



Future of manufacturing **Graphenea – Value chain case study**

[Born globals and their value chains](#)

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1. General identification of the born global enterprise and the global value chain members

1.1. Description of the born global enterprise: Graphenea

Graphenea is a Spanish company specialised in the production of high quality graphene in different formats for R&D and industrial applications. The company is classified under the NACE Rev 2. Code: 20.59 Manufacture of other chemical products. It was set up in 2010.

Graphene is a one-atom-thick two-dimensional structure based on graphite, which in turn is a crystallised form of carbon, one of the most abundant elements in the world. Graphene is flexible, tougher than a diamond and stronger than steel. It is also transparent, impermeable to gases and liquids, and an excellent conductor – even better than gold and copper. Graphene is subject to important research activities to identify its different properties and possible industrial applications, including flexible electronics, transistors, computer chips, high-capacity batteries, energy generation, optoelectronics, supercapacitors, DNA sequencing, water filters, antennas, composite materials, solar cells or spintronic-related products.

Graphenea is a leading supplier of high quality graphene oxide (producing dispersion and powder forms as well as reduced graphene oxide) and of chemical vapour deposition (CVD) graphene films. Graphene oxide is available in water dispersions in volumes up to 10 litres and concentrations up to 4mg/mL, and customers can also purchase dry graphene oxide powder and make their own dispersions, or get ready-made graphene oxide films obtained by filtration of the solutions. Meanwhile, CVD films are being offered on copper, in sizes ranging from 10x10 mm to 4 inch diameter. The same high quality graphene films are also available on SiO₂/Si, quartz, PET, suspended on TEM grids and cavities, and on custom substrates as required. For customers wishing to do their own transfer, CVD graphene is also available on polymer films for easy transfer.

Graphenea is a technology based private company and devotes a very large effort to R&D activities to improve the quality of the material and efficiency of the production process. It has developed eight own patents (either awarded or in the awarding process) as a result of its scientific activities, primarily in relation to the development of a number of techniques to produce graphene adapted to the range of customers' needs. In this respect, and in addition to graphene production, Graphenea is also particularly active in establishing technical and R&D cooperation activities with various national and international key players from academia and industry involved in the development of specific graphene formats and graphene-based applications. Graphenea has also published many peer-reviewed articles in top scientific publications.

This high innovation-orientation of Graphenea is also reflected in the characteristics of the workforce of the company. At the beginning of 2017, Graphenea had 22 employees, with an average age of 30. Three fourth of them (17 people) are employed in the R&D and production section, and they all hold a university degree (several have also PhDs), primarily in chemistry and physics. The other five people are the CEO of the company and the employees in the financial department (two people) and in the commercial department (two people). All 22 employees come from the local/regional area where the company is located. In addition, Graphenea collaborates with several external top international and Spanish scientific advisors specialised in graphene and graphene production, who are contracted on an ad-hoc basis for specific collaborations.

Graphenea's headquarters are located in San Sebastian (Spain). Overall, Graphenea has three main locations:

- Headquarters in the San Sebastian Technology Park, where Graphenea moved to in late 2016;
- A small laboratory located within NanoGUNE¹, a research centre specialised in nanoscience research and with a world-class unique infrastructure, including a cleanroom of nearly 300m²

¹ NanoGUNE is a non-profit making association promoted by the Basque Government in 2006. Its governing board is composed in early 2017 by different public and private Basque partners.

and 15 ultra-sensitive laboratories with state-of-the-art equipment. Graphenea pays NanoGUNE for the location of this space, which in turn allows Graphenea access to this state-of-the-art equipment and scientific personnel for their R&D projects. In fact, and according to the Graphenea interviewee, one of the main reasons for the location of Graphenea in San Sebastian (as well as its success) is related to the presence of NanoGUNE;

- A branch (Graphenea Inc) in the United States of America (USA) since 2014, geographically based in Cambridge (Boston), MA, primarily intended to act as a sales and services outpost for the company's North American customers. As of early 2017, there is only one person located there (the company CEO) on a temporary basis, but the idea is to increase commercial personnel in the coming years – while the scientific and production activities are to be kept in Spain.

The graphene world market size is still very small (approximately €14 million in 2016), and according to the interviewee, Graphenea has a 15-20% share of this world market in early 2017. Most of the existing competitors, particularly in relation to CVD graphene, are recently set-up small companies as Graphenea, and they are located primarily in the main graphene-consuming countries. Examples of main manufacturers include ACS Material, Graphene 3D Lab and PlanarTECH (USA), Graphene Platform Corp (Japan), Graphene Square (South Korea), Graphene Nanochem and Applied Graphene Materials (United Kingdom), NanoXplore and Northern Graphite Corporation (Canada), and CealTech (Norway). In 2017, Graphenea is the most important European graphene manufacturer in terms of output and sales.

The company is very active in international markets, reflected by the fact that approximately 98% of Graphenea's total sales are generated in foreign markets. Main clients include universities, technology centres and large companies' research services in the most advanced countries in the world (see next sections for more details). The company is able to produce around 150,000 cm² of CVD graphene and 50 kilos of graphene oxide per year (data for early 2017).

Graphenea was set up as the personal initiative of the company CEO, Mr Jesús de la Fuente. Mr de la Fuente is an engineer who worked in several large multinational consultancy companies before setting up Graphenea. Due to his interest and knowledge in the energy/new materials sector, he started considering the idea of starting up a company that may produce graphene already in 2008. In two years, he was able to convince several local private business angels as well as regional authorities to participate in the company. Finally, the company was set up in March 2010 with a company capital of €3 million, and the main initial partners included two local business angels, the CEO of the company and a small short-term participation of the Basque Government/Provincial Government as well as NanoGUNE for five years (Graphenea was the first NanoGUNE start-up company), via [Seed Gipuzkoa](#), a public risk capital company.

The first challenge of the company was to identify suitable and economically advantageous production methods that might generate high quality graphene (at that time this was not clear enough). For this purpose, Graphenea hired Mrs Zurutuza, a PhD polymer chemistry who joined the company as scientific director in April 2010. With a small group of staff members, they were able to start producing good quality graphene for the market, and in early 2012 they secured their first client (Nokia Finland). In December 2013, Graphenea signed an agreement with Repsol (a large Spanish Energy multinational)² through which €1 million were invested in the share capital of Graphenea. Since April 2015, both the Basque Government/Provincial Government and NanoGUNE are no longer shareholders of Graphenea as they had agreed a short term participation via risk capital. The withdrawn capital was replaced by resources generated by the company.

The company has experienced a rapid increase since its creation, following a very proactive and growth-oriented strategy. Thus, and whereas in 2012 the company had a turnover of approximately

² This investment was supported as well by Center for Industrial Technological Development, CDTI (an entity of the Ministry of Economy and Competitiveness, which fosters the technological development and innovation of Spanish companies), which has an agreement framework with Repsol called 'INNVIERTE Nuevas Energías'.

€130,000, in 2016 this figure increased to €1,280,000, with expectations for 2017 of a turnover of €1,650,000. Between 2014 and 2016, the company was able to generate a positive cash-flow, growing by 20% annually.

The company is following a detailed business plan, drafted and updated by the CEO in collaboration with the other members of the company's management (that is, the Business Development Director and the Scientific Director). In this sense, scaling up production, intense attention towards internationalisation and national/international cooperation, improvement of the quality of products, and limited strategic expansion of the product offering remain key strategies for Graphenea, as the company participates in the graphene market shift from the lab to consumer products. The company is actively engaged in price reductions (prices of CVD films dropped by 15% on average in 2016, and the price of graphene oxide was reduced by 30% on average in 2016), which are sustained by productivity improvements, capacity scale-up, and rising demand.

Interestingly also, Graphenea was named in the 2014 [Global Cleantech 100's Ones to Watch](#) list, produced by Cleantech Group and intended to identify those companies that are most likely to have big commercial impact in a 5-10 year timeframe. These companies are nominated by key corporations, investors, and Cleantech Group analysts within the Cleantech Group's Expert Panel.

Finally, Graphenea was selected in 2015 as one of Europe's top scale-ups – fast growing start-ups, presented at Silicon Valley's 'SEC2SV European Innovation Day (EID)'. The EID is an action oriented investors' day, bringing together stakeholders from the Silicon Valley and Europe's most promising start-up companies. 15 businesses from 10 European countries were selected.

1.2. Description of global value chain member 1: AIXTRON Ltd

AIXTRON is a German multinational technology-based company specialised in manufacturing deposition systems for the semiconductor industry, used for making a range of electronic and opto-electronic products containing compound, organic and silicon-based semiconductors as well as nanotubes, nanowires, nanofibers or graphene. AIXTRON's customers include market-leading companies, well-known institutions, and renowned universities around the world.

AIXTRON was founded as a spin-off from RWTH Aachen University in 1983. Since then, the company has made several acquisitions and mergers with different international companies. Since 2010, the company converted from a German public limited company to a *Societas Europaea*³ to reflect its European and international nature.

The company had a total turnover of €197.8 million in 2015, and approximately 750 employees all over the world. Approximately 60% of AIXTRON's revenues come from clients in Asia, around 18% from Europe and the remaining 22% from the USA.

Manufacturing sites are located in Herzogenrath (Germany), Cambridge (United Kingdom), and Sunnyvale (CA, USA), and they have selling and service customer points in Asia (China, India, Japan, Singapore, South Korea and Taiwan), USA, Europe (Germany, United Kingdom, Italy and Russia) and Oceania (Australia).

1.3. Description of global value chain member 2: Graphit Kropfmühl GmbH

Graphit Kropfmühl GmbH is an international company specialised in the extraction, processing and refining of natural crystalline graphite. The company portfolio includes the production of a large bandwidth of natural graphite in the most varied grain sizes, an extensive spectrum of synthetic graphite products, expandable graphite in many different specifications, finished graphite dispersions and powder premixes, and graphite parts in any geometric shapes. The company, set up in 1916, has its headquarters in Hauzenberg (Bavaria, Germany), as well as several subsidiaries located in Czech Republic, Sri Lanka, China and Mozambique, where it holds shares in underground mines and

³ The European Company (also known by its Latin name *Societas Europaea* or SE) is a type of public limited-liability company regulated under the EU law.

facilities. It is part of a larger mining group called AMG Mining AG, which has a participation of 60% in Graphit Kropfmühl GmbH. The company has around 480 employees worldwide, and its turnover was €52.8 million in 2015.

Graphit Kropfmühl GmbH is active in the international export markets, and particularly in EU markets, although it also exports to other markets such as Japan, the USA or South Korea. Main competitors are in China, where the most important graphite mines are located.

1.4. Description of global value chain member 3: GRoWater Inc

GRoWater Inc is a new company located in Cambridge, MA (USA). The company was set up in February 2015 by two persons, Steven Tozzi and Professor Rohit Karnik, from the Massachusetts Institute of Technology (MIT), and they have three employees in early 2017.

The company does not have any commercial activity, yet. They are developing in 2017 a transformative graphene-based membrane platform technology with significant applications in different fields such as organic solvent processing, oil and natural gas, as well as water purification and desalination activities. Professor Karnik is responsible for the scientific side of the company, whereas Mr Tozzi is involved in supporting the transfer of early stage technology from university/research to the commercial sector (he has participated in similar projects before). The company expects to need at least another 24 months before entering the commercial stage.

To develop this technology, in 2016 GRoWater Inc received an ad-hoc funding amounting to approximately US\$149,703.13 (€140,000) from the US Department of Energy for the ‘Development of Scalable Manufacturing Process for High-Selectivity Single-Layer Nanoporous Graphene Membranes’ project.

2. Internationalisation activities of the born global enterprise

2.1. Overview of the international activities of Graphenea

Graphenea is a highly internationalised company, whose main international activities include exporting and international technical cooperation. The company initiated its first international activities in early 2012 (that is within two years after start-up), when they got a first order to supply graphene to Nokia Finland. Since then, the company has been very active in international markets.

A key event in the internationalisation process of the company happened in 2013, when Graphenea became one of the partners of the [Graphene Flagship Initiative](#) of the European Commission (see section 3.2 for further information). This initiative provided the company with the possibility to access a very large network of key European universities, research centres and companies that are involved in the development of graphene-based applications, fostering useful contacts, networking activities with them, and giving a high visibility to Graphenea in the international markets. Interestingly, it was Nokia Finland who introduced Graphenea to the initiative, although the company was admitted only after a very strict scientific check.

Other key steps in the internationalisation of Graphenea include the launch of its [online store](#) in November 2012, as well as the opening up of a branch (Graphenea Inc) in the USA, based in Cambridge (Boston), MA, and intended to provide service to the company's North American customers and develop the company's sales in that country, avoiding at the same time certain administrative difficulties related to custom issues. Graphenea is also very active in establishing technical cooperation with relevant international players in order to identify and develop products adapted to the specific clients' needs.

2.2. Importance of internationalisation activities for the born global: main served markets

Graphenea exports around 98% of its total sales to foreign markets, where it has a 15-20% share of the whole world graphene market. These international activities have a regular nature, and they are key for the survival of the company as the graphene global market is still very small.

Graphenea has around 1,000 clients in more than 60 countries. Graphene is still in a research and prototyping phase, where industrial graphene-based applications are yet to appear. This situation explains that Graphenea's main clients include universities, technology centres and large companies' research services that are purchasing sample graphene lots for testing and analysing the different properties and possible industrial applications of graphene.

Precisely, universities are Graphenea's main clients, followed by private companies and technology centres (approximately 50%, 30% and 20% of sales, respectively). Most of these clients are located in a handful of countries with the highest R&D investments and the highest demand of graphene, namely the USA (30% of international sales), followed by South Korea, Japan and the European Union (primarily Germany, United Kingdom and France).

2.3. Reasons to go international and for the target market selection

The main reasons behind the strong internationalisation of Graphenea are explained by the nature of its product, characterised by a relatively small world market (approximately €14 million in 2016), coupled with an extremely small demand in Spain. In this context, internationalisation is seen as a straightforward decision for the company since the world is perceived as its natural marketplace. This decision was clear for the company founder from the very beginning. In addition, the desire to remove possible obstacles and fully exploit the existing business opportunities in some key foreign markets explains, for instance, the decision of the company to open up its branch in the USA.

Meanwhile, the current and future graphene demand in the target markets, as well as the need to develop successful technical cooperation activities with players located in these markets, are key reasons for their selection.

2.4. Main challenges to engage in international activities and solutions adopted

According to the Graphenea interviewee, clients particularly value the company for two main elements, this is, quality and rapidity in the delivery, while price plays a (relatively) minor role. Graphene deliveries are usually of very small quantities, where the business is based on very large margins rather than on large volumes.

For facilitating international sales, Graphenea has an online store since November 2012, where clients can buy directly from the company and Graphenea delivers their orders (using courier services). However, in some cases international clients from some countries are confronted with specific obstacles, particularly in terms of administrative difficulties related to custom issues (delays in the supply, additional custom checks resulting in delays, problems with exchange rates, etc.). To solve these difficulties, Graphenea has signed distribution agreements with a network of international distributors located in the main destinations in the USA, Europe (United Kingdom), Asia (India, Taiwan, Malaysia, Singapore, Japan, China and South Korea) and Turkey. These local distributors, identified by Graphenea via own research and/or recommendations from other distributors, facilitate the administrative procedures, as they are very familiar with them and have good access to custom authorities. However, the situation strongly varies according to the market. Whereas in Japan Graphenea works with a very efficient and reliable distributor, South Korea seems to be a very complicated market for them as they have signed several agreements with different distributors with relatively little positive results so far. Meanwhile, in the case of the USA (the largest graphene market in the world and the largest client for the company, too), an additional burden on top of the administrative difficulties related to custom issues relates to a certain tendency amongst American clients to prefer American companies to avoid custom duties. This explains why Graphenea, amongst other reasons such as the desire to have a more direct contact with US clients, has decided to open up a branch in the USA in 2014.

3. Global value chains of the born global

3.1. Identification of global value chain(s) of the born global

The high internationalisation of Graphenea is also reflected in its high activity in different global value chains. In this sense, Graphenea acts both as supplier of graphene to different clients as well as client for different suppliers. Also, Graphenea is very active in international research cooperation, reflected in their participation in both the EU Graphene Flagship Initiative and in several projects supported by the EU Framework Programmes.

3.2. Main roles of the born global and its partners and governance issues

Graphenea acts as supplier of graphene to different international clients. As already explained, main clients of Graphenea include universities, technology centres and large companies' research services, basically interested in purchasing sample graphene lots for testing and analysing the different properties and possible industrial applications of graphene.

Graphenea sells to some of the most advanced universities and research centres in the world, which usually have a special research department interested in analysing and testing the graphene properties and possible uses. Examples of clients suggested by the Graphenea interviewee include the MIT, Stanford or Harvard University in the USA, Cambridge University, Imperial College, the University of Manchester in the United Kingdom or the Chalmers University of Technology in Sweden.

Large technology corporations in many different sectors are also strongly investigating the opportunities that graphene could offer, with a small demand from projects looking into the eventual commercialisation of solutions. Examples of relevant companies included in Graphenea's customer portfolio include some of the largest and most relevant companies in the USA (Intel, Sigma-Aldrich Corporation, IBM), Japan (Toshiba, Tokyo Electron Ltd, Hitachi, Nissan) and Europe (Infineon, BASF, Airbus, Thales, Varta, STMicroelectronics, Repsol, Antolin Group). Meanwhile, some traditional key company clients of Graphenea such as Nokia or Phillips are no longer clients for different reasons (Nokia is now part of Alcatel-Lucent, Phillips has sold its LED-section). The relationship with these clients is usually on a purely commercial basis, meaning that they buy graphene directly from Graphenea or via authorised distributors, using standardised contracts provided by Graphenea. Typically, potential customers approach Graphenea, rather than the other way round. In some cases, Graphenea has participated in very interesting discussions with clients in order to develop graphene in specific formats and lay-outs according to the clients' needs (see a discussion on this in section 4 with the example of GRoWater Inc). Having in mind the relatively low graphene quantities requested by clients (mainly for scientific purposes), there are no unbalanced power relationships between Graphenea and its partners.

In addition to its activities as graphene supplier and to its network of international distributors (see section 2.4), Graphenea has a network of national and international suppliers⁴ that are part of the company's supply chain. Although limited in number, they play a significant role for the company as suppliers of raw materials and key specialised equipment. In relation to raw materials, Graphenea needs for a part of its production methods very high quality copper, which is obtained from a highly specialised Japanese supplier. The quantities required from this supplier are very small (approximately 100 m every two years), and the relationship is based on a pure standard commercial agreement. Since it is very dependent on the quality standards provided by this Japanese copper supplier, Graphenea is exploring the possibility to enlarge its network of suppliers (likely Chinese, German or other Japanese companies). Meanwhile, in relation to the equipment supply, Graphenea is using CVD equipment supplied by AIXTRON, a multinational technology-based company specialised in manufacturing deposition equipments (see more information in section 4). In addition, Graphenea is interested in

⁴ Graphenea works with several international companies that are either located in Spain or have specific commercialisation/service offices in Spain. They are engaged in the supply of special gases (particularly methane), synthetic graphite or special optical equipment. They are not taken into account in this analysis.

enlarging its supply of graphite, moving from synthetic to natural graphites with better properties in terms of higher crystallinity. For this purpose, they are collaborating with Graphit Kropfmühl GmbH (see more information in section 4). On the other hand, Graphenea wants to develop very strict quality control mechanisms that may even increase the current quality standards of their manufactured graphene. For this purpose, they are developing contacts with a German company called Rudolf Technologies, specialised amongst other products in defect inspection solutions via Automated Optical Inspection techniques. These contacts have not been formalised yet.

Finally, the company is very active in international research cooperation activities, done mainly through support from EU programmes. This is reflected in their participation in the EU Graphene Flagship Initiative and in several EU Framework Programmes, intended at supporting international R&D and innovation, both as coordinator or as project partner (see further information in section 6.2). Specifically, the Graphene Flagship Initiative coordinates over 150 academic and industrial research groups in 23 countries, and has close to 50 associate members, including Graphenea. Graphenea acts as the only CVD graphene supplier of the consortium, although there is no formal agreement to use only Graphenea's products if quality standards are not deemed satisfactory. This initiative is considered by Graphenea as a key event in its internationalisation process, particularly useful for facilitating business cooperation and networking activities with international partners as well as gaining visibility in international markets. As an example, within the framework of the initiative Graphenea worked in 2015 with several international research institutes in Belgium (IMEC), Germany (AMO) and Spain (ICFO) to overcome issues that arise when fabricating graphene devices, and collaborated with TU Delft (The Netherlands) to better define the required graphene material for sensor applications.

4. Cooperation between the born global and its selected international partners in value chains

4.1. Brief history and reasons of the cooperation(s) and reasons for initiating them

This chapter is analysing the existing cooperation between Graphenea and three selected global value chain partners. These partners are AIXTRON Ltd and Graphit Kropfmühl GmbH (both suppliers of Graphenea) and GRoWater Inc (a client of Graphenea).

The cooperation between AIXTRON and Graphenea was initiated in 2011, when Graphenea had to select a reliable supplier of equipment for producing CVD graphene. It was Graphenea who, after a careful identification of possible suppliers, decided to contact AIXTRON. This contact was established with the UK subsidiary (AIXTRON Ltd), located in Cambridge, which was the one specialised in the manufacturing deposition equipment for graphene. Indeed, the collaboration between Graphenea and AIXTRON has been always via this UK subsidiary.

The cooperation between Graphenea and Graphit Kropfmühl GmbH, a supplier of natural graphite, started in 2015. Graphenea is mainly using synthetic graphite as the initial raw material for a part of its graphene production methods, due to its superior consistency and purity to natural graphite.

Notwithstanding this, Graphenea is increasingly considering the possibility to use natural graphite, much more complex but with added properties that make it very interesting for producing graphene oxides. With this development in mind, Graphenea and Graphit Kropfmühl GmbH started their cooperation, having been introduced to each other by a Spanish specialised distributor company who knew the interest of Graphenea to find a reliable supplier of natural graphite.

The origin of the cooperation between Graphenea and the US company GRoWater Inc goes back to the work of Professor Rohit Karnik (one of the co-founders of GRoWater Inc), who leads the ‘Microfluidics and Nanofluidics’ research group in the MIT. For his research, he used Graphenea’s graphene, so it became quite natural to select Graphenea as a supplier of graphene for developing a transformative graphene-based membrane platform technology (the main goal of GRoWater Inc).

4.2. Roles of the born global and the selected partner(s) within the value chain

AIXTRON supplies specialised equipment for the production of graphene to Graphenea. It is important to stress that this supplied equipment has been mostly supplied for research and development purposes, in the sense that Graphenea was the first client of AIXTRON demanding specific equipment for producing graphene. This implies that there has been a very deep exchange between both parties in terms of identifying the needs and specificities of Graphenea, but also the weaknesses/strengths and possible ideas for improving the supplied equipment. Just to give an example, the Graphenea interviewee suggests that the first supplied equipment took approximately one year before it became fully productive, so a very strong communication flow was developed between both parties via different means (e-mails, phone/ skype calls, face-to-face visits).

In 2017, AIXTRON is supplying a new production equipment for Graphenea for its new pilot plan to be opened up in the same year (see sections 6 and 7). Also for this new equipment a complex process of communication, including email exchanges, phone/skype calls and direct face-to-face contacts, usually once every two weeks, is being developed between both parties in order to adapt the new prototype to the demands of Graphenea. This equipment has already been supplied, but both parties are developing and fine-tuning this equipment to make it fully operative. The Graphenea interviewee expects that this process will not take as long as previous time (perhaps 6-7 months).

Also Graphit Kropfmühl GmbH is acting as supplier (of natural graphite) to Graphenea, due to the interest of Graphenea to increasingly use natural graphite as a raw material instead of synthetic graphite. In early 2017, this cooperation is at a very initial testing stage. In practice, this means that Graphit Kropfmühl GmbH sends samples of different types of natural graphite to Graphenea, whereas Graphenea analyses and tests these samples and subsequently provides feedback to Graphit Kropfmühl

GmbH. In this way, both companies interact and learn from each other. So far, this cooperation is solely amongst the R&D departments of both companies, meaning that it is not of a commercial nature.

In the case of the cooperation between Graphenea and the GRoWater Inc, Graphenea acts primarily as a single-layer graphene supplier to GRoWater Inc. GRoWater Inc requires a very reliable graphene supplier who is able to provide a high quality and reproducible graphene, as is the case of Graphenea. Also, GRoWater Inc stresses the key role played by Graphenea as provider of technical/scientific graphene-related knowledge in addition to its role as graphene supplier.

Concerning the role that ICT and logistic services play in the relation between Graphenea and the selected value chain partners, the Graphenea interviewee stresses that both elements are key for sustaining and reinforcing their cooperation. To start with, the company has developed since its foundation a very well positioned webpage (only in English) to interact with clients and potential collaborators, which receives approximately 20,000 visits per month and includes an own-developed blog with key news on graphene-related issues. This has been reinforced with the online store, opened in November 2012 to facilitate both national and (particularly) international sales.

On the other hand, the company has a zero-stock policy, so it produces according to the clients' demands and usually requires 2-3 weeks' time to manufacture and deliver the products to the final client. For this purpose, Graphenea makes extensive use of courier services for sending the clients' orders to any part in the world, which requires a careful packaging of the products. Looking at the future, this situation is likely to change if new/more sophisticated/larger graphene formats are developed. The interviewed client company GRoWater Inc suggests that one of the strengths of Graphenea is related to their flexibility and reliability to deliver the requested materials in a relatively short time.

4.3. Governance issues and formalisation of the cooperation

In the case of AIXTRON, the equipment supply process is formalised via a conventional purchasing agreement, initially drafted by AIXTRON and discussed with Graphenea, stressing traditional aspects such as supply elements and characteristics, delays, etc. In addition to this, both parties participate in the Graphene Flagship Initiative⁵, which implies a non-written regular relationship in terms of shared activities and exchange of information related to the initiative. For instance, AIXTRON is leading the so-called 'Production' work package, in collaboration with Graphenea and Grupo Antolin. This work package is focused on technology development to enable cost effective and large scale production in the future with a strong industry focus. So far, no potential conflict issues have arisen between both parties.

The cooperation between Graphenea and Graphit Kropfmühl GmbH is not formalised yet, in the sense that there is no written agreement between both parties. Moreover, the small natural graphite samples are sent for free. So far, no conflict issues between partners have been identified. In case the cooperation between both companies became more regular (for instance Graphit Kropfmühl GmbH supplying larger natural graphite quantities), an agreement might be signed to regulate it. Power relationships within the cooperation can be labelled as balanced.

Graphenea and GRoWater Inc have a commercial relationship, so GRoWater Inc buys to Graphenea the single-layer graphene quantities it requires for its activities, according to the prices given on the webpage of Graphenea (in contrast to, for example, the cooperation with AIXTRON where specific

⁵ The EU Graphene Flagship Initiative is implemented in six divisions; four of them scientific and one each for Partnering Projects and Administration. Within the divisions there are a total of 20 work packages, 15 on research and innovation and five on operative management aspects. The Initiative is governed by two main decision-making bodies, including an Executive Board (including members of the Management Panel and ten members-at-large) and a General Assembly (comprising one representative for each partner institution from the consortium). Meanwhile, the Management Panel (including the Director, the Science and Technology Officer, the Head of Innovation and five of the Division Leaders) implements the decisions of the Executive Board and formulates proposals related to project management.. The whole initiative is coordinated by the Chalmers University of Technology based in Gothenburg, Sweden.

negotiations take place). The demanded quantities are not very large, due to the scientific nature of the activities conducted by GRowater Inc so far. The scientific collaboration between both parties is not formalised so far, apart from the technical specifications related to the quality standards for the supplied graphene. Also in this case, power relationships within the cooperation can be labelled as balanced.

4.4. Evolution of the cooperation over time

The cooperation between Graphenea and AIXTRON has been smooth during all these years, with regular briefing activities on the functioning of the equipment and ideas/suggestions for improvement. Indeed, this cooperation has been reinforced with the new supplied equipment, particularly since 2015 and reflected in regular weekly communications and information exchanges, as well as regular face-to-face meetings. The Graphenea interviewee stresses that during these years a strong trust and confidence has been built between both parties, where the role of concrete persons and individuals is very important behind this confidence (in this case, the cooperation between the managing Director of AIXTRON Ltd and some key personnel in Graphenea, including the scientific and the business development directors). Indeed, the Graphenea interviewee suggests that if some key people left either party, the relationship between Graphenea and AIXTRON Ltd would be negatively affected (at least in the short run) due to the existing links of personal trust and confidence.

According to both parties, since 2015 the cooperation between Graphenea and Graphit Kropfmühl GmbH has evolved and progressed quite well and, so far only on a scientific basis. It is expected that this cooperation may increase in the future, if Graphenea decides to rely much more on natural graphite as a raw material instead of synthetic graphite. Graphit Kropfmühl GmbH has visited Graphenea facilities several times since 2015, with the idea of deepening the existing relationship between both parties.

Finally, the needs of GRowater Inc are evolving in time, which requires periodic technical meetings between both parties to discuss needs and ideas identified by GRowater Inc in relation to its graphene requirements. The fact that Graphenea has an office nearby in the same area (Cambridge, Boston) facilitates the exchange and interaction between both companies. In this sense, and as GRowater Inc may grow in the future, it is very likely that the company may request graphene with different, more demanding specifications at a reasonable price which, in turn, may require additional collaboration efforts between both parties. According to the GRowater interviewee, time will tell whether Graphenea will be able to cover and supply the expected future company needs.

4.5. Results of the international cooperation for the different enterprises

The existing cooperation between Graphenea and its selected value chain partners is generating a number of positive results for both parties.

For Graphenea, the main result of the cooperation with AIXTRON refers to the development of unique machines, fine-tuned to the specific needs and requirements of Graphenea. Nevertheless, Graphenea is conscious that there are other highly competitive equipment manufacturers in the world. In this sense, it has accumulated a significant stock of knowledge during all these years about the specificities and characteristics of a well-running equipment. The Graphenea interviewee does not exclude future cooperation agreements with other international equipment suppliers.

In terms of the cooperation with Graphit Kropfmühl GmbH, Graphenea is benefitting from two main elements. On the one hand, Graphenea is benefitting from a scientific perspective (for instance, many of the techniques used by Graphit Kropfmühl GmbH for analysing natural graphite are of interest for Graphenea). On the other hand, Graphit Kropfmühl GmbH could become a key/highly specialised supplier of Graphenea in the future (this perspective is underlined primarily by the Graphit Kropfmühl GmbH interviewee).

Finally, GRowater Inc is seen by Graphenea as an interesting client, with limited demand at this stage but with positive expectations for the future. Also, the scientific/technical cooperation with GRowater

Inc is resulting in an interesting source of knowledge for Graphenea on the needs that the graphene-based membrane platform technology (one of the most promising graphene-based industrial applications in different areas such as desalination, water purification or chemical refining) is likely to request in the coming years.

All in all, the identified cooperation examples are beneficial for Graphenea, mainly due to the joint learning/knowledge exchange. It is also likely that this cooperation may have other future potential benefits for Graphenea, including the company's future sustainability and competitiveness resulting from better supplied products/materials or future enlarged demand coming from GRoWater Inc.

Referring to the results of the cooperation with Graphenea for its partners, in the case of AIXTRON these are particularly interesting from a strategic viewpoint. Indeed, the equipment supplied by AIXTRON to Graphenea represents a tiny percentage of the turnover of AIXTRON. Rather, the interest in the collaboration for AIXTRON refers to the development of very specific and specialised equipment that, eventually, might be sold to other third parties (the business of AIXTRON is selling machines, as stressed by the Graphenea interviewee). According to Graphenea, AIXTRON uses Graphenea as a reference, always asking Graphenea's permission to mention them in their commercial activities. The AIXTRON interviewee suggests that they are also benefitting by having access to knowledge on graphene production-related needs, a small but likely growing new market that is interesting for them. If Graphenea succeeds, as successful supplier of an effective graphene manufacturer AIXTRON will benefit in terms of increased reputation and visibility in the equipment production market, as well as of fostered future growth opportunities.

Graphit Kropfmühl GmbH benefits from different elements. To start with, Graphit Kropfmühl GmbH is not interested in producing graphene as it does not have the technology or the know-how for doing so, but the company is very interested in graphene as a product and the future business possibilities linked to it (see section 1.1). Also, Graphit Kropfmühl GmbH is learning a lot from the knowledge exchange with Graphenea, increasing its awareness of the needs and requirements linked to the manufacturing of graphene, which in turn results in a better understanding of the client's needs and a higher competitiveness. Last but not least, Graphenea is a potential future client for Graphit Kropfmühl GmbH, especially if Graphenea's manufacturing facilities and needs of natural graphite increase in the future (see sections 6 and 7). Incidentally, Graphit Kropfmühl GmbH is using some of the NanoGUNE's state-of-the-art equipment and scientific personnel for doing some specialised analysis. This cooperation was originated from one of the visits of Graphit Kropfmühl GmbH to Graphenea's facilities.

As far as GRoWater Inc is concerned, the main positive result from its collaboration with Graphenea is the availability of a reliable graphene supplier who is able to provide high quality and reproducible graphene for its scientific experiments. In this sense, the company interviewee stresses that Graphenea is a fast and flexible provider, able to supply the requested materials in a very short time (approximately two weeks) and with the required quality standards. This contributes to increase the competitiveness and productivity of GRoWater Inc.

5. Main challenges to engage in international cooperation activities

5.1. External and internal-to-the company barriers

Graphenea does not identify any element impeding its engagement in international cooperation activities. In the interviewee's view, international markets are the common playground for the company since its foundation, so the company is used and well adapted to interact with international partners. In any case, the most important identified difficulties are linked to the selling of products, particularly in terms of accessing clients in any part of the world and custom-related administrative difficulties (usually in some specific countries outside the EU and the USA).

Also, the Graphenea interviewee suggests that being a graphene world-reference results in the reception of many proposals for scientific and business collaboration, not all of which are of interest for Graphenea. In this sense, the interviewee stresses the importance of carefully checking these collaboration proposals for selecting those that have a feasible and realistic nature.

On the other hand, the AIXTRON interviewee identifies Brexit (and particularly the conditions under which the withdrawal of the United Kingdom from the European Union is taking place and the associated uncertainties) as one emerging challenge/obstacle for the international activities of its UK subsidiary. Examples mentioned include the selling of products and the participation of the subsidiary in EU-funded R&D projects.

5.2. Solutions adopted by the companies to solve these challenges

As mentioned in section 5.1, Graphenea is used and well adapted to interact with international partners. Since its foundation, it was clear for Graphenea that international markets would be the 'playing ground' for the company, so this international orientation is one of its key characteristics. For instance, the web page of Graphenea is only available in English, and all the company personnel has a good command of English, a requirement for working in Graphenea. Moreover, and for some key roles, fluency in English and experience in international environments is a must. For example, the scientific director obtained her PhD in Polymer Chemistry from the University of Strathclyde in Glasgow, whereas the business development director holds a Bachelor's Degree in Business Administration from the University of Wales. Both of them have also worked for several years for international companies, either in Spain or abroad. In addition to this, Graphenea has got a highly qualified and motivated workforce, as already shown in section 1.1.

Concerning the difficulties linked to the selling of products in international markets, the company has developed its own online store (strongly supported by very agile courier services) as well as a network of international distributors located in the main country destinations (for more information, please see section 2.4). Finally, Graphenea checks the collaboration proposals that it receives very carefully in order to select those that have a feasible and realistic nature. The criteria used to select suitable proposals include a thorough analysis of their nature and characteristics, the partners behind the idea, the possible risks and benefits associated to it and the commitments required for Graphenea.

Finally, and in relation to the challenges faced by AIXTRON Ltd, the British company has not developed (as of January 2017) any contingency plan yet in order to evaluate and minimise possible risks associated to Brexit. The elaboration of this plan is expected to happen once the company has clearer information on the specific conditions under which this Brexit is going to be agreed between both parties (the EU and the UK government).

6. External support to internationalisation and international cooperation

6.1. Main identified needs for external support

According to the Graphenea interviewee, the main difficulty experienced by the company refers to access to capital, both in the initial and the expansion phases of the business project. In this sense, any external public support in this field has been extremely important for the company. Also, for any new technology-based company the possibility to become known in the market and to develop a network of relevant clients/collaborators is crucial, particularly in the international domain having in mind the graphene specificities and market size. Other support needs related to R&D and product development were relatively less important for the company, although Graphenea has successfully benefitted from several existing support measures in the field (see section 6.2). No information on external support needs could be identified from the interviewed cooperation partners.

6.2. Use of external support

Graphenea has benefitted from several external sources of support, both public and private. Key support mechanisms used by Graphenea include:

- Access to finance. Several public short-term financial support (via Seed Gipuzkoa, a public risk capital company) by the Basque/Provincial Government and NanoGUNE that allowed, in collaboration with private business angels, the initiation of the activities of Graphenea in its start-up phase.
- Support to business cooperation and networking with international partners and to visibility in international markets. The EU Graphene Flagship Initiative was launched in 2013 by the European Commission in collaboration with other public and private agents. This 10-year project with a total budget of €1 billion is the main European initiative intended to take graphene from the realm of academic laboratories into European society. The Graphene Flagship Initiative coordinates over 150 academic and industrial research groups in 23 countries, and has close to 50 associate members, including Graphenea. The Graphene Flagship was, along with the Human Brain Project, the first of the European Commission's Future and Emerging Technology (FET) Flagships, whose mission was to address the big scientific and technological challenges of the age through long-term, multidisciplinary research and development efforts. This initiative has been a key event in the internationalisation process of the company (see sections 2.1. and 3.2.).
- Support to international R&D and innovation activities, through several EU Framework Programmes. As an example, under the Horizon 2020 programme, Graphenea coordinated the project '[GO4APP - Graphene oxide for advanced polymer applications](#)', developed in 2014-2015, and participated in four additional projects as project partner (2D-INK; PANG; GRAPHENECORE1 and GRAMOFON).
- Access to finance for developing R&D premises. In 2015, Graphenea was selected by the Horizon 2020 'SME Instrument' programme of the European Union for the enlargement and growth of its industrial project. The transaction involves an investment of €2.5 million, of which €1.8 million will be provided by the 'SME Instrument' (see section 6.3 for further explanation) and the rest is to be covered by Graphenea.
- Finally, Graphenea has benefitted from several national/regional measures specifically aimed at supporting the internationalisation of the company. The company has participated in several ICEX⁶-supported commercial missions to Japan, providing them with the opportunity to

⁶ ICEX is a public corporation of the Spanish Ministry of Economy and Competitiveness, and intended at supporting the internationalisation of Spanish companies to foster their competitiveness, as well as the attraction of foreign investment to Spain.

publicise themselves in several trade fairs and collective Spanish show-rooms. Also, Graphenea has benefitted from the Basque government ‘[Global Lehian](#)’ support, consisting of non-refundable grants for fostering different internationalisation activities of Basque companies (awareness services for new exporters; assistance and advice, consultancy services on internationalisation issues; organisation and assistance for business meetings/ trade missions/ matching events/ participation in trade fairs and exhibitions; provision of facilities/premises for international businesses).

6.3. Assessment of this external policy support

According to the Graphenea interviewee, the external support measures used by the company have been important for the development of the company. Nevertheless, the interviewee stresses that there are three support measures that have been particularly relevant for Graphenea as they provided the company with key resources (either in terms of access to finance or knowledge and networks) that the company would not have had otherwise at this stage. These measures include the initial short-term financial support provided by the Basque/Provincial government and NanoGUNE that facilitated the initiation of the activities in a moment of uncertainty, and when the positive expectations were not as clear as they are right now. Linked to this, the availability of NanoGUNE has been key to access to state-of-the-art equipment and scientific personnel that, otherwise, Graphenea could have not afforded. Another key support measure for Graphenea has been the Graphene Flagship Initiative, which represented a landmark for the company as it allowed it having access to the community of key European players (universities, research centres and companies) involved in the development of graphene-based applications.

Finally, the interviewee stresses that the recent selection by the Horizon 2020 programme 'SME Instrument' of the European Union has been another landmark for Graphenea. This external financial non-reimbursable contribution of €1.8 million is being used to construct, install and optimise a new production pilot plant of high-quality graphene for industrial applications. This production pilot plant is expected to become operative in late 2017. In this way, Graphenea will multiply production capacity by 200 times, becoming the first producer of graphene for industrial use in Europe (in addition to construction of the production plant, the project is expected to result in the additional hiring of 20 highly skilled jobs in the coming years). This support has been very important for the company as it has accelerated its business development and will allow the company to grow faster and consolidate its position as one of the global leaders in the graphene industry. As a result of this support, Graphenea has opened up a new premise in the San Sebastian Technology Park, where it has located its headquarters and its pilot plant. If this pilot phase plant is successful, Graphenea is expecting to move to an industrial phase that will require a larger future investment.

The other mentioned support measures are regarded as relevant but not key. Referring to the ICEX and Global Lehian measures, the interviewee stresses that the supported internationalisation activities would have been conducted even if the company had not received support. Nevertheless, he positively assesses the received support, which has produced some positive results for the company (for instance, the development of several relevant business contacts in the case of the ICEX measures).

Graphenea does not identify any gaps in the public support structure, in terms of any support needs they encountered that have not been satisfied.

7. Concluding remarks

7.1. Future plans regarding internationalisation and international cooperation

Graphenea is already strongly committed to internationalisation and international cooperation activities, where this commitment is not expected to significantly change in the coming years, in the sense that international markets will remain key in the coming years. For Graphenea, the most important future challenge lies in the mastering of the transition from the current research and prototyping phase to a more industrial phase where more and more products will integrate graphene-based materials and components. This transition will require manufacturing large quantities of high quality graphene, in various formats, and at an affordable price, accordingly to industrial needs. Hence, their strategic focus at this stage of the company development lies on product and production development rather than on distribution and sales (including internationalisation, whereby the latter is considered as ‘a given’ due to the nature of their product). Parallel to this, this transition will result in additional challenges linked to new delivery methods or increasing attention to production costs (particularly energy prices).

For this purpose, opening the new production pilot plant in late 2017 (largely financed by the Horizon 2020 programme ‘SME Instrument’ of the European Union) is expected to be a key landmark in the history of Graphenea as it will become the first producer of graphene for industrial use in Europe, allowing the company to grow faster and consolidate its position as one of the global leaders in the graphene industry.

Notwithstanding these growth plans, the Graphenea interviewee is fully conscious that the company is still small and very exposed to the attention of external investors/larger companies that might be interested in acquiring the company’s manufacturing capacities and know-how. In this sense, he underlines the idea of having a medium/long-term business perspective based on constant innovation and involvement in R&D activities, product competitiveness and service quality.

Finally, Graphenea is strongly committed to its original geographical location, so the company does not contemplate in the near future any relocation of its production and R&D facilities to other more central locations, either in Spain or somewhere else, due to the existing local/regional capacities in their surrounding area.

7.2. Conclusions and lessons learned

This case study has presented the experience of a successful technology-based born global enterprise (Graphenea) specialised in the production of a very innovative and ‘prototype-type’ product (graphene) that is subject to important research activities for the identification of its different properties and possible industrial applications.

International activities have proved important for a company like Graphenea, being reflected not only in the very high share that international sales represent for the company (98%) but also in the very active engagement in technical and R&D cooperation activities with key international players from academia and industry involved in the development of specific graphene formats and graphene-based applications.

This case study also shows that the success of these international value-chain cooperation activities are based on a mixture of pure business considerations (price, product quality or speediness in the delivery) and other ‘soft’ elements such as trust, personal relationships or reliability (of the company and the people). Also, it is worth highlighting the key role that ICT (Internet webpage, e-mails, online store, own blog) and logistics services play in sustaining the cooperation activities between Graphenea and its international partners.

Linked to the previous point, the case study of Graphenea also illustrates that a proactive problem-solving attitude has been key for the company to face possible challenges limiting its engagement in international activities. This attitude was motivated by a perceived higher value of the benefits resulting from cooperation activities as compared to the possible costs related to engaging in such

activities. For some of the analysed companies, external-to-the company obstacles (that is, custom-related administrative difficulties, Brexit) play a more important role than internal ones (that is, small size of the company, geographical location, differences in bargaining positions amongst partners, etc.). On the same line, this case study shows that some internal-to-the company elements (that is, availability of international managerial skills within the enterprise, proactive/growth-oriented attitudes, presence of a qualified and motivated workforce, etc.) are a necessary precondition to engage in international activities.

This case study also shows that one of the main reasons behind the success of the analysed born global lies in the fruitful and balanced combination of scientific excellence (represented by the scientific director and her team) with a sound business understanding (the responsibility of the CEO and the business development director) and reflected in a thorough business plan. In addition to this, this case study exemplifies the key role that an extensive and intelligent use of available external support policy measures (from local/regional, national and international institutions) can have in supporting and underpinning the initiation and consolidation of any new start-up company.

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