Swedish Research and Innovation Strategy for a Bio-based Economy

Swedish Research and Innovation
Strategy for a Bio-based Economy
Report: R3:2012
ISBN 978-91-540-6068-9
Graphic design: Lupo Design
Cover: Magnus Rietz
Photo credits: Page 4 Azote; page 8 Lars Högbom; page 12 Johnér; page 14 IBL Bildbyrå; page 17 Azote; page 18 Lupo Design; page 20 IBL Bildbyrå; page 22 Azote; page 25 Johnér; page 26 iStockphotos; page 31 Johnér.
Print: March 2012, Edita AB

Swedish Research and Innovation Strategy for a Bio-based Economy

Foreword

On 8 September 2011 the Swedish Government commissioned Formas, in consultation with VINNOVA and the Swedish Energy Agency, to prepare a national strategy for the generation of a bio-based economy and sustainable development. A dedicated steering group was established to manage the project, comprising Anna Ledin from Formas, (chairperson), Jan Svensson and Sara Österman from Formas, Martin Svensson from VINNOVA and Svante Söderholm from the Swedish Energy Agency. Magnus Brandel from MBenergistrategi AB also served as the secretary of the steering group. Contacts have been made and discussions held with a large number of stakeholders connected with bioeconomy efforts, both in Sweden and abroad.

Rolf Annerberg
Director General

6 February 2012

Rolf Annerberg
Director General

Anna Ledin
Secretary General

Anna Ledin
Secretary General

Contents

Summary

The conversion to a bio-based economy means a transition from an economy that to a large extent has been based on fossil fuels to a more resource-efficient economy based on renewable raw materials that are produced through the sustainable use of ecosystem services from land and water.

We have defined a bio-based economy (bioeconomy) as an economy based on:

- A sustainable production of biomass to enable increased use within a number of different sectors of society. The objective is to reduce climate effects and the use of fossil-based raw materials.
- An increased added value for biomass materials, concomitant with a reduction in energy consumption and recovery of nutrients and energy as additional end products. The objective is to optimize the value and contribution of ecosystem services to the economy.

Our analysis shows that Sweden, in comparison to many other countries, has good preconditions given by natural geographic conditions, traditional industry and infrastructure for being able to convert to a bio-based economy. Converting from the use of fossil fuels to renewable resources can also confer an inherent increase in competition for raw materials. This also provides new opportunities to complement traditional products with new products and services to maintain and improve Sweden's competitiveness. In addition to the potential within the industrial sector that has long been based on agriculture and forestry, the development of a bioeconomy also offers inherent opportunities for increased use of biomass raw materials within other commercial sectors. This applies, for example, to the transport sector, the motor industry, the construction sector and the chemical industry.

We have defined the following research and development needs:

- ***The replacement of fossil-based raw materials with bio-based raw materials***

  Some examples of this are:

  Intensified production of bio-based raw materials, Nutrient and fertilizer optimization systems, Crop and animal breeding, Cultivation system such asmulti-functional farming and forestry systems, Adaptation

of seeds, crops and production systems to cope with climate change, New and improved biomass properties, Use of ecosystems other than fields and forests for biomass production, for example marine ecosystems or urban environments.

- *Smarter products and smarter use of raw materials*
  Some examples of this are:
  Further refinement of biomass products, Bi-products and waste products become raw materials, New products, Biorefineries.

- *Change in consumption habits and attitudes*
  Some examples of this are:
  Increased product lifetimes, Increased recycling, More efficient transport, distribution and storage, New services, Consumer behaviour.

- *Prioritisation and choice of measures*
  Some examples of this are:
  Environmental consequences, Socio-economic consequences, Conflict of objectives, Governing policies.

Research and development must be complemented by innovation-fostering initiatives and measures that specifically address bioeconomy challenges. The nature and extent of these challenges necessitates widespread collaboration among actors and that sectors work together to be able to deal with the complex issues and demands for solutions that the challenges give rise to.

This includes:

- Stimulating cross-industry collaboration in research and development in order to develop and implement solutions that contribute to a growing bio-based economy. Universities and research institutes play a central role in forging links in such collaborations, but public actors and civilian society also has important roles.

- Stimulating the growth of strong research and innovation environments that contribute with relevant knowledge and create preconditions for innovation within the area. These strong environments gather together Swedish competence and actors and augment the innovative capabilities of regions and organisations.

- Accelerating development, verification and commercialisation of new bio-based solutions and provide continued support for the demonstration of products, systems and services other than fuels and energy technology solutions.

- Offering support to small and medium-sized enterprises for the commercialisation of new technologies. This

particularly applies to collaborations between these and larger companies in order to accelerate development and innovation.

It is the opinion of Formas, VINNOVA and the Swedish Energy Agency that the organisation of the funding of research, development and innovation within the area of bioeconomy functions well. Our analyses have however identified a need for the closer involvement of users/consumers in prioritising knowledge gaps and new problem areas. Formas will therefore establish a *User Forum* to function as an advisory resource for those funding the research.

Much of the work of implementing the strategy can be carried out within the framework of existing resources. If a major new initiative in the area is to be implemented then additional resources will be required. This presupposes that there are resources for this in state finances.

Purpose and aim of the assignment

Background

The conversion to a bio-based economy means a transition from an economy that to a large extent has been based on fossil materials to a more resource-efficient economy based on renewable raw materials. These raw materials should be produced through the sustainable use of ecosystem services from land and water. To achieve this requires both new knowledge and better utilization of existing knowledge. The development of a bio-based economy will require new knowledge that can only come from research and development, as well as measures to foster innovation that are linked to the research and development. This applies also to the development of overarching and interdisciplinary knowledge about how to implement new technologies and new products into what is, to a large extent, a fossil-based economy.

On 8 September 2011 the Government commissioned Formas, in consultation with VINNOVA and the Swedish Energy Agency to submit a proposal (D.no. L2011/2399) for a national strategy for the development of a bio-based economy (bioeconomy) and to propose a Swedish definition of the term. The mandate of the assignment was that the strategy should encompass research and development needs, the need for initiatives to promote innovation, the needs for coordination among research funding bodies, the performers of the research and the commercial sector, as well as the national potential.

The assignment will form a basis for work on the research and innovation bill that the Government plans to present to Parliament in the autumn of 2012. The Government needs background information about the knowledge gaps and preconditions that Sweden has before the conversion to a sustainable society based on raw materials and products from renewable biomass. Important driving forces underlying this assignment are the need to reduce the dependency on fossil-based raw materials and the emission of carbon dioxide and other greenhouse gases. The assignment also refers, among other things, to the efforts being made to make the Swedish transport pool independent of fossil fuels. A central measure in achieving this target is to develop the use and refinement of renewable biomass from agriculture and forestry, as well as marine and aquatic organisms. Another measure is the development of biological processes for use in process industries.

We have interpreted our assignment as being to develop a strategy for the investments that are needed in research, development and innovation in order to obtain the knowledge required for a transition to a bio-based economy. The strategy shall also contain proposals for organisational measures concerning research, development and innovation investments, if such are regarded to be required.

The natural geographic conditions in Sweden have meant that products from agriculture and forestry, as well as from fishing, have always been of great importance to societal development. Building materials and fibre-based products in the form of paper and textiles are only a few examples. The oil crisis of the 1970s and 1980s and current climate issues have contributed to new areas of use for bio-based raw materials. Driving forces behind such changes have been the sharply rising cost of crude oil, in combination with the introduction of policy measures, for example in the form of higher taxes and systems for trading in emission rights. An example that illustrates this is that in the past 30 years the use of fossil fuels for heating has been almost entirely replaced by biofuels. Within the fuel sector however there are still significant investments that have to be made to completely replace fossil fuels with biofuels. In the future it is expected that the use of biofuels will increase, even within the transport sector. A 2011 report on the topic of how far the transport sector is likely to have come in the quest to become fossil fuel independent by 2030 *(Fossilbränsleoberoende transportsektor 2030 – hur långt når fordonstekniken?)* from the government agency Transport Analysis illustrates however that there is still likely to be a significant dependency on fossil fuels in 2030, even with the most advanced technological development scenario.

In 2002 the EU Commission presented a *European strategy, Europe on life sciences and biotechnology*, with priorities for research concerning a knowledge-based bioeconomy under the Seventh Framework Programme for Research and Technological Development (FP7). In 2010 bioeconomy was included as an important aspect of the *Innovation Union Flagship Initiative.* In preparation for the compiling of the EU Commission report *Innovating for Sustainable Growth: A Bioeconomy for Europe,* the EU identified the following overall challenges:

- Ensuring food security
- Managing natural resources sustainably
- Reducing dependence on non-renewable resources
- Mitigating and adapting to climate change
- Creating jobs and maintaining European competitiveness

Bio-based economy covers a wide area. This means that knowledge will be required from a number of sources. These will include natural science research in the areas of agriculture and forestry, as well as fishing, ecology and the environment. Sources of knowledge will also include technological

research, primarily within the areas of biotechnology, nanotechnology, general material technology and environmental technology. In addition social science and humanities research will be required in areas such as economics, behavioural sciences and spatial planning, as well as information and communication. Many of the general issues necessitate interdisciplinary and trans-disciplinary efforts. Significant investments in development and innovation are also required.

Strategies for a bio-based and green economy in other countries

Many countries are developing strategies for a bio-based and fossil fuel independent economy. Some examples of completed and ongoing initiatives in this respect are the following:

- Denmark – *Agreement on Green Growth, Ministry of the Environment (Miljøministeriet) (June 2009)*,

- http://www.mim.dk/NR/rdonlyres/54887891-D450-4CD7-B823-CD5B12C6867A/0/DanishAgreementonGreenGrowth_300909.pdf

- Within the European Union, where bioeconomy is an important challenge in the upcoming Horizon 2020 Framework programme, a report will be released in February 2012, *Innovating for Sustainable Growth: A Bioeconomy for Europe,* based on opinions and a consultation process that took place during 2011. http://ec.europa.eu/research/consultations/bioeconomy/consultation_en.htm

- Finland – *A Natural Resource Strategy for Finland: Using natural resources intelligently (April 2009) and Sustainable Bio-economy: Potential, Challenges and Opportunities in Finland, Sitra, the Finnish Innovation Fund (March 2011),* http://www.sitra.fi/julkaisut/Selvityksi%C3%A4-sarja/Selvityksi%C3%A4%2051.pdf

- Ireland – *Developing the Green Economy in Ireland, Department of Enterprise, Trade and Employment (November 2009),* http://www.forfas.ie/media/dete091202_green_economy.pdf

- OECD – *Toward Green Growth, OECD (2011),* http://www.oecd.org/greengrowth

- Germany – *National Research Strategy BioEconomy 2030: Our Route towards a biobased economy BMBF- Federal Ministry of Education and Research (2011),* http://www.bmbf.de/pub/bioeconomy_2030.pdf

- USA – where President Obama's administration will present a strategy during 2012, *"The National Bioeconomy*

Blueprint", Office of Science and Technology Policy, The White House Administration, US Government, http://www.whitehouse.gov/blog/2011/10/12/building-bioeconomy

Methods used to perform the assignment

In connection with performing this assignment we have received a large number of suggestions for future research, development and innovation to promote a bio-based economy. We have held dialogue with a number of people, including representatives of research, companies and branch organisations and we have discussed a number of diverse issues within the area of bio-based economy. In general there is great deal of interest on the part of industry in taking an active role in the work of changing society by converting to a bio-based economy. This is applicable, for example, to the forest industry, where a proposal was presented for a programme of collaboration with the state that focussed on developing new products and materials. The chemical industry is also actively working in this area, including efforts of companies in Stenungsund and within the plastics and chemicals branch association Plast- & Kemiföretagen. The Swedish technology platform Food for Life, which is affiliated with the *European Technology Platform -Food for Life* has developed a common research agenda within the areas of food and nutrition. An example of collaboration between researchers and companies is provided by *Bio4Energy*, one of the Government's 20 national strategic research areas, where the vision is to create environmentally friendly and sustainable technologies that will make it possible to replace the oil refineries of today with bio-refineries.

Definition of a bio-based economy

Converting to a bio-based economy means a transition from an economy that to a large extent is based on fossil-derived raw materials to a more resource-efficient economy based on renewable raw materials produced by the sustainable use of ecosystem services from land and water. This means transforming biomass materials into different types of products, such as food, energy and industrial products (household products, composite materials, pharmaceuticals, paper, textiles etc.).

To achieve efficient utilization of renewable biomass in the process of converting raw materials into finished product, including efficient use of bi-products and waste products, requires knowledge-based innovation. Extensive research and development is required to obtain new knowledge. Investment is also required to enable existing knowledge to be utilized more rapidly. In a sustainable bioeconomy there is an increase in the added value of biomass materials, concomitant with a reduction in energy consumption, with

nutrients and energy being recycled from the end products. We have defined a bio-based economy (bioeconomy) as an economy based on:

- Sustainable production of biomass to enable a growth in use within a number of different social sectors. The objective is to reduce climate effects and the use of fossil-based raw materials.
- Increased added value for biomass materials, together with a reduction in energy consumption, and recovery of nutrients and energy from the end products. The objective is to optimize the value and contribution of ecosystem services to the economy.

Challenges in converting to a bio-based economy

We have identified some major challenges that have formed the basis for describing the research, development and innovation-fostering measures necessary to convert to a bio-based economy.

I. The replacement of fossil-based raw materials with bio-based raw materials
Examples include:
- Production of foodstuffs, new sources of protein
- Production of fuels, plastics and pharmaceuticals

II. Smarter products and smarter use of raw materials
Examples include:
- Health-promoting food products
- Use of fibres, for examples in textiles, composite materials, new paper, construction materials
- More efficient use of bi-products and recycling

III. Change in consumption habits and attitudes
Examples include:
- New products and services, as well as new forms of foodstuffs
- Personal travel/transportation

IV. Prioritisation and choice of measures
Examples include:
- Consequence analysis, conflict of objectives
- System optimization
- Policy instruments

Bioeconomy value chain – recycling that includes the ecosystem and the consumer

Ecosystem services – the foundation of a bio-based economy: In a bio-based economy raw materials originate as the products of different ecosystems. The framework for a bio-based economy is therefore imposed by the limitations of the ecosystem services that contribute to this production. Ecosystem

services comprise the benefits that people can derive from the ecosystem and can be subdivided into the following categories:

- Ecosystem provisioning services – food, drinking water, timber, biomass etc.
- Supporting and regulating ecosystem services – production and turnover of nutrients, carbon and oxygen, climate and air-quality regulation, pollination, controlling flooding etc.
- Cultural ecosystem services – recreation, tourism, ethical and esoteric value of the conservation of types of nature, plants and animal species, cultural heritage etc.

Increased use of one ecosystem service often has consequences for other ecosystem services and conflicts of objectives can arise. This must always be taken into consideration when managing an ecosystem and drawing on different ecosystem services. In these deliberations it is important to consider the value chain turnover in ecosystem services for a bio-based economy, as well as the challenges this leads to. Figure 1 illustrates the value chain from ecosystem services to the consumer via different refining stages.

Production of bio-based raw materials: Raw materials for a bioeconomy are produced from land and water-based ecosystems through different forms of husbandry. A challenge in achieving a growing bioeconomy and reduced use of fossil-based raw materials is how to increase production volumes and improve the quality of the raw materials. This applies to

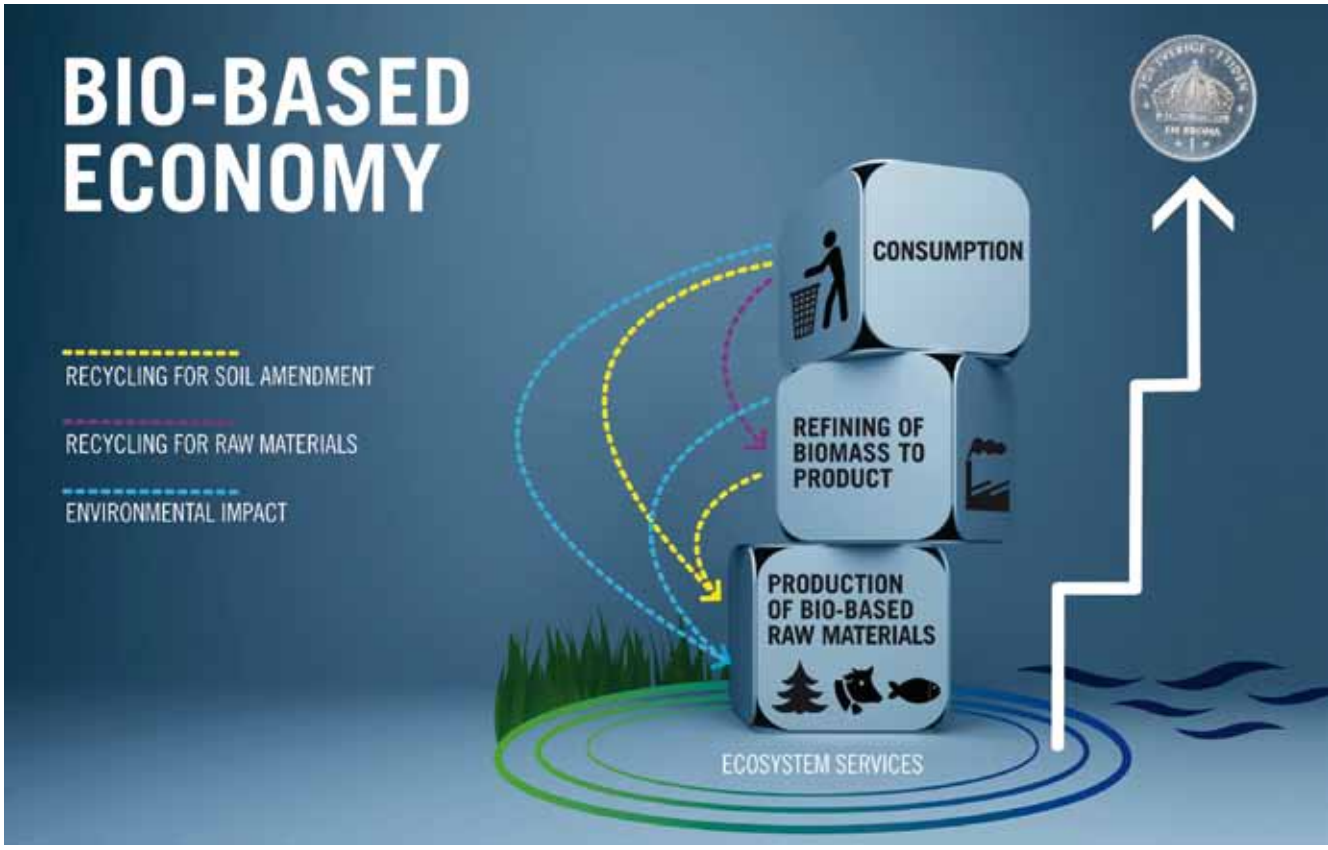

Figure 1. Refining stage with research, development and innovation contributions Refining/ processing steps showing the economic added value of raw materials on the way to the consumer

both animal and vegetable raw materials and presumes that social, economic and ecological consequences are taken into consideration.

Further refining of the biomass into products: The length of the refining/processing chain is dependent on the end product, but always aims to increase the value of the biomass. The path to the end product is currently short for many agricultural products, but forestry raw materials often require more downstream refining and processing. In both cases, however, there is great potential for generating added value in the further refining and use of bi-products. The challenges in this part of the value chain are to achieve 'smarter' products and more efficient processing and, through this, achieve a growing bioeconomy and generate more jobs. In addition, current refining processes can be made more efficient, resulting in a reduction in the negative impact on the environment. There are major opportunities to both improve existing and to create new profitable value chains.

Consumption: A bio-based economy cannot be achieved until the materials and products developed are sold on the market. The goods and products that are introduced must be as good as, or more attractive than, those they are intended to replace. The challenge here, in addition to offering attractive and competitive products, is also to achieve consumer awareness and a desire to contribute to switching to a bioeconomy, for example by changing purchasing and travel habits. New services, in combination with bio-based products, can also contribute to generating added value in a bioeconomy. Services in many cases do not need to be coupled to the consumption of resources and in this way can contribute to growth without depleting energy or material resources.

Replenishing and recycling: A prerequisite for a resource efficient and sustainable bioeconomy is that the raw materials are used optimally to generate added value and revenue for society. Bi-products and waste products can become new raw materials that can provide energy or can be refined into new products in the value chain. To maintain the production capacity of the ecosystem, the removal of nutrients and other substances important for the functioning of land and water-based ecosystems (for example substances that elevate pH levels or buffering substances) must be compensated for. This requires the development of efficient systems for replenishing nutrients and means of soil improvement, such as the use of ash and waste sludge.

These value chains are naturally not entirely new. Sweden has good preconditions for building further on existing structures within all stages of all value chains. There are therefore good preconditions for augmenting a bio-based economy by targeted research and development, as well as innovation-promoting initiatives linked to this. We must also find solutions to problems

that are multifaceted and complex in order to be successful in global competition in the area. This necessitates a global system perspective and initiatives for collaboration and interdisciplinary research, development and innovation. We must also be able to prioritize and analyse the consequences of conflict of objectives between different measures.

National potential – resources, actors and development opportunities

Sweden, in comparison to many other countries, has good preconditions to facilitate conversion to a bio-based economy. Traditionally production and refining of the biomass has contributed significantly to the economy by providing jobs and a relatively large net export revenue. Increased production and harvesting of the biomass through genetic breeding programmes, more efficient production and harvest methods and further processing has meant that industry has retained its competitiveness. Converting from the use of fossil-based raw materials to renewable resources can bring inherent challenges, in the form of increased competition for raw materials, but can also bring new opportunities to complement traditional products with new products and services.

In addition to the potential within the traditional industrial sector, based on agriculture and forestry, the development of a bio-based economy also provides good opportunities for an increased use of biomass raw materials within other commercial sectors. To develop bio-based fuels and technologies to enable the efficient use of these as a source of energy is a challenge for sectors such as transport and the motor industry. Potential also exists within the construction sector, where the development of bio-based materials with new properties can replace steel and concrete. The dependence of the chemical industry on fossil-based raw materials can be reduced through the introduction of new products based on renewable biomass resources. Cross-sector system solutions are also possible, such as biorefineries in the form of combinations and collaborations of the chemical industry, forestry and energy companies.

The Swedish Government and Parliament dictates the overarching prerequisites, in terms of legislation and governance etc., for promoting the transition to a bio-based economy.

Other important actors in creating preconditions for switching to a bio-based economy are universities, colleges and research institutes, as well as regions, municipalities and commerce. Achieving a bio-based economy necessitates overall system solutions. Developing these requires research in individual disciplines, interdisciplinary research and, most especially, transdisciplinary research projects where researchers and users collaborate and exchange knowledge in order to identify and develop these solutions. The strengthening of interdisciplinary research, development and innovation – preferably from a system perspective – is essential.

Regions and municipalities, with their administrative and developmental organisations, are a driving force, as they often develop regional research and innovation strategies jointly with commercial enterprise in order to utilize collective resources more efficiently. There are several examples of such successful clusters of actors within Sweden's regions. Government agencies who are involved also have important roles to play in the transition to a bio-based economy.

Universities, colleges and research institutes are of major importance when it comes to growth, innovation potential and competitiveness. Therefore increasing demands are being imposed on them to participate in providing knowledge and competence for the growth of a bio-based economy. The ability to act together with the surrounding society and at the same time to be at the cutting edge in terms of knowledge and competence is of major importance. Research institutes such as Skogforsk, IVL-The Swedish Environmental Research Institute, SP-Technical Research Institute of Sweden and Innventia collaborate with industry and academia within several relevant projects to promote bioeconomy development.

Other important actors in the area are *small innovation-driven companies,* which may be offshoots from universities and colleges. Another important role contextually is the *consumer* choice of goods and services in creating demand that can contribute to converting to a bioeconomy.

State funding and other research funding bodies, as well as universities and commercial enterprises are important in financing research and development to stimulate the transition to a bio-based economy. A great deal of the research that is supported today has associations with a bio-based economy. Major initiatives addressing climate change and globalisation have been initiated through the research foundation Mistra's support for *Future Forests* and SLU's own gathering of resources around *Future Agriculture*. VINNOVA and the Swedish Energy Agency provide long-term support for the development of the biorefinery of the future in Örnsköldsvik.

It is important to continue to develop collaborations within research and innovation, for example with other EU and partner countries. This applies for example to the proposal for the new EU research programme, Horizon 2020, and the industrial technology platforms for the food industry and forestry industry, European Technology Platform - Food for Life and the Forest-based sector Technology Platform, respectively, where Swedish industry has been a driving force. Within the Nordic countries there are several advantages when it comes to collaborating in the areas of research and innovation for the development of a bio-based economy, where the preconditions and needs are relatively similar for each country.


337

Strategy for research, development and innovation for a bio-based economy

Focus and approach

A research and innovation strategy that aims to promote the development of a bio-based economy should have both a *short-term and a long-term perspective*. Collaboration between the state, commercial enterprise and the performers of the research is an important prerequisite for the strategy being able to be carried out. The starting point is an analysis of the knowledge requirements of society and commerce in order to be able to implement existing plans and ensure the growth of a bio-based economy. Based on these needs the focus of research, development and innovation initiatives can be defined for different areas across the entire biomass value chain – production – refining – consumption.

Research and development initiatives

We have elected to structure our assessments of the needs for research, development and innovation on the basis of the four challenges presented on page 17. Achieving a bio-based economy also requires, in addition to research and development, demonstration and innovation incentive measures. Governance and investment in demonstrations is also required. This however lies outside of the remit of this strategy.

I. The replacement of fossil-based raw materials with bio-based raw materials

Intensified production of bio-based raw materials

Access to the biomass can be improved by directly increasing production per unit area, bringing larger areas into use or by further refining and utilising current biomass production. With the help of an improved knowledge of the ecosystem and the services it can provide, production of benefits can also increase. Sustainable use is a fundamental prerequisite for the ecosystem being able to maintain production capacity and stability or resilience and avoiding or mitigating negative environmental effects. Some examples in the area of intensified production include:

Nutrient and fertilizer optimization systems – more efficient use of nutrients and water for biomass production. Knowledge of how plant nutrients and water circulate and are released or

fixed by the ecosystem creates preconditions for being able to regulate availability in accordance with the needs of the plant, temporally and spatially.

Crop and animal breeding – genetic refinement and breeding contributes through the crossing and selection to the production of those plants and animals with the qualities demanded by the market. Knowledge of the interplay between genetics, physiology and ecology will open the way for more efficient control of characteristics, such that increased production and improved quality can be achieved and will be less sensitive to variations in climate conditions and needs for addition of fertilizers or other chemicals, for example pesticides and antibiotics, will be reduced.

Multifunctional cultivation systems – the biomass can be used as raw material within a number of different industrial sectors, depending on the quality and the cost. Forestry and agricultural land areas also provide other ecosystem services and the value of these to the economy should be taken into consideration when choosing methods of use. Energy from the biomass can be obtained either by directly taking raw materials from the forests or fields (energy crop) to the power plants or can be obtained as a bi-product from the harvest of agricultural crops or timber used by the forestry industry (energy assortment). Managing the bio-energy assortment from the production of raw materials for the food and forestry industries will require knowledge of logistics and technology for efficient and sustainable extraction in combination with the development of technologies for cultivating and harvesting ordinary crops and timber. The bio-energy value chain also encompasses issues concerning the return of ash and nutrients.

Adapting crops and production systems to climate change – intensified production and the use of bio-based raw materials presumes that we can also predict and counteract negative effects on the ecosystem due to climate change. Apart from direct climate damage caused by drought, flooding, storms and unseasonably warm or frosty periods, climate change may also favour both existing and new crop-damaging pests. These risks should be addressed within genetic breeding programmes, as well as in the development of more efficient cultivation/production systems.

New and improved biomass properties – in addition to genetic improvement the properties of the biomass can be improved by cultivation and harvesting technologies, including storage methods that reduce damage and loss of quality. New raw material properties can also mean a reduction in energy consumption for further processing and refining and may mean that quality can be retained, even after extended storage periods etc.

Use of other ecosystems for biomass production – the potential for improving access to biomass materials can increase by opening up new areas/ecosystems for biomass production. Examples of areas that have potential for increased production are:

- *Marine and aquatic systems* - Development of aquaculture with regard to the breeding as well as sustainable production techniques using aquatic animals/organisms. Sustainable use of marine resources.
- *Green areas in cities* – Urban environments for biomass production but also for environmental improvement and other ecosystem services.
- *Sustainable use of peat* – Better selection methods for peat extraction areas, improved production technologies, develop post-processing methods and consequence analyses.

II. Smarter products and smarter use of raw materials
Further refining of the biomass into products:

There is great potential to increase the added value of the renewable raw materials used by current process industries. A more efficient use of raw materials and use of leftovers, bi-products and waste would reduce the burden on the ecosystem and could also contribute raw materials for new products. The raw materials can be further refined/processed mechanically, chemically and biologically, for example using biotechnologies, to obtain the desired properties. It will be a challenge to identify and bring to the fore new products that meet the needs of the consumer in a bio-based economy. One way to make the use of raw materials and bi-products more efficient and create new products is through biorefineries, where biomass materials are used to produce materials (for example utilising valuable structures in plant materials), heat, electricity, biofuels and organic chemicals. Here research from a system perspective is needed to highlight the optimal use of resources and downstream processing.

Bi-products and waste products become raw materials – To achieve the goal of a bio-based economy requires improved utilization of resources by reducing wastage and improving efficiency in the utilization of bi-products and waste products. A great advantage of products of the biomass is that they can be recycled. This can be in the form of bi-products from different processes that are eventually converted to energy through incineration. It is important that the end product that has traditionally been regarded and handled as waste is also viewed as a resource. Replenishing, in the form of returning ash or sludge to the land, improves soil quality and plant nutrition. A system concept is necessary here, addressing the best ways to use the replenished nutrients optimally and how to minimize ecological and hygiene risks.

New products – A bio-based economy should be knowledge-based and resource efficient. Efficient use of materials and energy is required when products are developed and produced in order to be cost-competitive. New products of high value can contribute to bi-products of the processes being more competitive in comparison to fossil-based products, compared to if these would have comprised the sole product of further refinement. Biomimetics – copies of nature's solutions – is a very interesting research area, where the biology provides inspiration for such things as the development of new materials and technological solutions. Other examples of new materials and products based on renewable raw materials are packaging materials for the food industry, building materials, bio-based plastics and composites for various purposes, carbon fibres, textiles and organic chemicals. These products provide high added value and are built on both high quality research and an efficient innovation process. We need better knowledge of both the biochemical processes

in our cultivated plants and of how the processes in green refineries can be structured. More efficient plant breeding is also required that utilizes all of the possibilities presented by the new breeding and genetic improvement technologies. The development and use of new products should be preceded by the relevant risk assessments.

Biorefineries – A biorefinery is defined here as a facility where different components of bio-based materials are separated into a number of constituent parts that are then used for purposes other than solely providing energy. There are currently different components of the biomass being used in industrial processes, but these processes are generally focused on the production of a specific component and the rest of the material is not always used in a way that yields high added value. System studies within the biorefinery area, where different types of facility that use biomass as raw materials are broken down into sub-systems and further to the individual component level, create preconditions for dividing these into modules that can be assembled in a flexible way to form the different types of biorefineries required by society. The direct advantages of this approach are:

- Energy efficient and raw material efficient sub-processes can be used as components in a future biorefinery. Research, development and commercialisation can be performed at the sub-system and component level, which makes these less capital-intensive and therefore easier to fund.
- Categorizing into sub-systems can generate a structure for R&D initiatives and commercialisation where there are opportunities to coordinate investments.

Even if a major proportion of the system studies will be focussed on the production stages, it is important that system studies are also performed where the focus encompasses the downstream aspects of future bio-based value chains; preferably user stages. Better knowledge of the properties of the biological raw materials in different processes, in addition to the impact of the different processes on the properties of the end products, should dictate R&D investments. R&D investments may require to be complemented in several instances with support for demonstration facilities.

III. Change in consumption habits and attitudes

To be able to achieve a recycling-adapted society based on biological raw materials requires changing attitudes towards consumption and changing the consumption patterns of both producers and consumers.

Shelf-life, reuse – Bio-based products that because of pricing, quality or their utility areas, are equivalent to or better than existing products are prerequisite for being able to change consumption patterns.

Goods with a longer shelf-life are one avenue towards reducing consumption of goods without notably affecting consumer living standards. This can be achieved either through products of higher quality, such as in the case of clothes, or by taking into account the entire lifecycle of a product, such as the system for returning the product, second-hand markets and the final recycling of the product. Packaging should be reusable and adapted to reduce wastage, for example of foodstuffs.

Transport – To switch to using biofuels as the primary energy source for transport, large-scale and resource-efficient production of bio-based fuels and a widespread distribution network for these fuels are of central importance. To make the switch to biofuels possible requires both reduced consumption of fuels and more energy-efficient power sources. This can be achieved by more efficient transport systems, for example, where transport capacities are optimally utilized.

Distribution and storage – To achieve a more climate-efficient consumption (for example by reducing food wastage) research is required into the inter-relationships between the producer and the consumer. Important issues are, for example, how the distribution of goods can be improved and which new products are required for protection and storage.

New services – New services, in combination with bio-based products, contribute to economic growth. Services in many cases do not need to be coupled to the consumption of resources and in this way can contribute to growth without depleting energy or material resources.

Consumer behaviour – To achieve a change in consumer patterns requires research into how consumer behaviour can be affected.

IV. Prioritisation and choice of measures

Environmental consequences – Both increasing the productivity of the ecosystem and the production of new types of biomass, in the form of new crops, animal husbandry systems etc. will have an impact on the environment. The same is also true of the operations of the downstream refinement industry, consumer use of products and the management of waste. The collective environmental effects of the systems, both positive and negative, must form the starting point for sustainable production and use.

The challenges are to find solutions that both increase the commercial and environmental benefits. This could be a matter of methods of use that contribute to preserving or increasing biological diversity, reducing use and the leakage of, for example, nutrients, pesticides and antibiotics. A further task is to integrate ecosystem services and biological diversity,

for which a price is difficult to determine, into business models and the decision-making processes of society, something that requires research that combines the humanities and social sciences with natural science knowledge.

Another important perspective is access to clean water, where water regulation and water management in both forests and agricultural land can be integrated in the production of biomass. Research with a focus on the holistic system will therefore be required to ensure that a switch to a bio-based economy does not happen at the expense of the environment.

Socio-economic consequences – Increased productivity and the production of new types of biomass can impact other users of land, forests and water. This includes commercial reindeer farming, recreation, berry and mushroom-picking, hunting and fishing. Here the potential conflicts must be identified and solutions arrived at that both maximize the benefits and can be accepted by the stakeholders.

The development of a bio-based economy creates preconditions for new industries and other commercial companies within the bioeconomy value chains. This has consequences, for example, on infrastructure, transport, urban and rural development, education and employment.

Conflict of objectives – Solving conflicts between objectives concerning land use is an important research area. High and intensive production of biological raw materials can come into conflict with other land uses, environmental interests and animal welfare, for example. Finding solutions to such conflicts requires research into how conflicts of objectives at all levels can be handled at global, regional and local levels, encompassing also the links between these. The roles of international and national organisations in this context should be highlighted.

Policy instruments – To date much of the research and development in the area of governance and policy has not taken a lifecycle perspective into account and has instead primarily examined individual policy measures, individual sectors or individual links in the production chain, instead of the entire system. In recent years however, the need to change the function/design and consumption of products has been recognised. Policy instruments have different characteristics depending on the intended change and the potential for change. The development of policy measures that are both cost-effective and effective dynamically are required, that is to say that sufficient incentive must be provided for the actors involved to develop and implement new bio-based technologies. Research is also required to identify administrative, economic and other obstacles that limit the possibilities for introducing bio-based products.

Innovation incentives

One of the objectives of research and development initiatives is to create preconditions for products and services to be developed. Societal benefits will first be realised when the developed products and services achieve a relevant distribution throughout society. It is therefore important that research and development initiatives are complemented by innovation incentives.

Innovation incentives have their origins in the innovation systems of the various stakeholders, such as companies, universities, colleges, institutes and regions. Different clusters have been established around these actors and the competence of these can be augmented by cross-sector collaborations with other branches and sectors. As the biological resources (forests, arable land, wetlands etc.) are distributed throughout the country, these clusters also contribute to regional growth and initiatives can be combined with efficient use of EU structural funds.

In the *short term* (within 3–5 years) investments should be targeted towards the further development of the knowledge-base that has been established in the area of bio-based raw materials, by demonstrations that accelerate product development and commercialisation. This is both a matter of new applications for service companies and suppliers of equipment and the manufacture of end products.

In the *longer term* it is a matter of creating the prerequisites for utilising the full potential of the biomass under the guidance of the knowledge obtained through research and development. To achieve this objective, knowledge is required about the properties of the raw materials and the methods that can be used to affect these. The development of process technologies, material technologies and system solutions that enable efficient and sustainable product development are also required. Methods and tools need to be developed that can analyse and evaluate sustainability aspects, primarily in relation to bio-refineries. The impact of institutional preconditions, laws, policies and standardisation on the innovation system and the opportunities for the development of new products and services in a bioeconomy must also be considered.

The initiatives below have their origins in the development, from a system perspective, of cohesion throughout the entire value chain, from the raw material to the market. This is a matter of technological aspects, efficient use of resources and commercial potential. To improve commercial potential, and to ensure long term sustainability in the initiatives performed by different actors, it is important that decisions can be based on an overall system understanding. We propose the following measures:

- Develop initiatives that specifically deal with the challenges of a bioeconomy. Based on these challenges and driving forces new solutions can be created that lead to long term, sustainable growth. This is particularly important for a small, export-dependent country such as Sweden. The challenges are of such nature that they necessitate widespread collaboration between companies, sectors, universities, colleges, research institutes and public sector organisations. New technologies and knowledge requires multiple disciplines, subject areas and sectors to work together to be able to deal with the complex issues and demands for solutions that the challenges give rise to.

- Stimulate research and development collaborations that cross branch boundaries in order to develop and implement solutions that in different ways contribute to a growing national bioeconomy. Academia and institutes play a central role in forging links in such collaborations,

but public sector actors and civilian society also has important roles. Solutions and innovations are not limited only to new products and processes. When the markets and financial mechanisms for ecosystem services become established there will be an incipient will to pay for a well functioning ecosystem. Due to Sweden's developed agricultural sectors and long tradition of institutional frameworks for environmental management and nature conservation, we should be very well positioned to be leaders within new service innovations.

- Stimulate the growth of strong research and innovation environments that contribute to relevant knowledge being discovered and create preconditions for innovation within the area. These strong environments gather together Swedish competence and augment the innovative capabilities of regions and organisations. A prerequisite for being able to contribute to strong competitiveness is that these environments must also be at the international forefront in terms of skills and have a distinct attraction for foreign actors to carry out research and development operations in Sweden. Such initiatives can also be directed towards stimulating the emergence of new value chains based on new knowledge and technologies, or on business opportunities.

- Accelerate development, verification and commercialisation of new bio-based solutions and provide continued support for their demonstration, in a similar way to that provided by the Swedish Energy Agency, but expanded to encompass the demonstration of the production of products, systems and services other than fuels and energy technology solutions.

- Promote the market introduction of renewable energy conductors, chemicals, materials and technologies and a sustainable use of resources by overhauling and developing long-term governance. One example is providing support for the development of policy measures to stimulate the introduction of bio-based products, for example standardisation, marking, procurement, certification and taxation/legislation.

- Offer support for small and medium-sized enterprises to commercialise new technologies and offer the equivalent business development and growth support that the Swedish Energy Agency currently offers, in addition to encouraging collaborations between small, medium and large commercial enterprises to accelerate development and innovation.

- There are major initiatives currently ongoing within the biorefinery area, both within Europe and globally.

Therefore an international perspective is central to all initiatives, both with regard to working together with other countries and in following up on where knowledge and technologies can be obtained and brought to Sweden. Current European decisions concerning a common energy strategy and sustainable criteria for bioenergy will also bring new preconditions.

Need for coordination between research funding bodies, researchers and commerce

The implementation of a research and innovation strategy for a bio-based economy necessitates close collaboration between Formas, VINNOVA and the Swedish Energy Agency. It is our view that current divisions of roles and responsibilities are distinct and well functioning, but that these will be developed further. Collaboration agreements are in place between Formas and VINNOVA and between Formas and the Swedish Energy Agency. These agreements can form the basis for more developed forms of collaboration between the agencies in this area.

There are currently different forms of active collaboration between the agencies, where programmes are either co-funded (the Tvärlivs programme for example) or where we participate in joint calls with other funding bodies (such as the Nordic Top-level Research Initiative, Era-Net). Within strategic areas there are ongoing efforts to coordinate investments (such as in the area of transport).

The agencies intend to continue to support initiatives according to the proposals of this strategy and will continuously assess and agree on divisions of roles and responsibilities in connection with strategy implementation. The aim of this is to create synergistic effects in initiatives and to be able to follow up the concerted effects on a bio-based economy. Much of this work can be carried out within the framework of existing resources. If a major new initiative in the area is to be implemented then additional resources will be required. This presupposes that there are resources for this within state funding.

Formas will establish a *User Forum* comprising representatives of users (agencies, companies, members of the community) and other national and international stakeholders.

Report R3:2012

Formas, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, is a governmental research-funding agency. Formas encourages and supports scientifically significant research related to sustainable development.

Swedish Energy Agency

Energimyndigheten
Swedish Energy Agency
P.O. Box 130, SE-631 04 Eskilstuna, Sweden. Visitors: Kungsgatan 43
Phone: +46 16 544 2000, Fax: +46 16 544 2099
E-mail: registrator@energimyndigheten.se
www.energimyndigheten.se

VINNOVA

VINNOVA
101 58 Stockholm. Visitors: Mäster Samuelsgatan 56
Phone: +46 (0)8 473 30 00. Fax: +46 (0)8 473 30 05
E-mail: VINNOVA@VINNOVA.se
www.VINNOVA.se

formas

Forskningsrådet för miljö, areella näringar och samhällsbyggande, Formas
The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning

P.O. Box 1206, SE-111 82 Stockholm, Sweden. Visitors: Kungsbron 21
Phone: +46 (0)8 775 40 00, Fax: +46 (0)8 775 40 10
E-mail: registrator@formas.se
www.formas.se