European Commission

Business Innovation Observatory

Advanced Manufacturing

Smart Value Chains

Case study 5

Enterprise and Industry

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Advanced Manufacturing

Smart Value Chains

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Authors: Diederik Verzijl, Fabian Nagtegaal, Mark Lengton, Elco Rouwmaat, PwC Netherlands, and Laurent Probst, Erica Monfardini, Laurent Frideres, PwC Luxembourg.

Coordination: Directorate-General for Enterprise and Industry, Directorate B "Sustainable Growth and EU 2020", Unit B3 "Innovation Policy for Growth".

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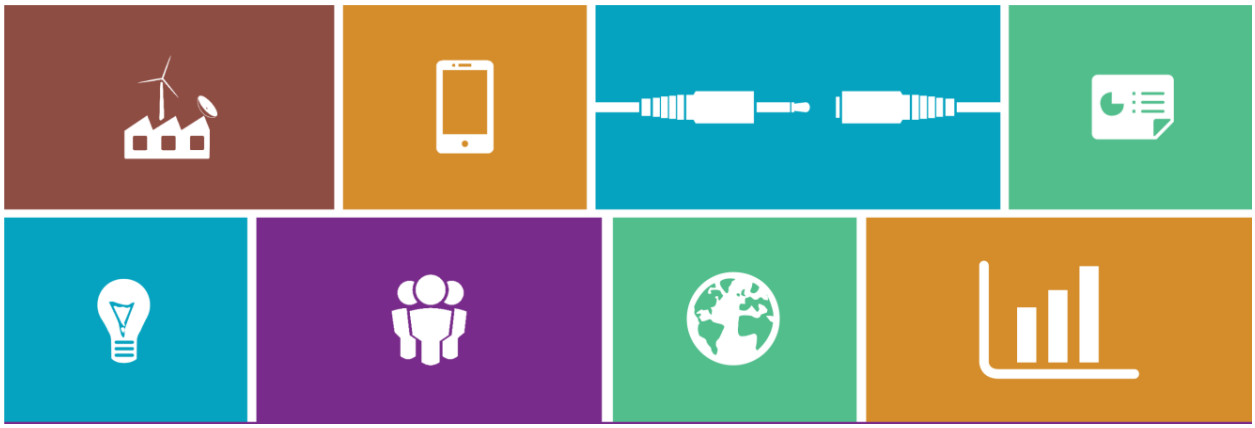


1. Executive summary

Advanced manufacturing has the potential to open up entirely new markets or underpin and enhance existing markets through accelerating technological progress, and can lead to trickle-down effects on productivity and efficiency. One of the latest developments in advanced manufacturing is the rise of smart value chain processes, which are defined as **new processes or new solutions which save at least one step in the value chain**, thereby achieving cost savings, time reduction and provide a better quality of output. Smart value chain manufacturing processes therefore have a direct impact on the competitiveness of European manufacturing companies.

One of the key drivers of the trend is a clear market demand for more flexible, agile and efficient manufacturing processes. By integrating various aspects of the value chain in the smart manufacturing processes, or by providing **innovative solutions that increase flexibility, agility and efficiency**, substantial gains can be made across the value chain. Various markets that are touched by this trend showcase a high growth potential, such as the market for additive manufacturing processes and the market for on-site hydrogen production.

In spite of this, smart value chain solutions face substantial barriers. For instance, in the case of highly conservative sectors, some smart value chain innovations are regarded with a high degree of scepticism by the market. Moreover, companies face barriers in attracting highly skilled human capital, thereby limiting their ability to implement such smart value chain solutions. Furthermore, access to finance is critical in this highly capital intensive industry, especially in the start-up stage of the company or when companies want to upscale their activities. The high amounts of capital, however, can typically only be provided by venture capitalists who may impose restrictions on an innovative company's strategy.

Several success factors were also identified. Companies typically provided **highly innovative solutions that have a clear competitive edge** over their competitors. Moreover, a combination of private funding, bank funding, venture capital funding and public funding provided a good mix of available resources. While some continue to struggle with finding highly skilled and specialised workers, others were able to attract talent by taking on PhD positions in the company or by establishing a name in the field.

Nevertheless, it is critical for companies to overcome the barriers and obstacles listed above. In order to do so, it is recommended that Europe: stimulates entrepreneurs to actively think of the market opportunities and commercealisation of the innovation before developing the innovative technology; stimulates the market uptake of innovative solutions in the sectors through e.g. public procurement; addresses the gap between the (lack of) availability of highly skilled workers and the growing demand for these; simplifies or shortens the administrative processes for public support; and provides access to finance for companies trying to upscale and commercialise their innovation.

If Europe succeeds in addressing the challenges, companies are helped in capitalising on the growing market demand for smart value chain manufacturing processes. This allows Europe to seize the opportunity of transitioning towards an advanced manufacturing sector that incorporates these processes, allowing the continent to maintain its manufacturing's prominence within the European economy.

2. Smart value chain manufacturing technologies and advanced manufacturing

Europe's manufacturing sector is a cornerstone of the continent's economy, as it accounts for more than EUR 6,500 billion of the continent's GDP, EUR 1,500 billion of value added each year, and over 30 million jobs[1]. Manufacturing therefore is of strategic importance for Europe. The European manufacturing sector, however, currently faces an intense and growing competitive pressure in global markets. Other developed economies, such as the U.S., Japan, Korea, but also China and Taiwan, increasingly gain a share of the high-tech manufacturing value chain.[2]

To maintain manufacturing's prominence within the European economy, the continent has to address the challenge of producing more products with less material, less energy and less waste. A wide array of resources will become scarce in the next 50 years or so[3], which implies the need for more efficient manufacturing processes. In addition, there is increasingly more customer demand for more flexible, dynamic rapid manufacturing solutions.

In order to do address these challenges, Europe is undergoing a transformation, away from traditional production systems to systems that adopt an advanced manufacturing approach. This advanced manufacturing approach aims to better apply high-tech production systems and associated services, processes, plants and equipment, including automation, robotics and measurement systems.[4] Advanced manufacturing enables a more rapid, more cost efficient and more resource efficient production process, while retaining or even improving operating precision[5].

Advanced manufacturing has the potential to open up entirely new markets or underpin and enhance existing markets. The High-Level Expert Group on Key Enabling Technologies (HLG KETs) expects this to occur through accelerating technological progress with trickle-down effects on productivity and concurrent leaps in efficiency levels.[6]

Should such an approach be integrated into the continent's manufacturing make-up, Europe would expect to:

- **be well-positioned to compete globally**, as Europe would be able to counter the US's resurgent manufacturing sector, and the shift of historically European value chains to the Far East[7];
- **be more environmentally friendly and energy efficient**, as Europe would be better equipped to manufacture more products with less material, energy and waste; and
- **be able to negate the pull factor that resources have on the location of manufacturing**.[8]

On this basis, Europe must seize the opportunity of transitioning towards an advanced manufacturing sector that incorporates smart value chain processes. Smart value chain processes are defined as new processes or new solutions which save at least one step in the value chain, generate cost savings, time reduction and provide a better quality output. Smart value chain manufacturing processes therefore have a direct impact on the competitiveness of European manufacturing companies.

European initiatives have spurred that take action to provide the necessary framework conditions within which advanced manufacturing technologies may be developed. This is exemplified by the European Commission's Task Force for Advanced Manufacturing Technologies for Clean Production. In the Industrial Policy Communication update of October 2012, a clear and ambitious target was set: to reverse the declining role of Europe's industry from its current level of around 16 percent of GDP to as much as 20 percent by 2020. To achieve this target the European Commission will engage in a partnership with the Member States and industry to considerably step up efforts to boost the market uptake of European advanced manufacturing technologies and give Europe a competitive lead in the new industrial revolution.[9]

In order to identify how existing framework conditions for supporting the advanced manufacturing trend of smart value chain processes may be improved, this case study will analyse the socio-economic relevance and use company cases to demonstrate the trend's market potential. Furthermore, this study will elaborate on the barriers obstructing the uptake of smart value chain processes in advanced manufacturing. By being able to address these difficulties, they will likely be well-positioned to develop competitive advantages within their industry or market, increasing their access to new clients, and, in some cases, increasing their margins through improved cost-effectiveness.

3. Socio-economic relevance

Advanced Manufacturing technologies have great market potential. Increasingly more companies decide to invest in new manufacturing processes. Innovative solutions, such as additive manufacturing, allow for clear benefits for both customers and producers. The companies analysed in this case study generally showcase awareness for this growing market segment.

3.1. The market potential of the trend

The advanced manufacturing market is rapidly changing. While in the semiconductor industry we see increasingly more buzz on the next manufacturing technology, i.e. 450mm production, we also see radical changes in other high-tech manufacturing markets. Recent research suggests that the market is moving towards an increasingly automated world that will continue to rely less on labour-intensive mechanical processes and more on sophisticated information-technology-intensive processes. This trend is likely to accelerate as advances in manufacturing are implemented.[10]

Energy and resource efficiency is also expected to strongly influence advanced manufacturing processes, as companies aim to integrate sustainable manufacturing solutions in their businesses. Not only do these solutions reduce the impact on the environment, they also lead to cost reductions, decrease supply-chain risks and provides new market opportunities in the green sector.[11]

One of the markets with high potential in advanced manufacturing processes is the market for additive manufacturing. Additive manufacturing is the direct fabrication of end-use products and components employing technologies that deposit material layer-by-layer, or depending on the technology even pixel-by-pixel. It enables the manufacture of geometrically complex, low to medium volume production components in a range of materials, with little, if any, fixed tooling or manual intervention beyond the initial product design[12].

The additive manufacturing market has showcased stunning numbers. The global market for it grew by 29.4 percent in 2011 alone, comprising a 1.7 billion USD global market.[13]

As a manufacturing technology, additive manufacturing enables a number of value chain configurations, such as personalised component part manufacture but also economic low volume production within high cost base economies. This innovative approach to manufacturing is now being embraced globally across industry sectors from high value aerospace and automotive manufacture to the creative and digital industries.

One of the main application areas of additive manufacturing is rapid tooling. Rapid tooling allows users to develop prototype castings for testing a design, faster delivery of production castings, and low-volume production of items.[14] Moreover, additive manufacturing allows for a high degree of customisability and flexibility with its high precision process that is quick to ramp up. Thus, even in industries where additive manufacturing cannot compete to produce final parts due to economies of scale, it can still provide moulds and tools. Additive techniques are a growing part of the jewellery and hearing aid industry, which is also evidenced by the success EnvisionTEC has had in these markets.

Against this conceptual backdrop, and as a result of the lack of transversal market data, this section of the case-study has drawn on data collected from the interviews. This data presents and details the market potential of the trend, i.e. the ability of companies to differentiate and redefine their strategy to leverage on market opportunities; and the socio-economic impact that smart value chain technologies may have at the industry-level, e.g. the reshaping of some key industries. A summary of the companies incorporated in this case study is provided in Table 1.

Table 1: Overview of the company cases referred to in this case study

Company	Location	Business innovation	Success signals
Claro Precision Engineering Ltd.	UK	Precision machined engineering	Was awarded “UKs Best Supply Chain Partner” at the MWP Awards 2012 and “UKs Best Sub Contractor” at Assembly & Finishing in both 2008 and 2010.
EnvisionTEC	DE/US	Additive manufacturing technology and process	EnvisionTEC enjoys more than 60% of the world market in the production of Hearing Aids as well as more than 50% of production in the Jewellery market. Their production technology is used by globally leading companies and has set the standard in the industry

Company	Location	Business innovation	Success signals
HyGear	NL	On-site miniaturised Hydrogen production facility	Mercedes-Benz awarded HyGear with the BlueEFFICIENCY Award (2012), nominated for Cleantech Star Award 2012.
Nanovia Ltd.	CZ	Industrial scale production of nanofibrous material	Nanovia Ltd is the first company in the Czech Republic and practically even the first one in Europe having the capacity for industrial production of nanofibrous material.
Peratech Ltd.	UK	Manufacture of radical new nanomaterial	The company has won many awards for its innovative business, including MADIRA: International Business of the Year 2012/13, the 2012 BVCA Regional Management Team of the Year Award, the 2012 Technology Strategy Board SMART Award, the Queen's Award for Innovation 2012, the 2011 Printed Electronics Award (Best Commercialisation), the 2011 British Engineering Excellence Award, the 2011 Growing Business Award, the 2011 Elektra Award (Finalist) and the Sensors Expo Detroit 2004 award.
RP2	NL	Additive manufacturing process	Business expansion, acquisition activities, client portfolio (including global firms such as Atos Worldline, Grolsch and Friesland Foods).

As demonstrated in Table 1, the analysed companies operate in various fields. It is therefore difficult to estimate the market potential for the trend as a whole, as a large part of the manufacturing value chain is affected. To get a feeling with the markets the selected companies have successfully entered, however, some of the underlying markets were considered in more detail.

HyGear operates in the hydrogen generation market by providing a solution that can be used on-site. The global hydrogen (on-purpose) generation market is expected to grow strongly in the coming years. Recent market estimated indicated that the hydrogen generation market will grow from an estimated 87.5 billion USD in 2011 to 118 billion USD by 2016; a CAGR of 6.2% during the same period. During the period, main growth drivers will be introduction of regulatory norms instructing lower sulphur level in petroleum products, decreasing crude oil quality, and search of cleaner fuel options.[15] Coupled with a demand for more flexible generation solutions, HyGear's innovation has high potential in a fast growing market.

EnvisionTEC provides a remarkable example of the market potential for the potential of the additive manufacturing market. Starting up only in 1998, they acknowledged the demand for this type of manufacturing. They developed a workable solution by 2001, acquired another company in 2002 and were shipping their machines at a healthy profit by 2003. Today, EnvisionTEC technology produces 60% of the world market hearing aids as well as 50% of the jewellery market.[16] They currently employ over 100 people, have production sites in Germany and the United States (California), and continue to grow at a strong 25% per year.

"EnvisionTec currently employs over 100 people and we continue to grow a strong 25% per year."
– EnvisionTEC

3.2. New technology and customer demand drive innovative solutions

The six companies we interviewed for this case study have used a variety of advanced manufacturing technologies that seek to optimise the value chain, reduce costs of production, increase production speed and agility, or react on a clear demand. Further detail regarding each company, and its innovative solution for each problem, is provided below.

Problem 1 – New materials and product innovations require innovation in manufacturing processes to allow industrial scale production

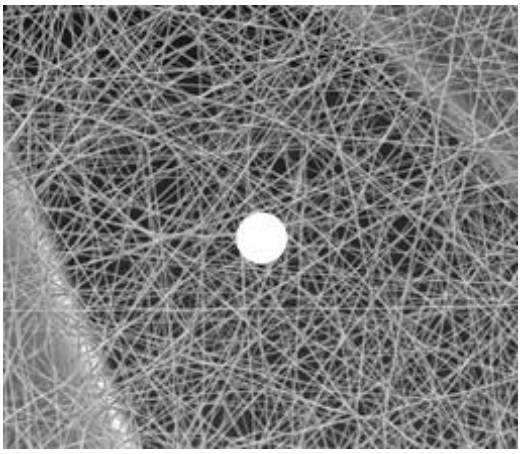
Innovative solution 1 – Peratech Limited was established in 1996 to exploit QTC™ Materials. Peratech's early years were spent investigating the repeatable manufacture of QTC™ Materials and categorising and quantifying their performance. This subsequently resulted in the filing of a number of worldwide patents for QTC™ Materials and the advanced manufacturing process needed. The revolutionary properties of the material as well as their revolutionary manufacturing process to print it as an ink, allows for a widespread of applications, including printing passive electronics. This simplifies the production of passive electronics greatly, improving speed, flexibility and reducing costs and waste.

Inside the integrated Clean Room of Peratech Ltd.

Source: Peratech Ltd.[17]

Innovative solution 2 – Nanovia Ltd, a Czech company, was founded to commercialise the research results of the Research and Development centre Nanotex. This centre is supported by the company Česká včela Ltd with the objective to develop and manufacture materials with the content of nanofibers intended to manufacture products with specific qualities. Nanovia Ltd is the first company in the Czech Republic and practically even the first one in Europe having the capacity for industrial production of nanofibrous material. They currently manufacture fabrics using the nanofibrous material. The products are launched to the market under their own brand names as Nanovia AntiAllergy fabric, Nanovia Antimicrobial fabric, Nanovia Waterproof fabric, and filtration materials Nanovia.

The size of the smallest allergen in contrast to the nanofibrous layer

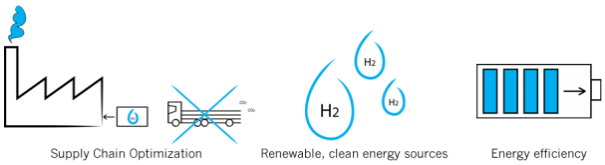


Source: Nanovia Ltd.[18]

Problem 2 – There is a need for more agile manufacturing facilities.

Innovative solution 3 – HyGear is a clean tech company, specialised in the downscaling of chemical processes. These miniaturised gas processing systems can be installed at the end users' sites, with which extensive inefficient supply chains become obsolete and local gaseous waste streams can be turned into valuable products. Not only does HyGear's solution reduce environmental impact, it also effectively optimises the value chain by eliminating the need to transport hydrogen from centralised production facilities to the end users' sites.

Supply chain optimisation by using HyGear's Hydrogen Generation Systems.



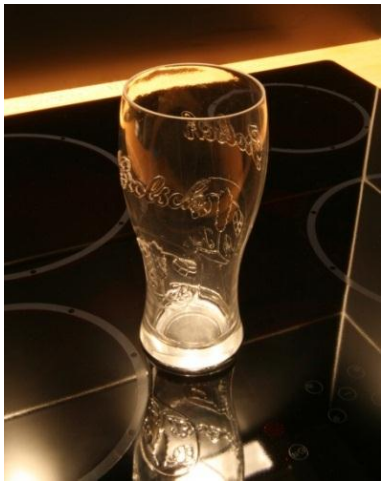
Source: HyGear

Problem 3 – There is a demand for more efficient, rapid, scalable and customisable manufacturing facilities.

Innovative solution 4 – RP2, a Dutch company founded in 1998, is a manufacturing company that has commercialised an Additive Manufacturing solution. Additive Manufacturing (AM) is the direct fabrication of end-use products and components employing technologies that deposit material layer-by-layer. Their manufacturing solution offers many clear-cut benefits to their customers, which include:

- Shorter "Time-to-Market" for new developed products;
- Identification of design errors and implementation of necessary or desired changes can be done in an early phase of the development process;
- Rapid Prototyping models are available in different materials, including rubber-like materials;
- Produce models with high accuracy and fine feature details;
- The models are also suitable to be used as master patterns vacuum casting.

A prototype glass produced for GrolschTM



Source: RP2[19]

Innovative solution 5 – EnvisionTEC is an innovative manufacturing company that has its corporate headquarters in Marl, Germany. Under the guidance of Mr. Siblani, Chairman of the Board, EnvisionTEC has become a world leader in Rapid Prototyping and Manufacturing equipment. Using a team of in-house experts in optical, mechanical, and electrical engineering, EnvisionTEC has been highly successful in producing the most reliable Rapid Prototyping system in the world using its core based technology of selective light modulation which is currently being utilised in its DLP® based systems. The simplicity of the technology has made the system very popular in Rapid Manufacturing markets such as the Hearing Aid market where EnvisionTEC enjoys more than 60% of the world market as well as more than 50% of the Jewellery market in the number of units produced on its Perfactory® system.

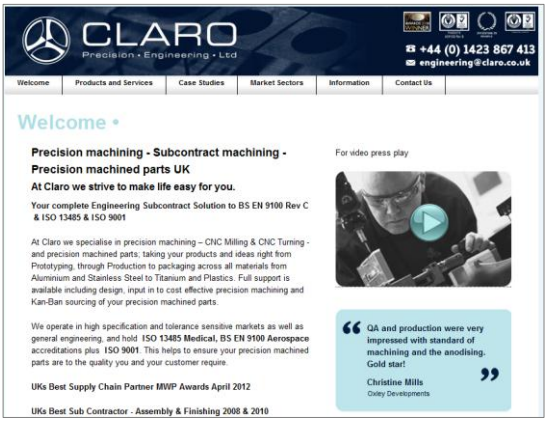
A rapid prototyping machine designed by EnvisionTEC

Source: EnvisionTEC[20]

Problem 4 – There is a demand for an integrated approach to manufacturing

Innovative solution 6 - Claro Precision Engineering Ltd., a UK-based company, specialises in precision machined parts, taking them from prototyping to production based on the customer's request and for all types of materials (aluminium, stainless steel, plastic, etc.). They also integrate surface treatment in the manufacturing process, providing a full service solution to their customer base. Their manufacturing solutions simplify the process for their customers, and applications such as lasers and audio equipment have greatly benefitted from the integrated approach.

Claro Precision Engineering's value proposition



Source: Claro Precision Engineering[21]

3.3. The creation of new markets and jobs

The application of smart manufacturing technologies in advanced manufacturing has a two-fold impact on the competitiveness of companies and industries. First, advanced manufacturing processes allow innovative companies to differentiate themselves from their competitors. Furthermore, these technologies are contributing to the carving out of new market segments, creating new jobs (based on complementary sets of expertise and competences) and fostering economic growth.

- The smart manufacturing technologies in this study can improve the competitiveness of advanced manufacturing companies by:
- Improving the cost-efficiency of manufacturing processes and procedures;
- Reducing time-to-market of products by introducing rapid prototyping processes;
- Optimising the value chain by integrating other parts in the manufacturing process;
- Allowing for greater production flexibility and greater customisability of end-products;
- Facilitating the production of highly advanced end-products and new materials, specifically in the domain of nanotechnologies.

Yet the extent to which companies can capitalise on this potential impact is largely determined by the availability of the technology itself, the capacity of the market to absorb the new technology or product, and the business environment. This sub-section of the case study tackles the potential impact of such smart manufacturing technologies, both in terms of their transversal impact in advanced manufacturing in general, but also their specific impact on the companies reviewed within this case study.

The use of smart manufacturing technologies may lead to three potential economic impacts, namely the:

- **Creation of new market niches** by leveraging on advanced manufacturing technologies and using unique selling points to differentiate from the competition and reshape market structures.
- **Improvement of existing products** by optimising manufacturing processes that allow for better precision or the use of better materials in the manufacturing process
- **Creation of jobs and the combining of competencies** resulting in technologies leading to new market opportunities and products that are expected to have a positive impact on job creation and often call for the innovative combination of expertise in order to develop further.

Therefore it is difficult to attribute the economic impact of smart manufacturing to a specific factor, as their economic impact will largely depend on the nature of the technology and the industry(ies) in which the technology may be applied. Nonetheless, it may be assumed that the economic impact of smart manufacturing technologies will be significant as it can lead to the development of new market niches, increasing demand for highly-skilled labour, and the manufacturing of new products. EnvisionTEC illustrates this multidimensional impact by developing a highly advanced additive manufacturing process which currently serves over 60% of the global hearing aid market and over 50% of the jewellery market.

3.4. Realising competitive advantages through smart value chain manufacturing

The extent to which the innovative solutions of the six companies may be deemed successes is determined by the following five criteria:

- Resource efficiency, i.e. the degree to which the solution saves on e.g. materials, effectively reducing cost of production;
- Time efficiency, i.e. the degree to which the manufacturing solution saves time not only on production, but also on e.g. transportation by eliminating steps in the value chain;
- Customisability, i.e. the degree to which the manufacturing solution allows for customisation of the product that is being produced;
- Agility, i.e. the degree to which the solution can respond quickly to customer needs and market changes;
- Economic viability, i.e. the cost effectiveness of the manufacturing process, including the cost effectiveness of the end product that is provided.

Resource efficient manufacturing processes can especially be found in the cases of **RP2** and **EnvisionTEC**. Both companies have successfully developed an additive manufacturing process. As the additive manufacturing processes build up the products layer by layer, less waste material is produced in the process. In addition, they yield highly accurate models with outstanding functional properties.

Most of the analysed solutions showcase an increase in time efficiency. The different additive manufacturing solutions in place at **RP2** and **EnvisionTEC** both allow for rapid prototyping. This process has enabled them to quickly respond to their customer's needs and reduce time-to-market for many of their clients. **HyGear** is an example of how an innovative solution can save time by optimising the value chain. HyGear's solution allows for on-site production of hydrogen, which saves factories the logistics of transporting hydrogen from centralised production facilities.

Customisability is a key point in the advanced manufacturing processes and it is hardly surprising that it is demonstrated in most of the solutions. While it is clear that the additive manufacturing processes are highly customisable, the manufacturing process of **Peratech Ltd**. is a remarkable example. Their proprietary new **QTC™ Materials** is so sensitive to production that its properties change with the specific manufacturing process that is being used. This has not only forced Peratech to develop their own manufacturing process, but also to allow the process to be fully customisable in production to allow for different properties in the end product.

Nanovia Ltd.'s manufacturing process approaches customisability from a different perspective. The nanofibrous materials they produce require completely new manufacturing processes, which Nanovia Ltd. successfully developed. As nanofibrous materials gain popularity over time and as Nanovia Ltd. practically has the only factory in Europe that is able to produce these at an industrial scale, they are expecting a tremendous market uptake in the coming years.

To give examples, the company expects that custom manufacturing of filtration is expected to grow by about 30-50% per year in Europe and the United States, that sales of their proprietary products using nanofibres has the potential to grow 50-70% per year, and that sales of their proprietary products in the medical sector have a potential growth rate of 20-40% per year. Moreover, as time progresses, Nanovia Ltd. expects new applications in other areas, such as functional membranes in clothing, increasing the potential of their market even more.

Agility is clearly demonstrated by **HyGear's** innovative Hydrogen Manufacturing Systems. Their solution not only allows for on-site production of hydrogen, which can already be deemed as highly agile. Their manufacturing process is also quick to start-up, allowing more flexibility in hydrogen production and effectively eliminating the need for on-site hydrogen storage.

Economic viability is demonstrated across the innovations as most of the analysed solutions report substantial cost reductions. For example, **HyGear's** manufacturing solution has the potential to reduce the costs of hydrogen for a company by an incredible 70%. Furthermore, **Claro Precision Engineering Ltd**.'s integrated approach simplifies the manufacturing process for their clients, which are also translated into efficiency gains for the clients.

The success of these innovations from a client perspective is also demonstrated by the visibility of the firm's solutions, their client portfolios and their market size. EnvisionTEC's exemplary growth in market share underlines this. The simplicity of the technology has made their system very popular in Rapid Manufacturing markets and as a result **EnvisionTEC** enjoys more than 60% of the world market in Hearing Aids as well as more than 50% of the Jewellery market in the number of units produced. Their solution is trusted by top clients, such as Disney, Cartier, Ford, P&G and Kraft Foods. Similarly, **RP2** has successfully helped top global clients like Grolsch to quickly produce prototypes.

Finally, many solutions have received prestigious awards, such as in the case of **Claro Precision Engineering Ltd.** who was awarded "UKs Best Supply Chain Partner" at the MWP Awards 2012 and "UKs Best Sub Contractor" at Assembly & Finishing in both 2008 and 2010.

3.5. Client perspectives and challenges related to the uptake of smart value chain Manufacturing

Various drivers and obstacles can be identified that are relevant to the market uptake of smart manufacturing. What truly defines the innovative companies included in this case, however, is the clear market demand they addressed. Whereas the uptake of eco-friendly technologies was deemed to rely on market pull from regulations, **successful uptake of smart value chain manufacturing is mostly driven by market demand**. Founders of the companies in most cases (e.g. **EnvisionTEC, RP2, HyGear**) capitalised on a market demand already when starting up the respective companies. Their impressive growth also underlines the high potential of the underlying markets.

Another interesting aspect of the market uptake of the innovations is that some of the companies indicated that it was **relatively straight forward to market the innovations from a marketing perspective**. As there was a demand for the solution and as their solution provided clear benefits over their competitors, the companies were often directly engaged by clients themselves. This, of course, is highly related to the fact that their founders capitalised on a clear market demand. Moreover, their innovations are typically so technically advanced, that they offer clear benefits over alternative solutions from competitors (if any).

Nevertheless, the innovative solutions that are developed were considered to be potentially **disruptive to the value chain.** Similar to the environmentally friendly manufacturing processes, some of the analysed companies were regarded with a high degree of scepticism by the market. **HyGear** still has to deal with a highly conservative industry, which is why they found that it works better to act on the companies that approach them instead of approaching established players in the industry to proof their technology. This allows them to focus on the clients' needs instead of convincing them that the technology works. By implementing the process successfully at these clients they could establish a proof of concept that showed the industry that their innovation works and is trusted by other established players in the industry.

While it took some time at first, HyGear has gained significant exposure and finds that increasingly more established players approach them. Moreover, as they are already well established among the early adopters, the industry is starting to accept their innovation.

The uptake of smart value chain manufacturing requires companies to attract highly skilled human capital. The growth in required staffing can especially explosive once the company starts to upscale its activities Attracting highly skilled human capital, however, is still a point some of the companies struggle with in Europe. The pool of graduate engineers continues to shrink in Europe and it is increasingly more difficult for companies to overcome this lack of availability. Their inability to hire qualified workers hinders their ability to scale up, and as result hinders their growth. Most of the analysed companies therefore took a very pro-active approach to tackle this barrier. **Peratech Ltd**. found a solution in involving PhD students in the company. Their research contributes to the continuous development of the processes and they get trained on the job at the same time. By the time they graduate, they typically stay within the company and have already received the necessary training.

4. Drivers and obstacles

This chapter explores in detail the factors that serve as drivers or obstacles to companies developing smart value chain manufacturing technologies in advanced manufacturing. Among the different needs discussed with companies for the present case studies, a demand driven approach was regarded as key for successful commercialisation and subsequently business growth. Access to a talented and a highly skilled labour force as well as having innovative technology in place that edges out competitors is also considered as a key enabling factor.

4.1. Access to finance is critical for company growth

As has been detailed in Section 3.5, having access to finance is critical for companies trying to capitalise on the market uptake of this trend. Several types of funds used to support the analysed innovations can be identified. Interestingly, the analysed companies suggest that funding was hardly an issue that blocked the progression of the innovation. While capital requirements can pose a barrier in the start-up of the companies, none of them faced particular difficulties in raising funds.

In most cases, the innovations were supported purely by private funds coming from own savings and company's own funds. **EnvisionTEC's** founder invested (part of) his earnings from a previous company in the development of the new manufacturing solution. **RP2's** founder even used earnings on his house and invested these in the company. With this start-up capital, both companies developed a business and used retained earnings for further investments.

In some cases, we also identified the use of Venture Capital (VC) or bank loans. **Peratech Ltd**. had to rely on external funding for the development of their innovation. In total they attracted VC of around 2.5 million GPB. Nevertheless, VC was noted to have some significant drawbacks for the development of the business. VC can be rather restrictive for firms as Venture Capital Funds typically have strong expectations of pay off in the short term, i.e. within 3 years. As innovations typically take longer to develop to fully mature products, there may be conflicting interests. Moreover, every equity investment dilutes ownership of the company, making it less attractive.

"Venture capital dilutes ownership of the company and restricts freedom compared to other forms of capital, but is a very helpful instrument." ***– Peratech Ltd.***

To overcome this, one possibility was to look for funding from pension funds. However, this funding source has, in light of the economic crisis, dried up. As a result, VC funding is often the only alternative companies have. Despite the drawbacks, companies did mention VC funding to be of great help in funding the innovation process. By convincing VC funds of the potential long term benefits, part of the drawbacks can also be mitigated. Nevertheless, they also indicated it would be helpful if VC's would approach the innovations more like engineers, not like bankers, to better understand the innovation process.

Claro Precision Engineering Ltd. used a different alternative to VC funding: bank loans. Apart from private funds, taken from e.g. mortgages on their houses, the company attracted bank capital to further develop the business. Bank funding was regarded as an easier alternative to VC funding as banks generally impose fewer requirements. As long as the bank is satisfied with the payback, companies are relatively free in their operations. The amount of funds raised through this channel, however, is typically lower, meaning that companies with a high capital requirement still need to turn to VC funding.

HyGear also presented an interesting case, as they used a combination of funding that has enabled them to expand their business with relatively few restrictions. In the early days of the company, HyGear used a combination of public funding and selling consulting services to finance the development of the innovation. The people that were involved at the time were all very knowledgeable of the industry. By leveraging their expertise, they advised clients on a fee basis. The income that was generated from this combined with the available public funding allowed HyGear to further develop the company.

HyGear used a combination of funding that has enabled them expand their business with relatively few restrictions

Once they moved from prototype to industrialisation, another two critical financing events can be observed. In 2005, when the product was taken to the market, a regional Venture Capital company, PPM Oost, provided the necessary funding. In 2009, when the next step in the industrialisation took place, Abengoa took a significant stake in the company. As Abengoa is an established multinational company and as they also conducted research in the same field, not only did they provide the necessary capital for further industrialisation, they also handed research projects to HyGear that eventually brought the innovation further.

4.2. Demand driven approach enables quick results

One of the patterns that clearly emerges across the analysed companies is that they provide an innovative solution to a clear market demand. This has turned out to be a crucial factor for most of the companies analysed in this case study. Specifically, it has allowed them to capitalise on their innovation in a relatively short timeframe.

EnvisionTEC was founded in 1998 on the basis of a clear market demand. The founder of the company signalled sold services and materials for companies that would turn out to be his direct competitors today. Being immersed in the industry allowed him to identify the flaws of the current additive manufacturing solutions and also to identify the market needs of customers. This is why in 1998 he started up EnvisionTEC and worked on developing a proprietary additive manufacturing process. Already in 2001 they had a working prototype and in 2002 they acquired a company that was working on a similar solution. By 2003, the first machines were sold with a profit and ever since, the company went from selling three machines per month to approximately 60 per month now.

While they were very aware of the market demand, they specifically targeted niche markets in which there would be a high demand for the solution. By entering these niche markets, they were able to quickly establish market leadership in these segments. The term niche markets, however, should not be confused with small markets. These markets have allowed EnvisionTEC to both diversify their portfolio and to grow from a single employee to over 100 in only 15 years, and they continue to grow a healthy 25% per year.

"By offering a superior solution to the market in specific niche segments, we were able to grow quickly and establish market leadership in segments such as the global hearing aids market."
– EnvisionTec

In the case of **RP2**, the company was also founded on the basis of an observed market demand for the manufacturing solution. The founder worked at a company that sold software for CAD/CAM and 3d-printing devices. He noticed, however, that at the time (1999), additive manufacturing solutions were too expensive for most potential clients. Yet there was a clear demand from these customers to benefit from additive manufacturing processes. On the basis of this, **RP2** was founded to provide such a solution to customers without requiring them to actually purchase the manufacturing facilities themselves. The clear demand for the innovation allowed **RP2** to gradually expand over time and enter the market with relative ease.

"Our unique manufacturing process allows us to manufacture at a very high quality without sacrificing speed. This was unprecedented at the time, which is why companies came to us to learn more about this." ***– EnvisionTEC***

From a material point of view, **Peratech Ltd**.'s manufacturing process addresses a clear need for advanced manufacturing. At Peratech Ltd., a revolutionary new material, **QTC™ Materials**, was developed. Manufacturing processes at the time were unsuitable for the production of the new material. The material was so sensitive that its properties change with different production methods and configurations. A proprietary manufacturing solution had to be developed that not only allowed for consistent production, but was also flexible and adaptable enough to manufacture the QTC™ Materials to the required specifications. Moreover, due to a high application area for QTC™ Materials as a printable ink, Peratech Ltd. is currently working with The Centre for Process Innovation (CPI) to develop new formulations for its award-winning QTC™ materials[22]. In addition, due to the novelty of the material, customers usually came to Peratech Ltd. instead of the other way around.

Similarly, **Nanovia Ltd.** had to develop a complete manufacturing process to produce nanofibrous material at industrial scale. The result is that they currently have the technology that enables them to produce this material at an industrial scale. Their factory is practically the only factory in Europe that allows for this scale and the key thing that hinders the current uptake is the relative lack of commercial applications currently available of nanofibrous materials.

4.3. Innovative technology "sells" itself

One of the key points discussed in the commercialisation of innovations is how the solutions can be diffused to the market. Sometimes market scepticism can lead to a slow uptake of innovative technologies as the market still needs to be convinced of the benefits the new technology can bring them. We have also established this in our case study on environmentally friendly manufacturing processes.

In the case of the analysed smart manufacturing processes, we found quite the opposite. Companies noted that it was relatively easy to gain market share or internationalise at the beginning. The innovative solutions set them apart from competitors in such a way, that large customers found the companies themselves.

EnvisionTEC provides a good example of this. Their unique manufacturing process allows them to manufacture at a very high quality without sacrificing speed. By comparison, in the early days they delivered quality that competitors could deliver in 3 days in roughly 8 hours. Moreover, their innovative manufacturing solution was highly adaptable and was able to use material solutions that improved the quality of the end product even more. As a result, their technology quickly became the buzz word in town and it was not long before they started shipping their first units at a profit. A mere 9 years later, EnvisionTEC's additive manufacturing technology dominates the global jewellery and hearing aids production market.

Similarly, **RP2** did not need to undertake strong marketing activities to gain clients. While they attend technical fairs approximately twice per year, global firms, such as Grolsch and Atos Worldline, found RP2 by themselves as they valued the solution RP2 could offer them. This has allowed the company to grow at a steady pace.

This does not only hold for the additive manufacturing processes. **Claro Precision Engineering Ltd**. experienced that internationalisation actually turned out to be a rather organic process. On the one hand, clients tend to find the company through Google and through expeditions they attend in the United Kingdom. This is where their solution turned out to be key, as this sparked the interest of potential customers. On the other hand, Claro Precision Engineering Ltd. benefitted from international Merger & Acquisition activities. For instance, they had multiple cases where companies from e.g. the United States would acquire one of their UK-based clients. This opened up opportunities for the company in other geographical areas by introducing their value proposition to new potential clients. Currently, Claro Precision Engineering Ltd. supplies companies particularly in the United Kingdom, United States and Australia.

Finally, **Peratech Ltd**. also confirmed that the novelty of their material proofed to be ground-breaking enough to gain attention from the market. The revolutionary product properties sparked interest from potential clients all over the world, who subsequently approach Peratech Ltd. to learn more about it.

HyGear's approach shares some similarities with the notion that "innovation sells itself". In this case, it also holds that the technology is so advanced and unique that it offers them a true competitive edge. The underlying reason for why this works for HyGear, however, is slightly different. HyGear's value proposition touches a highly conservative industry. As a result, not only do they have to bring up the patience, be persistent and be convincing of their approach, but the potential customer also needs to understand the approach. They found that it works best in cases where companies come to them, as they are by then already more aware of what HyGear is offering. This allows them to focus more on the client side, i.e. what the client actually wants and needs, allowing for a more focused marketing approach. As their solution is so unique, most of their clients approached HyGear themselves.

"We found it was a better approach if companies came to us instead of investing in convincing companies to thrust us by going to them. This allowed us to fully focus on the clients' needs and gain credibility on the market at the same time." ***– HyGear***

All in all, most of the analysed solutions present evidence for a rather straightforward commercialisation process. The innovative solutions proofed to be of such added value to the markets, that it was relatively easy for the companies to gain access to potential clients. This is also strongly linked to the observation that many of the companies tapped into a clear market demand from the start. This, however, does not mean that it was easy to commercialise the innovations. It does, however, provide insight in the channels through which the sales are generally made for these companies.

4.4. Increasingly more regulation imposes administrative burden on SMEs and start-ups

Although regulation was generally not found to drive the innovative trend in smart manufacturing nor significantly hinder it, some of the analysed companies noticed increasingly more pressure from regulation. Moreover, once manufacturing companies enter medical markets, regulatory burdens increase significantly. As a result, some companies indicated that they try to stay away from applications that require medical certifications.

In terms of regulatory pressure, **Peratech Ltd**. provided a clear example. In the manufacturing process, certain chemicals are used to manufacture the innovative QTC™ Materials. While this does not pose a lot of additional paper work for the manufacturing process, it becomes different when Peratech Ltd. wants to ship out the product to e.g. Japan. Shipping a small tin of the material requires them to go through many administrative processes, including ensuring proper packaging of the material. For a small company, this puts considerable strain on their resources. To overcome this, they have a full time lawyer employed on staff to deal with both IP related matters and with regulatory requirements.

"We have a full-time lawyer on staff that deals with regulatory issues for about 1/3rd of her time and the remainder on the legal aspects of our IP portfolio." ***– Peratech Ltd.***

Claro Precision Engineering Ltd. also noted the increasing amount of "red tape" they have to deal with. There are increasingly regulatory requirements they need to fulfil which include, but are not limited to, environmental policy regulation, health and safety regulation and changes in pension arrangements. For smaller companies, complying with all regulations can impose a burden as they strain some of their resources.

With respect to regulation in the medical sector, various companies indicated that the administrative burden is perceived so strong that they tend to stay away from medical applications. **Peratech Ltd**. and **Claro Precision Engineering Ltd**. generally prefer not to get involved in this sector, both as a result from the regulatory burden that is imposed and the potential law suits that can damage the company. **RP2** noted that they do manufacture some prototypes for the medical industry, as these are less

strongly regulated, but that they tend to stay away from end-user products or from medical applications that e.g. enter the body. Regulatory burden and potential law suits were also key reasons to stay away from this particular sector. The only exception can be found in **EnvisionTEC**, who has e.g. successfully entered the dental market. While they recognised that they had to deal with the regulatory burden imposed by the medical requirements, they also recognised the potential market. As a result they had to increase their efforts to fulfil the relevant requirements and acquire the proper certifications to deliver the products.

While the administrative burden of regulation was identified as a barrier, the companies we analysed have managed to deal with the administrative burden in one way or another. As such, it would be unjustified to say that the administrative burden has hampered the companies significantly in their growth. Nevertheless, the trend of increasingly more regulation being perceived remains a point that deserves attention.

4.5. Up scaling sometimes poses challenges

One of the key steps in the innovation processes of the manufacturing solutions concerns up scaling. With up scaling we particularly refer to the business side of the solution. In other words, some companies found it difficult in the early days to move from relatively low production for relatively few clients to high volume production for more clients.

Part of this is related to the capital intensity of the manufacturing industry. Up scaling requires significant capital expenditures to invest in the necessary machinery. Access to finance is thus critical for this and the barriers companies faced have been discussed there.

The availability of resources also plays a crucial role. Companies that are starting up typically have only a few number of employees. When activities increase, these employees get increasingly busier with daily activities and do not have the capacity to pick up new client leads. Hiring new employees, however, depends on the financial situation of the company and it may be difficult for them to time the up scaling process.

In the case of **RP2**, both the required capital expenditures and the few number of employees have restricted the growth path of the company in a way. While there is a market for their product in e.g. Germany, they are currently limited to the Dutch and Belgium markets due to the available resources. Nevertheless, by taking it step-by-step, sustainable company growth was realised. This was evidenced by their acquisition of Protometals and their relocation to a new production facility in 2011.

As outlined in Section 4.1, **HyGear's** way of financing the different stages has really helped them to overcome the potential access to finance barriers. Furthermore, **EnvisionTEC's** capital position also allowed it to overcome these difficulties, implying that managing your access to finance at the up scaling phase is crucial.

4.6. Access to highly skilled workforce is critical

One critical success factor in all cases was having access to a highly skilled workforce. The radical innovations require specific skills not only in the development phase, but also in operation. While some of the analysed companies have not particularly experienced a persistent problem in attracting highly skilled human capital, for others is continues to be a challenge.

EnvisionTEC experienced some difficulties in the early days in acquiring talent for their manufacturing facility in Germany. Being based in a rural area there, they missed the attractiveness of a metropolitan area. As a result, it was difficult to convince engineers to move to the area and work for them. With the quick business expansion, however, EnvisionTEC quickly became the buzz word. This has significantly helped the company to attract top engineers, as they started receiving applications from engineers from all places. As a result, they currently do not face many challenges in attracting top talent.

Peratech Ltd. found a different solution for attracting highly skilled human capital. Both the development and the manufacturing process at Peratech Ltd. require a set of highly specific skills. One of the methods for attracting top talent they had most success with is what they refer to as "growing your own". Peratech Ltd. has strong ties to universities in the UK, and particularly to Durham University. As a result, they always have PhD positions in the company. For these positions they attract top PhD students from universities that conduct research at Paratech Ltd. Aside from doing research, they get trained on the job immediately. By the time they finish their PhD, they have already picked up the desired skills and can easily integrate into the company.

"We get questions from other companies on how we managed our demand for highly skilled engineers. It is actually simple: we offer PhD positions, train them on the job and have found that they tend to like it here and stick around." ***– Peratech Ltd.***

For **HyGear** the explosive growth has brought about a number of challenges. In the early days, it was relatively easy to expand and hire new engineers as these could mostly be sourced from a friends and family perspective. Once they got beyond 5-10 employees, however, they needed to start looking through other channels. As the company continued to grow quickly, more and more engineers were hired. This posed the first challenge. As

employees at **HyGear** perform highly specialised work, they need to be trained on the job at first. At a certain point, the experienced employees were already supervising a high number of trainees. Put differently, HyGear reached its absorption capacity and while the business allowed for more job growth, they had to slow down in hiring people because there were not enough resources to train these new engineers.

Once this settled in, **HyGear** continued to grow explosively. They are now at a point, however, where they have a hard time finding highly skilled engineers to join the company. To overcome this, they are currently very pro-active in promoting the company to engineers all over Europe, e.g. when they are involved in European projects. Moreover, they promote the company at various colleges and universities by giving presentations about the company.

4.7. Public funding and incentives provides opportunities for the analysed companies

While different types of funding were identified across the analysed business cases, there was a remarkably low percentage coming from public funding. This, however, does not mean that public funding has not played a crucial role in any of the cases. In fact, for the three companies, **Peratech Ltd.**, **HyGear**, and **Nanoviá Ltd**., public funding was identified as a crucial instrument that has significantly helped the company.

For **Peratech Ltd.**, public funding proved to be one of the key alternatives to VC funding. In fact, public funding was regarded as critical in the development of the company. Part of the reason for this was that public funding has allowed them to organically grow the company. This type of funding relaxed the pressure that would be put on the company by VC funds. Moreover, public funding did not dilute ownership of the company and was therefore of great help. Moreover, Peratech Ltd. was involved in a consortium that received FP6 funding for researching the capabilities of printing chips on textiles, specifically through the use of QTC™ in the form of an ink. Public funding has allowed them to do this research, which may lead to additional market opportunities and improvements.

"Public funding has allowed us to conduct the research by providing us the necessary resources. This has been critical to the development process of our company." ***– Peratech Ltd.***

This also holds for **HyGear**, which made use of various public funding initiatives. One of the most interesting sources of funding they used concerns the "Innovatiekrediet" provided by the Dutch government (through AgentschapNL). The "Innovatiekrediet" is funding for innovative companies that specifically look for capital that is needed to go from a new product to successful commercialisation. They typically involve larger projects, as the eligible amount ranges from 125,000 EUR to 5M EUR. The funding is, however, a special loan; for innovative SMEs, 35% of the development costs of the project can be financed. If the project is a commercial success, the company has to start paying back the loan at a reduced interest rate. If, however, the project fails, the financial obligations can be nullified by the government. This instrument has allowed HyGear to raise the necessary capital, but without the perks of Venture Capital funding. In other words, they were not restricted by external parties in their company strategy, allowing them full freedom and control of the process.

Another financing instrument that proved to be helpful for **HyGear** was the use of European funding sources. Throughout the development of the innovation, they have been involved in a number of Framework Programme projects and also in a Eureka project. These projects have provided them the necessary resources to do further research in specific areas that have helped improve their innovation. The analysed companies, however, were critical of the administrative procedures of these funding sources. For some projects, it would take approximately a year to go from proposal to approval and start of contract. This was deemed too long by most of the innovative companies, as they try to capitalise on the market uptake of their industry. Missing a year of valuable research that could have been conducted runs the risk for the company of simply being too late with developing a solution for the identified market demand.

"Losing a year of research is losing valuable time in this industry. You also become less responsive to current demand on the market." ***– HyGear***

Nanovia Ltd. also emphasised the important role public funding has played for the development of their company. In fact, the project would likely not have been realised without public financial support. For the development of the technology, Nanovia Ltd. received funding from the EU Structural Funds and was supported by the Operational Programme of Enterprise and Innovation of the Ministry of Industry and Trade of the Czech Republic. They also received significant government subsidies for investment and operating costs. Moreover, as the Czech Republic considers the field of nanotechnology as a very promising sector, they organized different information seminars for innovative companies in the field. These seminars were specifically aimed at providing free information on funding of new projects, developments and issues in legislation, and potential risks for the businesses.

"Without European funding it would not have been possible to develop our manufacturing process, so it has been critical for the development of our company." ***– Nanovia Ltd.***

Apart from the public funding aspect, several companies appreciated the R&D tax incentives that were provided by governments. **Peratech Ltd**. made use of a tax deduction

scheme specifically for R&D investments and argued that it allowed for more resources going to R&D. They especially commended recent efforts on part of the UK government to simplify the process for applying for these R&D tax deductions. Furthermore, **RP2** claimed innovation vouchers for specific research in their manufacturing process and received tax deductions on wage for hours that were spent on R&D (WBSO). Similarly, **HyGear** made use of various R&D tax incentives. This has helped them to allocate resources to the research.

While the other company cases were less pronounced about the role of public funding and government incentives, it needs to be understood that they are increasingly more under discussion in Europe. In terms of R&D tax incentives, Europe already showcases a number of strong instruments. Many European countries offer tax relief for R&D activities in the form of R&D tax credits or through reduced tax rates on profits from patents or innovation. Examples of this include the "Innovation Box" in The Netherlands, the Patent Income Deduction (PID) in Belgium and the Patent Box in the United Kingdom. These incentives help companies in finding the resourced for their R&D work.

5. Policy recommendations

Smart value chain manufacturing processes can bring clear advantages to the table for companies adopting them. That being said, the following factors were identified as playing a role in stimulating as well as limiting Europe's uptake of these technologies in its integration of smart value chain technologies into advanced manufacturing.

Market uptake is favoured by a clear demand driven approach. When an innovative solution is developed as a reaction to existing demand, the potential for a good and swift market uptake is higher. This is a point that the successful cases we have analysed in this case study have in common. By capitalising on market demand, a new or improved solution can capture market share by having a clear competitive edge over other players. It is therefore crucial for companies to take have this clearly sorted out if they are looking to grow or expand their business in smart value chain manufacturing.

There is a need for opportunities to demonstrate proof-of-concept. Some of the interviewed companies deal with highly conservative industries. Similar to the environmentally friendly manufacturing industry, these industries are often sceptical towards innovations as these have not yet proven themselves on the market. As such, there is often a need to demonstrate the viability of these technologies and ultimately provide the market with a proof-of-concept in order to encourage their uptake. Companies can accommodate this by actively engaging with industry to proof the viability and reliability of their technology. It was suggested that the innovative technologies developed by the analysed companies provided such competitive advantages, that some companies approached them instead. This is also strongly linked to the clear demand driven approach. By taking the opportunity to provide solutions to the clients that approached them, they were both able to fully focus on the current clients' needs and showcase to the industry a proof-of-concept of the process.

It is critical that innovative companies and start-ups have access to finance, especially at the start-up and upscale stages of the company. Manufacturing companies are characterised by a high capital intensity. This requires significant investments in particularly the start-up and upscale stages of the company. It is therefore crucial for these companies to have access to ample amounts of capital. A lack of access to finance can bring company growth to a near standstill. The reason behind this is twofold. First, lack of funding can prevent companies from conducting necessary R&D to develop or improve the innovation. Second, lack of funding for the capital intense equipment and machinery limits the ability to demonstrate the final solution to potential clients. To overcome this, companies need to be able to attract ample resources. This can be facilitated through various channels, such as venture capitalists, private funding, bank loans and public funding.

For large capital investments, venture capital was considered a key channel. However, it was noted to have some significant drawbacks for the development of the business. Venture capital can be rather restrictive for firms as venture capital funds typically have strong expectations of pay off in the short term, i.e. within 3 years. In some cases, this conflicts with the development and diffusion path of the innovation. Moreover, venture capital funding dilutes company ownership, which is why companies found it less attractive.

Public funding therefore provides an important alternative for many innovative companies to cover their access to finance. Companies found that public funding mitigated the downsides of venture capital funding. Not only was public funding found to be less restrictive, they were also less risky for entrepreneurs if the developed innovation would fail to be a commercial success.

The "Innovatiekrediet" used by HyGear is a key example for an alternative approach to public funding.

Nevertheless, **to gain access to public funding, long bureaucratic procedures often need to be tackled.** It can take a year between the time a proposal for funding is submitted and the time the research is actually started. In a highly innovating industry, losing a year of valuable research time puts the companies at a competitive disadvantage.

The gap between the availability of and demand for highly skilled engineers needs to be addressed in Europe. Typically, innovative high-tech companies require access to highly skilled human capital and the smart value chain manufacturing companies are no different. The growing demand for highly skilled human capital, especially engineers, contrasts with the lack of availability. Attracting highly skilled human capital, however, is still something companies struggle with in Europe. The pool of graduate engineers continues to shrink in Europe and it is increasingly more difficult for companies to overcome this lack of availability. This is especially problematic for companies that are scaling up their activities, for which they typically require a significant inflow of skilled workers. Their inability to hire qualified workers hinders their ability to scale up, and as result hinders their growth.

On the basis of the abovementioned points, the following areas of policy should be considered to see how they could promote the transferability of the uptake of smart value chain manufacturing technologies:

- To **stimulate entrepreneurs to actively think of the market opportunities and commercialisation** of the innovation before developing the innovative technology. This increases the chance that successful commercialisation takes place. To facilitate this, public bodies can e.g. provide information on demand trends and high-tech application areas with a high growth potential.
- To **stimulate the market uptake** of innovative solutions in the smart value chain manufacturing industry, e.g. through the use of public procurement or by actively promoting innovative solutions that are trying to gain access to the market.
- To address the gap between the (lack of) availability of specialised and highly skilled human capital and the growing demand for these workers in Europe. Programmes can be undertaken to stimulate students to pursue a degree in engineering. For this not only programmes at the university level need to be considered, but also at the high school and the elementary school level, e.g. by showing that technical studies can be “fun” and engaging.
- To simplify or shorten the **administrative** processes for public support. A possible suggestion is to allow consortia applying for European funding to already start their research activities at their own risk after submission of their proposal. In case the project is approved, funding could be provided in retrospect for the already completed activities.
- To provide **access to finance** for companies trying to upscale and commercialise the innovation. The “Innovatiekrediet” in The Netherlands provides a key example for this and can be considered a valuable alternative to e.g. venture capital funds.

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6. Appendix

6.1. Interviews

Company	Interviewee	Position
Claro Precision Engineering Ltd.	Martin Doxey	CEO
EnvisionTEC	Al Siblani	CEO
HyGear	Allert de Witt	CTO
Nanovia Ltd.	Marcela Munzarová	Sales and Marketing Executive
Peratech Ltd.	David Lussey	CTO and co-founder
RP2	Mike de Winter	CEO

6.2. Websites

Claro Precision Engineering Ltd.	http://www.claro.co.uk/
EnvisionTEC	http://www.envisiontec.com/
HyGear	http://www.hygear.nl/
Nanovia Ltd.	http://www.nanovia.cz/
Peratech Ltd.	http://www.peratech.com/
RP2	http://www.rp2.nl/

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[19] Source: HyGear, http://www.hygear.nl/

[20] Source: EnvisionTec, http://www.envisiontec.com/

[21] Source: Claro Precision Engineering Ltd., http://www.claro.co.uk/

[22] Source: Peratech Ltd., http://www.peratech.com/