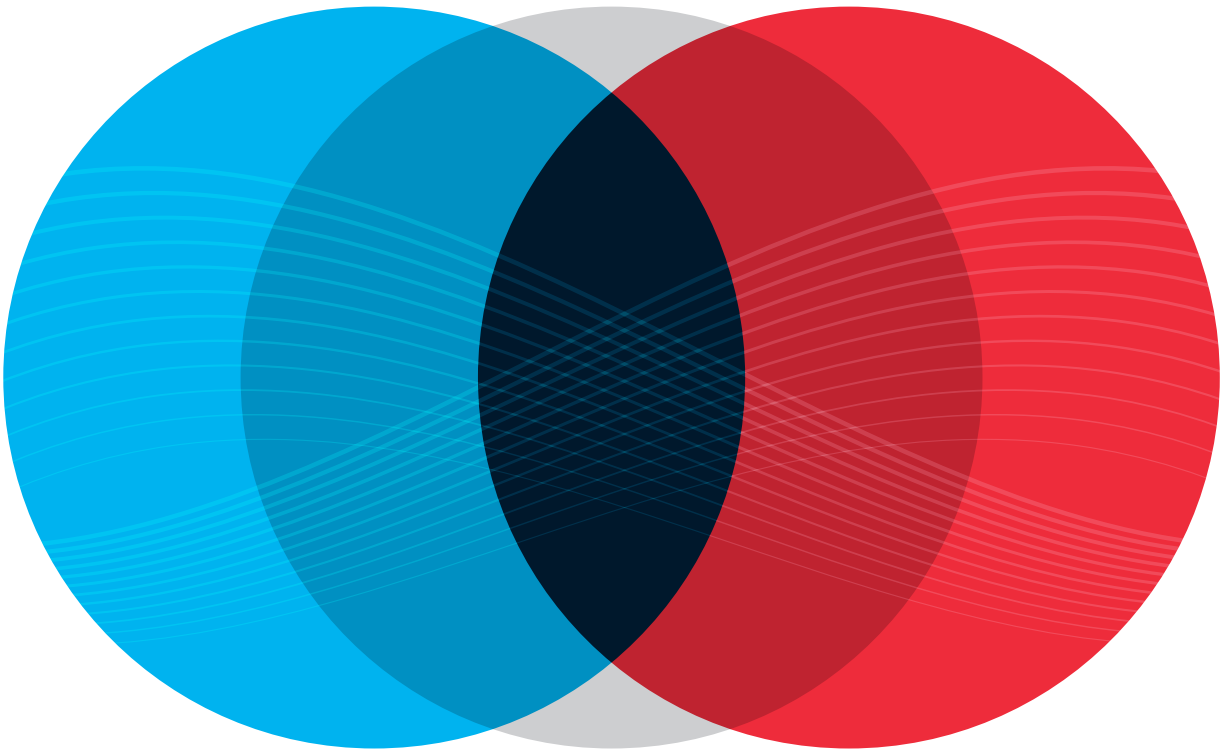
Life cycle based innovation (LINN)

A research and innovation agenda for a leading position within industrial and societal development where life cycle thinking and sustainability is used as a basis for innovation.



CPM The Swedish Life Cycle Center

CPM Report 2013:3, April 2013

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Innovation for long-term competitiveness

Within The Swedish Life Cycle Center (CPM) - industry, scientists, experts from academia and governmental agencies have worked together for a number of years enabling the development of more sustainable products with improved environmental performance.

During this work, we have learnt that to enable such a development, cooperation and generally accepted methods and data is required. These requirements in turn demands good research and recognized presence in international arenas such as the EU/JRC, UNEP/SETAC and ISO.

Through early activities in this field we have learnt more about the environmental impacts of products and processes. Today it is vital to take the life cycle thinking further and include life cycle innovation in the overall strategy and business plans to reach the sustainability targets.

The research and innovation agenda described, on life cycle based innovation, has been developed by the partners within The Swedish Life Cycle Center (CPM) together with other actors, and represents our shared vision of how to best promote development resulting in new products, services, business models and polices for a sustainable future.

This agenda will give Sweden a substantial competitive advantage and create legitimacy in the future by creating favorable conditions for pro-active actors aiming for a leading position within industrial development where life cycle thinking and sustainability is used as a basis for innovation.

Gothenburg, April 2013

Elisabet Olofsson

The Swedish Life Cycle Center CPM
Chairman

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Summary

We are collectively facing immense challenges, encompassing a growing population, increasing environmental impacts and a need for efficient and sustainable use of natural resources. These societal challenges can be turned into opportunities by actors, which are aware and proactive. In the challenges lay the opportunities for innovations.

The only long term sustainable way of addressing them is using a holistic life cycle perspective, which aims to resource efficiency and minimised environmental impacts without suboptimal solutions, while also creating new business opportunities and innovations. Sweden can take the lead.

The aim of the research and innovation agenda is to enable Swedish actors to see and act on such opportunities. In 2030 Sweden leads long term competitive sustainable innovation within products, services, public policy and businesses in a holistic perspective, encompassing environmental, economic and social resources in value chains.

This means that in strategic and operational decision-making within small and large companies, authorities and organizations, it is standard procedure that the environmental, social and economic aspects of products and services are optimized across the entire value chain. This result in long-term competitive businesses exploiting the opportunities presented by the life cycle perspective and with good preparedness to meet future challenges such as changes in resource availability, increased demands for information and new regulations.

Sweden is also recognized and acknowledged for its expertise and extensive cooperation within life cycle driven innovation, where cooperation between academia, industry, authorities and other organisations is leading to world-leading research and strongly proactive businesses in a changing world.

The supreme merit of a life cycle perspective is that it enables a focus on how the different parts of production and consumption systems are interlinked and highlights the fact that actions in one part of the chain have effects in other parts as well. With a life cycle perspective, sub-optimisations can be avoided and optimisations made over the whole product chains are encouraged. In other terms – a life cycle perspective is necessary for real environmental improvements.

In order to achieve the vision, there is a need for major changes and support. Three target areas that need to be strengthened and developed are identified and defined during development of the agenda.

A. Implementation of life cycle thinking in industry and society

B. Methods, data, tools and support

C. National joint effort for global leadership

Within the respective target areas, a number of measures are identified. These are measures that can contribute in different ways to achieve the objectives and which can be of varying importance for different perspectives and actors. Recommended ways forward have been identified for each measure.

We are now at a point were life cycle work has started to gain momentum. Life cycle assessment is an established method, although there are still gaps in the methodology and data availability. As regards implementation, we see a widespread use of the life cycle perspective. We also see frontrunner companies try out ways to work with life cycle management, both strategically and operationally. Even big international financial auditors start to include life cycle approaches in their evaluations. Life cycle based policies are formulated on an EU level.

This agenda suggests that this beginning momentum is capitalized upon, to bring us to a point in ten years' time where the life cycle perspective permeates both strategic and operational work, in business and in policy making. In particular its importance for innovation policy, innovation within companies and long-term competitiveness is demonstrated and recognized.

1 Societal challenges

We need to make collective effort to manage societal challenges and to achieve sustainable development. These societal challenges are challenges also for industry, but they can be turned into opportunities by actors which are aware and proactive. In the challenges lays the opportunities for innovations.

Goals are set by society: "The overall goal of Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside Sweden's borders." (The Swedish environmental generational goal)

The generational goal defines the direction of the changes in society that are needed if the environmental quality objectives are to be achieved. The prognosis at the moment is that 14 of 16 Swedish environmental quality objectives will not be reached by 2020 unless new measures are taken.

Well-renowned researchers have defined nine so called planetary boundaries. These boundaries are illustrating the action space that humanity has. To avoid catastrophic environmental change the researchers state that we need to stay within these boundaries, which relate to essential Earth-system processes: climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading. Three of the boundaries have already been exceeded (rate of biodiversity loss, climate change and human interference with the nitrogen cycle). (Rockström et al. 2009)

We are collectively facing immense challenges, encompassing a growing population, increasing environmental impacts and a need for efficient and sustainable use of natural resources. These challenges are being addressed, in many different ways, by nations, organisations and companies. The only long term sustainable way of addressing them is using a holistic life cycle perspective, which aims to resource efficiency and minimised environmental impacts without suboptimal solutions, while also creating new business opportunities and innovations. Sweden can take the lead.

The aim of the research and innovation agenda presented here is to enable Swedish actors to see and act on the opportunity for successful industrial development where life cycle thinking and sustainability is used as basis for innovation. This will be done by achieving implementation of life cycle thinking in industry and society; improved methods, data, tools and support; as well as providing a platform and means for national collaboration for global leadership.

2 Holistic perspective provides new opportunities

What is a life cycle perspective?

To address major societal challenges in a comprehensive manner the life cycle concept provides means for increasing efficiency, reducing environmental and societal impacts and conserving resources. All processes are covered - from raw material acquisition to end-of-life of a product, via production and use phases (Figure 1). The life cycle concept takes as its starting point physical and monetary flows and illustrates how the entire chain of actors works together to create products and services. When different actors adopt this approach and view the impact of products and services throughout the entire chain, irrespective of whether this is done through calculations or more qualitative appraisals, this is known as life cycle thinking (LCT). When the emphasis is on the coordination and control within and between various actors, this is known as life cycle management (LCM).

The life cycle concept has its origins in the analytical method life cycle assessment (LCA), which aims to calculate the potential impact on the environment that a product or service gives rise to throughout its life cycle from 'cradle to grave'. Concepts such as resource efficiency, cradle-to-cradle, ecodesign and circular economy are closely related to the life cycle concept. They also deal with optimising the resource use, reducing environmental impact and emphasise that organisations have to look outside their conventional beliefs on where an organisation's responsibilities begin and end. There is a joint purpose to consider the larger system of existing resources and how these can best be used in a more sustainable society.

Figure 1. The life cycle concept – from raw material to end-of-life handling.

Why is a life cycle perspective important?

All parts of the value chain have an impact on the sustainability of products and need to be considered. The supreme merit of a life cycle perspective is that it enables a focus on how the different parts of production and consumption systems are interlinked and highlights the fact that actions in one part of the

chain have effects in other parts as well. For instance, when designing more energy efficient products it should be carefully considered that it does not lead to additional environmental impacts e.g. in the raw material acquisition phase A company that contracts out processes with high environmental impacts to suppliers decreases its own impact on the environment, but in terms of the entire system improvement may not have occurred. With a life cycle perspective, such sub-optimisations can be avoided and optimisations made over the whole product chains are encouraged. In other terms – a life cycle perspective is necessary for real environmental improvements.

"Taking a life cycle perspective requires a policy developer, environmental manager or product designer to look beyond their own knowledge and in-house data. It requires cooperation up and down the supply chain. At the same time, it provides an opportunity to use this knowledge to gain significant economic advantages." (Joint Research Centre, 2012)

If we choose to consider Sweden's domestic emissions of greenhouse gases per person we have among the lowest emissions of all the industrialised nations. But Swedish consumption leads to considerable emissions in other countries as goods are imported. The greenhouse gas emissions due to Sweden's consumption were about 30% higher than those occurring within Sweden's borders and the emissions outside Sweden have increased (Brolinsson et al, 2012). Similar figures were reported for other environmental aspects. For land use it was found that land outside Sweden's borders provided 30-50% of the total land required for Swedish food consumption. Using a life cycle perspective gives more relevant information, and this is to an increasing extent being made.

Another example is the production and use of renewable fuels such as biodiesel and ethanol where the environmental impacts are strongly dependent on how the fuels are produced and from which land areas, clearly illustrating the need for a life cycle perspective. Yet another clear example is the development of advanced electronic products in high-income countries. Sometimes these products reduce environmental impacts when used, but production including raw materials extraction of metals that can cause environmental and social impacts when mined and are available in limited amounts world-wide, which may lead to overall negative impacts. Also, the positive and negative impacts can often occur in different countries.

It is important that the resources we use are not dissipated and lost. Conservation of resources has a major economic and social value to the extent that a number of past civilisations probably disappeared because of lack of resources such as fertile soil and water. Numerous industries have disappeared abruptly due to lack of raw materials, including fishing industries and coal mining. Business ideas and partnerships between companies that optimise resource use over time therefore have major potentials to be competitive in the long term.

These few examples illustrate that the Earth is one system and that a life cycle perspective is crucial for efficient environmental and social improvements as well as competitive businesses.

Foundation for innovation and competitiveness

The life cycle perspective drives innovation and competitiveness in several dimensions and on different time scales. In short terms, companies can reduce risks and obtain competitive advantages by environmental improvements of existing products and by product development and eco-design of new products. These improvements can be manifested as environmental labeling, environmental portfolios and by building stronger trademarks.

In longer terms, companies as well as the whole society will benefit from new technological innovations driven by environmental concerns and with a life cycle perspective. This is clear when considering the innovation system perspective – a life cycle perspective can contribute to important processes that are required for the development of innovation systems, such as knowledge development, legitimation and influence on the direction of search (Bergek et al. 2008).

A recent example is the ongoing structural changes of the energy system taking place globally and especially in Germany – a transformation that leads away from large plants fueled by fossils to decentralized systems of wind and solar power. Another example is the transformation of the transport system, where the development and introduction of biofuels and electric vehicles are driven by a life cycle perspective. Both these examples include the rise of numerous new innovation systems. A third example is the discussion on the environmental impact of food, primarily meat, which has been highly informed by life cycle assessments and lead to pioneering and much discussed initiatives such as 'meat-free Mondays' and synthetic meat. Such large transformations take long time and have arguably only begun in the examples mentioned above. Yet they are driven by both companies that see business opportunities and policy-makers, and the life cycle perspective constitutes the rationale behind these initiatives and technical innovations.

In summary, both short-term profit, long-term innovations, competitiveness and a sustainable society requires a life cycle approach. We already see new business models with a stronger focus on life cycle aspects, and taking the lead in this area would mean considerable and lasting opportunities for Swedish industry and the Swedish economy.

Life cycle based innovations

As companies often see their responsibility as limited to own activities or perhaps encompassing first tier suppliers, considering a life cycle perspective in product development and innovation is not self-evident and can include new challenges. There are however clear benefits of this perspective within product development and innovation. Eco-design has emerged as a popular concept among companies, aiming at designing products with lower environmental impact and resource use. Typical examples include designing products that can be recycled or do not contain any toxic substances. Another example, highlighted in the EU Eco-design directive, is the design of products that use less energy during their use phase. Another area where eco-design has become prominent is architecture and sustainable buildings, where examples of designs

Account for biodiversity

In the year 2005 VATTENFALL developed the so called Biotope method, a methodology for how to account for biodiversity changes and losses from a life cycle perspective. The methodology has been used in connection with Vattenfall's certified Environmental Product Declarations (EPDs) and has been applied in many contexts and on many different parts of the life cycle. As a result of this work a few of Vattenfall's suppliers has started to use the model to follow up their own impact on biodiversity. This shows that if you can work together with your suppliers in a consistent way, you can influence your suppliers to increase their own environmental awareness and hopefully decrease the overall environmental impact of products. Furthermore one of these suppliers has developed their own EPD and are nowadays more aware of their own life cycle impacts. This is an example where innovations in information systems can influence actors in the supply chain. (Mikael Ekhagen, Environmental Advisor, Vattenfall)

Environmental performance pays off

An interesting policy innovation with significant impact on the life cycle cost and, consequently, on the energy market is the feed-in tariffs in Germany. This is a policy that ensures that producers of renewable electricity receive a certain price for supplying the electricity to the grid. The price is constant over a number of years and is related to the life cycle environmental performance of the energy production. This policy innovation has made Germany world leading in production of solar energy – to the extent that installation firms for solar cells are beginning to face a shortage in suitable roof area! This policy has of course also increased the interest in technological development of solar cells. In this way, policy can promote product development towards.

include thick isolation, solar panels, reused or recycled building materials, rainwater harvesting and green roofs.

The on-going development and introduction of electrified vehicles can be taken as another example of a large scale and radical technological change, driven by life cycle concerns, in essence the need to reduce tail pipe emissions of greenhouse gases from vehicles. There are many life cycle aspects to consider in this process. For instance, little or no over-all reduction of greenhouse gas emissions can be expected unless the electricity is produced at low carbon intensity. In addition, electrified vehicles use several resources with limited availability, including lithium, which must be recycled to enable large scale introduction of lithium ion batteries. Many different actors are involved in the innovation system around electrification of vehicles, including automakers, electricity companies, and, not least, policy actors.

The need for a life cycle perspective in developing sustainable business models is illustrated in archetypes of sustainable business models developed by Bocken et al. (2013) and includes various eco-design strategies:

- Maximise energy and material efficiency, e.g. dematerialization, green chemistry.
- Create value from "waste", e.g. circular economy, industrial symbiosis
- Deliver functionality, rather than ownership, e.g. leasing, rental
- Encourage sufficiency, e.g. slow fashion, premium branding
- Adopt a stewardship role, e.g. biodiversity protection, fair trade
- Re-purpose the business for society/environment, i.e. focusing the business on delivering social and environmental benefits, rather than economic profit maximisation.
- Integrate business into the community, e.g. through alternative ownership
- Delivering sustainable solutions at a large scale to maximise benefits for society and the environment, e.g. licensing, franchising
- Radical innovation, i.e. introduce system change through introduction of radical new technologies to facilitate a greener economy, e.g. in renewable energy.

All of these will require a certain amount of life cycle thinking and cooperation between different stakeholders in the value-chain. The lack of life cycle thinking and such cooperation is also recognised as one reason why several opportunities have not been exploited by companies (Bocken and Alwood, 2012). There is thus a need for bundling competences to create win-win-win business models. Governments and NGOs have important enabling roles to accelerate industry change (ibid).

New pathways for collaboration

When beginning to evaluate the environmental impact of washing machines over their life cycle, it became clear that the greatest impact lay in the use phase. Instead of accepting that this lay outside the area of responsibility of washing machine manufacturers, work was begun with detergent manufacturers in order to develop detergents that could wash clean at lower temperatures. This required new pathways for collaboration between machine manufacturers and detergent manufacturers and communication measures to raise awareness and change behaviour among consumers. Although this is a relatively incremental change, it has significantly lowered the energy use of society (Electrolux, 2013)

Policy actors play many different roles in innovation processes. They make rules and other institutional arrangements but they also support technology development, initiate and finance competence build-up and support of introduction on the market for new products. The latter is in particular true for diverse "green" products, where examples include tax reduction for environmental vehicles (in Sweden) and feed-in tariffs for green electricity (in Germany).

But policy makers also invent new policy instruments and ways to work with them. Not least is this true for environmental policy, which originally was focused on regulating end-of pipe emissions. However, during the last decades the importance of diffuse emissions sources has been increasingly recognized and policies targeting products with a life cycle perspective have been introduced. Examples include take-back directives, the bio-fuels directive, eco-labeling schemes, the product design directive (EuP) and the end-of-life for vehicles directive (ELV). More recently, the proposal for a directive on public procurement can potentially have a strong impact. (European Commission, 2011b).

WEEE recycle more

Policies on Extended Producer Responsibility are developed in Sweden, within the European Union and in many other countries. They aim at extending the responsibility of the producers to also include the end of life phase of the products. For example, the Waste Electrical and Electronic Equipment Directive (WEEE directive) strives for more recycling of electronic waste. This is an example of a policy instrument where the life cycle perspective is integrated. By requiring a take-back and recycling a proper waste management can be secured.

Life cycle based requirements

The Ecodesign Directive, one of the key instruments in EU policy on Sustainable Consumption and Production, is based on lifecycle thinking and life cycle methodology is used in the process of defining energy requirement on selected product groups. The Ecodesign requirements mean that products must have a certain energy efficiency and resource efficiency in order to be put on the EU common market. This is governed by product-specific EU regulations. The focus has so far been on the energy requirements, but in the future the requirements may also include other aspects related to for example hazardous chemicals and waste generation. Established LCA methods are prerequisites for the inclusion of such aspects.

Waste prevention

A current national example in which the life cycle concept plays an important role is in the preparation of a Swedish program to prevent waste, to be launched in 2013. Measures in this program are aiming at reducing the amount of waste and content of hazardous substances in the products. Four product groups have been selected to focus on based on their environmental impact along the life cycle. They are food, textiles, electronics and building products. In order to reduce environmental impact downstream measures are to be taken upstream in the product chains. Life cycle methodology is used to identify the need for actions and policy instruments.

3 Vision

In 2030 Sweden leads long term competitive sustainable innovation within products, services, public policy and businesses in a holistic perspective, encompassing environmental, economic and social resources in value chains.

This means that in strategic and operational decision-making within small and large companies, authorities and organisations, it is standard procedure that the environmental, social and economic aspects of products and services are optimized across the entire value chain. This result in long-term competitive businesses exploiting the opportunities presented by the life cycle perspective and with good preparedness to meet future challenges such as changes in resource availability, increased demands for information and new regulations.

Sweden is also recognized and acknowledged for its expertise and extensive cooperation within life cycle-driven innovation, where cooperation between academia, industry, authorities and other organisations is leading to world-leading research and strongly proactive businesses in a changing world.

4 Practice, trends and outlook

Global interest

As a response to the increasing needs of discussing and analysing the environmental impacts of products, global harmonisation and standardisation of life cycle assessment began in the early 1990's largely driven by large consumer product companies. This development has continued for example by the development of a series of international standards, the establishment of LCA as a scientific field and a number of international initiatives.

In 2002, the United Nations Environment Programme (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC) jointly launched the Life Cycle Initiative, with the aim of promoting the concrete use of life cycle thinking in practice in different activities. The Initiative recently started its' third phase (2012-2016) with several sponsors from industry, governments and academia.

Several countries have also seen the importance of life cycle thinking. In Canada, a special enquiry carried out in 2012 reached the conclusion that "We identify clear risks to Canada's competitiveness and environmental reputation if we don't take steps to use Life Cycle Approaches for our own advantage." (Canada National Round Table, 2012). Also in Germany a program has been developed from a life cycle perspective, called German Resource Efficiency Programme (ProgRess), "a program for the sustainable use and conservation of natural resources". (Federal ministry for the Environment, nature Conservation and nuclear Safety (BmU), 2012). France has acted strongly in recent years introducing mandatory, life cycle based environmental communication on products put on the French market, however conditioned by a trial phase and, possibly, a first period of voluntary communication.

A number of globally active companies work with establishing life cycle thinking in a business context. An international forum for their collaboration is the World Business Council for Sustainable Development (WBCSD), which has a dedicated work stream for Sustainable Value Chains.

Global frontrunners companies

When the global LCA development took off in the early 90's, major global companies such as TetraPak, Unilever and Procter & Gamble, were among the most active together with different industry associations. Many Swedish industries were also seen as global leaders. Companies such as Volvo, Stora, SCA, Electrolux, ABB, AkzoNobel and Vattenfall were internationally recognized for picking up the life cycle perspective early, often using it in a proactive way for developing more sustainable products. Many of these companies were also active when the first phase of CPM (now the Swedish Life Cycle Center) started in the mid 90's.

The interest in the life cycle perspective has gone through several phases. It is now generally accepted that it is necessary for a holistic assessment of products and services. LCA has become an established tool also in many major companies. The strong commitment to the life cycle perspective in the Swedish companies is also demonstrated by continued support of CPM. The fact that this center continues also after the end of the period of base funding from VINNOVA (former NUTEK) shows clearly the commitment between industry, institutes, academia and the Swedish EPA. The center has also been able to renew itself by involving new partners from industry, institutes and universities. Many industries not currently active in CPM are also using LCA and life cycle thinking such as Ericsson, TetraPak, TeliaSonera, Scania and Bombardier.

Although the importance of the life cycle perspective is generally accepted in many parts of society and used in some contexts, its potential is not yet fully utilised in industrial and societal decision-making in areas such as product development, public and private procurement and policy-making. This research agenda is addressing some of the barriers related to institutions, education and research and data needs that need to be overcome.

Clear direction within European policy

There has been a distinct trend in recent years, not least within European legislation, of attention being directed to the impact of products in a life cycle perspective Examples include both policy documents such as the Roadmap for a Resource Efficient Europe as well as more specific directives such on Public Procurement. This work is also backed up by significant efforts of developing harmonised methodological guidelines and databases by the Joint Research Centre of the European Commission.

Development of a joint method for calculating the footprint of products and organisations such as PEF (Product Environmental Footprint) and OEF (Organisation Environmental Footprint) is underway within the EU. The new methodology is based on international LCA standards and will be used in EU policy on sustainable consumption and production. EU Commission recommends all member states, companies and other organisations should use PEF and OEF when it comes to communication of environmental performance of products. EU also recommends the financial sector to use PEF and OEF when assessing the financial risks associated with the life cycle performance (EU, 2013). This is one of three Communications by EU Commissions, which will be published in the spring 2013 in order to accelerate the transition to more sustainable consumption and production patterns: Greening of the inner market, Sustainable Food and Sustainable Buildings. All of them use life cycle thinking as a starting point for suggested policy initiatives.

In parallel to the PEF guide, the Food Sustainable Production and Consumption Round Table (RT) have developed a methodology for the calculation of environmental footprints from food and beverage, the ENVIFOOD protocol, to be adopted at the end of 2013, serving as an "umbrella document" for product category rules for the food sector. Future work of the RT also includes the development of calculation and communication tools and databases.

Many initiatives within standards, harmonisation and sectors

In parallel with policy initiatives, a large number of initiatives are also being taken by other actors, including individual companies and different forms and constellations of organisations. Companies find gaps, which needs to be filled. A result can be seen in all new methods developed by single companies, with consideration of specific company interests. Such methods are developed

18% reduction of Carbon Footprint

SCA started to work with Life cycle Assessments in the early 90s. Our environmental work today is based on a life cycle approach including what we source, how we produce and what we finally deliver to our consumer and customers. This work has resulted in a reduction by up to 18% of Carbon Footprint for our products like TENA, Libero and Libresse during 2008-2011. This reduction has mainly been reduced by smart product design, together with other step by step improvements by suppliers, SCA production and transports. (Susan Iliefski- Janols, Director Environment & Product Safety, SCA Hygiene)

FairPhone

FAIRPHONE is a social enterprise based in the Netherlands with the aim of producing a mobile phone considering the environmental and social aspects of the whole value chain. This includes issues like conflicts around mineral mining in Congo, poor working conditions in factories in for example Mexico and China, and waste management. Designing and creating fair electronics through learning from other initiatives and adopting best practice can be a force of change of current consumption models that fail to measure the environmental and social costs of production.
Taking a step-by-step approach, FairPhone aims to make the story behind the production of electronics more transparent, raising the bar for the industry and giving consumers a choice for fairer electronics. It's supported by Waag Society, Schrijf-Schrijf, ActionAid, Stichting Doen, Vodafone, Bethnal Green Ventures, KPN, Rabo Mobiel, GSM RetourPlan, GSM Loket, Podio and many other organisations and individuals.

although they often require large resources to develop, have low legitimacy and will not be used by many others, indicating the perceived needs for tools that can be used.

Different systems for information are being created by non-public actors, such as product declarations, e.g. Environmental Product Declarations (EPD), which exists for many different types of products, including building products, Carbon Footprints, information systems for the content of electronic products and the International Material Data System (IMDS) for the automotive industry. Protocols for measuring and reporting emissions of greenhouse gases have been developed for the World Business Council for Sustainable Development (WBCSD) together with the World Resource Institute (WRI).

The European standard EN 15804 "Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products" provides rules for the calculation of LCA based EPDs of construction products. It is linked to the new Construction Products Regulations (CPR), which identifies EPDs of construction products as a mean to communicate the environmental performance of construction products in relation to the CE mark.

As regards social aspects, projects within the UNEP/SETAC Life cycle initiative are devising guidelines for Social LCA.

Sweden has strong actors

Collaboration in value chains and dealing with environmental impacts in a life cycle perspective are areas where Swedish actors are strong. Sweden was among the first to build up the research area of life cycle assessment among universities and research institutes. Also, a number of Swedish companies are globally acknowledged as being very prominent within the area. Not least, Sweden is recognised for its close cooperation between industrial, research and public actors.

Within the work with this agenda, a survey of actors in the area of life cycle thinking was conducted. It was done with a snow-ball approach in the distribution, starting off with well-known actors. In total 108 replies were collected, an unexpectedly large response considering the limited distribution. This in itself indicates the interest for life cycle issues among the actors reached; industry, academia, institutions and authorities.

The outcome revealed that among those working with methodological develop-

ment, the largest individual area of activity was sector adaptation, followed by database construction. Other developments are taking place in e.g. applications within product development and communication (Figure 2).

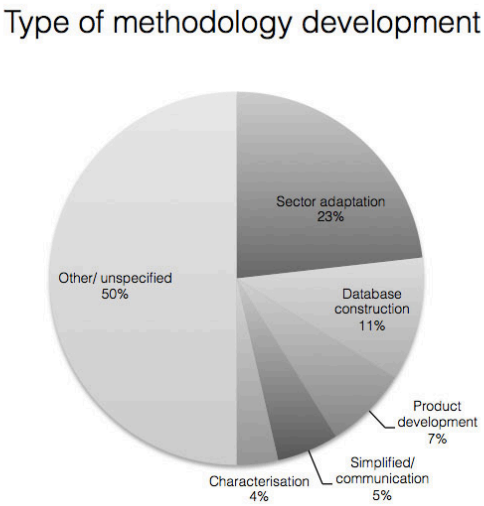

Figure 2. Largest individual area of activity in methodological development from survey results.

Life cycle management was used to a more limited extent. Those who reported using LCM were working mainly within R&D, communication and marketing. Many were also involved in various forms of standardisation work, particularly within LCA as such and Carbon Footprint.

Prominent actors, according to the respondents of the survey, are SCA, Volvo, Akzo Nobel, Unilever, Vattenfall, ABB and SKF among others within industry. Within the academy, Chalmers and KTH but also The Faculty of Engineering at Lund and Linköping Universities are seen as leading. Other important actors mentioned in the survey are IVL, CPM The Swedish Life Cycle Center, SIK, SP and Miljöstyrningsrådet.

The respondents were asked to list measures to increase the use of life cycle thinking in society and the responses revealed a wide range of measures. The majority of the responses concerned method development and data handling, followed by the need for taking measures in industry, and for society to exert an influence through e.g. new legislation. Increased communication about the value of life cycle thinking was also regarded as important, as was education and cooperation (Figure 3).

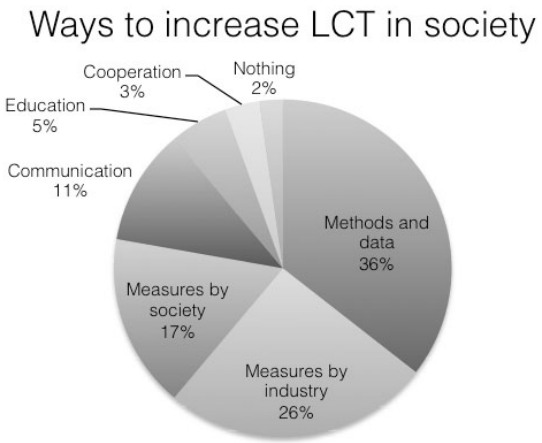

Figure 3. Most important measures to increase the use of life cycle thinking in society from survey results.

5 Opportunities and challenges

Swedish opportunities to become a world leader

As mentioned, Swedish actors are strong in life cycle thinking. Not least, Sweden is very strong in having close and fruitful cooperation between different actors, such as institutes, academia, businesses and authorities. This collaboration facilitates the joint development of assessment tools as well as business models and policy providing opportunities for innovation.

Specifically in CPM The Swedish Life Cycle Center, major actors in the life cycle field have a long tradition in joint projects, exchange of experiences and support.

CPM has a good reputation internationally. As a result, CPM was in 2010 appointed host of the 6th International Conference on Life Cycle Management to be held in Gothenburg 2013. In 2011, CPM was ranked No. 1 within the field of sustainable innovation of products, appointed by the Basque environmental agency Ihobe. Their analysis highlighted CPM's long experiences and enduring collaborations. The power in CPM was deduced to the active industry representation and the unique ability to find similarities and common denominators between different industries. CPM was also seen as having an exceptional infrastructure, networking scheme and way of working.

CPM is and has been active in a number of international standardisations in e.g. ISO, including LCA, data formats, Environmental Product Declarations (EPD) and Eco-efficiency (EE). The center was also a pioneer in building up an open cross-sectorial database for LCI data (Life Cycle Inventory data), and in making this database open to use free of charge. This is well known internationally, especially within EU.

A number of major global industrial groups are opting to keep their environmental departments and sustainability experts in Sweden even if the head office is moved overseas. AkzoNobel, AB Volvo and SCA are some examples. There is also a strong demand from industry to create links with Swedish research within the area. When SKF opened its 3rd University Technology Centre (UTC), this time specialising in sustainability, the choice of host college was Chalmers in Gothenburg. The other UTCs are located at Cambridge, Imperial Collage and Luleå.

In the academic field LCA/LCM is now formally established as a research and an educational topic, and has considerable volume at both KTH and Chalmers, as well as other universities. The organisation of the biannual Life Cycle Management Conference by CPM in 2013 marks Sweden's importance in the global context. Swedish LCA researchers also have a good track record in terms of scientific publications.

90 million tonnes of CO2

AKZONOBEL recently developed an antifouling paint for large ships with considerable improvements for the environment and profitability in a life cycle perspective. For this type of antifouling paint, the greatest impact on the environment and on profits occurs in the use phase. In contrast to conventional products, the new paint has a smoother surface, which results in lower friction and around 7% lower fuel consumption. If this new paint were to be used to replace conventional paint on 3 000 large ships, the savings could amount to up to 90 million tonnes of carbon dioxide (which is 50% more than the amount generated annually by the population of Sweden). It would also represent a major cost decrease for the shipping industry. (Klas Hallberg, Manager Sustainable Development, AkzoNobel)

High production of scientific papers

A simple search in the scientific database Scopus for the combination "LCA" and "X" where X is a country gave 1256 hits for Sweden, 743 hits for Denmark, 1323, for Italy, 1374 for the Netherlands, 1965 for Germany and 2107 for Japan. In Sweden the most frequent affiliations are Chalmers (198 papers), KTH (118), Swedish Agricultural University (63), Lund University (57) and SIK (as part of SP) (54). The most frequent authors in this search were G. Finnveden (KTH, 54 papers), T. Ekvall (IVL, 26), U. Sonesson (SIK, 24), PA Hansson (SLU, 20) and AM Tillman (Chalmers, 20).

The only and most recognised LCA educational book is The Hitch Hiker's Guide to LCA. This student literature was written by Prof.. Anne-Marie Tillman and Associate Prof. Henrikke Baumann (Chalmers University of Technology) and is today used and spread all over the world.

The increasing interest in the field of life cycle studies can be illustrated by related departments in universities and institutes which are steadily growing. Furthermore, in 2010 the Swedish Environmental Protection Agency decided to invest in internal expertise within the life cycle area. It is crucial to make the most out of this positive trend and act to maintain a high level of activity in continued competence provision and support in the surrounding society in order for Sweden to retain a leading position.

All of the above forms an excellent basis for taking a leading position within industrial and societal development where life cycle thinking and sustainability is used as a basis for innovation.

Challenges

Despite the opportunities outlined and the great potential for economic and environmental gains, life cycle based innovations are still not an essential part of companies' product development and business strategy operations.

The problem lies partly in lack of knowledge, tools and data…

To some extent there is a lack of knowledge, tools and data to determine the impact of a certain product, how resources can best be used to improve environmental performance and how information can be supplied and communicated in the best way.

Certain areas continue to have a need for method development. Within for example biodiversity, land use and toxicity, there are still major uncertainties regarding how to calculate the environmental consequences of different alternatives. Also areas such as social LCA and valuation/weighting need further attention.

For nearly all types of assessments, availability of data is a major obstacle. The cost of data collection is a particular obstacle for small and medium-sized businesses. Sweden has no continuously updated national database of data that are relevant for Swedish conditions. Today analysts are referred to commercial databases or other national databases, with data for non-Swedish conditions also in cases where Swedish data would be appropriate.

For those who are new within the area, there is also a great demand for information, training, guidelines and advice.

… but mainly in culture, organisation and incentive structures

In order for a life cycle perspective to permeate organisations, changes are needed in structure and practice, but also the right incentives need to be in place. A life cycle perspective needs to be implemented and integrated in processes throughout the organisations; in product development, in procurement, in marketing and in production as well as in technical development and strategic activities. With a group of expert LCA people performing excellent work in a group separated from the basic processes and the "real" decision-making in an organisation there will be no action. This is a true challenge and needs to be addressed in several ways.

Lack of an actor's perspective. Not all functions in a company can influence all parts of the product chain. Certain functions or activities can influence the use phase (e.g. product design) whereas sourcing and purchasing department have the contact with suppliers and are able to influence those. There is need to develop a better understanding how different functions within a company may work with the life cycle perspective, as part of their daily operations.

Monitoring and incentives can influence the focus taken by the individual person or department. Most environmental and sustainability objectives still focus on internal processes within companies, and seldom adopt a perspective that views the entire life cycle. Investment assessments, both internal and those performed by financial analysts and external investors, will drive more long-term thinking and enable greater use of a life cycle perspective (see e.g. Cerin and Belhaj, 2009). Conventional business relations and business models present challenges. For optimisation of environmental, social and economic effects over the entire value chain, new pathways for business and exchange of information may be necessary. An important example is various means to increase and improve information flows between producers and recyclers to enable efficient reuse and recycling. But not only information flows present possible ways forward, another option is new business models where producers retain control over their products and make business from for example remanufacturing and dedicated recycling.

Ownership and responsibility relations, between different departments within organisations and between companies are one substantial reason for sub-optimisation. Lack of investment in energy efficiency within the construction industry is one example. Since different actors in the value chain of buildings build, own and manage the property and each actor optimises their own profits, there are few incentives for construction companies to invest in more energy-efficient solutions that save money in the management phase. Such incentives could potentially be created by means of a different business model.

But not only firms can induce change. Indeed, in order to achieve substantial and widespread change in existing production and consumption systems, there is a need for societal development in the same direction, whereby political and societal structures promote life cycle-based products and businesses, through making use of a whole series of policy instruments, such as legislation, economic incentives, enabling policy instruments, public procurement and information to consumers. The understanding of how to fine tune mixes of policy instruments and adjust them with respect to which actors in the value chain are targeted is still limited.

Three target areas for achieving the vision

Based on the above opportunities and challenges it can be concluded that in order to achieve the vision of Sweden as leading long term competitive sustainable innovation on a broad front within Swedish businesses, authorities and organisations, there is a need for major changes and support. Changes in ways of thinking and in practices, support in maintaining knowledge, competence and existing collaboration are needed.

In Sweden there is a very good foundation upon which to build, with good awareness, established methods and a critical mass of already proactive industry, and excellent research organisations, well-established industry-academia networks, and established education. All this which bodes well for success – if a collective effort is made at national level!

There are three target areas, which have been identified and defined during the process of developing this agenda, that need to be strengthened and developed in order to achieve the stated vision.

A. Implementation of life cycle thinking in industry and society

B. Methods, data, tools and support

C. National joint effort for global leadership

These areas are closely related to each other and need to be developed in parallel.

6 Objectives

The three target areas presented in the previous chapter have been broken down into six objectives in a 10-year perspective. These objectives are considered critical for achieving the vision of long term competitive sustainable innovation through life cycle-based innovation. In order to achieve these objectives, various measures of different types and by different actors are needed. These are described in more detail in chapters 7-9.

10-year objectives

In order to achieve the vision, parallel work is required within implementation, methods and tools and global leadership. The below objectives were formulated based on:

- Open dialogue meetings with interested stakeholders and experts (in Stockholm on 17 October 2012 and in Gothenburg on 29 January 2013).
- Survey aimed broadly at industry, institutes, academia and authorities (108 responses)
- Discussions within steering group, working group and reference group to the Agenda development project

Within the respective target areas, during the course of the process developing the agenda a number of measures were identified. These are measures that can contribute in different ways to achieve the objectives and which can be of varying importance for different perspectives and actors. These measures are listed in the following chapters.

The 10-year objectives are the following:

A. Implementation of life cycle thinking in industry and society

- There is a distinct awareness and legitimacy of life cycle thinking and proven links between long-term competitiveness and the life cycle approach.
- The life cycle perspective permeates both strategic guidelines and process flows such as measurement and monitoring within businesses, authorities and organisations.

B. Methods, data, tools and support

- Businesses, authorities and organisations have access to relevant, scientifically supported and internationally accepted methods and tools so that they can apply and communicate the life cycle perspective.
- Sweden has an established national database with appraised life cycle-related data that are continuously updated.

C. National joint effort for global leadership

- Swedish actors are working together to proactively influence and take

leading roles in international standards, declarations, directives, etc.

- Swedish actors are attracting leading expertise for qualification and exchanges and are in demand as partners in international projects.

7 Implementation of life cycle thinking in industry and society

The objectives set in the agenda for this area are the following

- There is a distinct awareness and legitimacy of life cycle thinking and proven links between long-term competitiveness and the life cycle approach.
- The life cycle perspective permeates both strategic guidelines and process flows as measurement and monitoring within businesses, authorities and organisations.

For Sweden to be a global leader in life cycle based innovations, it is crucial that the life cycle perspective is implemented on a broad scale in industry and society and that societal structures support companies and academia to be frontrunners in this development. Measures A1-A6 which will contribute to the achievement of the objectives are presented below.

Broader implementation in industry and society

There is an increased awareness that sustainable development is an emerging and important area for long term business competitiveness. However, the linkages from sustainable development in general and the life cycle perspective in particular to daily operations and current business opportunities are less evident in industry, especially for those not working in environmental departments. In addition, sustainable production needs to be followed by sustainable consumption in order to achieve a sustainable society. Public awareness of the environmental impact of their actions is limited and needs to be addressed.

A1. Incentives for increased coordination across functions and actors

A main characteristic of the life cycle perspective is the close collaboration among functions and actors along the value chain in order to optimize the whole system and not only the performance of specific actors or departments. Current industrial structures of e.g. responsibilities, ownership, performance indicators, financial analyses etc. are most often not adapted to this broader systems perspective. Profits are calculated on each function separately and the responsibility for sustainability goals is often allocated to a few business units. This limits driving forces for each actor/function to optimize the whole system, and can counteract a broader implementation of a life cycle perspective in industry.

We need to understand the drivers and barriers to implementation, and to identify and present the situations where a life cycle perspective will make a difference. The presentation needs to be clear and relevant to people within product development, technical development, procurement, marketing, policy

making, and so on.

There is a need to create new incentives for life cycle thinking and increased collaboration across functions and actors in industry and organisations and further develop existing ones. Furthermore, to better understand premises for innovations in business models and be able to more clearly show the linkages between life cycle considerations and profit and competitiveness.

The necessary changes in institutions and practices are large. However, we have particularly good possibilities for creating role models in Sweden. Sweden has a high general awareness about sustainability concerns but also a tradition of collaboration and rather flat hierarchical structures with high employee involvement. Sweden also has many large companies with substantial experience from life cycle work.

To further the implementation of life cycle thinking, there is a need for more knowledge on existing cultural/behavioral and structural drivers and barriers as well as an analysis of possible opportunities and incentives to enhance coordination and collaboration across actors and functions.

We therefore recommend:

- A systematic analysis of drivers and barriers for broader implementation of life cycle thinking in industry and society.
- Collection and provision of good examples/best practices where life cycle thinking has been integrated into "ordinary" processes in business, such as sourcing, product development, investment decisions, production and marketing.
- Based on such examples, new incentive structures should be analyzed and suggested to enhance the integration of life cycle thinking in different business functions (monitoring, key performance indicators, collaboration formats, bonus systems, investors' assessments, etc.).
- Adaption of life cycle methods to better suit different kinds of decision-making processes. Examples of areas to investigate are: What does it take to implement life cycle thinking in product design? and How can life cycle information be integrated in existing systems such as CAD?

A2. Clearer linkages to profit and competitiveness

In order to enter into strategic business processes, it is often argued that a clear connection to finance and competitiveness is needed. Swedish minister of environment Lena Ek recently argued in the area of climate change that "There is an obvious need to present arguments for how to make money on energy investment, innovation, cost of health - yes, in general the use of the smart technology that is on the way, but not always industrialized," (Miljöaktuellt 2012-11-29, author's trasl.). The same applies to the integration of a life cycle perspective.

Some of the arguments are already in place, but could be used to a larger extent. For instance it is clear that cost reduction often goes hand in hand with environmental savings. This is true when resources, e.g. energy and raw materials, are used more efficiently. Sometimes associated cost saving are outweighed by investment in more resource efficient equipment, but sometimes the economic benefits of, say, reduction in energy use, is simply not seen. This may be because no-one bothered to look (e.g. measure energy use on a detailed level or calculate the total cost of ownership) or because cost reductions and investment cost fall into different organisations along the product chain, or even different parts of

one and the same organisation.

It is also clear that there exist markets for higher value, environmentally and/or socially preferable products. Eco-labeled products usually fetch a higher price, and so do fair trade products. There are also up-market brands of green products. But more could be done in terms of investigating the demand for environmentally and/or socially responsible products, and to create markets for such products.

As natural raw materials become scarcer, it becomes increasingly more important for companies to assure that their suppliers can provide a long term supply of suitable raw materials. Also, with growing environmental and social concern from authorities, NGOs and consumers in general, in addition to price competition, it becomes ever more important to make sure that the whole supply chain is optimized and just. Risk minimization, highly linked to competitiveness, is thus an important driver for life cycle work.

Much of currently on-going technology development is driven by environmental concern, sometimes with a life cycle perspective. Future return on such investment is expected, albeit uncertain, both a societal level (when policy actors support technology development) and at a company level. However, the links between the life cycle perspective and expected profit may be hard to prove, since proactive actors do not always want to reveal their business strategies and results.

We therefore recommend:

- Identification and communication of quantified examples and best practices showing the link between the life cycle approach and its impact on economic performance and competitiveness, including both inspiring case studies and an estimation of the business potential at large in different industries.
- Identification and communication of examples and best practices showing how life cycle approaches may be used to create market opportunities for environmentally and/or socially responsible products and to minimize business risk.
- Identification of types of ownership relations and incentive structures that hinder implementation of resource efficient solutions.
- Development of indicators for following the relationship between life cycle activity and competiveness, on a societal, organisational and product level.
- Development of methods for calculating and displaying business benefits of a life cycle perspective (for further suggestions see section 8)

There is also a need to develop and introduce supporting policy incentives that enhance the economic benefits of having a life cycle perspective (e.g. taxes on natural resources and emissions) as described below.

A3. Development and monitoring of sustainable business models

Life cycle thinking can be used to develop new business logics with the potential of radical changes in environmental and social impact at the same time as it leads to higher profits and long term competitiveness. This is illustrated in the seven archetypes of sustainable business models described in section 2 (Bocken et al, 2013) which requires a life cycle perspective and cooperation in the value chain. Two examples are business models based on delivering functionality and remanufacturing. The use of more high quality materials could for example make a product easier to repair and provide a higher material value at recovery. With a more service-based economy the opportunities for job creation in

SKF beyondzero portfolio

SKF launched the SKF BeyondZero portfolio in May 2012. The portfolio defines and quantifies the solutions that help customers reduce their environmental impact in a life cycle perspective. The environmental improvements provided by the various solutions in the portfolio are validated through a LCA-based method. The growth of the SKF BeyondZero portfolio forms an important part of the Group's overall business and environmental strategy. The aim is to increase the revenue from SEK 2.5 billion in 2011 to SEK 10 billion by 2016. In March 2013 the portfolio contained 35 solutions, one of them the SKF Low Friction Engine Seal which reduces friction by up to 55% and when installed in a car engine provides a CO_2 savings of over 1 g per kilometre. (Mats Berglund, team leader environment R&D, SKF)

Sweden will be several.

The general economic and environmental benefits of such business models has been argued from different perspectives (e.g. Sundin & Lee 2011, King & Burgess 2005 and Kerr & Ryan, 2001), although there is still need for assessing the environmental benefits of different sustainable business models in practice.

The currently prevailing practice in society is products designed for short lifetimes and planned obsolescence (see e.g. Bernhard London that already in 1932 wrote the paper "Ending the Depression Through Planned Obsolescence"). Today added value for customers is often introduction of new products (new versions of smart phones are constantly introduced on the market) and components and subscriptions are designed for certain time intervals (see e.g. Slade 2006, or printers designed for certain number of printouts at http://www.atomicshrimp.com/st/content/inkjet_printer). The cost of repair has generally increased much more than product costs and now often exceed purchasing costs (e.g. in consumer electronics).

There are fundamental economic barriers and risks for companies to change their business strategies including that it takes very long time to validate new business models, the uncertainties in up scaling of pilots, and existing key performance indicators (the share of employed capital is for example often higher in circular-based business models than in linear ones).

It is important that industry, academy and society act together to increase knowledge and incentives, test solutions and provide good examples for others to follow.

As the uncertainties and risks for companies to introduce new business models are high, there is a need for research and knowledge building of how new business logics can be implemented and what the effects are. There is also a need to develop, test and demonstrate "new" business models and how this can be operationalized in practice.

We therefore recommend:

- Identification and understanding of drivers and barriers to overcome today's prevailing business models.
- Monitoring of existing examples and development of new case studies to broadcast the merits and effects of alternate business models, including assessment of these.
- Defining ways to predict and assess the environmental, social and economic consequences of business models based on a life cycle perspective used in

a broad scale.

- Support in operationalization of sustainable business models such as a) how to design products with an "optimal" number of life cycles (several is not always better then few, see e.g. Gutowski, et al. 2011), b) how to handle relations in the value chain, c) specific conditions for various industries and product categories etc.

A4. The financial sector's perspective

In an earlier project within CPM The Swedish Life Cycle Center about the finance sectors evaluations of companies included a seminar. Auditors from the finance sector found the life cycle approach interesting and also had the opportunity to meet and exchanged their experience with others auditors, also in discussion with industry (Cerin and Belhaj, 2009).

EU Commission now recommends the financial sector to include the life cycle perspective in their evaluations of organisations (EU, 2013). The EU Communications around PEF and OEF will have an impact on future evaluations and the investors' perspective, but how?

We therefore recommend:

- Build up knowledge around the life cycle perspective in evaluations of companies.
- Round table discussions between industry and the financial sector

Supportive societal structures

Supportive societal structures ranging from policymakers and funding agencies to purchasing managers and awareness of the general public are all important to encourage and provide beneficial conditions for life cycle based innovations. This includes both a clear direction in policy instruments and an increasing demand broadly in society that benefits a life cycle thinking industry.

A5. Clear direction in policy instruments

Sweden is recognized for being a pioneer in environmental policies, e.g. with the tax on carbon dioxide. We should act in order to stay a leader and further develop policy incentives facilitating a co-evolution of life cycle thinking and innovation/business development. This will require courageous politicians devoted to profound changes towards sustainable development. The importance of the life cycle perspective for sustainable production and consumption is also stressed by the Swedish EPA in their latest evaluation of the Swedish Environmental Quality Objectives.

A wide range of policy instruments are based on life cycle thinking. Some act through restricting what actors on the market can do in various ways (e.g. legislation and environmental taxes or other economic instruments) or mandate them to do things, such as recycling legislation. Other policy instruments work through enabling and/or encouraging actors on the market. Examples include information schemes, such as eco-labeling and environmental product declarations, support to technology development and subsidies for emerging environmental technology. A recent example of a massive information scheme is in France, where legislation is expected to make life cycle environmental communication mandatory for products put on the French market, conditioned by a positive evaluation of the ongoing trial phase.

There is a need to better understand how life cycle thinking can be used in policy development and how different policy instruments can be used in combination, supporting and not counteracting one another in the aim for increased implementation of life cycle thinking in industry and society. There is also a need to better understand what role assessments, including life cycle assessment play in policy processes.

We therefore recommend:

- Analysis of existing and potential policy incentives with regard to the balance and interplay between different types of instruments, in particular the balance between restrictive and enabling types of policy instruments and how policy may support the transition towards wider life cycle thinking.
- Analysis of the role played by LCA studies (and other types of assessments) in policy making processes and how life cycle thinking is otherwise used in policy making.
- Expressed political ambitions regarding life cycle thinking and support for its practical implementation in e.g. regional and national visions and actions.
- National research policy applying a life cycle perspective, in particular as regards the development of new technology, and which encourages interdisciplinary research with close involvement of both large and small/medium sized companies.

A6. Demands that benefits a life cycle thinking industry and society

A proactive and encouraging market is key to stimulate goods and services having environmental, social and economic merits in a life cycle perspective. There is a need for demands from both public and private organisations, as well as consumers. Various means can be used to increase this demand, including information and labeling, public administration acting as role models in purchasing, and increased awareness and actions by private business and consumers.

Public and private procurement work under different conditions. Public procurement may be used as a policy instrument in itself, to create demand for products that perform well in a life cycle perspective. The effects of such policies may be substantial, since large volumes of goods and services are bought by public bodies. It is also often argued that public procurement should be used to set a good example. At the same time public procurement is hedged by legislation intended to stimulate competition, but which may hinder life cycle consideration from being taken.

Private purchasing business-to-business, on the other hand, is often closely linked to product development, with product development efforts being done in collaboration with, or even outsourced to, suppliers. Taking life cycle issues into consideration in the sourcing of raw materials is a relatively new aspect in the sourcing process and many companies are still struggling with how it can be done. At the same time, control over supply chains is becoming increasingly important, from a risk management perspective. Not least does this apply to phenomena such as child labour and land grabbing, but also to pollution, as current trends towards “core business” imply the risk that polluting processes are out-sourced. In addition, traceability may be foreseen to become increasingly important, as highlighted by recent food scandals.

Private purchasing by consumers, again is different. Private consumers have less competence and time to spend on evaluating the sustainability of their purchases and they are under heavy influence by strong market actors. Taken

one by one they are small, but collectively, they create a large demand, indeed. This is true, even when regarded as market segments.

There are also aspects that are similar to all sorts of purchases. Prices matter, as well as quality. If environmental, social and more long-term economic aspects are to be considered in purchasing decisions, information is one key element.

We therefore recommend:

- Understanding of the barriers and drivers in making the life cycle perspective a guiding principle in different types of purchases. What makes these actors evaluate environmental and social effects in a life cycle perspective? and What makes them evaluate cost as life cycle costs/total cost of ownership rather than purchasing price only?
- Guidelines for public procurement which include the need to consider life cycle aspects.
- The life cycle perspective being integrated in declarations and certifications regarding products and their acquisitions and disposal.
- More sophisticated market analyses, which investigates the demand for more sustainable products and use such information for market formation.
- To succeed with the above on a long term basis, a general awareness rising and change of preferences on a broad scale is needed among customers, consumers, governmental organisations, the general public, etc. This is further described in chapter 9.

8 Methods, data, tools and support

The objectives set in the agenda for this area are the following

- Businesses, authorities and organisations have access to relevant, scientifically supported and internationally accepted methods and tools so that they can apply and communicate the life cycle perspective.
- Sweden has an established national database with appraised life cycle-related data that are continuously updated.

The life cycle concept has its origins in the LCA method, which is standardised in ISO 14040 and 14044. Due to the standardisation this method can be regarded as both scientifically supported and internationally recognized. Based on this approach, many related methods and tools are developed, such as different footprinting approaches and EPDs. These can also be seen as established methods, and there are guidance issued for those as well.

Measures B1-B10 which will contribute to the achievement of the objectives are presented below.

Scientifically based and internationally accepted methods

It is important to have scientifically based and internationally accepted methods, and these need to be based on interdisciplinary science.

B1. Identify need for (assessment) methods and tools

In order to implement life cycle thinking in operational and strategic processes needs for methods and tools must be fulfilled. There are already methods and tools available for inventorying, impact assessment, streamlined assessments, etc. Some methods and tools need major further development for example considering biodiversity, land use and toxicity, also social LCA and valuation/weighting need further attention. These are specifically mentioned as measures below. However, there may be other issues that can be identified where (further) development of methods and tools are necessary. This may be for example regarding the handling of biogenic emissions and effects of these emissions, where some examples from agricultural production are CO_2 emissions due to land use change, CH_4 from animal enteric fermentation and soil N_2O emissions and leaching of plant nutrients from soil. A continuous process where the identification of needs for (assessment) methods and tools is made is necessary to enable prioritisation and the further the development in relevant areas.

Life cycle thinking can influence decision-making in industries and public authorities at a number of different levels in many situations including product and process development, procurement, planning and policy making. In these different situations, different types of tools and methods may be useful. These can include streamlined LCA and LCC spreadsheet tools, on-line web tools and

checklists. In order to meet this demand a number of tools have been developed both internally by companies and by academia or public organisations in order to support the use. There is however a need to study the actual use of and need for different tools in different situations.

We therefore recommend:

- Identification of needs for assessment methods and tools and the subsequent initiation of development of methodology and case studies for testing methodology.
- Studies of the actual use of different tools and methods in companies and public authorities. This should result in a better understanding of what tools are available, which are used, what are best practices and what has supported a successful implementation.
- Studies of situations where life cycle thinking could be further used in decision-making. This should result in a better understanding of what is blocking the use of life cycle approaches, institutional factors that are beneficial or blocking, and what tools could be further developed for different situations.

B2. Social aspects

The globalization of production and the increasing global exchange of knowledge has increased awareness about working conditions in the now global production chains, but also their impact on the local community. Examples of the latter are beverage producers being criticized for their use of water in water-scarce areas, and several cases of attention to child labor in the garment industry. In order to analyze these impacts a tool for social LCA has systematically been developed (Benoît & Majzin 2009), based on the established, environmentally oriented LCA. However, the use of this method encounter various difficulties, such as when social factors to some extent can be seen as culturally conditioned, and they are sometimes more difficult to quantify and therefore assess compared to environmental impacts.

Method development is in progress, however, in the research community, and Sweden is at the forefront internationally with a relatively large number of already completed, ongoing and planned case studies (Blom and Solmar 2009; Ekener-Petersen and Finnveden 2012; Baumann et al. 2013) and with an economy that is open to the idea that social LCA could be a way to address social aspects of production. This was demonstrated at the project dialogue meeting in Gothenburg on 29 February 2013, when the Social LCA was one of the methodological areas receiving the most attention. There is hence a momentum right now for Sweden to take on a leading role in this area.

We therefore recommend:

- Performing methodological development and data inventory buildup through concrete and industry relevant case studies
- Creating a platform for excellence development through exchange of results and experiences among researchers and linking with industry to understand their needs
- Participation in international initiatives and working groups

B3. Biodiversity and land use

Looking at the natural boundaries of our planet, it becomes clear that the impacts from human activities are moving dangerously close towards them and

even surpass them in several cases. A boundary which is particularly sensitive is the one for biodiversity implying that the continued impact from land use activities could lead to a collapse if we do not change our behavior dramatically.

Sweden has a long and successful history of using its natural resources to achieve social well-being, economic growth and competitiveness on an international level.

Current efforts to mitigate climate change drive a development towards an economy increasingly based on renewables and biomass, which places an even higher demand on natural resources. Such a new bio-based economy needs to be implemented in a responsible manner, implying a sustainable use of resources and ecosystem services, and hence sustained biodiversity. For this reason, impact from land use on biodiversity and other aspects such as carbon balances, soil erosion and water balances needs to be assessed and considered in decision processes for long-term policy formulation and industrial development.

LCA is one such decision support tool, which is widely used and recognized. However, LCA rarely includes assessment of effects of land use. This is partly due to that the cause-effect chains are complex and not completely understood but also that impacts from land use are heavily geographically dependent. Methods exist, but they are complex, incomplete, data demanding and regionally bound. None of the methods suggested so far cover all aspects of land use. Rather, what exists is a patchwork of methods, with gaps and overlaps. For this reason, research is needed to include effects of land use in LCA, research which comprise the conceptualisation of impact from land use, the development of new methods and the harmonisation of existing methods. In addition, ways to supply assessment methods with data are needed. The goal would be a coherent methodology, without gaps and without overlaps with regard to how impacts are described, and supplied with relevant data. Such a methodology would be important to Sweden's forefront position in a sustainability focused economy.

We therefore recommend:

- Development of methods to include impact from land use, including biodiversity, in life cycle impact assessment.
- Initiation and participating in international working groups aiming for development and harmonising of methods for assessment of impact of land use in LCA.
- Method testing on concrete and relevant case studies.
- Dedicated data collection activities within representative regions.
- Establishment of a data portal for data relevant for biodiversity assessments connected to representative regions.

B4. Resources and resource efficiency

During the last 100 years there has been an unprecedented exploitation of natural resources in human history. This is clearly not sustainable, as is also evident from the attention placed on topics such as critical materials and food prices in recent years. That is why we need to innovate new, resource efficient technical solution, and ways to economise existing resources. For this reason we also need good and relevant metrics for resource use.

Producing companies can address resource efficiency through a number of means, where product design is one key activity. Products can be designed to demand less energy during use, to last longer and be more repairable and to technically fit into recycling processes (e.g. design for disassembly and prod-

ucts with less content of hazardous substances). Such technical innovation is necessary, but not enough; the whole downstream product chain (sales and distribution, use and maintenance, remanufacturing/recycling/ waste management) needs to be addressed. This is why business, organisational and policy innovation becomes important. How can the actors along the chain interact, what sort of business models can deliver efficient maintenance, remanufacturing or recycling? What sort of institutional support is needed to achieve such solutions? Policy actors have been very creative in designing policy instruments such as producer responsibility and take-back directives (with Sweden as a frontrunner), but more needs to be done or done in smarter ways. Also, institutional arrangements other than policy could support resource efficiency, such as standardisation and information systems.

Resources are used in all product chains, and thus we need good ways to measure and assess resource use. In LCA there are methods for this, e.g. research at Chalmers (Steen, 1999) and KTH (Finnveden and Östlund, 1997) are internationally recognized contributions on how to assess impacts on abiotic resources in LCA. However, overall methods to assess resource use are incomplete (covering only certain resources) and resting on data that is sometimes obsolete. There may also be better ways to conceptualise resource depletion, and hence to construct indicators, than what is currently done.

We therefore recommend:

- Case studies of companies' work and potential to address resource efficiency, whether through addressing the downstream activities or through product design. Such case studies would build a knowledge base for corporate response to demands for resource efficiency.
- Studies of reuse/recycling/waste management systems as innovation systems. What does it take to change the way things are done, in terms or technology, business relations, policy incentives and other institutions, knowledge build-up etc?
- Development of a comprehensive set of indicators for life cycle impact assessment that address resource use.
- Participation in international LCA research forums for resource issues, such as ISO, SETAC, UNEP and EU/ILCD.

B5. Monetarisation/get the prices right

Innovation is about increasing value in relation to cost. Having environmental impacts expressed in monetary terms, e.g. damage costs or resource values, will facilitate its integration in the innovation processes. The "polluter pays principle" is since long accepted in environmental policy. During the EU IPP initiative it was rephrased as "get the prices right". But what are right prices? There are several ways of calculating environmental costs and values. The outcomes differ due to differences on what is included, whose values that are represented, and assumptions about the future.

Research is needed to develop methodology for calculating environmental costs to enable consideration of environmental impacts of goods and services in monetary terms. This development could include the harmonisation of methods, but not values, since values vary depending on the context which they are reflecting.

Swedish research is well established both on environmental economics in general (Brännlund & Kriström 1998, Sterner 2008) and in using monetized impact values for weighting in LCA (Ahlroth and Finnveden, 2011, Finnveden et al 2006, Steen 1999, Steen and Borg 2002). The EPS system, an LCA methodology

using monetary values for environmental impacts was originally developed in cooperation with Volvo, and has been used by other companies inside and outside Sweden. It is well known internationally and mentioned as an example for impact assessment in ISO/TR 14047. Alternative methods such as Ecotax and Ecovalue has since then been developed (Ahlroth and Finnveden, 2011, Finnveden et al, 2006, 2013). An outline of a method for estimating the economic value for a company of improving its environmental performance is proposed by Steen et al (2006). It takes it start in the EEA report "Late lessons from early warnings" describing how different environmental impacts (e.g. acidification) were discovered, debated and finally regulated and influencing the economy of companies. Taking early lessons from these warnings may offer business opportunities to companies.

We therefore recommend:

- Development of methods for assessing externalities and its value for companies.
- Case studies in parallel with method development. The case studies should address issues like energy savings, recycling and consumption or production alliances.
- Initiating and participating in international development of methods for monetary valuation.

B6. Assessing and managing toxic substances

The number of known substances has increased at a remarkably stable rate of ~5% per year for 200 years. Today, several tens of thousands of chemicals are commercially relevant. However, as of July 2012 only 7663 substances were registered under REACH. Along with the number of substances, production volumes of chemicals are also growing at a rate that outpaces the growth of the human population. For example, the global production of plastics has increased by 9% per year from 1.7 Mtons in 1950 to 265 Mtons in 2010. The increase in plastics production is paralleled by an increase in production of the additives that give plastics their specific functional properties, e.g. colouring, flame-protection, stain resistance, and waterproofing. Many of these are proven to be persistent, bioaccumulating, toxic (PBT) and disruptive to the endocrine system (EDC). Considering the vast number of chemicals and products containing potentially hazardous chemicals, the total leachate of organic chemicals from products may be considerable and occur during a long time span (i.e. during the whole life cycle).

The overall need can be expressed as a need for enhancement of the capability of industry to select more environmentally benign chemicals and processes. This need covers the possibility to allow chemical impacts to be included in LCA, which is hardly ever the case today due to the fact that methods for characterisation of eco/human toxicity within life cycle impact assessment (LCIA) provide doubtful or contradictory results, or are, for some groups of compounds, lacking. A considerable confusion also exists over the applicability domains of risk assessment (RA) and environmental risk assessment (ERA) methodology

Chemicals along the life cycle

The life cycle perspective has fostered a large number of important policy innovations which in turn has led to more sustainable technology. One example is the REACH legislation for chemicals, where there is a considerable emphasis on the information about chemicals along the life cycle (European Chemical Agency, 2010).

and LCIA methods, which are distinct but partly overlapping.

The number of chemicals registered in European Chemicals Agency (ECHA) is however steadily increasing and the information contained in the ECHA database is partly being made accessible, so new opportunities need be explored for efficient use of this information source to develop better, chemically safer, products

We therefore recommend:

- To develop and maintain a knowledge-based management system, making use of new developments and information sources such as the public domain of the ECHA database, supporting responsiveness-to-market, finally leading to products with the potential of improved life cycle performance.
- To develop this knowledge base to provide a basis for improved inclusion of chemical impacts in LCA and related LCM activities, and for further work on standardisation, making certification of methods and procedures possible.
- To build knowledge and capability in companies how to make use of this knowledge base, and promote substitution of chemicals in real case studies.

B7. Quantitative methods to illustrate environmental benefit and customer value

For a company to achieve profit and competitiveness from an innovative product or service with environmental benefits, it is vital that this advantage can be determined, and communicated to customers. In other words, it is necessary for industry to be able to communicate the environmental benefit of products and services to customers - but how? There is a lack of common methods for doing this; some companies develop their own methods, which may lower the credibility of claims. Furthermore, it is challenging for companies to reach a credible claim without spending too much time and effort quantifying the benefit, especially for small and medium sized companies. There are also methodological problems, e.g. how is a relevant baseline defined? Naturally, the benefit very much depends on what you compare against. In order to help companies make credible claims, methods for quantifying and communicating environmental benefits, that is internationally accepted amongst industry and consumers, is needed.

We therefore recommend:

- Development of streamlined LCA methods for quantifying environmental benefits.
- Build-up of reliable LCI data to use in quantification (see also B8).
- Participating in international initiatives and working groups on harmonisation of methods (e.g. product category rules that includes a baseline definition).

Infrastructure for data and data handling

Acquiring data with sufficient quality to function as decision support for life cycle considerations is today very costly. The need for user-friendly databases with open/inexpensive, easily accessible, transparent and reliable data was clearly apparent in the survey as one of the highest priority areas for improvement. Larger companies and organisations with sufficient resources may have the possibility to address this need by building up in-house competence, information infrastructure, and databases. This is however not an option for smaller

organisations, making the lack of data a major barrier to implement life cycle practices. Moreover, the access to open/inexpensive, easily accessible, well-documented/transparent and reliable data is vital for educational purposes.

B8. Construction of a national database for LCA data

Today the public LCA information market is dominated by a few actors with commercial databases. Even though these actors´ ambitions are to provide high quality objective data, they are not always transparent and they are inaccessible to all who do not pay the license fees. Swedish collaboration and provision of data to these databases have been relatively low and hence data for Swedish conditions are poorly represented. There is thus currently a lack of product-related environmental ¬¬¬data for Swedish conditions provided in a systematic and accessible format. To solve these problems by hire expertise to interpret and remodel the data, or to invest in collection of new data for Swedish conditions, is too large a hurdle to most actors.

A national LCA database would be a valuable asset for Swedish companies and authorities in the rapid development now taking place within the EU, with e.g. extended design directives and demands for an ecological footprint, in particular for small and medium-sized companies that do not have the capacity to build up or buy databases. A national database would also provide unique research opportunities e.g. for assessing emerging technology so that Sweden in general has very high quality and also long time series of data.

Sweden has unique opportunities to produce good data and to produce values over time. A number of more local databases with different specialisations already exist at academia (e.g. CTH and KTH), institutes (e.g. IVL, SP, SIK) and major actors (such as SCB and NTM). There is strong consensus among these actors that their local databases all would gain from having a shared platform. There is a need for coordination and in particular a great need to fill gaps in data volumes, continuity, docu¬mentation and updating for important Swedish core processes.

Further, an international move towards coordination and sharing of product-related environmental ¬data is underway (e.g. International Reference Life Cycle Data System, ILCD). Several countries have established their own national initiatives (e.g. Switzerland, USA, France, Japan and Australia). In order to maintain its status as a leading LCA nation, Sweden needs likewise to contribute to such international development.

A national database for product-related environmental data can provide easily accessible and high quality background data for Swedish conditions, contain data on important Swedish key processes such as energy, transport, waste, agriculture, land use etc. (LCA and LCIA data), and provide opportunities for peer-reviewed publication of research results and more effective dissemination of results from publicly funded research.

With data for Swedish conditions increased competitiveness for Swedish industries would be facilitated, by allowing them to demonstrate low emissions (e.g. Swedish electricity mix), to confirm important infrastructure data for Swedish conditions and to have access to free relevant data (e.g. for SME and within education).

In research where LCA is used as a method a national database would give access to high quality data and unique possibilities to assess future technological systems. Gathering data in a common database would also avoid duplication of work.

We therefore recommend:

- To build up a national database for LCA/LCI/LCIA data by the establishment of infrastructure for sharing and making available nationally important data, coupled with means and incentives to disseminate and complement existing data and for continual updating and appraisal of data.
- Taking a national initiative to integrate the national database into the ILCD structure to spread results.

B9. Corporate LCM data and knowledge management

To put life cycle management into practical operation, an organisational internal capacity and capability building will be required. A particular challenge is to organise a cost-efficient and effective information flow among and between functions within the company. This need for increased efficiency in information flow extends also to business-to-business information.

Many of the pieces of data needed are already generated and collected somewhere in the organisation. Also, many of the necessary components of a more integrated information system are already available, such as many primary data sources, environmental expertise, useful methods and tools, and documented user requirements. However, these data sources, components and working methods are typically not linked to each other. Integration of existing information system is therefore an opportunity. In the integrated system, the common parts of different information systems, which can be both information management tools and databases, are shared in order to decrease costs, improve quality and increase availability of data.

We therefore recommend:

- To develop integrated information systems for LCM information management in corporations.
- Methods and system for collecting information from suppliers in a number of steps.
- Ways to evaluate data for technology under development (i.e. whether we want to use LCA approaches in order to guide technological development processes)
- More capable IT infrastructure and software to support data management and analysis.

Inspiration, help and support

The life cycle approach introduces a huge complexity, therefore it is of importance to inspire and support organisations.

B 10. Simplified tools and node for information and support

Organisations need to be aware of sustainability aspects outside of their own core activities, both up streams and downstream. With the expected growing future requirements on taking a life cycle perspective, lack of resources and/or competence in this area are issues that need to be solved for SMEs in particular, but also for other actors.

The potential for Swedish actors is great, there is already considerable collaboration between companies and academia and many organisations want to do the right thing, but do not know how. Ambitions need to turn into practice. Here

support from a national node could be facilitating such processes. As inspiration, there is a Basque initiative (Ihobe) where a helpdesk for ecodesign and life cycle thinking has been formed, which has proved helpful for mainly SMEs.

Furthermore, there is always a need for user friendly methods and simplified tools to handle a complex reality, especially when it comes to life cycle related methods. Today companies find it expensive and time consuming to make LCAs, and would like to see simpler tools. The challenge is to make the results of using such tools reliable and credible. Still, this may be necessary in order to make the life cycle perspective well spread.

We therefore recommend:

- Build up a national information portal to gather and collect good methods, results, contacts etc.
- Translation of hands on guidelines to fit better for different target groups.
- Seminar series/forums on practical issues and hands on LCA.
- Projects regarding development of simple tools (based on input from B1 regardin actual needs).
- Good examples which give inspiration and illustrates the value of the process of making own LCAs, learning by doing and identify unique possibilities for innovations.
- Integrate LCT in existing systems, e.g. a design tool in CAD.

9 National joint effort for global leadership

The objectives set in the agenda for this area are the following

- Swedish actors are working together to proactively influence and take leading roles in international standards, declarations, directives, etc.
- Swedish actors are attracting leading expertise for qualification and exchanges and are in demand as partners in international projects.

For Sweden to take global leadership, national collaborations between different decision-makers, as well as practitioners, within industry and society are crucial. Knowledge on sustainable development including the understanding of the need for a life cycle perspective needs to be well-established in different professions and at different levels. Therefore we need to build competence and knowledge among students, professionals and also raise the public awareness. Active and strong engagement is also necessary from different actors to provide for positive and durable progress.

Measures C1-C6 which will contribute to the achievement of the objectives are presented below.

Build up and maintain knowledge and competence

The life cycle perspective is gaining increased importance worldwide in business and in society. The result is seen in the many international initiatives on legislations, standardi¬sations, handbooks etc. Also, there is a higher and more spread general awareness about products' and services' impact on the environment. This increases the demand for life cycle expertise among government, industry and academia.

There is a strong competence and knowledge base in the life cycle field in Sweden. However, as demand for life cycle studies and life cycle thinking in daily operation as well as strategic planning is increasing at different levels we need to build up the awareness and competence among new groups of actors and also increase and maintain the already existing competence and knowledge base.

C1. Broader understanding and demand of the life cycle perspective

The life cycle perspective is generally well accepted in society, even if we do not always think about it in those terms, For instance, every time a consumer buys an eco-labelled or fair trade product there are life cycle consideration behind those labels, and every time the origin of our food is being discussed in media, the life cycle of the food that is scrutinised. Companies conduct LCA studies, policy makers make life cycle oriented policies. However, what is still lacking in many cases is the integration of life cycle considerations into "ordinary" decision making processes. Many companies that do LCA studies struggle to integrate the life cycle perspective into product development, sourcing, produc-

Meat guide & Climate smart meal planning

There are some simple tools based on LCA and systems thinking aimed at guiding purchasing decisions in both the public and the private sector towards more sustainable sourcing. Examples of tools mainly aimed at private consumers are the climate labeling developed by KRAV and Swedish Seal (Svenskt Sigill) and the "Meat Guide" (www.kottguiden.se). A tool developed for professional buyers is "A simple guide for climate smart meal planning" (http://www.sik.se/archive/pdf-filer-katalog/SR841.pdf). There is however a big and increasing demand for more elaborate tools that also can be integrated in present meal planning and that quantify other environmental impacts along with greenhouse gases.

tion, marketing and so forth, which may be difficult, even when dedication from top management exist. A similar tendency can be observed in policy making. Environmental policy is in many ways permeated by life cycle thinking, but where is the life cycle perspective in, for instance, industrial policy?

As stated in the introduction to this agenda, the only long term sustainable way of addressing major societal challenges is by using a holistic life cycle perspective, which aims to resource efficiency and minimised environmental impacts without suboptimal solutions, while also creating new business opportunities and innovations. It is a challenge and not self-evident for different actors to take on a more holistic responsibility in daily, as well as more strategic actions. A broader understanding and demand of the life cycle perspective is necessary to act on challenges and see the opportunites. We need to raise awareness about the life cycle concept and demonstrate its usefulness

We therefore recommend:

- Communication of the importance of the life cycle perspective, adapted and targeted to different actors.
- Use of LCA studies as a means of education, through making results widely available in attractive and comprehensible formats.
- Good examples of how different actors can use life cycle thinking in practice (e.g. within product development, marketing, policy making etc.). The good examples can serve both as demonstration and as a basis for building more generic knowledge about implementation of life cycle thinking.
- Good examples of successful innovations based on a life cycle perspective (companies, products, policies, business models, organisational structures etc.). The good examples can serve both as demonstration and as a basis for building more generic knowledge about implementation of life cycle thinking.

C2. Competence and international expertise

To secure competence and international expertise in the life cycle field in Sweden, efforts are needed in basic education as well as in PhD studies and post doctoral research. In order to inspire and strengthen PhD students in the life cycle field collaboration between strong academic actors will be beneficial. This could be made through joint courses and supervision as well as through exchange. Exchange could also be made with internationally strong actors. By providing an interesting and competitive PhD-programme for students in the life cycle field international collaboration will be facilitated as more PhD students will be attracted

Furthermore industrial PhDs students should be encouraged and supported. This will lead to increased and up-to-date competence in industry. Also the access provided by means of industrial PhD students allows for unique research opportunities to understand the industry-perspective and application in practice.

Many Swedish companies look for competence in the life cycle field. This could be specialists, but also a life cycle competence for other professions. This could be provided for by including understanding of the need for a life cycle perspective in the Swedish educational goals. Here the universities could also be proactive and include this goal in their own programmes. Furthermore, education of professionals in different sectors should be provided and encouraged.

We therefore recommend:

- Development of a national post-graduate school as collaboration between Swedish universities with research in life cycle field.
- Increased dedicated PostDoc financing, targeting international researchers invited to Sweden and Swedish PhDs going abroad to the most excellent international life cycle research groups.
- Incentives for industrial PhD students.
- Life cycle perspective in the System of Qualification of higher education in technical and planning fields.
- Integration of life cycle perspective in courses in higher education in technical and planning fields.

C3. Build up competence among professionals

To ensure that there is sufficient competence in industry and other organisations competence should be built and maintained. Education that is dedicated to professionals, both those who are directly active in the life cycle field and those who are not, enables high competence and also collaboration within organisations.

Also, platforms for discussions and exchange of ideas are important.

We therefore recommend:

- Education for professionals at universities targeting professionals directly active in life cycle work and in conducting LCA studies.
- Education for professionals at universities, targeting professionals with potential to use life cycle approaches in their daily work (product innovation, planning, policy, and decision making.)
- Providing on-line university courses targeting Swedish professionals.

National infrastructure for joint effort/Global leadership

Swedish actors are well acknowledged, recognized as leading experts, front running industries and for a unique tradition of collaboration across sectors. To use this reputation in order to take a leading role globally coordination and proactive initiatives are needed. A joint and targeted approach is necessary to gather our forces and get a stronger international impact.

"We need to safeguard a leading position when it comes to initiating and developing new international standards and handbooks. Today, new standards and handbooks are being developed in a defensive way which is not beneficial for Swedish proactive companies, trying to promote eco-innovation." (Bengt Steen, adj Professor, Chalmers University of Technology).

C4. Joint strategic intelligence

To be aware of and follow all new development and initiatives requires time and prioritizing. This could be more efficiently handled by national coordination. With all wide range of new initiatives, there is a need for collaboration also in manning the most important initiatives. A national roadmap with continuous dialogue could provide Swedish actors with strategic intelligence in the field.

With long tradition of collaboration between industries as well as between industry and academia this kind of joint strategic intelligence is paved for. Also, with the infrastructure of CPM already being in place this kind of measure is easy to get in place.

We therefore recommend:

- Nationally coordinated joint strategic intelligence regarding initiatives related to the life cycle perspective.
- Support for large and small businesses, authorities, politicians, academia and research institutes.

C5. Platform for knowledge sharing between experts

To provide a neutral place of meeting for experts is important in order to keep and develop the Swedish international position. An established and interdisciplinary platform for exchange of information, knowledge and ideas will increase the possibilities for sustainable and innovative solutions throughout value chains. Each actor has limited resources for each specific area and this calls for joint and integrated competence building, with knowledge exchange new ways of working and new ways of thinking.

We therefore recommend:

- National node for increased close collaboration in the innovation chain, i.e. between academia, applied research institutes, authorities and proactive companies.
- Support and coordination to drive, observe and take part in international expert groups and initiatives.
- Maintain and develop existing neutral arenas where exchange between experts will continue on a high quality level.

C6. International acceptance of used methods

For LCA and related methods, standardisation and harmonisation is of great importance for credibility and acceptance. Product chains are global, LCA data and information are being gathered and presented all over the world by different actors, and it is important that all organisations make use of methods in a transparent and consistent way.

Swedish actors need to be involved in international work on standardisation and harmonisation, set the international agenda (both regarding standardisations and research, which tend to be iterative). We need to be visible, recognized and well known.

Swedish actors have been active and recognized internationally when it comes to standardisation work (e.g. ISO 14040, 14044 and 14045). Many new initiatives are taken internationally and Sweden needs to find a new way to influence and spread usable and robust results and methods to set the agenda also in the

current and upcoming processes.

We therefore recommend:

- Establishment and coordination of a support function, to gather and communicate information regarding methods, tools, knowledge, etc., but also to identify gaps and activate Swedish actors in these areas.
- Increased representation in international activities, such as standardisation and other international working groups and initiatives. Funding for national experts would facilitate this.

10 In conclusion

Life cycle work has had a long formative phase, starting in the early 1990-ies, industrially with Design for Environment efforts and with policies on producer responsibility (see figure 4). At the same time LCA methodology development was intense, on a Swedish basis as well as internationally. The international standard was launched from 1997 and the years following. National networks were established, including CPM.

We are now, 2013, at a point where life cycle work has started to gain momentum. LCA is an established method, although there are still gaps in the methodology as regards land use and biodiversity, chemicals/toxicity and resource efficiency and assessment. Social LCA has started to be formulated and tested in case studies. Databases and ways of working with data collection have been tried out and we are now at a point where they can be built on to a coherent national database and methodology for data collection. The existing strong industry-academia-government network for life cycle work, CPM, has reformulated itself into The Swedish Life Cycle Center, which gathers the Swedish competence in the area. As regards implementation, we see a widespread use of the life cycle concept. We also see front-runner companies try out ways to work with life cycle management, both strategically and operationally, and we even see big international financial auditors start to include life cycle approaches in their evaluations. Life cycle based policies are formulated on an EU level.

This agenda suggests that this beginning momentum is capitalized upon, to bring us to a point in ten years' time where the life cycle perspective permeates both strategic and operational work, in business and in policy making. In particular its importance for innovation policy, innovation within companies and long-term competitiveness is demonstrated and recognized. Research on, and collection of experience from, the implementation of life cycle approaches will build new knowledge, where the practicality and benefits of life cycle work, in industry and in policy making, is demonstrated. Indicators to follow the relationship between life cycle activities and competiveness, on a societal, company and product level, are suggested to be created and followed. Through dedicated and coordinated methodology development and test in case studies, where participating companies act as test beds, and following international harmonisation/standardisation, the methodology gaps in LCA will be filled. The gathering and reinforcement of competence in the field will enable the build-up of a national database and creation of efficient support for data collection activities. The agenda also suggests that now is the time when a national information portal on life cycle work can be built. Such a portal will be based on the experience from life cycle front-runners, which is suggested to be collected and presented in a digestible format, together with checklists and other support tools[1]. Now is also the time when the international attractiveness in the academic milieus behind the agenda can be given even greater momentum. Swedish life cycle work, and in particular our strong industry-academia collab-

1. The feasibility and value of such information portals has recently been demonstrated through the award of the TOSCA project, which resulted in an experience based information portal on environmental work with supply chains, to Best LIFE Environment project 2012.

oration, is internationally recognized, e.g. as shown by our hosting of the LCM 2013 international conference. Such recognition can, and should, be capitalized on, through a greater Swedish participation in international working groups, projects and standardisation efforts. Finally, the consolidation of the network on life cycle innovation, already established through the Swedish Life Cycle Center is an important strategy, if not a goal in itself, for the sharing of knowledge and experience, but also for the opportunity it creates for a small country to take a leading role in life cycle based innovation.

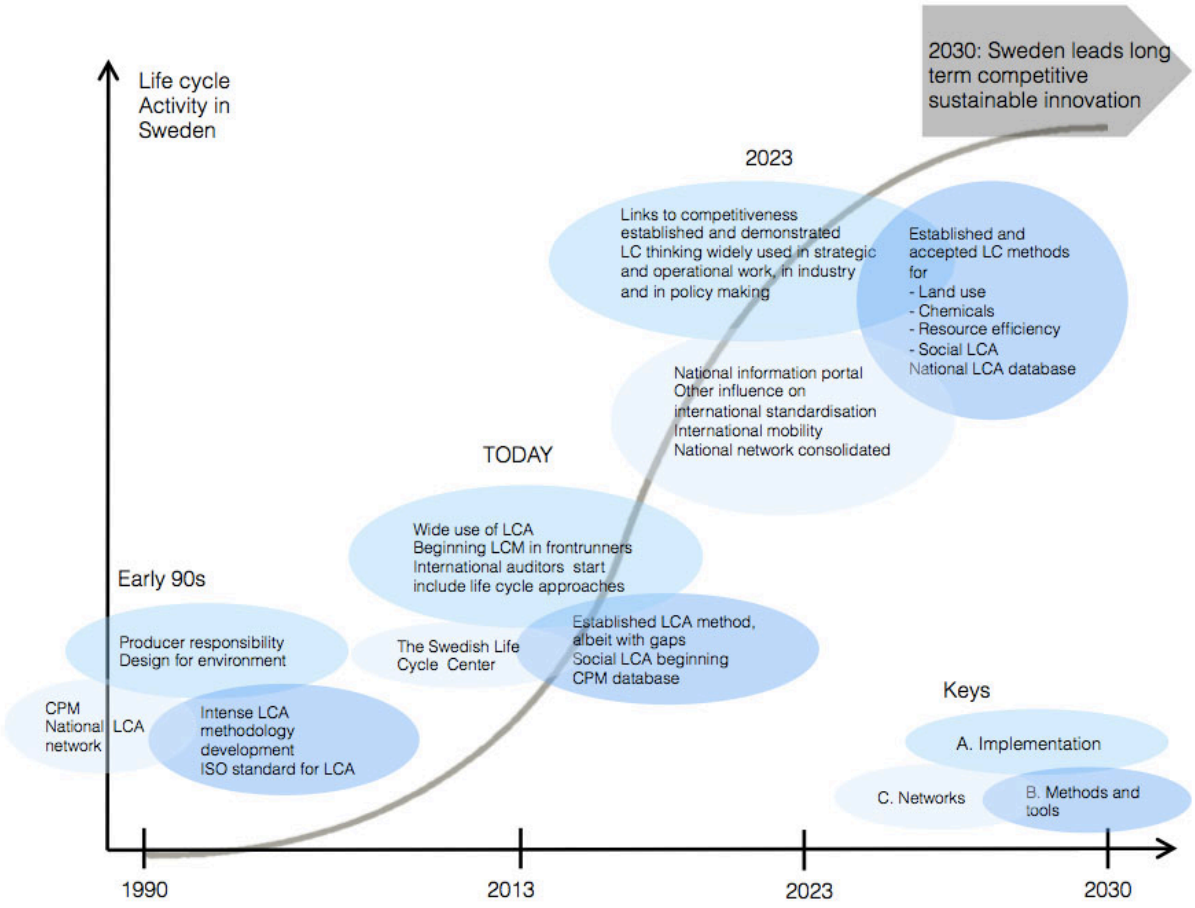

Figure 4. The development of the life cycle perspective, from 1990 to 2030.

11 Development of the agenda

The Swedish Life Cycle Center CPM was selected by VINNOVA to develop a national research and innovation agenda focusing how Swedish actors through a life cycle perspective can strengthen their competitiveness, attractiveness and global leadership.

Organisation behind the agenda

The Swedish Life Cycle Center CPM is a center of excellence for the advance of applied life cycle thinking in industry and other parts of society. Improvement of the environmental performance of products and services is by CPM seen as an important and natural part of sustainable development. The work within CPM is characterized by close and continuous interaction between academia, applied research institutes, industry and government in the common aim of credible and applied life cycle thinking globally. For more information, visit www.lifecyclecenter.se.

This agenda was initiated and driven by the Swedish Life Cycle Center and the project manager has been Emma Rex (CPM), assistant project manager Åsa Moberg (KTH), communications officer Sara Palander (CPM) and project participant Elisabeth Ekener Petersen (KTH).

A working group was added to the project, which has been discussing vision and objectives as well as measure, processing text material and preparing workshops and other meetings.

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Carin Ström, Volvo Group
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Broad interest among different actors and industry

The interest in the development of a research and innovation agenda for life cycle based innovations has been high. The following actors have been involved in different ways in the development of the agenda; through discussions in CPM the Swedish Life Cycle Center, participation in dialogue meetings, participation in the reference group or working group, consultation or taking part in the survey.

Industry/Business

ABB
Akzo Nobel
Argentum Environment AB
Bombardier
Eco2win AB
ESAB
Husqvarna AB
Lantmännen
Miljögiraff
NCC
OKQ8
Posten Meddelande
Ragn-Sells AB
Saint-Gobain Byggprodukter AB
Sandvik
SCA
Sjölanders och Thyselius
SKF
Stena Metall
Stena Recycling
TeliaSonera
Vattenfall
Volvo Group
Xylem Water Solutions
Yara AB

Research institutes

Innventia
IVL Swedish Environmental Research Institute
SIK The Swedish Institute for Food and Biotechnology
SP Technical Research Institute of Sweden
Svenska Petroleum och Biodrivmedel Institutet
Swerea IVF
Viktoria Swedish ICT

Government

Ihobe
Ministry of the Environment
Ministry for Finance
Statistics Sweden, SCB
Swedish Energy Agency
Swedish Environmental Protection Agency
VINNOVA

Academia

Blekinge Institute of Technology
Chalmers University of Technology
Karlstad University
KTH, Royal Institute of Technology
The School of Business, Economics and Law, University of Gothenburg
The International Institute for Industrial Environmental Economics, IIIEE, Lund University

Other organisations

Automotive Sweden (BRG)
Basque Ecodesign Centre
BIL Sweden
Center for sustainable communications CESC
Eco2 Centre for Vehicle Design
GMV Centre for Environment and Sustainability
Jernkontoret
Logistik och Transport Stiftelsen LTS Swedish Standards Institute, SIS
Swedish Forest Industries Federation
The Royal Swedish Academy of Engineering Sciences, IVA Teknikföretagen
The Swedish Construction Federation
The Swedish Environmental Management Council
The Swedish Life Cycle Center CPM
The Swedish Plastics and Chemicals Federation

Relation to and collaboration with other Agendas

The LINN Agenda has a scope which is relevant in all sectors of society. Potentially, the agenda could thus merge with many. We do however believe that there is a need for specific efforts to develop life cycle tools and perspectives which are neutral and not related to any specific sector in society. The broad interest from a number of actors indicates that this is a standpoint shared by many. Thus at an early stage the decision was made not to merge with other agendas but in some cases collaborate and support other agendas. The closest collaboration has been with the Agenda on Resource-smart material use lead by Stena Metall where continuous discussions have taken place and where different actors (such as IVL and KTH) have taken part in both agenda processes. In this agenda the life cycle perspective is important since efforts to increase resource-efficiency in a life cycle perspective is common and efforts to reduce, reuse and recycle will affect to whole life cycle.

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