Invest in Sweden

Packaging Materials

Roadmap 2005-2010

Contents

1 Executive summary

The development of sustainable material has been a key issue for a long time in Sweden. Universities, research institutes and industry have been working in order to create a strong platform for further development. Key issues are pre-process competence, identification of the innovation system and the function of materials in order to reduce the amount of material needed for a certain application

Swedish packaging industry and their suppliers are well in the front of the development of new material concepts. An important part of the development concerns renewable raw materials for the production of materials, which can be used in packaging and packaging systems. That is lighter material and carbon dioxide neutral material leads to less strain on the sustainable society. Another important field is new intelligent materials that can be used in barriers in order to protect the goods from liquids or gases. Material development also includes the development of new production processes as many of the old ones are adapted to the process requirements defined by the traditional material selection.

A major obstacle on the road to the introduction of new materials and products is the so called pre-process development. That is all the work connected with choice of system, production technology, design, prototype development and testing. The pre-process area is a field under strong development where Sweden is in the front when materials and product classification and certification are concerned.

New materials and products need to fit into the sustainable society and hence material development is performed in collaboration with the recovery and recycling industries.

This road map contains a listing of driving forces and trends in material development coupled with an overview of areas where Swedish actors are active and what is going on world wide.

Some promising renewable packaging materials under development are whey, chitosan, gluten and hemi-celluloses.

2 Introduction

This study was carried out during November 2005 by the Packaging & Logistics division[1] at STFI-Packforsk in Stockholm under commission from Invest in Sweden Agency (ISA). The overall purpose was to formulate a roadmap for the Packaging area from today to 2010.

Four strong areas within research and development related to the Swedish packaging industry have been identified. These are:

- Packaging Materials
- Human Product Interaction
- Systems and Processes
- Prevention and Recovery.

Each of these areas will be covered in separate roadmaps. Section 2.1 describes the packaging value chain and is common in the four reports.

2.1 Packaging value chain and terminology

The term "value chain" covers all stages from raw material to the finished, packed product, and its use until recycling, including working up or value-adding part-processes.

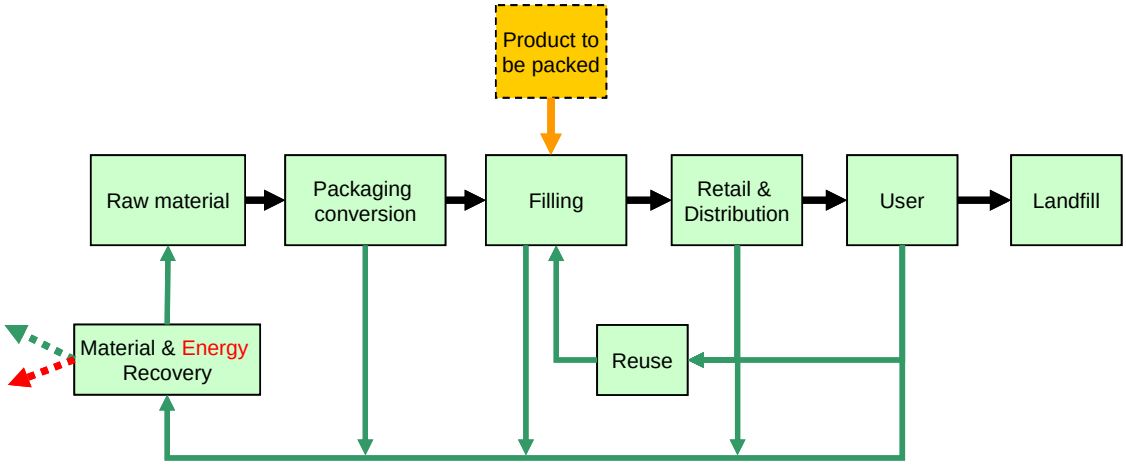

Figure 1. Packaging value chain from raw material to recovery

Directive 94/62/EC, on packaging and packaging waste, contains a very general packaging definition:

“Packaging shall mean all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer.

[1] This study is written by Mikael Lindström, Bo Lindskog and Mikael Gällstedt

'Non-returnable' items used for the same purposes shall also be considered to constitute packaging."

Packaging system

Often the terms packaging or package are used when referring to a packaging system containing several levels as described in *Figure 2*.

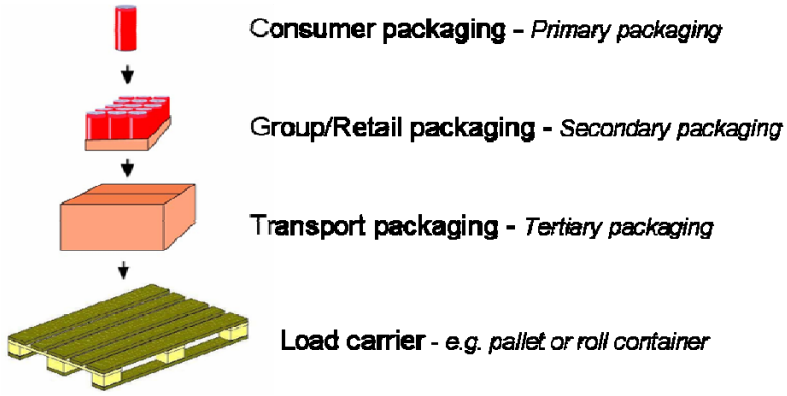

Figure 2. Different levels of the packaging system.

The primary packaging is closest to the product. Examples of primary packaging types are jar, cardboard box, bottle, bag, sack, pail, tube and wrap. The secondary packaging contains a number of primary packages and is also called group or retail packaging. The tertiary packaging is a transport packaging normally containing a number of secondary packages.

Main demands on the packaging system

There are many different types of demands placed on the packaging system. It should protect the product, facilitate handling and be an information carrier, but it must also protect the surrounding world from contact with its contents.

Which of these functions is considered most important depends on where in the value chain the package is to serve. In the distribution stage, for instance, the package makes it possible to reduce product quantities to handle-able units, regardless of contents.

From an overall view, the demands on the packaging system can be divided into three groups; flow demands, market demands and environmental demands (as described in Figure 3)

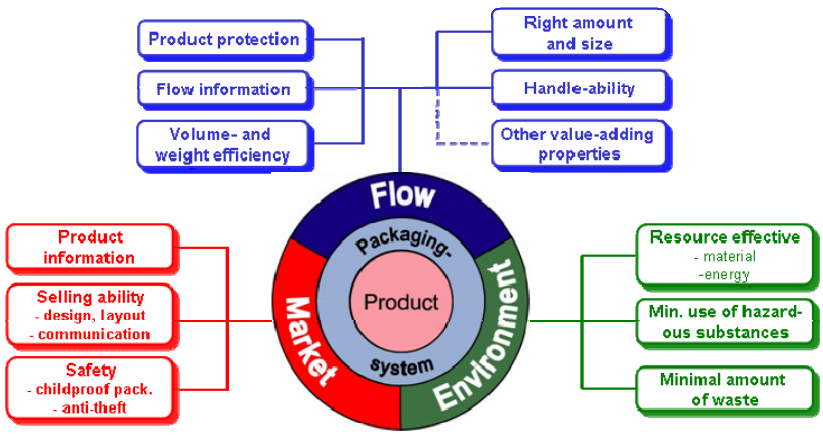

Figure 3. Main demands on the packaging system (Packforsk 2000).

2.2 The assignment

The purpose of this study is to formulate a roadmap for material development concerning packaging from today to 2010. More specifically, this report covers:

- Sustainable materials
- Composites
- Barriers

The purpose of the road map is to support a dialogue with both Swedish and international actors within the packaging industry.

The concept of roadmap is interpreted in a broad sense. It is a description of the expected technology and business development in this field during the coming years, which also shows in what way Swedish technology and Swedish actors may be of importance.

3 Background trends

3.1 General trends in a global perspective

Some general global trends can be identified, i.e. trends pointed out in many international and national foresight studies.

Globalization
With increasing global trade liberalization and increasing trade across borders, enhances worldwide competition. Developing countries offer lower labor and production costs to international companies.

Urbanization
According to the UN Habitat report there are approximately 175 million documented international migrants worldwide and the flow of people into the world's cities is fuelling a new multiculturalism that has the potential to broaden the cultural and ethnic dimensions of cities.

Regionalization
Increased regionalization is an important development trend, which will enable development also in regions outside the major cities. With regionalization also follows specialization.

Economic growth
Several international foresights point out the global economy to be well-positioned to achieve a sustained period of dynamism for several decades. Dynamism will be strongest among so-called “emerging markets”- especially in the two Asian giants, China and India - but will be broadly based worldwide, including both industrialized and developing countries.

Technology development
Technology development - especially new applications in the fields of information and communication (ICT) and biotechnology - is pointed out as a key driver in a global perspective.

Population dynamics
The ageing population in industrialized countries puts pressure on the welfare system. In developing countries there is still high nativity and young population.

Knowledgeable society
Upcoming is a society based more on information, knowledge and expertise. Globalization carries with it increased competition for this knowledge. Globalization and technological development will mean greater importance of and intensified demand for knowledge and expertise. While simple tasks are being sent to low-wage countries, there is increasing competition for investments and skilled labor between nations and regions.

Climate change and other environmental issues
Contemporary environmental problems will persist and in many instances grow over the next decades. Environmental issues will become mainstream issues in several countries, particularly in the developed world. The consensus on the need to deal with environmental issues will strengthen; however, progress in dealing with them will be uneven. The developing countries will face intensified

environmental problems as a result of population growth, economic development and rapid urbanization.

Issues of security

Regions, countries, and/or groups will be left behind facing deepening economic stagnation, political instability, and cultural alienation. This will cultivate political, ethnic, ideological, and/or religious extremism, along with the violence that often accompanies those. The trend away from state-supported political terrorism towards more diverse trans-national networks will probably continue. Terrorist tactics may become increasingly sophisticated and designed to achieve mass casualties; sadly, the trend towards more lethal terrorist attacks is expected to continue.

3.2 Consumer trends and drivers in developed countries

In this section, a number of consumer trends and drivers (from a European perspective) influencing the packaging area are presented.

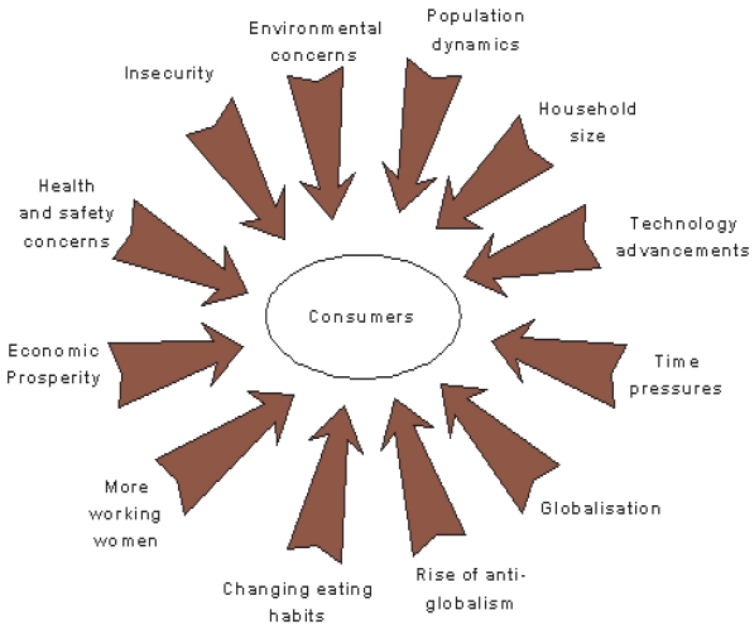

Figure 4. Consumer trends and drivers in Europe (Sustainpack project - Report on future market needs and SWOT analysis - Deliverable 1.7, PIRA, Aug 2005).

Economic Prosperity

Purchasing power mirrors GDP and is the underlying economic fundamental that drives packaging growth. In countries with higher GDP per capita, packaging consumption per capita is higher.

As GDP per capita has grown, so has disposable income, making premium products more widely accessible. However, polarization of wealth is a very real concern in many European countries.

Population dynamics

The population structure in Europe is changing, we are getting older. The average fertility rate per woman has fallen from 2.2 in 1970-75 to 1.5 in 2000-05 and average life expectancy has increased from 71.4 years to 76.9 years. These trends are predicted to continue into the future.

An aging population will further nurture an ongoing trend towards easy-to-handle packaging, i.e. easy opening, emptying and closing.

Household size

Households are becoming smaller. Smaller family sizes mean smaller household sizes. Elderly widows and widowers are outliving their partners for many years. Improving health and support services means there are more single pensioners, furthermore, increasing numbers are able to take care of themselves or live alone with support rather than living in care homes or with family. The trend of marrying later in life means that there are more young people choosing to live alone. Smaller households are also a direct result of falling birth rates in Europe.

One-child families mean that both parents and grandparents are focusing upon fewer children, who therefore have a much greater influence over household consumption. This means that the role of packaging as a salesperson to children is much more important.

Technology advancements

IT development is resulting in faster, smaller and cheaper computers and advanced information management programs. The effect is more information channels and more information availability. The rapid growth of Internet use is a strong force, giving people a new impression of other cultures and opening people's minds to new experiences. Mobile communication technology is also changing our perceptions and expectations as consumers.

The growth in ownership of refrigerators and freezers has facilitated the expansion of the chilled and frozen food markets. Microwave ovens have also had a major impact on the consumption of frozen and convenience foods.

Time pressures

The perception that work is taking up a greater proportion of our time is not borne out by available statistics. This contrasts with the general perceptions and feelings expressed by working people.

Research suggests that people generally feel more time-pressured and stressed, not only at work but also in all aspects of their life. Some researchers put this down to the increasing complexity of our lives and our increasing pre-occupation in individualism.

Globalization - A smaller world and borderless society

Travel is increasing and destinations are becoming more exotic. On their travels, consumers develop a taste for the exotic, but they also wish to be able to find their favorite brands in a similar format.

However, the smaller world concept is about more than just increased business and leisure travel. The borders between countries, cultures and companies are successively being erased so that goods, capital, labor and information are moving more freely across borders.

Rise of anti-globalization

In response to the perceived power and influence of multi-nationals, anti- globalization has emerged as a new socio-political movement. Many groups with different agendas are grouped under the anti-globalization banner.

Changing eating habits

The modern diet is significantly different from that of a generation ago. Advances in food and packaging technology, logistics and supply chain management and kitchen appliances combined with time pressures and changing tastes have influenced eating habits. Consumers eat more prepared and convenience food products, and demand more on-the-go food and beverage products. Nationally, there are major differences between food consumption patterns.

The increasing trend in demand for transparent packaging (so that consumers can see the product within) is regarded as having forced a large number of packers and fillers to switch from fiber based materials to plastics.

Individualism

Functional foods appear to be the next big thing in the food industry. These foodstuffs are part of the normal food intake, but have been modified in some way to achieve a certain physiological effect. In the US, functional foods, including low-calorie and low fat products, already represent 54 % of the value of the foodstuff market. Behind this lies the increased health awareness among consumers. Food allergies are also becoming an important influence on the food industry.

More working women

The proportion of women working outside the home has been increasing steadily in all EU countries. The increase has now slowed down for most Northern European countries, where this change no longer presents a new driver; however, in the more Southern countries an increasing trend is still being seen.

As well as changing the way we buy and prepare food because of the time pressures this creates, it has led to a blurring of male/female roles and responsibilities in the household. Men contribute more to the day to day running of the household (food shopping, food preparation, cleaning, etc) while women have a greater involvement in major decisions than was historically the case.

Health and safety concerns

People are increasingly concerned about how the food they eat and the products they use in their homes affect their health and well-being. This is reflected in the growing markets for organic, locally produced foods, health foods and functional foods.

These concerns generally lead to a need for more product information to be placed on the package, examples of which could include the presence of GMO originating ingredients, product origin or even individual ingredient origin. However, there are concerns that too much information (or information overloading) could disrupt purchasing, resulting in more buying pattern as consumers do not have the time to read several paragraphs of text on each pack.

Insecurity

Many people feel insecure of the future in a turbulent world with violence, unemployment, corporate downsizing and government spending cuts. This anxiety factor has been increased by the advent of the war on terror. Insecurity is highest in low and mid levels in society. This gives opportunities for brands to promote and provide a feeling of safety and security; packaging may be an important communicator of this message.

Environmental concerns

Consumers are aware of environmental issues but are normally not prepared to pay more for an "environmentally friendly" product. However, the consumers' expectations are rising on the industry to deal with environmental issues, i.e. to develop products with sound environmental profiles.

4 Current issues

4.1 Driving forces in Europe

The sixth Framework program comprises the world's largest ever packaging research project named 'Sustainpack'. The project mobilizes the European scientific expertise in the packaging value chain to establish the European forest industry cluster as the dominant player in the packaging area within a decade. It is coordinated by STFI-Packforsk AB in Sweden.

The overall objective of the RTD activities is to develop and implement a Sustainable Packaging Tool Platform based on renewable resources, giving innovative properties to packaging, thereby offering new value added packaging options for packaging users and for consumers. The Tool Platform comprises New Innovative Material Properties and New Innovative Process Developments to transform these materials into new packaging solutions. The processing part will be the main area for introducing SMEs in the project.

Packaging is a true multifunctional product and RTD involves a broad area of research. Packaging involves all partners in the supply chain from production and manufacturing, through filling, warehousing and distribution, retail and consumers. Together they impose many demands on the packaging functionality that are often diverse and contradictory. Against this background, the IP-instrument has been chosen because the development needs exploitation of many research disciplines, many industrial players and a well developed dissemination plan. The different RTD components integrated in the project are: Technology mapping of the fiber based value chain; lean fiber based packaging; fiber based composite films; protective coatings; 3D composite packaging; and communicative packaging. *A truly innovative packaging should fulfill the needs of the whole packaging and supply value chain.*

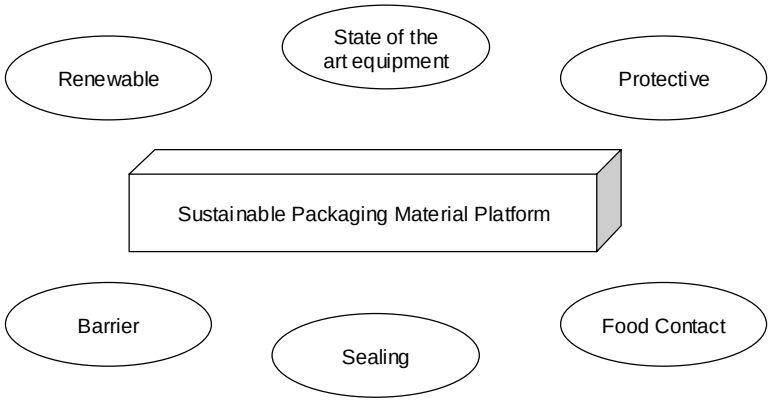

Figure 5. Sustainable Packaging Material Platform. The overall objective of the research activities is to develop a Sustainable Packaging Material Platform, on renewable resources that can be manufactured in state-of–the-art converting equipment, thereby offering new value-added options for packaging users and consumers. The Platform comprises New Innovative Packaging Material Properties and Process Development to transform these materials into new packaging solutions.

4.2 Driving forces in Sweden

In recent years, environment issues have been in the focus. The importance of an increased share of environmental materials is expected to grow further in the future and leading to a reduced share of non-renewable plastics and fibers. This is due to an increasingly afflicted environment and growing oil prices.

In a futurology report, the Swedish government has laid down the following three headlines along which an ecologically sustainable society could be achieved:

1. Environment protection. Emissions of pollutants shall not damage human health or exceed what nature has the capacity to absorb or break down.
2. Efficient utilization of resources. The utilization of energy and other natural resources must be more effective than is done today. Also, renewable resources should be the basis. Efficient use of natural resources: The use of energy and other natural resources has to be more efficient than what is the case today. Focus must be on renewable resources.
3. Sustainable supply. The production capacity must be secured.

Driving forces in Swedish packaging material research
The overall objective of the research activities is to develop sustainable packaging solutions. These are based on renewable resources, thereby offering new value-added options for packaging users and for consumers.

This will be obtained by replacing the petroleum-based plastic components with renewable material sources. Petroleum-based plastic materials will be replaced by renewable materials for a sustainable society. The packaging substrates should be sustainable and renewable alternatives to existing metal and fossil plastic packaging concepts.

The vision of the work for environmentally sustainable solutions is further strengthened by ongoing work in a wider bio-refinery system also including renewable bio-fuels.

The deep integration of packaging in consumers' everyday life, and its influence on ecology and economy, makes packaging an important part in achieving sustainable growth.

Outlook – Packaging raw material supply
The raw material supply to chemicals and materials is anticipated to develop according to Figure *6*.

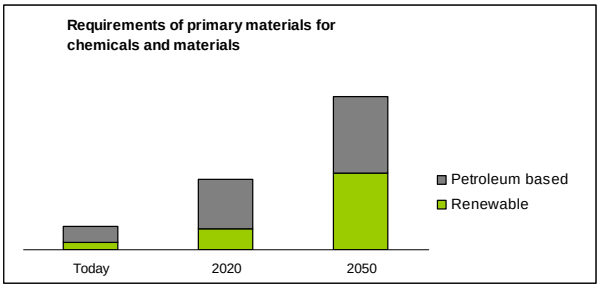

Figure 6. Requirements of primary materials for chemicals.
Source: Technology roadmap for Plant/Crop-based renewable resources 2020.

The use of petroleum-based materials will continue to grow at least until 2020. Thereafter the global demand is expected to remain at a constant level. Renewable materials will grow in an accelerating mode as of today.

In the packaging market of today, the main renewable material is cellulose fibers in e.g. corrugated boxes, paper and paperboard that are renewable. These materials can be used as a mono-material in many applications, but more commonly they need additional properties such as gas barrier, seal-ability, food contact status, etc. to be fully utilized as packaging material. Various combinations with plastics and other materials typically achieve this. This is illustrated by a common orange juice package, TetraBrik, which consists of paperboard, aluminum and plastics.

Considerable efforts have been made in the packaging arena to replace metal and fossil plastics with renewable plastics. For several reasons, this process has been much slower than anticipated. The high price of renewable plastics compared to petroleum based plastics and the fact that available renewable materials are not suitable for conventional converting (extrusion) equipment are important reasons.
One important factor for the low cost of petroleum-based plastics is the sophisticated oil refinery technology, which offers substantial volumes combined with many alternative uses of materials.

Bio-refinery vision
If the development of renewable materials is combined with a bio-refinery vision, these materials could contribute to an effective use of natural resources. The environmental benefits of the bio-refinery technology system in projects are manifold. Renewable materials will replace fossil plastics in packaging applications and this will also contribute to renewable bio-fuel replacing fossil fuel.

The need of ethanol as a bio-fuel is described in the EU bio-fuel directive of 2003, which states that there will be a more than six fold increase in the production of bio-ethanol by the year 2010. Wheat is the main raw material produced in EU for this production. The Swedish petrol market requires at least 318 000 m^3 ethanol in 2010, which can be produced from 860 000 tons of wheat (equivalent to ca 85% of the current Swedish surplus). In a bio-refinery concept, the protein (wheat gluten) constitutes about 10% of the weight and can not be fermented to ethanol. The protein is today mainly used as low-value cow feed. This is as an example of a renewable material source for packaging barrier materials.

Packaging barrier developments
Several renewable materials are promising packaging barrier materials. Starch and protein-based materials demonstrate excellent oxygen barrier properties. For example, the barrier performance of gluten films is in the same range as that of the best fossil plastics, such as EVOH (polyethylene –co-vinyl alcohol). The market price of EVOH is about €7/kg, while the market price of several renewable material candidates is considerably lower. Hence, there is a sufficient driving force in this margin to ensure a broad market penetration of renewable barrier materials.

Certain foodstuffs, such as cultured dairy products, could have a desired tailored sparkling taste if the packaging-substrate provides controlled perm selectivity. It is known that proteins, and also PLA have a large CO_2/O_2 perm selectivity. This can be altered through different compositions of tailored barrier materials. This ability is suitable for packaging of respiring foodstuffs, e.g. fermented milk and cheese.

4.3 Some general aspects of bio-composites and sustainability

Important and driving issues in the material development field are reduced weight, higher functionality, and carbon dioxide-neutral materials. Waste volumes continue to grow. The unsustainable trends in waste generation and the policy issues are of concern in EU because the generation of waste can be a symptom of environmentally inefficient use of resources. Furthermore, waste management generates emissions to air, water and soil as well as noise and other nuisances which contribute to environmental problems.

Current EU waste policy is based on a concept known as 'the waste hierarchy'. This means that, ideally, waste should be prevented and what cannot be prevented should be reused, recycled and recovered as much as is feasible, with landfill being used as little as possible.

Despite important progress made, overall waste volumes are growing and the absolute amount of waste going into landfill is not decreasing. Between 1990 and 1995 the total waste generation in the EU and EFTA increased by 10%, whilst GDP increased by 6.5%. With anticipated higher levels of economic growth, this trend is predicted to continue and will concern most wastes. For example, the European Environmental Agency predicts that paper/ board, glass, and plastic waste will increase by 40% in 2020 compared to 1990 levels.

While recycling and incineration are increasing, the absolute amounts of waste land filled are not decreasing in the same magnitude due to the growth of waste generation.

There is a growing need to develop novel bio-based products and other innovative technologies that can reduce the widespread dependence on non-renewable resources, e.g. fossil fuel. Biopolymers and other materials from renewable sources could contribute to this development.

A sustainable product has been described as follows: "A bio-based product derived from renewable resources, having recycling capacity and triggered biodegradability as well as commercial viability" (Mohanty, 2002). The most important criteria for bio-based products, according to Mohanty et al, are that such products should be stable in their intended lifetime and degrade after disposal – such behavior is named "triggered biodegradable".

Strictly, bio-composites consist of renewable bio-fiber and plastic from renewable resources and are thus expected to be biodegradable after intended use. Bio-composites are now emerging as a realistic alternative to wood-filled and glass-reinforced plastics, e.g. in the automotive industry (Mohanty, 2002). Wood fiber composites are for example used in decking, fences and other building applications (Peijs, 2002).

The advantages of natural fibers over synthetic or man-made fibers such as carbon or glass are: low density, acceptable specific strength properties, ease of separation, carbon dioxide sequestration and biodegradability . Compared to synthetic materials, natural fibers also have the advantage of low production energy requirements (Evans, 2002). The hydrophilic nature and therefore low moisture resistance of bio-fibers is its major drawback. Other disadvantages to overcome are lowering tensile, compressive and impact strength, dimensional and thermal instability (Peijs, 2002; Kandachar, 2002).

The low density will contribute to decreasing the weight of products. In many cases, this can be of great importance to reducing the environmental impact during the lifetime of a product. If bio-

composites are going to contribute to a more sustainable production and consumption of products, a key issue is that the functionality and economy of products built of bio-composites are just as good as, or even better than, products built of conventional materials.

Renewable barrier plastics from industrial by-products

Environmental issues related to packaging materials have been discussed in recent years. An increase of the consumers' environment considerations results in a demand for environment-friendly materials. Using renewable materials instead of metals or synthetic petroleum-based polymers can result in several environmental benefits. By combining renewable packaging materials to meet the demands of today, these materials may be a good alternative to many synthetic packaging materials.

Several renewable polymers have a potential as oxygen barrier layers in packages. However, the final cost/performance ratio is the most interesting factor for packaging companies, after including the entire packaging chain, from the manufacturing of raw materials to the final disposal expenses. Even if a biomaterial is more expensive than synthetic polymers, environment-friendliness is a rather good sales argument in less cost-sensitive countries. When developing new materials, two main factors have to be taken into consideration; firstly: the raw material cost, and the finished material's performance. Also, in order to get a new material on the market it is of great importance that the industries do not have to change their process equipment.

Three of the most interesting renewable materials from a waste disposal point of view are chitosan, whey protein and wheat gluten protein. The packaging related properties of films made of these materials have been investigated for several years by many research groups around the world. It is however still a rather narrow field and many questions are remaining for future investigation.

The use of protein in packaging often involves allergenic risks. These risks can be reduced by coating the protein films, or prevented by limiting the application to just a few specific types of food. By packing dairy products in whey protein films, the risks are limited, since people who are whey protein intolerant do not eat dairy products anyway.

A commercial inducement could be to package e.g. milk in whey protein, shrimps in chitosan and bread in gluten films. This concept can be compared to fruit pulp in fruit shells. Package and foodstuff from the same source!

Whey protein

The raw material for whey protein is liquid whey, which is a by-product in the dairy industries. Almost 50% of the whey protein is wasted today, but the interest in whey based applications has grown.

Whey protein belongs to the most studied proteins today, especially in applications such as additives in medicines, as nutrition agents, and in human and animal foods, etc. The four main whey-proteins are β-lactoglobulin, α-lactalbumin, bovine serumalbumin and immunoglobulins (IgA, IgE, IgM and IgG), with a distribution of about 50**,** 20, 10 and 10% respectively of the total whey protein in bovine milk.

The quality of the whey protein used in this study is whey protein concentrate (WPC), which is refined from liquid whey by spray drying and ultra filtration. This results in protein concentrations of 35-87%. This can be further purified by fractionation to concentrations of up to 95%, and is then referred to as whey protein isolate (WPI). The reason for not using WPI is the higher cost due to the more demanding protein purification.

Whey protein, like many other proteins, has strong intermolecular hydrogen bonds under dry conditions and is a good barrier to non-polar gases and liquids. Its gas barrier properties make it potentially useful for packaging films.

Films are produced by solving the protein in water to form a solution that is then cast and dried. Intermolecular bonds are necessary to get a rigid material. This is achieved by heating the solution to the denaturation temperature, T_d, where disulphide bonds are created by thiol-oxidation and thiol-disulphide interchange reactions.

Since β-lactoglobulin is the dominating protein in whey, it tends to dominate the properties as well. The thermal behaviour of β-lactoglobulin is rather complex, involving both molecular unfolding and subsequent aggregation. The barrier properties are thus dependant on the protein concentration.

The drying rate affects the properties as well. Reduced drying rate, at lower drying temperature and higher air humidity, has been found to give the best mechanical properties. Increased drying rate influences the film thickness, tensile properties and water vapor transmission rate significantly. Faster drying was found to result in less flexible films with higher Young's modulus and slightly lower fracture strain.

Chitosan

Chitosan is a derivative of chitin, which in turn is extracted from by-products of the fish industry. The interest in chitosan, and the development of new applications, has increased due to large surpluses of the raw materials, which is waste from the fish industry.

Chitosan is a derivative of chitin, which is the second most abundant natural polymer after cellulose. Chitin is the load-bearing component in the shells of exoskeleton fishes, fungi, insects, krill, zooplankton, etc. Shells from crustaceans provide the most important source of chitin today. The shells are built as a composite structure with, besides chitin, proteins, minerals (mostly $CaCO_3$ and $MgCO_3$) and residues of pigment (astanthin). The yield of chitosan is about 20-30 wt% from crab shells, and about 10 wt% from shrimp shells. The largest producers of chitin are Japan, India, China and France, due to their large fish industries.

Chitosan is produced by grinding the crustacean shells, which thereafter are treated in a dilute solution of NaOH in order to remove the protein. This is followed by rinsing and decalcification by mixing with a dilute solution of HCl. Since there are pigment residues, it is eventually also bleached in a solution of $KMnO_4$ or oxalic acid. Chitin is insoluble in water, organic acids, dilute acids and alkali. By derivation to chitosan, which is soluble in pH<6.5, it can be solved in water and cast to films.

The amino groups on chitosan are protonized ($-NH_2 \rightarrow -NH_3+$) in an acidic solution resulting in a shear thinning viscous liquid, possible to cast and dry into transparent films. The films are sensitive to polar gases and liquids, due to the cationic nature of the amino groups. This is the reason why they have to be protected from water and water vapor.

Like cellulose, both chitin and chitosan are crystalline due to their linear linkages. Chitosan can be found in three different configurations which each gives rise to different crystal structures: α, β and γ. They have good fiber and film properties, two of the most important properties for future packaging applications. The crystallinity reduces the gas transmission rate to a level that makes them interesting

as packaging materials. Several papers have been written about the film properties of chitosan. Biodegradable packaging materials, like chitosan, without harmless degradation products are very advantageous from an environmental perspective.

Wheat gluten

There is a large surplus of wheat gluten protein from the manufacture of ethanol and sweeteners. Today it is used mostly for forage and other low cost applications. However, it could instead be used as a cost-effective barrier material.

Several studies have been performed on solution-cast wheat gluten films.
The rheological properties of wheat gluten have been the subject of several studies and will be further investigated in connection with extrusion of packaging films.

The most studied field, temperature induced changes of wheat gluten, is in bakery applications. The shear, in extruders or thermo formers for synthetic polymers induces a temperature increase of the wheat gluten-glycerol mixture. The temperature, together with the long dwell times, results in a high degree of disulphide crosslink's, resulting in a too brittle material.

Natural Plasticizers

A plasticizer is necessary since protein films turn brittle during the drying process due to the strong intermolecular interactions. The most commonly used plasticizers are polyfunctional alcohols, such as polyethylene glycol, glycerol and sorbitol. These result in increased mobility of the peptide chains but, as a by-effect, also increased permeability. This is of course a drawback for packaging film applications and a compromise between permeability and flexibility is necessary.

5 Most impacting trends in 3-5 year perspective

5.1 Packaging statistics

The Swedish Environmental authority (EPA) reports national Swedish packaging data annually to the European Commission. The results for 2003 are presented below[2]. Sweden is above the Directive's maximum rates for recovery and recycling. All material-specific targets have been reached.

Packaging	Placed on the market (tonnes)	Recycled, (tonnes)	Energy recovery (tonnes)	Recycled %	Recovery %
Glass	165,000	151,229	-	92	-
Plastics, not PET	149,095	26,916	75,588	18	69
PET, one-way	13,488	10,652	-	79	-
Paper, cardboard	200,000	75,020	1,482	38	38
Corrugated cardboard	422,000	359,000	-	85	85
Steel	41,700	30,400	-	73	73
Aluminum	9,000	2,500	-	28	28
Reusable beverage cans	15,547	13,266	-	85	85
Wood	393,131	63,028	328,848	16	100
Total	**1,408,961**	**732,011**	**405,918**	**52**	**81**

5.2 Reuse & Recycling

Material recovery is expected to grow. Authorities both in EU and in Sweden consider material recovery in general to be preferred to other waste handling alternatives. This is in agreement with the image that a sustainable society uses recovered material. However, material recovery is more expensive than waste incineration. There are ongoing discussions about what material recovery may cost.

EU standards for recycling are expected to be developed not only for environmental protection but also for business reasons – to promote a level playing field for recycled materials. Recycling without standards presents an environmental problem as some recycling facilities can cause pollution if badly operated.

Under the period, collection systems will be built and made more efficient in many of the new EU member states. Sweden, thanks to its geographic location and previous cooperation with these countries, is already participating actively in this development.

In Sweden all implicates that the demands for a high degree of collection of used packaging will remain. The producer responsibility is expected to remain in force and the distribution of responsibility for the collection activities will most likely be the same.
The trend with increasingly improved quality of the collected fractions continues, partly thanks to the consumers' growing knowledge about the collection. Sorting and collection of used materials from trade and industry are expected to grow.

[2] Samla in, återvinn, Uppföljning av producentansvaret för 2003, Naturvårdsverkets rapport 5380, juni 2004

The Swedish collection system is well-functioning and carefully built and can be expected to remain in its present form. Additional cost cutting measures are introduced during the period.

The utilization of recovered plastics is expected to grow. The development continues as regards both improved sorting of collected material and knowledge about how the collected material can be used. This trend is strengthened by continued high oil prices. In addition, the recently introduced trade with CO_2 emission rights will make virgin plastic raw materials more expensive. Already now, there is a shortage of collected PET in many parts of the world.

Recovery rates

The Ordinance lays down requirements on certain recovery rates for the following materials: glass, metal, cardboard and paperboard, corrugated cardboard and other materials, as well as beverage containers of glass, aluminum and PET. Recovery can take the form of reuse, recycling or energy recovery, or a combination of these. Sweden has adopted higher target rates than those in the EU Directive.

The following table illustrates the target rates for the different packaging types:

Packaging types	Recovering target
All packaging waste	Up to and including year 2008: 505 of which at least 25 percentage units are material reuse
	From year 2009: 60% of which at least 55 percentage units are material reuse
Metal, not beverage containers	70% recycling
Cardboard, paper and corrugated cardboard	65 % recycling
Plastic, not PET bottles	70 % recovery, at least 30% recycling
Glass	70 % recycling
Metal beverage containers	90 % recycling
PET bottles	90 % recycling
Wood packaging	70% recovery, at least15% recycling
Packaging of other material	30% recovery, at least 15% recycling per material

In practice different packages are recovered in different ways. Certain glass and PET bottles are reused, other materials such as glass, metal, cardboard and paperboard, corrugated board and rigid plastic are recycled as new materials, while plastic films and end-of-life paper packages are often incinerated.

Energy recovery takes place in waste incineration plants that make use of the energy. A ban on land filling of combustible waste was enacted on 1 January 2002 in Sweden. It will be followed in 2005 by a ban on land filling of compost able waste.

5.3 Energy recovery

Incineration with energy recovery is growing in Sweden. But despite the fact that more incineration plants are being built there will be a want for such household waste handling capacity in Sweden for the foreseeable future.

At present the incineration capacity is expanded in Sweden. A demand is that the furnaces be designed for maximum flexibility, i.e. they should be able to burn also other types of solid fuels. In connection to this, the district heating nets are also expanded.

The demand for waste incineration is expected to grow. The ban introduced in 2005 on placing combustible waste in landfill is expected to have full impact in the next few years. Increased material recovery giving rise to residue products also increases the demand for incineration. In addition, this method is necessary as a receiver of certain waste flows for which incineration is the most suitable treatment.

Studies calculate the theoretical potential for waste fuels (household waste, industry waste, landfill gas and sludge incineration) to 21 TWh/year in Sweden. The same study calculated the practical potential (market potential) to 7-13 TWh/year.

To a large extent waste consists of materials that can be used for energy recovery. In Sweden today energy is extracted from waste in mainly two ways: by incineration and by the production and use of biogas. Together these two ways of energy production contribute with about 5 TWh/year to the Swedish energy system.

Sweden has a high and growing share of waste incineration. All in all more than 3.1 million tons waste is incinerated annually. In 2003 a total of 9.3 TWh energy, in the form of heat (6.8 TWh) and electricity (0.7 TWh), was extracted through waste incineration. Of all collected packages about 0.4 million tons go to energy recovery.

Not quite 5% of the waste incinerated in the Swedish plants is imported. The imports mainly consist of return chips, crushed fuels and rubber. Only 1.7% of imported waste is household waste.

Ca. 45% of Swedish household waste goes to incineration. This means that each Swede contributes with 210 kg household waste to be incinerated. Household waste consists mainly of so called renewable materials – bio-fuel. It contributes only marginally to the greenhouse effect when it is incinerated. Combustible waste replaces fossil fuels and other bio-fuels.

A number of factors have contributed to considerably reducing the emissions to the environment over the years: increased requirements for lower emissions to air and water, a continuous technical development and not least a markedly improved sorting of the incinerated waste.

Waste incineration in Sweden is today except from energy and emission taxes. This means that waste incineration is favored in comparison with other fuels and treatment methods. This effect could be substantial. If carbon dioxide and energy taxes were to be imposed on the incineration of plastic waste, these taxes would be more than SEK 3000/ton of waste (SOU 2005). If such a tax were imposed, the competitiveness of plastic recovery would increase considerably.

5.4 Environmental legislation

The Directive 94/62/EC on packaging and packaging waste (PPWD) was adopted in 1994. It aims to harmonize national measures in order to prevent or reduce the impact of packaging and packaging waste on the environment and to ensure the functioning of the Internal Market. It contains provisions

on the prevention of packaging waste, on the re-use of packaging and on the recovery and recycling of packaging waste.

A tool to reach the prevention provision is the essential requirements on the packaging construction. The directive states that:

- Packaging shall be so manufactured that the packaging volume and weight be limited to the minimum adequate amount to maintain the necessary level of safety, hygiene and acceptance for the packed product and for the consumer.
- Packaging shall be designed, produced and commercialized in such a way as to permit its reuse or recovery, including recycling, and to minimize its impact on the environment when packaging waste or residues from packaging waste management operations are disposed of.
- Packaging shall be so manufactured that the presence of noxious and other hazardous substances and materials as constituents of the packaging material or of any of the packaging components is minimized with regard to their presence in emissions, ash or leach ate when packaging or residues from management operations or packaging waste are incinerated or land filled.

.

6 Packaging materials beyond 2010

In a sustainable society, the use of renewable materials must increase from today's levels. It can be anticipated that the packaging market will take the lead in this transformation.

Renewable material sources are a major factor to achieve this long term goal. There are many new material sources under development but in most cases they need further research to be commercial alternatives to the non renewable packaging materials used today.

It is anticipated that the use of petroleum-based materials will continue to grow at least until 2020. Thereafter the global demand will remain at a constant level. Renewable materials will have an accelerated growth from today.

The long-term goal for EU is to become a recycling society. This will be reached through maximum recovery of materials where this makes environmental and economic sense, and energy recovery where this is the more efficient alternative. With environmental reference standards, the EU internal market will facilitate recycling and recovery activities.

Collection of materials for recovery should be based on kind of material by 2015. To reach higher collection levels it is necessary that sorting is made easier for consumers. To request sorting of one material into different fractions for different products is hardly feasible. The producer responsibility is expected to remain, albeit in a changed form.

The collection organizations in EU today have been built nationally which is a result of the varying legislation in different countries. This has resulted in different cost structures in different countries. Also the distribution of responsibility varies. By 2015 this should be more uniform to make it easier for companies active on several markets.

7 Competitive Advantages of the Swedish Industry

- Pre-Process
- Material testing and certification
- Sustainable materials
- Energy recovery

8 Conclusions

This road map of packaging materials covers the period 2005 – 2015.
Sweden's competitive advantages in the area are:

- The innovation system and the pre process competence.
- High technological competence in industry, and academia as well as individuals.
- Both world-leading manufacturers and small entrepreneurial companies.

9 List of references

Dominic C, *"Integrating packaging suppliers into the supply/demand chain",* Packaging Technology and Science, Volume 18,m Number 3, May 2005, pp. 151-160.

Dominc et al., *"Förpackningslogistik – 2:a utgåvan",* Packforsk, Kista 2000.

Evans, W.J., D.H. Isaac, B.C. Suddell, A. Crosky. 2002. "*Natural fibres and their composites: a global perspective".* Sustainable natural and polymeric composites: science and technology, Proceedings of the 23rd Riso international symposium on materials science, Roskilde, Denmark 2-5 September 2002, pp 1-14.

Johansson B et al., *" Förpackningens roll i strävan efter hållbar tillväxt",* Packforsk rapport 202, maj 2002.

Kandachar, P. 2002. "*Opportunities for product development for industrial applications in polymers reinforced with natural fibres"*. Sustainable natural and polymeric composites: science and technology, Proceedings of the 23rd Riso international symposium on materials science, Roskilde, Denmark 2-5 September 2002, pp 15-33.

Kooijman JM Dr., *"Towards greener households",* Incpen, 2001.

Mohanty, A.K., M. Misra, L.T. Drzal. 2002. "Sustainable biocomposites from renewable resources: Opportunities an challenges in the green materials world". Polymeric Materials: *Science & Engineering* 2002, 86, pp 341-342.

Olsmats C. *"The business Mission of Packaging. Packaging as a Strategic Tool for Business Development towards the future."* Åbo akademi University Press, Turku.

Peijs, T. 2002. "*Novel concepts for obtaining sustainable composites based on synthetic polymers".* Sustainable natural and polymeric composites: science and technology, Proceedings of the 23rd Riso international symposium on materials science, Roskilde, Denmark 2-5 September 2002, pp 61-75.

PIRA, *"Report on future market needs and SWOT analysis"* .Sustainpack project Deliverable 1.7, PIRA, Aug 2005.

"Technology roadmap for Plant/Crop based renewable resources 2020", Vinnova report 2002.

Invest in Sweden Agency
PO BOX 90, SE-101 21 STOCKHOLM, SWEDEN • WTC, KLARABERGSVIADUKTEN 70, B6
TEL +46 8 402 78 00 • FAX +46 8 402 78 78 • http://www.ISA.se • E-MAIL isa@isa.se