

# Innovation opportunity mapping – MFC film as a packaging barrier

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**KTH Industrial Engineering  
and Management**

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## Abstract

This thesis provides insight into the key factors affecting the commercialization process of microfibrillated cellulose (MFC) barrier films in packaging applications. MFC is presented and the technical properties affecting its performance as a packaging barrier are investigated. This is done based on previous research and the knowledge of an experienced team with focus on MFC research. The target market of high barrier packaging with the specific segments of grease and oxygen barriers is further analyzed and future forecasts for the market presented.

Organizational innovation adoption theory by Frambach and Schillewaert (2002) is used as a theoretical framework with a deep connection to Rogers' (1983) adoption theory. Since MFC is a bio-based material, specific focus is on the characteristics of launching eco-innovations. While the general rules of launching innovations also apply to eco-innovations, characteristics such as institutional interference can play a large part. Semi-Structured interviews with representatives from both innovators and potential customers' side are used to gain an extensive picture about the situation. Evidence based on the interviews is compared to the theoretical framework and based on this comparison, vital actions and determinants of successful commercialization are proposed. The diffusion process of eco-innovations is often rather slow, and therefore strategies to speed up the diffusion process are presented.

Extensive research about the technical properties of MFC has been conducted previously but there is lack of research on market diffusion and market pull effects in barrier packaging. This thesis aims to provide a connection of an industry under transition with scientific research on innovation diffusion and contribute to the process of forest-based industry to become more customer oriented. The key component when commercializing eco-innovations is identified to be the importance of creating awareness about the innovation among customers.

**Keywords:** Microfibrillated cellulose, diffusion of innovations, packaging barriers, eco-innovations, organizational innovation adoption

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## 1. Introduction

Consumption of packaging materials is increasing globally (Smithers Pira, 2013). This is an effect of increased welfare and consumption. Environmental awareness among individuals has increased due to easier access to information and the visible consequences of global warming. Global interest in environmental questions has created a demand larger than ever before for environmentally friendly packaging solutions (Smithers Pira, 2013). Food packaging is no difference to the trend. At the moment a substantial share of food packaging is made of nonrenewable materials, such as petroleum-based polymers (Mikkonen and Tenkanen, 2012). Even though new green materials and biopolymers are heavily investigated, only paper and paperboard are currently widely used in packaging applications. Application of these new green materials is often limited because of lacking barrier properties and high moisture sensitivity. If one were to find an environmentally friendly material which could seriously challenge the use of petroleum-based polymers in barrier packaging, it would fit well in the global sustainability trend and could give positive externalities to the surroundings in the form of reduced environmental impact.

The thesis starts with presenting the technical specifications and barrier properties of microfibrillated cellulose (MFC), which is largely investigated to become a possible solution for this environmental challenge. Current barrier packaging market is then analyzed with forecast for future direction of the market. After the market analysis, previous research on innovation diffusion and organizational innovation adoption is presented. Based on previous research, a qualitative case study about the current situation is conducted. Empirical evidence is presented and then compared to the previous research results.

### 1.1. Background

Advances in technology have set the traditional pulp & paper industry to a time of recurrence. These large companies have understood the changing environment and are making large changes in strategy to adopt. Stora Enso, which is the partner in this thesis, is systematically taking steps towards evolving from a traditional paper and board producer to a global renewable growth materials company (Sundström, 2015).

A trend in food packaging technology that has been active during the latest years is development of new materials that possess very high barrier properties. Materials with high barrier reduce the total amount of packaging materials needed by enabling thinner or lightweight layers with high-barrier properties. Introduction of an effective high barrier packaging material reduces material handling, distribution and transportation costs, as well as the amount of waste (Han, 2013).

Food packaging today should be natural and environmentally friendly. In order to design more natural and environmentally friendly packaging systems, a partial replacement of synthetic materials with biodegradable ones is needed. There is a growing interest in making sustainability a function of food packaging, although the primary functions should not be negatively influenced by the addition of sustainability (Han, 2013). The great challenge faced by the world today is to connect environmental sustainability with economic growth and welfare. Rethinking materials and their use is vital to more sustainable products and production processes (Crabbé et al., 2013). In the search of environmentally friendly packaging materials, microfibrillated cellulose (MFC) is an interesting material. Cellulose,

which is the most abundant polymer on earth, is also renewable, biodegradable and non-toxic (Dufresne, 2013). MFC was first introduced in the early 1980s (Ankerfors, 2015). MFC has been in the radar of most pulp & paper companies and a great deal of research has been conducted around the subject. The major problem with MFC has been the high energy consumption in manufacturing. However, recently there have been successful trials in reducing the energy demands within MFC manufacturing (Ankerfors, 2015). Several companies have built pre-commercial plants for MFC production. The time for upscaling is approaching and thereby it is important to identify potential end-uses for the product.

## 1.2. Purpose

Companies within the forest-based industry have invested heavily on fine-tuning the production process of MFC in order to create a competitive bulk-product for the future. Now, when the moment of commercialization is approaching, it is essential to learn how the brand-owners see the future of MFC and what their attitudes towards adoption are. So far, companies have focused mainly on the technology-push side in the innovation theory, mainly improving the production processes and material characteristics. This work focuses on analyzing the demand-pull effects. Demand from markets enables innovations to adapt to market needs in order to favor its adoption and diffusion (Di Stefano et al., 2012). According to previous research (Dosi 1982; Kline and Rosenberg 2009; Di Stefano et al, 2012), science and technology provide the trajectories of innovation but demand is a crucial component directing the trajectory towards the right economic venues.

The purpose of this research is to shed light on the determinants of innovation adoption in the context of barrier packaging market and with help of these determinants analyze the potential of MFC as a packaging barrier film. Organizational innovation adoption theory by Frambach and Schillewaert (2002) is utilized to improve the planned process of commercialization and up scaling of the product. The aim is to investigate if there is market potential for MFC barrier films and the research is conducted using exploratory research methods. Research is done to find answers to the following research questions:

1. *How should the diffusion process of MFC barrier packaging films be approached?*
2. *What are the most important aspects for development in order to successfully commercialize MFC in barrier packaging?*

### 1.3. Reliability and Validity

Reliability of research is generally measured by repeatability. However, in qualitative research, reliability is measured by the repeatability of the analysis, meaning that the researcher needs to follow the rules of classification and interpretation (Uusitalo, 1999).

Validity of research means the ability of the indicator to correctly measure the target (Uusitalo, 1999). With qualitative research the validity is easier to achieve than reliability. The use of semi-structured interview methods is likely to increase the validity, due to the flexibility in the interview situation. The names or companies of the interviewees will not be disclosed. This is due to the request of both the research partner and the interviewees. The anonymity has likely increased the validity of this research. The anonymity makes the interviewees more open and willing to provide answers (Yin, 2003). Answers to the interviews are presented as a collected opinion of the respondents. Individual specific answers are not presented because of requests from interviewees.

This thesis is conducted in cooperation with Stora Enso and three out of five interviewed brand owners are existing customers for the company. Thereby there is a possibility that the interviewees perceive the interviews as part of the negotiation game between a material producer and the customer brand owner. This might influence the results and thereby decrease the validity of research.

In this research, only one material with a specific application is investigated. Although findings from qualitative data can often be extended to other cases with similar characteristics, gaining a rich and complex understanding of a specific case is seen as more important in this case than succeeding to draw generalizable conclusions. Thereby the results of this research should only be taken as directive with other cases.

## 2. Methods

This is a case study research about the market potential of MFC films in barrier packaging. A case study is an empirical study where a current phenomenon is studied in its real context. The use of case studies is appropriate when the aim is to illuminate a decision, to gain knowledge about why this decision was made, how that was implemented and where the results led to (Yin, 2003). This case study focuses on questions regarding the potential of MFC barrier packaging films and possible solutions to enhance the diffusion. To understand what MFC is and the potential of MFC as a packaging barrier, both the material properties and market situation are investigated. In order to gain better knowledge about the applicability of MFC as a packaging material, the characteristics of the material and its barrier properties are presented first. Then both the current market situation and future forecasts in barrier packaging is summarized. The market data is collected mainly from reports from Smithers PIRA and Euromonitor database. Both of these are trusted research organizations used by the major industrial players.

To build a framework for interviews, previous research around commercialization and adoption of innovations is investigated. Organizational innovation adoption theory by Frambach and Schillewaert (2002) is used as a theoretical framework with a deep connection to Rogers' (1983) adoption theory. Since MFC is a bio-based material, specific focus is on the characteristics of launching eco-innovations. While the general rules of launching innovations also apply to eco-innovations, there are some characteristics specific to the branch.

Evidence is collected by interviewing relevant stakeholders. Semi-structured interviews with representatives from several angles in the process are used to gain an extensive picture about the situation. In semi-structured interviews, a guide is used about which questions and topics that must be covered, but the interviewer has the ability to ask further questions in order to receive adequate answers. Semi-structured interviews are often used to dive deeply into a topic and to understand thoroughly the answers provided (Harrell and Bradley, 2009). Additionally some structured questions are used to receive measurable data to draw conclusions. The aim of this research is to shed light on commercialization of an innovation in business-to-business environment and the results are compared to previous findings.

Sampling of interviewees is done using the snowball sampling method, also known as chain referral sampling. In snowball sampling participants or informants with whom contact has already been made use their social networks to refer other people who are suitable for the research (Mack and Woodson, 2005). This is done in order to gain access to groups otherwise not accessible for interviews. Table 1 presents the different groups interviewed and the goals with these interviews. In order to understand the technical possibilities, four technical experts from different R&D functions within Stora Enso are interviewed. During the research these persons are contacted continuously when new questions arise. To understand the diffusion process from the innovation provider's side, seven sales managers from different categories and markets are interviewed. Lastly, to understand the market demands, five representatives, who work in connection with packaging development, of brand owners are interviewed. The interviewees are selected based on availability and the aim to find answers from players with different market positions. Three of the brand owners interviewed represent large multinational companies with a wide portfolio of goods with different packaging demands. One of the interviewees is a medium size company manufacturing a smaller portfolio of food products. The last one is a start-up within the food sector, which has received international recognition and thereby is expected to have large growth potential.



Group	Amount	Goal
Technical experts	4	Technical possibilities of MFC barrier films
Sales managers	7	Diffusion process
Brand Owners	5	Market demand factors

*Table 1: Interviewee groups and the goals of interviews*

Interviews as sources of evidence have both positive and negative attributes. On one hand, the interviews are targeted and thereby focus directly on the topic. Interviews are also insightful; they provide perceived causal inferences. On the other hand, interviews also have weaknesses. The research relies on other people's words and phenomena such as reflexivity, meaning that the interviewee tells what the interviewer wants to hear, can thus occur (Yin, 2003).

### 3. Technical specifications of MFC and its barrier properties

#### 3.1. MFC

Microfibrillated cellulose (MFC) is a material consisting of cellulose microfibrils that can be separated from cellulose fiber walls. The main source for MFC is wood pulp, but also other sources can be used, such as sugar beet and potato pulp (Malainine, Mahrouz, and Dufresne 2005). According to Lavoine et al. (2012), MFC was first developed in 1983 by Turbak et al., who disintegrated wood pulp several times in a high-pressure homogenizer, aiming to obtain a viscous and shear thinning aqueous gel at a very low concentration. One cellulose microfibril has a typical diameter of 2-10nm and length can be up to tens of micrometers. Cellulose microfibrils are bound to one another through strong hydrogen bonds. A bond of several cellulose microfibrils forms microfibril aggregates, which are called microfibrillated cellulose. Figure 1 illustrates what MFC is and where it can be found.

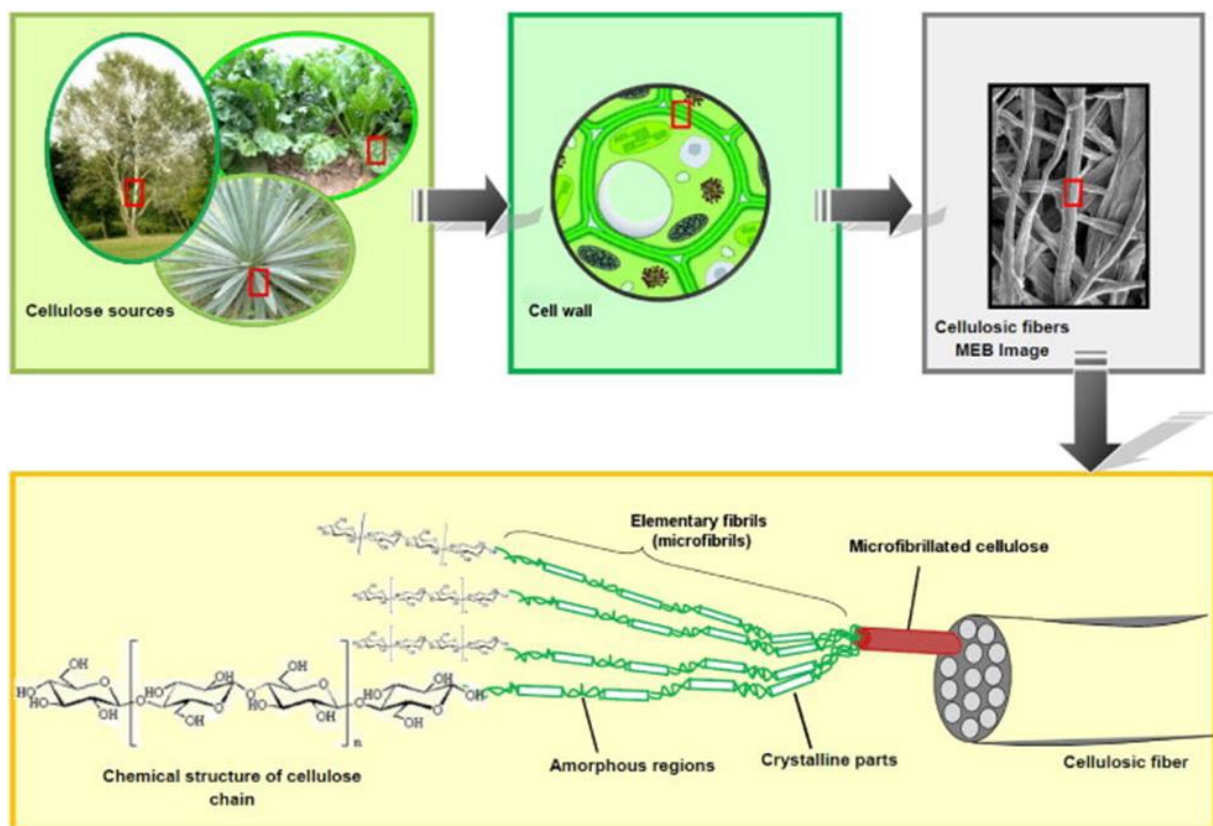


Figure 1: From macro to micro, what MFC is and where it can be found (Lavoine et al., 2012)

MFC has a network consisting of both amorphous and crystalline parts, which enables it to create strong hydrogen bonds. Due to that and high aspect ratio, MFC has a good ability to form a rigid and strong network (Lavoine et al. 2012). MFC serves as a promising material to various applications, such as bio-composites and packaging, due to its abundance, high strength, low weight and biodegradability (Siró and Plackett 2010). Current research is focused much on the use of MFC as a coating for packaging. A finding of relatively small improvement in barrier properties would make MFC suitable for various industrial applications.

The traditional way of producing MFC is by treating wood-based cellulose fibre suspensions with a high-pressure homogenizer. The problem with this method is that the fibers need to be run through the homogenizers several times, which results in high energy consumption, typically approximately 27000 kWh/ton (Ankerfors, 2015). Upscaling of MFC production demands a more energy efficient process, which leads to a search for other production opportunities. Latest results presented by Ankerfors (2015) claim that MFC can be produced with energy consumption as low as 500-2300 kWh/ton. These results are promising for the potential of upscaling and commercializing the product.

### 3.2. Barrier properties

The barrier performance of a film is measured by the Water Vapor Transmission Rate (WVTR) and Oxygen Transmission Rate (OTR). WVTR measures the rate at which water vapor permeates through the film at a specified temperature and relative humidity. OTR measures the amount of oxygen gas passing through the film over a given period. Barrier classifications of the films, based on these two characteristics, are presented in table 2.

Barrier classification		
Classification	OTR, $\text{cm}^3/\text{m}^2/\text{d}$	WVTR, $\text{gms}/\text{m}^2/\text{d}$
Low	>100	>100
Medium	6–100	6–100
High	1–5	1–5
Very high	<1	<1

Table 2: Barrier classification of films based on OTR and WVTR values (Platt, 2013a)

The barrier properties of MFC films are determined largely by the crystallinity and the network structure formed by fibers in a dry film. It is difficult for other molecules to penetrate the crystalline parts or the very dense network (Kumar et al., 2014). MFC is considered as a relatively good barrier material, due to high crystallinity and dense network structure (Lavoine et al., 2012). Kumar et al. (2104) report that previous research of MFC has indicated high to very high barrier properties against oxygen, but only medium water vapor barrier. Water vapor barrier is challenging due to the hydrophilic nature of cellulose molecule. However, the water vapor transfer rates can be decreased, and thereby the barrier properties improved, by different pre- and post-treatments during the production process (Kumar et al., 2014). Figure 2 presents barrier performance values of different materials used for barrier packaging. Here, when the focus is on MFC, the relevant ones for comparison are ethylene vinyl alcohol (EVOH) and polyvinylidene chloride (PVdC).

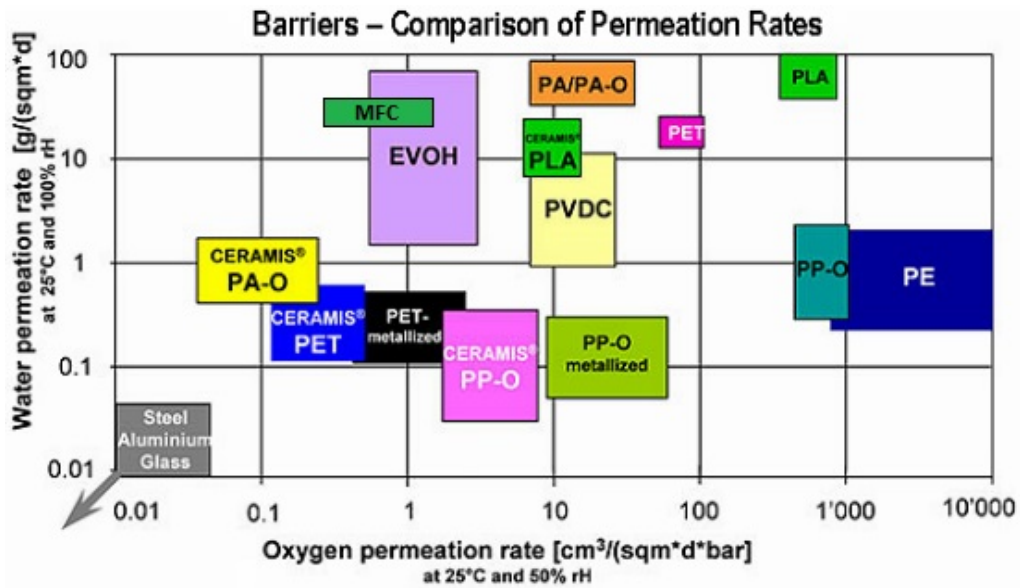


Figure 2: Comparison of barrier properties of different materials (Rosato, n.d.) (edited).

MFC barrier films seem to overlap with ethylene vinyl alcohol (EVOH), which indicates that EVOH is an interesting material for comparison with regards to market potential. EVOH has gained market share from polyvinylidene chloride (PVdC) during the recent years. Table 3 presents the measured values of EVOH, MFC and PVdC.

Barrier material	Thickness	OTR (cm <sup>3</sup> /m <sup>2</sup> /d)	WVTR (g/m <sup>2</sup> /d)	Source
EVOH	24µm	0,16-1,86	NA	(Platt, 2013a)
MFC	25µm	0,5-2,3	47-55	(Kumar et al., 2014)
PVdC	24µm	8	0,3	(Platt, 2013a)

Table 3: Barrier performance of different barrier films. (Platt, 2013a and Kumar et al., 2014)

MFC provides a good grease barrier, due to the small porosity of the film. Kumar et al. (2014) tested the grease barrier properties with mineral oil and vegetable oil in the period of 4 weeks. The results showed that the oils did not pass through the MFC films during the period. The molecule size of these oils is larger than the porosity of an MFC film and therefore the oil is unable to pass through the MFC-barrier. Figure 3 illustrates the barrier difference between plain paper and paper coated with MFC.

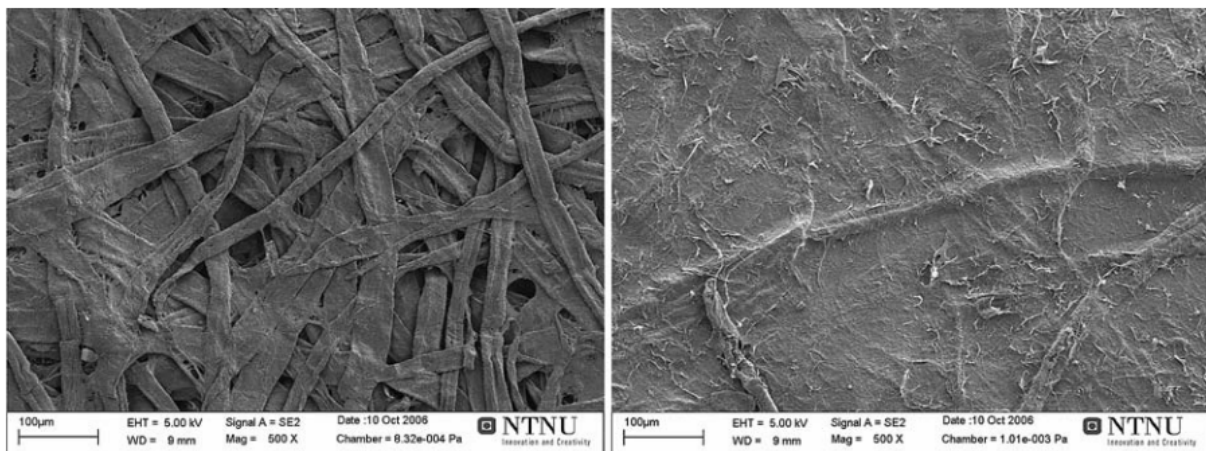


Figure 3: Base paper (left) and the same base paper coated with 8 g/m<sup>2</sup> MFC (Syverud and Stenius, 2008)

#### 4. Market overview - presenting the barrier packaging market and future forecasts

This chapter gives an overview onto the development of MFC and the largest players in the field. Additionally the barrier packaging film market is presented. Since MFC film gives an excellent oxygen and grease barrier, the focus is on these applications. Two sectors within barrier packaging, namely dried food packaging and snack foods and confectionary packaging are identified as potential markets for MFC barrier films and therefore the market situation in these markets is analyzed. Lastly, some materials with potential to compete against MFC in the future markets are presented.

##### 4.1. Development of MFC

MFC has gained global attention over the years and it is noteworthy that the majority of new patents in MFC are coming from Asia. Figure 4 presents the major global patent issuers for MFC.

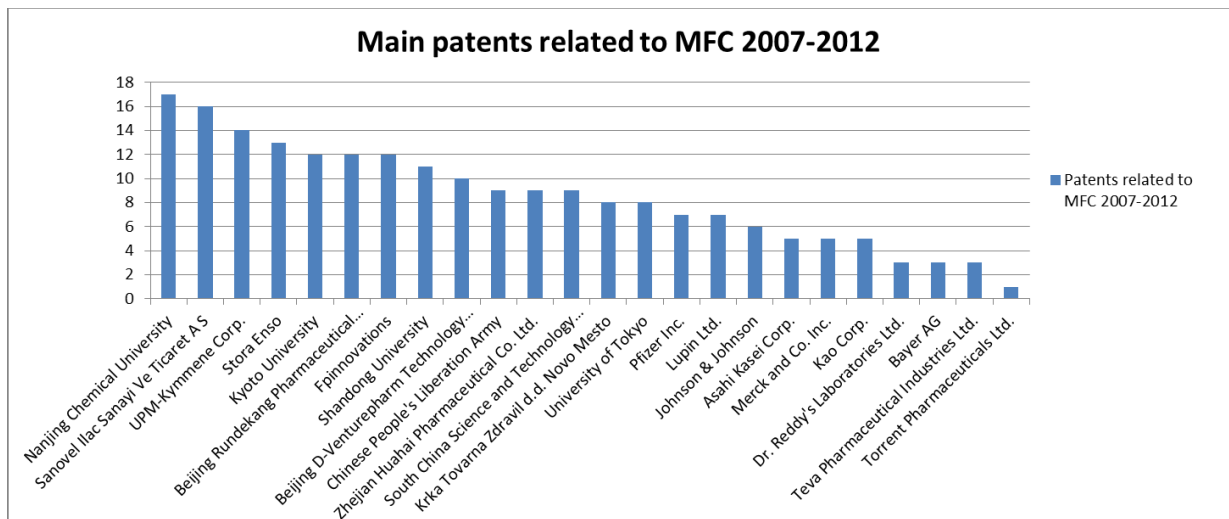


Figure 4: Main patents related to MFC in 2007-2012 (Data source: NISCluster Ltd, 2013)

MFC has been in the attention of forest based industry for many years and several companies around the world have introduced pre-commercial production facilities. Some of the companies with pre-commercial MFC production are listed in Table 4.

Company	Country	Trademark
Rettenmaier	Germany	
DaiCel	Japan	
Nippon Paper	Japan	Cellenpia
Oji Paper	Japan	
Stora Enso	Finland	
UPM-Kymmene	Finland	Biofibrils
Verso Paper	USA	
Borregaard	Norway	
Norske Skog	Norway	
Kruger	Canada	
Imerys	France	FiberLean

Table 4: Pre-commercial MFC production facilities (Sources: Seppänen, 2014; Ankerfors, 2015)

The use of MFC as a packaging barrier film is one of many possible application areas. It is particularly interesting now when better protection for packed goods and extension of products' shelf life are gaining more importance. High diffusion barrier, protecting the goods from external influences, such as oxygen and water vapor, is a large topic in the food packaging industry (Platt, 2013a). High barrier demands are commonly satisfied with multilayer packaging. However, brand owners and other stakeholders all would prefer sustainable packaging and would like to move from multilayers to monolayers, if this could be done economically while still retaining the barrier properties. Unfortunately there is no efficient monolayer barrier technology currently in the market (Cooper, 2014).

In food packaging MFC can provide oxygen and grease barrier. The main challenges with the use of MFC in food packaging are that the material is not heat sealable, and that the level of moisture barrier is only medium. Heat-sealability is important because it is widely used in different packaging applications. Moisture barrier is relevant with products that are in contact with moisture and also ones, such as cigarettes, that require a high level of freshness inside the packaging. On the other hand, dried food packaging and snack foods and confectionary are sectors where might be opportunities for the use of MFC barrier.

#### 4.2. High barrier packaging film market

In the food industry, there is a growing demand for packaging materials with great protection of the contents. With more common usage of plastics, concerns have risen about their ability to protect the product against gases and vapor (Platt, 2014). Besides being renewable and biodegradable and hence considered a sustainable packaging material option, another advantage with MFC as a packaging film material is the protective properties. The relevant market potential of MFC barrier films is likely to be found within the high barrier packaging film market. Thereby it is essential to analyze the high barrier packaging film market.

Platt (2014) defines high barrier packaging films as flexible films that are smaller than 250 $\mu$  in gauge with an oxygen gas transmission rate in the range <5cm<sup>3</sup>/m<sup>2</sup>/day (25 $\mu$  films) and water vapor transmission rates of <5gm<sup>2</sup>/m<sup>2</sup>/day (25 $\mu$  films).

In market reports and statistical data, Europe is generally divided in Western and Eastern parts. Western Europe is generally considered as the forerunner in sustainability trends, whereas in Eastern Europe the sustainability trends are not as visible.

Table 5 presents the size and value of high barrier packaging film market by region in 2014 and forecast to 2019. In 2014, the global high barrier packaging film consumption was approximately 1,76 million tonnes with a value of \$15,9 billion. The CAGR between 2014 and 2019 is forecast to be 5,0%. Western Europe accounts for 28,0% of the world total consumption adding up to 493000 tonnes with a value of \$4,9 billion. Eastern Europe accounts for 4,3% of the world total consumption adding up to 75 600 tonnes with a value of \$675 million. Between 2014 and 2019 the global market is forecast to grow at a CAGR of 5,0% to 2,24 million tonnes in 2019, with a value of \$20,0 billion.

High barrier packaging film market by region					
	2014		2019		2014-2019
	000 tonnes	\$ billion	000 tonnes	\$ billion	CAGR (%)
Global	1760	15,9	2240	20	5
Western Europe	493	4,9	566,6	5,6	2,8
Eastern Europe	75,6	0,675	98,8	0,882	5,50

Table 5: Size and value of high barrier packaging film market by region (data source: Platt, 2014)

High barrier packaging film demand is largely influenced by technology developments, such as polymer nanocomposites with enhanced barrier protection but high price, and barrier coatings based on sustainable resources. Currently barrier packaging is restricted by factors such as recycling problems and cost. Multilayer structures are common in barrier packaging, and this structure makes mechanical recycling problematic, since the different layers are complicated to be separated.

Global high barrier packaging film consumption by material, 2009, 2013, 2014 and 2019 forecast (000 tonnes)						
	2009	2013	2014 (p)	CAGR (%)		
				2009-14	2019 (f)	2014-19
Metallised film	483.8	562.4	587.0	3.9	730.9	4.5
Total high barrier transparent films	348.6	419.7	442.5	4.9	601.0	6.3
Organic high barrier coatings	505.0	558.8	574.5	2.6	678.7	3.4
Inorganic oxide coatings	93.6	141.4	154.2	10.5	233.7	8.7
<b>Total</b>	<b>1,430.9</b>	<b>1,682.4</b>	<b>1,758.3</b>	<b>4.2</b>	<b>2,244.3</b>	<b>5.0</b>

Table 6: Global high barrier packaging film consumption by material 2009-2014 and forecast of 2019 (source: Platt, 2014)

High barrier packaging films can be separated into three categories: metallised film, transparent high barrier films and barrier coatings. Table 6 presents the global consumption of these categories. Metallised films consist of metallised polymers, such as PE or PP, which have barrier properties depending on application. Transparent high barrier films are made of, for example, ethylene vinyl alcohol (EVOH), polyacrylonitrile (PAN) or polychlorotrifluoroethylene (PCTFE). Barrier coatings can be organic, such as polyvinylidene chloride (PVdC) or inorganic, such as silicon oxide (SiOx) (Platt, 2014).

Metallised film is currently the largest category, followed by PVdC and EVOH. EVOH and inorganic oxide coatings are growing the most. EVOH is gaining market share from PVdC due to environmental concerns, especially in Western Europe (Platt, 2014).

Barriers can be classified according to their resistance to different substances, such as grease, oxygen, moisture, odor, flavor and UV light (Platt, 2013a). Two types of barriers, grease and oxygen, are the most relevant when analyzing the market opportunity of MFC barrier films. These types are presented next.

### 4.3. Grease barriers

Currently the most common grease barrier materials are fluorocarbons. Grease barrier can also be achieved with dispersions and many of these dispersion products are based on styrene-acrylate or pure acrylates. The global market for acrylic barrier coatings alone, as can be seen from table 7, is forecast to reach a value of \$72,2 million in 2018, with CAGR of 3,8%. Table 8 shows that the predicted CAGR in 2013-2018 in Western Europe is 1,0%. Based on the demands, MFC as a barrier film would be suitable to compete against acrylic barrier coatings in the confectionary market.

<b>Acrylic barrier coatings: forecast market value for plastic packaging by end-use sector, 2008–18 (\$ million)</b>							
	<b>2008</b>	<b>2011</b>	<b>2012</b>	<b>2013 (p)</b>	<b>CAGR (%) 2008–13</b>	<b>2018 (f)</b>	<b>CAGR (%) 2013–18</b>
Confectionery	47.8	56.3	58.1	60.1	4.7	72.2	3.8

Table 7: Market value of acrylic barrier coatings for plastic packaging in 2008-2013 and forecast to 2018 (Source: Platt, 2013b)

<b>Acrylic barrier coatings: forecast market value for plastic packaging by region, 2008–18 (\$ million)</b>							
	<b>2008</b>	<b>2011</b>	<b>2012</b>	<b>2013 (p)</b>	<b>CAGR (%) 2008–13</b>	<b>2018 (f)</b>	<b>CAGR (%) 2013–18</b>
Western Europe	14.8	16.1	16.1	16.2	1.9	17.1	1.0
Central and eastern Europe	4.8	5.8	6.0	6.2	5.4	7.6	4.0
North America	7.3	8.1	8.3	8.4	3.0	9.0	1.3
South and Central America	2.4	2.9	3.0	3.1	5.7	4.1	5.5
Asia Pacific	16.2	20.6	21.7	23.0	7.2	30.8	6.0
Middle East and Africa	2.4	2.8	3.0	3.1	5.3	3.7	4.0
<b>Total</b>	<b>47.8</b>	<b>56.3</b>	<b>58.1</b>	<b>60.1</b>	<b>4.7</b>	<b>72.2</b>	<b>3.8</b>

Table 8: Market value of acrylic barrier coatings for plastic packaging by region in 2008-2013 and forecast to 2018 (Source: Platt, 2013b)



#### 4.4. Oxygen barriers

Global consumption of oxygen- and other gas barrier films was 919 100 tonnes in 2013. Polyester (PET) film is the most commonly used material in these applications. However, PET is rarely used alone because of only moderate gas barrier properties. PET is used as a web material in multilayer structures together with materials providing better barrier protection, such as EVOH and PVdC. Among transparent films, both PVdC and EVOH provide robust oxygen barrier. However, more evident barrier protection with PVdC is against flavor and aroma. The packaging must be able to be sealed airtight with seams and closures, in order to gain the benefits of such barriers (Platt, 2013a). This is one of the challenges with MFC barrier films, since the material is not heat sealable. In order to use MFC films in these applications, other methods than heat sealing must be used. The global oxygen and other gas-barrier film consumption is presented in table 9.

<b>Oxygen and other gas-barrier film consumption by material type, 2008–13 and 2018 forecast (000 tonnes)</b>									
	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013 (p)</b>	<b>CAGR (%)</b>	<b>2018 (f)</b>	<b>CAGR (%)</b>
							<b>2008–13</b>	<b>2013–18</b>	
PET	513.8	554.9	599.3	641.2	676.5	713.7	6.8	987.0	6.7
PEN	10.9	11.2	11.8	12.3	12.7	13.1	3.8	16.5	4.7
PA	38.6	39.8	41.8	43.4	45.0	46.5	3.8	58.5	4.7
PVdC	23.3	23.1	23.5	23.9	24.2	24.5	1.0	26.9	1.9
EVOH	92.4	94.2	100.4	106.4	112.2	118.4	5.1	157.7	5.9
LCP	2.4	2.3	2.4	2.5	2.7	2.8	3.2	3.7	5.8
<b>Total</b>	<b>681.4</b>	<b>725.5</b>	<b>779.2</b>	<b>829.8</b>	<b>873.3</b>	<b>919.1</b>	<b>6.2</b>	<b>1,250.4</b>	<b>6.3</b>

Table 9: Global oxygen and other gas-barrier film consumption by material type in 2008–2013 and forecast of 2018. (Source: Platt, 2014)

##### 4.4.1. Ethylene vinyl alcohol (EVOH)

EVOH is an interesting material for comparison with the potential use of MFC in barrier films, since it has similar characteristics and a growing market. Like MFC's, the barrier properties of EVOH are compromised by high moisture and humidity. EVOH copolymers are gas-barrier semi crystalline materials with great chemical resistance. They are commonly used in packaging applications, such as food products. One of the most common applications is as an intermediate barrier layer in multilayer structures. EVOH barrier increases food quality and safety by delaying the ingress of oxygen (López-Rubio et al., 2005). In addition to oxygen barrier, EVOH is also barrier for odor and aroma. The downsides of EVOH are that the barrier properties decrease at higher relative humidity levels and the moisture barrier properties are only moderate. EVOH is commonly used in both fresh food and dry food packaging (Platt, 2014).

The global EVOH film consumption is presented in table 10. The largest market area is Western Europe with over 130 000 tonnes, but the area is forecast to have the smallest CAGR of 4,5% between 2014 and 2019. In Western Europe, where the environmental concerns are most evident, EVOH has already replaced PVdC in a higher magnitude than in other areas and thereby growth of EVOH market relies more on packaging product growth than substitution in that area (Platt, 2014).

<b>EVOH packaging film: consumption by world region, 2009, 2013, 2014 and 2019 forecast (000 tonnes)</b>						
	<b>2009</b>	<b>2013</b>	<b>2014 (p)</b>	<b>CAGR (%) 2009-14</b>	<b>2019 (f)</b>	<b>CAGR (%) 2014-19</b>
Western Europe	108.4	127.5	133.8	4.3	166.8	4.5
Eastern Europe	11.5	13.8	14.6	4.9	20.9	7.5
North America	105.1	118.3	121.8	3.0	159.2	5.5
South & Central America	13.1	16.7	18.5	7.1	26.6	7.5
Asia Pacific	73.9	98.4	105.9	7.5	165.3	9.3
Middle East & Africa	16.4	21.6	23.4	7.3	32.0	6.5
<b>Total</b>	<b>328.4</b>	<b>396.2</b>	<b>418.1</b>	<b>4.9</b>	<b>570.8</b>	<b>6.4</b>

Table 10: Global EVOH packaging film consumption by region in 2009-2014 and forecast to 2019 (Source: Platt, 2014)

#### 4.5. Dried food packaging

The dried food sector consists of a wide variety of products, including dried fruit and nuts, packet soups, spices and flavorings, rice, pasta and breakfast cereals. Drying is an effective way of extending the useful life of a food product. Dried food product retains its nutritional value and texture as long as it's safely protected from light and gases. Typical packaging for dried food is a flexible PE film or a flexible film bag, often inside a cardboard box. At the moment bags and pouches dominate the market, but they are losing market share to alternative pack formats, such as films. Metallized coatings are most common with dried food packaging, but PVOH has a small share as well. Barrier bags and flexible pouches are gaining market share from rigid boxes and glass, due to a good product quantity to packaging ratio, lighter weight and ability to be reclosed. Overall sales growth in dried food (see table 13), and especially dried processed food (see table 12) packaging is relatively low. However, as seen in table 12, there are some specific sub-segments, such as meal replacement packaging, which are growing relatively fast (Platt, 2014).

<b>Application</b>	<b>Area</b>	<b>2014-19 CAGR (&amp;)</b>
Dried Processed Food Packaging	World	2,90
	Eastern Europe	1,20
	Western Europe	1,20
Meal Replacement Packaging	World	8,10
	Eastern Europe	10,20
	Western Europe	4,20

Table 12: Compound average growth rates of dried processed food and meal replacement packaging by region. (data source: Euromonitor)

According to table 13, Western Europe is showing only a CAGR of 1,4% in high barrier packaging film consumption for dried food in 2014-2019, whereas Eastern Europe has a CAGR of 3,7%.

<b>High barrier packaging film consumption for dried food by world region, 2009, 2013, 2014 and 2019 forecast (000 tonnes)</b>						
	<b>2009</b>	<b>2013</b>	<b>2014 (p)</b>	<b>CAGR (%) 2009-14</b>	<b>2019 (f)</b>	<b>CAGR (%) 2014-19</b>
Western Europe	35.4	36.0	37.0	0.9	39.7	1.4
Eastern Europe	3.9	4.3	4.5	2.9	5.4	3.7
North America	28.6	30.3	31.0	1.6	35.5	2.8
South & Central America	6.3	7.7	8.2	5.4	10.8	5.7
Asia Pacific	26.3	33.4	36.0	6.4	50.7	7.1
Middle East & Africa	8.8	6.9	7.3	-3.6	9.0	4.3
<b>Total</b>	<b>109.4</b>	<b>118.6</b>	<b>124.0</b>	<b>2.5</b>	<b>151.1</b>	<b>4.0</b>

*Table 13: High barrier packaging film consumption for dried food by region 2009-2014 and forecast to 2019 (Source: Platt, 2014)*

#### **4.6. Snack foods and confectionary**

Another interesting market for MFC barrier films is within snack foods and confectionary. Window packaging in confectionary is raising interests especially in Western Europe (Dussimon, 2015) due to enabling the inner product to be seen on shelf and growing demand for environmentally friendly packaging in the sector. MFC films, which can be made transparent and are sustainable, have an opportunity with this sector. Platt (2014) divides the confectionary market into three categories: chocolate, sugar confectionary and gum. Chocolate is the largest category with 55% share of the total market. In some products, where a long shelf life is demanded, the products need a packaging with barrier against oxygen, light, oil and moisture. Currently the most widely used barrier coating for plastic packaging in confectionary is acrylics. Typical multilayer barrier films use EVOH or PVdC as barrier material (Platt, 2014).

In the snack foods packaging market bags and pouches dominate. Folding cartons and paperboard tubes are used for premium products. In plastic packaging, PVdC-coated and metallised films are most commonly used. Platt (2014) claims that there are opportunities for clear barrier films to enter the market and take share from metallised films.

Barrier-coated plastic films have been replacing aluminum foil in snacks and confectionary packaging. While barrier films will continue to challenge aluminum foil, most of the replacement in the sector has already happened. Market growth for barrier films in the sector is forecast to grow mainly along the sector growth rather than substitution (Platt, 2014). Table 14 presents the high barrier packaging film consumption for snack foods and confectionary in different areas. Western Europe and North America are the largest markets, accounting more than 50% of global sales. Markets in these areas are, however, mature and face a slow sales growth in the future. A threat for plastic barrier film packaging and an opportunity for MFC films is the growing demand from large brand owners for environmental-friendly image. Paper packaging is one obvious way to enhance this image, but with customer education the same can be achieved with MFC films.

<b>High barrier packaging film consumption for snack foods and confectionery food by world region, 2009, 2013, 2014 and 2019 forecast (000 tonnes)</b>						
	<b>2009</b>	<b>2013</b>	<b>2014 (p)</b>	<b>CAGR (%) 2009-14</b>	<b>2019 (f)</b>	<b>CAGR (%) 2014-19</b>
Western Europe	70.2	73.3	75.2	1.4	83.3	2.1
Eastern Europe	12.4	13.7	14.4	3.0	17.8	4.3
North America	61.3	65.5	67.1	1.8	76.5	2.7
South & Central America	14.0	16.7	17.9	5.0	22.9	5.1
Asia Pacific	33.8	41.4	44.6	5.7	60.0	6.1
Middle East & Africa	11.5	7.7	8.2	-6.6	9.9	3.9
<b>Total</b>	<b>203.2</b>	<b>218.4</b>	<b>227.2</b>	<b>2.3</b>	<b>270.4</b>	<b>3.5</b>

Table 14: High barrier packaging film consumption for snack foods and confectionery by region 2009-2014 and forecast to 2019 (Source: Platt, 2014)

Table 15 shows the CAGR for confectionery and snack bars packaging. The global CAGR is around 2% in both confectionery and snack bars. Value for snack bars is used to reflect the values of the total snack foods sector, due to limited availability of data. Noteworthy is that paper-based containers are predicted to face high growth in Eastern Europe.

<b>Application</b>	<b>Packaging type</b>	<b>Area</b>	<b>2014-19 CAGR (&amp;)</b>
Confectionery Packaging	Paper-based containers	World	2,10
		Eastern Europe	4,90
		Western Europe	0,80
	Flexible packaging	World	3,30
		Eastern Europe	0,90
		Western Europe	1,00
Snack Bars Packaging	Paper-based containers	World	2,00
		Eastern Europe	15,90
		Western Europe	1,90
	Flexible packaging	World	2,60
		Eastern Europe	4,60
		Western Europe	1,70

Table 15: CAGR forecast for confectionery and snack bars packaging globally and in Europe 2014-2019 (Source: Euromonitor)

#### 4.7. New technologies

There are several new technologies to create high barrier packaging films. According to Platt (2014) the most promising ones are:

- Nanocomposite coatings: Potential to produce ultra-thin surface coatings and barriers to provide oxygen scavenging, shelf life extension and other beneficial properties. The major constraint for market adoption is high price.
- Multilayer films: Provide strong barriers but problems with recycling, high volume of packaging and cost.
- Ormocers: Possibility to become a very competitive packaging product in the coming years but not yet cost effective enough.
- Sustainable barrier coatings: Gives an alternative to traditional coatings such as EVOH.
- Melamine barrier coatings: Existing commercial applications within food and beverage packaging. Predicted to have major potential in pharmaceutical and medical devices packaging.
- Besela barrier films: Possibility to replace glass food jars and metal cans.
- New barrier pack product developments: Continued development. Potential to replace rigid plastics.

These technologies are not analyzed further in this thesis, since the future of them is as uncertain as the future MFC. Proper analysis of any of these technologies would require a wider research which is unsuitable for the purposes of this thesis.

## 5. Theoretical framework and literature review

### 5.1. Diffusion of innovation

*"The process by which an innovation is communicated through certain channels over time among members of a social system. It is a special type of communication that the messages are concerned with new ideas."*

- Definition of the diffusion of innovation by Rogers (1983; p 5)

To develop realistic plans of launching an innovation, an understanding of how and why innovations are adopted is needed. Empirical evidence suggests that around half of all innovations never reach the intended markets. Conventional marketing efforts work fine for many existing products and service, but they generally do not work for innovations. To generate more successful innovations, we need a deeper understanding about the factors promoting and constraining adoption, and how these influence the rate and level of diffusion within different markets (Tidd and Bessant, 2009).

According to the economists' view, the innovation process is simply the cumulative aggregation of individual, rational calculations. These rational calculations are based on the costs and benefits. These calculations are made under conditions of limited information and environmental uncertainty. The assumption is that adoption represents sunk cost and any net benefit is perceived to be positive. Under uncertainty about the future benefits of adopting an innovation, there is an option value in postponing adoption, and that will slow down diffusion. The economists' view completely ignores the value of social feedback, learning and externalities. Meanwhile the initial benefits may be small, the overall benefits can increase and the costs decrease with improvement, re-invention and positive externalities. These value increasing factors are particularly evident in innovation clusters and networks, where standards and complementary assets are important (Tidd, 2010).

Rogers (1983) describe diffusion as a social process where different actors communicate and thereby create and share information. Focus on the relative advantage is insufficient, since different social systems influence the costs, benefits and compatibility of an innovation. Social structures determine the most appropriate channels of communication as well as the type and influence of opinion leaders and change agents. These advantages are impossible to be seen beforehand.

#### 5.1.1. Diffusion barriers

In the search for successful activities in innovation launches, the concept of diffusion barriers becomes relevant. Diffusion barriers are the obstacles that are hindering the innovation's market diffusion (Talke and Hultink, 2010). Tidd (2010) identifies four main barrier groups to the widespread adoption of innovations: economic, behavioral, organizational and structural. The economic barriers refer to the personal costs versus social benefits, limited access to information and insufficient incentives. The one making adoption decisions must be able to motivate the economic benefits of adopting an innovation to the other stakeholders. Additionally the adoption of innovation demands change, which comes with an immediate cost compared to continuing the same way as before. Behavioral barriers consist of ones priorities, motivations, rationality, inertia and propensity for change and risk. It is generally

assumed that people are usually rational and process the available information before acting. Within the organizational innovation adoption concept, this means that in order for a firm to adopt an innovation, it must set a goal to achieve by adoption. Simplified, this means that a firm must be willing to change, to innovate (Montalvo, 2006). Without sufficient goals the innovation is less likely to be adopted. Within the concept of eco-innovations, the adopter must value the effect of reduced environmental impact enough to adopt the innovation. Goals, routines, power, influence, culture and different stakeholders form the organizational barriers. The culture of an organization is an important aspect in its innovation adoption behavior. The attitude towards innovation adoption is an index of the degree to which the firms managers like or dislike the engagement and consequences of engagement with innovative activities (Montalvo, 2006). Institutional factors, such as infrastructure and governance form the structural barriers. Kolade, Harpham and Kibreab (2014) found that institutional factors can behave either as a driver or a barrier towards innovation adoption. In the case of MFC barrier films, a possible structural barrier would be the introduction of regulations prohibiting the use of Nano-sized particles in food packaging.

### 5.1.2. Rate of adoption

Time dimension is important for the successful innovation launches. Rate of adoption is the relative speed with which an innovation is adopted by the consumers. Most innovations have an S-shaped rate of adoption like the one in figure 5. In the beginning, when the innovation is new, only a small share of actors is willing to adopt it. This share is called the innovators. The diffusion curve begins to climb over time, as an increasing number of actors adopt the innovation. Once the majority has adopted the innovation, due to a small share of actors new to it, the diffusion curve slows down. When the curve reaches its asymptote, the diffusion process is finished (Rogers 1983).

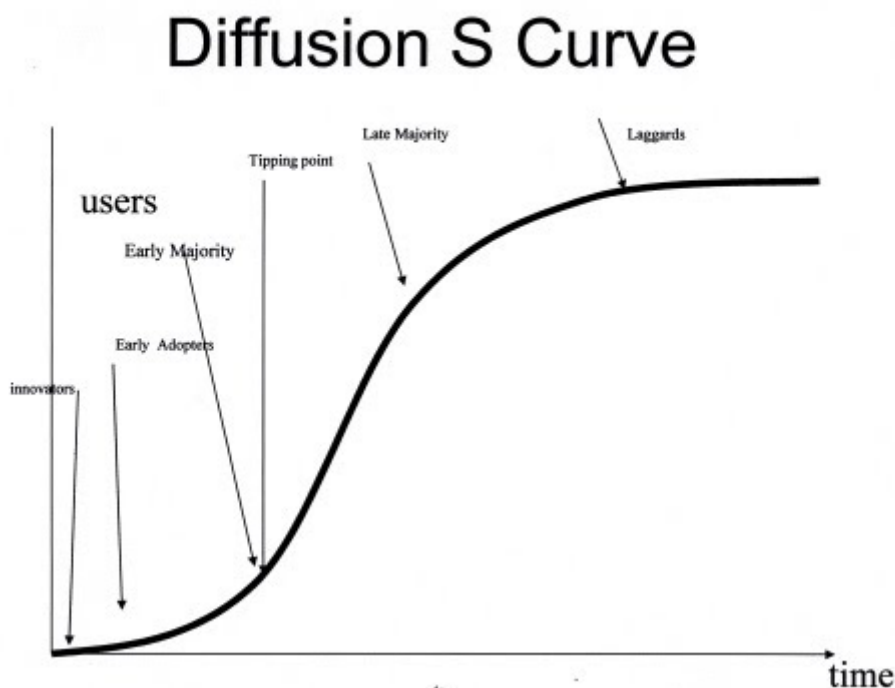


Figure 5: The diffusion S-curve of innovations. (Source: Rogers 1983)

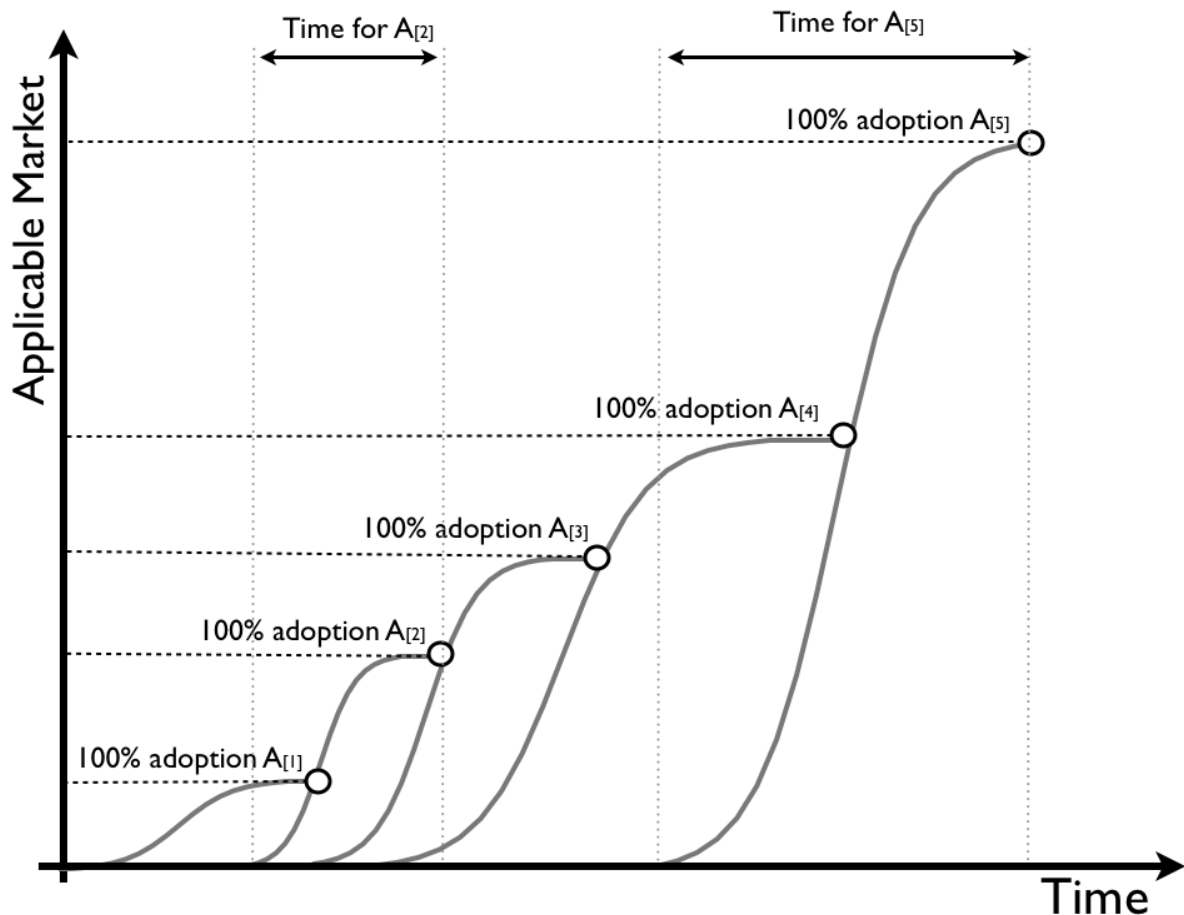


Figure 6: Multiple diffusion curves. A(1-5) represent different markets for the same innovation. (Source: Wardley, 2014)

Both the innovation and the market can, and often will, also evolve during the adoption phase. This makes it problematic to measure the adoption characteristics, such as rate of diffusion and the asymptote of innovation adoption. Figure 6 presents an innovation that spreads over markets A(1) to A(5). Initially, the innovation is diffusing to one market A(1). Later, once the innovation has gained some recognition, it will awake the interest of market A(2) and the diffusion starts. This way the innovation penetrates ever larger markets. As a consequence of this variability you can't effectively map over the diffusion rate and the life cycle of an innovation (Wardley, 2014). This is especially evident in innovations, such as MFC, where there are several potential application markets.

The surroundings need to be ready in order for an innovation to be adopted. The slope of the s-curve varies between innovations. Adoption of innovation is often a long process; it can take years after the innovation process before the innovation is adopted and in use. Empirical evidence shows that this is the case also with environmental innovations. Eco-innovations require a lengthy period of time before they are adopted and it is directly related to their diffusion rate and diffusion path (Karakaya, Hidalgo, and Nuur, 2014; Ozaki, 2010).

In order to hold the adoption period as short as possible, communication and knowledge spreading is essential. Innovators constantly need to balance between spreading the necessary information without revealing trade secrets to the competitors. Mass marketing media channels are effective in creating awareness, whereas interpersonal channels are more important in the decision-making and action stages (Tidd, 2010). Rogers (1983) divides the



decision-making about the adoption of an innovation in three types: individual, collective and authoritative. Individual decision making refers to the process when an individual makes a purchasing or adoption decision independently. When peer pressure or a formal requirement is in place, such as recycling of domestic waste, the decision-making is collective. Since this study focuses on the adoption decisions made by large companies, the most interesting decision-making process is authoritative. Authoritative decision-making happens when few individuals have the power to make decisions with a large impact. This is evident when company executives are choosing the materials to use in packaging.

**5.1.3. Diffusion of eco-innovations**

OECD (2010; s 15) define eco-innovation as “an innovation that results in a reduction of environmental impact, no matter whether or not that effect is intended”.

Eco-innovations provide positive externalities to the general public in the form of reduced environmental impact. In some cases the slow diffusion speed of eco-innovations can be explained with a higher price, poorer functionality or the requirement of behavior change among customers (Ozaki, 2010). Positive externalities for society in some cases motivate regulatory support in the form of incentive policies or restrictive regulations in the market for the eco-innovation. A simple framework where Horbach, Rammer, and Rennings (2012) have separated four main determinants of eco-innovation in the literature is presented in figure 7.

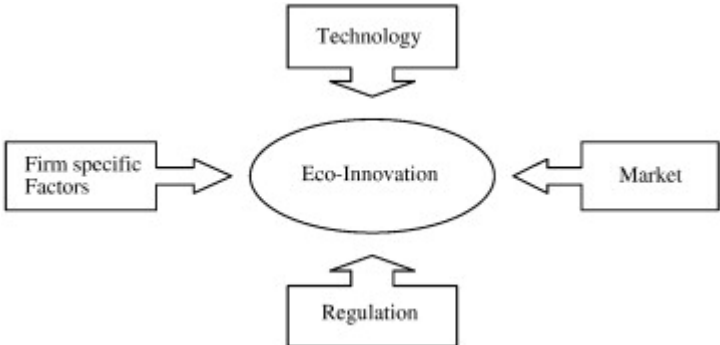


Figure 7: Determinants of eco-innovations (Horbach, Rammer, and Rennings, 2012)

The four main determinants of eco-innovation in the literature are: firm specific factors, technology, market and regulation. Companies’ innovation decisions are largely driven by national regulation. Regulations motivate the introduction of eco-innovations. These regulatory push and pull effects are effective tools for governments to manipulate the markets. Market pull factors are determinants for eco-innovations when the innovations create customer benefits. Customer benefits can come in many forms, but specific for eco-innovations are the perceived images of environmental friendliness. Supply factors are also important for the diffusion of eco-innovations. Improvements in technological capabilities by R&D trigger eco-innovations. Finally the firm specific factors, such as networking capabilities and knowledge transfer mechanisms, also have an influence on the innovation decisions (Horbach, Rammer, and Rennings, 2012).

A firm's decision to adopt eco-innovations is influenced by several factors, including technology push, market pull, policy and firm specific aspects (Horbach, Rammer, and Rennings, 2012). The major motivators, for example for a brand owner to use an ecological packaging are, in addition to product quality, the demands from the end customers and environmental policies in the region. Secondary factors are the increased variety of options and firm specific values. According to econometric research by Horbach, Rammer, and Rennings (2012), German firms in their sample expect a growing importance of future regulation for all environmental product innovations.

## **5.2. Organizational innovation adoption**

Many innovations fail because of the inability to fulfill customers' needs or the inability to provide a better solution compared to the alternatives. An understanding of potential customers and the factors influencing their adoption decision is important for a firm, in order to successfully bring innovations to market. The adoption process for an innovation in an organization consists of stages the organization passes through before the accepting decision (Frambach & Schillewaert, 2002). Zaltman et al. (1976) distinguish two stages in organizational innovation adoption: initiation and implementation. The adoption decision occurs between these stages. In the initiation stage, the organization examines the due diligence for the innovation. After discovering the innovation, the organization forms an attitude and evaluates it: sub-stages here are awareness, consideration and intention. The decision to purchase and make use of the innovation is the beginning of implementation stage. Thereafter the acceptance or assimilation within the organization becomes important. The innovation process can from a supplier's perspective be considered successful only when the innovation is accepted and integrated into the organization and the target adopters are committed to the product by continued using over a period of time.

A conceptual framework for organizational innovation adoption, created by Frambach & Schillewaert (2002), can be seen in Figure 8. The framework is based on previous empirical studies and consists of the different factors influencing the acceptance of new products by organizations. In the framework, both direct and indirect effects are considered. The perceived characteristics, introduced by Rogers (1983) are at the heart of the model. These characteristics, together with organizational adopter characteristics, drive the adoption process. The characteristics are influenced by external variables, i.e. supplier marketing efforts, social network and environmental influences. The framework is consistent with classical models of organizational buying behavior, which include individual characteristics, interpersonal factors and organizational factors as the key variables affecting the buying decision process of an organization.

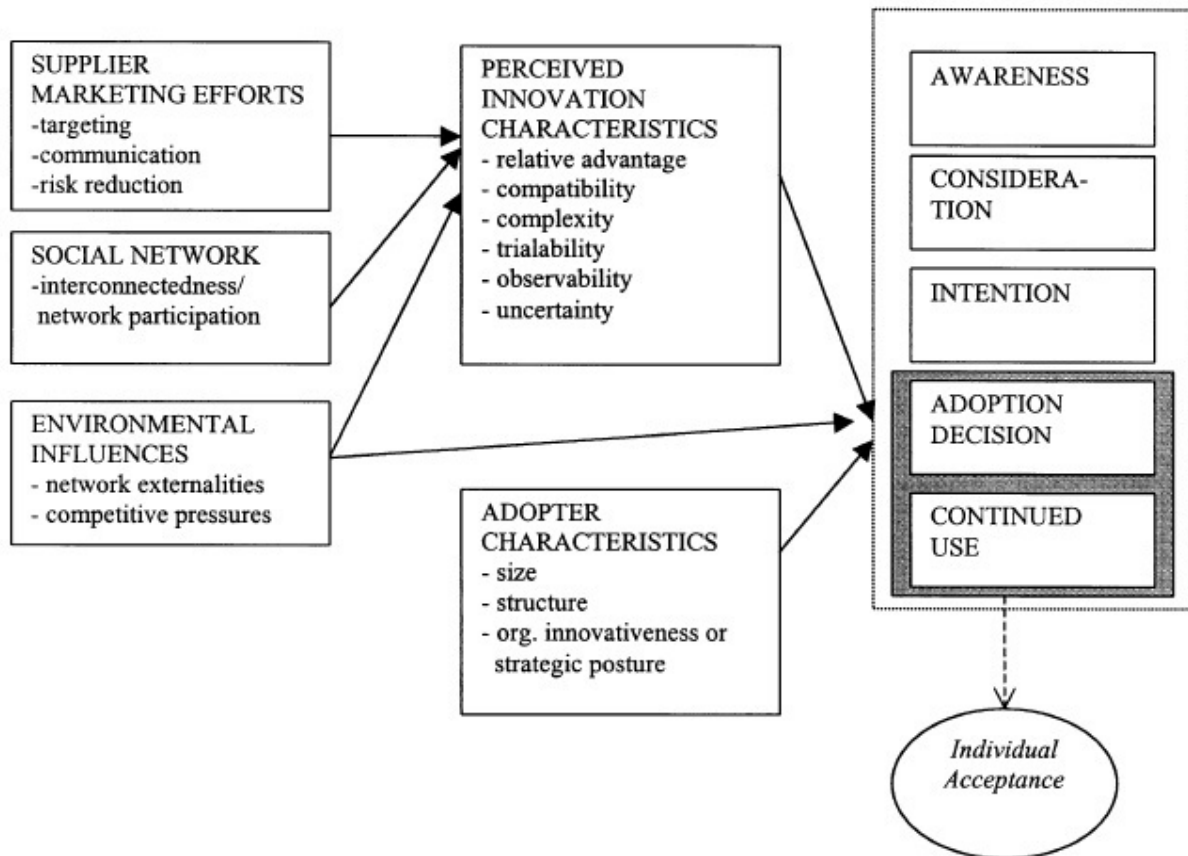


Figure 8: A conceptual framework of organizational innovation adaption (Frambach and Schillewaert, 2002)

### 5.2.1. Perceived innovation characteristics

The rate of adoption of an innovation is determined by how the members of a social system perceive the characteristics of it (Rogers, 1983). In organizational innovation adoption, the way the members of an organization's decision-making unit perceive an innovation, affect their evaluation of a new product and propensity to adopt it (Ostlund, 1974; Tornazky and Klein, 1982 and Rogers, 1983). The perceived benefits should exceed the ones provided by alternatives, in order for an organization to consider adopting. Rogers (1983) introduces five attributes of innovations: relative advantage, compatibility, complexity, trialability and observability. Rogers (1983) claims these to be the most important ones affecting the adoption decision. Frambach & Schillewaert (2002) add perceived uncertainty, introduced by Nootboom (1989), to the list.

#### *Relative advantage*

How much better the innovation is perceived than the existing solutions is called relative advantage. It is often measured in economic terms but other terms, such as convenience, satisfaction and social prestige are also important components. In fact, the objective advantage is unimportant compared to the perceived advantage. The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption will be (Rogers, 1983).

### ***Compatibility***

Compatibility is the degree to which the innovation is perceived to be consistent with existing values, needs and experiences. A high degree of compatibility leads to faster rate of adoption. Cultural and religious aspects often play a significant role in the questions with regards to compatibility. Thereby for an innovator it is essential to know the cultural atmosphere of the target market when aiming to commercialize innovations (Rogers, 1983).

### ***Complexity***

If an innovation is easy to understand and use, it will be adopted more rapidly. It takes more time to educate people about the use of an innovation with high complexity, and thereby the adoption takes more time (Rogers, 1983).

### ***Trialability***

Dealing with large volumes in the packaging industry, product changes are big projects which need careful planning and several test rounds. Trialability is essential in order a product to be even considered. With low level of trialability, the adoption of innovations leans on the leap-of-faith, which might never occur (Rogers, 1983).

### ***Observability***

Observability is the degree to which the results of adoption can be seen. The more visible results are for individuals, the more likely they are to adopt the innovation (Rogers, 1983).

### ***Uncertainty***

The adoption of an innovation entails uncertainty. It is impossible to know precisely beforehand if the expectations concerning cost saving or quality improvement are realistic or what unforeseen challenges will arise during the adoption. The crucial question remains to be: how much spending and for how long might be required before the performance is up to the required standards or observations and is there a risk that this will never be achieved (Nooteboom, 1989).

## **5.2.2. Adopter characteristics**

Relying on earlier research, Frambach and Schillewaert (2002) identify three types of adopter characteristics at the organizational level: organization size, organization structure and organizational innovativeness. Size is usually found to be positively related to adoption. That is because larger organizations might feel a greater need to adopt innovations in order to improve their performance. It is somewhat controversial to the common belief that small organizations are more flexible and innovative, leading to an enhanced receptiveness of new innovations. To find consensus to these two contrary arguments other factors need to be considered at the same time. These factors are structure, strategy and culture. Organization structure can either facilitate or inhibit innovation adoption. According to Zaltman et al. (1976), more formalized and centralized organizations are less likely to initiate innovation adoption decisions, but are better equipped to implement these innovations. Highly complex or specialized organizations are relatively poorly equipped for innovation implementation. The degree to which an organization is receptive to new products or ideas will influence its propensity to adopt new products.

### **5.2.3. Environmental influences**

The business environment has a significant effect to the adoption behavior. A potential adopter may gain intrinsic benefits in the form of network externalities if business partners within their network have previously adapted the innovation. In the case of organizational adoption, there are positive externalities if the intrinsic utility of an innovation increases when a firm's suppliers, customers, competitors or other organizations also use the innovation. In highly competitive markets, one might be forced to adopt an innovation in order to maintain market position. Not adopting an innovation everyone else is using might lead to competitive disadvantage. Higher levels of competition are found to stimulate innovation adoption (Robertson and Gatignon, 1986).

### **5.2.4. Supplier marketing efforts**

Successful supplier marketing can increase the probability of innovation adoption by organizations. The three most important factors within supplier marketing efforts are targeting, communication and risk reduction. Targeting, when executed carefully and in a specific way towards selected potential adopters, can facilitate acceptance in the market. Some organizations might be more adoptive to the innovation than others, the key is to identify these organizations and target them in marketing efforts. Innovation adoption is largely an innovation-processing activity. Thereby supplier communication activities will not only create awareness, but also influence the adopters' perceptions of the innovation. Adoption of innovations is often perceived risky. By reducing the implementation, financial and operation risks, the adoption of innovation can be stimulated. Some ways to demonstrate risk reduction are free trials and lower introduction prices (Frambach and Schillewaert, 2002).

### **5.2.5. Social network**

The interaction between members of a social network can enhance the speed and rate of innovation adoption. Interaction in networks increases the spreading of information and mutual trust, which positively affects innovation adoption. Such networks can consist of contacts within one industry or across different industries. The degrees to which organizations share information with others are referred as their interconnectedness. The higher degree of interconnectedness, the more likely they are exposed to new innovations (Frambach and Schillewaert, 2002).

## 6. Empirical evidence

In order to properly analyze the different stakeholders' points of interest it is vital to understand the shape of supply chain in the packaging industry. The supply chain consists of the material producer, packaging converter and brand owner. The material producer manufactures the base material used in packaging. The task of packaging converter is to convert the material manufactured by material producer into a desirable shape for the brand owner. They turn the board into a packaging box. Brand owner uses the packaging to protect his product and is thereby the customer for both material producers and packaging converters. Introduction of sustainable packaging benefits the whole supply chain in the form of more sustainable image. Packaging converter able to handle a new sustainable material can differentiate from the competitors by offering the ability to convert the material into packaging. Improved barrier in packaging benefits in first hand the brand owner by enabling improved shelf life and better protection to the packed goods.

The results presented here are based on the semi-structured interviews conducted with different stakeholders; including R&D personnel and sales people from the supply side and packaging managers from the brand owners' side. Empirical results are summarized in table 16.

Sustainability	Level of importance is market specific Change in sustainability of packaging alone not enough to cause wide diffusion Company value in each company, but not one of the most important ones	
Price premium	3-5% acceptable	
	In some cases a premium up to 10% possible Price premium more common in high-end products	
Adoption barriers	Lack of information Insufficient product performance Reluctance for change among packaging converters Risk aversion among brand owners	
Market potential	Potential in several markets once material characteristics are sufficient	
	Market readiness towards adoption is already evident	
Future forecast	At least 10% market share in next 10 years in barrier packaging	
	Multiple diffusion curves in several markets Sustainability in packaging is a growing trend	
Institutional effects	Government intervention not likely to affect diffusion	
Challenges in early adoption	Compatibility in the production process	Lot of challenges
	Supply chain	Little (Big companies), A lot (Small companies)
	Waste management	Positive effect
	Trialability	Mixed results
Market demand	Retailers	Important, but not evident yet
	Consumers	Likely to arise in the near future
	Connected to demand towards organic food products	
Sustainability in packaging	Year 2010: All about minimizing amount of packaging material	
	Year 2015: Minimizing amount of packaging, recyclability, reducing product waste with better barriers	
	Future: Growing trend towards optimizing packaging materials	
Perceived innovation characteristics	Relative advantage	
	Compatibility Reduction of uncertainty	
Adopter characteristics	Organization size connected to opinion leadership Size likely to enhance adoption but not adoption speed	
Environmental influences	Reluctant converters a serious barrier for adoption	
	Competition enhance innovation and willingness to take risks	
	Increased amount of suppliers enhance diffusion	
Supplier marketing efforts	Marketing and information spreading essential	
	New product offerings more suitable markets than traditional products	
Social network	Joint development speed up adoption and give credibility	
	Brand owners as development partners beneficial	

Table 16: Summary of the empirical results

## 6.1. Diffusion barriers

Economic, behavioral, organizational and structural barriers are all evident when commercializing MFC barrier films. In order to incentivize companies to adopt the technology, the economic benefits must be evident. The brand owners are not willing to change packaging solutions by the argument of improved sustainability alone. In order to awake the interests of brand owners to consider changing packaging materials, the new material must have greater barrier properties, lower price or other benefits in addition to improved sustainability. Brand owners were unanimous in that they would not change to a barrier with improved sustainability but similar other characteristics. However, they did not demand all the characteristics to be improved. The packaging industry is very price sensitive, especially in the bulk products. Some high-end products are less price-sensitive and thereby in those products companies are more willing to pay a premium from improved packaging. A premium of 3-5% percent is acceptable with an improved product and one interviewee stated that: *“for the right offering a premium can be up to 10%”*.

The interviewees from smaller companies reported especially the lacking access to information to be a barrier. These companies are highly under the influence of their packaging converters, since they have no resources for in-house packaging development. They reported high willingness to achieve more information about possible packaging solutions and considered the packaging converters as reluctant in introducing new possibilities. They considered that the packaging converters would not want to introduce any new solutions because that would distract the existing business relationship.

Behavioral barriers were evident especially in the tendency for risk-aversion. All the brand owners were considered as risk-averse and especially larger corporations were unwilling to adopt anything without clear evidence about improved profitability. Smaller companies, while being risk-averse, showed interest in new solutions but considered the lack of information as a large barrier. Other actors in the supply chain can either be a barrier or a driver towards diffusion of sustainable packaging barriers. When a retailer makes a decision to improve sustainability in their products, it is clearly a driver. Packaging converters reluctant to change can be seen as a barrier and the significance is dependent on the negotiation power situation between the actors. Interviewee of the small start-up company summarized the situation with the following words: *“Being a small customer for a packaging converter is frustrating; you often need to be the one providing solutions for the supplier whose task is to provide solutions.”* The technical team identified structural barriers as a challenge. Within food products the regulation is high and the need to pass all necessary approvals was identified as a time consuming challenge. On the other hand, an introduction of regulation demanding more sustainable packaging would be extremely beneficial for the diffusion of MFC barrier films.

## 6.2. Rate of adoption

The sales team saw a lot of opportunities with the use of MFC. They suggested many different end uses and saw large potential with MFC once the material characteristics are in shape. Also the brand owners were confident that sustainable packaging barriers will gain at least a 10% market share within the next 10 years and become serious complements to traditional barriers. This indicates that MFC as a packaging barrier is not likely to have a singular diffusion S-curve, but rather multiple diffusion curves. It is not worthwhile to put too much effort in selecting a specific market based on the volume potential alone, since the

product is likely to penetrate other end-use markets after the initial diffusion. The results showed that the surrounding atmosphere is ready for MFC barrier films, once the material characteristics are in appropriate level. Additionally the significance of sustainability in packaging is growing, which indicates a growing market potential in the near future. However, the average diffusion time from the first introduction in packaging solutions was reported to be between 1 and 3 years. This time could in some situations be reduced to 6 months if the solution can be produced on the existing packaging lines.

The main decision makers with regards to adoption of new packaging barrier solutions are, among the large corporations, the packaging developers. According to an interviewee: *“The company needs to contact the true influencers who can make the call and they are the packaging developers”*. Since smaller companies do not have the resources to employ packaging developers, the packaging converters have much of the authority. Managers of these companies are highly influenced by the packaging converters. However, in the end the final decision maker is the end-customer. End-customers direct the retailers by their purchasing decisions, which in turn give demands to the brand owners. Retailers need to see the customer interest in order to accept products with divergent price or shelf life, caused by the packaging.

### **6.3. Diffusion of eco-innovations**

The sustainable nature of MFC gives possibilities. Since the change to sustainable MFC barrier film from other materials would bring positive externalities to society by reduced environmental impact, there is a possibility of new regulations to be introduced. This is not likely to affect the market penetration of MFC barrier films, since a well-known, alternative, solution is needed before these regulations can be considered. The interviewees saw no regulation today and predicted no regulation changes that would radically affect the diffusion of MFC barrier films in the next 5-7 years.

The brand owners saw a lot of challenges with a shift to sustainable barrier packaging with regards to compatibility in the production process. The shift would, according to the results, introduce only small challenges with regards to supply chain for the large corporations and larger challenges for the small companies. The interviewees predicted a somewhat positive effect to waste-management process with the shift. The interviewees gave mixed results about the challenges in executing a trial in the production process and markets.

The brand owners saw the demand from retailers' side to be an important driver towards adoption of sustainable packaging, but could not in fact identify this demand yet. Still, the interviewees identified sustainability as a growing trend in packaging applications. Companies are very much product focused. The growing consumer demand towards sustainability has led to the introduction of more sustainable products that are then packed with traditional materials. The interviewees, however, expected this demand to spread towards sustainability also in packaging.

### **6.4. What is sustainable packaging?**

A majority of the brand owners ranked minimizing the amount of packaging material as the most important part of sustainability for them. This way of thinking has been popular during the recent years. However, according to Innventia (2013), by 2020 the question of how to best



achieve sustainable packaging will increasingly be seen as a challenge of optimizing packaging material instead of minimizing it. This goes hand in hand with the change of attitudes towards packaging. When today packaging is for many consumers seen as excessive and bad for the environment, the attitudes will partly change towards embracing the role of packaging due to technological advances and more holistic approaches in packaging. During the last decade, sustainability has become the main concept used to frame environmental issues. For packaging, sustainability is often about trade-offs and optimizing packaging material rather than minimizing it (Innventia, 2013). Five years ago the attempts to increase sustainability was mainly done by aiming of reduction in packaging materials. Today the focus has shifted to reducing product waste with help of better barriers and also partly towards recyclability.

All of the interviewed companies identified sustainability as one of their company values. However, in none of the companies was sustainability seen as the most important value; other factors come first. Sustainability was seen as important both as a corporate responsibility and a customer demand aspect. The customer demand side was generally seen as a more important part, but it is highly dependent on the market. In Western Europe, where there is visible demand for sustainability from the customers, it is seen as important. On the other hand, in Eastern Europe, the interviewees did not recognize any consumer demand towards sustainability. Sustainability in that market was mainly considered a corporate responsibility. Overall sustainability in packaging applications was seen as a good tool to increase brand reputation. However, sustainability in barrier packaging, being less observable, was seen only as a possible branding tool.

From the consumers' side they interpreted the demand to be connected with the demand for organic products. The group of people demanding organic food products is likely to also want sustainable packaging. The main customer benefit in eco-innovations is the perceived image of environmental friendliness. This is also expected to be the main driver in introducing MFC barrier films in packaging applications. Problematic with barrier packaging is that the end-customers know very little about it. The perceived image requires marketing efforts. The demand from retailers' side requires better knowledge among customers about the current solutions. In addition to the previous, a better knowledge about possible future solutions among the brand owners is needed, in order to direct them towards adoption. Once the demand towards sustainable barrier packaging comes from the retailer's side, they are more willing to accept a higher price. In adoption of MFC barrier films, the secondary factors of increased variety of options and firm specific values was seen as less important by the brand owners.

## **6.5. Organizational innovation adoption**

The initiation stage of organizational innovation adoption starts when the packaging developer becomes aware of a possible new solution. All the brand owners in this study responded to be willing to receive more information about new sustainable barrier solutions. They considered their current range of knowledge as average. With this the overall opinion was that the brand owners in general have quite little knowledge about the possible solutions. They were, however, skeptical about the ability of sustainable barrier packaging to meet the criteria of their packaging. The main perceived problems were the problems with water-vapor barrier and sealability. They were, however, confident that these problems will be solved within the coming 10 years and then the solutions will be suitable.

### **6.5.1. Perceived innovation characteristics**

From the perceived innovation characteristics, especially three factors were considered of high importance; relative advantage, compatibility and uncertainty. Relative advantage was the most important, since the industry is very price sensitive and also the demand for better barrier protection is evident. The brand owners were most interested in whether the product would bring cost savings or improved barrier protection. Compatibility was seen as something that would seriously speed up the diffusion process. Goods are packed in large packaging lines with high speed and a better product that could be packed in the existing packaging lines would be attractive. Risk-averseness among the brand owners can be seen by the demand for proof of concept in actual use before adoption. The large corporations are seen as opinion leaders but they, however, demand evidence that the product is actually in use and functional. The large corporations want to reduce the uncertainty, maybe even with the cost of missing valuable first-mover advantages. The complexity and lack of observability of the innovation was not seen as a problem from the brand owners' side, but the poor visibility of the change for the end-consumers was considered problematic. Trialability was seen as important, because without trials the product will never be adopted. Some interviewees, however, mentioned that once the product has been introduced to the market, it will also be used in the long term.

During the last five years, the focus in barrier packaging has shifted from price being the most important factor to product safety today. The significance of product safety is clearly visible, but price still remains highly important. Among product safety and price, the quality of barrier is also important. Increased barrier quality was also seen as a tool to increase sustainability, because longer shelf lives reduce the amount of product waste.

### **6.5.2. Adopter characteristics**

The adopter characteristics were investigated by interviewing different brand owners and comparing the results. Organization size seems to be connected with opinion leadership and is also with the attractiveness due to large production volumes. Large companies often have clear strategies and more standardized processes than the smaller companies. The companies with clearly defined strategies were less willing to shake the system by considering new packaging solutions. However, the organization size enables resources, which leads to better knowledge about possible solutions. Thereby the size is likely to enhance adoption but not adoption speed.

### **6.5.3. Environmental influences**

Environmental influences play a large role in the adoption of new barrier packaging solutions. All the actors in the supply chain must adapt to the new packaging material. The business environment also has significant effects. Firstly, if the converters are unwilling to introduce new solutions it is hard for a solution to penetrate the market. Secondly a highly competitive business environment will direct the brand owners to seek competitive advantage from a wide variety of solutions. One of the solutions is a differentiating packaging on the market shelf. Lastly, if several packaging producers provide the same packaging material, this will reduce the risk of adoption by increasing the amount of possible suppliers.

#### **6.5.4. Supplier marketing efforts**

Since the converters are hesitant in introducing new solutions, supplier marketing is vital for a packaging producer. The decision makers among brand owners need to be targeted in information distribution. That might not, however, be enough. The companies are reluctant to change packaging materials of their existing products, because that introduces risks in customer behavior. Companies are more willing to accept new packaging solutions to completely new products. Targeting in this case would be most effective when directed to companies which are about to launch new product categories or penetrate new markets. Offering free trials to potential customers was seen as a much better tool to enhance adoption than lower introduction prices. In packaging products, the focus is on long term costs, where introduction discounts have relatively low importance.

#### **6.5.5. Social network**

Interaction in joint development projects has been important for the development of MFC. In this way, the knowledge of several organizations can be combined. These efforts also increase the credibility of the developer. One should not be too worried about revealing the technology to the competitors, since competition in the market, especially in the early stages, can also be a good thing. Brand owners are reluctant to order products with only one supplier. This would give too much power to the supplier and make it hard for the brand owner to know the correct price level of the product. Interaction with possible customers would also be beneficial. These project development partnerships would speed the rate of adoption by the earlier start of diffusion process and increased mutual trust.

## 7. Actions

Although large corporations are seen as opinion leaders within packaging, they might not be optimal in the beginning of diffusion process. Risk-averseness among large corporations indicates that they might not be the optimal early adopters in the diffusion of MFC barrier films. Large corporations are attractive due to the volume they bring to the table. However, as mentioned before, one should not put too much effort in chasing appropriate volumes right from the beginning, since the diffusion is likely to occur in multiple waves. A good strategy could be to partner with either a smaller company with high growth potential, or with a company that is about to bring a completely new product family to the market. My suggestion is to find a development partner with desired characteristics as soon as the product has sufficient characteristics in order start trials and gain valuable feedback from the customers' side. This would also enable the proof gathering and ability to show successful trial reports to the large corporations. Then, when approaching the tipping point in the diffusion S curve, the up scaling could be done hand-in-hand with the diffusion to larger corporations. Another factor that motivates the early cooperation with customers is the relatively long shelf life of the products, up to more than one year. If necessary, free trials should be offered, since they are identified to work as a motivator for earlier adoption. The partner should be active on a field that is not extremely price sensitive and can gain brand benefits from using sustainable barrier packaging. Possible fields suitable to start with are premium dry food products such as dietary supplements, ecological dry food products, or premium confectionary boxes.

In line with Rogers' definition about diffusion, different actors need to communicate and thereby create and share information. This information towards brand owners is vital in order to enable adoption. According to the results, it takes between 1-3 years from the first contact before the product can be in use. Thereby it is essential to start the communication about new barrier film opportunities as soon as the products under development start to show signs of the desired properties. In the sales point of view, the number one priority is to be present on the customers' considerations. Since the packaging developers among large brand owners have the power to make decisions with regards to packaging changes, it is essential to hold close ties with these actors. It is vital to inform them about new possible solutions in as early stage as possible. In this way they can start the initiation stage of adoption process in time for the product not to be delayed due to hesitance from their part.

The company should not be too worried about revealing the end use targets for competitors, since the competition is often perceived as a good thing when launching a new product for high volume markets. It is easier to build a market when several actors are providing similar products. From the customers' side, possibility to choose between several suppliers speeds up adoption due to reduced risk and better negotiation situation. Competition additionally enables the customer to understand the market price for the product.

Legislation can be an enabling force in diffusion of MFC packaging barriers. However, it will not be the starting force that will introduce the product to the markets. At first, the product needs to gain public recognition, so that the decision makers are aware of these possibilities. This means that legislation will not play, at least any significant, part manipulating the adoption decisions of early adopters. In later stages, if a legislation demanding sustainable barrier packaging would be introduced, it would speed the adoption in a high magnitude.

Brand owners are not willing to use sustainable products with worse barrier qualities than the existing ones. This is especially evident in the food products already in the market. The reason

behind this is that the retailers and end-consumers have already been introduced about how long the shelf life of certain products is. A deduction of this shelf life would not be accepted by retailers and end-consumers. Thereby a wise choice might be to target companies about to launch products in new markets or completely new products, especially in a market segment where ecological values are respected.

There is a lot of uncertainty involved when commercializing new innovations. In order to make rational decisions, careful planning is needed to identify the existence and measure the level of uncertainty. The SWOT analysis in figure 9 illustrates the climate of uncertainty and also possibilities in the commercialization process.

<p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Sustainability and biodegradability</li> <li>• Monolayer packaging</li> <li>• Abundance of the raw material</li> <li>• MFC is a material with a lot of possibilities and application areas</li> <li>• Strong material with unique properties</li> </ul>	<p><b>Weaknesses</b></p> <ul style="list-style-type: none"> <li>• Price</li> <li>• Unability to be heat sealed</li> <li>• Moisture sensitivity</li> </ul>
<p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Trend towards sustainability in packaging</li> <li>• Several possible end markets</li> <li>• Climate change forces institutions and companies to support sustainable packaging</li> <li>• Increasing demand for high-barrier packaging</li> </ul>	<p><b>Threats</b></p> <ul style="list-style-type: none"> <li>• Risk-aversion among brand owners</li> <li>• Packaging converters reluctant for change</li> <li>• Legislation against nano-material</li> <li>• Other sustainable materials currently under development might outperform MFC barrier films</li> </ul>

Figure 9: SWOT analysis about commercialization of MFC barrier films

Based on the results received from interviews, in figure 10 I propose a framework to successfully commercialize MFC barrier films.



Figure 10: Set of tools to enhance and speed up the diffusion of MFC barrier films

The key areas in figure 10 consist of following determinants:

1. Technology improvement
  - a. Barrier properties
  - b. Price reduction
  - c. Sealability
  - d. Compliance with existing packaging lines
2. Marketing efforts
  - a. Contact with packaging developers
  - b. Early-stage development partners
  - c. Participation in the public debate (lobbying)
  - d. End-customer education
3. Strategic diffusion
  - a. First diffusion through new product offerings / smaller companies with growth potential
  - b. Early stage development partners – successful trials
  - c. Proof of concept for the corporations that join after the tipping point

*Technology improvements* should be concentrated on following areas: The level of barrier properties is essential; the brand owners demand greater protection and if this can be achieved with even smaller amounts of packaging, that is extremely attractive. Price needs to be on a competitive level. The brand owners are in some cases prepared to pay a premium price up to 10%, but not without performance improvements. The problem with heat sealing must be solved; either with alternative sealing options or a way to enable heat sealing. Compliance with existing packaging lines is essential. The diffusion process will be significantly harder and slower if new packaging lines are needed.

*Marketing efforts* have a large effect on the diffusion speed. It is essential to hold close contact with packaging developers of the brand owners. The packaging developers are the ones with power to influence in the case of companies who have resources to employ packaging developers. Smaller companies rely on influence from packaging converters, who are identified as a diffusion barrier for new innovative solutions. In this case, direct contact with brand owners is a good strategy to get the message to the converters on both suppliers and customer's side. Creating development partnerships with potential customers in an early stage have the potential to speed up the diffusion process. Even when regulations are not likely to have an effect on the initial diffusion, introduction of beneficial regulations can have a large beneficial effect on the level of diffusion in later stages. Thereby participation in the public debate and knowledge spreading are good ways to influence the decision makers. End-customers have little knowledge about packaging barriers. In order to create a demand for sustainable barrier packaging, end-customers need to be educated about packaging barriers. One should not be too secretive about the commercialization goals because competition in early stages can be beneficial. Launching a completely new product alone can seem tempting due to the temporary monopoly situation in the specific market. However, the market has to be built and it is easier and less resource demanding if competitors also take part to the commercialization. Additionally, the diffusion is likely to occur faster if there are several alternatives for the brand owners to choose from. Alternatives reduce their risk and liability on only one supplier.

### *Strategic diffusion*

A good way to start the diffusion process is to target the companies creating new products to new markets. Alternatively small companies with growth potential could be suitable development partners. Trials executed with these smaller customers gives credibility and proof of concept to target larger corporations. In this way the time required to reach the tipping point can be reduced.

When launching new innovations, different strategies should be used compared to existing, mature products. The allocation of resources and expected returns are not comparable to mature products and should thereby be considered separately. Experimentation and gaining proof of concept via smaller partnerships can be a good tool to build credibility and attract larger customers.

Looking at the interview results, current market share and predicted CAGR of EVOH for comparison, it is motivated to predict that if 1) films with sufficient characteristics of MFC can be made cost effectively and 2) the packaging market will continue to grow as predicted, there is a large market and a bright future for MFC barrier films. It is impossible to give reliable predictions about the market asymptote, since the diffusion of MFC is highly likely to follow the path similar to the one shown in figure 6.

## 8. Conclusions and suggestions for further research

This thesis has provided a connection of an industry under transition with scientific research on innovation diffusion. I have taken a market-oriented focus on a field that has traditionally been product focused and, with support from previous research, contributed on the transition process of forest-based industry becoming more customer oriented. In this thesis the focus is on the behavior and consequences in commercialization activities when launching an eco-innovation. The empirical evidence supports the theory of organizational innovation adoption by Frambach and Schillewaert (2002) in that the outcome of organizational innovation diffusion is dependent on supplier actions in creating awareness, customers perception of innovation characteristics and characteristics of the customer organization; with additional factors affecting these determinants.

The empirical evidence collected here approves the fact, in line with the framework by Horbach, Rammer, and Rennings (2012), that the diffusion of eco-innovations should be approached with the determinants specific to the field in mind: technology, market, firm specific factors and regulation. However, these results indicate that much attention, when commercializing eco-innovations, should be focused on creating awareness about the technology and marketing the beneficial effects of adopting it. Frambach and Schillewaert (2002) highlight awareness as a crucial element of innovation diffusion and I claim this to be a key element in the case of eco-innovations. Also Viberg (2013) conclude that a major point about launching an eco-innovation is the communication towards the brand owners and end-customers. When the benefits of the innovation are not communicated well enough to these groups, there is a hesitance to adopt the innovation.

From the market perspective I have gained similar results as Erdogan (2013) in that the packaging material market is perceived as highly cost sensitive. Erdogan (2013) analyzed the adoption behavior of the Indian food packaging industry towards bio-based plastic packaging. Even when the market and material differ, the general conclusion about the brand owners' attitudes gives similar results: the brand owners are not willing to pay a premium price for an environmentally friendly packaging material. Thereby the adoption of MFC barrier packaging film needs to bring other perceived benefits in order for diffusion to occur. The brand owners and end-customers need to be educated about the benefits of adopting the new innovation. Erdogan (2013) did not identify any increase of interest towards bio-based packaging, whereas results in this thesis give signals towards that. The reason for controversial results may be in the 2-year time distance or the different regional focus.

Leaning on empirical findings I suggest that, when the suggested actions stated in the previous chapter are taken, there is potential for wide spread adoption of MFC barrier films.

### *Suggestions for further research:*

Technical research and development should focus on improving the previously mentioned characteristics: level of barrier, costs, sealing options and compliance with existing packaging lines. The next logical step in commercialization research is to focus on identifying the optimal business model in commercializing the product. One major challenge is to educate customers about barriers and to get the benefits of MFC barrier films known to the public. Optimal marketing strategies should be investigated. Whether it is more viable to out license the product or produce in-house, is out of the scope of this study and should be further investigated. Firm specific complementary assets that are highly relevant in successful product launches also needs to be taken into account. Additionally, when a new innovation is



introduced to a large portfolio of products, the market positioning should be considered in terms of how the innovation fits the existing product portfolio. This has to be considered before the production is scaled up and the product is ready to go to market. Once the diffusion process of MFC packaging barrier film has occurred, it would be interesting to study how the determinants analyzed in this work have contributed and how the diffusion has occurred in real life. In that way, the results of this study can be challenged.

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## 10. Appendix

### Appendix A) Sustainable barrier packaging –questionnaire for brand owners

#### Company values and sustainability

1. Do you consider sustainability as one of your company's values? How can you see that in practice?
  2. Why is sustainability important for your company? Do you see it more as a corporate responsibility aspect or a way to meet the consumer demands?
    - 1 – Corporate responsibility is more important
    - 2 – Corporate responsibility a bit more important
    - 3 – Both equally important
    - 4 – Consumer demand a bit more important
    - 5 – Consumer demand is more important
  3. Rank the following characteristics in preference when adopting a new product (1 – most important; 5 – least important):
    - 1 - Relative advantage (Introduction of the product is likely to reduce costs.)
    - 2 - Compatibility (The product fits well in your production process.)
    - 3 - Complexity (The product is easy to understand and to be used.)
    - 4 - Trialability (The product can easily be experimented before the adoption.)
    - 5 - Observability (The results of adopting the product are clearly visible.)
4. Selecting barrier packaging solutions today, rank the following characteristics in preference (1 – most important, 5 or 6 – least important):
  - Product safety
  - Logistics
  - Price
  - Sustainability
  - Quality
  - Other (which?)
5. Selecting barrier packaging solutions in year 2010, to your understanding, what was the preference order of the following characteristics (1 – most important, 5 or 6 – least important):
  - Product safety
  - Logistics
  - Price
  - Sustainability
  - Quality
  - Other (which?)
6. What is the key component of sustainability in packaging for your company? (Mark the most relevant/important):
  - Recyclability
  - Biodegradability
  - Minimized amount of packaging
  - Renewability
  - Minimized product waste (due to improved packaging solution)
  - Other factor (please write which)

7. To your understanding, what was the key component of sustainability in packaging for your company in year 2010? (Mark the most relevant/important):

- Recyclability
- Biodegradability
- Minimized amount of packaging
- Renewability
- Minimized product waste (due to improved packaging solution)
- Other factor (please write which)

8. Give an example of sustainable barrier packaging (preferably something you are using):

9. Do you believe sustainability to be an important tool to increase brand reputation?

- 1 - Very important tool
- 2 – Good tool
- 3 – Possible tool
- 4 – Poor tool
- 5 – Irrelevant for brand reputation

10. Do you believe sustainability in barrier packaging materials to be an important tool to increase brand reputation?

- 1 - Very important tool
- 2 – Good tool
- 3 – Possible tool
- 4 – Poor tool
- 5 – Irrelevant for brand reputation

11. Has your company shifted packaging materials in recent years, or do you plan to do so, to improve sustainability? If so, in which products and when?

#### Product segment

12. From your product family, can you identify any categories/products where the use of environmentally friendly barrier packaging would be especially beneficial from the brand perspective? Which?

13. From your product family, can you identify any categories/products where you or other stakeholders are not satisfied with current packaging barrier solutions? Which?

#### External factors

14. From your product family, can you identify any category/products where the end customers will demand the use of environmentally friendly barrier packaging in the next 5-7 years? Which ones and how soon?

15. Do you see any incentives in the legislation today to shift to a more sustainable barrier packaging? What? How does this affect your decision making?

16. Do you expect any changes to happen in the legislation around barrier packaging in the coming 5-7 years? In which markets especially?

17. Do you see any incentives from other actors in the supply chain for more sustainable barrier packaging? How does this affect your strategy?

18. Do you expect the other actors in the supply chain to be a barrier or driver to the adoption of more sustainable barrier packaging for you?

- 1 – Other actors are clear drivers towards sustainable barrier packaging.
- 2 – Other actors have somewhat positive impact towards the adoption of sustainable packaging
- 3 – Other actors are neither drivers nor barriers
- 4 – Other actors have somewhat negative impact towards the adoption
- 5 – Other actors are a clear barrier to the adoption of sustainable barrier packaging

#### Economic aspects

19. Do you expect that consumers are willing to pay a premium price for products with sustainable barrier packaging? How big premium and what percentage of customers?

- Size of premium:
- Percentage of customers:

20. Would you expect any change in your revenue if you were to shift to more sustainable barrier packaging?

- Short term:
- Long term:

21. Do you believe the price to be the most important factor when considering a shift from oil-based polymers to more sustainable materials in barrier packaging? What other factors affect and how big is their importance compared to the price?

- Other factors:
- Importance compared to price:

22. Is your company interesting in paying a premium price for a sustainable product with similar properties than existing solutions?

- 1 - Yes, that is very likely
- 2 - Yes, possibly
- 3 - Uncertain
- 4 - Not likely
- 5 - No, absolutely not

23. How big a premium would be negotiable?

- 1 - 10 % or over
- 2 - 6-9%
- 3 - 3-5%
- 4 - 1-2%
- 5 - No premium

#### Compatibility

24. Do you think that a shift to a more sustainable barrier packaging would introduce challenges with regards to compatibility in your production processes?

- 1 – No problems at all
- 2 – Only small challenges
- 3 – Uncertain
- 4 – Some challenges
- 5 – A lot of challenges

25. Do you think that a shift to a more sustainable barrier packaging would introduce challenges with regards to compatibility in your supply chain?

- 1 – No problems at all
- 2 – Only small challenges
- 3 – Uncertain
- 4 – Some challenges
- 5 – A lot of challenges

26. How do you expect a shift to more sustainable barrier packaging to affect your waste-management process?

- 1 – Improved waste management
- 2 – Somewhat positive effect
- 3 – Uncertain
- 4 – Some challenges
- 5 – A lot of challenges

27. Do you expect a trial with more sustainable barrier packaging to be easy to execute in the production process?

- 1 – No problems at all
- 2 – Only small challenges
- 3 – Uncertain
- 4 – Some challenges
- 5 – A lot of challenges

28. Do you expect a trial with more sustainable barrier packaging to be easy to execute in the markets?

- 1 – No problems at all
- 2 – Only small challenges
- 3 – Uncertain
- 4 – Some challenges
- 5 – A lot of challenges

29. How long does it approximately take from the first contact before a new barrier packaging product is applied to your packaging process?

- 1 – Less than 6 months
- 2 – Less than 1 year
- 3 – Between 1 and 3 years
- 4 – Between 3 and 5 years
- 5 – More than 5 years

#### Consumers

30. Do you consider the demand from your retailers to be an important driver for adoption of more sustainable packaging?

31. Do you consider the demand from your end-consumers to be an important driver for adoption of more sustainable packaging?

#### Information

32. How would you rank your range of knowledge about possible sustainable barrier packaging solutions:

- 1 - Very good - Extensive knowledge
- 2 - Good - Fairly good knowledge
- 3 - Average knowledge
- 4 - Less than average knowledge
- 5 - No knowledge



33. Would you like to have more knowledge about possible sustainable barrier packaging solutions:

- 1 - No need
- 2 - Not really
- 3 - Indifferent
- 4 - Yes, some additional knowledge would be good
- 5 - Yes, I would like to know a lot more

Product performance

34. According to your knowledge, do the sustainable barrier packaging solutions have sufficient characteristics to be used in your products?

- 1 - Yes
- 2 - No

35. If you answered no, please describe the lacking characteristics:

36. Would you consider using a sustainable barrier product with weaker barrier properties than in your current (non-wood-based) solution? In which products?

37. Do you believe that sustainable barrier products with adequate properties for your needs will be introduced in the next 10 years?

38. What is your prediction for the next 10 years with regards to sustainable barrier packaging?

- 1 – Sustainable barriers will replace the traditional barriers in packaging completely
- 2 – Sustainable barriers will become serious complements to the traditional barriers
- 3 – Sustainable barriers will gain a market share over 10%
- 4 – Sustainable barriers will gain a market share less than 10%
- 5 – Sustainable barriers will not be able to achieve markets from traditional barriers

## **Appendix B) Questionnaire for sales managers**

Please describe the typical sales process of your packaging products.

Describe also your interpretation of the customers' decision making process. What are the most important factors to consider?

What is the most important criteria the brand owners look for in packaging?

What kind of minimum criteria do they have with regards to barrier properties, strength, price, appearance and sustainability? How would you rank these aspects in significance?

Are the customers at all flexible with the price when some of the other factors would improve significantly? How about sustainability in specific?

Which are the segments where demands for oxygen and grease -barriers are specifically important?

Can you identify any products or segments where the sustainability would be of high importance? Any other segments that would be relevant?

In the recent years, have you identified any shifts in the customers' interests? Elaborate with regards to the above mentioned characteristics.

## **Appendix C) Questionnaire for technical team**

Where would MFC be suitable?

I understand that an MFC film gives an oxygen and grease barrier, but what about other properties?

What do you think about possible markets for MFC films?

How is the price compared to substitutes?

Does the solution give any additional benefits?

How does the solution differ from substitutes?

What is the predicted timeline for the product?

How does the R&D process work with a new innovation?

At the moment, when there basically is no clear market for MFC films, how do you determine on where to focus on?

What is your prediction on the legislation and how will changes in it affect the commercialization?

What could the innovator do with regards to government decisions?

Customer behavior:

Markets:

Competition:

Additional information: