.

For the business sector the bio-economy would mean the possibility for new products, but most important, new services and expertise that can be marketed. The business development is ensured for the companies that involve themselves in the bio-economy. Additional financing may be drawn due to the importance of the bio-economic solutions for the economy of the country and overall sustainability. In addition resource efficiency, which is the prerequisite for the bio-economy, is a direct opportunity to reduce production costs for each separate enterprise or commercial unit.

6 Main Findings and Recommendations

6.2 Main Findings

The bio-economic solutions discussed in this report are a promising start for the future bio-economy in Finland. The ideas behind them are both economically and environmentally beneficial. There is the potential to create a knowledge-intensive industry in the country and export this knowledge abroad. Distributed solutions are what can make the Finnish bio-economy indeed sustainable and economically feasible since they may be replicated in other locations more easily.

However there is still the need for more credibility for the concept. There is currently a lack of a common goal and supportive legislation on the country level that would help development in the right direction towards a sustainable bio-economy. Moreover it is challenging to spread the idea of a sustainable bio-economy, its benefits and ensure the commitment of the actors that are required for its implementation.

Besides the community's overall acceptance and understanding of the bio-economy, special capabilities need to be developed by the business actors to develop the bio-economic solutions. The ability to work as part of the bio-economic system is something that proves to be difficult for individual businesses. In a bio-economy the requirement is to work together rather than compete. A common effort is able to generate more benefits, so-called system benefits, which otherwise are unachievable for separate businesses and industries.

The need for these new capabilities, as well as for the commitment from authorities, municipalities and other stakeholders, requires specific ways to share benefits and risks, ways which are still to be developed. The bio-economy is striving for clear roles and responsibilities for the actors, but first of all they need to be interested in taking part in it. The incentives for this should be created and clearly communicated to the business world and authorities, and someone needs to take responsibility for this.

The development of a bio-economy is a lengthy but worthy process, which cannot be done by one entity from the governmental or business world. Moreover, current efforts show that there are already certain practical steps towards the bio-economy in various sectors. The need is therefore to combine efforts and manage the development to reach a sustainable and feasible bio-economy in Finland.

6.3 Recommendations

6.3.1 Create a Bio-economy Developer Company

A company that focuses on developing sustainable solutions by integrating local needs and resources with technical part solutions is needed. The company develops and organises delivery of purchased solutions and is responsible for operation at least until the solution has paid itself back (and can also provide operation after that point).

Solutions are developed by:

- scouting for local needs and resources;
- communicating with technology providers about possible solutions.

The company maintains a large database of needs and resources (locations, amount) and of alternative and complementary technical solutions. By maintaining a large database of potential projects volumes can be identified. This compensates for the typically small scale of distributed bio-economic solutions and makes the company attractive to technology providers.

Technology suppliers are allowed and encouraged to present different solutions which are then used in the purchasing process (which in some cases may be public tendering). Presenting solutions does not put the supplier in a formal priority position but allows them to influence the purchasing process.

Earning Logic

The company's earning logic is based on creating value in terms of bio-economic solutions. It is important that the company's earning logic is not based on hourly cost of design, for example, as this would function as a negative incentive to creating standardised solutions.

By basing the earning logic on the value created the company has an incentive to develop mass-customised solutions that can be replicated and entail lower installation costs which in turn increases the market.

Ownership

It is important that the majority of the ownership is not biased to any particular technology or raw material. It is therefore recommended that Sitra maintains a majority in the company. Technology suppliers can hold minority posts in the company. This gives the supplier priority in information on suitable objects. It also gives the supplier priority in presenting different technical solutions.

Capabilities

The company works in a networked way maintaining steady contact with the key actors in developing bio-economic solutions:

- technology suppliers
- financing
- municipalities
- local engineering companies
- researchers.

In addition to the capabilities available through the network the company has in-house capabilities that enable it to integrate needs, technologies and resources in a way that maximises both primary and side benefits.

Part of the in-house capabilities is a standard modular solution consisting of needs, resources and technologies that can be applied in different combinations depending on the case. The solutions need to be modular in order to enable economies of scale. The modules consist of both services and products and are functional.

6.3.2 Companies to Develop Outward-oriented Business Models

Companies need to develop outward-oriented business models that take into account the needs and priorities of the key companies and stakeholders they work with. This will enable companies to integrate their operations with other businesses.

Outward-oriented business models can be realised through industrial services whereby companies manage the benefit they provide to other actors, for example, by taking care of their bakery waste. Other examples of services that appear to be necessary for the development of bio-economic solutions include mapping of material potential in the area, fertilisation services, knowledge management and others. Introduction of such services is able to make the current business models outward oriented in the sense that the use and turnover of biomass and biomass-derived products is supported by accompanying services, which would otherwise be the costly and resource-consuming duty of the consumer.

This will also allow companies to develop modular solutions and thereby achieve economies of scale through mass customisation.

6.3.3 Increase Credibility of the Bio-economy

The credibility of the bio-economy needs to be increased. At the moment the bio-economy suffers from a lack of credibility. There is also very little understanding of the bio-economy and its potential. This influences legislation and decisions on the municipal level.

When promoting the bio-economy arguments have to be factually based since there will be many sceptics and detractors. Questioning other sustainable bio-economic solutions, rather than promoting sustainability, causes confusion and reduces the credibility of the bio-economy as such.

Governmental support in the form of solid policies, legislation, recommendations and visions regarding the bio-economy on the country level would contribute significantly to the concept's credibility. The business actors and individuals would this way feel more confident about the future of the bio-economic solutions, which would result in their willingness to get involved in the development of the bio-economic solutions. The example of the reluctance to purchase biogas-fuelled cars shows how legislative instability is able to affect the development of biotech in this country.

Education in terms of the bio-economy is another prerequisite for its successful development in Finland. There is a need for a common and system-like understanding of bio-economic concepts by various actors:

- for authorities in order to help in elaborating the legislation and communicating with the business actors;
- for businesses in order to understand the way industries should be restructured in a bio-economy and increase their credibility;
- for individuals in order to understand the benefits of the bio-economy and support it by getting involved in the bio-economic solutions (as in the case of farmers, individual taxi drivers, and so on).

Education about the bio-economy needs to take the life cycle approach, as the basis of understanding how bio-economic solutions truly contribute to reducing industry's environmental impact and fighting resource depletion. A fair assessment of the sustainability of these solutions is also an instrument to increase the common trust in society and follow the country brand of "problem solver".

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