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INSPIRE

Towards growth for business by flexible processing in customer-driven value chain

EC GA 723748

Deliverable D3.1
Report on Spatial Flexibility
V 1.4

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D 3.1 – Report on Spatial Flexibility

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Chapter 1

Introduction

This report contains the findings from a study on innovative business models that ITIA, PNO, TNO, and ZLC have conducted on behalf of the European Commission for WP3 of the GA Nr.723748 - INSPIRE under H2020-IND-CE-2016-17/H2020-SPIRE-2016.

As one of the major motivations of the INSPIRE project is to develop mechanisms and solutions to make European process industry more competitive and relocalize high-value added activities in the medium term, we first present the results of our research on the major drivers of the delocalization (both the reasons why European firms offshore and/or reshore) in Chapter 2. This helps us understand what factors to focus on when developing novel business models for deliverable D3.2. Based on the aforementioned research, we find that "*flexibility and ability to supply*" emerges as one of the major drivers for companies to retain (to maintain high-value added activities in Europe) and/or reshore (to bring back high-value added activities to Europe). Reshoring is preferred by companies in order to attain operations that are more flexible. This flexibility enables the firm to respond to changes in demand faster as a result of reduced lead times. In addition to being more responsive, this flexibility also allows firms to customize products/services and reduces the difficulty of organizing production overseas. Therefore, we think that it is imperative for the European process industry to employ business models that would allow them to dynamically respond to changes in the business environment leading to sustainable growth. Following a brief introduction to the business model archetypes that were selected in WP1, we present our preliminary findings in regards to the value of developing flexibility in reversing the delocalization trend and how the business model archetypes facilitate this process in Chapter 2. Although it is discussed in more detail in Chapter 2, the figure below from the 2016 ERM report (in addition to other similar findings presented in Chapter 2, where flexibility emerges as a driving force for reshoring) shows that flexibility is a key element for reshoring back to Europe for not only the chemical industry, but other manufacturing sectors as well:

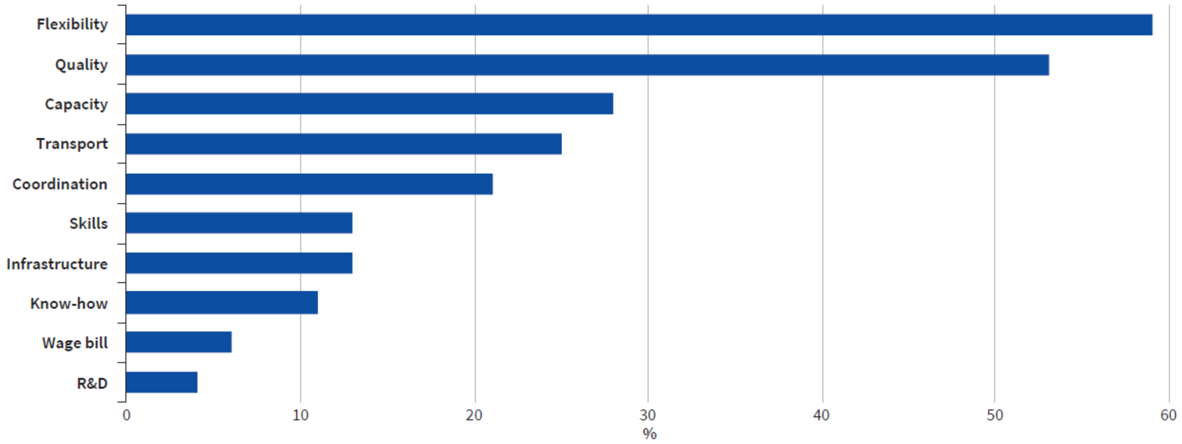

Figure 1: Main reasons for reshoring reported by German manufacturers Source: ERM

We continue with the detailed evaluation of the business model archetypes developed in WP1 in Chapter 3. The four business model archetypes are **Decentralized and/or Modular Production, Mass Customization, Servitization and/or PSS, Reuse – Sustainability**. The The business model archetypes we have chosen are similar to those suggested in Bocken et al. (2014) (i.e., "*Maximize material and energy efficiency; Create value from 'waste'; Substitute with renewables and natural processes; Deliver functionality rather than ownership; Adopt a stewardship role; Encourage sufficiency; Re-purpose the business for society/environment; and Develop scale-up solutions*"). Bocken et al. (2014) claim that categorizing business models as such will help companies embed sustainability into their existing systems in a dynamic fashion. It also facilitates the establishment of the future research agenda for sustainable business models. Following a similar approach, in Chapter 3, we specifically discuss the challenges and issues that might potentially hinder the successful diffusion of the associated business models, which in turn helps us prioritize and figure out the most critical issues based on the needs of firms in the process industry. We also report opportunities that these models may bring so that the modified/proposed models and recommendations enable firms to take full advantage of these models in terms of creating and capturing value.

In Chapter 4, we provide a summary of the detailed analysis of some real life examples of the deployment of these business models in the process industry in order to have a better understanding of the practical challenges/opportunities that firms in the process industry face. The goal is to enrich the evaluation of the business models based on desk research and make sure that the insights are grounded in reality as well. The detailed analyses of the business cases are provided in the Appendix.

In addition to investigating the potential of these business model archetypes in developing flexibility and leading to sustainable growth in the long run, we have analyzed the impact of the archetypes on different objectives defined in the proposal stage of the INSPIRE project. Although not explicitly categorized in the list of objectives, the "*triple bottom line*" approach has been employed, as most sustainable business models need to consider the "economic, environmental, and social" aspects (see Elkington 1997). In some cases, these objectives might create some conflicts (e.g., using fossil fuel might be cheaper although it may not be the most environmentally friendly form of energy) and it may not be possible to design solutions that satisfy all such requirements. Therefore, the triple bottom line approach is necessary and quite instrumental to make sure that the business models, either alone or used in combination, would result in net positive impact on the economic gains while providing social benefits and yielding more environmentally friendly operations. We provide this analysis based on both the desk research and the business cases analyzed in Chapter 3.

The results presented in this deliverable will form the foundation of the novel business models that will be proposed later in WP 3. We aim to design and present innovative models based on this prioritization of the key challenges in the next deliverable D3.2. These innovative approaches will be validated through workshops, surveys with the relevant stakeholders (e.g., representatives from industry, academic communities aligned with the project scope) in the final deliverable of the Work Package 3, D3.3.

The methodology we followed is presented in details as follows:

- Based on *desk research* (academic peer-reviewed papers, business journals, etc.), we summarize the main challenges/risks associated with the business model archetypes in general, as well as the possibly untapped business opportunities. The objective of this exercise is to *identify potential problems with the successful diffusion of these business models* for both large and small firms, as well as the other stakeholders (e.g., governments). We plan to consider these findings when proposing innovative business models later in work package 3.
- In addition to the desk research, *based on the interviews and publicly available information*, we have analyzed eight (8) business cases in detail. The number of the cases was limited to eight (8) at this stage in order to have a detailed analysis and the selection was based on the relevance and potential impact. We have chosen the business cases that had a high score from WP 1and were representative of the process

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industry, making sure that there were two (2) cases per business model archetype. The idea is to have an in-depth analysis of these business cases to make sure that our findings are grounded in reality, and to provide illustrative examples of how these business models can be implemented and what kind of issues emerge. A detailed template is provided for all the partners to follow the same methodology when analyzing the business cases. We have taken a similar approach to the "*value-chain perspective*" (see UNEP, 2008), and considered the implications of applying the business models to activities such as "*Plan (R&D, Product Design, Testing, etc.), Sourcing, Demand Management, Manufacturing and Distribution, Pricing, Waste/Recycling, remanufacturing, Collaboration*". Collaboration was included mainly because of the value-network perspective. The template used for business case analysis is included in the Appendix.

- We provided a list of objectives (e.g., primary objectives such as flexibility and sustainability and some secondary objectives such as lower carbon emissions, labor costs, etc.) and a scoring model to investigate the potential of the business model archetypes in optimizing the aforementioned objectives. Please keep in mind that the scores in this document are mostly based on qualitative arguments, and not based on a rigorous mathematical model. The matrix that we have proposed and the scoring model is included in the Appendix.
- Based on the findings from the desk research on delocalization, business model archetypes and the analyses of the business cases, we have extracted the relevant information pertaining to the spatial flexibility. Chapter 2 of this deliverable is dedicated to the drivers of the delocalization trend in Europe and process industry, as well as the potential of the business models in developing spatial flexibility to reverse this trend.

The discussion on spatial flexibility in relation to the business model archetypes is presented in Chapter 2, followed by the general overview of the business model archetypes and the specific business case analyses are provided in Chapters 3 and 4. We conclude with general insights in Chapter 5.

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Chapter 2

2. Spatial Flexibility – Impact on Delocalization

2.1. The current situation in Europe

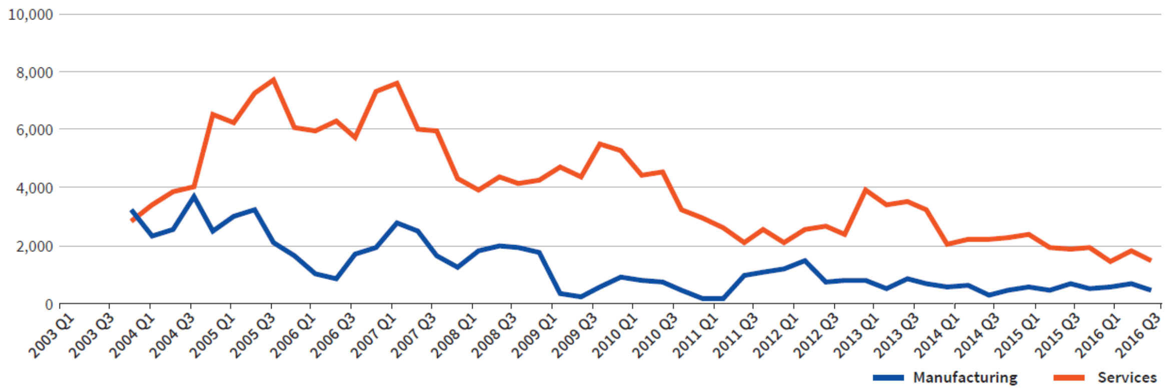
As previously defined, according to the European Commission (European Commission, 2005) delocalization (also known as relocation) is understood as "*the closing or scaling down of a firm's activities in the home market following the shifting of part of the production chain abroad*".

There is no overall indicator of the production shifting abroad from Europe, as this information is not collected across sectors neither across the countries (European Parliament, 2006). In any case, the EU considers several indicators to infer the implications of delocalization in Europe, mainly employment statistics, but also investments and sector-specific surveys to company directors.

These indicators are mainly collected for the manufacturing sector, as it is the largest sector subject to delocalization. One of these is the evolution of the manufacturing share in the total employment, even though delocalization is not the only cause for manufacturing jobs loss, as it can also be linked to automation and change in consumption patterns, among others.

Indeed, according to the ERM Annual Report (European Foundation for the Improvement of Living and Working Conditions, 2016), the share of jobs lost to regions outside Europe has decreased from 14% to 7% in the last decade. The main sectors affected by delocalization (defined also as offshoring in the Report) are motor vehicles, electronics and electrical products, amounting to 60% of the loss of manufacturing jobs. Other sectors affected by delocalization were textiles, clothing and leather, chemical and pharmaceutical sectors.

The above mentioned report shows that between January 2003 and the end of June 2016, 912 cases of offshoring ("*when a company moves some part of its activity to another country*" – EMR, 2016), including 105 cases of partial offshoring, occurred in Europe. Out of these 912 cases, 752 happened in the manufacturing sector, which translated into 209,000 manufacturing jobs being relocated outside Europe. This can be seen in the figure below:



Note: *Four-quarter moving average.*
Source: *ERM*

Figure 2: Announced offshoring job loss in manufacturing and services, 2003-2016 (Source: ERM)

In the early 2000s, the main concern was delocalization affecting high added-value areas, such as R&D. Nevertheless this concern has not been realised, as shown by ERM 2016 report. It states that whereas the manufacturing jobs lost due to offshoring represents 10% of the total jobs lost; the overall offshoring rate is 5%. It can be inferred from this is that services have had a minor contribution to the total offshoring.

Indeed, the main offshored process has been the relocation of labour –intensive parts of production to countries with lower wages, with the aim of reducing manufacturing costs.

Delocalization can obey to different causes, related to cost differences or to market expansion (European Parliament, 2006). Cost differences can be related to the availability of key infrastructure or production factors, such as labour. Market expansion factors are those linked with the willingness to be closed to suppliers, customers, raw materials, etc.

In its Global Services Location Index A.T. Kearney (A.T. Kearney, 2011) evaluates the desirability of a country for relocation against three major categories: financial attractiveness, people skills and availability, and business environment. This can be seen in the table below:

Category	Subcategories	Metrics
Financial attractiveness (40%)	Compensation costs	• Average wages • Median compensation costs for relevant positions (call-center representatives, BPO analysts, IT programmers and local operations managers)
	Infrastructure costs	• Rental costs • Commercial electricity rates • International telecom costs • Travel to major customer destinations (New York, London and Tokyo)
	Tax and regulatory costs	• Relative tax burden • Corruption perception • Currency appreciation or depreciation
People skills and availability (30%)	Remote services sector experience and quality ratings	• Size of existing IT and BPO sectors • Contact center and IT center quality certifications • Quality ratings of management schools and IT training
	Labor force availability	• Total workforce • University-educated workforce • Workforce flexibility
	Education and language	• Scores on standardized education and language tests
	Attrition risk	• Relative IT and BPO sector growth and unemployment rates
Business environment (30%)	Country environment	• Investor and analyst ratings of overall business and political environment • A.T. Kearney Foreign Direct Investment Confidence Index™ • Security risk • Regulatory burden and employment rigidity • Government support for the information and communications technology (ICT) sector
	Infrastructure	• Overall infrastructure quality • Quality of telecom, Internet and electricity infrastructure
	Cultural exposure	• Personal interaction score from A.T. Kearney Globalization Index™
	Security of intellectual property (IP)	• Investor ratings of IP protection and ICT laws • Software piracy rates • Information security certifications

Table 1: Global Services Location Index Metrix (Source: A.T.Kearney)

Specific studies have analysed the driving forces for delocalization in Europe. Kinkel & Maloca (2009) analysed in through three rounds of surveys 1663 German manufacturing companies, and questioned them, among others, on the motives for delocalising their activities.

The results of these surveys showed that the main driving force behind delocalization was the decrease in labour costs abroad compared to local costs, as indicated by 80 of the companies (see figure below). Other motives were capacity bottlenecks, opening new markets abroad, and willingness to be near customers, as well as taxes and subsidies.

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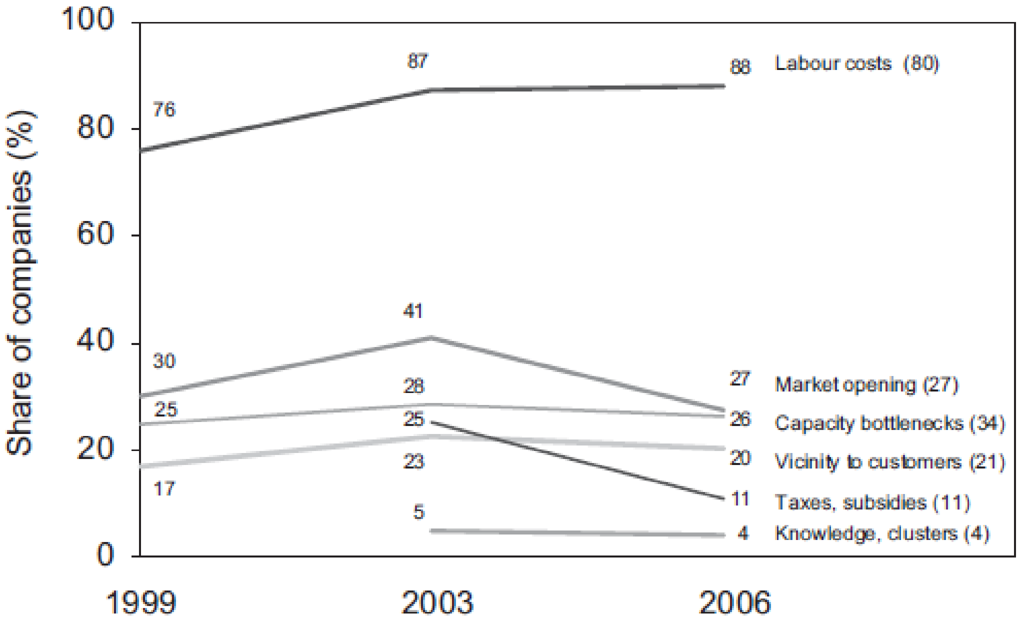

Figure 3: Motives for production offshoring over time (Kinkel et al, 2009)

Moreover, the European Manufacturing Survey (EMS) (Dachs, et al., 2006) collected data at European level on manufacturing and offshoring strategies. In its survey dated from 2003/2004 are introduced key questions on why companies offshore production facilities; these questions continue to be relevant today as this trend still exists showing that companies need to deal with these issues to have sustainable growth in the long run. This survey yielded similar results at European scale to the ones obtained at German level:

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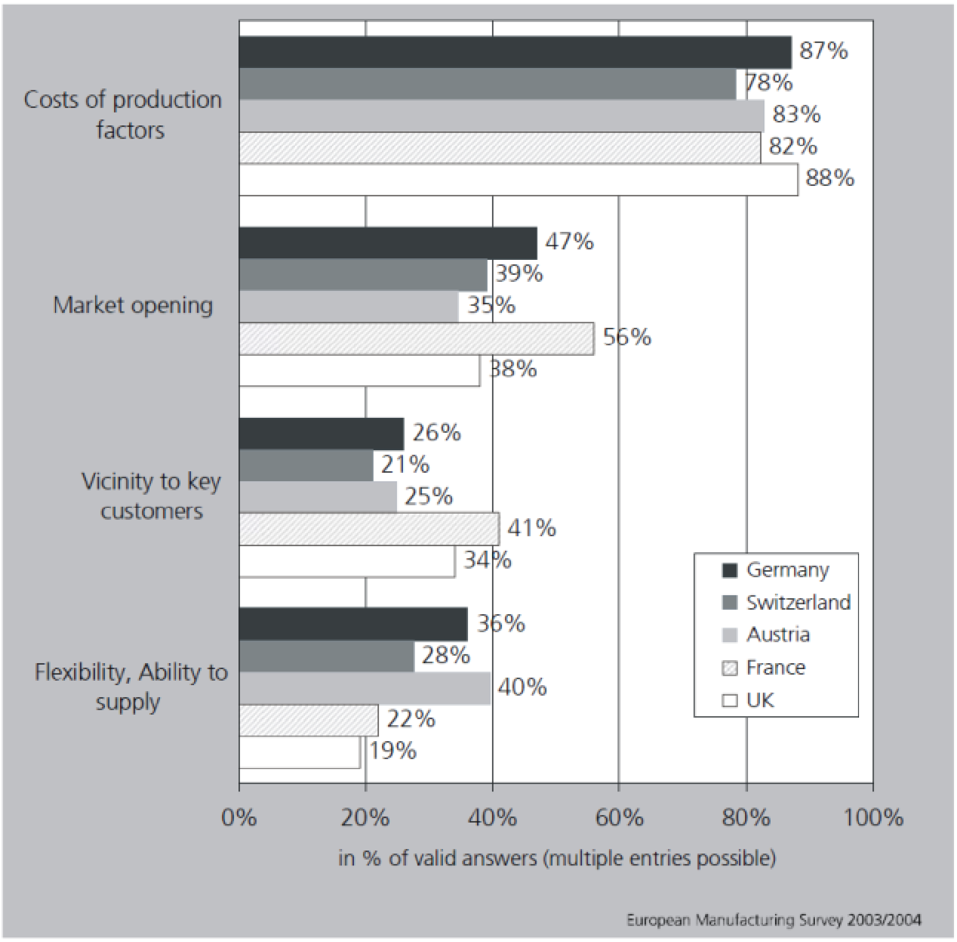

Figure 4: Motives for production offshoring. Source: EMS

The Offshoring Research Network (Ricart & Rosatti, 2009) has analysed the main activities being delocalized by industry. Specifically in Spain, the main activities offshored to elsewhere are those related with IT, sourcing and other manufacturing processes. This can be seen in the graph below:

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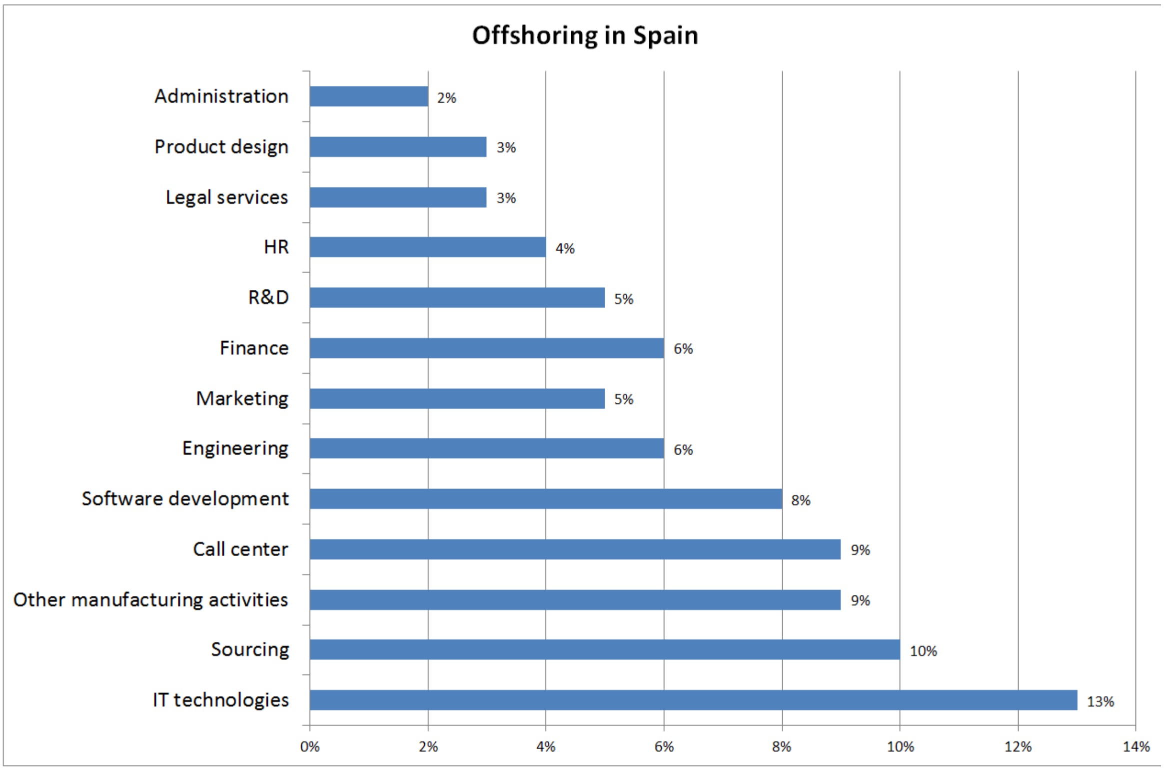

Figure 5: Activities offshored in Spain. Source: IESE

To sum up, delocalization started in Europe when the rise of globalisation was at its peak, with manufacturing industry facing competition not only from other developed economies, but also from countries with lower labour costs.

Even though there were other threats for the European manufacturing industry (da Costa, 2005), such as not investing enough in R&D, the main concern was the fact that developing countries were building competing products, with low-wage countries threatening traditional manufacturing and competing in labour intensive products from low-wage economies. Initiatives such as MANUFUTURE (Manufacture, 2016) and INSPIRE (2012) were created to design a long-term sustainable manufacturing strategy for Europe based on research. But delocalization also appeared as a trend to decrease costs and enable European companies to compete in this complex manufacturing market. However, is also necessary to contemplate the scenario where, as certain processes of the company are offshored, the ownership of these processes is also restructured, moving from a traditional fully controlled business model to one where not all operations are under full control of the company offshoring company.

But with the pace of globalization declining, there has been lower activity (of EU companies) in global value chains (ERM report 2016). This deceleration coincides with a decrease in offshoring from EU outwards that started with the global financial crisis. On the one hand, it can be argued that companies willing to offshore may have already done so in the peak of the globalization trend; on the other, as delocalizing implies major investments (redundancy costs, new facilities, etc.) it is less likely to occur during recession periods (as the perspective of returns is less appealing).

Currently the strength of the European industry lays in its know-how (ECORYS, 2009). Nevertheless, in a rapidly changing and volatile market, flexibility will be the key factor to strengthen the position of Europe.

Specifically, European process industry is facing competitive pressure, more so for commodities (energy and feedstock), but also for pharmaceutical or chemical industry. Indeed, in the chemical industry the market has become global. Worldwide chemical sales increased 14% in 2013 (CEFIC, 2016).

From a global chemical production of €3156 billion in 2013, only €527 billion were produced in the EU. Even though the sales of chemicals in Europe has almost doubled in 20 years, the European market share in the global chemical industry almost halved during this period. The figure below shows illustrates this situation:

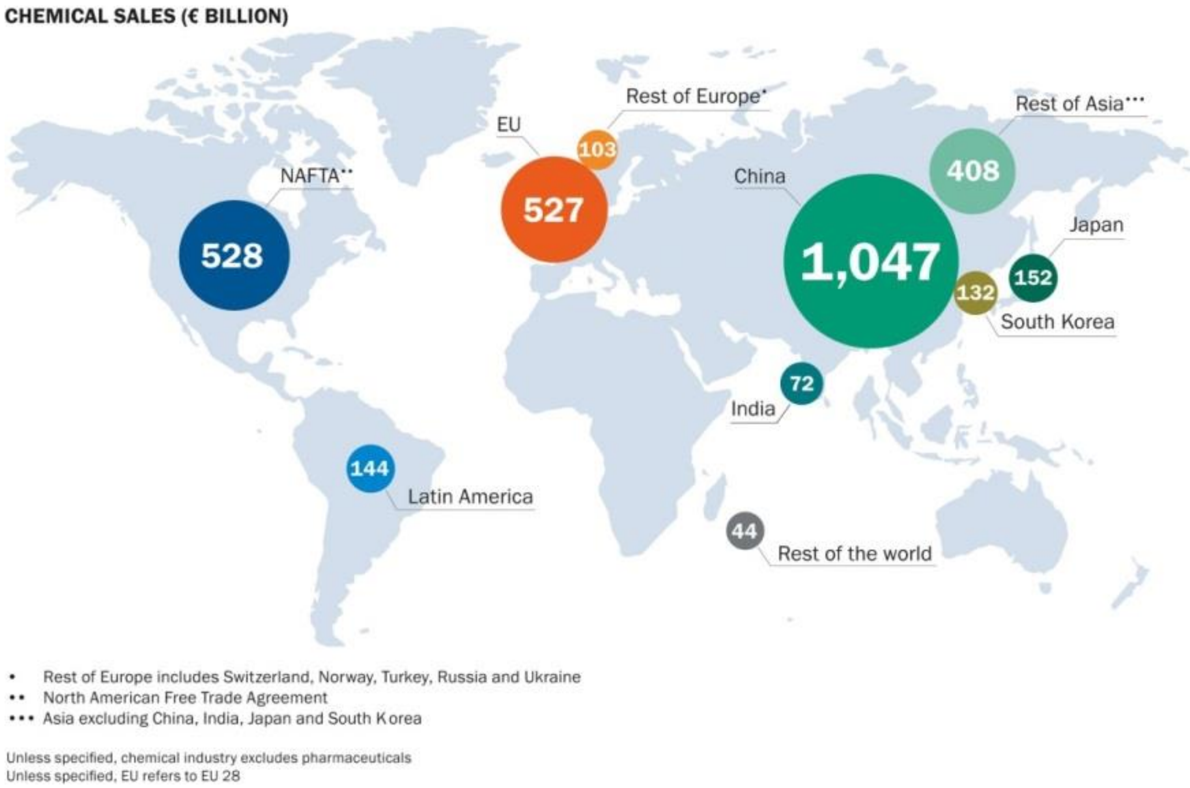

Figure 6: Worldwide chemical sales (€ billion). Source: CEFIC

Generalizing from the chemical industry, flexibility is also considered as a key element for other manufacturing sectors. As stated in the 2016 ERM report, the main reason for reshoring back to Europe is flexibility (see figure below):

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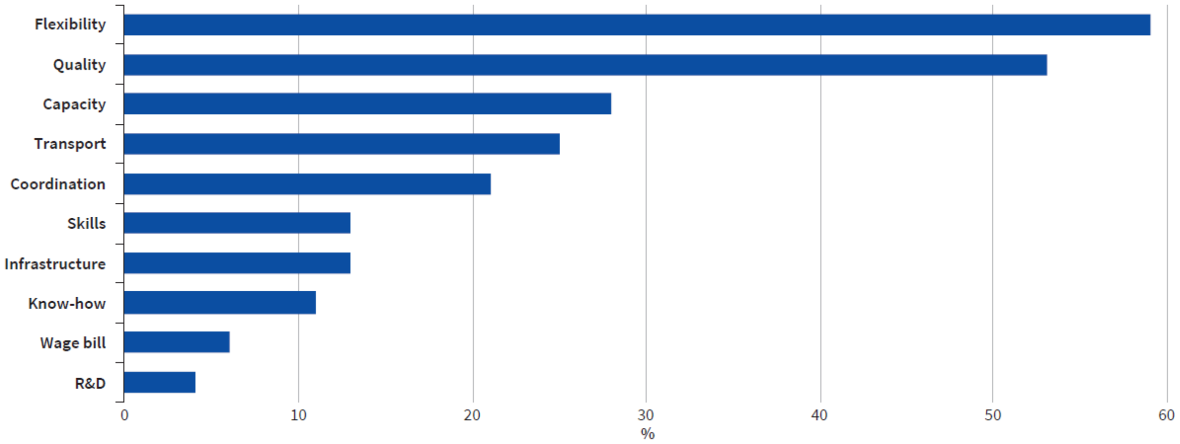

Figure 7: Main reasons for reshoring reported by German manufacturers Source: ERM

The flexibility attained through reshoring reduces the difficulty of organizing production overseas by increasing the operational control of the company over different processes (just the mere effect of being closer to where operations take place), reduces time lags to respond to demand changes, as well as lead times, resulting in higher responsiveness and higher potential for customization.

These results are also backed by the European Manufacturing Survey 2003/2004, which are shown in the following figure:

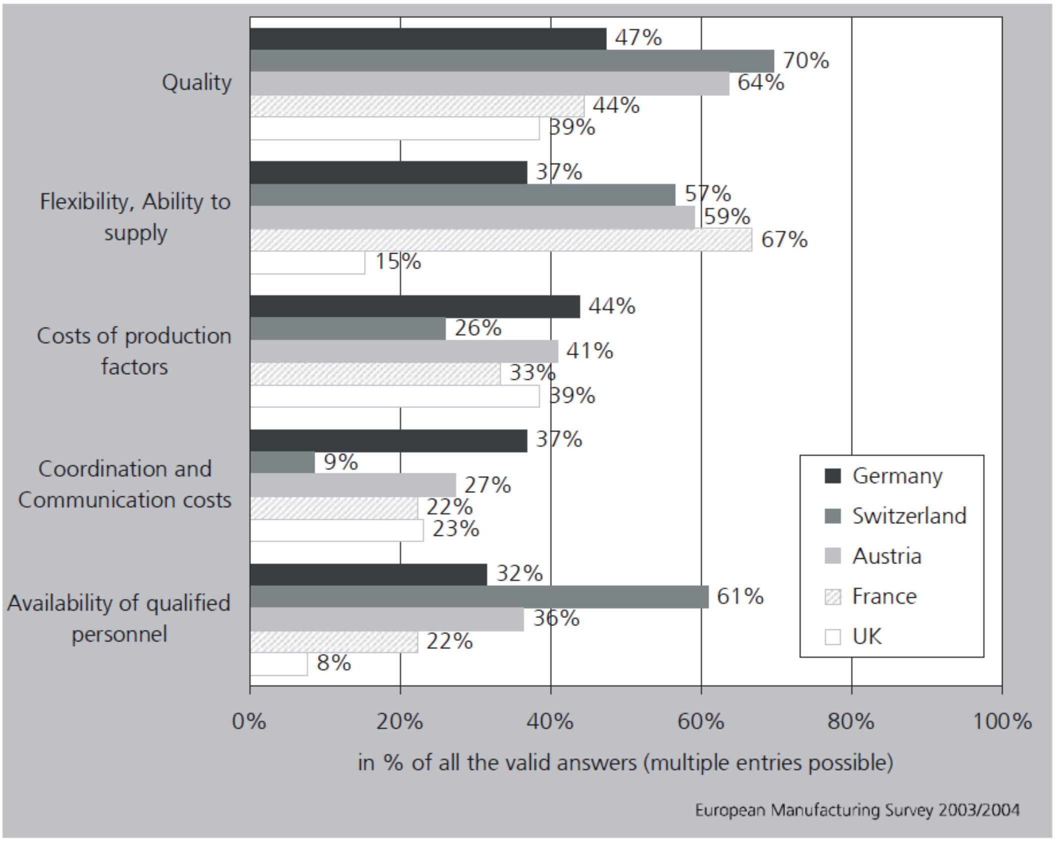

Figure 8: Motives for backsourcing. Source: EMS

These are therefore the factors driving backshoring (defined as "*the act of reintroducing domestic manufacturing to a country*" - Oak, 2010), the phenomenon of bringing manufacturing back to Europe. There may be other external circumstances resulting in a decline in offshoring. Some of them could be, according to ERM:

- reduction in the labour costs differentials between Europe and destination countries
- less labour-intensive manufacturing
- awareness of the costs of managing complexity overseas
- higher transportation costs
- synergies between R&D, product development and manufacturing when all take place in the same location

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2.2. Spatial flexibility

Spatial flexibility is determined by different parameters and "*reflects which operations can be performed where, at what scale, at which performance level and in which timeframe*" (INSPIRE, 2017). As stated in the previous section, drivers of delocalization will be less powerful if European companies, and process industry at large, makes investments in creating more "flexible" sourcing/production/distribution/recycling systems. Major drivers such as high labor cost, high and volatile feedstock prices, availability of raw materials, and market expansion will be mostly addressed by more flexible systems. In order to illustrate spatial flexibility implications, those parameters have been analyzed in the proposed business model archetypes/cases. In what follows, we explain what is meant by the parameters defining spatial flexibility (e.g., "where", "scale", "performance level", and "time frame") as defined in the INSPIRE project:

- **WHERE**: The flexibility here refers to the locations where the firms can deploy the particular business model and be competitive. It evaluates the flexibility regarding at what locations the firms would be able to source/manufacture/sell, secure the necessary raw materials/feedstock/energy/water, can construct factories for manufacturing, design products, and recycle/reuse the excess stock or wasted items/materials. The more flexible a firm is in this regard, the more potential it has to adapt or expand its operations and be present in different locations and markets. More flexibility in this aspect would help reverse the delocalization trend if more locations within Europe would become candidates for firms to operate at, creating an overall more competitive European Process Industry.
- **SCALE**: The flexibility here refers to the ability to increase or decrease the production levels when necessary based on the input parameters (demand, raw material costs, etc.). It is also about the ability to be able to produce (offer) different types of products (services) at reasonable cost. Therefore, we aimly consider the "capacity" and "product" flexibility in this section. Combined with "where" the same business model can be implemented for a particular firm, it defined the capacity of the firm to produce/offer as many as it wishes of as many different types of products/services.
- **PERFORMANCE LEVEL**: This section mainly considers the feedstock flexibility (being able to work with alternative feedstock available), the flexibility that would facilitate the optimization of resource usage, cost and environmental impact reduction techniques, new business opportunities and job creation. The more flexible the firm is

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in this aspect, the better able to control these key performance indicators and achieve improvements.

- **TIME FRAME**: Here, we mainly discuss in which time frame these business models can be deployed, and how fast they are able to respond to changes in customer demand, input parameters (cost of raw materials, availability of energy/water etc.). The more flexible the firm is in this sense, the quicker the business models can be deployed as well as the faster it adopts to changing requirements/market conditions.

In the following section, we present a summary of our findings regarding spatial flexibility for each business model archetype. In the previous section, we have already established the link between flexibility and delocalization, with the conclusion that flexibility will enable companies retain or bring back manufacturing to Europe. Therefore, in the following section, our main objective here is to evaluate the potential of the business model archetypes in their contribution to the creation of more flexible systems, as well as pointing out the major limiting factors that might make it more difficult to improve spatial flexibility. We present the summaries in the following four tables:

Spatial Flexibility	DECENTRALIZED/MODULAR
WHERE	Increased flexibility to reconfigure (where local sources available): Processes to adopt to local sourcing/resources
	Increased location flexibility: Can respond to demand and products can be upgraded at different locations based on customer taste
	Increased location flexibility: Modular plants can be transported to a new location if need be and smaller plants have less restrictions because of simpler design and materials
	Increased flexibility because of reduced risk of disruptions as a result of not having all capacity at one location
	Increased flexibility: possible to move from one location to another when input factors change (cheaper raw materials, energy, …)
	Limiting factor: Where standardization is possible to make sure all products coming from different locations are identical and where maintenance/repair is possible (relatively cheap)
	Limiting factor: Not ideal in locations where IP rights are not well established/protected as it is easier to copy by competitors
	Limiting factor: Not easy to operate in locations where there are more strict local regulations/standards (e.g., production/storage of certain chemicals may be prohibited in certain locations)
SCALE	Increased capacity flexibility: More modular plants can be installed and easier to scale up and down
	Increased product flexibility: Many combinations/permutations can be offered to create new products and easier to switch from one product to another (intensified processing)
	Lower capacity per plant: Each modular plant can only produce a fraction of the centralized version
PERFORMANCE LEVEL	Increased resource flexibility: More efficient allocation of raw materials per product type stored/sourced closer to demand
	Increased flexibility to serve customers: larger product variety, localization
	Increased resource flexibility: Reuse of common modules
	Increased flexibility to serve customers: Being closer to customers, reduced outbound transport cost
	Increased flexibility to serve customers based on demand: MTO (Make to Order) rather than MTS (Make to Stock) due to smaller batch sizing
	Increased flexibility to change capacity: Lower investment to install plants and reduced costs of moving their locations
	Increased capacity flexibility: Less disruptions due to easier maintenance/repair and improved working conditions (smaller plants)
	Limiting factor: Loss of economies of scale due to production in smaller batches
	Limiting factor: Potential increase in inbound transportation costs (shipping input materials to the plant)
TIME FRAME	Increased flexibility to meet customers needs: Better (reduced) response time due to being closer to consumers (lower transportation lead time) and being able to distribute production to many locations (lower production lead time)
	Increased flexibility to meet customers needs: Reduced new product development time due to allowing parallel development, and smaller plants being more appropriate for testing new things
	Increased flexibilty to resolve quality issues: Easier to spot quality issues without a complete recall (shorter response time to failures)
	Limiting factor: Successful implementation possible when TRL is high enough (ICT and electronics especially). Intensified processing (scaled down chemical processes) is an intensive research project requiring multiple testing (e.g., Solvay)

Table 2: Spatial Flexibility for Decentralized/Modular archetype

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Spatial Flexibility	MASS CUSTOMIZATION
WHERE	Increased location flexibility: can be implemented where local skilled workforce is available who can design/produce (even consumers in case of 3D printing)
	Increased location flexibility: Localization is made possible by responding to local tastes and using local resources for production
	Increased location flexibility: Can be implemented where knowledge-based software/hardware (integration between algorithms, Computer Aided Design, Materials) exist to configure products
	Increased flexibility because of reduced risk of disruptions as a result of not having all capacity at one location
	Increased flexibility: possible to move from one location to another when input factors change (cheaper raw materials, energy, …)
	Increased location flexibility: possible to move from one location to another as long as a 3D printing machines (or modular products/components in other cases) are available as sharing the code to congifure products is quite cheap compared to installing new plants
	Limiting factor: Where standardization is possible to make sure all products coming from different locations are identical
	Limiting factor: Not ideal in locations where IP rights are not well established/protected or software piracy is common practice, as it is easier to copy by competitors
	Limiting factor: Not easy to operate in locations where there are more strict local regulations/standards
SCALE	Increased capacity flexibility: Large scale because of modularization of products and processes
	Increased capacity flexibility: More producers (even consumers called "prosumers") can be involved in production such as SMEs as it requires less investment
	Increased product flexibility: Able to change from one configuration to another quickly
	Excess stock: Likelihood of a significant increase in the number of SKUs leading to considerable costs
PERFORMANCE LEVEL	Increased capacity flexibility (warehouse and capacity): Less inventory and transportation costs because of the lack of necessity to carry/transport components/subassemblies/tools because of additive manufacturing
	Increased flexibility to serve customers: larger product variety, localization
	Increased resource flexibility: Less input materials (raw materials, energy) used and waste generated because of additive manufacturing. Also waste streams can be reused for production in some cases
	Increased product flexibility: New product development without limits (e.g., complex geomerty) is possible and easier to switch production from one to another
	Increased flexibility to serve customers based on demand: MTO (Make to Order) rather than MTS (Make to Stock) due to smaller batch sizing
	Increased capacity flexibility: Flexible automation and ability to scale production up with lower labor cost
	Limiting factor: Loss of economies of scale due to production in smaller batches of unique products
	Limiting factor: Potential increase in the number of SKUs, especially for products where the demand is unstable and hard to forecast
	Limiting factor: "Choice" becomes an issue for customers, too many possibilities to select from
TIME FRAME	Increased flexibility to meet customers needs: Better (reduced) response time due to quicker design/protoyping/production for new product development and because of shorter production runs given that modular components and raw materials are available
	Increased flexibility to meet customers needs: Reduced new product development time due to allowing parallel development
	Increased flexibilty to resolve quality issues: Easier to spot quality issues without a complete recall (shorter response time to failures)
	Limiting factor: Successful implementation possible when TRL is high enough (flexible automation available and more widespread; ICT for communication between suppliers, manufacturers, consumers as well as additive manufacturing, advanced robotics and digital simulation for complex products)

Table 3: Spatial Flexibility for Mass Customization archetype

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Spatial Flexibility	PSS/SERVITIZATION
WHERE	Increased flexibility to reconfigure: Processes to adopt to the needs of the particular customer (localization easier)
	Increased location flexibility: Can replicate the product/service offering in different locations
	Increased resource flexibility as the supplier may be able to reuse the products and/or optimize maintenance/repair operations locally
	Increased resource flexibility because of reduced risk of product misuse and increased lifetime and therefore "less" need for being located where virgin raw materials are necessary
	Limiting factor: Applicable in locations where suppliers are not short of cash and not concerned with uncertainty in future cash flows (revenues)
	Limiting factor: Applicable where long term relationships between suppliers and users exist, suppliers are knowledgeable of users' operations and are located closeby, and where LCA can be performed by both parties
	Limiting factor: Not ideal in locations where IP rights are not well established/protected as it is easier to copy by competitors. Also, not recommendable in location where knowledge-leakage is likely and suppliers can become competitors
	Limiting factor: Applicable only in situations where monitoring of performance/results is possible so that the user and supplier can agree on the "service" being delivered as promised
SCALE	Increased capacity flexibility: Can be scaled up at different locations of the same customer and supplier if "formalization" can be done efficiently with standard services and contracts
	Increased product flexibility: Many product&service combinations can be offered with reduced investment
	Limiting factor: Hard for a small supplier to manage administrative/operational complexity of offering additional services, so this model might be limited to "large" companies only
PERFORMANCE LEVEL	Increased resource flexibility: Increased lifetime of products leading to reduced environmental impact
	Increased flexibility to serve customers: higher revenues due to additional services which in turn leads to more capable suppliers for better service providing more convenient service
	Increased resource flexibility: Maintenance, reuse, resource optimization is easier
	Increased flexibility to serve customers: Less returns from the consumers and the reduction in associated costs (return, recycling, etc.)
	Increased flexibility to serve customers based on the needs: Infinite possibilities of Product/Service combinations
	Increased flexibility to change capacity: Better visibility of customer usage (as the supplier manages the use of product in most cases) and therefore optimized capacity planning
	Increased capacity flexibility: Less disruptions due to proper use and maintenance during the use of the product, and safer environments as the suppliers may be more knowledgeable about proper working conditions when the product is in use
	Limiting factor: Less careful behavior on behalf of consumers as they don't own the products anymore in most cases, that might lead to increased consumption and waste
	Limiting factor: Potential significant increase in administrative cost and burden of managing the delivery of the services
TIME FRAME	Increased flexibility to meet customers needs: Better (reduced) response time to make the necessary changes in the product/service combination as a result of more intense relationship between the supplier and the user
	Increased flexibility to meet customers needs: Reduced new product/service design time due to increased speed of innovation/co-innovation because of better knolwedge about the customers' operations and needs
	Limiting factor: Successful implementation possible when consumers are more used to the idea of "ownerless" solutions
	Limiting factor: Successful implementation possible when TRL is high enough (ICT , enabling/mediating/facilitating technologies are availabe)
	Limiting factor: Successful coordination/integration possible when trust between partners exist and monitoring technologies to measure/validate the performance are available

Table 4: Spatial Flexibility for PSS/Servitization archetype

Spatial Flexibility	REUSE
WHERE	Increased location flexibility: As there is a new source of raw materials, plants can be located in a larger number of potential regions where previously location depended on the existance of virgin raw materials
	Increased location flexibility: Can be implemented in locations where remanufacturing industry is developed
	Increased resource flexibility because of the "**co-location**" of companies exchanging inputs & outputs
	Limiting factor: Where industrial parks/clusters exist making industrial symbiosis possible. It is more difficult to implemente reuse at remote locations
	Limiting factor: Possible in locations/regions where platforms for collection/allocation/distribution of "waste" are available and reasonably cheap for reuse and recycling
SCALE	Increased capacity flexibility: Large scale at industrial parks/clusters
	Increased capacity flexibility: Large companies as well as SMEs could integrate and/or coordinate collection/recycling/reuse so that production can be scaled up
	Limiting factor: The collection/recycling capabilities could form the bottleneck in such systems
PERFORMANCE LEVEL	Increased resource flexibility: Reduction in the use of virgin raw materials and a new source of feedstock (waste from other processes such as the petrochemical feedstock production from plastic waste/companies being reused)
	Increased feedstock flexibility: Less use of energy/water
	Increased resource/capacity flexibility: Transportation/production capacity normally used for shipping waste to landfills and/or disposal could be shifted to other processes because of less "waste"
	Increased capacity flexibility: Savings from reduced production costs could be used in increasing capacity
	Limiting factor: Potential of costs of recycling/collection/separation being too high
	Limiting factor: Potential increase in inbound transportation costs (shipping input materials to the plant)
TIME FRAME	Increased flexibility to meet customers needs: Reduced time to meet demand by creating two customer segments (new and refurbished products) and allocating capacity accordingly and optimizing resources
	Increased capacity flexibility: Faster sourcing of raw materials for production as there is a new source of raw materials in addition to virgin materials (waste from other companies)
	Limiting factor: Successful implementation possible when TRL is high enough (ICT for companies/platforms to share information, coordinate opportunities to reuse)

Table 5: Spatial Flexibility for Reuse archetype

	Impact based on flexibility type				
Business Model Archetypes	*Capacity*	*Product*	*Location*	*Innovative*	*Feedstock*
Decentralized/Modular	Medium	Medium	High	Medium	High
Mass Customization	Medium	High	High	High	Medium
PSS/Servitization	Medium	Medium	Low	Medium	High
Reuse	Medium	Low	Low	Medium	High

Table 6: Impact of business model archetypes on flexibility types

Table 6 above summarizes the overall impact of the business model archetypes on the five flexibility types described in WP1. In general, they all have positive contributions to increased flexibility, albeit to different extent. Depending on what a particular firm wants to achieve (e.g., increasing the feedstock flexibility), the information above would provide the decision maker with a simple tool to select the right business model archetype (e.g., Decentralized/Modular, PSS, and Reuse would have the highest potential). Also, if possible, different business model archetypes could be combined to obtain a “hybrid” business model (e.g., Mass Customization and PSS combined to have considerable impact on "location flexibility"). All the business model archetypes have mostly positive overall contributions to the performance level (e.g., better service, more product offerings, improved response time, better quality management, lower labor cost, less waste generated, more jobs created). The time it would take to deploy these models would depend also on the particular archetype. ICT is a common requirement to all the business model archetypes. The decentralized/modular, mass customization, and reuse archetypes require high TRL and development of new equipment and materials. PSS (as well as reuse) on the other hand requires more collaboration/coordination among different actors in value chains, while decentralized/modular and mass customization could be deployed in a relatively easier manner as they do not require the same level of collaboration, coordination, and trust among partners in the value chain.

It is clear from the tables above that most business model archetypes can significantly contribute to the objective of building a flexible process industry, although there are some issues that need proper attention (i.e., *limiting factors*). As shown in other studies which are presented in this chapter, we also argue that "flexibility" is key for the European process industry and the related discrete manufacturing sectors to remain competitive in the global arena. A flexible system would be crucial for any firm operating in business environments where input/output prices fluctuate wildly, customer demand (location and product choices) changes constantly with shortened product life cycles, the labor/production costs are significant and uncertain, government regulations change frequently (e.g., main KPI to focus on changing from profit (economic) to offering green products (environmental) or creating more jobs (social).

Therefore, we believe that business model archetypes that would meet the following conditions would be essential for maintaining or bringing back high-value added activities to Europe and therefore stop or reverse the delocalization trend:

a) make processes less labor-intensive (*e.g., 3D printing for mass customization, process intensification, automation, virtual factory networks or flexible reconfigurable supply chains enabled by IT platform value chains*),
b) foster high-value added activities such the design of better product & service combinations through (*3D printing, PSS*),
c) switch to alternative sources of input to mitigate the risk of highly uncertain input prices (*e.g. energy flexibility created via decentralized/modular production enabling the move from fossil fuels to renewable energy*), and
d) optimize resource usage and reduce dependence on virgin materials through reuse (*e.g., the reuse archetype*).

Europe is already one of the leading forces in research and development and providing high-value added products/services. As a result, our focus will be on leveraging this competitive advantage to propose novel business models creating flexible value chains in the process industry.

In the following two chapters, we delve into the opportunities and challenges a particular firm can have when the proposed business model archetypes are employed. Chapter 3 presents the findings from desk research, whereas in Chapter 4 we summarize the key points from 8 different business cases (more detailed analyses of these cases are in the Appendix). These results will form the basis of the "novel business models" that will be proposed and validated in deliverables D3.2 and D3.3. In WP4, we aim to evaluate the potential of these business models in developing flexibility, the impact on key objectives, and the costs of doing so (especially for investments that are "irreversible", to be able to determine whether the business will be profitable in the long run). This would provide the process industry a guideline before they make decisions on investing "new" systems (e.g., switching from centralized to a modular production setting).

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Chapter 3

3. Archetypes: an introduction

Mainly driven by technological changes, global market integration, glocal (global + local) competition and customer desires, the pace at which the world is changing is growing exponentially. Europe, being one of the largest trade partners in the world, also needs to face this constant-fast change. Therefore, it is important to understand what the upcoming changes are in the global market and to learn how to deal with them in advance, to be in the edge of innovation.

As a world economic leader, Europe has taken advantage of technology (past and modern) to create more mature manufacturing processes, but at the same time, technology has placed the local production in a difficult position facing a crossroad between two main problems "*(1) delocalisation and competition from (often low cost) non-EU country producers and (2) the environmental and climate changes with in consequence the related cost and availability of raw materials and energy*" (INSPIRE, 2017). These large problems are faced by almost every industry, deeming their performance and possible innovation.

To provide a solution to the presented issues and the need for a fast adaptation from the companies and industries, four archetypes, based on the mapping of recent trends (technological and non-technological) affecting business, are presented. Based on literature review, case studies, interviews with companies, different industry reports, and the analyses from previous deliverables (refer to WP1 and WP2) the following archetypes were derived and proposed for further study (refer to D1.2 from INSPIRE project):

1. **Decentralised or modular production** covers industries that decentralize their manufacturing and split their production processes into various locations or regions.
2. **(Mass) customization** combines the personalization and flexibility of custom-made business manufacturing with the traditional principles of mass production;
3. **Servitisation of the process industry** considers deliver functionality, rather than ownership;

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4. **Reuse and sustainability** focusses on mechanism for a more sustainable and competitive industry through improvements in resource and energy efficiency;

As presented in D1.2, the archetypes aim to provide a top-down (from general to detail) approach to the different problems faced by the characterized industries in Europe. In the present document, a more detailed look to the different opportunities, challenges and the impact that each of these have at the different objectives (European region, industry and/or business level, company level). Each subchapter of the archetypes consists of the following structure:

- A **brief description of the business model** provides background based on interviews and the literature study, for a better understanding of the archetype;
- The **potential opportunities** provides a more detailed explanation on the current situation of the archetypes regarding problems they face and what are the opportunities of the new business models;
- The **potential challenges** identifies the potential challenges that business models are facing and could face in the future;
- The **impact of business models on the objectives** presents the possible impacts on each of the objectives of the industry, company, region and European zone

Finally, a **summary section** is introduced, where a general summary of the common challenges, opportunities and impacts on objectives are presented.

3.1. Decentralised or modular production

Delocalization was born as a companies' response to market needs and constantly changing customer needs, "*moving away from traditional process-centered work practices in favor of concurrent engineering methods*" (Rogers & Bottaci, 1997).

One of the most accepted definitions for the delocalization (also known as relocation) is the one given by the European Commission, which describes the concept as "*the closing or scaling down of a firm's activities in the home market following the shifting of part of the production chain abroad"* (European Commission, 2005).
The modular (or decentralized) manufacturing systems (MPS) change the way products are currently manufactured, mainly aims to reduce the production cost and lead times of consumer goods. However, the design of the MPS brings a new set of problems on addressing how the current organization and business structures can be adapted to the new technology.

Having a modularized or decentralized production has an impact in the supply chain as it means moving from having the final product assembled to individual production sites that generate interchangeable parts able to fit together to create a final product; moreover, having the possibility of combining these parts offer many combinations and permutations and create different products. However, with the pace of globalization declining, there has been lower activity in global value chains (ERM, 2016). This deceleration coincides with a decrease in offshoring that started with the global financial crisis. On the one hand, it can be argued that companies willing to offshore may have already done so in the peak of the globalization trend; on the other, as delocalizing implies major investments (redundancy costs, new facilities, etc.) it is less likely to occur during recession periods.

3.1.1. Potential benefits/opportunities

Decentralization brings many different benefits to companies who decide to implement them, such as flexibility, being closer to customers, improvement on the information management, and lowering labor costs by having different manufacturing locations. Moreover, decentralized manufacturing could bring the possibility to generate different combinations of parts and assemblies, resulting in different product configurations.

Modular or decentralized production introduces many opportunities and benefits for companies, such as the following:

- Increased responsiveness to changes in demand and resource availability:
    - Increased product flexibility could easily facilitate reconfiguration processes for new product development, mainly focusing on new resource configuration (Teece, 2007). It means, that as product of decentralized production, companies can generate different processes to adapt to local sourcing, local resources and any other particular local condition.
    - Adapt and generate changes to response quickly to changes in the market, such as competitor innovation (Teece, 2007), demand and business environments (Parente & Gu, 2005) and changing local regulations.
    - The modularization of products can have a positive effect for a more efficient allocation of local resources (Baldwin & Clark, 2000). As opposed to having all the raw materials centralized in a single location (which could be an optimal strategy), allocating them in places closer to the demand per product type might lead to a better policy.
- More customization opportunities:
    - Increase product variety as result of the strategic approach to customer needs (Worren, Moore, & Cardona, 2002) and reuse of common modules with the inclusion of fewer minor components (Partanen & Haapasalo, 2004). This could also have a larger impact if it is shared with other archetypes, such as reuse or PSS.
- Improved efficiency in manufacturing and distribution:
    - Take advantages of local economies of scale (O'Grady, 1999) as production could be made in different locations at the same time, reducing local production cost per batch.
    - Allows parallel development of independent modules, decouples tasks and reduces development time (Sanchez, 1999). An example of this is the aviation industry, where several companies, specialized in some type of product (wing, tail, flaps, etc.), work together to create the final product assembly.
    - Reduction of total operating costs, working capital and supply chain & logistics cost (Brull & Kessler, 2014) by moving closer to the customer.
    - Less energy consumption and waste (Brull & Kessler, 2014) at individual level for each of the modular manufacturing plants.
    - Transportation costs may also go down as result of products being closer to the customer.

- Increased ability to test new products/systems:
    - Easier to perform product upgrades, maintenance, repair and disposal while maintaining lower capital and overall costs (Parente, Baack, & Hahn, 2011). As an example, we can consider the mobile phone industry, were production happens in several different locations without preventing companies from upgrading their products at any time.
    - Dynamic capabilities are part of a company strategy to compete in the market, under the development of new products, innovative resource configuration (flexibility) and knowledge transfer (Eisenhardt & Martin, 2000). These dynamic capabilities could be understood as how companies "acquire, integrate, and shed resources, and reconfigure internal and external competencies" (Parente, Baack, & Hahn, 2011) to meet constant changing business environments.
    - Can create a positive influence on the relationship development on external (between buyers and suppliers) and internal (between design and engineering process) levels (Baldwin & Clark, 2000)
    - Generates a greater leverage of modules between product development projects (Hargadon & Eisenhardt, 2000), by using the full capacity of the modules and adapting them easily for the new product.
- Improved quality control processes:
    - Localizing quality problems at component level, which eases maintenance and service (Lau, 2011). This is particularly helpful when companies have different specialized products, and need to identify a particular issue in one of them, knowing at detailed-level where it was produced and reducing the need for a complete recall of the product.
    - Improving system reliability due to high production volume and experience curve, as the local production is smaller, implying lower volumes of production (Shibata, 2009)

3.1.2. Potential challenges and risks

In the process industry, small-scale plants are shaping the market, evolving rapidly from pilot design plants and/or demo projects, to a key integral part of the industrial processes. Examples of shifting from traditional processes into smaller areas of the business model are: small-scale suppliers (Vorley, Lundy, & MacGregor, 2008), primary producers (Rabellotti & Schmitz, 1999), small-scale retailers (Wilkinson & Rocha, 2009), food industry (Dennis, Aguilera, & Satin, 2009) and small-scale producers (Berdegué, Biénabe, & Peppelenbos, 2008). However, these changes face also many challenges, many of which are introduced as follows:

- Modularization processes require much effort as it requires large involvement of the companies leaders for a successful implementation process (Worren, Moore, & Cardona, 2002). This could generate a negative impact in the company revenue as it requires large investment and huge commitment from the administration to succeed.
- Easy for competitors to potentially copy the design and/or the product system (Persson & Ahlstrom, 2006), as a result of multiple manufacturing sites, raw materials providers and the information shared among them, making it possible that a single leakage of information generates new competitors.
- Although with smaller plants using local resources and creating products catering to local demand it is possible to increase the product offerings, there is the risk of potential reduction of product differentiation at the same time as most of the products become similar as consequence of the standardization (Nobelius & Sundgren, 2002)
- Product components could become expensive if they are over-designed (regular products with parts of luxury products) or under-designed (luxury products made with basic components) (Lau, 2011). An example related to petrochemical industry is the use of high quality degree gas oil for a simple combustion process where a lower quality degree gas oil could have worked better.
- Standardization could be the most crucial challenge for highly modular production systems as it will require every single production facility to have the same settings (Weyer, Schmitt, Ohmer, & Gorecky, 2015)
- Lack of integrated design process, which increases the logistic problems making them more costly, as many of the products will be made to meet local demand (Concordia University, 2015)
- As mentioned above, some level of standardization is necessary for a successful deployment of a decentralized/modular system. However, it could be a challenge to meet local standards and regulations, making difficult to have standard products capable of meeting every regulation in the different countries or territories where the products are sold (Concordia University, 2015)
- Transportation cost increases as result of difficulties of delivering specific raw materials to the plant site (Baldea, Edgar, Stanley, & Kiss, 2017)
- Loss of control degrees of freedom, as many of the processes change from a single centralized location to multiple one, requiring an strong dynamic interactions on modular systems (Baldea, Edgar, Stanley, & Kiss, 2017)

- Loss of economies of scale, as result of individual production in different manufacturing sites, instead of a centralized production of large batches
- Another downside could be the possibility that not all the plants are able to produce all products, generating stock out in certain specific products.
- Difficulty in making use of pooled resources, such as common raw materials, tools, etc., as each manufacturing plant should provide itself with the materials.
- With the implementation of decentralized production, different technologies are required to make the modular production a successful implementation. Among them, the principal ones are the Information and Communication Technologies (ICT) and the electronics (Baldwin & Clark, 2000). From the ICT side, an efficient and well-connected network is required, as it will allow easiness of communication and knowledge management tool to enable better collaboration among the different partiers or actors involved in the process. Proper process control mechanisms, virtual factory concepts and sound supply chain management principles need to be put in place for the "system of decentralized locations" to be competitive with the "centralized" counterpart. Some examples of these ICT technologies are e-mail, e-mail list-servers, smartphones, cloud computing, chat tools (mobile based included), conferencing tools, shared information systems, collaborative virtual tools, group decision support systems, process control, virtual factory, virtual reality, mobile web and workflow control tools (Kock, 2002) (Kotabe, Parente, & Murray, 2007). By having these working together, companies can easily implement modularization.

3.1.3. Impact on the objectives

Companies deploying decentralized or modular production systems are capable of improving performance in efficiency, employment level, quality, waste generation, etc. Therefore, here are presented the main impacts (positive and negative) at different levels (Company, Industry, Region, and European Zone) that could come as a result of the implementation of decentralized or modular production. Please bear in mind that this is a qualitative evaluation of the decentralized/modular production based on the findings from the desk research. Based on the frequency of comments related to the "objectives" listed in the table and the nature of these (positive or negative impact) in the literature reviewed, we have come up with the scores as can be seen in the below table (as well as the similar tables for the other business model archetypes).

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In the following table, the positive numbers indicate an "improvement". The number itself indicates how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact. Please note that positive (negative) impact does not always mean an increase (decrease) in the absolute figure. For example, the impact will be "positive (negative)" if the "production costs decrease (increase)" or "if there are more (less) jobs available".

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing			2	
	Efficient and sustainable distribution			2	
	More flexible			3	
	Less delocalized			-2	
	Competitive advantage via intensified processing			0	
Industry / Company / Region specific objectives	Reduced production costs			1	
	Increased product quality			2	
	Minimized time to market			3	
	Higher throughput with smaller batches			2	
	Reduced response time to changes in demand			3	
	Jobs creation			2	
	Limit employment reduction			1	
	Improving working conditions for workers			0	
	Sustainable development promotion			0	
	Increased local business opportunities - SMEs			2	
	Shorter lead times			2	
	Less stock			2	
	Reduction of raw material by 15%			1	
	Less waste			2	
	Reduction in environmental footprint by 10%			2	
	More interaction with the end users			1	
	Customer driven SC business models based on Intensified Processing.			0	

Table 7: Analysis of impacts on the objectives from Decentralization archetype

The largest impact will happen in the following objectives:

- The production will become **more flexible** as the modules could be located anywhere (or moved to if necessary) and can easily be adapted to produce virtually any product of the company.

- The **time to market** will decrease significantly as the design/production could be made anywhere because of the ability to design/produce in parallel and moving closer to the customer.
- Minimized **response time to changes in demand as** result of understanding and providing prompt solutions to the constantly changing customer needs.

Some objectives probably will not be affected by the changes, such as:

- As the modularity allows moving production virtually anywhere, the **intensified processing** is simply split into different locations; as well, production specialization is relocated affecting **business models** depending on it.
- **Working conditions** are not directly improved by having a modular processing; it depends on a case-to-case basis.
- The promotion of **sustainable development** can be debated, with a minor positive effect by reducing the amount of waste produced; however, it could only be split into different locations, unless the waste generated is not used locally for other processes

There are also few negative impacts:

- As modularization increases and production moves closer to the customer, a larger number of individual scattered production sites is created, increasing the **delocalization** pattern (this argument is correct assuming that for most companies majority of the customers will be outside Europe, otherwise modularization might help bring manufacturing back to Europe), unless these sites remain in Europe.

3.2. Mass customization

Mass customization consist of a combination of mass production (large batching production) with the elements of tailoring products in a way they meet each customer individual needs. The advantage of mass customization is the usage of mass production techniques (e.g. small number of platforms that underlie different product) to create individual products (Pine & Gilmore, The four faces of mass customisation, 1997)

An increasing number of manufacturing industries and brands are adopting the business concept "Mass Customization (MC)" nowadays. This concept has found its perfect fit in the discrete manufacturing, taking into account the expectations of targeted customers of the business, as is currently adding more flexibility on different practices related to process industry. MC first was production driven; then became connected with the internet and today has evolved towards connecting customized mass production along the value chain including online communities from resources up to final products. For example, as categorized by Hindle (2008) "*in the case of a watch, the internal mechanism is a platform to which can be added a wide variety of personalized options at later stages of production*" (Hindle, 2008). Then, the purchaser has access to different options (color, strap, etc.) based in the same platform (basic watch mechanism).

According to Ramani et al (2006), what enables the mass customization are *"a series of industrial shifts: (a) Modularization of products and processes has enabled management of product variety: and (b) The ability of "knowledge-based" software to configure products and (c) Flexible automation for manufacturing has been enabled because of improved low cost technologies"* (Ramani, Cunningham, Devanathan, Subramaniam, & Patwardhan, 2006)

With mass customization, customers become part of the design process that enables them to get a product that meats their individual preferences. Customer interaction is in an operational scalable form and must be easy to perform and to be controlled by the company. With MC products are not invented but configured (customized) to meet specific needs. The use of information technology and internet has made possible an increase on the number of products offered by companies. For example, Dell has "*established its leadership for the pc market by allowing components as requested at the last minute before delivery*" (Hindle, 2008); as well, Ford allows customer to build a vehicle online from a large pallet of options, in the same way that BMW has make customization easier to customer via their webpage, guaranteeing that not two cars are identical (Pine & Gilmore, 1999). Another example, from SPIRE, is the case of the PRINTCR3DIT research project, which aims to understand and investigate the 3D

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printing of equipment, namely chemical reactors as well as catalysts; by changing the traditional way that chemical reactors are made, this adds a level of flexibility and customization under the specific requirements of each customer.

3.2.1. Potential benefits/opportunities

The shift towards MC is reinforced by new manufacturing technology trends. Fast increasing rates of investment in advanced robotics, additive manufacturing and advanced digital simulation of manufacturing processes all lend themselves to shorter production runs and more unit-level customization. Many different tools are used in the MC, such as Three Dimensional (3D) Printing, Fused Deposition Modeling, Selective Laser Sintering, Stereolithography, 3D Plotting/Direct-Write/Bioprinting (Chia & Wu, 2015), Additive Manufacturing (AM), Rapid Prototyping (RP) and Rapid Manufacturing (RM).
In what follows, we provide a list of potential benefits that prove how the Mass Customization business model could create value for the firm, its partners, and its customers:

- Creation of efficient production of custom products with high added value. These systems will be suitable for rapid change in their configuration to satisfy custom requirements, but they must also guarantee a high level of integration with the clients, who become the main creators of the solution produced.
- Mass customization obliges companies to rethink operations strategies to become more proactive and quickly respond to changing market requirements, meaning that companies must adapt their production systems to meet customer needs in a rapid manner.
- Some of the technologies for mass customization (i.e., 3D printing, additive manufacturing, etc.) offers unprecedented possibilities for product creation, in shape complexity and custom geometry (Doubrovski, Verlinden, & Geraedts, 2011).
- Mass customizer identifying customer problems and solutions while minimizing complexity and the burden of choice.
- Products created in a customized manner and using a 3D printing technology can be up to 50% lighter than products conventionally-made, while complying with mechanical requirements (Doubrovski, Verlinden, & Geraedts, 2011)
- Allows reduction of tooling and part consolidation in the production of end products (Wohlers, 2010) as most of the parts are already standardized.

- Functional customization of products, not only to create one-off products, but to create custom perfect-fit products to meet every person needs over a basis of an standard product (Slabaugh, Fang, Mcbagonluri, & Zouhar, 2008)
- Product variety is directly related to the type of materials used in the manufacturing; hence, one of the biggest advantages is the possibility of using different materials, such as polymers, metals, ceramics and organics (Gibson, Rosen, & Stucker, 2010)
- Digitization of manufacturing process allows analyzing production at a unit level, not only in batches, focusing mainly in quality, resulting in higher precision at lower cost (O'Marah, 2015).
- Mass customization offers the opportunity to transform "customers' heterogeneous needs" into a value creation proposition, as it moves from the traditional "one size fits all" mass production to individually (mass) customized products (Salvador, de Holan, & Piller, 2009)
- Customization of goods based on parametric settings, supported by math-based design software that allows simple modifications, submitted by customer to drive the individually customized desired design (Eyers & Dotchev, 2010)
- Mass customization offers the possibility for process industry to improve their competitive capacity.
- In the process industry, is possible to minimize the total cost on the Customer Order Decoupling Point (CODP), defined as "*the breaking point between productions for stock based on forecast and customization that respond to customer demand*" by implementing mass customization (Jian-hua, Li-li, & Qiao-lun, 2007)
- A particular feature from 3D printing is that reduces complexity in the supply chain, from the consolidation of components into a single product: by replacing previously assembled parts with a single component, the manufacturing process can be simplified significantly" (Gao, et al., 2015).
- Product design for printing could be a new industry, including the development of a more professional software industry (Campbell, Williams, Ivanova, & Garrett, 2011)
- Increasing savings on time and money by reduced individual product complexity, making flow of material more transparent and easier to control (Janssen, Blankers, Moolenburgh, & Posthumus, 2014)
- Potential democratization of the design and manufacturing of goods, as it grants access to a wider audience to create and submit and specific type of product (Mertz, 2013)

- Production of customized, high value-added products offers European companies a key opportunity to foster their competitiveness by entering new niche markets like for example products for target groups such as medical appliances, personal transportation, customized apparel, etc. (Fornasiero and Zangiacomi 2012).
- In a wider product offer based on a same product platform (i.e., watches, computers, etc.) the need for specialized individual process per product is decreased, hence having a direct impact in the amount of waste generated, the energy required for the different processes and the raw material used.
- Increased revenue from manufacturing cost reduction, as customized end products are made with combinations and permutations of the same basic elements. As well, companies could add an extra charge on customers asking for some specific features.
- From the industrial point of view, the MC takes advantage of additive manufacturing, flexible manufacturing, advanced robotics and 3D printing.
- From the customer point of view, MC is linked to the need to understand and meet customer needs and manufacture specific and individualized goods at mass-production costs. Examples of this are home appliances such as 3D printers, that allow any person to print their own product ideas.

3.2.2. Potential challenges and risks

The challenge of mass customization is linked to unpredictable and seasonal demand, which is difficult to forecast. This perspective is strengthened by the fact that, for example, consumer goods (particularly fashion products) have being recently facing the need of an increased number of products while reducing its life cycle. Mass customization also brings its own set of challenges, from which we list the more representative as follows:

- Development and implementation of innovative managerial models and methods to support collaborative practices downstream with customers (as well as discrete manufacturing) and upstream with suppliers (i.e., process industry) (Dyer and Singh, 1998; Camarinha-Matos et al., 2005).
- Is important to consider that, if customers are offered with too many options, they could face the "*paradox of choice*" (Salvador, de Holan, & Piller, 2009) making it even difficult to reach a final decision and finding themselves classifying vendor as difficult.

- The challenge of mass customization is linked to unpredictable and seasonal demand, which is difficult to be forecasted. Higher number of product variation with shorter life cycles.
- Development of a fast/responsive production system for the different elements, capable of produce based on "observed demand". If this is not employed, high levels of inventories can be expected to customize so many different products.
- The new paradigm of demand-driven supply networks emerges as a collaborative scheme to better respond to consumers' direct signals and needs. This represents a new challenge for companies as they need to share more information with others (suppliers & competitors) to be able to answer to the changing needs.
- Increased number of SKUs could have an impact in the management cost (inventories, forecasting, procurement, customized pricing, etc.) that could exceed the expected benefits for companies
- Customized production mainly implicates the centrality of the consumer, which requires a revision of the production chain management models as well as the use of innovative technologies (3D printers, new materials, etc.)
- Consumer potentially reproducing several parts of patented combinations with a 3D printing tool, having legal implications (Wilbanks, 2013). Furthermore, there are different parts of dangerous products (mainly weapons) that can be easily designed using Computer Assisted Design (CAD) and then printed, generating a new different type of problems that have not foreseen.
- Related to the above phenomenon, the number of "customers" for many industries (e.g., process) might increase exponentially. The companies in the process industry might need to design new network management strategies that will make it possible to deliver materials for 3D printing to a large number of customers, rather than a small number of intermediate businesses (the current situation). The potential "disintermediation" of the middleman, and the need to establish a direct link between the firms in process industry and end consumers might prove to be quite challenging.
- Designs for products potentially can be widely disseminated through software piracy, generating a new black market for "not authentic products".
- Integration between algorithms, Computer Assisted Design (CAD) programs and materials in the design of the product
- In process industry, customization level could have an impact not only in the demand but also in the price, as different demand levels could be satisfied leading to changes in prices of the products (Jian-hua, Li-li, & Qiao-lun, 2007)
- Generation of by-products, as result of customization in process industry, could lead to an unexpected increase in the product portfolio.

- Increase of buffer inventories to meet the order demands as product of disconnection between forecasting and customization (Jian-hua, Li-li, & Qiao-lun, 2007).
- In the biomedical field, one big challenge is the adaptation of existing systems for specific biological materials and the development of novel deposition systems designed for biologically relevant materials (Mironov, Kasyanov, Drake, & Markwald, 2008)
- Finding the optimal way of putting all the technological components together, into well integrated and scalable industrial technologies (Mironov, Kasyanov, Drake, & Markwald, 2008)
- As mass customization becomes more popular, it detracts customers from more profitable sales, cannibalizing sales on more traditional products (Hindle, 2008) As a case study introduced by Hindle (2008) "*a company in California, offered booths in record shops where customers could put together cassette tapes from the recordings of a wide range of artists. It soon found that the service was such a hit that it was cannibalising sales of traditional cassettes and cds*" (Hindle, 2008)
- As product variety becomes larger (more customization), the unsold stock problem would generally become more serious, as it is harder to manage the inventory of a larger portfolio, resulting generally on higher inventory levels when there are more products offered.
- Despite considering all the possible tools available for mass customization, it is necessary to understand that it is made possible only by the use of information technology.
- For some specific industries, such as biomedical field, some specific technologies must be developed to meet the final product requirements, such as:
    - Computer-aided design tailored on organ design
    - Bio-printer, capable of printing the organ with the required specifications and organic biomaterials
    - Cartridge, capable of dispensing biomaterials and living cells or cell aggregates
    - Processible biomimetic hydrogel, which works in a similar way to paper in a regular printer, capable of receiving the printout.
    - Self-assembling cell aggregates, which are similar to ink in a regular printing process, capable of producing the final shape of the product (Mironov, Kasyanov, Drake, & Markwald, 2008)

3.2.3. Impact on the objectives

Companies who have decided to include mass customization among their development strategies will have different impacts in a large variety of topics, such as customized production, materials management, waste reduction, etc. Therefore, here are presented the main impacts (positive and negative) at different levels (Company, Industry, Region, and European Zone) that could come as result of its implementation. Please bear in mind that this is a qualitative evaluation of the mass customization based on the findings from the desk research. Based on the frequency of comments related to the "objectives" listed in the table and the nature of these (positive or negative impact) in the literature reviewed, we have come up with the scores as can be seen in the below table (as well as the similar tables for the other business model archetypes).

In the following table, the positive numbers indicate an "improvement". The number itself indicates how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact. Please note that positive (negative) impact does not always mean an increase (decrease) in the absolute figure. For example, the impact will be "positive (negative)" if the "production costs decrease (increase)" or "if there are more (less) jobs available".

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		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing	3			
	Efficient and sustainable distribution	0			
	More flexible	3			
	Less delocalized	-2			
	Competitive advantage via intensified processing	1			
Industry / Company / Region specific objectives	Reduced production costs	2			
	Increased product quality	2			
	Minimized time to market	3			
	Higher throughput with smaller batches	2			
	Reduced response time to changes in demand	3			
	Jobs creation	2			
	Limit employment reduction	-1			
	Improving working conditions for workers	0			
	Sustainable development promotion	1			
	Increased local business opportunities - SMEs	3			
	Shorter lead times	2			
	Less stock	2			
	Reduction of raw material by 15%	0			
	Less waste	2			
	Reduction in environmental footprint by 10%	2			
	More interaction with the end users	2			
	Customer driven SC business models based on Intensified Processing.	1			

Table 8: Analysis of impacts on the objectives from Mass Customization archetype

The largest impact will happen in the following objectives:

- In the discrete manufacturing industry, the production will become **more flexible** as the mass customization allows having different and innovative products, as well as an easiness for development of new products in virtually any location. In the specific case of the process industry, one way to reduce the complexity in product development and increase the flexibility in production is by managing production activities from a central product management department (Kohr, Budde, & Friedli, 2017).
- Manufacturing will become **efficient and sustainable** as the design for new products will be made on computers before final printing (in the case of 3D printing), saving raw materials and reducing the amount of waste. In the case of other mass customization types, manufacturing will rely heavily on the supply chain (SC) configuration in the sense of selling a larger variety of the products using the same SC structure and standard modules and components, therefore making things quite

complicated, and unless the extra money paid by customers exceed the extra costs, it will not be beneficial for the firm.

- A minimization in the **time to market** will be seen, as product customization and new product development will happen faster.
- Minimized **response time to changes in demand as** result of understanding and providing the exact customized solution to the customer needs. As a tool for the process industry, implementing a "portfolio-review-process" help to increase accuracy on product production, increasing responsiveness on changes in demand.
- Inclusion of **SMEs opportunities** will be a result of more variety of products, allowing these SMEs to become part of the conversation.

Some objectives probably will not be affected by the changes, such as:

- The **distribution** of final products to the customer will only suffer a minor change on the proximity; however, it has a minor effect on the transportation cost. However, if the business model switches to a more involved consumer in the production process (prosumer), then transportation cost of final products will be highly impacted being decreased to virtually zero, but moving this cost to the raw material transportation.
- **Working conditions** are not directly improved by introducing different technology, as also will require different training and a more skilled workforce to operate these technologies.
- The amount of required **raw material** will increase as a consequence of scattered production sites to meet customer customized product demand. On the other hand, less raw material will be needed because of the "additive nature of production" (as opposed to subtractive in traditional production). Then, the overall effect, will be neutral.

There are also few negative impacts:

- Mass customization will generate a higher **delocalized** pattern, as it will move production closer to the customer, generating a larger number of scattered production sites. In the case of process industry, this could be seen as an increase in modular product structures that could become difficult to coordinate, adding an additional layer of complexity to the production process (Kohr, Budde, & Friedli, 2017).
- Moving into a new technology-based production will require more skilled workforce, as consequence, **employment** rate could be impacted for unskilled employees, and, as the customization could be made in the customer hands, will likely reduce employment positions along the supply chain.

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3.3. Servitization of the process industry (PSS)

One commonly used definition of a PSS is the "*integrated system of products, services, and socio-economical stakeholder, designed to fulfill a specific need*" (Goedkoop et al., 1999). The "system" here refers to a collection of products and services offered to the customers, as well as the group of actors who work together to deliver these products/services. "Servitization" is another term commonly used, referring to the same concept. This approach practically forces the company to move away from a transactional business model (only selling the product at a single point) to establishing an ongoing relationship with the customer.

According to the analysis made by Schenkl et al. (2014), based on Geum et al., (2011), there are "*three different types of technologies within PSS: "Enabler technologies" (1) enable the direct integration of product and services. The technology may be embedded into the product (e.g. actors or sensors) or be independent. "Mediator technologies" (2) are available already in a product or service and are used for servitization (or productization). "Facilitator technologies" (3) are applied additionally for servitization and facilitate the problem solving. A condition monitoring system may for example facilitate the operation of a maintenance contract.*" (Geum, Lee, Kang, & Park, 2011) (Schenkl, Sauer, & Mörtl, 2014)

Lee et al (2014) suggest that current technologies interacting (or even integrated) with PSS are "*big data analytics for accelerated innovation, Prognostics and Health Management and Cyber Physical Systems*" (Lee, Kao, & Yang, 2014).

The concept has become famous because of the well-known "*document management*" by *Xerox* (instead of only selling printers) using the pay-per-copy model or the "Power-by-the-Hour" service package by *Rolls-Royce* for aircraft engines where the maintenance and repair, and overhaul services are charged per hour of flight and Rolls-Royce owns the engines. Reim, Parida, & Örtqvist (2015) discuss three categories of business models (PO: Product-Oriented, UO: User-Oriented, and RO: Result-Oriented), which differ significantly how the risks, responsibilities, ownership are shared among the PSS provider and its partners in a value chain. The PO type is when the PSS provider offers services related to the product (e.g., maintenance, repair, taking back after use, etc.) that is sold to the customer (customer owns the product). The UO type is when the PSS provider still owns the product and ensures its availability/usability over a certain period of time (e.g., leasing of baby prams, see Mont &

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Tukker, 2006). When the RO type is deployed, the PSS provider offers a specified "result (outcome)", instead of selling a bundle of products and services (e.g., see Stoughton & Votta, 2003 for the case of suppliers charging for chemical services rather than the sales volume).

In general, the risks and responsibilities for the PSS provider increase as one moves from the PO to UO, and finally to RO. Consequently, the benefits and challenges vary depending on what type of PSS Business Model (PO, UO, or RO) is deployed (a combination of these types could also be used by the same provider).

However, in this document we present the general results for all types, and indicate whenever it only applies to a particular type. Here, the benefits and challenges stem from the business model itself and the tactics that the PSS provider employs. Tactics related to *contracts, marketing, network, product and service design, and sustainability* as defined in the paper by Reim, Parida, & Örtqvist (2015) determine "how much" value is created when a particular business model is implemented.

3.3.1. Potential benefits/opportunities

In what follows, we provide a list of potential benefits that prove how the PSS business model could create value for the firm, its partners, and its customers:

- Increased revenues over the life cycle of the PSS because of additional sources of revenue and the "services" having higher margins
- Sales of additional "products" (not the core product). For example, service parts, recycled materials, etc.
- Meeting dual goals of economic and environmental benefits
- Higher value to the customers through the better delivery of the product and service leading to more satisfied consumers who demand more services
- Reduced life cycle costs. For example, if the manufacturer maintains the ownership of the product during its use at the consumer site, s/he will most likely (not guaranteed) to have the incentive to deliver long lasting solutions in order to reduce maintenance and disposal costs (Halme, Jasch, & Scharp, 2004).
- More sustainable operations and better resource use through improving efficiency, increasing the life time of the product, reducing the amount of materials/number of products used (via sharing, recycling, repairing, better maintenance, etc.), better product design aligned with the service offer, and less number of returns because of better use of the product and the proper monitoring

- Allowing for the reuse by improving resource efficiency through intermediate PSS business models (e.g., see Överholm, 2017 for "ventures that are purpose-built for intermediary PSS business models" such as the small-scale water recycling systems Seven Seas Water, 2014)
- Closer ongoing relationship with the customer (maintaining the customers over longer periods of time) and locking-in the customer (risk for a customer by the way), as it becomes harder for them to switch to a different provider
- Sustainable competitive advantage as a result of the above two benefits (increase revenues and better value) and the services being harder to imitate
- Coordination could be an opportunity, partners know each other better and design better products and services
- Risk sharing partnerships: Instead of one SC partner assuming a 100% of the risk, different partners usually share the risk with the PSS model as the ownership of the product and responsibilities for different tasks change with the PSS model
- single point of contact, one throat-to-choke in case of problems: Example → customer's main relationship is now with the "manufacturing and maintenance center", which is most of the time perceived as a better service (Lockett, Johnson, Evans, & Bastl, 2011)
- "Contracts" may provide incentives to perform better
- Differentiating the PSS provider from the competitors by offering valuable services, especially useful when competing with low-cost producers. This would help European firms reverse the delocalization trends.
- Increase customer centricity through better knowledge about the operations at the customers' facilities and the increased ability to identify their current/future needs. This gives the PSS provider the opportunity to develop new products and services to be offered in the future and create more value if the offer can be customized
- Better data about the functionality of the product, the service itself, and customers' habits during use which helps design new products and services as well as increase speed of innovation via co-innovation with customers and external partners (see Azarenko, Roy, Shebab, & Tiwari, 2009)
- Better control of demand and inventory as it is easier to predict consumer's needs/consumption
- Changes in financial flows: more sources of revenues for the PSS provider, revenue sharing agreements between different actors (e.g., the Finnish Energy Service Companies (ESCO) offering comprehensive energy solutions gain their returns by receiving a share of the energy costs saved by their customers. For more details, see Ceschin, 2013).

3.3.2. Potential challenges and risks

Even though Product Service Systems (PSS) are widely seen as the differentiating factor leading to enhanced competitive advantage, its adoption is somewhat limited because of cultural, regulatory, and corporate barriers (Ceschin, 2013), making it still not as common as one would expect. Some challenges that might potentially hinder the successful implementation and the diffusion of the PSS business model are as follows:

- <u>Design of the contracts to determine the liabilities and rights of the parties involved</u>: PSS model leads to a move away from a transactional business model (only selling the product at a single point) to establishing an ongoing relationship with the customer. Therefore, this model introduces additional activities (e.g., maintenance, recycling) and possibly more intense coordination with external partners. The obvious impact is the contracts being much more complex with the following challenges:
    - Clear definition of the product, service, and the outcome (result) and the financial flows in the value chain (payment terms and time frames). Details on how the "result" and "service level" will be measured and by who needs to be clearly specified in order to prevent misunderstandings and to avoid undesirable disputes
    - Clearly defining the responsibilities of parties involved related to the product/service/outcome(result) over a certain period of time
    - Sound risk assessment, specification of unexpected and/or adverse events, risk-sharing agreements and incentive clauses to mitigate risks, and determining the risk-premium for the risk-bearing party (for both upside/downside risks)
    - <u>Formalization</u> of these contracts: being able to standardize so that similar contracts can be used for different customers with different needs or for different products/services/partners. Formalization is easier with PO type PSS business models, whereas it is more difficult with the RO type. This issue is critical for the "replicability" of the PSS model.
    - <u>Complexity of these contracts:</u> Significant effort is required to develop complex contracts as the responsibility and the risk for the PSS provider increases (e.g., RO PSS business model type). This becomes even more important for partners who are committed to a long-term relationship
    - Involving a third neutral party for monitoring, verification, and dispute resolution
- Information Sharing: The contract between the PSS provider and other parties should clearly indicate what kind of information will be shared over time, who will have

access to sensitive data/information, and details regarding the IP rights (see the failure of the ARISTON PayXUse case, reported in Ceschin, 2013). IT infrastructures should also be developed to ensure safe/secure data exchange.

- Lack of "sense of control", which is missing in "ownerless" solutions such as the PSS: Customers may reject this solution as they may not be able to assess the life-cycle costs of owning the product and therefore the added value of the PSS model. Similarly, customers may also misbehave as someone else owns the product and therefore do not feel the responsibility for proper use.
- Provider's lack of knowledge about and capability to measure the life cycle costs: Customers may have difficulty understanding the economic advantages of ownerless based solutions
- PSS Provider may not be able to optimize operations (maintenance, use, recycling, waste management) at the customer's facility, and therefore the expected benefits may not realize
- PSS provider's tasks at the customer's facilities may be disruptive to the customers' operations, reducing performance. A particular customer may not have the ability to host multiple PSS providers managing their operations in its facility
- Rewards for environmental impact may not materialize or may not be obvious: Insufficient incentives for different actors in supply chains to engage in Eco-efficient Product Service Systems
- Risky if the customer switches to a different provider shortly after huge investments are made by the PSS provider
- Innovation inertia from the established cultural, organizational, and regulatory rules.
- Difficulty in quantifying the economic savings and environmental benefits from the PSS: convincing all parties that it is a "win" for all
- Large investments and uncertainties in the future cash flows (both timing and amount as in many cases payments will be linked to the "result" which is uncertain)
- Incentive misalignment: sometimes PSS models could have unexpected consequences where the manufacturer prefers "replacement" rather than "repair/maintenance" if there are economic gains in doing so (i.e., manufacturer makes more money selling new products to replace the old ones, instead of repairing the old products). In this case, the PSS model would have a negative environmental impact, and only aim economic gains for the PSS provider.
- Change management: PSS business model requires a radical shift in the way products and services are delivered to the customers, having considerable impact on the financial/information/physical flow in supply chains.

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- Coordination and Integration Issues: More coordination and integration between the actors in the value chain, where the "services" might be provided by the partners in the chain and not the manufacturer. This would also increase the "dependence" among partners, which may be perceived as a risk by some partners. More interaction with the customer is also essential for the successful deployment of the PSS business model.
- Knowledge leakage allowing suppliers develop new capabilities, loss of control, unexpected competition between supply chain partners, and/or partnering with potential competitors are factors that generally slow down the adoption of the PSS business model. The model is more suited (and more likely to be adopted) by companies selling complex long-life products requiring through life support (Voss, 2005).
- Lack of subsidies in the beginning of the implementation
- Lack of incentives from the regulatory bodies to reward environmentally friendly practices: "*Governments face difficulties in implementing appropriate policies to create corporate drivers to facilitate the promotion and diffusion of this kind of innovations*" (Mont & Lindhqvist, 2003; Ceschin & Vezzoli, 2010).
- Less careful behavior by the consumers as they no longer "own" the product in some PSS models
- Larger administrative costs due to more complex contracts and increased coordination. Especially challenging for SMEs as they would not be able to have such relationships (PSS) with multiple customers if these models are not easily replicable (e.g., RO PSS Business Model type).
- Larger variety: Significant number of product and service bundles exists for different customer segments, which increases operational and administrative burden. Different service offers need to be developed for different customers, even for the same product.
- Product Design: Aligning the product characteristics with the services offered considering the entire life-cycle of the product. For example, with the take-back offers, the product should be designed in a way that it can be easily reused or disposed. Similarly, if maintenance is offered as a service, the product design should deliver products that are easy to maintain (see Sundin & Bras, 2005; Williams, 2007). Products that are easily upgradable or can be remanufactured should be designed to increase the life time of the product as the PSS provider is usually responsible for the product's use.
- How are the initial and recurring costs (e.g., investment and maintenance) shared between the partners in case it is not the same company selling the product and

providing all the services? How are the revenues shared based on the service/result? Adequate r*evenue sharing agreements and Performance Based Logistics (PBL) contracts* linking the payments to the result/outcome/service level between different actors need to be in place (e.g., the Finnish Energy Service Companies (ESCO) offering comprehensive energy solutions gain their returns by receiving a share of the energy costs saved by their customers. For more details, see Ceschin, 2013).

3.3.3. Impact on the objectives

Companies who have decided to develop services related to their products (PSS) as part of their development strategies will face different challenges, impacts and benefits in a large variety of topics, such as customized production, materials management, waste reduction, etc. Therefore, here are presented the main impacts (positive and negative) at different levels (Company, Industry, Region, and European Zone) that could come as result of its implementation. Please bear in mind that this is a qualitative evaluation of the decentralized/modular production based on the findings from the desk research. Based on the frequency of comments related to the "objectives" listed in the table and the nature of these (positive or negative impact) in the literature reviewed, we have come up with the scores as can be seen in the below table (as well as the similar tables for the other business model archetypes).

In the following table, the positive numbers indicate an "improvement". The number itself indicates how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact. Please note that positive (negative) impact does not always mean an increase (decrease) in the absolute figure. For example, the impact will be "positive (negative)" if the "production costs decrease (increase)" or "if there are more (less) jobs available".

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing				1
	Efficient and sustainable distribution				3
	More flexible				1
	Less delocalized				1
	Competitive advantage via intensified processing				0
Industry / Company / Region specific objectives	Reduced production costs				-1
	Increased product quality				2
	Minimized time to market				0
	Higher throughput with smaller batches				0
	Reduced response time to changes in demand				0
	Jobs creation				1
	Limit employment reduction				0
	Improving working conditions for workers				1
	Sustainable development promotion				0
	Increased local business opportunities - SMEs				1
	Shorter lead times				1
	Less stock				0
	Reduction of raw material by 15%				0
	Less waste				0
	Reduction in environmental footprint by 10%				0
	More interaction with the end users				3
	Customer driven SC business models based on Intensified Processing.				3

Table 9: Analysis of impacts on the objectives from Sevitisation of the Process Industry (PSS) archetype

The largest impact will happen in the following objectives:

- The **distribution/delivery** of the servicewill become **more efficient and sustainable** as the products will have an added value on the service provided, guaranteeing that distribution is linked with the spirit of the brand and the expectations of customer
- An increased **interaction with end users** will be possible as the company offers an added value on the product: service.
- **Business models** will be shaped to **satisfy customer needs**, therefore supply chains will likely change to adapt this new trends.
- Because of the increased co-innovation capabilities, time to market could be shorter as new products/services would be developed faster and response time to changes in demand/customer needs is also likely to decrease
- As a result of the increased lifetime, better of use of resources, waste reduction and the possibility to reuse waste, the environmental impact will likely be reduced with this business model.

Many of the objectives probably will not be affected by the changes, such as:

- The **delocalization** strategy probably will not change if it was already adapted to meet customer needs. If there is a new product, then is possible that services will also be delocalized. However, in cases where the additional services offered make the manufacturing more attractive in Europe instead of importing from outside Europe (e.g., recycling), PSS would help bring manufacturing jobs back to Europe.
- **Production in batches** is unlikely to be affected
- In the case of **employment reduction** could be argued that servitization will offer new jobs and opportunities, but are likely to keep the same.
- As products are linked with the services, is probable that some products will be purchased more often than others, but in the long run it does not have a major effect on the **stock**
- Is it possible to have a minor impact in the **environmental footprint**, but it could be increased as many new products could be required in the market.

There are also few negative impacts:

- Is likely that, as servitization is included in the design of a product, the **production costs** will increase as well, having a negative impact on the objectives.

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3.4. Reuse - Sustainability

The concept of sustainability appeared in the corporate agendas in the decade of 1980, when the Brundtland Commission, after being requested to analyze the "*accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development*" (Hindle, 2008). As a result of the research, the commission presented the idea of sustainable development, defined as the development that "*meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Hindle, 2008).

After the commission presented a global issue that requires global solutions, many initiatives were developed. Many companies presented different approaches to tackle this problem, as they are the main consumers of natural resources and raw material that can be manufactured into end products and further services related to these. Ranging from reduction of raw materials, recycling initiatives, design of office building, more eco-friendly vehicle fleet, among others, the solutions provided by companies have had an enormous impact on how consumers perceive a brand and its products. The research performed by a consulting firm named SustainAbility identified industrial sectors that "*will have profound impact upon the sustainability agenda*" (Rainey, 2006) if they include accurately the sustainability concept in their strategies. The six industrial sectors defined in the study are chemicals, energy, finance and capital markets, food and beverages, healthcare, and the knowledge economy (Hindle, 2008). A McKinsey & Co. report by P. Eykerman for example reports chemistry innovations for GHG (Greenhouse Gas) reductions, arguing that innovations in production, disposal, and extraction would greatly reduce carbon emissions (the main contributors being insulation, fertilizer & crop protection, and lighting) (Eykerman, 2009).

Since many initiatives were introduced by companies, many changes have been seen in recent years, focusing on the sustainability area. For example, sustainable production systems, cleaner production, resources and raw material management, sustainable transportation, reverse supply chains, closed loop supply chains, and more recently circular economy.

The importance of the closed loops in the supply chains becomes critical, as it plays a key role in the production, distribution and consumption of goods and services; these provide an opportunity to all the different actors involved, to recycle and reuse any material along any part of the product development, as well as giving a new added value to a product by repurpose or refurbishing the product for another use cycle (World Economic Forum, 2017), (EMF, 2013). Important to note is that "*reuse in the supply chain gives the impression that* *material loops should be, literally, closed, in the sense that materials or components must go back to the original parts or product manufacturer*" (Mentink, 2014). However, another manufacturer can use the material, as long as the materials can flow back in the original material pool (EMF, 2013),.

Also, it should be considered that the circular economy (CE) requires a "glocal" (global + local) approach, as it must include the collaboration of the global partners and stakeholders to achieve a change in the current system (technology, supply chain, finance, teamwork, etc.) but it should also include the specific needs and changes at local level, considering the customers, local regulations, policies, etc. (Witjes & Lozanoa, 2016).

The important trend to manage resource streams focus on solutions of collaboration between industries based on novel advanced energy and resource management concepts. Reuse and sustainability optimizes both input and reuse of raw materials, energy and water streams in a synergetic way. These processes are based on cross sectional collaboration concepts, developed under the principles of Circular Economy and efficiency in energy, resource and carbon-neutral processes. The simplest but more precise definition of CE is given by Bas, who defines "*A circular economy is an economic system with closed material loops*" (Mentink, 2014) By this definition, it is easy to understand that it requires "closed material loops" as a prerequisite, implying materials that can be reused again (as raw material, part of the product, components, etc.) (EMF, 2012), facilitating the economic activities related to it, such as refurbishment, recycling, separation, etc. According to the report by the World Economic Forum (WEF), it is important to recuperate the value of the product when it comes to the end of its life cycle (World Economic Forum, 2017).

3.4.1. Potential benefits/opportunities

In what follows, a list of potential benefits for the introduction of more reuse - sustainable business models is provided:

- Development of supply chains that can handle coordinated forward and reverse flows of materials, to take full advantage of materials management, including the participation of different parties. This could provide further integration opportunities among large companies (or SMEs) and the possibility to include potential SMEs.
- Achieving the same industrial output while using less energy and fewer raw materials at reasonable cost while producing less pollution (Geng & Doberstein, 2008).

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- Meeting dual goals of economic and environmental benefits, by using more efficient marketing techniques to raise brand awareness among customers, having a direct impact on sales to more environmentally friendly customers.
- More sustainable operations and better resource use through improving efficiency, increasing the life time of the product and reducing the amount of materials/number of products used (via sharing, recycling, repairing, better maintenance, etc.)
- Stakeholders (i.e. industry, government, education institutions and community) will be more involved on seeking for better manage of natural resources, and assuring fair and equitable allocation of different resources
- Including environmental and social issues in managing the supply chain, as they are increasingly on the public agenda (Seuring & Muller, 2008)
- Manufacturing companies can attain several benefits, such as enhanced supplier engagement, reduced production cost and minimized environmental impact (Zailani, Jeyaraman, Vengadasan, & Premkumar, 2012)
- Products easier to repair and longer lasting (higher life cycle), with incentives to take old products back (Wijkman & Skanberg, 2016) could be one interesting approach to incentivize customers to get this kind of products.
- Circular economy can cut unemployment and save people money (Green Alliance, 2015) as increases the sale for products for reuse and support more jobs on remanufacturing industry.
- Consumers need for more repairable products instead of one-life (one use) products (Green Alliance, 2015) would be an interesting approach as nowadays customers look for companies which products have an environmentally friendly component.
- The increase in global competition, shorter life cycles, expanded environmental legislations and other commercial take-back policies will allow customers to return products in an easier way, increasing the potential of unnecessary products and demand volatility (Guide, Harrison, & Van Wassenhove, 2003). Therefore, having reuse initiatives would make easier for companies to use components from the different products instead of generating more waste from raw materials.
- Increased revenues over the life cycle of the product because of additional sources of revenue such as recycling, remanufacturing, waste management and sub-products industries.
- Reduced life cycle costs, as the product will have not only parts made from virgin raw materials, but including also remanufactured and/or recycled components, reducing maintenance and disposal costs.

- Coordination among the different parties in the supply chain could be an opportunity as each other provides information to generate better-designed products (and services).
- A new opportunity for risk sharing arises, as many parties along the supply chain will share the risk instead of the traditional model were only one partner of the supply chain assumes 100% of the risk.
- Including reuse among the company strategies will allow also the collaboration with other archetypes, such as mass customization by using the reverse supply chain as a tool for recollection of different elements, or PSS were companies can offer additional services over the end products, finding a new service from some elements (e.g., see Överholm 2017 for "ventures that are purpose-built for intermediary PSS business models" such as the small-scale water recycling systems Seven Seas Water, 2014)
- Technology as simple as online communication is available for companies to start sharing information about their reverse supply chains, showing what type of products can be shared with other companies and even which processes. Tools such as "*crowd-sourcing, collaborative virtual environments, online software design tools and open-source forms of intellectual property*" (Preston, 2012) can be used to meet the companies' need for sustainable processes.
- According to Van Houten, what the companies need to think is if they, as the original product designer of manufacturer, want to have the product back, to consider the real implications of selling the product, when the consumer is merely interested in the benefit of the product (Van Houten, 2016), changing the concept of ownership of the product and the benefit of owning it.

3.4.2. Potential challenges and risks

Even when the reuse and sustainable development related to supply chains apparently should not face many challenges, here are mentioned some critical ones:

- Despite the largely discussed convention on the importance of sustainability aspects for the long-term competitive advantage of a company, trying to meet different triggers like legal regulations, requests from stakeholders, customer demand, environmental and social groups' pressure, among others, there are barriers on implementing Sustainable Supply Chain (SSC) mainly directly linked to costs of measurement systems focused on sustainability along the network (Piplani, Pujavan, & Ray, 2007). Drawbacks are set with respect to environmental outcomes, as there is a misperception that data collection from different actors in the network is difficult to manage, and it will have a low impact on the global outcome.

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- Sharing information with other companies and parties among the supply chain, through common IT systems for effective planning and management, including the creation of scenarios for optimal reduction, reuse and recycling
- Companies will need to invest more on understanding the life-cycle approach of their products, integrating all product returns into the business model (Guide, Harrison, & Van Wassenhove, 2003), contemplating also the forward and reverse supply chain. Thorough analysis of the value of the products over its useful time (a product now having more value as the product itself or its parts can be reused later on in production of other products) is necessary and challenging. Careful life-cycle analysis needs to be performed, which is challenging as standard LCA approaches are hard to ecnounter for specific businesses.
- Engaging in development of more environmental friendly products could be costly, as there is a requirement for new suppliers, different raw materials and/or new transportation partners.
- Management reluctant to change as it will require money investment, as well as adaptation in the traditional supply chain and the business model.
- Creation of a uniform platform for promoting the collaboration among companies and industries, to achieve a more collaborative sustainable environment (Geng & Doberstein, 2008). In addition, this will require companies to share information that could be sensitive.
- Data sharing under homogeneous and normalized conditions present itself a big challenge when trying to compare and analyze them together in a holistic view. Networked companies possess data of its different components along the network, however when analyzing environmental impact, it seems that data sharing is considered confidential (e.g. energy consumption, release on water and heating).
- Taxing systems that consider the value-added of recycled materials higher than virgin materials, resulting on companies paying higher taxes for being sustainable (Geng & Doberstein, 2008)
- Lack of government and industry mandates in which sustainability is made a mandatory requirement for businesses, as it could change at any time, and companies must be prepared in advance to face this challenge (Gopalakrishnan, Yusuf, Musa, Abubakar, & Ambursa, 2012)
- Alignment of strategies from the different companies along the supply chain (Ageron, Gunasekaran, & Spalanzani, 2012)
- A growing demand for remanufactured products does not often present overlapping with disposal of used products; therefore is necessary to balance these two, as some products are the result of this intersection. (Umeda, Kondoh, & Sugino, 2005)

3.4.3. Impact on the objectives

Companies who have decided to include sustainable strategies will have different impacts in a large variety of topics, mainly allocated on those related to environmental efficiency, materials management, waste reduction, etc. Therefore, here are presented the main impacts (positive and negative) at different levels (Company, Industry, Region, and European Zone) that could come as result of its implementation. Please bear in mind that this is a qualitative evaluation of the decentralized/modular production based on the findings from the desk research. Based on the frequency of comments related to the "objectives" listed in the table and the nature of these (positive or negative impact) in the literature reviewed, we have come up with the scores as can be seen in the below table (as well as the similar tables for the other business model archetypes).

In the following table, the positive numbers indicate an "improvement". The number itself indicates how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact. Please note that positive (negative) impact does not always mean an increase (decrease) in the absolute figure. For example, the impact will be "positive (negative)" if the "production costs decrease (increase)" or "if there are more (less) jobs available".

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		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing		3		
	Efficient and sustainable distribution		3		
	More flexible		2		
	Less delocalized		1		
	Competitive advantage via intensified processing		0		
Industry / Company / Region specific objectives	Reduced production costs		2		
	Increased product quality		3		
	Minimized time to market		1		
	Higher throughput with smaller batches		0		
	Reduced response time to changes in demand		0		
	Jobs creation		3		
	Limit employment reduction		2		
	Improving working conditions for workers		2		
	Sustainable development promotion		3		
	Increased local business opportunities - SMEs		2		
	Shorter lead times		0		
	Less stock		2		
	Reduction of raw material by 15%		3		
	Less waste		3		
	Reduction in environmental footprint by 10%		3		
	More interaction with the end users		1		
	Customer driven SC business models based on Intensified Processing.		1		

Table 10: Analysis of impacts on the objectives from Reuse archetype

The largest impact will happen in the following objectives:

- The **distribution and manufacturing** will become **more efficient and sustainable** as the business models will be reshaped to adapt to the new trend.
- An increased **product quality** will be possible as the customers are looking for better products, more efficient and more environmentally friendly.
- **Job creation** as result of a growing remanufacturing industry, new equipment providers for recycling along with skilled/unskilled labor required for recycling companies
- **Reducing raw materials** and generating **less waste** are tighten together in this business model, which leads into the reduction in the **environmental footprint** of companies and products

Many of the objectives probably will not be affected by the changes, such as:

- The **intensified processing** strategy probably will change if it was not adapted to meet the new customer needs. However, under the introduction of more sustainable supply chains, the need for high intense processed products will likely decrease.
- **Smaller batches** are likely to become the norm if they include more sustainable processes, however, the changes in production are not meaningful.
- **Lead times** and **response to changes in demand** could be lightly impacted as the products will still be required to go under remanufacturing processing times.
- **Delocalization trend** may be affected, although slightly. It would be more difficult for a company in Europe go elsewhere as with the reuse model there is more dependency on other companies (e.g., collaboration in industrial parks). However, if similar industrial parks exist or are developed in other parts of the world, the situation would be different.

There are not identifiable negative impacts in the objectives, as the reuse-sustainable business models have proven to add more value than to create problems to companies.

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3.5. General Summary

In the following table, a general summary of the four archetypes is presented, highlighting cells with both the larger positive (green) and all negative (red) impacts on the objectives. Moreover, we have categorized the industry/company/region specific objectives into three categories (economic: red, social: blue, and environmental: green) in the table.

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing	3	3	2	1
	Efficient and sustainable distribution	0	3	2	3
	More flexible	3	2	3	1
	Less delocalized	-2	1	-2	1
	Competitive advantage via intensified processing	1	0	0	0
Industry / Company / Region specific objectives	Reduced production costs	2	2	1	-1
	Increased product quality	2	3	2	2
	Minimized time to market	3	1	3	0
	Higher throughput with smaller batches	2	0	2	0
	Reduced response time to changes in demand	3	0	3	0
	Jobs creation	2	3	2	1
	Limit employment reduction	-1	2	1	0
	Improving working conditions for workers	0	2	0	1
	Sustainable development promotion	1	3	0	0
	Increased local business opportunities - SMEs	3	2	2	1
	Shorter lead times	2	0	2	1
	Less stock	2	2	2	0
	Reduction of raw material by 15%	0	3	1	0
	Less waste	2	3	2	0
	Reduction in environmental footprint by 10%	2	3	2	0
	More interaction with the end users	2	1	1	3
	Customer driven SC business models based on Intensified Processing.	1	1	0	3

Table 11: General summary of analysis of impacts on the objectives from the four archetypes

We remind the reader these scores are based on the frequency and nature (positive/negative) of the comments regarding these objectives in the literature reviewed. We also use our own judgment to further predict what the impact would be. The scores for a particular company might be significantly different from the above, depending on the business environment. As can be interpreted from the general summary table, the archetypes have many more positive impacts than negative impacts in the objectives. The Reuse archetype provides the largest positive impacts (compared to the other archetypes) as result of better use of current business model infrastructure and easiness to generate positive changes. In the other hand, the Mass Customization archetype, although it generates positive impacts, is also the one with the larger negative impacts as result of the required changes that would take place when implemented.

In the case of the decentralized production system, the business model archetype presents many opportunities for companies as it offers entirely new perspectives in terms of reduced cost by having smaller working crews, investing in duplicating and customizing designs over creating new ones every time, offering safer fabrication facilities, requiring smaller on-site spaces and generating customized products, and achieving higher quality assemblies.

Besides, a decentralized or modular production system allows quick response and scale flexibly where production units operate in a complementary part of the value chain.

When talking about mass customization, several models aiming to optimize it have been proposed, making a trade-off between cost and variety, focusing on manufacturing processes and assembly lines. The mass customization paradox between scale production and customized demand requires a coexistence of make-to-order and make-to stock supply chain. A hybrid approach where mass customization archetype along with the decentralized/modular production might make it possible to run companies with low levels of inventory and make them flexible in order to quickly respond to changes in demand.

Mass customization brings a new broad range of possibilities, especially considering the different technologies available and how companies can take advantage of them in the different industries. Most of the required technology for a successful implementation of this strategy is already available and has been around since the early 1980's, however lately has been involved in scientific and industrial developments, ranging from housing customization, electronics customization to human organ 3D printing, creating a wide range of opportunities for companies to venture on different business models.

The inclusion of computational and communication technologies have produced a new market, supported by the Internet of Things (IoT) evolution, which links sensors, standards-based networks and smart analytics, to offer a new experience to the customer, where everything is connected to the internet. This offers a new possibility of innovative concepts and virtually interconnected processes and reconfigurable value chains that could accelerate production of customized goods in the most cost-effective way, as well as offering new additional services over the use of the product. The process industry being the supplier of many firms in discrete manufacturing sector and potentially end consumers (e.g., emergence of "prosumers" with the 3D printing), would benefit largely from these developments, which would allow it connect better to its customers and offer PSS (being better able to measure the performance of the service because of enhanced communication), mass customization, create virtual factories in case decentralized/modular production systems, and increase reuse opportunities.

Regarding the Product Servitization, there are many possible benefits that could be perceived as result of its implementation, as this archetype has the potential to offer a closer relationship with the customer, facilitating mass customization. In the other hand, this proximity to the final customer could be translated into more costs on the operation side. Based on this, Tukker (2004) explains that product-related services have marginal "*environmental benefits since mainly incremental change, such as better maintenance, can be expected*" (Tukker, 2004) from the producer point of view, while all the responsibility careful use of the product will be moved into the customer hands, generating a debate on how efficient and eco-friendly could it become. If the firm extends its services not only covering the "use of the product" but also the reuse of recyclable materials at the end of life of the product (i.e., a hybrid model combining PSS and reuse), then the environmental benefits would be significant.

Servitization influences the entire value chain while the product becomes part of the offering. This is an incentive for the provider to add related services to its product offering and lock the costumer into a long-term relationship. Improved knowledge through better insight of product use implies that integrated solutions are a lasting source for differentiation, as they are less easy to copy.

Finally, thinking about sustainability as a possible business model as introduced on the reuse archetype, it is necessary to think about the environmental, social and economic impacts that a company could have. As defined by Bellos & Ferguson (2017) "*it is clear that any business model that relies on a disposable society cannot be sustainable long-term model*" (Bellos & Ferguson, 2017). For this reason, enabling sustainable business models (such as circular economy, closed loop supply chain, reverse supply chain, etc.), aiming to minimizes waste by re-using, repairing, refurbishing, and recycling materials and products are the best possible solution to overcome difficulties (European Commission, 2014).

Industrialization process developed under past business models has brought serious negative environmental impacts, resulting in a crisis that calls for a better and smarter management of resources, as well as the adoption of a more environmentally responsible development strategies.

3.5.1. Discussion

The aim of the INSPIRE project is to help industries and companies to select and develop the proper archetype (or hybrids) to meet their own needs and requirements, generating positive impact. Given the complexity of each of the archetypes, is necessary to understand their impact in current business models (or practices) and how these can affect the general objectives.

Among all of the archetypes, the objectives that are mainly affected in a positive way are related to more efficient and sustainable processes, as well as flexible, with higher quality, providing opportunities for the small and medium enterprises (SMEs) and increasing the job creation in the region.

The more positive impacts on the objectives are provided by the reuse (sustainability) archetype, where every single objective receives a positive or at least a non-negative number, achieving improvement in almost all of the presented objectives. There are some neutral impacts (meaning zero impact) on the objectives, as the archetype does not affect directly any of them.

On the other hand, the archetype that has the lower global impact on the objectives is the Product Servitization archetype, as it only generates significant changes in the downstream of the supply chain, facing the customer and how they receive the products in a more sustainable and efficient distribution way. However, careful design and implementation of this business model archetype could have significant impact on the objectives. For example, if the services offered by the firm provides an incentive to the customer to get closer to the provider, certain actors in the downstream supply chain might come back to Europe (or similarly, it would be easier to retain firms in Europe as the PSS model helps lock-in the customers with the extended services). Finally, the PSS model allows companies to develop "high-value added" products by combining product and the service offerings.

The mass customization is the one that, besides having a large positive impact in most of the objectives, is also the one with the two most negative impacts specific objectives, increasing the delocalization problem and theoretically having a risk of increasing the unemployment rate. The situation might be different though if the mass customization (e.g., 3D printing) makes it easier to produce goods at home locally (e.g., small shops or consumers producing in Europe) at reasonable cost, then there might be fewer business outsourcing production. Besides, as the mass customization is usually done with less labor intensive equipment, one

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major driver of moving production to outside Europe (which is the labor cost) is no longer that important, and more companies might come back to Europe. Nevertheless, it is important to understand that each of these impacts (positive and negative) will depend on the type of product and industry and the way the particular business model is designed.

However, when some negative effect can be seen in one of the objectives from one of the archetypes, it is possible to make a hybrid with a positive and complementary archetype, balancing the negative effect and turning it into a positive effect. For example, to limit the employment reduction as a result from the mass customization trend, it could be included a reuse strategy, generating new employment opportunities as result of the recycling and reusing processes, such as: recycled material collection, recycled components separation, circular economy patterns generated by the interaction of different companies sharing different components and materials.

The advantage of INSPIRE's look at the four defined archetypes is that all of them can be combined together, as they are not overlapping and neither opposing, thus taking the advantage of each to generate higher positive impacts in the new proposed business model.

3.5.2. Recommendations

Companies interested in developing any of the proposed archetypes (or hybrids from them) to create new business model should consider not only the potential benefits, but also the challenges and risks they could face, moreover, what would be the implications of not implementing them in the best proper manner.

For the development of WP4, it is necessary to understand how companies could successfully implement the proposed business models to prepare different "case scenarios" which include existing facilities.

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Chapter 4

4. Case studies: an introduction

As presented in WP1, the selection of the case studies was made considering different factors and the information collected in the first interview with companies. For each of the four archetypes, case studies were selected, which are examples of companies that have incorporated different solutions. The selection of the case studies was made considering the previous findings and archetypes from D1.2 (refer to D1.2 from INSPIRE project):

1. **Decentralised or modular production** covers industries that decentralize their manufacturing and split their production processes into various locations or regions.
   - *A.1. Business case 1: Small Scale Local production.*
   - *A.2. Business case 2: Emerging Energy Carriers and Energy Flexibility*
2. **(Mass) customization** combines the personalization and flexibility of custom-made business manufacturing with the traditional principles of mass production;
   - *A.1. Business case 3: Flexible Manufacturing in Footwear Sector*
   - *A.2. Business case 4: Customized Leather Fabrication*
   - *A.3. Business case 5: 3D Food Printing*
3. **Servitisation of the process industry** considers deliver functionality, rather than ownership;
   - *A.1. Business case 6: Implantable Drug Delivery System*
   - *A.2. Business case 7: Chemical reasing - TabaChem*
4. **Reuse and sustainability** focusses on mechanism for a more sustainable and competitive industry through improvements in resource and energy efficiency;
   - *A.1. Business case 8: Smart Delta Resources (SDR)*
   - *A.2. Business case 9: Chemical reusing - TabaChem*

A **summary section** is introduced in this Chapter 4, where a general summary of the common challenges, opportunities and impacts on objectives are presented.

4.1. Case studies: a brief description

In this section, a brief description of the different case studies is presented. However, for a full detailed description about the nine (9) case studies, we encourage the reader to refer to **Appendix A – "Case Studies"**. For each of the case studies presented in the **Appendix A**, the following structure is followed:

- A **brief description of the case** provides the information about the company and how does it fits under the archetype background;
- The **supply chain** part provides a more detailed explanation on the current and future situation of the company's supply chain;
- In the **changes in the value chain** section, the potential changes for each component of the value chain are presented;
- The **opportunities and challenges** section presents the company's current issues, and those that could face in the future;

A brief introduction for each of the nine case studies is presented in the following section. For further information about each case study, please refer to Appendix A, where these are discussed in detail, providing insightful information about each one.

Business case 1: Small Scale Local production

This business case identifies the potential for the chemical industry to change the traditional manufacturing process based on large plants designed to take advantages of economies of scale (larger production quantities, lower price) and move to possibilities that are more flexible, aiming to adapt quickly to market changes, reducing production costs and lowering, as well, the transportation costs.

Business case 2: Emerging Energy Carriers and Energy Flexibility

In this business case, the chemical industry is analyzed under the perspective of an energy intensive industry and its impact in the production costs for the industry, as well as the carbon footprint generated due to it. The case introduces the idea of the energy sector about moving from traditional centralized fossil-powered plants to more decentralized renewable energy powered plants.

Business case 3: Flexible Manufacturing in Footwear Sector

In this business case, the impact of mass customization in a high-performance shoes' company is presented, mainly focusing in the results of this implementation and how it has helped the company to become a sole manufacturer for a main group of interest: mountaineers.

Business case 4: Customized Leather Fabrication

Similar to previous business case, a practical application of the mass customization on a leather company in Italy is presented. For the company is important that sustainability and safety are always linked with their high quality products.

Business case 5: 3D Food Printing

This business case introduces an innovative concept and use for the 3D printing: Food. The goal of the company is to create value for its customers by reducing the hard work of preparing food but adding value on the final product presentation and contributing to a healthier eating lifestyle.

Business case 6: Implantable Drug Delivery System

A practical solution for different problems faced by health industry, regarding patients self-management and self-awareness is presented in this business case, introducing a new product and a service around it.

Business case 7: Chemical leasing - TabaChem

A project based around the leasing of chemicals is introduced in this business case. On this sense, the chemical industry could take advantage of changes on the traditional system, where supplier only offers the raw material (products), to a model focused on the service around the product.

Business case 8: Smart Delta Resources (SDR)

This business case presents an initiative of eleven power companies and raw material-based manufacturers in the Zealand Delta region in the Netherlands. They explore the possibility of sharing materials and waste, increasing the benefits for all the participants.

Business case 9: Chemical reusing - TabaChem

From the reusing perspective, TaBaChem project aims to develop the necessary tools and ecosystems, as well as regulatory and policy framework for a successful implementation, considering the implications of reusing chemical products and waste among different organizations and industries.

4.2. General findings on Case Studies

It was found that most of the companies that are presented in the case studies have applied somehow part of the archetypes and are getting benefits from the implementation of these strategies on their own objectives. Given the situation that Central European production is already offshoring, these business models increases possibilities to stay in Europe

Most of companies have found benefits in the sustainability part, by reducing the amount of raw materials required to create their products, having efficient and "cleaner" production systems that allow them to reduce emissions, incorporating policies and strategies that enhance the reduction of waste as result of their production processes. As well, the companies intend to include the customer as integral part of the process and as a key actor, not only of the supply chain, but also as the cornerstone of the business.

As a result of the implementation of these strategies, the largest alterations faced by the supply chain are related to changes in the way the sourcing is made; for example, in some cases the companies had to switch to more local partners when doing decentralized manufacturing, while in other cases, to meet the objectives, companies had to switch to a different supplier of raw materials, incurring in some additional costs. The supply chain is getting less efficient in the decentral case, this also means that there are more jobs needed.

For most of the companies in the case studies, the technology was designed and developed by the companies (or industries) to meet their requirements. In other cases, technology development is still required (or is currently under development) to generate a larger impact in the business model.

Flexibility in the production process is a result of the implementation of the archetypes, as it creates new possibilities to be closer to the customer or to use different types of material (including recycled), and promotes collaboration with other companies or industries (Business cases 2, 4, 5, 8). As an indirect result of the flexibility, the creation of jobs has a positive impact as many different industries can work together or even generate by-products as result of these interactions (Business cases 2, 3). On the other hand, one of the disadvantages of the flexibility is that there is an impact in the production cost by having to redesign the supply chain or by adding more manufacturing facilities, which results in an increase of the price paid by the customer (Business cases 1, 2, 6, 7).

As well, having a production facility at the customer location greatly reduces lead times. In the servitization model (Business cases 6, 7), lead-time reduction is strived for in an optimal supply chain. In addition, placing a facility closer to the customer increases collaboration and interaction, which at the end is translated into more benefits for the company as they are paying direct attention to what the customer is requesting; moreover, it increases the impact of the customer on the supply chain. In the servitization model, specific customer choices are made.

In the decentralized archetype (business cases 1, 2), production is done at the customer location, so distribution of the product is "cut out". In the servitization case, we strive for an optimal supply chain, which will be a mix of central and decentral production, so some distribution remains.

The main risks lie in higher complexity and uncertainty as result of the implementation of the archetypes without deeper analysis, compared to the current traditional model. As many parts of the value chain must be under control by managing and monitoring them, complexity becomes the key word here as, the business model is changing but must continue operating efficiently.

According to Chapter 3, the reuse (sustainability) archetype has the largest positive impact in the general objectives presented in the matrix. In the case studies was confirmed that all of the interviewed companies benefit from implementing (directly or indirectly) strategies that aim for more sustainable processes (Business cases 2, 7, 8, 9).

As well, in the servitization archetype was found that it had the lesser disruptive impacts on the value chain, which was confirmed by the case studies. The most important change comes directly in the planning of the product, when it is designed and tested, as the product offers an additional service rather than "simply" being a product (Business cases 6, 7). Complexity is also added as the product has to balance the cost-to-benefit ratio, as customers are not willing to pay high prices if they do not see an exceptional additional benefit from one product, when they could easily afford to get two (or more) separate products that meet the requirements they are looking for.

As proposed in Chapter 3, mixing some characteristics of the different archetypes is possible, as long as they contribute to improving the performance. Some of the business case studies showed that companies implementing some parts of the archetypes are also including parts from others, which reinforce the positive impact and balance the possible negative effects from one specific archetype.

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Chapter 5

5. Findings and future steps

In today's world, almost everything happens faster, including but not limited to what customers want and when, how companies produce their products and from where they source their raw materials. Consequently, companies have to quickly adapt to the changes in demand, designing products that usually have shorter life cycles and changing as well the design cycles of the product, to adapt to the changing needs of customers.

As there are many opportunities for companies with the globalization and the inter-industry collaboration, there are also downsides of it, as the competition can come from any unexpected place. For instance, with the "Mass Customization" archetype, the next competitor could be the final customer as they can decide what the particular features of their product are, based on a current model, generating different versions of the same product.

As most companies look for profitable investments, it is safe to say that the interviewed companies make sure that revenue comes with some extra insight, heavily based on the efficiency and sustainability. These two concepts have slowly become a cornerstone in the companies' strategies willing to increase their market share and the number of customers, which are more interested on sustainable companies with products that can satisfy their specific needs. One of the objectives related to this cornerstone is to reduce waste from manufacturing processes, which is also directly linked to a reduction on the carbon footprint, having a positive impact in the companies' financial goals, the environment and the society.

One of the objectives proposed by the European zone is to make companies less delocalized, meaning that companies could be able to source raw materials, produce at a reasonable cost and have a pool of customers ready within the same European Region. This objective could be met by most of the archetypes as presented in the case studies and the interviews; however, some business models would increase the delocalization as they allow the final product to be manufactured in regions outside Europe, due to lower costs and/or better conditions than offered within the region. To reverse the delocalization trend, it is necessary for companies and policy makers to work together to find the best solution that fit the interests of all the parties involved.

The decentralized or modular production can have large benefits for companies willing to split their manufacturing processes into several regions or locations, with the main purpose of being closer to the final customer. The main reason to do this is that different customers in different regions have different needs, making it difficult for companies to standardize the products on a "one size fits all" style. Thus, creativity could be increased by giving some decision making power to local/regional managers, which improves efficiency, influencing positively the performance in distribution/delivery process. On the other hand, the downside of the modular production is that cost could increase as result of opening different manufacturing sites instead of having one central and increased unit production cost.

Based on the desk research and the analyses of the business cases from industry, we find that three out of four have a minor impact on the job creation or limiting the employment reduction; this was confirmed by the case studies and interviews. The key insight here is that most of the archetypes bring different processes that aim to improve the performance of companies, reducing the non-productive areas, which sometimes end up in reducing jobs rather than creating new ones. This statement is not true for all of the archetypes though, such as the reuse archetype, where different jobs can be created as result of including, for example, new processes in the reverse supply chain or generation of by-products.

An important feature of all archetypes is that they could all be implemented by Small and Medium Enterprises (SMEs), as a result of enabling them to be more flexible while conserving product quality (producing in smaller batches at different locations under same specifications) and increasing their production capacity (by having more locations with different capabilities). Information management (information exchange platforms) plays a key role to allow SMEs achieve flexible production and facilitate innovation.

Flexibility, considered one of the key objectives of the project, is impacted by most of the archetypes. The more flexible companies come to be, the easier communication becomes, decisions are made, new products are generated and customers are more satisfied by being closer to the manufacturer and being heard. The flexibility introduced by these business model archetypes create companies that are better able to mitigate risks in relation to the fluctuating input/output prices, energy and raw material availability, increases in labor/production/distribution costs, changing regulations due to new government policies. Most of the business cases also point out that European firms should continue investing in high-value added activities (e.g., R&D) to maintain its leading position. The novel business models that will be proposed in D3.2 and D3.3 will take this aspect into account, in order to leverage the already existing competitive advantage.

In the upcoming deliverables of this working package (WP3) and the next one (WP4) an exploratory analysis with an expert board will be made to validate the findings, as well as corroborate the proposed roadmap for the development of proposed business models, verify the proposed strategies and KPIs and follow the accurate research directions from business models from a regional system perspective that can be replicated and scaled up for use elsewhere.

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Annexes

Appendix A - Case Studies

A.1. Decentralized or modular production

A.1.1 Business case 1: Small Scale Local Production

A.1.1.1 Description of the case

The chemical industry, especially bulk chemicals, is focused mainly on 'economies of scale'. This strategy leads to large plants that are designed to produce large amounts of chemicals at the lowest price. These large plants are inflexible, need high investments to be realized and are subject to restrictions due to safety and environmental regulations. Furthermore, due to a large customer base the transportation costs from production plant to customer can be high, especially when customers are at remote locations. In many cases fluctuations in both energy and feedstock prices affect the prices of the chemical. Chemical companies are looking more and more for flexible possibilities to adapt to market fluctuations and possibilities to reduce transportation costs. We will elaborate on two business cases for small scale production:

- A small scale ammonia production plant developed by Proton Ventures
- The MyH_2O_2 peroxide plant of Solvay.

We will first shortly introduce these cases.

Proton Ventures is a company that develops and produces plants for decentral, small scale ammonia production. These plants are especially applicable in agriculture where ammonia is used as fertilizer. Two plants have been developed to produce ammonia on a small scale, one for production from natural gas and one for production by electrolysis. The business case is based on delivering increased flexibility and independence of volatile ammonia prices to the customer and reducing transportation in the supply chain. Ammonia production is mainly dominated by China. India, Russia and the US are the next major producers (USGS, 2017). The main use of ammonia is as fertilizer in agriculture. This sector is the main focus for the business case of Proton Ventures.

Solvay is a chemical production company that among other chemicals produces hydrogen peroxide (H_2O_2). Hydrogen peroxide is used for paper and pulp bleaching, for other chemical processing and for several domestic applications. Solvay mainly operates large plants for producing hydrogen peroxide. The exception is the MyH_2O_2 plant, which is a small scale hydrogen peroxide plant. These small plants are operated at the site of customers, mainly focused on remote customers. Local operation of these plants avoids transportation of H_2O_2 from the central production plant to the customer. These avoided transportation costs are the cornerstone for the business case of these MyH_2O_2 plants.

A.1.1.2 Description of the current supply chain

The current supply chain for ammonia and hydrogen peroxide is characterized by large scale central production (Figure 1). The main influencers of the supply chain are the producing companies. This is translated into a supply chain based on economies of scale. We will describe the current supply chain for the case of ammonia and hydrogen peroxide production.

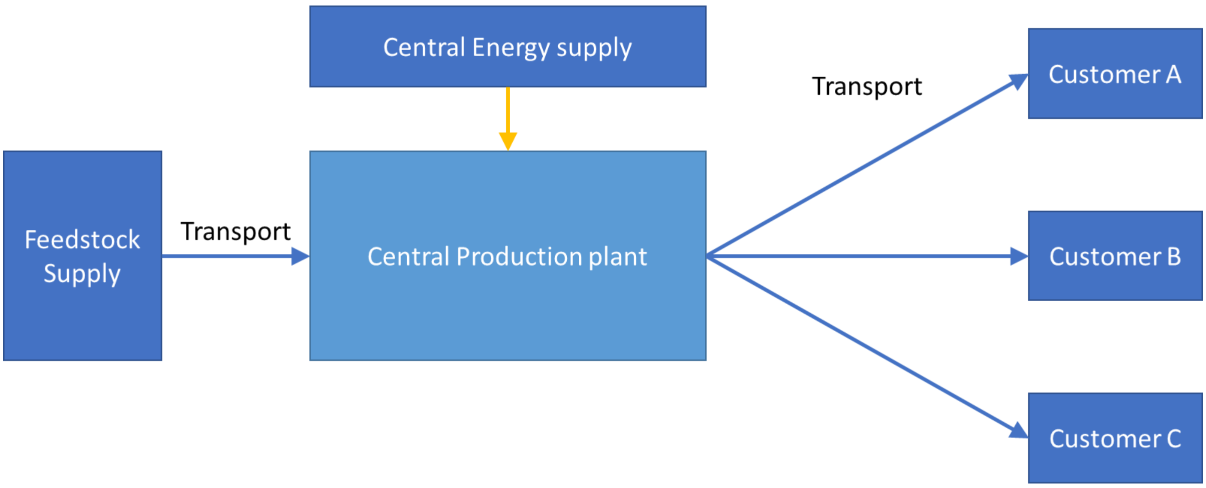

Figure 9: Current Supply Chain: central production

The case of Proton Ventures is about ammonia production. Note that this is not the actual supply chain of Proton Ventures but the supply chain that is impacted by the innovation, since Proton Ventures is an equipment provider. In large scale central production facilities, ammonia is produced by companies like OCI Nitrogen and Yara, using a Haber-Bosch

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process. The feedstocks for this process are natural gas, water and air. In this process energy is also used as input. The facility produces ammonia, which is stored on site and distributed to the customers. The most used application of ammonia is as fertilizer in agriculture.

The MyH_2O_2 case from Solvay is based on hydrogen peroxide production. The conventional way to produce hydrogen peroxide is by the anthraquinone process. In this process hydrogen and oxygen react to hydrogen peroxide by using anthraquinone as a catalyst. Hydrogen, oxygen and anthraquinone are used as feedstock. Hydrogen and oxygen can be produced from several sources. The anthraquinone acts as a catalysator and therefore it can be reused. After production, the hydrogen peroxide is stored and distributed to the customers. Hydrogen peroxide is used for bleaching in paper and pulp mills, and for other chemical processing. The catalyst is collected and upgraded in a centralized facility.

A.1.1.3 Description of the future supply chain

The business case of small scale production is mainly focused on bringing the production facility to the customer. This changes a pivotal part of the supply chain in the manufacturing and sourcing stages (Figure 2). In this case a small, modular production facility is placed at the customer. We will look at the supply chain for the cases of Proton Ventures and Solvay.

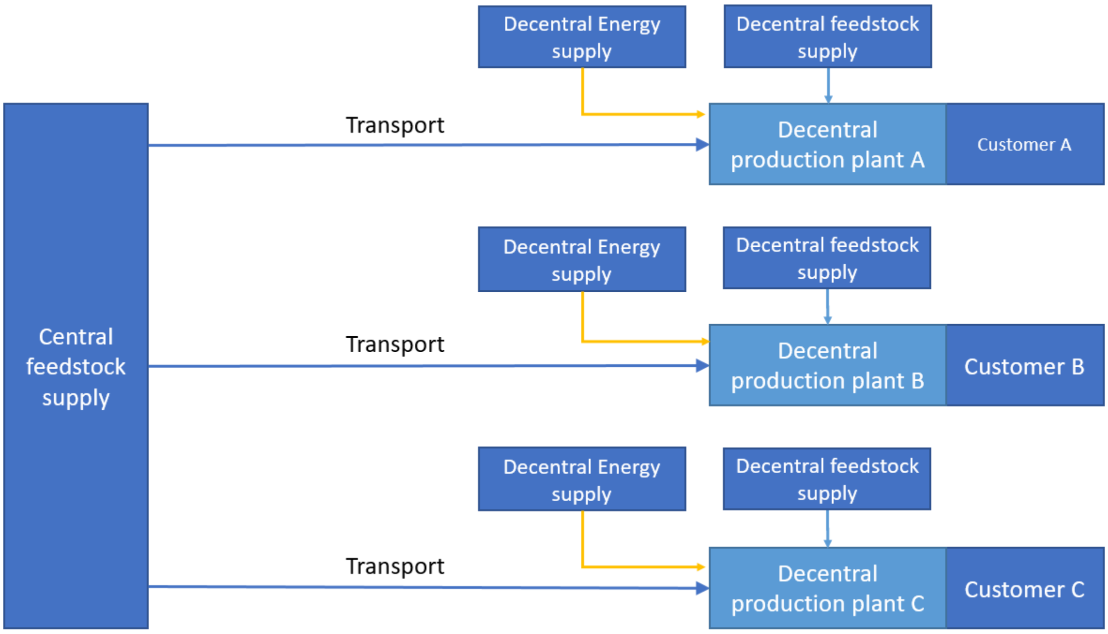

Figure 10: Future supply chain: decentral production

Proton Ventures supplies two kinds of small scale production facilities. Both facilities are modular and can be installed in a plug & play fashion. This means that the size of the facility can be adjusted to the demand of the customer. The first facility is based on the Haber-Bosch process. That means that the input feedstock is still natural gas, water and air. The business case benefits when feedstock is available at the customer site (e.g. through existing pipe infrastructure). Energy supply is also available at the customer location, so no extra logistics is required to provide feedstock. The second facility is based on electrolysis. In this case the feedstock is water, air and electric power. Also this feedstock can be provided locally and this offers the possibility to produce ammonia without the need of natural gas (infrastructure). In both facilities the ammonia is stored on site until used by the customer. There is also no transport needed in the distribution of the ammonia. The only added transportation in this case is the logistics needed to place the production plant at the customer site.

The MyH_2O_2 satellite peroxide production unit of Solvay is placed at the location of a paper and pulp mill in Brazil (Solvay, 2016). This production facility can also be placed at other customer locations. The production plant can work with a local hydrogen supply, either from reuse from the customer's production process or from local production. There is some central feedstock supply needed in the form of a catalyst and solvent (Solvay, 2017). The hydrogen peroxide is stored on site until it is used by the customer. There is no transport needed in the distribution of the peroxide. The extra transportation of the catalyst and solvent is very small compared to the avoided transportation of finished hydrogen peroxide.

A.1.1.4 Technology required and advanced technologies

Ammonia (Proton Ventures):

- Proton Ventures developed a small scale facility to produce ammonia from nitrogen and hydrogen. This is a pivotal technology for the small scale business case.
- In order to reduce the logistics for feedstock supply, small scale production units for Hydrogen and Nitrogen are needed. In this case these units are supplied by Air Products, who specialize in gas and chemicals production.
- A main part of the small scale ammonia case is the modular and containerized concept. The facility can be easily scaled up or down and offers flexibility in the supply chain. The development of modular building is important for this part of the business case.

MyH_2O_2 (Solvay):

- In the MyH_2O_2 project a solution is found to scale down the production process of peroxide production. This solution required a lot of R&D investment, time and innovations (Solvay, 2013).
- The MyH_2O_2 facility is still in contact with a mother plant for central supply and for remote control (Solvay, 2017). Developments in remote control of the plant makes this new supply chain feasible to operate.
- Placing the MyH_2O_2 plant on a customer location means that the facility needs to be tailored to this specific location. The investment needs to be low for the business case, so opportunities in customization benefit this business case.

A.1.1.5 Changes in the Value/Supply Chain Configurations with the business model:

- **PLAN (R&D, Product Design, Testing, etc.):**
    - To make the shift from a central supply chain to a decentral supply chain it is pivotal that small scale production plants are available. The design of such a plant can be an expensive and time consuming effort. However, this design is required only once, instead of custom-design-and-build large scale facilities. *(Both)* Because of the small scale and associated limited risks, technical dimensions become less restrictive, implying simpler design and standard components and materials. (*Proton Ventures*).
    - The possibility of small scale production is an opportunity for the servitization business model archetype. The optimization of the supply chain by using both central and decentral facilities can be offered as a service to the sector. This optimization relates to the planning and design of the supply chain. *(Both)*

- **Sourcing:**
    - The production of ammonia mainly uses hydrogen, nitrogen and energy. Hydrogen can be produced from natural gas or through electrolysis, whereas nitrogen can be subtracted from air. This means that the feedstock of a local plant can be supplied through the regular gas, electricity and water grid. *(Proton Ventures)*
    - In the case of hydrogen peroxide, the main feedstock is hydrogen, electricity and a catalyst. As in the ammonia case, hydrogen and electricity can be soured locally. There is still a central supply needed in the form of a catalyst and solvent (Solvay, 2017). *(myH2O2)*

- **Demand:**
    - The new business model creates a demand for small scale production facilities. This is the business case for a supplier of production facilities such as Proton Ventures. *(Proton Ventures)*
    - The business case for Solvay is different. Solvay operates large production facilities and offers small scale plants. The business model for Solvay is to create a more efficient supply chain for remote customers. The demand does not change for Solvay, but the costs are lower, due to avoidance of transportation cost. *(myH2O2)*

- The demand for power (gas and electricity) at the site of the consumer will increase. he customer will, in general, be located more downstream (decentral) in the energy infrastructure as the large chemical producer. This may create extra stress in the local grid infrastructure. *(Both)*
- Demand for transportation services will decrease. *(Both)*

- **Manufacturing and Distribution to customer:**
  - The manufacturing process is relocated from a large central plant to a small-scale plant at the customer site. This also implies that the manufacturing strategy will shift from a "make to stock" to a "make to order" strategy. This shift reduces the stock and lead time of finished product significantly. As from the location of the user of these plants (e.g. farmer or paper-mill) the downward stream to the end user (e.g. food consumer or book reader) is not affected. *(Both)*
  - The available infrastructure on water, gas and this infrastructure can accommodate immediate demand. This reduces the stock and the lead time in the supply chain of unfinished goods even more. *(Both)*
  - Localized production in a "make to order" strategy loses efficiency from the "economies of scale". Therefore it should be expected that the local manufacturing process, when scoped to the sheer transformation from inputs to outputs, is less efficient. *(Both)*
  - Producing the product at the customer's site greatly reduces transport movements in distribution. Because of available infrastructure, the needed transportation for feedstock supply does not increase (Proton Ventures) or increases slightly (Solvay). This reduction of transport in the supply chain is a major part of the business case. *(Both)*
  - Ammonia and hydrogen peroxide both have some risks on health and safety (e.g. inflammation, irritation on contact). The risks for the environment and the staff of the production plant decrease when the amount of chemicals decreases. Therefore a small scale production plant has less risk and therefore it also has less restrictions. Also the risks during transportation are eliminated. *(Both)*

- **Pricing:**
  - Producing a chemical product locally implies that the price of feedstock and energy will be the main drivers of the product price. Using locally produced or sourced feedstock increases stability in the price. For instance, the market

price of ammonia fluctuates between $200-$1000 per tonne whereas the local ammonia production has a stable price at $400 per tonne. *(Proton Ventures)*
  - When producing locally at small scale, benefits from economies of scale will decrease. In the business case reduction in transport and storage cost should make up for this loss. *(Both)*

- **Waste/Recycling, remanufacturing:**
  - Local production facilities in general may have a shorter lifetime than central large facilities with proper maintenance. Maintenance and repair of small scale facilities, due to standardisation, may however be economical. The local facility has less benefit from economies of scale. Furthermore, when a customer does not need the product anymore, the facility loses its value at the customer site. In that case it can be relocated. *(Both)*
  - The small scale plant of Proton Ventures is modularised (plug & play) and delivered in a container. This means that at the end of use by a customer the plant (or modules) can be reused at another customer. Proton Ventures is currently investigating the different ownership options, e.g. lease. *(Proton Ventures)*
  - Producing locally can increase the possibilities for reuse. In the case of myH_2O_2 at a paper and pulp mill, waste hydrogen from the bleaching process can be reused as feedstock in the myH_2O_2 facility. *(Solvay)*

- **Collaboration:**
  - Proton Ventures is a supplier of production facilities. In order to realize the small scale supply chain new collaborations with the original ammonia producer and customer should be realized. This is a challenge as they are not yet part of the supply chain and because they are a relatively small company. *(Proton Ventures)*
  - Solvay is already a supplier of hydrogen peroxide. In order to use the small scale business model they have to increase collaboration with their customers. This applies especially for remote customers, for whom they can add value in terms of cost and lead time. This does imply some challenges on mutual trust and collaboration between the firms but Solvay has a good starting point from the supplier-customer relation. *(Solvay)*

A.1.1.6 Opportunities and Challenges/Risks

There are some challenges that can be identified for widespread adoption of small scale production facilities. Some are listed below:

- To effectively apply the small scale business case, increased collaboration between the supplier and the customer is needed. When the innovation is promoted by a party outside the existing supply chain *(Proton Ventures)* the challenge to realize this business model is higher than when the technology is owned by a party that already exists in the supply chain *(like Solvay)*, but may also improve independence of supplier choice.
- Developing and placing the local production facilities requires an investment at the site of the customer. The feasibility of the business case depends on the size of the investment and who makes the investment. *(Proton Ventures)*
- Ammonia is a hazardous gas which is inflammable and toxic. This leads to the perception that local ammonia production facilities are hazardous as well. Therefore security measures and explanation are important, especially when the size of the production facility increases. *(Proton Ventures)*
- Location of the small scale production facility is important for economic feasibility. *(Both)*
- Developing a method to scale down chemical processes is an intensive research project which requires multiple testing (Solvay, 2013). *(Solvay)*
- Operating a chemical plant on the site of the customer requires specific knowledge. This knowledge either needs to be supplied with the production plant or it has to be developed by the customer. *(Both)*

Moving towards small scale production also creates more business opportunities related to these chemical processes, such as:

- Local scale production has more flexibility in the production process. This opens possibilities for business cases on energy flexibility, by offering demand-side response.
- Adapting production at the customer site creates opportunities for Servitization (Internet-of-Things) applications. This can be optimizing the supply chain as a service or local integration of Internet-of-Things. For example, using measurements of the soil at the farmer the production facility gets a signal to alter production.

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A.1.1.7 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing			-2	2
	Efficient and sustainable distribution			3	2
	More flexible			2	3
	Less delocalized (limits non-EU offshoring)			1	2
	Competitive advantage via intensified processing			0	
Industry / Company / Region specific objectives	Reduced production costs			-1	1
	Increased product quality			0	
	Minimized time to market			0	
	Higher throughput with smaller batches			0	
	Reduced response time to changes in demand			2	3
	Jobs creation	1		1	1
	Limit employment reduction	1		0	0
	Improving working conditions for workers			2	
	Sustainable development promotion		3	2	2
	Increased local business opportunities - SMEs		2	2	
	Shorter lead times			3	3
	Less stock			3	3
	Reduction of raw material by 15%		2	0	
	Less waste		2	0	
	Reduction in environmental footprint by 10%		2	2	2
	More interaction with the end users			3	1
	Customer driven SC business models based on Intensified Processing.			3	1

Table 12: Analysis of impacts on the objectives for Business Case 1: Small Scale Local Production

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

A.1.2 Business case 2: Emerging Energy Carriers and Energy Flexibility

A.1.2.1 Description of the case

The chemical industry is an energy intensive industry. This is because of energy intensive processes but also because energy carriers are used as and for feedstock production (e.g. natural gas or electrolysis for hydrogen production). Trends in the energy sector can therefore influence the chemical sector. Energy use is seen as a cost center and as a large part of the carbon footprint in the chemical supply chain. Chemical companies are therefore looking to optimize their energy use and sourcing.

A trend is seen in the energy sector which moves from central fossil power plants to decentral renewable energy production (for example solar, wind or biomass). Solar and wind power are large contributors to the renewable energy production. These power sources have as a drawback that they are inflexible, it is not possible to shift the amount of power at will. Demand-response and energy storage are the key technology solutions to maximally integrate renewable energy at the lowest grid infrastructure cost. Demand-response has applications in energy intensive industries and energy storage in industries which process or produce materials that can act as energy carriers. Both solutions can possibly be applied in chemical industries. We will elaborate on two business cases based on demand response and/or energy storage:

- The small scale ammonia production plant developed by Proton Ventures
- The ammonia production process of OCI Nitrogen.

Proton Ventures is a company that develops and produces plants for decentral, small scale ammonia production. These plants are especially applicable in agriculture where ammonia is used as fertilizer. Two plants have been developed to produce ammonia on a small scale, one for production from hydrogen made from natural gas and one for production from hydrogen made by electrolysis of water. Proton Ventures considers electricity storage in ammonia as a business case for the small scale electrolysis plant. The main drivers of this business case are sustainability (carbon neutral ammonia production from renewables), reducing the energy cost and using excess ammonia to feed electricity to the power grid.

OCI Nitrogen is a producer of ammonia, fertilizer and melamine. Ammonia production is mainly dominated by China. India, Russia and the US are the next major producers (USGS, 2017). The main use of ammonia is as fertilizer in the agriculture. For the production of ammonia, OCI Nitrogen uses natural gas. This induces a large carbon footprint for the company and a trend is recognized to phase out natural gas (in NL/EU) on the long term. OCI also expects a trend that increases the demand in fertilizer because of the world population growth. OCI works on several energy related developments as a result of these trends: Energy efficiency, biogas feedstock, electrification and CCS (Carbon Capture and Storage). The drivers are energy cost, added value of sustainable products and security of supply.

A.1.2.2 Description of the current supply chain

The current supply chain of ammonia production is characterized by large scale central production. This impacts the entire supply chain. The supply chain is based on "economies of scale". The main influencers of the supply chain are the producing companies, for instance OCI Nitrogen. Proton Ventures is an equipment supplier and as such not represented in the operational supply chain. In large scale central production facilities, ammonia is produced using a Haber-Bosch process. The feedstock for this process is natural gas, steam and air. In this process energy is also used as input, the main goal for with respect to energy management is to keep the costs associated to energy use as low as possible. The facility produces ammonia, which is stored on site and distributed to the customers. The most used application of ammonia is as fertilizer in the agriculture. It is also used to for other chemical processing.

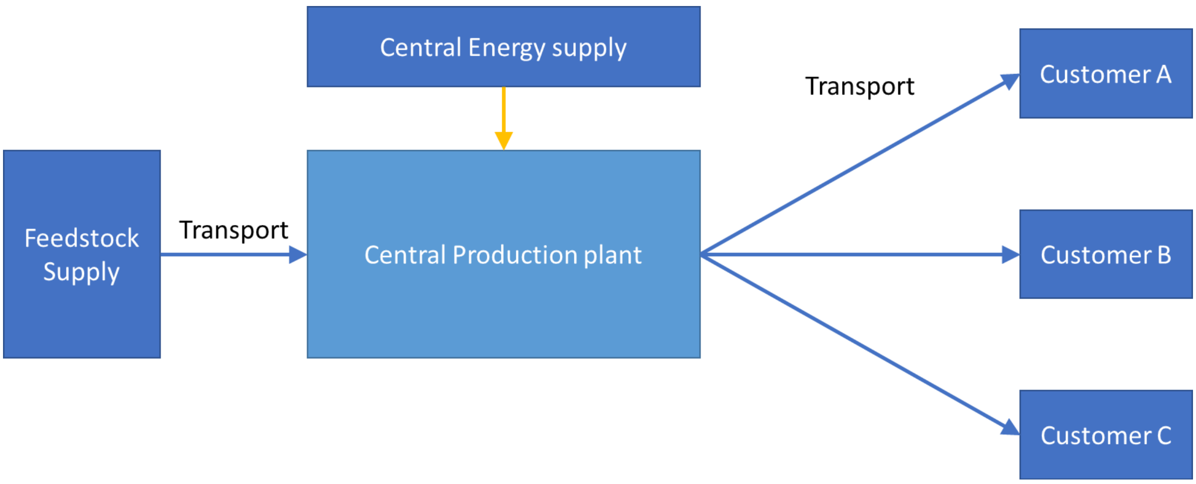

Figure 11: Current supply chain: central production

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A.1.2.3 Description of the future supply chain

In the future supply chain, power is not only regarded as feedstock but also as a product. Power can be regarded as a product in two ways: through demand-side response and by electricity production. In the first case, the producer allows a grid operator to reduce (or shut down) the production process to reduce power overshoot in the grid. The chemical producer receives a fee when this service is used by the grid operator. The second case is that the chemical product, or a byproduct, with high energy capacity and electrical conversion properties is stored at the producer. In case of an electricity shortage the stored chemical can be used for electricity production, again the producer gains an additional fee when this service is coordinated by the grid operator. The main impact would be that ammonia (as electricity) would be bought and sold through to the (15-minute) electricity market or directly to the grid operator.

In the case of OCI Nitrogen (Figure 2), the supply chain to deliver ammonia to the regular customers stays intact. The difference is that the electricity supply (Power grid) is taking a more prominent role in the supply chain. The electricity demand from the production process can be shifted (demand-response) to reduce stresses on the power grid. The possibilities of this demand-response application increases when electrolysis is applied in the ammonia production instead of the conventional process with natural gas as feedstock. One should note that shifting the electricity demand has a direct impact of the stored amount of ammonia. Ammonia can also be ordered directly from the storage unit to produce electricity. This does require additional electricity production facilities. The demand-response and generation options can be operated based on the electricity price or based on a control signal from the grid operator for which the chemical produces receives a fee. The storage and distribution part plays an important part in the supply chain as the new demand for electricity distribution has to be managed alongside with the demand from existing customers.

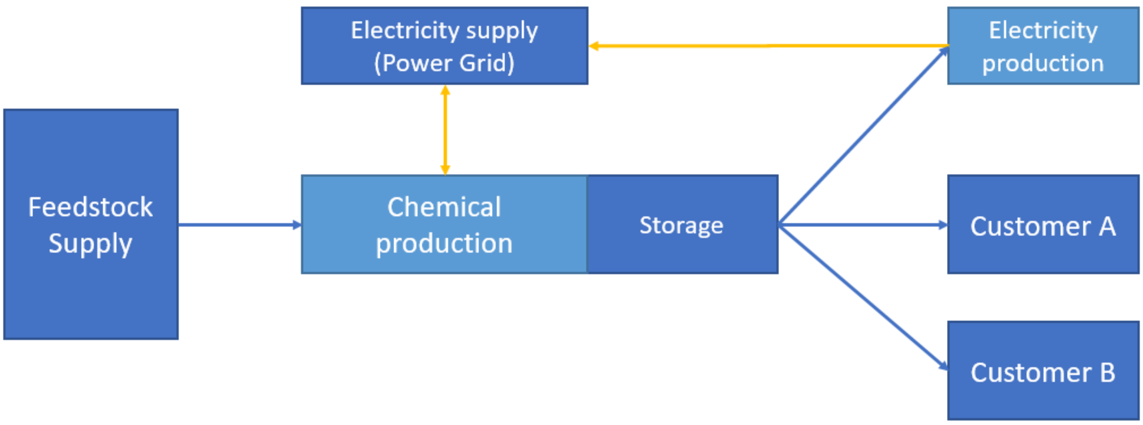

Figure 12: Supply chain (OCI case)

In the case of small scale ammonia production (Figure 3), the system can be operated flexibly and thus used to do local grid balancing. In this case the electrolysis plant of Proton Ventures is placed at the customer location (usually a farmer). This plant only relies on electricity (and water) as feedstock to produce hydrogen. Additionally nitrogen is required as feedstock for ammonia production in a scaled-down Haber-Bosch reactor. Electricity can be supplied by the power grid or by locally generated renewable power. The production of ammonia can be operated to only use electricity from the renewable supply. The power grid is then only used in emergency situations. This leads to carbon free production of ammonia. The facility can also be used for demand response and electricity generation purposes at the electricity market. As the impact of these facilities are low, this will generally not be operated through a control signal from the grid operator.

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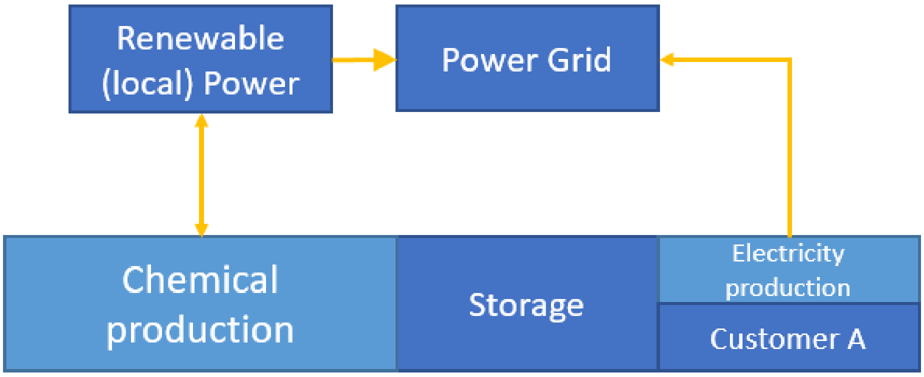

Figure 13: Supply chain (Proton Ventures case)

A.1.2.4 Technology required and advanced technologies

In these business cases technologies related to electricity flexibility are enabling:

- Electrification of chemical processes increases the amount of electricity used in the chemical process and therefore increases the amount of demand-side response that can be offered to the grid operator. Incorporating electrification in the process can enable more demand-side response. Electrification of the ammonia process can be achieved either by producing hydrogen by electrolysis of water and further reaction of hydrogen with nitrogen in a Haber-Bosch reactor or by direct electrochemical synthesis from steam and nitrogen using an electrochemical cell with either a proton or a oxide conducting membrane.
- Developing processes that can produce electricity from chemicals create the potential for emerging energy carriers. This process should be economically feasible at the market price for offering electricity flexibility services. To generate power, ammonia can be either combusted in a gas turbine, oxidized in a fuel cell (SOFC), or reconverted into nitrogen and hydrogen with hydrogen being oxidez in a fuel cell and nitrogen being stored until it can be recylced fro ammonia production again.
- The business case for energy services relies on the storage of chemicals. Safe, scalable and accesible storage and distribution inreases the potential to use chemicals as energy carrier. Ammonia storage and transport at large scale is proven technology and already in place.
- Flexibility in the process of chemical production can increase the possibilities for demand-side response. Usually equipment is operated continuously and is not

designed to be shut down frequently. Developments that reduce the penalty when the process is shut down enable demand-side response. The Haber-Bosch process that is operated at high pressure and at high temperature and that operates with a large recycle stream, is not likely to be oprated in discontinuous mode. Direct electrochemical reactors appear mor suitable for demand-side response.

A.1.2.5 Changes in the Value/Supply Chain Configurations with the business model:

- **PLAN (R&D, Product Design, Testing, etc.):**
  - Design of the process equipment should incorporate possibilities in demand-response and expected revenues from utilizing these possibilities.
  - Design of the generation and storage unit should include flexible production of electricity and short lead times to accommodate to the power market (15-minute orders).
  - In testing production facilities, the reliability of the energy consumption and energy production should be accounted for as incorrect power flexibility can increase costs.

- **Sourcing:**
  - When electrification is applied, then electricity sourcing will be the most important sourcing process with a high impact on the cost price of the ammonia.
  - The electricity sector changes from being a supplier to being both a supplier and a customer. This changes the sourcing relationship with the energy sector.

- **Demand:**
  - The energy sector is a new customer for the supply chain of the chemical provider. This also means a change in the demand for the chemical product (or an intermediate chemical product). This is a new customer for the producing company. This development increases demand in the supply chain and increases the volatility in the demand.
  - In the energy sector, a lot of substitutes are available for the power generated (or shifted) at a chemical production plant. Power generation by solar, wind, biomass and fossil fuels are all competing on the power market. In this

business model, the chemical producer should focus on the added value it has for the energy sector in the form of buffers and demand-side response. Effectively promoting and using this added value needs new knowledge on the operations of the power grid.

- Adding the energy sector as a customer to the supply chain also creates competition between the "regular" customers of the chemical product and the power sector. The power market operates on a small timescale (can be as fast as 15 minutes) and can demand large quantities of power. At certain price and power levels the demand from the power sector may compete with existing orders for the product and, vice versa, large priority customer orders may be delivered from the power buffer. The dynamics between these markets are new and knowledge on the customer base and power dynamics should be combined in demand forecasting and planning.

- **Manufacturing and Distribution to customer:**
  - Using the chemical production process to provide buffer and demand-side response services to the power grid implies that (a part of) the production process needs to be flexible. For some chemical processes, completely shutting down the chemical production process decreases the lifetime of the plant significantly. This means that not all processes are suited to be operated flexibly. The business model is only feasible if (a part of) the chemical process, with high energy consumption, can be turned down economically or a chemical product with efficient energy conversion properties can be stored. Also the investment cost for chemical equipment are significant. Leaving production capacity idle needs sufficient economic compensation to be feasible. This economic feasibility is reached earlier by the small scale production facilities.
  - This business model can make electrification of the production process economically feasible. An increased electricity consumption will lead to larger possibilities for delivering demand-side response services. One should note that this business model does not promote using more electricity, but shifting consumption from other sources to electricity consumption (for instance in the "Power-to-Ammonia" case where natural gas consumption is shifted to electricity consumption).

- **Pricing:**
  - The business model is based on adding revenues for the chemical producer by offering power flexibility. This should lead to reduced power cost or even revenues from the energy sector and thus to a lower cost price of ammonia.
  - With increased electrification, the price of ammonia becomes linked with the price of electricity. This price is expected to become more volatile due to increased renewable generation.
  - Just as in the case of demand planning, pricing of the product should be adjusted for integration of the power market in the supply.

- **Waste/Recycling, remanufacturing:**
  - This business model can enable electrification of the production process. This reduces the fossil or resource footprint as it becomes more feasible to use electricity (which is becoming more and more renewable) in combination with less impactful resources. In the case of "Power-to-ammonia" the change is made from natural gas, where a large carbon footprint emerges, to electricity.
  - Adding flexibility to the power grid increases the possibility to integrate non-flexible renewable resources in the power system. Integrating renewables will decrease the use of fossil fuels and the resulting carbon emissions for electricity production.

- **Collaboration:**
  - This business model increases collaboration between grid operators and chemical producers which was not there yet. From the view of the grid operator, the chemical producer needs to be positioned as a reliable demand-response or electricity production service supplier. From the view of the chemical supplier, the grid operator should be seen as a customer instead of a supplier. This needs different relationships between these parties.
  - The revenue split of employing energy flexibility solutions is important in this business case and depends on the volatility of electricity prices and the flexibility pricing by grid operators.

A.1.2.6 Opportunities and Challenges/Risks

Using ammonia as an emerging energy carrier for demand-response and buffer purposes imposes some challenges:

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- The relation between chemical producers and the energy sector changes. The business model of these both sectors will become more related, bidirectional, to each other. This needs new collaboration between these sectors and new competences in both sectors.
- Several chemicals are possible energy carriers, several different properties of chemicals have to be analysed to select possible carriers. These properties are at least (but not limited to) safety, storage possibilities (including transformation efficiency) and calorific value. Which chemicals are the best carriers is still ongoing research and subject to testing. (This includes both technical and practical considerations.)
- Electrification of the ammonia production process is an enabler for demand-side response and sustainability. At the moment electrifying large ammonia production plants have high investment costs. This makes the economic feasibility of the business case difficult. Also hybrid transition scenarios (both conventional and electrified) will be challenging, since utilization rates will be low).
- The energy sector has a higher volatility and imposes shorter response times as the regular customers of ammonia. This creates stresses between the different kinds of demand that exists in the new business model.
- The model of Proton Ventures has the shortest return on investment time as it makes use of a smaller production facility. However, Proton Ventures is a party outside the regular supply chain of ammonia. This increases the challenge to adapt the technology. Furthermore, ammonia produced with the small scale Proton Ventures modular plant will have a higher CAPEX contribution to the cost price compared to large scale conventional plants because the scale-effect is lacking. This may be offset by a lower transportation cost component.

There are also some opportunities related with the business case for demand-response and energy production:

- The current strategy of chemical producers is a “make-to-stock” strategy. This strategy synergises effectively with the need for buffers in the energy system.
- Increasing the energy flexibility of ammonia production opens up a possibility to produce ammonia only by renewable resources.

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A.1.2.7 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing			1	0
	Efficient and sustainable distribution			0	-1
	More flexible			3	1
	Less delocalized			2	3
	Competitive advantage via intensified processing			2	2
Industry / Company / Region specific objectives	Reduced production costs			2	1
	Increased product quality			0	0
	Minimized time to market			0	2
	Higher throughput with smaller batches			0	0
	Reduced response time to changes in demand			3	2
	Jobs creation			2	1
	Limit employment reduction			2	2
	Improving working conditions for workers			-2	-1
	Sustainable development promotion			3	3
	Increased local business opportunities - SMEs			3	2
	Shorter lead times			-1	0
	Less stock			-2	-1
	Reduction of raw material by 15%			0	0
	Less waste		1	0	0
	Reduction in environmental footprint by 10%			2	2
	More interaction with the end users			0	0
	Customer driven SC business models based on Intensified Processing.			0	0

Table 13: Analysis of impacts on the objectives for Business Case 2: Emerging Energy Carriers and Energy Flexibility

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

A.2. Mass customization

A.2.1 Business case 3: Flexible Manufacturing in Footwear Sector

A.2.1.1 Description of the firm/industry/sector

Vibram is a company that operates in the high-performance soles industry and currently has a leading position in its market. The company started from the idea of developing a soles capable of having a perfect grip on mixed surfaces. The focus and the evolution of vulcanized rubber has enabled the company to become a big sole manufacturer, remaining today still the top choice for mountaineers.

The Headquarter is located in Albizzate, near Varese, together with one of its manufacturing plants; the company is present in 5 other locations among USA, China, Japan and Brazil, with over 650 employees (of these 1/3 are in Italy). During the last years, the revenue has always been over €150 million, with the 80-85% coming from the soles sold as shoe components to footwear producers, and 15-20% from the Fivefingers (special shoes assembled by the company itself) and other finished products. The company produces over 40 million pairs of soles and develops over 300 new products each year. Most important applications in the footwear sector are soles for: mountain, snow-sports, work safety, military, lifestyle, outdoor, motorcycling and repair.

The sole is an important component of the shoe: also known as the outsole, the sole is the bottom part of the shoe that comes in direct contact with the ground. Shoe soles are made from a variety of different materials, including natural rubber, leather, polyurethane and PVC compounds. The material used to make the sole depends upon the style and purpose of the shoe.

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Shoe sole	Fivefingers

Figure 14: Vibram shoes

A.2.1.2 Description of the Vibram supply chain

The European contractors are managed by the headquarter. Contractors handle sole production, but they do not have the development and design capabilities that Vibram has. Vibram performs quality control checks on random samples and controls their production process. The sole production is based on mixing different types of raw materials with many different formulas to obtain different properties on the product (flexibility, rigidity, shock-absorption, waterproof, etc.).

75% of the products are manufactured externally with the support of contractors, so the need for a global activity management is necessary, both from a logistics standpoint and a legal and contractual one. Most of the production is in China, where a local unit takes care of logistics, contractor management, quality control and product industrialization. The relationship with contractors is not exclusive, which is not considered important at the moment by the company. Indeed, non-Disclosure Agreements are signed with them to assure IP management. When a shoe factory needs to make a new sole, the production process starts with a briefing to understand their needs and an initial concept. The proposal is shared with the Vibram designers, who develop the concept and chooses the best materials for that type of product, which may be already available or designed specifically for the application. After that, the 2D drawing, then the sole maquette; both are shown to the client for approval before realizing the mold from which the first sample products are cast.

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The sample products are tested on a real shoe either by Vibram or by the client directly, depending on the kind of product. Professional testers (size 42 for men, 39 for women) perform the testing and validate the product: if the client approves it and performance is satisfactory, the industrial casting molds are realized. External companies create around 10 molds (sizes 39 to 47 for men and 37 to 40 for women), and the soles are cast either internally or by one of the contractors.

For what concerns product performance, they are completely different from other sectors: for example, the specifications for a tire, which works at high temperatures, are usually different from the ones for a shoe sole, which never does. So usually, the supplier of rubber needs to take into consideration this difference in the performance of the raw material. Roughly, 10% of the raw materials are custom-made: some examples are deodorants, anti-oxidants, and expanding materials such as ethylene vinyl acetate for compression foam. Vulcanizing agents are one example of raw materials, which are standardized, with little possibility for customization. Vibram controls all the steps of the production process: molds, chemical composition, process control, everything but the raw materials.

Marketing is directed to the final product, Vibram sponsors events as the Monte Bianco run, and running in general, always aimed at the end consumer. There is a lot of co-marketing with shoe producers, for example with La Sportiva shoe.

From an environmental perspective, an issue that is very seldom addressed is the product's end-of-life stage: at the end of its cycle, the shoe is discarded and there is no recycling because the shoe is made of multiple materials (strings, fabrics, metal). Therefore, the induction of a limit to the percentage of recycling could pose a problem (e.g. as in the car industry).

The fashion sector is becoming interesting sector for Vibram: in this case, the color of the soles is very important; orders are usually small and with very diverse colors and shapes. Since the sector requires delivery within a week, there are two alternatives: keeping materials of each color in stock, or finding a very flexible supplier.

A.2.1.3 Technology required and advanced technologies.

- Additive printing: the company is testing additive manufacturing as 3D molding plant with powder sintering by means of laser (see figure below).

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The next step is to carry out long-term and assessment tests; when the pilot production line is completed, additional modules will be integrated (cleaning parts, controls, etc.) and the personalized sole design will be automated. Finally, if Vibram implement the pilot program in their processes (even involving contractors), it opens the door for the analysis and development of new materials. The company has low responsiveness in terms of driven automation, partly due to its lack of experience, partly because the company considers the current production process stable.

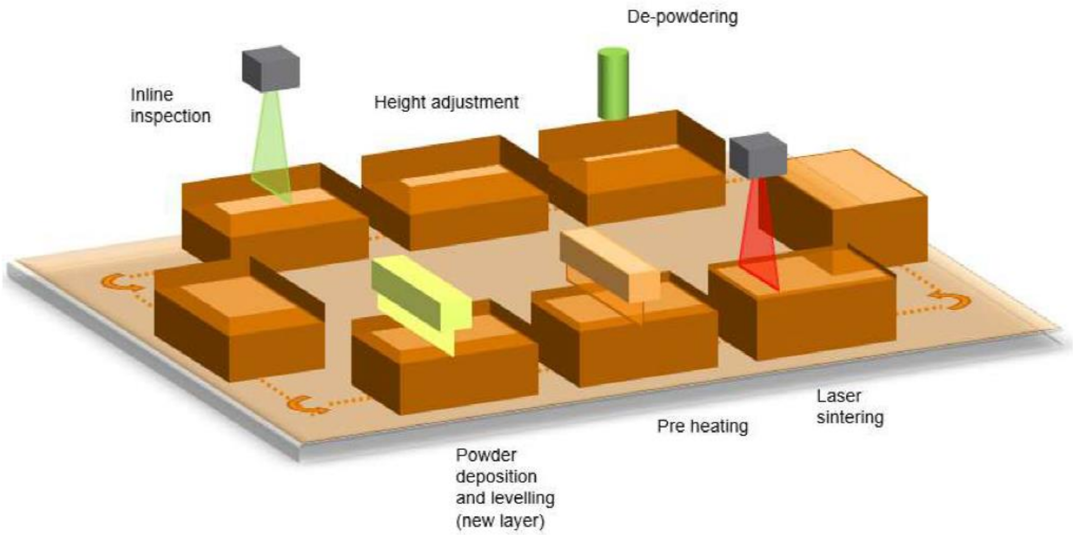

Figure 15: Vibram production model

- The company uses RFID for tracking products with contractors, footwear producers and in its own plants.
- Big Data are used for monitoring of workers under high vibration conditions and to check working conditions. Cooperative robots to support automated production.

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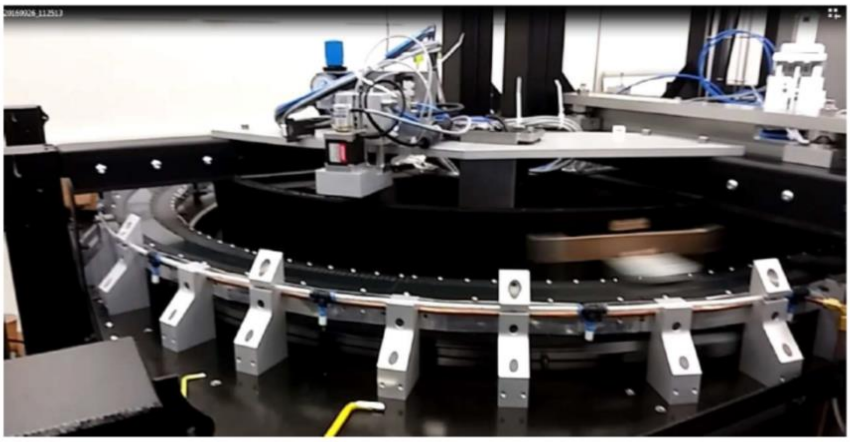

Figure 16: Vibram production facility

In terms of potential application of 3D-printing, the idea is to use it for the management of small lots and customization; improvements are still necessary for the full implementation of the 3D printing technology, both at machinery level and materials . Currently, there are no suppliers who produce materials for industrial processes (apart from metal on the aeronautics market and turbines). Certainly, there would be a great impact in terms of management of the suppliers and contractors: the processes of the present ones are aligned to Vibram, while aiming to the 3D-printing the business model would be reinvented. It would be necessary to look for the most appropriate machine suppliers with appropriate materials, suitable for new technologies.

Due to company's analysis on the impact of the new technologies, Selective Laser Sintering is expected to lead to several benefits:

- mass customization trend
- cost reduction
- time-to-market reduction (up to 100 pieces/year for small series)
- mold removal for limited series of functional components with thermoplastic resins
- customized soles based on individual biometric data (performance, comfort, safety)

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A.2.1.4 Changes in the Value/Supply Chain Configurations with the business model. Score and discussion:

- **Capacity: high.** It is expected in the future a greater flexibility regarding production capacity, thanks to the introduction of 3D printing capabilities; this will allow to handle the production of smaller batches
- **Product: high.** Good capability to react and to propose large variety of products. Very high flexibility, both currently and in the future, given the situation of the market and the solidity of the supply chain
- **Feedstock: medium/high.** Many different raw materials that form the products are mixed to obtain different properties.
- **Location: medium/high.** Also very high flexibility, as a result of strategic choice and adaptability of factories and processes to environmental and socio-economic conditions.
- **Supply Chain - contractors: high.** High number of contractors, resulting in high flexibility both now and in the future. The large number of contractors, working for many different companies, mainly determines this factor; thanks to this the contractors are never saturated.
- **Supply chain - suppliers: low.** This element may change in the future if 3D printing technologies start being adopted: the suppliers will change, becoming technologies suppliers.

A.2.1.5 Changes in the Value/Supply Chain Configurations with the business model.

- **PLAN (R&D, Product Design, Testing, etc.):**
    - So far, the customers input is considered in product design/testing, but it is something that will be implemented thanks to the new technologies. The products are customized at the design stage, and there is an information exchange and collaboration among supply chain actors. Concerning the case study, the lead time for designing and testing is not long; but if we looked at competitors, such as SMEs in this sector, the answer might be different.

- A challenging topic is the use of the recycled raw materials/parts in the product design phase: due to Vibram's comment on this item, they haven't put so much effort in recycle and waste management.

- **Sourcing:**
  - Concerning the sourcing process, the firm procure from multiple and global suppliers? A competitive strength is the present business model which is very flexible since they time after time select their decentralized locations where the markets is likely to maintain or grow. The procurement cost of raw materials/parts is a major part of the total cost but, on the other hand, they do not take so long to get the items at the factory and markets are usually well served.

- **Demand:**
  - Customers is asking for smallest batches and this will be probably solved thanks to the upcoming technologies. Vibram has a couple of pilot programs and it could be a good point to deepen in the next meeting. Knowing the kind of products being tested with the pilot programs might provide useful information as to which type of product is suitable for the 3D; and possibly it would be easier to estimate the potential of 3D for the whole product family.

- **Manufacturing and Distribution to customer:**
  - Major costs concern even research and development activities, both on products and on materials and components. Then they have to have a good inventory management. Labor average cost is about 20% of the total costs, but it can significantly vary depending on the product and concerning the upcoming technologies. For example, the company states that keeping the production in Italy should increase some costs, and at the same time reduce the uncertainty and the lead-time. This is something they are willing to test soon.
  - Almost all the production process is decentralized to contractors: the emerging trend is the demand for smallest batches from customers and this will be probably solved thanks to the upcoming technologies; Vibram has a couple of pilot programs that will be developed in the next year.
  - A factor to keep into consideration is that the sector requires delivery within a week, there are two alternatives: keeping materials of each color in stock, or finding a very flexible supplier. As we said before, Vibram flexibly moves its plants due to each specific case and quickly opens up new collaborations with

local suppliers. This is a strength for the company because 3D impact will be lower due to their ability to decentralize production and to move from one location to another easily.

- **Pricing:**
  - *Due to the short length of the interviews with the company, we did not have time to deeply analyze this topic. We will discuss it (and other open questions) during the next meeting.*

- **Waste/Recycling, remanufacturing:**
  - Concerning the end of the production cycle, the shoe is discarded: so far, there is no recycling because the shoe is made of multiple materials (strings, fabrics, metal). Basically, the problem is the that shoe is made of multiple materials (strings, fabrics, metal) and each of them require a different recycle process. In order to reduce environmental impact, more collaboration may have a positive impact and the company is aware of it. Concerning the overall process, new form of collaboration may grow concerning the new technologies and new providers, which will be different from the materials suppliers they have collaborated with to date.
  - If we do not consider the materials for a moment, there is another point. Compared to the traditional "subtractive" manufacturing, one of the natural consequences of the implementation of the 3D printing "additive" is the reduction of waste in manufacturing. This will also have a positive impact on inventory management.

- **Collaboration:**
  - Finally, the company underlined the importance of the computer tools, such as big data's management and information sharing; they also signed some NDA in order to declare the opportunities and limits, but the collaboration and relationship with suppliers has been well developed over the years.

A.2.1.6 Score and discussion about future trends

- **Capacity: high.** It is expected in the future a greater flexibility regarding production capacity, thanks to the introduction of 3D printing capabilities; this will allow to handle the production of smaller batches
- **Product: high.** Good capability to react and to propose large variety of products. Very high flexibility, both currently and in the future, given the situation of the market and the solidity of the supply chain
- **Feedstock: medium/high.** Many different raw materials that form the products are mixed to obtain different properties.
- **Location: medium/high.** Also very high flexibility, as a result of strategic choice and adaptability of factories and processes to environmental and socio-economic conditions.
- **Supply Chain - contractors: high.** High number of contractors, resulting in high flexibility both now and in the future. The large number of contractors, working for many different companies, mainly determines this factor; thanks to this the contractors are never saturated.
- **Supply chain - suppliers: low.** This element may change in the future if 3D printing technologies start being adopted: the suppliers will change, becoming technologies suppliers.

A.2.1.7 Opportunities & Challenges/Risks

Mass customization obliges companies to rethink their supply networks and operations strategies to create proactive responses to market requirements. Within such a context the production of customized, high value-added products offers European companies a key opportunity to foster their competitiveness by entering new niche markets like for example products for target groups (Fornasiero and Zangiacomi, 2012).

The challenge of mass customization is linked to unpredictable and seasonal demand which is difficult to be forecast. As defined by Fornasiero et al. (2016), "*this reality is intensified by the fact that, for example consumer goods, in particular innovative and fashion products have in the last decades been facing the need of an increased number of product variants with a dramatic reduction of products life-cycle*" (Fornasiero, et al., 2016).

The key issues are how to develop and implement innovative managerial models and methods to support collaborative practices (Dyer and Singh 1998, Camarinha-Matos et al. 2005) downstream with customers and upstream with suppliers. The new paradigm of demand-driven supply networks emerges as a collaborative scheme to better respond to consumers' direct signals and needs.

For companies, personalized production mainly implicates the centrality of the consumer, with a revision of the production chain management models as well as the use of innovative technologies (3D printers, new materials, etc.), which can simplify the production of components and specialized products.

It is necessary to create industrial models and systems for the efficient production of custom products with high added value. These systems will be suitable for rapid change in their configuration to satisfy custom requirements, but they must also guarantee a high level of integration with the clients, who become the main creators of the solution produced.

In this specific business case, we imagine a future where the company uses 3D machines at the suppliers and sends them the "codes (and updates)" for new products over time. Just to clarify it at a formal level, the 3D machine could be the "product" and "the codes over time" could be the "service". Machines could also be sent to customer sites, where they could easily produce prototypes or smaller batches: inside this vision, the binomial 3D printing – local sourcing

The main research and innovation topics are associated with different aspects of product development, such as ICT solutions for the acquisition of the client's requirements, product configurators, advanced measuring systems, platforms for client monitoring and innovative technologies for personalized production, such as additive manufacturing, micro-manufacturing, hybrid processes, etc. Furthermore, there is a need for new flexible and agile supply chain models that consider product modularization strategies, postponement and "multi decoupling points' with a view to custom production.

A.2.1.8 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing	1	2		2
	Efficient and sustainable distribution	2			2
	More flexible	3			
	Less delocalized	2		2	
	Competitive advantage via intensified processing	-1			
Industry / Company / Region specific objectives	Reduced production costs	1			
	Increased product quality	3			
	Minimized time to market	2			
	Higher throughput with smaller batches	3			
	Reduced response time to changes in demand	3			
	Jobs creation	2			
	Limit employment reduction	-1			
	Improving working conditions for workers	not applicable			
	Sustainable development promotion				
	Increased local business opportunities - SMEs	2			
	Shorter lead times	2			
	Less stock	3			
	Reduction of raw material by 15%	2			
	Less waste	2			
	Reduction in environmental footprint by 10%	2			
	More interaction with the end users	3			2
	Customer driven SC business models based on Intensified Processing.	2			

Table 14: Analysis of impacts on the objectives for Business Case 3: Flexible Manufacturing in Footwear Sector

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

A.2.2 Business case 4: Customized leather fabrication

A.2.2.1 Description of the firm/industry/sector

Dani SpA was created as a small family tannery, and after the fusion between Gruppo Dani SpA and Dani Automotive SpA it now has about 1,000 employees. The company is based in Arzignano (Vicenza), the biggest tanning district in the world, and it produces fine Italian quality leather for different markets: automotive, furniture, IT, footwear, and clothing.

The Dani label is synonymous of product quality, sustainability (EPD, carbon footprint), and innovation. The company defines itself as environment- and safety-conscious, as well as focused on research aimed at the development of high-quality innovative products. It has managed to get certified as a sustainable enterprise, and was the first in the world in this sector to obtain the Carbon Foot Print Certification.

The leather of the slaughtered animal is the raw material used by the tannery. The main phases of the tanning process are mechanical threshing, soaking and liming/unhairing. The tanning is a series of chemical and mechanical operations to make the leather rotproof and resistant to several chemicals. There are two kinds of tanning processes:

- chrome-based, for finished leather with different uses;
- vegetable-based, for sole leather.

Dani is a company open to experimentation, as well as a key innovation user, in order to keep improving the product. The automotive sector is the biggest customer , followed by furniture and footwear. In case of specific choices a new product can be designed, but only for some customers or after market research or trade fair feedback.

A.2.2.2 Description of the supply chain

The company has a structured supply chain, based on the principle that sustainability cannot be achieved by a single company, but only with a global supply chain approach. The company has recently done a life cycle assessment to measure the impact of the whole chain, starting from the raw materials. The project involved several actors of the supply chain, both upstream and downstream: chemical producers, shoemakers, water treatment plants for fertilizers and biostimulants.

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The company is always looking for new trends and collaboration in order to keep and develop the sustainability trends. The company is building a structured approach to search new processes and create new chemical components that will enable to realize more and more "green" products. At the moment, this is handled in ad hoc research projects in partnership with other companies and suppliers: one of the first key outcome is the zero impact leather.

The oxidative depilation obtained with the use of hydrogen peroxide was introduced in a special polypropylene stick. This technology enables to obtain re-used by-products in the industrial, agro-industrial and energy sectors. This process, at a semi-industrial scale, will completely replace the current production over the next few years.

New tin-free metal-based technologies have been developed, based on the use of enzymes and polysaccharides that give the skin the same physical and mechanical characteristics of skins treated with traditional tanning. Concerning the recoating and finishing phases, they select ad-hoc products with a very low metal content, so as not to compromise the results obtained during the tanning phase.

Finally, water-based products have been chosen for the refining phase. The below picture shows the current basic production cycle: as we'll better explain in the following section, the company is not going to change the process steps (this was unnecessary so far), because they are interested in the product innovation more than in process innovation.

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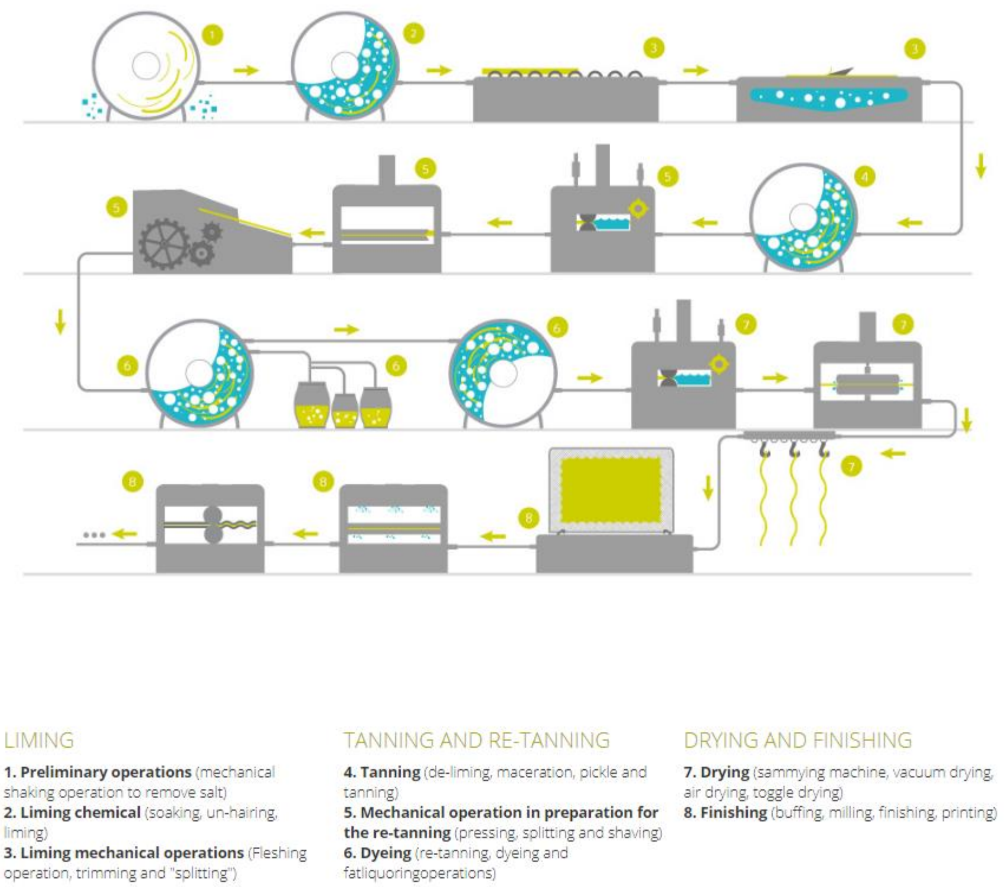

Figure 17: The Production Cycle

A.2.2.3 Technology required and advanced technologies.

Socio economic impacts are expected both from the effects of the new technologies on the water treatment system at district levels and from the recovery, treatment and valorization of by-products in the industrial, agro-industrial and energy sectors.

Oxidation-based unhairing is the most relevant innovation in zero impact leather production. Dani is the only company in Italy with the polypropylene drums that can exploit this technology, which uses oxidants instead of reducting agents (sodium sulphide and disulphide). The polypropylene drum allows to keep the temperature under control with external cooling and IT integration.

They developed new metal-free tanning technologies based on enzymes and polysaccharides: they both they reduce the environmental impact (in terms of waste) and, at the same time, they give leather the same physical and mechanical features as traditionally tanned leather. Also for the retanning and finishing phases specific products with very low content of metals have been developed and selected. The automotive sector uses "wet white" aldehyde tanning.

Aside from water- or fire-proofing, there are no special treatments: some specifications have to be met, but the treatments for water-proofing are not nanotech-based. This road has been tried, but it has not been interesting enough to justify further efforts.

An important innovation is linked to the introduction of a drum allowing to process a single piece of leather instead of the current 400-600 pieces; the same goes for the wet processing in the same drum. Another innovation is in refining sprinklers for tanning process. Basically the company is more interested in the product innovation (in terms of new materials or new treatments) more than in process innovation.

A.2.2.4 Changes in the Value/Supply Chain Configurations with the business model.

- **PLAN (R&D, Product Design, Testing, etc.):**
  - The design/testing is an important stage, but customers input is only partially considered; in case of specific choices a new product can be designed, but only for some customers or after market research or trade fair feedback. The products are customized at the design stage or standard; the lead time could be longer, but the partnerships helps to reduce the design and testing lead time and the company usually gets it before competitors. The company has both small and medium, and large customers which requests are variable along the year; Dani's process is able to respond to changing needs. This characteristic and the below considerations are important in terms of replicability of their approach for the SMEs.
  - Designing new products is not relevant on the total costs. Regarding design and test stages, there is an information exchange and collaboration among

supply chain actors that keep the costs moderate. Nevertheless, Dani is working hard both on sustainability and choice/use of materials; this is a good practice that they internalized and it is no more challenging at this point. There are partnerships with companies to develop lower-impact tanning agents and definition products.

- **Sourcing:**
    - The firm procure from about 15 suppliers that make up 80% of the chemical product turnover; another 15% is made up by ten others (these 25 companies make up 95% of the market), while the remaining 5% is divided among small-scale enterprises. Supplier selection is based on parameters like: closeness (they are local suppliers mainly), low risk, good environmental performance and ability to innovate with the company. They will keep the location in Vicenza because of the closeness of providers within the district.
    - The Dani company manages 1500-1600 chemicals, for which it tries to be a "critical utilizer": for this reason, there are partnerships with companies to develop lower-impact tanning agents and definition products. The procurement cost can increase when it comes to choice of materials: we do not have quantitative data, but the effort on quality and sustainability can lead to higher prices. If the need for a special color arises, it can be ordered directly from the supplier, without keeping samples internally. The cost of offering a larger variety" for this company seems to be high inventory costs, as production in smaller batches seems difficult: these factors open the door for further analysis on the "postponement" as a new business model for this company.

- **Demand:**
    - Until 2009, the company was not present in the automotive market, and it entered it with an acquisition: it is an extremely stable sector. The company acts as a automotive sector supplier more than as a tannery. Concerning other sectors, the company feels the need for the production of small batches because it moved towards customers with a larger buying power, such as Apple or important footwear companies. In order to fulfil small orders, the company keeps an inventory with ample choice and small codes with many variations, e.g., for customers who need a specific color.

- **Manufacturing and Distribution to customer:**
    - Customers in the tanning industries are mostly Italian (20-30%) and European firms (50%, with Germany as an important market). The rest of the market is divided between Asia and America. The tanning sector is very international, and companies have a strong focus on export. Overall, customers are worldwide and the relationship with them is different from case to case, even in terms of inventory management.
    - Concerning manufacturing and distribution to customers, 50% of the income goes into raw material costs, while 10 to 15% goes into chemical products. As we said before, the production is locally done and it is centralized the company benefits in terms of economies of scale, even thanks to the closeness of the industrial district.
    - The upcoming trends highlight the need to produce in smaller lots at a low cost to respond to changing customer demand and reduce inventory costs? So far it is not possible and it is an issue that will be discussed when the new technologies are available. Concerning other sectors, the company feels the need for the production of small batches because it moved towards customers with a larger buying power, such as Apple or important footwear companies. In order to fulfill small orders, the company keeps an inventory with ample choice and small codes with many variations, e.g., for customers who need a specific color.

- **Pricing:**
    - *Due to the short length of the interviews with the company, we did not have time to deeply analyze this topic. We will discuss it (and other open questions) during the next meeting.*

- **Waste/Recycling, remanufacturing:**
    - The company's focus is even on waste/recycling. The finish is composed of three layers: bottom, covering and shine; in the next steps we could conduct a deeper analysis of the different kind of wastes of the process. Finally, the printing, performed by pressing the leather between two rollers, one of which has the given shape, or using a flat press. Dani removes all unneeded elements

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from the leather, throwing away cheratin, proteins, etc., which could be reused.

- So, the firm both recycle and send the waste to the landfills; but they try not to seriously impact on the environment: new tin-free metal-based technologies have been developed, based on the use of enzymes and polysaccharides that give the skin the same physical and mechanical characteristics of skins treated with traditional tanning. Also for the recoating and finishing phases are selected ad hoc products, which have a very low metal content, so as not to compromise the results obtained during the tanning phase. Finally, water-based products have been chosen for the refining phase.
- In general, the company is more interested in the product innovation (in terms of new materials or new treatments) more than in process innovation. Their mission and effort help reduce environmental impact and the main trend affecting the future business model and choices is sustainability as well: so far, there is evidence of reduction of waste (e.g. less metal content used), but not elimination of waste yet. Another interesting trend the company is working on is the circular economy, which will increases the potential income.

- **Collaboration:**
  - Regarding the upcoming trends of the Industry 4.0, new form of collaboration may grow concerning the new technologies and new providers, which will be different from the materials suppliers they have collaborated with to date. The company aims to increase its role of key innovation user strengthening collaboration with chemical suppliers in order to improve their products and reduce the impact of production processes. Increase collaboration to innovate both with upstream and downstream actors: chemical suppliers, fertilizers producers, competitors. Research and development, and training are two issues they are going to focus on, and the ICT is the major tool required for collaboration and alignment. To complete the picture, the company signed some contract in order to facilitate the communication and declare the goals and responsibility of each partner: this does not mean lack of trust; on the contrary, this is a signal of seriousness and foresight. Trust issue is not a matter.

A.2.2.5 Opportunities & Challenges/Risks

As presented by Brondi et al (2014), "*the high variability of the customer demand and the legislative pressure in the EU Countries on environmental aspects, push academic and industrial communities to tackle the question related on how to implement sustainable production systems*" (Brondi et al., 2014).

The development of customized products and their related services seems implicitly to call for new collaborative supply chains (Romero, Cavalieri, & Resta, 2014) requiring quality assessment criteria. At the same time new reliable models for sustainability characterization are necessary to go beyond pure economic value of products (Kohtala, 2015). Literature emphasizes the lack of criteria in case of diverging effects on environment due to customization policies. There is a trade-off in the environmental effects of customization: positive effects account the reduction of product rejection, the minor product replacement, reduction of unsold stock, the reduction of steps along the supply chain and the extension of the use-phase for customized products. Possible negative effects instead account the augmented difficulties in optimizing transportation of the final products, the need of highly flexible production process, the exposition to uncontrolled emission in local environments and the possible failure in the replacement of traditional mass production.

One minor comment is that when the product variety is larger (this is the current and future trend for mass customization), the unsold stock problem could be more serious, as it is harder to manage the inventory of a larger portfolio). Here it is mentioned as a positive solution that the company is benefit from; unless, the company is quite flexible and can provide the goods based on demand, usually higher inventories are kept when there are more products offered. This is a factor to deeply analyze in the further steps.

Brondi et al. (2016) also state that "*despite the large agreement on the importance of sustainability aspects for the long-term competitive advantages, and despite triggers like legal regulations, requests from stakeholders, customer demand, reputation loss, environmental and social groups' pressure, some barriers to implement actions for Sustainable Supply Chain (SSC) are linked to costs to implement measurement systems for sustainability along the network; hitch to define a value for the output with respect to environmental outcomes; perception that data to be collected from different actors in the*

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network are not manageable and in some cases having low impact on the global outcome; difficulties to take no popular and high-priced decisions" (Brondi et al., 2014).

A.2.2.6 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing	2			
	Efficient and sustainable distribution	1			
	More flexible	2			
	Less delocalized	2			
	Competitive advantage via intensified processing	1			
Industry / Company / Region specific objectives	Reduced production costs	1			
	Increased product quality	3			
	Minimized time to market	2			
	Higher throughput with smaller batches	2			
	Reduced response time to changes in demand	3			
	Jobs creation	1			
	Limit employment reduction	-1			
	Improving working conditions for workers	2			
	Sustainable development promotion	3			
	Increased local business opportunities - SMEs	2			
	Shorter lead times	1			
	Less stock	2			
	Reduction of raw material by 15%	1			
	Less waste	2	2		
	Reduction in environmental footprint by 10%	3			
	More interaction with the end users	1			
	Customer driven SC business models based on Intensified Processing.	2			

Table 15: Analysis of impacts on the objectives for Business Case 4: Customized leather fabrication

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

A.2.3 Business case 5: 3D Food Printing

A.2.3.1 Description of the firm/industry/sector

Natural Machines, a Spanish start-up was founded in May 2012 and is based in the Glòries Incubator in the Barcelona Activa center, in Barcelona, is developing a 'new generation kitchen appliance': a 3D food printer that can create gastronomic delights at the flick of a switch: the Foodini **Invalid source specified.**. With Foodini, Natural Machines is going to make preparing food healthier, easier, and so much fun.

Foodini is the first 3D printer to print all types of real, fresh, nutritious foods, from savory to sweet. It uses fresh, real ingredients and enter the recipe into a touch-screen interface, making the Foodini the first 3D food printer kitchen appliance to contribute to a healthy eating lifestyle. As well, is possible to share the creations with other chefs via online.

"*Foodini takes on the difficult parts of making food that is hard and/or time consuming to make fully by hand*" **Invalid source specified.**. One of the goals of Natural Machine is to streamline some of the routine cooking activities and make it easier for people to eat healthy foods. Foodini uses prepared capsules of fresh food, prepared by the final customer under some specifications, to print dishes at the press of a button. Dishes can vary from raviolis, pasta, pizza, cookies to chocolate and almost anything.

A.2.3.2 Description of the supply chain

Natural Machines faces two different process: Industrial processes and Consumer processes. However, having these two-different processes does not necessarily mean to have two different supply chains.

From the industrial point of view, the manufacturing of the 3D food printer faces the same production process as any regular mobile device. This process takes place in China, where the contractor produces the machine, sourcing parts from places nearby or in the Asia region, and assembles the machine including, but not limiting to: electronic parts, mechanical parts (aluminum and steel), standard engines and plastic cases.

From the customer point of view, Natural Machines is responsible for offering the 3D printing machine and bring it to the customer place. The ingredients used in the machine are

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"any food ingredient that the customer might want to eat, that can be purchased directly in any supermarket", transforming it into the finished goods.

The current supply chain for the food industry is straight forward, starting with the harvesting of the fresh products and ending with the consumer usage and final waste disposal.

In a very traditional agricultural society, the simplest form of supply chain, the number of actors and processes might be relatively few because most of the producers and customers are the same. In the other hand, the modern food supply chain is extremely complex as the production and delivery involves many actors to arrive to the final customer.

The following figure shows a simplified version of the delivery of a product, form the primary production (harvesting), through the processing in a manufacturing industry, then the transportation of the processed product to the point of consumption, such as retailer or a food service provider, where the final customer can enjoy the product and finally the waste can be disposed and recycled.

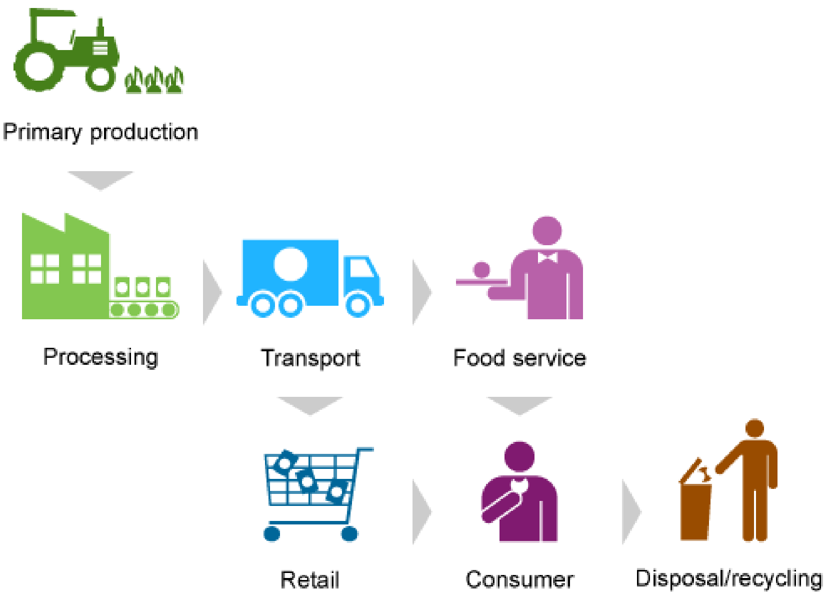

Figure 18: Traditional food supply chain Invalid source specified.

The changes that the food supply chain could face under the implementation of 3D printing technology could be of great proportions. It could have a big impact specially in the

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manufacturing stage, as the products would be directly manufactured by the final customer, changing also the way raw materials are delivered and to whom, as now these could be placed near to the customer who is requesting these items. Also, the disposal part could change as some of the products could be reused in the 3D printer as raw materials. A scheme of the possible change that could occur in the supply chain is presented in the following figure, where the manufacturing before transportation has moved downstream to the customer and to the food service.

Figure 19: Changes in the food supply chain. Adapted by the authors from SpeechFoodie (2015)

A.2.3.3 Technology required and advanced technologies

Most of the identified technology for 3D food printing is based in the traditional 3D printing business model, which means it does not require the development of new technologies. Rather, the same 3D printing technologies can be combined with different components and equipment, to generate the required machinery to 3D print food, avoiding waste and allowing the reuse of food as raw materials. This implies not considerable initial investments in technological assets besides than a 3D food printer machine. Training of new staff will not be required, as current staff working on 3D printer will understand the basics based on their current skills to operate the equipment.

A.2.3.4 Changes in the Value/Supply Chain Configurations with the business model:

- **PLAN (R&D, Product Design, Testing, etc.):**
  - Customers have the final word on what they want to eat and how do they want to make it. Customers can share their ideas online through the screen of the 3D printer. In the other hand, if talking about the product design (3D printer), it has been standardized but can be customized (color) upon request.
  - Food products are customized at every single stage of the design, including raw materials and final shape of the product, making it highly customizable. However, the printer machine is standardized.
  - The time to design and test adaptations to current product is relatively small as it is made by one of the partners.
  - Talking about the food, has no cost to create new products, as the raw materials can be easily changed. When talking about the printer, develop a new machine requires some investment, but can be produced per the requested specifications.
  - Natural Machines is working hardly on incorporating recycled raw materials/parts, as well as some other components into other machines (mainly electronics) to make the design easier.

- **Sourcing:**
  - Natural Machines deals mainly with a supplier, which has different suppliers for the raw materials for the printer. Meaning that there are deep tier suppliers that Natural Machines is not aware of.
  - For the 3D printer, the main suppliers are located in Asia. Regarding the food, main suppliers are local, within Europe, or where the printer has been set.

- Transportation cost could be increased as the raw materials are transported directly (or closely) to the customer.

- **Demand:**
  - 3D printers are taking part of a growing market, which has been unattended until now. There is large potential for growth, especially as a kitchen appliance in the long run. In the meantime, Natural Machines is trying to common in top professional kitchens
  - New products are being developed, for more specialized market (professional kitchens) and also for a broader common market (home kitchen appliances). The impact of including this technology in the kitchen could be as large as the microwave.
  - As each of the products being designed and offered by Natural Machines have a specific market, cannibalization is not a possibility.

- **Manufacturing and Distribution to customer:**
  - As the 3D printers are standardized but are not fully commercial yet, their manufacturing is in small batches
  - Customers are located worldwide, thus, transportation costs may vary depending on the type of transport used, distance covered and location of the customer.

- **Pricing**
  - Prices are mostly standardized for most of the printers, however for special features (full customization of the printer), the price increases accordingly.
  - Natural Machines has partnership with the manufacturing company, which makes it easier to share the revenues according to the initial agreements.

- **Waste/Recycling, remanufacturing:**
  - There is few waste produced as most of the parts are customized for the machines, making them unique.
  - The manufacturing partner takes care of all the details and creates the recycling plan when it applies.

- In the production phase, there is little to be recycled or go to the landfills as most of the pieces are customized. Also, partners are involved in eliminating waste at any of the production process
- The main trend affecting the future business model and choices is sustainability. The manufacturing company creates electronic components that can be used also by other industries, which makes part of a collaborative and circular economy. As well, the main goal behind the 3D printer is to reduce the food waste.
- As the manufacturing process is made by the main partner in Asia, there are many uncertainties about the recycling processes, such as: the quality of recycled materials, the quantity of usable material from the recycling process, the quantity of waste that can be collected, etc.

- **Collaboration:**
  - New forms of collaboration might include working together with other customers to co-create recipes online.
  - The printer has a screen incorporated that allows customers to communicate easily. The technology that is behind this would be the Internet of Things (IoT).

A.2.3.5 Opportunities & Challenges/Risks

There are some risks that the 3D food printer will face, such as food hazard, cybersecurity, review the designs and the recipes. According to Mike Thoma, VP Chief Underwriting Officer – Global Technology at Travelers **Invalid source specified.**, the following are the problems more likely to be faced by 3D food printers' companies nowadays and in the near future:

- *Conduct robust hazard analysis*: There are different methods that companies can use to make sure that products are safe, such as fault tree analysis (FTA), failure mode and effects analysis (FMEA), and hazard and operability analysis (HAZOP).
- *Conduct routine design reviews*: 3D printer manufacturers should assess and categorize the potential damages that could be caused by the machines, to avoid any severe or frequent problem.

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- *Build in cybersecurity*: As products will be connected to the internet (IoT) the need for better security systems takes an important role. Is key to make sure that all the relevant information shared is being kept safe.

A.2.3.6 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing	3			
	Efficient and sustainable distribution				3
	More flexible	3			
	Less delocalized	-2		2	
	Competitive advantage via intensified processing	1			
Industry / Company / Region specific objectives	Reduced production costs	1			
	Increased product quality	2			
	Minimized time to market	1			
	Higher throughput with smaller batches	1			
	Reduced response time to changes in demand	3			
	Jobs creation		1		
	Limit employment reduction		1		
	Improving working conditions for workers	0			
	Sustainable development promotion	2	1		
	Increased local business opportunities - SMEs	3	2	2	
	Shorter lead times	3			
	Less stock	3		1	
	Reduction of raw material by 15%	3	3		
	Less waste	3	3		
	Reduction in environmental footprint by 10%	2	3		
	More interaction with the end users	3			3
	Customer driven SC business models based on Intensified Processing.	1			
	Increased demand and/or revenues	2			3

Table 16: Analysis of impacts on the objectives for Business Case 5: 3D Food Printing

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

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A.3. Servitization of the process industry (PSS)

A.3.1 Business case 6: Implantable Drug Delivery System

A.3.1.1 Description of the case

The increasing number of people with chronic diseases (e.g., cardiovascular diseases, cancer, osteoporosis, chronic respiratory conditions, diabetes) and growing elderly population worldwide and in Europe along with the limited budgets for health care necessitates patient compliance and reduced medication errors. There are significant costs related to reducing medication errors, monitoring and conforming proper drug administration, and the annual revenue loss for the Pharma industry globally is estimated to be around $30 billion (Forissier & Firlik, 2012). More than 80% of the people of age over 65 in Europe suffer from chronic diseases and Europe has the highest burden of chronic diseases globally causing 86% of all deaths. Significant budget is allocated to chronic diseases (75% of healthcare costs), which equals to €700 billion in the EU and this figure is expected to increase in the future (European Commission, 2010).

Health care providers recently have been considering patient awareness programs to improve self-management for people with chronic diseases (e.g., diabetes) to change patient behavior aiming self-efficacy along with some apps for monitoring purposes, for reducing drug and treatment costs and hospital utilisation. An alternative solution to patient non-compliance (which is around 50%) (Matheson, 2015) is offered by the collaboration between Teva Pharmaceuticals (number 1 global generics producer) and Microchips Biotech (an MIT startup developing applications with microchip-based implant for diseases such as diabetes, osteoporosis, multiple sclerosis, women's contraception). Teva paid $35 million for the cooperation with Microchips Biotech (Matheson, 2015). This joint project offers a solution to the aforementioned problem. The responsive drug delivery system, which works like an artificial organ acting like a gland sending endocrine or chemical signals, with the implantable chip is designed to address the non-adherence (patient compliance issues) problem and reduce otherwise avoidable medical spending due to medication errors (over/under dosage) and increase revenues for the Pharmaceutical industry. First human trials for osteoporosis in 2011 with 7 elderly women: success with no side effects (Farra, et al., 2012). The potential ultimate effect of this new way of administering such drugs goes beyond the immediate implications of improved efficiency and reduced long-term costs. As a result of the increased compliance, the implantable devices will reduce the productive life years lost

(3.4 million among people aged 25-64 in EU countries, 2013) due to non-communicable diseases in EU countries (European Commission, 2016).

In addition to the primary objective as defined above, this innovative method of administering such drugs will also lead to use of less chemical and other raw materials in the production of the medicine (higher adherence will lower the amount consumed as the release of the drug will be controlled by the device). It will also result in the elimination of supplementary products (e.g., syringes, needles, vacutainers, etc.) as it replaces injections and pills, as well as reducing the burden of medical waste management for proper sharps waste disposal and save energy, contributing to environmental protection.

Personalized health care will be the norm in the near future, and therefore to maintain or increase its position (market share) in this sector, the Pharmaceutical firms and biotech firms in the EU need to invest in this innovative system of drug delivery as the chip production and the ICT for controlled release of the medicine through wireless communication is a high value added product/service. Mere production of the drugs can be made by generic producers once the patent expires, however the "service" (the drug and the administration of it over time with the chip and monitoring the patient's condition in real time) is more difficult to imitate and EU with its know-how in this industry has the competitive advantage.

A.3.1.2 Description of the supply chain

The extended supply chain includes pharmaceutical companies, biotech firms, producers of supplementary products (syringes, packages, needles, etc.), health care providers (hospitals, clinics, pharmacies, etc.), payers (insurance companies, governments). The focal firms promoting this new method of drug delivery in this particular business case are the pharmaceutical company and the biotech firm (e.g., Teva and MicroChips BioTech). The conventional way of administering the drug and the new method (responsive drug delivery system via the microchip) is illustrated below (focusing on the pharmaceutical firm's operations):

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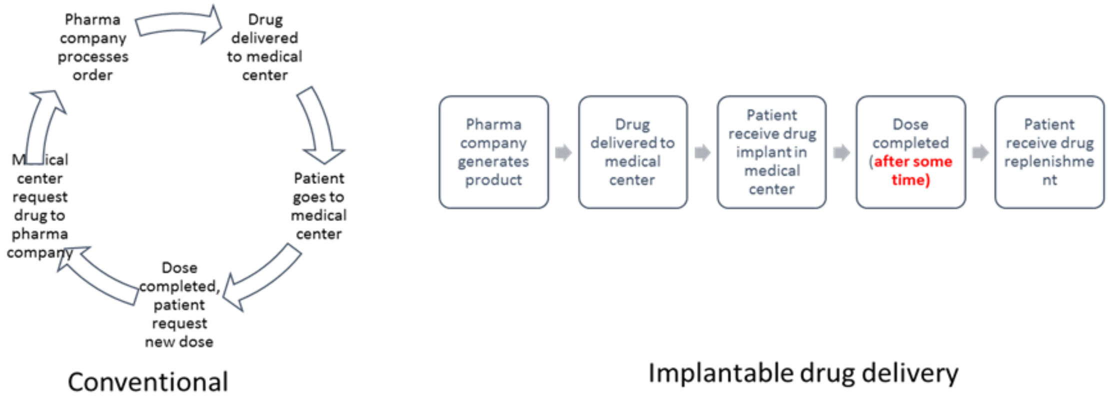

Figure 20: Implantable drug delivery - supply chain

The major change is that rather than the microchip will be sufficient to administer the drug for a longer term (e.g. six months) and therefore the "frequency of replenishment" is much lower. Note that the above figure does not illustrate the procurement of raw materials or supplementary products and the reverse supply chain. The number of suppliers in the conventional method is higher because the pharmaceutical firm needs to source supplementary products (e.g., vacutainers, needles, syringes, etc.) to allow for the administration of the drug. With the new system, the pharma company only needs to procure the chips. In regards to the reverse supply chain, the conventional method requires proper medical waste management activities in the supply chain, whereas the implantable chip will not result in such materials to be disposed. These will be discussed in more detail later in this document.

A.3.1.3 Technology required and advanced technologies

Two different methodologies are offered with this new system:

1. Fabrication of a delivery system that releases its payload at a predetermined time or in pulses of a predetermined sequence.
2. Development of a system that can respond to changes in the local environment.

In order to make this possible and design a chip which is biocompatible, the following enabling technologies are required (Arps, 2013), (Trohman, Glassco, Draganoiu, & Boyum, 2015), (Meng & Hoang, 2012)

- *Microelectromechanical systems* → for the production of the chips to be commercialized.
- *Cold-welding* → For depositing a soft, gold alloy in patterns on the top of the chip to create tongues, and grooves on the base. Tongues fitted into the groves by pressing the top and base pieces together, plastically deforming to weld the metal together.
- *Biodegradable material, such as PLGA* → for the controllable release of the drug while essentially "dissolving away" by hydrolysis to produce lactic and glycolic acid.
- *Non-biodegradable materials, such as PDMS* → works to deliver drugs via diffusion or osmosis through a matrix, reservoir, or osmotic systems. It is designed to reduce costs compared to biodegradable devices
- *Micro and nano-fabrication technologies* → "*Surface modification techniques and biocompatible material selection have been utilized to provide a stable, chemically inert interface between the implant and the body. These technologies have enabled tunable drug-release mechanisms to achieve great control of drug-release profiles including programmable, cyclic, pulsatile or continuous*".
- *Microfluidics* → "*implantable drug-delivery systems that achieve the desired drug-dosing profile in a miniaturized form factor suitable for surgical placement and operation in vivo*"
- *Biocompatible biosensors* → to enable the chip to release adjusted amounts of medicine in response to continuously monitored physiologic conditions to meet the patient's needs

A.3.1.4 Changes in the Value/Supply Chain Configurations with the business model:

- **PLAN (R&D, Product Design, Testing, etc.):**
  - The design of the new product (microchip), compared to the traditional way of taking medicine, has another layer of complexity and groundbreaking technology as it needs to be biocompatible. This requires certain materials and

technology as defined before to be used in the manufacturing of the chip. Moreover, the delivery of the drug requires wireless communication and ICT between the chip and the health care provider (e.g., doctor). However, the more complicated design of the product pays off as the microchip is designed in such a way that the required amount of the medicine based on the needs of a particular patient can be loaded on the chip. The precise amounts of the drug will be released over a certain amount of time. Therefore, rather than determining a product portfolio (a group of SKUs for a particular medicine) for the general population, the same microchip can be customized to meet the needs of a single patient. This new design provides mass customization and greatly simplifies the further activities down the value chain (sourcing of complementary products necessary to take the drug such as needles, syringes; patients visiting hospitals for injections; disposal of hazardous materials; etc.).

  - The testing and efficacy of the medicine is also easier with the microchip as it enables the care givers to collect valuable and reliable information about drug effectiveness (primary indications, adverse interaction with other drugs taken, side effects of the drug, and conditions of the body can be tracked on almost real time) thanks to the wireless communication between the chip and the system. This would potentially facilitate the development of new drugs or improvements to the existing drugs in the portfolio. Clearly, there is the issue of "patient privacy" and with whom this type of data can be shared. However, in any case, the new system has the potential to store and extract information from such data.

- **Sourcing:**
  - The conventional drug delivery process for most chronic diseases requires supplementary products in addition to the medicine itself. The pharmaceutical company needs to also procure items such as syringes, needles, manuals, pills, vacutainers, packages in order for the patients to be able to take the medicine. The pharmaceutical company needs to also source equipment for the proper sharps waste disposal of the medical waste, which is a top priority (e.g., Pharma supplying self-injection is responsible for the disposal of spent needles (wikipedia: sharps waste)). The small sized product (chip) replaces most of these supplementary products once the active ingredient of the medicine is loaded on the chip. Therefore, sourcing would most likely be easier with this

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new drug delivery system. However, one needs to keep in mind that the sourcing of the raw materials for the manufacturing of the chip has to be considered as well. Moreover, as most pharmaceutical firms would probably keep both the conventional way and the new delivery system in the future, the sourcing would involve more suppliers and raw materials/products, but the overall sourcing would be less complicated when part of the demand for conventional treatment is replaced by the new drug delivery system.

- The inbound transportation costs would be relatively cheaper as the Pharma would probably need to receive the microchips only instead of a multitude of supplementary products as mentioned above. There would be savings as a result of the economies of scale, and procurement from a single supplier (chip producer).
- The procurement cost would be a major part of this new responsive drug delivery system, as the precise release of the drug will happen through wireless communication at lower costs. However, as explained before, the impact on the total unit cost (related to procurement) is not clear at the moment.
- The production of the chip currently needs materials such as gold, silicon, stainless steel that might be more critical and harder to source. The chip producer needs to ensure steady supply of such materials.

- **Demand:**
    - There might be a new source of demand, as some people who currently do not tolerate needles or self-administered injections may be willing to go for the implant option.
    - Because the "value added services" (not just the medicine, but continuous monitoring of drug effectiveness, side/interaction effects, convenience of administering the drug), the patients/payers may be "willing to pay (WTP)" more. This increased WTP might increase overall demand in a given market.
    - The product assortment changes, as most pharma companies will keep the conventional form and this new system with the new chip. The new product will cannibalize some of the demand for the conventional form.
    - It will be easier to estimate the demand with the new system with the capabilities to monitor inventory levels (you know the consumption rate when the patient will need another batch with the chip as opposed to patients

showing up with the request for another batch) and SKU reduction (no need to keep inventories of different presentations which are combinations of "dosage/package size/dosage form"). This ultimately makes demand forecasts significantly more reliable and provides opportunities to optimize inventory management and distribution. Inventory pooling can be possible because of the simplification of product portfolio (SKU rationalization), leading to reduced inventory/distribution costs.

- **Manufacturing and Distribution to customer:**
    - Majority of the costs will be due to manufacturing of the chip itself and the drug.
    - At the moment, the project is carried out by Teva (in Israel) and Microchips Biotech. However, there are other initiatives (e.g., Novartis as a firm located in Europe collaborating with Rani Therapeutics for developing a robotic pill) that EU member countries can undertake and locally produce similar products in Europe.
    - The batch sizes are not as critical with the new system as with the conventional way. Because, the amount of payload on a particular chip (which will determine how long the chip will last for a patient) will be the only differentiating factor. Therefore, manufacturing in smaller batches will be easier with the new system.
    - We conjecture that to comply with quality standards and make sure that the highly complex product is up to standards, the manufacturing will be centralized. This will benefit the firms in economies of scale.
    - The chip will be "stored in the body of the patient" for long durations, and therefore some of the supply chain complexities (e.g., cold chains for drugs/injections) will be eliminated.
    - As the chip will most likely last much longer compared to a "package" of the same drug, the patients do not need to visit medical centers that often, and therefore patients located farther can also be served without much inconvenience with the new system. Therefore, we believe the coverage will increase. This will reduce the effort to administer and ensure the availability of the drug for the hospitals/pharmacies as well as lead to lower traveling costs for the patients.

- The outbound costs (from the pharmaceutical firm to the pharmacies/hospitals/medical centers) will also go down as the product shipped is "simpler and smaller sized" (only the chip compared to medicine plus supplementary products). Moreover, the shipment frequency will be lower (as the chips last longer), which will further reduce the outbound distribution costs.

- **Pricing:**
  - The pricing decision is complicated and depends on what kind of strategy the pharmaceutical company employs. If it is "cost based pricing", then the price will be the unit cost of plus the profit margin. In this particular case, it is hard to estimate to predict the unit cost and this is something that needs to be studies in detail. Even though the microchip itself will probably be expensive, the net effect on the total unit cost is hard to predict. One chip might carry medicine that will last a year, and this practically means that the future costs of packaging, capsules, needles, syringes, trips to the hospital by the patient to take medicine, taking tests to measure the effect of the medicine, disposal of madiecal waste needs to be taken into account. This is quite a difficult task, but for proper pricing, this analysis must be made. Our belief is that when one compares the total unit cost over a certain duration (e.g. one year) for a particular patient, the drug delivery via the chip will be cheaper, and price will be lower as well. This will increase the patient welfare, and ease the burden on the limited health budgets that is a significant problem in many countries, including the EU members. Moreover, the revenues will increase with the new way because of the improved adherence. Therefore, the conjecture is that some of this benefit will be shared with the patients and payers. If the firm uses a "market based pricing" (based on competitors pricing schemes) or "value based pricing", then the analysis gets a bit more complicated as one needs to have information about the alternatives available in the market. The idea is to make the treatment more convenient for the patients (once the chip is implanted, almost no effort by the patient is required) and the care givers (the burden on the hospitals, clinics will also be reduced). Besides the convenience factor, the patients/payers might also be willing to pay more as the medicine

(drug delivery) is customized for a particular patient. This generally either increases the demand (given that price does not change) or the price of the product itself. Therefore, we think that the "value" provided to the patient is higher, and therefore the price might be higher as well. However, as mentioned before, some of the savings from the increased revenue may be shared with the patients so that the risk of losing market share can be mitigated.

- **Waste/Recycling, remanufacturing:**
    - As a result of the chip replacing pills and injections, there will be less waste (positive environmental impact)
    - There will be reduced risk of biohazardous material disposal (improved safety of people) and the need for equipment for proper sharps waste disposal (e.g., autoenclaves) will be less
    - Energy spent for such disposal will be reduced by eliminating the process of disposing which requires high temperature and pressure.
    - Disposal by truck by trained personnel collecting medical waste at point of generation and hauling it back to destruction facility will no longer be necessary for the chip as the chip will dispose itself. This will reduce the transportation costs related to waste management.

- **Collaboration:**
    - The biotech companies and pharmaceutical firms need to collaborate starting from the design stage of the product to the administration of the drug. The product is quite complex and requires significant input from these actors. This is different to the conventional method, where the Pharmaceutical firm produces the product and sources the other components to be able to administer the drug. Here, the chip and the wireless communication to administer might require more effort from the biotech firms and the ICT providers (to ensure safe/secure data exchange and the control of the release of the payload on the chips).

- The sharing of revenues is a major concern, as it depends on where the "value added service" is originating from. If the patients think most of it is due to the technology and the chip itself, then the biotech firms might ask for a larger share of the profits.
- The patients need to trust this new system that a device implemented in their own bodies will work properly and be under the control of the assigned doctor and not anyone else.

A.3.1.5 Opportunities & Challenges/Risks

There are pros and cons with the new drug delivery system combined with the "servitisation (or Product Service System)" that need to be carefully considered to evaluate the potential of this business model. In what follows, some of these are listed:

Challenges & Risks:

- Cost-to-benefit ratio (cost/benefit) may be very high if the chip production becomes too costly, potentially restricting the implementation of the new system over conventional dosage forms
- Risk of the patient stopping the treatment early or switching to an alternative treatment before the payload in the chip is entirely consumed (high risk if the chip costs are too high): the chip must be reasonably priced for adaption by health care payers.
- Technology is still new and the implants are still being developed and tested. Rigorous and extensive clinical trials are necessary for the commercialization at a larger scale
- Regulatory requirements to ensure patient safety and proper functioning of the product: Electromechanical nature and the high water content of the human body pose challenges. Safety, toxicitiy, carcinogenicity, physiologic responses, biocompatibility and biodegradability concerns and the reactions of the body to a foreign substance (i.e., the implant), effect of radio frequencies and magnetic fields, and drug release system failures (over/under dose) need to be considered (Jones, et al., 2015).
- The issue of pricing as the pharmaceutical company no longer offers the product only, but also the service of drug administration and additional value added services. This

necessitates careful analysis to decide whether Performance Based Logistics (PBL) Contract would be appropriate in this setting or not, and if so, how would the "result/success" be linked to the service offered? The impact on the revenues need to be analyzed in detail, as the PBL contracts makes the revenues more uncertain (not volume based, but depending on the health outcome, where it is easier to link the use of the medicine to the health outcome with the chip, but risky as the health outcome may depend on so many other factors)

- Patients' trust is a big issue, especially at the initial stages where only a small fraction of the population would most likely be willing to have an implant in their bodies
- Patient privacy and data confidentiality limiting the use of the data that could be collected
- Safe/secure IT infrastructure must be in place that needs to remove/reduce the risks of system being hacked and data insecurity. For example, an alarm and a kill switch that could be activated either by the patient or the doctor in the case of hacking could be installed.
- Strong collaboration among pharmaceutical companies, biotech firms, ICT providers necessary for the successful implementation
- Capacity allocation for the production of the drugs with the conventional method and the new delivery system

Opportunities:

- Reduced burden on the health care system and patients because of the much more convenient administration of the drug (e.g., eliminating frequent visits to the hospital, reduced need for home case nurse appointments for intravenous injections)
- Increased adherence rates leading to improved drug effectiveness and reduction in revenues lost for the pharmaceutical companies and the otherwise avoidable costs for the health care system. This will enable policy makers to allocate more budget (resulting from the savings) to other critical health care issues.
- Less chemicals used for drug manufacturing because of improved consumption patterns without worsening drug effectiveness.
- More environmentally friendly system because of the elimination of the waste from the use of supplementary products with the conventional system (e.g., packaging (pills, packages), vacutainers, needles) and the energy saved due to elimination of the sharps waste disposal process
- Improved safety of workers because of reduced risk of biohazardous material disposal

- Increased revenue streams for the Pharmaceutical firms because of the "high-value added services" offered with the use of the chip (drug administration being more convenient for the patient)
- Reduced logistics related costs (lower inventory and distribution costs)
- Capability to gather reliable information about drug effectiveness and side effects and monitoring, which is a very important VAS (Panda & Carrasco, 2016), that will be critical for the improvement in design and new product development
- Ensured product safety as the chip is stored in the body of the patient under control
- Personalized health care through technologies such as ingestible biosensors to respond to changes in conditions of the patients

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A.3.1.6 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing	2			
	Efficient and sustainable distribution				3
	More flexible				2
	Less delocalized				1
	Competitive advantage via intensified processing	1			
Industry / Company / Region specific objectives	Reduced production costs	-1			
	Increased product quality				2
	Minimized time to market	1			
	Higher throughput with smaller batches	2			
	Reduced response time to changes in demand	2			
	Jobs creation				-1
	Limit employment reduction				-1
	Improving working conditions for workers				3
	Sustainable development promotion	2			2
	Increased local business opportunities - SMEs	1			1
	Shorter lead times	0			2
	Less stock	3			
	Reduction of raw material by 15%	1			
	Less waste	3			3
	Reduction in environmental footprint by 10%	2			3
	More interaction with the end users				3
	Customer driven SC business models based on Intensified Processing.				1
	Increased demand and/or revenues	2			3

Table 17: Analysis of impacts on the objectives for Business Case 6: Implantable Drug Delivery System

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

A.3.2 Business case 7: Chemical leasing - TabaChem

A.3.2.1 Description of the case

"Take Back Chemicals" (TaBaChem) is a project based around the leasing of chemicals. Chemical leasing means that the chemical supplier not only offers the material as a product but an application of this chemical as a service, a so-called Product Service System (PSS). The service offer thus comprises a discrete application to achieve predefined defined results. The service is charged as a package depending on the service specification and regardless of the amount of chemicals used.

This changes the incentive and logistics structure of the transaction. The product/service provider had an interest in selling as much of the chemical to its customer as possible, since the customer would pay for them. In the PSS, it is now in their best interest to avoid the use of chemicals and the associated cost as much as the adequate realisation of application allows. Thus, the producer has an incentive to be as resource efficient as possible. While this already avoids waste, recycling and reuse of the chemicals also becomes more attractive. This is because of the different logistic system required for the PSS. Since the entire logistic is now with the product/service provider, they have cheaper access to the waste chemicals and better control over their quantity and quality.

The TaBaChem project aims to develop necessary business models and gain insights over the necessary, ecosystems as well as regulatory and policy framework for their implementation. This is done by realising a chemical leasing-based business model among different industrial organizations.

A.3.2.2 Description of the supply chain

To switch from a product based to a service based model, comprehensive adaptions of the provider's supply chain are necessary. This not only comprises more elaborate logistics and the establishment of a comprehensive service department, but affects the entire value chain. Changes include but are not limited to:

- A service organization with staff that realises the PSS projects at the customers' facilities with associated project management
- A different sales organization specialized on selling project instead of products

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- More comprehensive outbound logistics to get the necessary tools, devices, and materials to the customers' facilities
- Reverse logistics to remove excess and waste materials from the customer's site

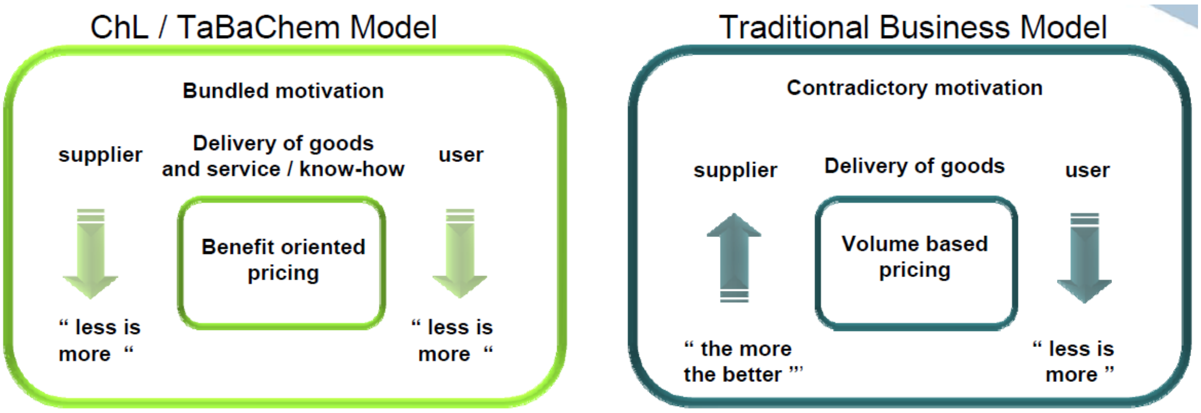

Figure 21: Differences in pricing and motivation

To help industry in Flanders identify the value potentials of chemical leasing PSS, the project team develops a 'Chemical Leasing Scan'.

A.3.2.3 Technology required and advanced technologies

– To help industry in Flanders identify the value potentials of chemical leasing PSS, the project team develops a 'Chemical Leasing Scan'. Most of the identified PSS for chemical leasing do not require the development of new technologies. Rather, the same production technologies can be combined with equipment necessary for the application of the chemicals to deliver the service and technology to recycle or reuse waste and excess chemicals from the service provision. This implies not only considerable initial investments in technological assets but also new capabilities within the company. Not at least retraining of existing and hiring of new staff to acquire the necessary skills to operate the equipment.

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A.3.2.4 Changes in the Value/Supply Chain Configurations with the business model:

- **PLAN (R&D, Product Design, Testing, etc.):**
  - Customers input is considered in product design/testing? Not at the moment
  - Are the products customized at the design stage or standard? Standard
  - Does it take too long to design and test (to get the product to the market before competition)? Concerning the case study, the answer is no. Concerning competitors, such as SMEs in this sector, the answer might be different.
  - Is it too costly to design new products? No
  - Is it particularly challenging when the recycled raw materials/parts are used in the product design phase? No, it is adding value/avoiding costs

- **Sourcing:**
  - Does the firm procure from a single supplier or multiple suppliers? Multiple ones.
  - Do they procure from local suppliers (in Europe) or global suppliers (outside Europe)? Local
  - How are the inbound transportation costs affected by the business model (e.g., economies of scale in inbound transport when raw materials are brought to the central location in a centralized production model as opposed to decentralized)? The transportation cost will go up while material costs will go down.
  - Is the procurement cost (of raw materials, parts) a major part of the total cost? Yes, it is.
  - Does it take too long to get the items at the factory? What is the lead time? We don't have an accurate estimation but the evidence is that they do not take so long and markets are usually well served.
  - Are there critical materials, that are short of supply or very expensive? No.

- **Demand:**
  - Does it create new demand for the same product assortment? A service might be preferred to a product, in which case it would allow to acquire market share from competitors.

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- Does the product assortment change, are there new products? or new subassemblies or complementary products that go with it? how is the demand (for the focal product or the others that are related) changing? An additional service portfolio is offered.
- cannibalization of demand for existing products in case a new product/service is introduced? This is not a concern as long as profits are higher for the service system.

- **Manufacturing and Distribution to customer:**
  - Are the manufacturing costs a major part of the total cost? Yes
  - labor cost? machinery? Labour will make for a bigger share of the costs and additional equipment will be needed.
  - is the production done locally? The service delivery is local.
  - how long does it take to produce a standard batch? Not discussed.
  - What are the batch sizes? Is it possible to produce in smaller lots at a low cost to respond to changing customer demand and reduce inventory costs? Not discussed.
  - Is the manufacturing centralized? Economies of scale? The production of the chemicals is not changed in the first instance, while service delivery is localised to the customers' facilities
  - Are the customers located close by or far away? Are there significant outbound (from the firm to the customer site) transportation costs? For example, are the customers mostly outside Europe (assuming the firm is in Europe)? Or vice-versa? The service delivery takes place at the customers' facilities

- **Pricing:**
  - How does the business model affect the prices? For example, does the firm charge higher prices when PSS model is used, and services are bundled with the product? How does the firm do the life cycle analysis and calculate the prices to offer in this case? Since more of the value generation is created by the firm itself, a higher product/service bundle price is expected
  - When products are customized, does the price increase (as a result of higher willingness to pay)? Since more of the value generation is more customised for each customer, a higher product/service bundle price is expected

  - If certain services are jointly delivered (through collaboration of several supply chain actors), how are the revenues shared? How are the sales figures monitored and audited if such practices are necessary? Not discussed.

- **Waste/Recycling, remanufacturing:**
  - What kind of waste is produced? A high rate of recyclable chemicals is desirable, while some mixing of different substances during service delivery might cause waste that is hard to recycle
  - How is it managed? Is it collected by the firm itself or is there a sector-wide organization that does the collection of the waste? The firm itself will handle the reverse logistics as part of the offered service package
  - Does the firm recycle or mostly send the waste to the landfills? A high rate of recyclable chemicals is aimed at, while some mixing of different substances during service delivery might cause waste that is hard to recycle
  - Does the business case/model help eliminate part of the waste? or are there added recycling opportunities with the business model? The PSS sets additional incentives for and provides the necessary access to recycle waste products
  - Does the business case help reduce environmental impact (e.g., carbon)? The PSS sets incentives to employ less chemicals and recycle a greater share of them reducing pollution and resource depletion.
  - If there is a feedback loop (circular economy), are the recycled materials as good (in terms of quality) as the new ones? Depends on the service provided, respectively the employed chemicals.
  - Is it costly to recycle? See above.
  - Does it take long to recycle and have them as raw materials back in production? See above.
  - Are there uncertainties related to the recycling process (the quality of recycled materials, the quantity of usable material from the recycling process, the quantity of waste that can be collected, etc.)? See above.

- **Collaboration:**
  - Does the business case require any collaboration that were not initially there? For example, if the capabilities needed to run the PSS cannot be acquired

adequately or additional substances are required, additional partners and suppliers have to be involved.

- How are revenues/costs shared? Not discussed
- What technology (e.g. ICT) is required for collaboration? Not discussed
- Trust issues? Not discussed

A.3.2.5 Opportunities & Challenges/Risks

The main opportunities of chemical leasing are represented by monetary incentives. Because a greater share of the value creation necessary to provide the respective value proposition of a service is internalized within the PSS provider, higher prices can be achieved. With adequate cost management, higher these prices for services compared to products can be translated into higher profits. A potential for leaner cost management lies in the better control of the configuration and implementation of the value creation activities. Processes that were managed by the customer in the traditional model can be optimized by the provider in the PSS.

- The main risks lie in higher complexity and uncertainty of the PSS compared to the traditional model. Since more of the value chain has to be managed and monitored, a considerable amount of complexity is added. But not only this complexity bears challenges for efficient operations and decision-making, but also that the providers have less experience with PSS than with the current system. This is aggravated by fewer implemented cases in the own and similar industries that could be used for benchmarking.

A.3.2.6 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing				3
	Efficient and sustainable distribution				2
	More flexible				-1
	Less delocalized				2
	Competitive advantage via intensified processing				0
Industry / Company / Region specific objectives	Reduced production costs				0
	Increased product quality				0
	Minimized time to market				0
	Higher throughput with smaller batches				0
	Reduced response time to changes in demand				0
	Jobs creation				1
	Limit employment reduction				2
	Improving working conditions for workers				0
	Sustainable development promotion				2
	Increased local business opportunities - SMEs				2
	Shorter lead times				-1
	Less stock				-1
	Reduction of raw material by 15%				3
	Less waste				2
	Reduction in environmental footprint by 10%				3
	More interaction with the end users				2
	Customer driven SC business models based on Intensified Processing.				0

Table 18: Analysis of impacts on the objectives for Business Case 7: Chemical Leasing - TabaChem

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

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A.4. Reuse - Sustainability

A.4.1 Business case 8: Smart Delta Resources (SDR)

A.4.1.1 Description of the firm/industry/sector

The Smart Delta Resource (SDR) platform is an initiative of eleven power companies and raw material-based manufacturers in the Zealand Delta region in the Netherlands. The platform aims to strengthen the competitive power of the local industry. The participating organizations launched a platform to explore the possibilities for exchanging energy and raw materials that are waste for one firm and valuable process inputs for the other. Thus, companies from the chemical, energy, food and steel industry try to define identify so-called "industrial symbiosis" potentials and use these as a basis for the development of concrete business cases. Besides higher overall efficiency and lower material costs, this also helps to realise ecological and social benefits. The platform thus contributes to the transition towards a cyclical or circular economy, for both existing fossil-based and future renewable energy and raw materials based organizations. The aim is to improve competition through: (1) complementary cross-sector innovations in energy and resource efficiencies in the chemical, steel, food and energy industry; (2) through collaboration to realise new opportunities, especially in regard to industrial symbiosis and (3) growth opportunities for local companies outside of SDR. The collaboration contributes to the national targets for sustainable economic development, reduction of greenhouse gases such as CO_2 and reduction of the fossil footprint and is actively supported by the Province of Zeeland and Zeeland Seaports. NV Economische Impuls Zeeland facilitates the platform.

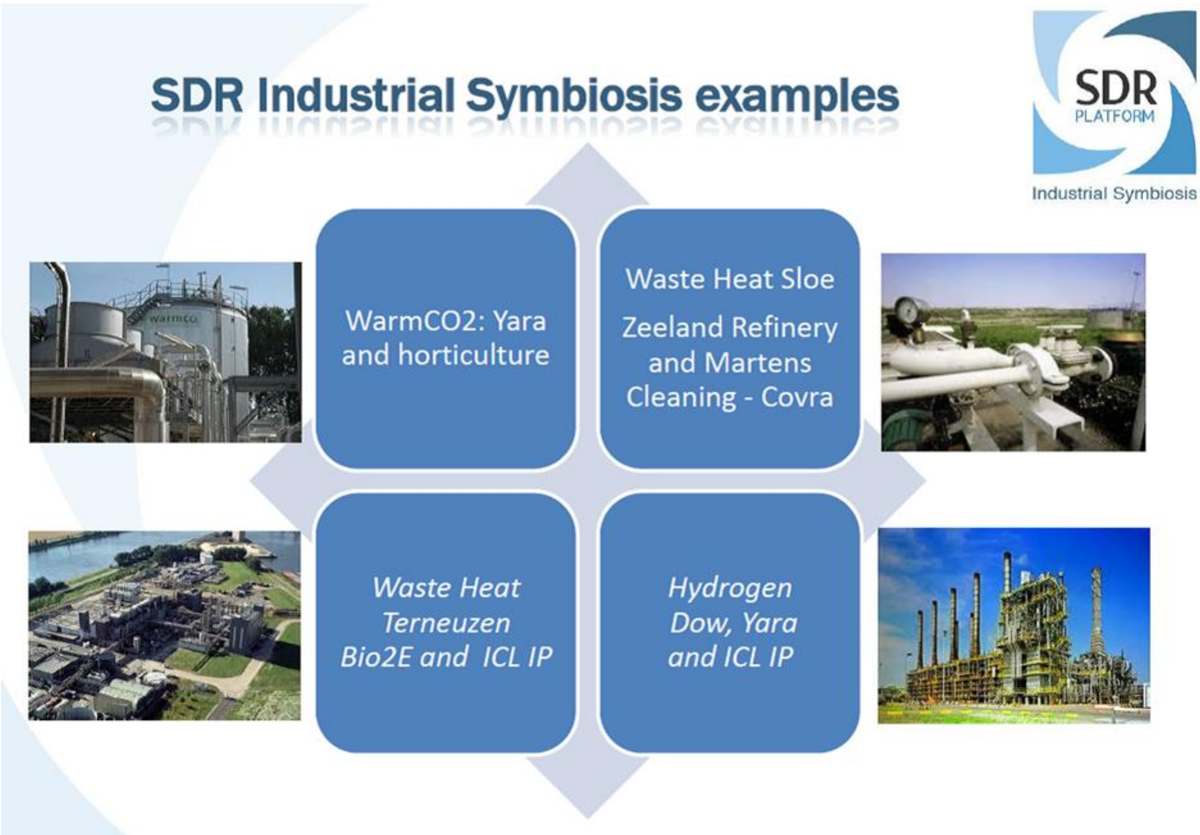

Figure 22: Industrial symbiosis examples within SDR

A.4.1.2 Description of the supply chain

The province of Zeeland provides a strategic location to serve markets within Europe,. The geographical position of Zeeland is central in the European Union with excellent infrastructure and market access. The region is strategically located in the Southwest of the Netherlands, between the important international seaports of Rotterdam and Antwerp. The location of the SDR partners is shown in Figure 15.

Figure 23: SDR's location within Zealand

SDR is an initiative of eleven energy- and feedstock intensive companies, illustrated in Figure 3, that seek to reduce their energy and feedstock throughput through industrial symbiosis. The SDR companies are in the steel, energy, chemical and food industry and work together to create industrial connections and develop new business cases. While the main incentive is economic, it also aims at process sustainability. ECN has researched the feedstock, energy and material flows of the companies in the Delta region, and their research confirms that there are various potentials for the exchange of (residual) materials. Through industrial symbiosis, innovative concepts and plans are created, without the need to necessarily develop new technologies.

For the configuration and implementation of industrial symbiosis systems between the eleven partners, comprehensive changes in the supply chain are necessary. An overview of selected SDR supply chain elements is provided in Table 1.

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Table 19: Overview of selected SDR supply chain elements

Key partners	See above
Key Activities	Different process and manufacturing
Key Resources	Multiple
Value Proposition	A Cluster Initiative Model is favoured because it has been well regarded as one of the most effective approach for regional economic development. Furthermore, the collaboration and the implementation of a facilitator has accomplished successes in many regions that have certain similarities to SDR. The SDR Cluster Initiative is an agglomeration of clusters that are either inter-related and/or supporting/ complementing to the main industry sector(s). Geographically, the SDR is not bounded by geographical/ physical location. Instead, given the very nature of Zeelands geographical condition, the value proposition is very much determined by linkages & critical mass factors that drive competitive advantages.
Customer Relationship	In the platform; Board is formed by participant company CEOs.
channels	Magazine, website, flyers
Customer segments	The implementation of collaboration can help the SDR companies to predict the loyalty, performance, stability, and capacity for growth of suppliers, distributors, and retail partners – identifying vulnerabilities and opportunities to address them. It can help the participating companies answer questions like: Do the suppliers have what it takes to attract other customers, expand production capacity, and achieve economies of scale? Can the retail partners afford to invest in added infrastructure? Where do they need help from external stakeholders – like governments, investors etc.?

Figure 24: SDR partner organizations

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A.4.1.3 Technology required and advanced technologies.

SDR searches for ways to reduce the use of energy and feedstock through industrial symbiosis, in collaboration with the industry. This is done to unify knowledge, optimise subsidies and operate more efficiently. Through this industrial collaboration the involved organizations can also leverage policy advice of the Dutch government and the EU. To do so, new opportunities for the exchange of energy and feedstock are identified, and new business cases are developed and implemented. Symbiotic collaboration opportunities with outside companies are realised and new businesses are attracted to the region.

The main challenge for SDR's industrial symbiosis system is the exchange of information rather than technological gaps. This means that existing processes can either be used as is, or that only minor adjustments are necessary. If the output of one process has to be reprocessed considerably to be suitable as an input for another process, this sometimes leads to difficulties in identifying industrial symbiosis potentials and requires the development of new processes and technologies. Thus, technologies not only comprise new manufacturing equipment but also software solution to facilitate the identification of complementary materials.

A.4.1.4 Changes in the Value/Supply Chain Configurations with the business model.

- **PLAN (R&D, Product Design, Testing, etc.):**
    - Customers input is considered in product design/testing? Based on the individual practices of the participating organizations.
    - Are the products customized at the design stage or standard? Usually they are standard.
    - Does it take too long to design and test (to get the product to the market before competition)? Usually not for most of the participating companies.
    - Is it too costly to design new products? Depending on the products, usually not for most of the participating companies.

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- Is it particularly challenging when the recycled raw materials/parts are used in the product design phase? No, it is part of the underlying concept of industrial symbiosis.

- **Sourcing:**
  - Does the firm procure from a single supplier or multiple suppliers? Multiple firms procure from multiple suppliers in this case.
  - Do they procure from local suppliers (in Europe) or global suppliers (outside Europe)? There are only limited companies outside the SDR area that are participating in the industrial symbiosis operations.
  - How are the inbound transportation costs affected by the business model (e.g., economies of scale in inbound transport when raw materials are brought to the central location in a centralized production model as opposed to decentralized)? In industrial symbiosis systems, the transportation cost tend to be higher while the material costs are lower.
  - Is the procurement cost (of raw materials, parts) a major part of the total cost? Yes, it is for most organization in the SDR.
  - Does it take too long to get the items at the factory? What is the lead time? We don't have an accurate estimation but we assume that they do not take longer than usual and markets are well served.
  - Are there critical materials, that are short of supply or very expensive? No

- **Demand:**
  - Does it create new demand for the same product assortment? No
  - Does the product assortment change, are there new products? or new subassemblies or complementary products that go with it? how is the demand (for the focal product or the others that are related) changing? No
  - cannibalization of demand for existing products in case a new product/service is introduced? Since production costs are assumed to be lower, this is probably not a concern.

- **Manufacturing and Distribution to customer:**
  - Are the manufacturing costs a major part of the total cost? Yes, for most organizations in the cluster.

- Labor cost? machinery? Both labour cost and machinery play a considerable role. Both are likely to go up in the beginning as processes must be adapted and potentially more complex process are required.
- Is the production done locally? The production is mainly taking place in the Dutch Zealand region.
- How long does it take to produce a standard batch? Production times depend on the product and company considered within SDR.
- What are the batch sizes? Is it possible to produce in smaller lots at a low cost to respond to changing customer demand and reduce inventory costs? Batch sizes depend on the product and company considered within SDR.
- Is the manufacturing centralized? Economies of scale? The production mainly takes place within the Ducth Zealand region. Economies of scale vary depending on the product and company considered within SDR.
- Are the customers located close by or far away? Are there significant outbound (from the firm to the customer site) transportation costs? For example, are the customers mostly outside Europe (assuming the firm is in Europe)? Or vice-versa? The location of customers outside the SDR vary, depending on the product and company considered.

- **Pricing:**
  - How does the business model affect the prices? For example, does the firm charge higher prices when PSS model is used, and services are bundled with the product? How does the firm do the life cycle analysis and calculate the prices to offer in this case? Reduction in material costs might create discretionary space to lower prices.
  - When products are customized, does the price increase (as a result of higher willingness to pay)? Yes, customised product are usually more expensive.
  - If certain services are jointly delivered (through collaboration of several supply chain actors), how are the revenues shared? How are the sales figures monitored and audited if such practices are necessary? Not discussed.

- **Waste/Recycling, remanufacturing:**
  - What kind of waste is produced? Less waste is produced and mainly of the sort that cannot be used or reprocessed to become an input for another production process.

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  - How is it managed? Is it collected by the firm itself or is there a sector-wide organization that does the collection of the waste? The output/input material exchange is coordinated bilaterally between the affected SDR organizations.
  - Does the firm recycle or mostly send the waste to the landfills? The recycling rate is particularly high due to the industrial symbiosis element of SDR.
  - Does the business case/model help eliminate part of the waste? or are there added recycling opportunities with the business model? Yes, the industrial symbioses element of SDR allows for new high-value recycling opportunities and reduced waste output.
  - Does the business case help reduce environmental impact (e.g., carbon)? Yes, the industrial symbioses element of SDR allows for new higher value recycling opportunities and reduced waste and emission output, which mitigates the environmental impact of production.
  - If there is a feedback loop (circular economy), are the recycled materials as good (in terms of quality) as the new ones? The feedback loop is on a sub-product stage of the manufacturing, near valueless or even costly waste is transformed into valuable input materials.
  - Is it costly to recycle? Only for waste materials that cannot be used in the industrial symbiosis processes.
  - Does it take long to recycle and have them as raw materials back in production? There is a broad range of different materials involved and some will take longer to process than conventional recycling.
  - Are there uncertainties related to the recycling process (the quality of recycled materials, the quantity of usable material from the recycling process, the quantity of waste that can be collected, etc.)? Yes, in some processes this will be a problem.

- **Collaboration:**
  - Does the business case require any collaboration that were not initially there? Yes, industrial symbiosis offers a lot of potential new material and information exchanges, not considered in classical production systems.
  - How are revenues/costs shared? Yes through the market mechanism, respectively bilateral negotiations between the partners
  - What technology (e.g. ICT) is required for collaboration? New technology might be necessary to reprocess waste materials.

- Trust issues? Through technological lock-ins new dependencies and therefore trust issues could arise.

A.4.1.5 Opportunities & Challenges/Risks

There are considerable opportunities to reduce material cost and waste emission for the involved partners. By repurposing waste, waste leakage out of the system is minimised, additional value creation opportunities are created for the producer that sells the output, and cost saving potentials for the manufacturer that buys the input materials. Even in cases where the output material is made available freely, disposal and recycling costs can be reduced.

The main challenges lie with the lack of information and difficulties with information exchange. Often, both parties are not aware that a waste stream can be transformed into an input material, or how this could be done. This issue is amplified, if the reprocessing technology is not yet available. And even if the awareness of the value potential was created, both parties have to identify each other and coordinate the industrial symbiosis system. Finally, for this system to be viable other factors like logistic costs, waste regulations, and subsidies play an important role.

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A.4.1.6 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing		3		
	Efficient and sustainable distribution		2		
	More flexible		-2		
	Less delocalized		3		
	Competitive advantage via intensified processing		0		
Industry / Company / Region specific objectives	Reduced production costs		1		
	Increased product quality		0		
	Minimized time to market		-2		
	Higher throughput with smaller batches		0		
	Reduced response time to changes in demand		-2		
	Jobs creation		1		
	Limit employment reduction		0		
	Improving working conditions for workers		0		
	Sustainable development promotion		3		
	Increased local business opportunities - SMEs		2		
	Shorter lead times		0		
	Less stock		-1		
	Reduction of raw material by 15%		3		
	Less waste		3		
	Reduction in environmental footprint by 10%		3		
	More interaction with the end users		0		
	Customer driven SC business models based on Intensified Processing.		0		

Table 20: Analysis of impacts on the objectives for Business Case 8: Smart Delta Resources (SDR)

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

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A.4.2 Business case 9: Chemical reusing - TabaChem

A.4.2.1 Description of the case

As specified before, "Take Back Chemicals" (TaBaChem) is a project based around the leasing of chemicals. For this particular case, TabaChem also has an important component in the reuse archetype.

The TaBaChem project aims to develop necessary business models and ecosystems, as well as regulatory and policy framework for their implementation. This is done by generating a chemical leasing and reusing-based business model among different industrial organizations.

A.4.2.2 Description of the supply chain

As described before, to create a reuse environment for the chemical industry, comprehensive adaptions of the provider's supply chain are necessary. This not only comprises more elaborate logistics and the establishment of a comprehensive department focused on the reuse of the chemical components. Changes include, but are not limited to:

- A service organization with staff that realizes the reuse projects at the customers' facilities with associated project management
- A different sales organization specialized on reuse of products
- More comprehensive outbound logistics to get the necessary tools, devices, and materials to the customers' facilities
- Reverse logistics to remove excess and waste materials from the customer's site

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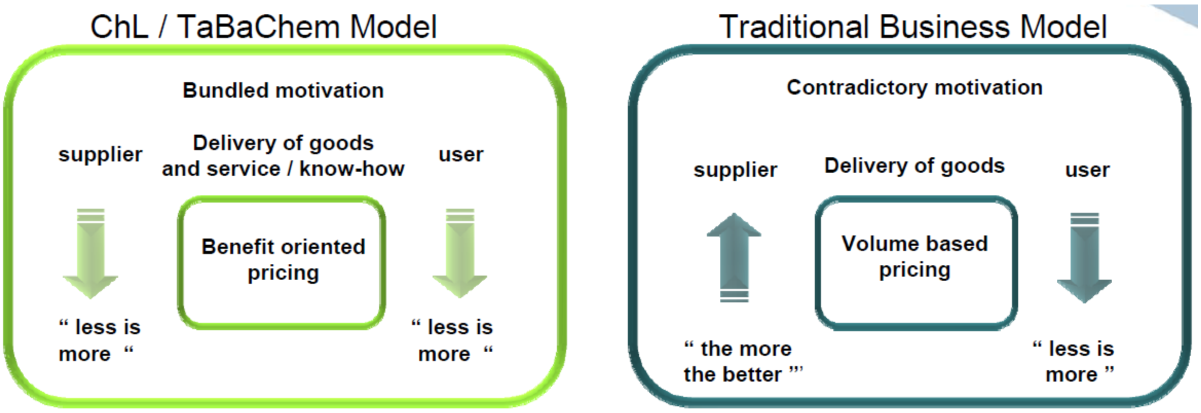

Figure 25: Differences in pricing and motivation

To help industry in Flanders identify the value potentials of chemical leasing PSS, the project team develops a 'Chemical Leasing Scan'.

A.4.2.3 Technology required and advanced technologies

– To help industry in Flanders identify the value potentials of chemical leasing, the project team develops a 'Chemical Leasing Scan'. Most of the identified reuse for chemical leasing do not require the development of new technologies. Rather, the same production technologies can be combined with equipment necessary for the application of the chemicals to deliver the service and technology to recycle or reuse waste and excess chemicals from the service provision. This implies not only considerable initial investments in technological assets but also new capabilities within the company. Not at least retraining of existing and hiring of new staff to acquire the necessary skills to operate the equipment.

A.4.2.4 Changes in the Value/Supply Chain Configurations with the business model:

- **PLAN (R&D, Product Design, Testing, etc.):**
    - Customers input is considered in product design/testing? Not at the moment

- Are the products customized at the design stage or standard? Standard
- Does it take too long to design and test (to get the product to the market before competition)? Concerning the case study, the answer is no. Concerning competitors, such as SMEs in this sector, the answer might be different.
- Is it too costly to design new products? No
- Is it particularly challenging when the recycled raw materials/parts are used in the product design phase? No, it is adding value/avoiding costs

- **Sourcing:**
  - Does the firm procure from a single supplier or multiple suppliers? Multiple ones.
  - Do they procure from local suppliers (in Europe) or global suppliers (outside Europe)? Local
  - How are the inbound transportation costs affected by the business model (e.g., economies of scale in inbound transport when raw materials are brought to the central location in a centralized production model as opposed to decentralized)? The transportation cost will go up while material costs will go down.
  - Is the procurement cost (of raw materials, parts) a major part of the total cost? Yes, it is.
  - Does it take too long to get the items at the factory? What is the lead time? We don't have an accurate estimation but the evidence is that they do not take so long and markets are usually well served.
  - Are there critical materials, that are short of supply or very expensive? No.

- **Demand:**
  - Does it create new demand for the same product assortment? A service might be preferred to a product, in which case it would allow to acquire market share from competitors.
  - Does the product assortment change, are there new products? or new subassemblies or complementary products that go with it? how is the demand (for the focal product or the others that are related) changing? An additional service portfolio is offered.

  - cannibalization of demand for existing products in case a new product/service is introduced? This is not a concern as long as profits are higher for the service system.

- **Manufacturing and Distribution to customer:**
  - Are the manufacturing costs a major part of the total cost? Yes
  - labor cost? machinery? Labour will make for a bigger share of the costs and additional equipment will be needed.
  - is the production done locally? The service delivery is local.
  - how long does it take to produce a standard batch? Not discussed.
  - What are the batch sizes? Is it possible to produce in smaller lots at a low cost to respond to changing customer demand and reduce inventory costs? Not discussed.
  - Is the manufacturing centralized? Economies of scale? The production of the chemicals is not changed in the first instance, while service delivery is localised to the customers' facilities
  - Are the customers located close by or far away? Are there significant outbound (from the firm to the customer site) transportation costs? For example, are the customers mostly outside Europe (assuming the firm is in Europe)? Or vice-versa? The service delivery takes place at the customers' facilities

- **Pricing:**
  - How does the business model affect the prices? For example, does the firm charge higher prices when PSS model is used, and services are bundled with the product? How does the firm do the life cycle analysis and calculate the prices to offer in this case? Since more of the value generation is created by the firm itself, a higher product/service bundle price is expected
  - When products are customized, does the price increase (as a result of higher willingness to pay)? Since more of the value generation is more customised for each customer, a higher product/service bundle price is expected
  - If certain services are jointly delivered (through collaboration of several supply chain actors), how are the revenues shared? How are the sales figures monitored and audited if such practices are necessary? Not discussed.

- **Waste/Recycling, remanufacturing:**
  - What kind of waste is produced? A high rate of recyclable chemicals is desirable, while some mixing of different substances during service delivery might cause waste that is hard to recycle
  - How is it managed? Is it collected by the firm itself or is there a sector-wide organization that does the collection of the waste? The firm itself will handle the reverse logistics as part of the offered service package
  - Does the firm recycle or mostly send the waste to the landfills? A high rate of recyclable chemicals is aimed at, while some mixing of different substances during service delivery might cause waste that is hard to recycle
  - Does the business case/model help eliminate part of the waste? or are there added recycling opportunities with the business model? The PSS sets additional incentives for and provides the necessary access to recycle waste products
  - Does the business case help reduce environmental impact (e.g., carbon)? The PSS sets incentives to employ less chemicals and recycle a greater share of them reducing pollution and resource depletion.
  - If there is a feedback loop (circular economy), are the recycled materials as good (in terms of quality) as the new ones? Depends on the service provided, respectively the employed chemicals.
  - Is it costly to recycle? See above.
  - Does it take long to recycle and have them as raw materials back in production? See above.
  - Are there uncertainties related to the recycling process (the quality of recycled materials, the quantity of usable material from the recycling process, the quantity of waste that can be collected, etc.)? See above.

- **Collaboration:**
  - Does the business case require any collaboration that were not initially there? For example, if the capabilities needed to run the PSS cannot be acquired adequately or additional substances are required, additional partners and suppliers have to be involved.
  - How are revenues/costs shared? Not discussed

- What technology (e.g. ICT) is required for collaboration? Not discussed
- Trust issues? Not discussed

A.4.2.5 Opportunities & Challenges/Risks

The main opportunities of chemical leasing are represented by monetary incentives. Because a greater share of the value creation necessary to provide the respective value proposition of a service is internalized within the PSS provider, higher prices can be achieved. With adequate cost management, higher these prices for services compared to products can be translated into higher profits. A potential for leaner cost management lies in the better control of the configuration and implementation of the value creation activities. Processes that were managed by the customer in the traditional model can be optimized by the provider in the PSS.

- The main risks lie in higher complexity and uncertainty of the PSS compared to the traditional model. Since more of the value chain has to be managed and monitored, a considerable amount of complexity is added. But not only this complexity bears challenges for efficient operations and decision-making, but also that the providers have less experience with PSS than with the current system. This is aggravated by fewer implemented cases in the own and similar industries that could be used for benchmarking.

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A.4.2.6 Impact of business models on the objectives:

		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing		3		
	Efficient and sustainable distribution		2		
	More flexible		-1		
	Less delocalized		3		
	Competitive advantage via intensified processing		1		
Industry / Company / Region specific objectives	Reduced production costs		2		
	Increased product quality		0		
	Minimized time to market		-1		
	Higher throughput with smaller batches		0		
	Reduced response time to changes in demand		-1		
	Jobs creation		1		
	Limit employment reduction		0		
	Improving working conditions for workers		0		
	Sustainable development promotion		3		
	Increased local business opportunities - SMEs		2		
	Shorter lead times		0		
	Less stock		-1		
	Reduction of raw material by 15%		3		
	Less waste		3		
	Reduction in environmental footprint by 10%		3		
	More interaction with the end users		0		
	Customer driven SC business models based on Intensified Processing.		0		

Table 21: Analysis of impacts on the objectives for Business Case 9: Chemical Reusing - TabaChem

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*

Appendix B - Case Description Structure

WP 3 Detailed Business Case Description -- Structure

Please fill in the matrix first (sent as an attachment in the email), which would help write the report for each business case. A particular business case might be related to more than one business model, and therefore please consider all cells in the matrix (i.e., you don't have to focus only one business model, please indicate whichever business model is relevant for a particular objective). Once the matrix is filled in, we all will have a better idea and focus on the right issues. The report is basically to "zoom in" and elaborate more on the issues that emerge from the matrices, in addition to the basic description of the business case and model. While filling in the matrix, you can either give a score (just like we did at the "business case selection process" where we "scored from 1 to 5 different aspects) or a specific number (if a particular objective can be measured and quantified). Please remember that "*one matrix need to be filled in for each business case*". If there are objectives that are not in the excel sheet, please add the rows necessary and in the end we will have the full list in the final reports.

For the word document that we will need from each partner (one document for each business case, of around 5 pages), please consider the following approach although there might be variation as we have very different business cases. The report could be longer of course, but it would be best if they don't exceed 10 pages.

Please include the following in your report (given that it applies to the case):

Description of the firm/industry/sector: here please try to give as much information as possible, relevant to the specific issues addressed by the business model in the case:

- what are the products? How many (variety)?
- which supply chain activities (manufacturing, recycling, raw material sourcing, etc.) are outsourced (mainly outside Europe) in general in this sector and to what extent (mostly outsourced, mostly local?)? This is going to be useful to relate the findings to "delocalization"
- where are the customers located in this industry in general (e.g., 40% in Europe, and the rest outside)
- high-value products or commodities that are cheap?
- more SMEs or big firms? fragmented? concentrated?

- More…

Description of the supply chain:

- Here, first please describe the supply chain activities in as much detail as possible (**PLAN** (R&D, Design, Test, etc.) / **SOURCE** (Local/Global Procurement of raw materials, parts, energy, etc.) / **MANUFACTURE or BUY** / **STORAGE** (inventories) / **MARKETING** (Pricing, Service Definition, etc.) / **DISTRIBUTION and/or SERVICE DELIVERY** / **DEMAND** / **COLLECT;RECYCLE;REUSE; REMANUFACTURE; WASTE MANAGEMENT**). And then, please focus on the specific activities that the particular business model in this case is addressing (basically providing the analysis of what kind of changes this "business model" would bring (or did bring)). It would be quite useful to provide a figure of the supply chains with (after) and without (before) the implementation of the particular business model, if the business model is already implemented. If the case is forward looking, then please elaborate the changes it would bring when these ideas become a reality in the future. In what follows, I have included some sample questions that might help think of what factors might be important. However, these would heavily depend on the specific business case, and therefore this is not a check list of the factors that should be included. Only to facilitate the process.

- **PLAN (R&D, Product Design, Testing, etc.):**
    - Customers input is considered in product design/testing?
    - Are the products customized at the design stage or standard?
    - Does it take too long to design and test (to get the product to the market before competition)?
    - Is it too costly to design new products?
    - Is it particularly challenging when the recycled raw materials/parts are used in the product design phase?
    - *Note: many of these questions are particularly relevant for 3D printing/mass customization*

- **Sourcing:**
    - Does the firm procure from a single supplier or multiple suppliers?
    - Do they procure from local suppliers (in Europe) or global suppliers (outside Europe)?
    - How are the inbound transportation costs affected by the business model (e.g., economies of scale in inbound transport when raw materials are brought to the

central location in a centralized production model as opposed to decentralized)?
  - Is the procurement cost (of raw materials, parts) a major part of the total cost?
  - Does it take too long to get the items at the factory? What is the lead time?
  - Are there critical materials, that are short of supply or very expensive?

- **Demand:**
  - does it create new demand for the same product assortment? either the same people wanting more (improved WTP like in 3D) or opens up new markets for the same product...
  - does the product assortment change, are there new products? or new subassemlies or complementary products that go with it? how is the demand (for the focal product or the others that are related) changing?
  - cannibalization of demand for existing products in case a new product/service is introduced?

- **Manufacturing and Distribution to customer:**
  - Are the manufacturing costs a major part of the total cost?
  - labor cost? machinery?
  - is the production done locally?
  - how long does it take to produce a standard batch?
  - What are the batch sizes? Is it possible to produce in smaller lots at a low cost to respond to changing customer demand and reduce inventory costs?
  - Is the manufacturing centralized? Economies of scale?
  - Are the customers located close by or far away? Are there significant outbound (from the firm to the customer site) transportation costs? For example, are the customers mostly outside Europe (assuming the firm is in Europe)? Or vice-versa?

- **Pricing:**
  - How does the business model affect the prices? For example, does the firm charge higher prices when PSS model is used, and services are bundled with the product? How does the firm do the life cycle analysis and calculate the prices to offer in this case?
  - When products are customized, does the price increase (as a result of higher willingness to pay)?

- If certain services re jointly delivered (through collaboration of several supply chain actors), how are the revenues shared? How are the sales figures monitored and audited if such practices are necessary?

- **Waste/Recycling, remanufacturing:**
  - What kind of waste is produced?
  - How is it managed? Is it collected by the firm itself or is there a sector wide organization that does the collection of the waste?
  - Does the firm recycle or mostly send the waste to the landfills?
  - Does the business case/model help eliminate part of the waste? or are there added recycling opportunities with the business model?
  - Does the business case help reduce environmental impact (e.g., carbon)?
  - If there is a feedback loop (circular economy), are the recycled materials as good (in terms of quality) as the new ones?
  - Is it costly to recycle? What is the cost of this process?
  - Does it take long to recycle and have them as raw materials back in production?
  - Are there uncertainties related to the recycling process (the quality of recycled materials, the quantity of usable material from the recycling process, the quantity of waste that can be collected, etc.)?

- **Collaboration:**
  - Does the business case require any collaboration that were not initially there?
  - How are revenues/costs shared?
  - What technology (e.g. ICT) is required for collaboration?
  - Trust issues?

Challenges and opportunities:

- In the end, please elaborate on the challenges and opportunities discovered (desk research, interview, etc.). It is also important to consider the risks, that might make the business model to look less attractive in the future. This would help us formulate the "scenarios" later in WP 4. This part of the report will be necessary for the proposal of "new" models that might have the potential to address these, in later stages of WP 3.

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Appendix C – Matrix and Scoring

		Archetypes and Business Cases			
		Mass Customization (3D and more)	Reuse	Decentralized and/or modular production	PSS/Servitization
European Zone Objectives	Efficient and sustainable manufacturing				
	Efficient and sustainable distribution				
	More flexible				
	Less delocalized				
	Competitive advantage via intensified processing				
Industry / Company / Region specific objectives	Reduced production costs				
	Increased product quality				
	Minimized time to market				
	Higher throughput with smaller batches				
	Reduced response time to changes in demand				
	Jobs creation				
	Limit employment reduction				
	Improving working conditions for workers				
	Sustainable development promotion				
	Increased local business opportunities - SMEs				
	Shorter lead times				
	Less stock				
	Reduction of raw material by 15%				
	Less waste				
	Reduction in environmental footprint by 10%				
	More interaction with the end users				
	Customer driven SC business models based on Intensified Processing.				

Table 22: Analysis of impacts on the objectives for each business case

**Note: In the table above, the positive numbers indicate an "improvement". The number itself measures how strong the impact is. That is, +1 means low, +2 means moderate, and +3 means high positive impact. Please note that, positive impact does not always mean an increase in the absolute figure. For example, the impact will be "positive" if the "production costs decrease" or "if there are more jobs available". Similarly, negative numbers indicate a "worsening of the situation", with the intensity changing from low to high as you move from -1 to -3. "0" means "neutral", that there is no clear/visible impact.*