European Commission

Business Innovation Observatory

Advanced Manufacturing

Environmentally friendly technologies and energy efficiency

Case study 1

Enterprise and Industry

The views expressed in this report, as well as the information included in it, do not necessarily reflect the opinion or position of the European Commission and in no way commit the institution.

Advanced Manufacturing

Environmentally friendly technologies and energy efficiency

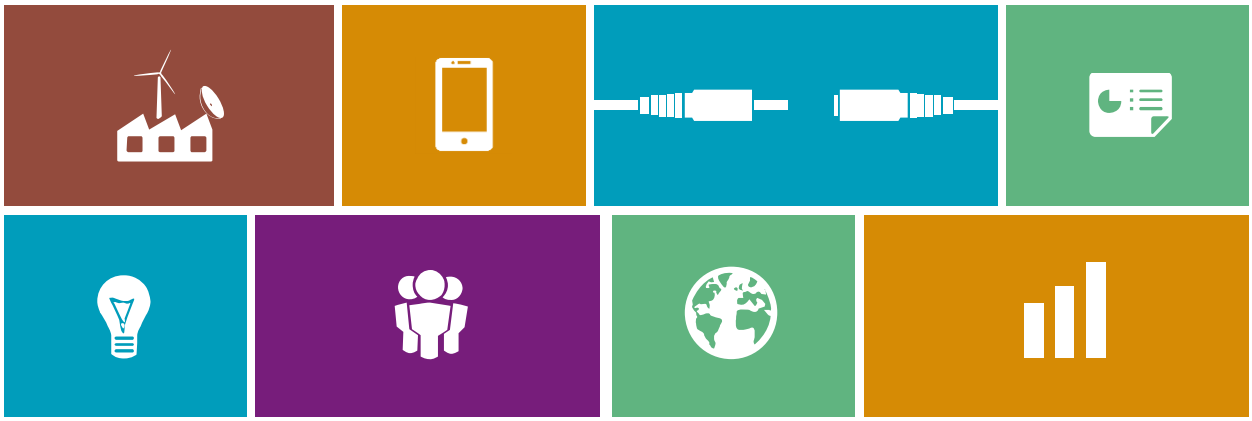
Business Innovation Observatory
Contract No 190/PP/ENT/CIP/12/C/N03C01

Authors: Laurent Probst, Erica Monfardini, Laurent Frideres, Dawit Demetri, Lina Schnabel, Alain Kauffmann & Steven Clarke, PwC Luxembourg.

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

European Union, September 2013.

Table of Contents



1. Executive summary

The rise of environmentally friendly technologies is closely linked to the resource-conscious mindset that has emerged since the global oil crisis of the 1970s. Forty years on, Europe continues to face similar environmental issues, whether it be resource depletion, climate change or pollution. However Europe's cultural mindset has changed and sustainable growth is a key priority in the Europe 2020 strategy. In achieving the strategy's sustainable growth objectives**, environmentally friendly technologies and energy efficiency** will be key as they apply cutting edge knowledge and non-technological innovations to improve existing products, processes and business models. In doing so, environmentally friendly technologies present Europe with the opportunity to create regional competitive advantages in advanced manufacturing.

One of the drivers of this trend is the emerging raft of environmental regulations, as there is a clear push from regulators for industry to implement more sustainable and energy efficient technologies. This push is coupled with a market pull, which is encouraging industries to reduce their ecological footprint by focusing on eco-friendly products and related services.

Yet there are several barriers inhibiting companies from taking advantage of the potential of these technologies in advanced manufacturing. For instance, there is a need to ensure that environmental regulations are implemented at an appropriate time within the innovation sequence. It is also necessary to tackle the issues faced by advanced manufacturing SMEs, particularly public sector financing which is burdened with complex administrative procedures.

Additional barriers to the uptake of environmentally friendly technologies are client-based, as these technologies can **disrupt value chains** and lead to the **redesigning of production lines**. They are also likely to have an impact on the employees of the client by **requiring new skillsets** for their implementation or operation. Furthermore, financing the adoption of the technologies can be challenging due to the need for investors with long time horizons and the lack of certainty regarding the benefits of the technology.

In order to overcome the aforementioned obstacles, it is recommended that Europe: increases and simplifies access to finance for SMEs; provides firms with personnel with multifaceted skill-sets that are applicable to environmentally friendly technologies; and educates the marketplace of the merits of these new technologies. In the case of the latter, it is suggested that public awareness campaigns be used to encourage the uptake of environmentally friendly solutions and reduce public scepticism towards the costs and benefits of the technologies.

Finally, it is recommended that environmentally friendly technologies be given a platform from which they can demonstrate proof-of-concept. Such platforms include **large-scale demonstrators and small-scale testing units**, which should provide environmentally friendly technologies with the necessary exposure to showcase their reliability, sustainability and viability.

2. Environmentally friendly technologies and energy efficiency

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]. Yet to maintain manufacturing's prominence, the continent must seek to counteract resource depletion, as a wide array of resources will become scarce in the next 50 years or so[2]. In addition, the use of energy resources that emit greenhouse gases should be reduced so that the world's climate is not destabilised further[3].

In order to do so, 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[4]. 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[5];
- **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**[6].

On this basis, Europe must seize the opportunity of transitioning towards an Advanced Manufacturing sector that incorporates environmentally friendly technologies that are energy efficient. The need for such a transformation has been apparent since the oil crisis of the 1970s. But, forty years on, the world is still seeking environmentally friendly technologies that will reduce the rate at which the Earth's natural resources are being depleted, and Europe has yet to convert to a low-carbon economy.

Europe has recently taken action to provide framework conditions within which environmentally friendly and energy efficient Advanced Manufacturing may be developed. This was exemplified by Europe's 2020 strategy that launched the Flagship Initiative entitled "Resource efficient Europe", which aims to use the Earth's finite resources in a sustainable manner in order to keep the economy functioning[7]. In addition, the EC launched the Communication on Energy 2020, which devised a strategy for the transitioning of Europe into a continent with access to competitive, sustainable and secure energy.

In order to identify how existing framework conditions for supporting the trend of environmentally friendly and energy efficient technologies may be improved, this case study analyses environmental technology's socio-economic relevance, and uses company cases to demonstrate the trend's market potential. Furthermore, this study elaborates on the barriers obstructing the uptake of environmentally friendly technologies in advanced manufacturing. After all, manufacturing firms are already encountering difficulties in: aligning themselves with increasingly demanding environmental standards; using energy supplied by renewable sources; and collecting and recycling waste generated by their manufacturing processes.

Nevertheless, should companies overcome these difficulties; they will likely be well-positioned to develop competitive advantages within their industry or market, thereby increasing their access to new clients, and in some cases, increasing their margins through improved cost-effectiveness.

3. Socio-Economic Relevance

As a result of growing concerns related to climate change, energy security, the scarcity of natural resources and increasing environmental regulations, industries are showing more interest in sustainable production, as well as in the undertaking of corporate social responsibility (CSR) initiatives. In order to capitalise on this, there is a drive towards the development and application of novel technologies that will help reduce impacts on the environment and improve energy efficiency.

3.1. The market potential of the trend

The impact of environmentally friendly technologies is transversal, as they are not applied to one type of manufacturing nor one type of market. Furthermore, the degree to which technologies can be considered environmentally friendly may depend on a number of factors, including: the abundance of the resource that is being sustained by the technology; and the urgency with which the environmentally friendly technology needs to be applied in order to fulfil an innovative solution.

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 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 environmentally friendly 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	Signals of success
Avantium	NL	Manufacture of next generation bio-based plastics	Three consecutive years in the Global Cleantech 100; shortlisted for 2012 Red Herring's Top 100 Europe Award; 2010 Clean Technology Business Award; Amsterdam Inventor Award 2009; Dutch Good Industrial Design award 2009; Succesful first and second fund raising; commercial contracts with Coca Cola and Danone.
Balmart	ES	Wireless monitoring solutions for agriculture and water treatment	Active member of Freescale (Motorola) Design Alliance and was awarded "best company"; 4 commercial success stories
BFS Bio Fuel Systems	ES	Large scale autotrophic technology to convert CO2 into energy	Extensive media coverage; Ecofira Innovation Award 2009
CPM Compact Power Motors	DE	Compact electric drives for all types of vehicles, power units and generator-related applications	Global Cleantech 2010; commercial contracts; media coverage; successful first and second fund raising
Felor	FR	Algal-based paint products	Winner of the French Crisalido Eco Activites Award ; selected by Cleantech Open France
Innowattech	IL	Piezoelectric technology to generate green electricity and heating	Extensive media coverage worldwide; nominee for the 2011 Katerva Awards in global sustainability
Perpetum	BE	Industrial solar photovoltaics	Commercial contracts; media
TruEnergy	BE/UA	Advanced thermal gasification technology for conversion of organic waste into energy	Received the much coveted Eureka Label in 2011; Eurec Agency highlighted the research priorities for renewable energy and advanced gasification processes by 2020 in a policy paper for the European Commission
Visuol Technologies	FR	Smart automated control painting system for automotive industry	Commercial contracts; SPE best paper award

As illustrated in Table 1, environmentally friendly technologies are applied to a variety of industries, including: energy generation; automotives; construction; water treatment; and waste management. Nevertheless, early adopters of environmentally friendly technologies seem to be industries that are intensive in terms of their use of natural resources and energy.

Companies interviewed suggested that there were very few competitors operating within their respective industries. This uncompetitive situation is attributed to their markets being immature and the fact that TruEnergy, Innowattech, Avantium, CPM, Balmart, BFS and Visuol Technologies have used cutting-edge, environmentally friendly technologies to offer potent, innovative and unique products.

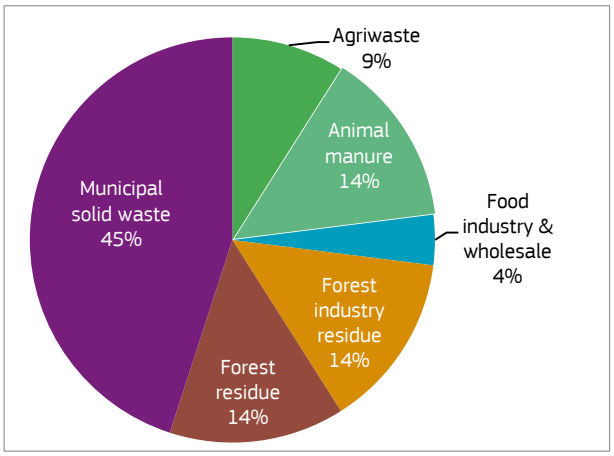
Companies included in this case study also demonstrate close ties to the information and communications technology (ICT) sector. This is exemplified by both Balmart's technology for wireless sensor networks, and Visuol Technology's use of ICT, in combination with the principles of material science and optics, to develop a smart control painting system.

Most of the technologies presented are enabling technologies, and aim to be integrated into existing value chains in the near future, across a large and diversified panel of industry sectors. For this reason, quantifying the potential global market for environmentally friendly technologies results to be rather complex.

Therefore, this case study presents examples of the different markets which these disruptive technologies will seek to enter, and some of the old technologies these new ones are seeking at replacing.

For instance, the European gasification industry has a potential annual market of over EUR 10 billion. Potential target markets in which gasification technologies may be leveraged upon are highlighted in Figure 1. Of particular interest to the gasification industry would be municipalities' high production of waste, which could be used to generate energy through gasification processes[8].

Figure 1: The sources of waste produced in Europe



Source: Herranen et al.[9]

One of the major contributors to Municipal Solid Waste are hospitals, whose total number in the EU is estimated to be 14,000 tons[10]. Therefore, assuming that each hospital would buy a TruMED gasifier product, TruEnergy would have the opportunity to target a market worth over EUR 1 billion[11].

Another potential market for TruEnergy is food waste, as European food manufacturing and processing produces 36 million tons of waste annually. It is estimated that this waste could be transformed into 4.5 GigaWatt of capacity by gasification processes[12]. A summary of the estimated energy potential of food waste in Europe is provided in Table 2, which indicates a potential market of EUR 10.5 billion[13].

Photovoltaics (PV), the market in which Perpetum is active, is not as economically viable in the current market climate, as unlike the gasification industry, it relies heavily on support systems. Furthermore, the demand for the purchase of photovoltaics seems to fluctuate drastically year-on-year[14]. In addition, the maturity of the PV market differs significantly from country-to-country. For instance, Belgium (241 W/habitant in 2012) and Germany (398 W/habitant in 2012) are considered developed markets, while the United Kingdom is considered a nascent market (29 W/habitant in 2012)[15].

Table 2: Overview of the estimated energy potential of food waste in Europe

Food Waste	Ton	Gasifier equivalent 250kWe	GW capacity
Food manufacturing & processing	36 million	18,000	4.5
Wholesale & Retail including market waste	6 million	3,000	0.75
Households	30 million	15,000	3.75
Food service & restaurant	12 million	6,000	1.25
Total	84 million	42,000	10.50
Potential market	€ 10.5 billion		

Source: TruEnergy[16]

In conjunction with their impact at the industry level, environmentally friendly technologies also impact specific markets with the new products they are able to manufacture. These environmentally friendly products provide a unique selling point for companies, helping them to differentiate from competitors, and access new clients. Two companies, Avantium and Felor Algo illustrate this market impact.

In the case of Avantium, its environmentally friendly technology is used to manufacture products that may be applied in three different markets: the film market; the fiber market; and the plastic bottle market. The third market is $30 billion in size, as it manufactures 66 million tons of bottles every year, and is expected to expand at a compound annual growth rate of 6% to 8%. Yet this market is concentrated in the hands of few, as it is dominated by major brand owners supplying the multinationals operating in the chemicals, drinks, toiletries, cosmetics and edible oil industries. However, all of these suppliers have near-optimised the manufacturing of their light-weighting bottles. Therefore, Avantium's new technology has the potential to disrupt the market, as it is lighter, has better barrier

performance, and has a smaller environmental footprint. Furthermore, Avantium anticipates that the scaling-up of its innovative solution may lead to the production of approximately 6 million tons of PEF, capturing around 10% of the world growth in demand for PET by 2027.

Felor Algo's situation differs from Avantium in that it is a mature company, having operated in the painting industry for more than 40 years. Yet Felor Algo appreciated that the painting industry was saturated and firms were facing diminishing margins. Consequently, Felor Algo recognised its need to differentiate itself from competitors, and so started to focus on developing environmentally friendly paints. Six years on since it altered its business model, Felor Algo has created a new environmentally-friendly painting industry in its local market. Therefore, the scalability of Felor Algo's product has yet to be determined, nevertheless, the company's management now seek to target the entire French market by expanding its professional networks. Following this, Felor Algo would like to establish an international presence in the next two to three years.

Thus, Avantium and Felor Algo illustrate the extent to which environmentally friendly technologies support companies in differentiating themselves, expanding within existing markets, and nurturing the development of new markets. These market opportunities reflect the reshaping of industries.

3.2. Aligning strategies to Horizon 2020: resolving environmental and energy efficiency issues

All companies interviewed for this case study were established around the 2000's. The timing of their establishment draws parallels with the growing rhetoric regarding environmentally friendly technologies and energy efficiency in Europe's manufacturing sector. The outcome of such rhetoric was the implementation of policy related to Europe's sustainable consumption and production policies, including European Commission's (EC) Communications on: integrated product policy (COM(2003) 302 final), which seeks to identify and stimulate action on products with the greatest potential for environmental improvement; taking sustainable use of resources forward: a thematic strategy on the prevention and recycling of waste (COM(2005) 666 final); and a Thematic Strategy on the sustainable use of resources (COM(2005) 670 final).

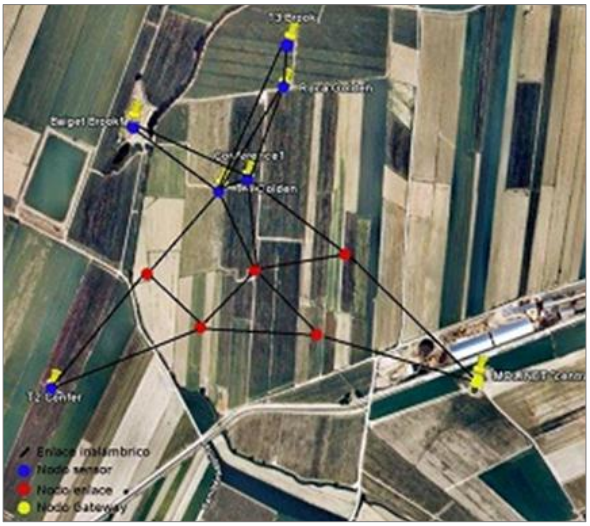
Against this policy backdrop, the nine companies included in this case study have sought to tackle the following nine environmental and energy efficiency problems that may hinder Europe's achievement of smart, sustainable and inclusive growth.

Problem 1 – There is a need to manufacture products that monitor environmental parameters, including crop, air and water quality.

Innovative solution 1 – Balmart, which span-off from the Technical University of Valencia, is an engineering firm specialising in the design and manufacturing of electronic equipment for communications and radio frequency. More specifically, Balmart produces wireless monitoring solutions of ultra-low power, powered solar panel with thousands of devices distributed through crops, forests, cities and industries. These products and systems allow the measuring of hundreds of environments, including: agricultural soils; forests; greenhouses; and golf courses.

"Focusing on environmentally friendly technology has clearly been a winning strategy for us" – ***Felor Algo***

A map indicating the network of equipment used to monitor agro-climatic parameters in POAL-Lleida



Source: Balmart[17]

Problem 2 – There is a need to make the manufacturing of packaging and products more renewable.

Innovative solution 2 – Avantium, which span-off from Royal Dutch Shell, is a renewable chemicals company based in the Netherlands. Avantium considers itself a creative accelerator, specialising in providing innovative solutions for catalytic R&D services and systems. One of Avantium's innovations is the PEF[18] bottle, which is made from biomass. The selling point of PEF bottles is that they offer improved CO2, O2 and H2O barriers than the incumbent packaging, PET bottles. These enhanced performances will increase the bottles shelf life and can even replace cans and triple-layer bottles, by one-layer bottles.

Press release cutting of Avantium's partnership with the Coca-Cola Company

press release 15.12.2011

Avantium and The Coca-Cola Company sign partnership agreement to develop next generation 100% plant based plastic: PEF

Exceptional functional properties make biobased plastic PEF a suitable alternative for future beverage packaging following technology break-through by Avantium.

Dutch research and technology company Avantium has developed a patented technology YXY to produce 100% biobased PEF bottles. Currently PET is the most widely used oil-based polyester. Based on the performance of the new PEF material, Avantium believes PEF will become the next-generation biobased polyester.

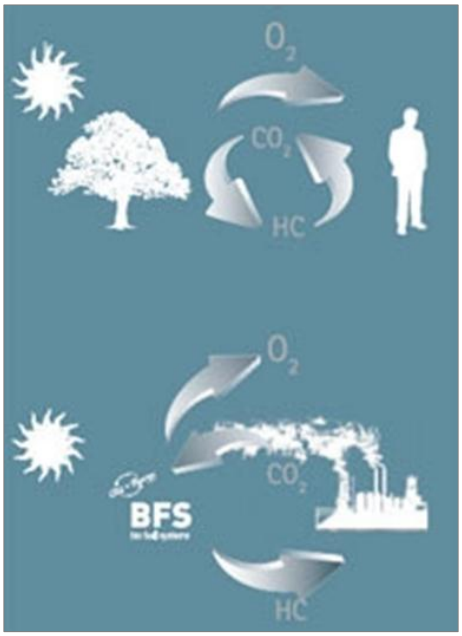
Source: Avantium[19]

Problem 3 – Forming natural fossil fuels takes millions of years, as no innovative solution to accelerate the formation process has been developed.

Innovative solution 3 – BFS Bio Fuel Systems, a company founded in Alicante in 2006, is researching large scale autotrophic technology that simulates and accelerates the creation of fuel by neutralising CO2. To do so, BFS Bio Fuel Systems is working on how:

- Industrial CO2 can be converted into fuels that are compatible with transport and electrical production structures;
- An artificial anthropic CO2 cycle can be created in order to avoid saturating the natural cycle with industrial emissions, thereby reducing the greenhouse effect;
- The organic chain above the mineral chain (of CO2 transformation) can be used to separate protein constituents and essential fatty acids for healthier nutrition for people.

An artist's impression of how BFS Bio Fuel Systems can neutralise CO2 to create a new fuel



Source: BFS Bio Fuel System

Problem 4 – The structural increase in oil prices, pollution caused by fossil fuels and the harmful effect of Volatile Organic Compounds (VOCs) requires that paint products become more green (65% of the composition of traditional water-based paint products is petroleum substances).

Innovative solution 4 – Felor Algo, a firm based just outsides of Rennes in France, produces paints that derive from natural algae rather than traditional petroleum products. The main advantages of the new product include its: long lasting nature; ability to "breathe", resulting in air in the vicinity being of better quality than with traditional paints; and use of ingredients that are electrostatic-free.

A photograph of algo PRIMAIRE

Source: Felor Algo[20]

Problem 5 – There is a lack of products that can be used to convert biomass and carbon containing waste into high quality energy.

Innovative solution 5 – TruEnergy, a division of Indra Scientific SA, is a Belgian company specialising in the development of next generation energy and energy efficiency technologies. TruEnergy has now developed three gasifier products that are available for commercial trials, namely:

- TruMED, a gasifier developed for the thermal conversion of medical waste;
- TruMSW, a gasifier developed for the thermal conversion of Municipal Solid Waste (MSW) and other waste streams with similar energy density characteristics; and
- TruOIL, a gasifier developed for the thermal conversion of used tyres.

These gasifier solution works efficiently by producing approximately 1 kWh per 1 kg of dry waste. Compared to older gasification systems TruEnergy's technology can operate 24 hours per day, and produce energy 24 hours per day. Energy can also be put into the electricity grid and used for water heating. In 2011, TruEnergy received the Eureka/Eurogia+ label for its gasification solution.

Problem 6 – Traditional electric motors are big, heavy, expensive and energy inefficient.

Innovative solution 6 – CPM Compact Power Motors, founded in 2008, is a German company active in the area of electric motors and drive systems. The aim of the company's founders (Dr. Leiber and Mr. Windecker) is to provide customers with the smallest and most efficient drive solution by offering cutting-edge products and expert advice, thereby contributing to energy efficiency. CPM Compact Power Motors now supplies the most compact electric drives in the world for all types of vehicles, power units and generator-related applications. For instance, the patented 4 kW electric motor with integrated controller has the dimension of a can, and the highest level of efficiency in this size and performance class. In addition, CPM Compact Power Motors have successfully developed engines with 5-25% better efficiency, and fuel consumption savings of 5-10%.

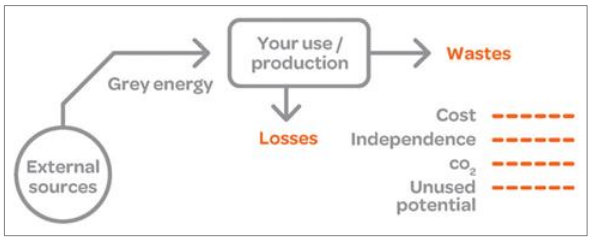
The CPM90 Power Pack – the eMobility drive train

Source: CPM Motors[21]

Problem 7 – Companies have yet to undertake initiatives in which they source their own energy, thereby: reducing their reliance on external energy sources; reducing pollution; and mitigating rising energy costs.

Innovative solution 7 – Perpetum began as a startup in Belgium in 2007, and has from then on sought to deploy integrated energy solutions for companies. These energy solutions are based on the engineering, construction, and installation of photovoltaics, wind, and biomass with cogeneration on company sites.

Perpetum's "Before" Approach

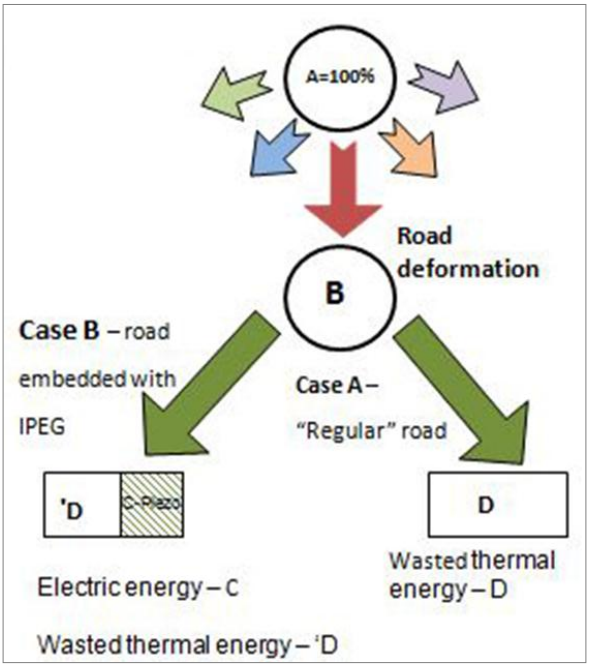


Source: Perpetum[22]

Problem 8 – Technologies fail to benefit from harvesting waste kinetic energy and transforming it into electricity.

Innovative solution 8 – Innowattech, a privately-held firm in Ra'anana and Haifa, Israel, specializes in the development of custom piezoelectric generators for specific purposes. One of the ways in which this technology is applied is in road solutions, in which harvested energy can be used to fuel local lighting and signalling systems, particularly those using light emitting diodes. The advantages of Innowattech's solutions include, its ability to: rely solely on "parasitic" energy; function in all weather conditions; be theft and damage proof; collect data (creating, inter alia, Smart Roads); and providing electricitiy to remote areas from main electricity lines.

Flowchart illustrating the concept of Innowattech road solution



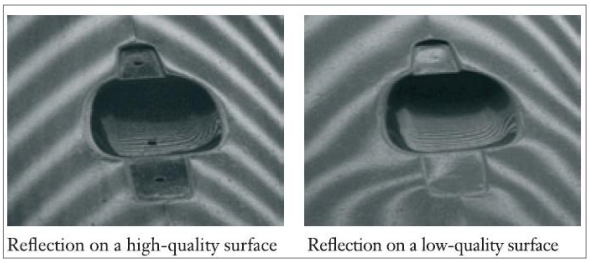
Source: Innowattech[23]

Problem 9 – There is still scope for improvement in the quality inspection of Class A surfaces and glass in the automotive and aeronautical industries.

Innovative solution 9 – Visuol Technologies is a company based in Metz, France, which has developed an alternative approach to conducting surface quality inspections. The solution is called ONDULO, and is the result of research in the field of optical metrology. The key differentiating factor of this solution is its high resolution camera that performs a better inspection of surfaces than alternative methods (e.g. visual inspection, fringe projection or interferometric moiré). The camera works by quantifying the distortion of light reflected from the inspected surface. The benefits of this solution include: the identification of quality defaults; and

the ability to conduct smart control painting (reducing costs by increasing resource efficiency).

Visuol Technologies' approach to performing quality inspections of surfaces



Source: Visuol Technologies[24]

3.3. The creation of new markets and jobs

The application of environmentally friendly and more energy efficient technologies impacts the competitiveness of companies and industries, as it leads to the implementation of more sustainable production processes. In addition, these technologies contribute to: the carving out of new market segments that use unique selling points to reshape market structures; the improvement of existing products by making manufacturing more cost-efficient in terms of energy and resource usage; and job creation.

In the case of the latter, the development of new market niches increase demand for highly-skilled labour. For instance, Visuol Technologies' environmentally friendly control surface solutions are expected to lead to the creation of 100 jobs in the next 5 years.

In using algae to produce paint products for the construction industry, Felor has been able to differentiate and create a new market in which it could become the nation's leading supplier.

3.4. Realising competitive advantages through environmentally friendly technologies

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

- **Resource efficiency**, i.e. the degree to which the solution draws on environmentally friendly technologies to minimise the depletion of non-energy resources;
- **Energy efficiency**, i.e. the degree to which the innovative solution uses environmentally friendly technologies to manufacture products with the minimal use of fossil fuels, thereby minimising manufacturing's contribution to greenhouse gas emissions that are triggering climate change;
- **Economic viability**, i.e. the cost effectiveness of manufacturing an improved product that draws on environmentally friendly technologies, and the degree to which such benefits can be passed on to the end-user in the form of reduced prices for purchasing the new product.

One of the resource efficient success stories of Balmart is the firm's manufacturing and deployment of a network of 150 wireless and ultra-low consumption sensors in Valencia. This network has enabled the city's Water Department to monitor soil characteristics, like humidity and temperature. This enables the Department to optimise its: irrigation of vegetation; forest fire prevention and detection; and reforestation.

TruEnergy's innovative solution demonstrates success in the area of energy efficiency, as its gasifiers are able to convert waste products into energy. For instance, one of the firm's premier target markets is hospitals that may use the company's TruMED technology to generate c.50 kWh of energy by gasifying the c.50 kg of waste produced per hour by a medium-sized hospital.

Finally, Avantium has well exemplified economic viability, as its PEF bottles are cost-competitive as they use catalytic processes, use the existing supply chain for polymer production and processing, and are working towards being 100% recyclable.

The success of these innovations from a client perspective is also demonstrated by the visibility of the firm's solutions, the agreements engaged in with partners, and company growth. This has been typified by TruEnergy, which was selected as the winner of the PwC Accelerator's "Most Promising Company" award at a recent Expo[25]. Similarly, in the past two years, Avantium has signed development partnerships with the likes of the Coca-Cola Company, and Danone. Finally, the success of Perpetum is reflected in the company's growth from a start-up in 2007, with just two employees and five customers, to an international company with offices in Flanders, France, and distribution channels in the UK.

3.5. Client perspectives and challenges related to the uptake of environmentally friendly technologies

Yet in spite of their ability to create competitive advantages, there are a number of issues and problems that hinder clients' uptake of environmentally friendly technologies. For instance, innovative technologies may **disrupt value chains and production lines**. In doing so, they might require the fundamental rethinking and redesigning of the client's manufacturing structures and production flows. This is

exemplified by Balmart's technology, which is designed for the intelligent control of the environment in order to improve decision making and increase agricultural production. Yet in implementing Balmart's technology, the traditional working practices of farmers are disrupted, and as a result, prospective clients have demonstrated a resistance to technological change.

This resistance to change is often linked to clients having a lack of understanding of the new value chains and the technologies being employed. For instance, BFS explained how its groundbreaking innovation for converting industrial CO2 into fuels is not well understood by stakeholders with non-technical backgrounds. Consequently, BFS has been challenged in achieving the necessary buy-in for further investment in its environmentally friendly technologies.

Environmentally friendly technologies may also have an impact on the employment of clients in terms of headcount and competencies, as their adoption can lead to both **increases or decreases in staffing levels**, which may be desirable and/or practical. For instance, if implemented, Visuol Technologies' innovative solution for the quality inspection of surfaces would likely lead to a reduction in jobs in quality control departments within manufacturing firms. However, the integration of such technologies also results in the training and employment of a smaller but more highly skilled workforce, able to implement, control and monitor the newly integrated technology.

There are also financial considerations related to the integration of environmentally friendly technologies, as **significant upfront expenditures** and **long investment horizons** are typically required. Moreover, the adoption of these technologies is further hindered by a technology's lack of proof-of-concept, as well as the lack of cost-benefits analyses regarding some technologies deployment. For example, BFS's photo-bio-reactors are capital intensive and the development of its first industrial-scale plant ecofield will require a significant amount of initial investment. However, Perpetum demonstrated that suppliers can help customers overcome this problem by offering flexible financing solutions, like the leasing models it suggests for its renewable energy installations.

In the absence of an established track record or a market accepted proof-of-concept, as is often the case for innovative startups and young SMEs, **demonstrators and testing units** play a crucial role for validating and industrialising technologies. CPM Compact Power Motors demonstrates their technology for electric motors at trade shows. Similarly, TruEnergy currently has one pilot plant for validating the technology within their gasifier products and is planning to create several demonstrators in Western Europe. Thus, by being able to showcase their advanced technologies in prototype and production mode, innovative companies are able to ensure clients of the viability of their solution.

Moving forward, it will also be crucial that environmentally friendly technologies demonstrate **scalability**, i.e. how production may be ramped up from a pilot plant, to a pre-production plant and finally, a full-scale commercial plant. The need to do so has been exemplified by Avantium, who established a pilot plant in 2011 to demonstrate on a larger scale how their technology works. The plant also provides Avantium's clients with the possibility to perform their own pilot runs, nevertheless, Avantium has acknowledged its need to build a commercial plant.

Clients also need to be ensured of the reliability, viability and sustainability of both the technology and the company supplying the technology. When investing in a particular technology, manufacturing companies need to be sure that they will be able to receive the necessary support throughout the life cycle of a particular technology. Strategic partnerships and collaboration agreements with other companies and suppliers could be used to address bottlenecks in this area. For example, CPM Compact Power Motors can compete with larger companies on the technology but when it comes to research and development issues with a client, they would not have the required financial and personnel resources to dedicate to solving problems when needed. Thus, CPM Compact Power Motors' collaboration with larger companies is seen as a solution to this problem.

Linkages further down the value chain and **strategic partnerships between suppliers and innovative companies** also need to be established. For instance, Avantium has a clear need to ensure the supply of sufficient quantities of biomass feedstock for the full-scale production of their innovative biobased plastic bottles. Similarly, Innowattech also needs to establish relationships with local manufacturers to assemble their product and access new markets. These relationships will be key for scaling up, particularly if the company maintains its focus on research and development.

Finally, it is worth noting that environmental or energy efficiency considerations may not be sufficient selling points for an innovative technologies. Ultimately, the **end products on the client side need to meet or exceed consumer expectations** in terms of quality and cost. Thus, the environmentally friendly technologies need to meet these specifications as well. For instance, Avantium's biobased plastic bottle has superior properties compared to traditional PET bottles, as its: O2 barrier is x10 better; CO2 barrier is x4 better; and H2O barrier is x2 better.

4. Drivers and obstacles

The primary factor driving the uptake of eco-friendly technologies and energy-efficiency is the need to be compliant with environmental and pollution regulations. Yet this driver is countered by businesses **waiting for the resulting market pull of environmental regulations**, and Europe's **cultural scepticism** towards the adoption of new technologies. Such obstacles in the development and adoption of environmentally friendly technologies are further detailed hereunder.

4.1. Access to financial solutions

A common theme from companies was the difficulties they face in accessing the necessary financing to support their development processes and growth. The sales process of environmentally friendly technologies in advanced manufacturing is long (typically over one year) and so investors are often reluctant to commit over such an investment horizon. Balmart, TruEnergy, Innowattech, Visuol Technologies and BFS all ranked access to finance as the most important need for their future development. However, financial needs differ from one company to the other. If some companies require additional finance to develop their research, such as TruEnergy, others intend to use finance to expand nationally or internationally, like Felor Algo.

When considering regional financial support, companies often present these measures as acceleration support for initiating their business. In that perspective, interviewees identified national measures set up to support research and start-ups such as tax credit initiatives or subsidies. However, as mentioned by CPM and BFS, the administrative process to benefit from these measures is often perceived as complex and the related technical requirements can be too complex to comply with.

Access to finance was the main concern of CPM during their first year. They needed to demonstrate proof-of-concept to venture capitalists with only a few sales. CPM's business is however very capital intensive, requiring EUR 200,000/month. They finally met their business angel on the train, on their way back from a conference. Thanks to this meeting they were able to start their manufacturing process.

"Getting finance has been our main obstacle during the first year. Venture capital generally only invests in you if you have a proof of concept, first revenues and a strong team. [...] In the end we were simply lucky to meet these people (BA) by chance on the train." ***– CPM***

TruEnergy provides insights on challenges induced by regional financial support. The company built its first pilot plant with own funding (EUR 400,000) and with the support of a potential client, a hospital. Since their pilot plant is based in Ukraine the company could not receive funding or financial support from the local government, the Belgian state or the EU authorities. Hence, it took its technology to Luxembourg where it will receive public funding for development activities. Funding is received from the Luxembourgish government's regional innovation agency, which advises companies operating in the eco-innovation sector.

BFS raised EUR 30 million from relatives, friends and venture capitalists. It did not receive public support from the EU, national or local authorities. The company has been able to develop without specific support because its return on investment occurs in a 2-3 year timespan. However, BFS has high costs for investment whose negative impact could be reduced thanks to public support.

"When developing innovative technologies and creating innovative businesses we always struggle with the handicap of the investment. It is very difficult to receive funding." ***– BFS***

4.2. Managing trade-offs when choosing locations

From an industrial point of view, companies developing environmentally friendly technologies regionally benefit from (1) the economic fabric surrounding them and (2) the possibility to set up local strategic alliances to develop. Indeed, a critical mass of other companies in the same industry and related industries as well as communications and transport infrastructures are cited as key strengths for the regional business environment.

For instance, by being located in Munich, CPM takes advantage of its proximity to clients located around the city, including BMW. Their location has facilitated their integration into the automotive production chain and the development of an automated manufacturing process. Similarly, Felor has been able to develop eco-friendly paint based on algae, thanks to its position in the Brittany Region in France. This location also helps to ensure its supply thanks to collaboration with local suppliers of algae.

Choice for a locality often involves trade-offs such as for Visuol Technologies which benefits from the presence of a critical mass of automotive suppliers and manufacturers for one of its key segments. On the other hand, Visuol Technologies lacks the presence of industry leaders in medical implants and luxury goods in the region where it is located. The key strategic locations for those industries are better represented by the USA and Switzerland.

When developing at an international scale, the choice of location actually illustrates a strategic decision to implement a factory, plant or office where the combination of opportunities and infrastructure facilities is the most appropriate. As such, Avantium is currently considering several different locations for its first commercial plant, which could be built either in Europe or in the United States. The company's criteria for choosing are (by order of importance): access to finance, proximity to feedstock, access to skilled labour and availability of existing infrastructures.

"We underestimated the difficulty in getting people to uptake innovative technologies. People here in Europe are very sceptical about innovation."People don't think that anything good can come from outside of Europe".
– TruEnergy

As follows, localities are actually competing to offer the most appropriate industrial environment to newcomers, including companies using environmentally friendly technologies to improve their manufacturing processes.

4.3. Regulation driving the growth of the European market

Access to market - and so barriers to entry and support to newcomers - is the main commercial driver for any business. Market characteristics include a critical mass of consumers, a consumer driven market, the ease of exchanging goods and services, and the ease of establishing and running a business.

For companies developing environmentally friendly technologies, the market they target is typically national. The reason being that issues and challenges faced by one company in a specific sector are not always similar in different parts of the European Union.

For instance, Perpetum is active on the photovoltaic (PV) market. It is a very competitive market in which it is difficult to remain a leader. Due to cost structures, the first solution to be provided in the PV market is the improvement of companies' operational efficiency. This is the actual business focus of Perpetum. The second focus of a company in the PV business should be its internationalisation. In parallel, these companies may develop one of two different strategies: a top-down approach by looking for financing before commercialising or they adopt; or a bottom-up approach by rapidly commercialising their first project. According to Perpetum, the top-down approach is operational as long as a company has good support and high cost per KWh. This is not the case in Europe, and is arguably the reason why Europe has lost its leading position in the production of PV modules.

Even if viable solutions to address big societal changes are provided by all these companies, market adoption remains a challenge, especially at the regional and national levels. The impact of disruptive technologies on the cannibalisation of other players' market share, and on the creation of new markets is difficult to quantify. This is even more relevant when new technologies imply a whole re-thinking of existing value chains. One example of this issue has been formalized by Truenergy, for which the full-scale deployment of the technology would have had a tremendous impact on the current ways of producing and exploiting energy, especially in the EU.

4.4. Cultural scepticism towards new technologies

The cultural business background of a region corresponds to the set of shared attitudes, values, goals and practices occurring in the locality, as well the overall entrepreneurial culture existing in the region and country. Knowing the business culture of a region is also a key enabler for a company.

Several companies interviewed for the present case study face issues relating to the lack of shared societal values. Many of them have a common feeling that new technologies are not very well perceived by society (TruEnergy, Innowattech, Balmart, BFS and Visuol Technologies). This was translated into scepticism towards their environmentally friendly technologies and the raison d'être behind developing these technologies.

For instance BFS feels its innovation of large-scale autotrophic technology to convert CO2 into energy is not well understood or well perceived by the public. The company feels that in addition to a lack of technical understanding, there is also a lack of interest for such innovative technologies. This is despite the fact that the innovation offers solutions to environmental and employment issues.

Such scepticism is also translated into difficulties in accessing financing. Visuol Technologies needs financing to build up demonstrators in order to sell its technology to industrial clients. However, in a period of crisis, industrial companies defer innovative investments even if the time for return of investments is less than a year.

4.5. Links with research centres

According to Eurostat, a quarter (26.5%) of innovative enterprises in the EU-27 cooperated with other enterprises, universities or public research institutes. The remaining 73,5% relied on internal sources alone[26]. The skills and expertise that a company recruits and develops are thus key for its development. Setting up strategic cooperations with research institutes has also been crucial for many companies leveraging on environmentally friendly technologies. However, both recruitment and partnerships are major challenges for the companies addressed in the present case study.

Strategies may differ when recruiting appropriate personnel. Firstly, recruitment could either be local as for Felor in France and BFS in Spain (70% of staff), or global, as for Innowattech. Thus, regions offer favorable business environments when nearby education and training programmes are relevant to the companies.

Secondly, recruitment may either be standardised or personalised. Balmart is for instance comfortable hiring people through an external recruitment agency. In contrast, BFS presents its multidisciplinary team composed of biologists and physicians as a key success factor. To do so, the company has a very personalised recruitment strategy leveraging personal networks with universities and alumni societies. BFS also highly prioritises internal training for their employees. Felor also seeks to diversify its team, for instance, the company recruits people with experience in the construction industry in order to better understand how its paint products ought to be used.

When considering cooperation with research facilities, Innowattech highly benefits from Prof. Abramovich's position as a professor at the Technion, the Israeli Institute of Technology. The Technion is well known for its active research and development environment, particularly in engineering. Innowatech also cooperates with universities in the United States. Such cooperations with universities build trust with clients and support the soundness of projects.

Overall, recruitment results are faster, easier, and more efficient when connections exist with the potential providers of talents, and where potential barriers such as high wage structures, or a small skilled workforce are noexisting-existent. Therefore, a regional environment with policies and business frameworks endorsing the attraction of a critical mass of professionals in similar sectors would be the most suitable option for these high-potential companies.

4.6. Achieving a more favourable market through environmental policy

To foster the integration of environmentally friendly technologies in advanced manufacturing, regulatory and policy measures play a key role. The introduction of new standards, eco-incentives and requirements in a specific sector helps to frame the market and the relations between stakeholders, whether public or private entities. For instance regulatory incentives may be provided in the form of reducing reporting, monitoring, and inspection requirements.

Felor benefits from present and future environmental regulations for its sector. For instance, the reform of the French regulation touching upon "air intérieur[27]" for 2015-2023 constitutes an opportunity for Felor since its paint will easily comply with the regulation, unlike the paint of its competitors. By using environmentally friendly technology - algae - to develop its paint, the company offers better guarantees for low exposure to toxic components. This is a crucial competitive advantage that enables the company to benefit from its market leading position in this specific sector.

In parallel, the lack of regulation may reduce the potential of some companies. BFS has the potential to create a significant number of new jobs. To do so, the company needs (1) policy measures defining better ways to save and store energy, (2) awareness raising campaigns emphasizing the need for behavioural and mentalities change to avoid waste and better integrate environmental issues in our living standards.

By influencing habits and shaping market structures, regulations are key elements able to favour a technology or diminish its potential. However, their scope is often national and do not imply regional differences or competition.

4.7. The need for public support

Innovative companies such as the enterprises interviewed for the present case study are usually looking for support from regional, national and EU authorities. This support may include support in: financing; legal advice; networking activities; nurturing cooperation between stakeholders; knowledge transfer; and going international.

This support is often restrictive so as to ensure public entities finance companies with the best potential. As a result of this, most companies developing environmentally friendly technologies have received public support.

Thanks to the support of an accelerator to get funding, Visuol Technology was able to finance demonstrators and access international markets. Balmart also used an accelerator for fundraising purposes. They have not received financial support from the Spanish government, but they received partial support from ICEX, a government institution for trade promotion. In parallel, the company also cooperated with a number of Spanish (e.g. Repsol, Agbar) and international companies to improve its product portfolio. Finally, they plan on building a strategic partnership with a university in the future.

As for support, CPM has developed a strategic partnership with a Spanish manufacturer of electric scooters by becoming their exclusive supplier of electric drives[28]. The company also intends to develop cooperations with universities for the development of future concepts. However, such cooperations may raise financing challenges since universities also face financing issues and CPM cannot provide free motors for research programmes. External financing support would consequently be needed to make such cooperation a success.

TruEnergy has developed an innovation eligible for local financing support from the City of Brussels. It has nonetheless not received this support due to restrictions in financial spending decided by the City. In parallel, the company cannot benefit from EU support since its development units are based in Ukraine, a non-EU country. Despite these restraints, its technology has been officially recognised by the well-recognised Eureka label[29], and has received support from the the European Renewable Energy Research Centres Agency (EUREC). The EU defined Eurec's research priorities for renewable energy for 2020 and beyond as follows: "advanced gasification processes should be developed for power and hydrogen and/or syngas production using biomass-fired integrated gasification combined cycle turbine plants. Gasification needs to be demonstrated for small-scale, decentralised applications"[30]. This objective is fully aligned with TruEnergy's innovative technology solution.

Public financial support is often perceived to come at the cost of administrative burdens. This is the view of BFS, which has decided not to ask for public support because of the administrative effort it would have to make. The company also feels that close communication with policy makers aimed at outlining the scope, and the potential impact of the technology is needed to obtain such support. This approach would be extremely time consuming and inefficient for such a small firm. Instead, an efficient and standardised system conveying market potential estimates and information on the possible impact of the technology to policy makers should be put in place. In parallel, large French companies intended to attract BFS by offering financial aid in return for its patents and intellectual property, which BFS was not willing to do. That is why BFS's business innovation is currently exclusively financed by family and personal networks.

As presented above, support to innovative companies developing environmentally friendly technologies has diverse forms. Further to the public financing needs of these companies, they also require a business environment where different firms working in the same sector can easily coordinate, network and transfer knowledge.

5. Policy recommendations

Provided the technological challenge of environmentally friendly technologies is overcome, and they are successfully developed and brought to market, then their implementation help compliance with environmental regulations and the meeting of market demand for "greener" products. That being said, the following factors were identified as playing a role in the limiting of Europe's uptake of these technologies in its integration of energy-efficient and environmentally friendly technologies into advanced manufacturing.

The market needs to be better educated as to the benefits from these new technologies. Environmentally friendly technologies are often disruptive to the value chains and production lines. The implementations of these technologies often replace or change either the product or the process by which it is made. Any kind of change is obviously to the product or the production process means that any decisions to implement eco-friendly technologies are met with a degree of reservation.

In addition, the implementation of these technologies will have an impact on the workforce. First of all, it might result in a redistribution of human resources as the new process might require more, or fewer, workers. Secondly, as a result of the implementation of the new advanced manufacturing technology, there might be a change in the skills needed in the workforce. This might mean that incumbent labour might become ineffective in the new production process without additional training or certifications.

Finally, implementation of these technologies will necessitate important investments. A company using a particular type of manufacturing process will have made a sizeable investment in order to acquire it. Consequently, it will not be as flexible in updating its production process every time a new modification comes along, as this cost would be economically unfeasible. In addition, large investments often result in a reduction of profits, which may lead to companies reconsidering the merits of the technology.

There is a need for opportunities to demonstrate proof of concept. Some interviewed companies indicated that a reason for the limited uptake of environmentally friendly solutions is Europe's market scepticism towards new technologies. 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. Interviewed companies often stated that the development phase of a new technology, after applied research, and prior to bringing it on to the market, is the most difficult stage for a start-up. Attracting investment is difficult at this stage, and without demonstrating proof-of-concept (which often comes at a cost) it is even more difficult.

Ensuring support systems and regulations are delivered on time, kept in place and enforced. Many of the interviewed companies had developed business models

which were at least partially reliant on environmental regulations as well as support systems (like feed-in tariffs for the photovoltaic market) in order to encourage the market to develop. However, a concern raised is that the enforcement of these regulations as well as the support systems are prone to be reduced should there be a loss of political will. For example, a sudden reduction of the feed-in tariffs for the photovoltaic market resulted in many businesses having to very rapidly adapt to the new market environment by becoming lean businesses. Such market uncertainty does not encourage more competitors to enter the market, nor does it encourage investment.

There is a need for more specific and tailored support systems for SMEs trying to bring these technologies to market. There is a need for the creation of an environment that is conducive to the emergence of start-ups. In that respect, most of the companies interviewed underlined the added value of incubators and accelerators to the success of their development. That said, some of the interviewed companies expressed a concern with the lack of public aid solutions that benefit exclusively SMEs. Furthermore, some went on to state that there is a movement in Europe to target support (through competitiveness-clusters or awards) towards larger, more established companies in industry rather than start-ups. Larger companies, they argued, were less in need of public support than smaller companies for whom small amounts of aid can help drive their initial growth as they start to generate revenue.

Competitiveness-clusters, incubators and accelerators ought to be as open as possible and need to look for new relevant projects: "the German government built electric mobility clusters, but it comprises only the usual suspects and no young innovative companies." ***– CPM***

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 environmentally friendly and energy efficient technologies:

- To develop **awareness** at the public level, highlighting the benefit of these novel technologies so as to encourage the uptake of these solutions and reduce public scepticism. This could be done through public education campaigns, or through dedicated trade-fairs supported by the public sector.
- The creation of **large-scale demonstrators and small-scale testing units** dedicated to environmentally friendly and energy efficient technologies. The location of such settings ought to depend on regional competitive advantages that could help support researchers demonstrate proof-of-concept.
- To support **SMEs bringing environmentally friendly technologies to market**, leading to the creation of start-ups and SMEs operating in advanced manufacturing industries. This could be achieved through the promotion of dedicated business clusters and business incubators, and through the exclusive allocation of public-support funds (e.g. research grants) to SMEs.
- To consider the possibility of simplifying **administrative** processes for public support. For example, through a "tell us a single time" principle, allowing companies to give their information to any administration which is then in charge of informing other administrations.
- To provide **access to finance** for companies experiencing a financing shortfall when adopting environmentally friendly technologies.

6. Appendix

6.1. Interviews

Company	Interviewee	Position
Avantium	Anouk Kruijf	Corporate Development
Balmart	Roberto Milan	CEO
BFS Bio Fuel Systems	Bernard Stroïazzo-Mougin	CEO
CPM Compact Power Motors	Nico Windecker	CEO
Felor	Louis Bouillon	CEO
Innowattech	Haim Abramovich	President and co-founder
Perpetum	Luc Leenkegt	CEO
TruEnergy	Guus Keder	CEO
Visuol Technologies	Gerard Baseotto	CEO

6.2. Websites

Avantium	http://www.avantium.com/
Balmart	http://www.balmart.es/
BFS Bio Fuel Systems	http://www.biopetroleo.com/english
CPM Compact Power Motors	http://www.cpmotors.eu/en/home/
Felor	http://www.peinture-algo.fr/
Innowattech	http://www.innowattech.co.il/
Perpetum	http://www.perpetum.be/
TruEnergy	http://www.tru-en.com/TruEnergy/Home.html
Visuol Technologies	http://www.visuol.com/

6.3. References

1 Source: http://ec.europa.eu/research/industrial_technologies/fof-facts-and-figures_en.html

2 FutMan (2003) The future of manufacturing in Europe 2015-2020: the challenge for sustainability, Final Report

3 Stern, N. (2006) Stern Review: the Economics of Climate Change, HM Treasury.

4 High Level Group on Key Enabling Technologies (2010= Thematic Report by the Working Team on Advanced Manufacturing Systems.

5 Geerts, F. (2011) Why and how to keep European Advanced Manufacturing globally competitive ? Manufacture 2011 conference, The European Association of the Machine Tools Industries, Wroclaw 24-25 October 2011.

6 Montalvo, C., Tang, P., Mollas-Gallart, J., Vivarelli, M., Marsilli, O., Hoogendorn, J., Butter, M., Jansen, G. and Braun, A. (2006) Driving factors and challenges for EU industry and the role of R&D and innovation, Brussels: European Techno-Economic Policy Support Network.

7 European Commission (2010) Communication on Europe 2020: A strategy for smart, sustainable and inclusive growth, COM (2010) 2020 final, Brussels, 3.3.2010.

8 See: FINDING NEW APPLICATIONS TO INDRA SCIENTIFIC GASIFICATION TECHNOLOGY, FINAL REPORT, Jyväskylä University, Jyväskylä University School of Business and Economics, 2012, Olli Herranen, Janne Ruuth, Ville Kaipainen; report prepared for Indra Scientific SA / TruEnergy

[9] See: FINDING NEW APPLICATIONS TO INDRA SCIENTIFIC GASIFICATION TECHNOLOGY, FINAL REPORT, Jyväskylä University, Jyväskylä University School of Business and Economics, 2012, Olli Herranen, Janne Ruuth, Ville Kaipainen; report prepared for Indra Scientific SA / TruEnergy

[10] Dexia Hope

[11] See: TruEnergy, corporate presentation, February 2013.

[12] See: V. Monier et al., Preparatory study on food waste across EU 27, Final report, European Commission (2010). Available online: http://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf

[13] See: TruEnergy, corporate presentation, February 2013.

[14] See: Flemish Regulator of the Electricity and Gas market (VREG), http://www.vreg.be/halfjaarlijkse-statistieken-groene-stroom

[15] Source: Global Market Outlook For Photovoltaics 2013-2017

[16] See: TruEnergy, corporate presentation, February 2013.

[17] Balmart (2013) Success Stories. Available at: http://www.balmart.es/9. [Accessed on 15 May 2013].

[18] Polyethylene Furanoate

[19] Avantium (2011) Avantium and The Coca-Cola Company sign partnership agreement to develop next generation 100% plant based plastic: PEF. Available at: http://www.avantium.com/news-events/press-releases/Avantium-and-The-Coca-Cola-Company-sign-partnership-agreement-to-develop-next-generation-100-plant-based-plastic-PEF/. [Accessed on 15 May 2013].

[20] Felor Algo (2013) algo PRIMAIRE. Available at: http://www.peinture-algo.fr/algo-primaire.html. [Accessed on 15 May 2013].

[21] CPM Compact Power Motors (2012) CPM90 Power Packs – The eMobility drive train. Available at: http://www.cpmotors.eu/fileadmin/media/downloads/Flyer/CPM_Applications_EN_2012.pdf. [Accessed on 15 May 2013]

[22] Perpetum (2012) Energy Autonomy & Resource Valorisation Audit. Available at: http://perpetum.be/b2b_p_audits. [Accessed on 15 May 2013].

[23] Innowattech (2007-2013) Technical Information: IPEGs harvest energy ordinarily wasted by vehicles. Available at: http://www.innowattech.co.il/techInfo.aspx. [Accessed on 15 May 2013].

[24] Visuol Technologies (2006) Ondulo brochure: Technical and advertising brochure. Available at: http://www.visuol.com/upload/4d1e1_AdvertisingBrochure_Ondulo.pdf. [Accessed on 15 May 2013].

[25] TruEnergy (2013) TruEnergy receives Award for “Most Promising Company” at the PwC Accelerator Expo in Luxembourg, 21 March 2013. Available at: http://www.tru-en.com/TruEnergy/Press_Release_130402.html. [Accessed on 15 May 2013].

[26] Science, technology and innovation in Europe, 2013 edition, Eurostat Pocketbooks http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-GN-13-001/EN/KS-GN-13-001-EN.PDF

[27] See : http://www.airaq.asso.fr/air-interieur/reglementations-air-interieur/404-le-nouveau-dispositif-reglementaire-2015-2023.html

[28] See : http://www.cpmotors.eu/en/news/press-releases/25022011-cpm-and-rieju-seal-cooperation-deal/

[29] Eureka is platform for R&D-performing entrepreneurs in Europe and beyond. See www.eurekanetwork.org.

[30] http://www.eurec.be/en/upload/docs/pdf/EUREC_09_DEF.pdf