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Speciality Chemicals

Source: Eikon Thomson Reuters

Market data

EPIC/TKR	**HAYD**
Price (p)	43
12m High (p)	120
12m Low (p)	41
Shares (m)	27.2
Mkt Cap (£m)	11.7
EV (£m)	7.5
Free Float*	100%
Market	AIM

**As defined by AIM Rule 26*

Description

Haydale is involved in the production and functionalisation of nanomaterials, predominantly graphene and silicon carbide micro-fibres. Europe represents around 21% of sales, the US 55% and the Far East 20%.

Company information

CEO	To be appointed
CFO	Matt Wood
COO	Keith Broadbent
Interim Executive Chairman	David Banks

+44 01269 842946
www.haydale.co.uk

Key shareholders

Lynchwood Nominees	7.8%
Advanced Waste & Water Technology Environ' Ltd *	7.2%
Credit Suisse Group	5.2%
Cheviot Capital	4.5%
Directors	3.4%
Others	71.8%

**Previously Everpower Ltd*

Diary

Dec'18	AGM

Analyst

Paul Singer 020 7194 7622
ps@hardmanandco.com

Haydale

Exuberance, reality; enlightenment now to follow

Haydale is competitively well-positioned within the nanomaterial industry, with a unique patented functionalisation process – currently focused on, but not limited to, graphene. Commercial developments for graphene and silicon carbide are progressing well and, while timings of commensurate news releases may be lagging, the long-term risk/reward balance remains favourable. The shares are attractively valued compared with their peer group, on P/NAV and EV/sales, and also on a DCF basis.

- **Competitive position:** Haydale is competitively well-positioned – a top-quartile status – within the nanomaterial industry, with a unique process for graphene functionalisation, addressing a diverse range of industries and geographies.
- **Strategy:** The group's key strategic objective is now to further accelerate the transition of the business into a sales and marketing organisation from an R&D-focused operation. The group plans to further commercialise its functionalisation process by providing solutions to both raw material producers and industrial corporations, initially in non-regulated markets.
- **Market potential for graphene and functionalised derivatives:** The market potential, while difficult to ascertain, given the barriers and – often – slowness of customer adoption, is still believed to be significant. Currently at around $75m, the global market for raw graphene materials is expected to grow at over 35% p.a., covering a diversity of industries and geographies, attaining $250m by 2025. Commercial traction is evident, but has been limited, owing to the time-consuming nature of customer adoption.
- **Management changes:** Recent senior management changes and expansion, including the appointment of Keith Broadbent as COO, should be deemed positive, and will allow experienced and key personnel to concentrate fully on the principal activities of business development and monetisation of commercial deals.
- **Investment summary:** Commercial traction is good, and the group has entered FY19 with a healthy order book, which was increased post year-end, and cautious optimism. We believe our forecasts are conservative for FY19, with strong growth expected in FY20. The shares have performed poorly recently, largely reflecting the difficulties in revealing the positive commercial news. The risk/reward balance remains favourable on a long-term basis, with net cash at £4.2m, and with additional debt facilities of £1.4m. The shares are attractively valued vs. their peer group, on P/NAV and EV/sales, and also on a DCF basis (see page 24).

Financial summary and valuation

Year-end June (£m)	2017	2018	2019E	2020E
Sales	3.0	3.4	4.0	6.0
Gross profit	2.1	2.0	2.6	4.2
Grant income	0.9	0.8	0.9	0.9
EBITDA	-4.3	-4.9	-4.4	-3.1
Underlying EBIT	-5.0	-5.7	-5.3	-4.0
Reported EBIT	-5.3	-6.0	-5.6	-4.3
Underlying PTP	-5.3	-5.8	-5.2	-3.9
Underlying EPS (p)	-0.3	-22.4	-17.2	-12.8
Statutory EPS (p)	-0.3	-23.7	-18.2	-13.8
Net (debt)/cash	0.8	4.2	-0.2	-3.2
EV/sales (x)	2.8	2.4	2.1	1.4

Source: Hardman & Co Research

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Executive summary

Investment conclusion

Haydale is competitively well-positioned within the graphene industry, with a unique process for the functionalisation of nanomaterials – predominately graphene. The group has received strong endorsement from independent resources, and has strong intellectual property (IP) rights and a very experienced management team. The company is highly respected in the graphene industry, and is seen as one of the market leaders. Commercial traction is healthy, with growth enhanced through collaboration arrangements and deals.

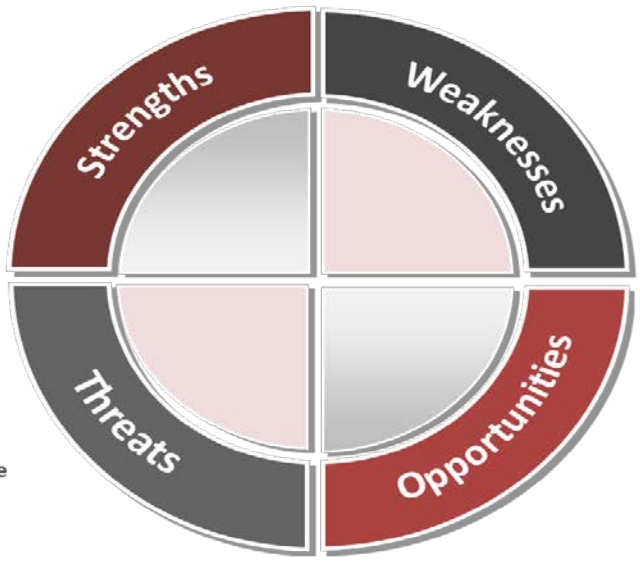
Haydale's shares have performed poorly recently, largely reflecting the difficulties in revealing the positive commercial news. Commercial developments are very positive and, while commensurate news release may be lagging, the risk/reward balance remains favourable on a long-term basis, and we believe the shares are attractively valued compared with their peer group, on P/NAV and EV/sales, and also on a DCF basis.

Strong competitive standing

We believe Haydale has a favourable competitive position, with a functionalisation process that is already capable of producing consistent, commercially viable graphene.

We note that Haydale does not actually produce the graphene that it functionalises. The company sources the appropriate graphene materials in the market place with the correct characterisation according to the quality deemed most suitable to meet the specification required to enhance the customer's existing product or application. This should be regarded as a key competitive strength, and not a weakness.

Competitive standing – SWOT analysis



Strengths
- Company does not produce graphene - only functionalises the product type
- Unique, proven nanomaterial functionalisation process
- Good collaboration traction
- Good product distribution
- Geographically diverse
- Silicon carbide sales provide an underlying revenue base
- Experienced management

Weaknesses
- Industry hype yet to be delivered
- Slow industry adoption of technology
- Recent management changes
- Time delays for revenue recognition

Threats
- Experienced, numerous well-resourced competition in market place
- Industry developing too slowly
- Threat from lower-performance products
- IP leakage
- Cash shortage/unfavourable currency movements
- Brexit uncertainties

Opportunities
- Global and growing market
- Commercial development within existing markets
- Commercial extension into new geographies/high-growth emerging markets
- New product development
- Selected acquisitions/JVs in key markets

Source: Hardman & Co Research

Strategic thrust

New product development, new market entry

The group is now focused on growing its sales through product commercialisation in its key chosen markets of composites, elastomers, ceramics, and speciality inks and coatings. Commercial agreements and collaborations are already in place and the thrust now is to further concentrate sales efforts and target customers who typically operate internationally across a variety of sectors. The group has a diverse portfolio of collaborations across a wide range of industries and geographies.

Although the absolute number of agreements announced by Haydale may not be as high compared with some of its peers, we note that not many of the industry-wide agreements reveal details on timing, value and volumes of material used. Haydale has delivered sales of graphene-related products and services of more than £1.0m in FY19, which we believe to be significantly ahead of its peers. Consequently, we believe that commercial traction is good and compares favourably with the other leading industry players.

Evolution into three regional performance reporting areas

The setting up of two strategic business units (SBUs) from July 2017 delivered success and ensured growth in all areas of the global business. However, the dynamic nature of the industries has necessitated an evolution in this approach. Consequently, FY19 will see the three regional areas – the USA, the UK (and Europe) and the Far East – being brought together as a team under the newly created position of the group's Chief Operating Officer (COO).

This change is aimed at facilitating greater cross-selling and accountability across the group. Success has already been seen, with commercial activities on coatings with silicon carbide (SiC) now starting in the UK, and graphene initiatives being targeted with major players in the US. Furthermore, the combination of ink expertise in the UK with that in the Taiwan facility is bearing fruit on the technology side.

Fundamental prospects

Market potential for nanomaterials and graphene significant

The market potential for graphene, while difficult to ascertain given the current barriers and slowness of customer adoption, is believed to be significant. Currently at around $75m, the market for graphene is expected to grow at over 35% p.a., covering a diversity of industries and geographies, and attaining $250m by 2025. Commercial traction is evident but has been limited owing to the time-consuming nature of customer industry adoption.

Growth driven by collaborations

Growth at Haydale is driven primarily by the degree at which its solution-based technologies will gain significant commercial traction. Industries' adoption of products with enhanced physical properties will take time. Commercial deals are in place, including collaborations with Huntsman and Graphit Krofmühl and several other unnamed (for confidentiality reasons) industrial concerns. Around 38% of SiC sales depend upon one customer, with a further 10% accountable to a second customer.

Most recently, Haydale has developed and extended a previously announced four-year agreement to supply SiC micro-fibre to a global group selling tooling and wear-resistant solutions. This new sole supply agreement has a potential sales value of more than $3.3m over a now five-year term. The agreement represents an increase of $1.35m in the HCT order book value, which now stands at $5.46m.

Furthermore, having only commenced supply in October 2017, Haydale has recently received a purchase-order moving from a monthly order to a three-month supply of SiC by a global paint and coatings company for its anti-corrosion product. This

contract, worth over $0.1m per quarter, represents a 33% increase on previous monthly purchase orders. Further product testing is being carried out on a second industrial application, where expected positive results will lead to a second product launch, such that order values should continue to rise in the near future.

Management changes

Recent senior management changes – positive

Recent senior management changes and expansion, including the Board of Directors appointment of Keith Broadbent as Chief Operating Officer, should be deemed as positive. They will allow experienced and key personnel to fully concentrate on the principal activities of business development, and monetisation of commercial deals with personnel across the group working with greater cross-selling and accountability.

Trading updates

Trading update cautiously optimistic

The group's recent trading update continues to view medium-term prospects for improved performance: "We enter FY19 with cautious optimism. The recently announced five-year SiC contract extension with an existing cutting tool customer has provided even more sales visibility for our US operation and our steadily increasing graphene ink sales to several print houses for the bio-medical sensor market is an encouraging start to the financial year.

We are delighted to be a Tier-1 partner to the new Graphene Engineering Innovation Centre (GEIC) at the University of Manchester, where we will install and showcase one of our HT60 plasma reactors. The enhanced functionalisation now being generated from upgrades we have made to the reactor makes for exciting product improvement opportunities for the myriad of companies now looking at collaborating with the GEIC and its Tier-1 Graphene partners. The facility officially opens in December 2018.

There are significant growth opportunities with the new and adapted approach of using our global footprint as one team, with cross-selling and cross R&D focus, and a re-orientation to organic growth and cost monitoring. Business development surrounding the major advances we have seen in the core skills on inks, functionalisation and dispersion of graphene, in conjunction with the new market segment of SiC, sets Haydale up for the next phase of evolution and scale up… "

Finances

Results for 2017/18 reflect challenging operating environment

2017/18 total income was as previously indicated, with commercial revenues (excluding grant income) up 15% to £3.4m from the £3.0m generated in 2016/17. The gross margin for the year was 59%, with a similar margin in both interim periods. Loss before taxation was £6.1m, with net cash at 31 June 2018 of £4.2m.

Order book healthy, reduction in losses in 2018/19

The group's order book is healthy, standing at £5.19m as at 10 September 2018, compared with £4.67m at the end of FY18. Our forecasts, which we believe to be conservative, suggest around 25% p.a. group sales growth over the medium term, as the group continues to benefit from cross-selling opportunities. Loss before taxation should be around £5.5m in 2018/19, on our estimates. The group's cash position will decline from £4.2m, but we note that the company has debt facilities of £1.4m to utilise.

Risks

Product acceptance and competition developments

There are a number of potential risks and uncertainties that could have a material impact on the group's performance: the global macroeconomic environment; product acceptance; the ability to fully develop, scale up and commercialise the product; competition developments with the industry; the emergence of as yet unseen and improved technologies; foreign currency fluctuations; specific market deterioration and production failures; obtaining and retaining key skilled personnel. Overall, we are confident that management is taking appropriate action to mitigate these risks.

Valuation

Shares appear undervalued

Given the embryonic state of the graphene industry and Haydale itself, conventional valuation methodologies are not that appropriate and, furthermore, there are few quoted competitors that could be considered as comparative companies for valuation purposes. Accordingly, we consider only P/NAV and EV/Sales, with both metrics suggesting an undervaluation compared with the peer group.

DCF valuation suggests significant undervaluation

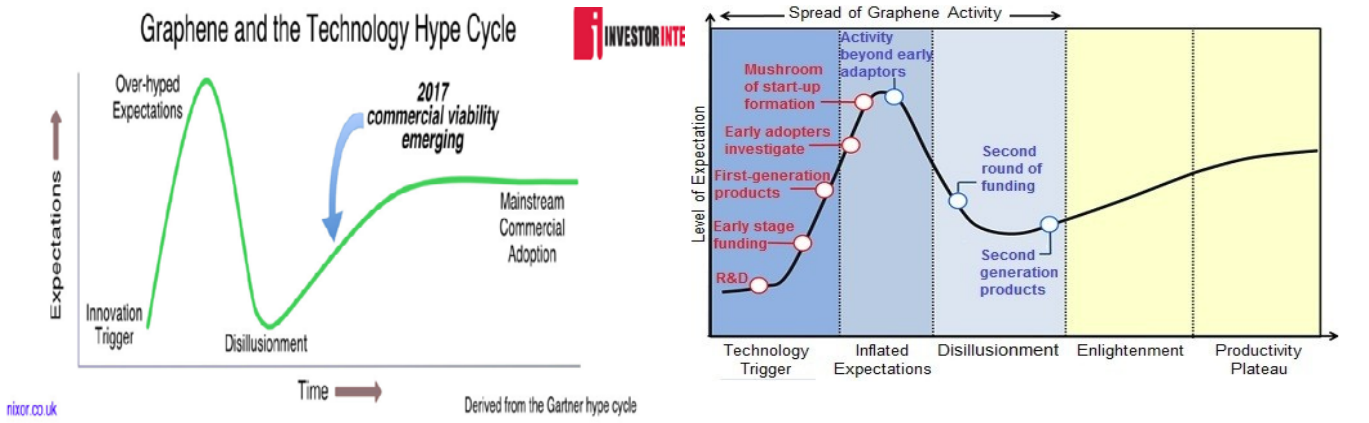
A DCF valuation methodology, using a WACC of 10%, also suggests that the shares are undervalued. See more detailed valuation section on page 24.

Share price performance

Shares now entering the enlightenment phase

Haydale's shares have performed very similarly to the performance experienced by many emerging technology companies. After the technology trigger and inflated expectations for the technology, a period of disillusionment sets in, largely reflecting the difficulties of industry and market adoption.

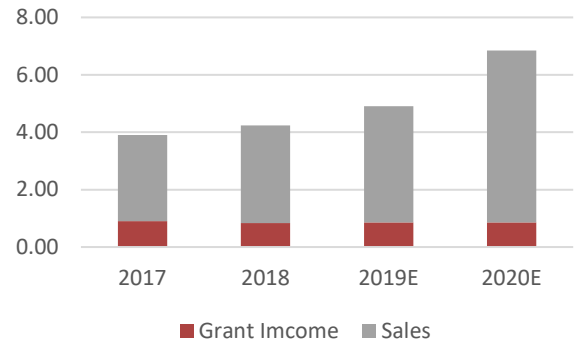
The Graphene Technology hype cycle



Source: Gartner, Hardman & Co Research

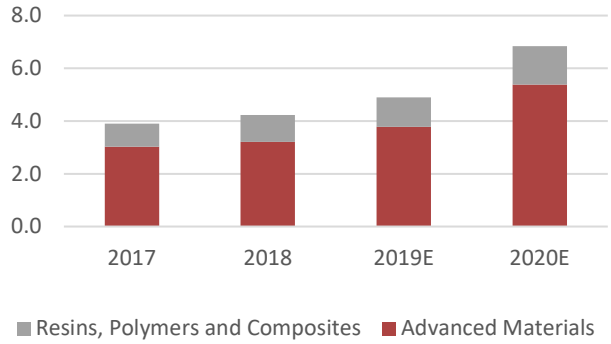
We have certainly seen this disillusionment period for Haydale's shares, and we are now confident that full commercial viability will emerge with mainstream market adoption, and that Haydale shares will benefit as the company consolidates through its enlightenment phase.

Total income (£m)



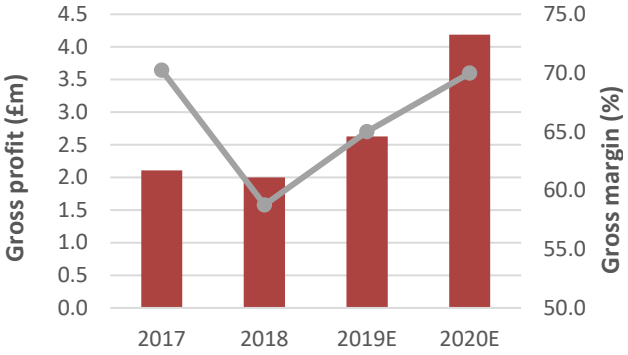
- Company forward order book at 10/08/18 stood at £5.2m (£4.7m at 31/06/18), providing good visibility on future income. Commercial revenues attained £3.4m in 2017/18 and are set to grow at 20% in 2018/19 and over 50% in 2019/20, reflecting the healthy order book and new commercial agreements.
- Grant income should be maintained at £0.86m p.a. over the medium term.

Sales by SBU – 2017/18 basis (£m)



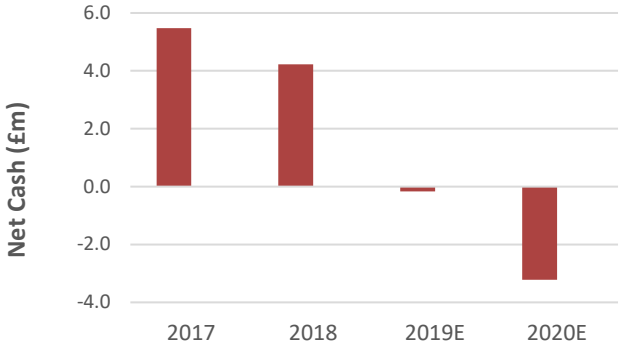
- SBU (2017/18 basis) revenue forecasts are driven by growth in Advanced Materials (AMAT) – the SiC business. The SiC business has an order book of around £4.15m. We are forecasting just over 20% revenue growth in 2018/19, accelerating thereafter, reflecting the new contract that HCT secured and the marketing of cutting tool blanks.
- The Resins, Polymers and Composites (RPC) business growth was more modest, at around 15% for 2017/18. Growth in 2018/19 will be around 10%, accelerating to over 20% in 2019/20, reflecting new grant wins.

Gross profit and gross margin



- The gross margin declined in 2017/18 to 59%, compared with historical levels of 70%, reflecting changes in product mix sales from the group's US operations, as it looked to expand into other markets. The AMAT segment reported margins of 60% (90% FY17) and RPC 45% (26% in FY17).
- Medium-term margin assumptions are based on group gross margin levels of around 65%, largely reflecting sales of the high-margin SiC-cutting tool blanks product.

Net cash



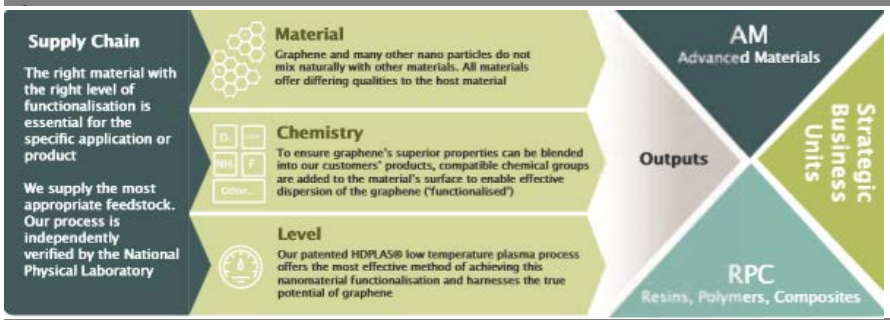
- The group had a net cash position at 30 June 2018 of £4.2m (£7.0m at December 2017), reflecting the share Placing and Offer in October 2017 of £9.3m (before expenses).
- The group will just be in a net debt position in 2018/19.
- In October 2016, a five-year bank loan of $1.72m (£1.4m) was drawn, secured on its US fixed assets. This loan carries an interest rate of 4% and is repayable in equal instalments. Haydale can draw on this as required, and will probably do so in 2018/19.

Source: Company data, Hardman & Co Research

The company

Haydale is a global technologies group that uses advanced materials – nanomaterials (including graphene and SiC) – to enhance the quality and performance of its customers' existing materials and products.

The company



Source: Company reports, Hardman & Co Research

Haydale works on functionalising graphene using its HDPlas™ process

The group's current focus is the addition of functionalised graphenes within resin and composite materials, as well as graphene-based inks and coatings to deliver improvements in electrical, thermal and mechanical properties, in addition to toughness. Such products can be used in smart packaging, printed batteries, electrochemical sensors, flexible displays and, potentially, touch screens.

The company has a solid supply chain, with a global presence not only in European markets, but also in Asian and American markets, where 11 Haydale-patented plasma reactors are now deployed, operating from six sites, with another reactor to be sited in the GEIC in Manchester by the end of 1H FY19. Haydale currently has almost 80 staff worldwide.

Haydale – global operations

Source: Company reports, Hardman & Co Research

Haydale now has routes to geographical markets, with a range of novel speciality performance-enhancing nanomaterials and products to add to its product portfolio and graphene expertise.

Crucially, the group now has the capabilities to combine its graphene and other nanomaterials and produce hybrid 'masterbatches'. We see this as the optimal way to significantly improve end-product performance, without crucially changing downstream customer processing, and overcome the industry's reluctance to handle powders.

HDPlas™ process

Graphene and many other nanoparticles do not mix naturally with other materials. To ensure that its superior properties can be blended into customers' products, graphene needs to be 'functionalised' – compatible chemical groups are added to the material's surface and ends to enable effective exfoliation and subsequent homogenous dispersion of the graphene.

It is essential to source the right material with the right level of functionalisation for the specific application or product. Markets have often struggled with impure materials or the wrong surface chemistry.

Haydale's *HDPlas®* low-temperature plasma process offers the most effective method of achieving this nanomaterial functionalisation and harnesses the true potential of graphene to make materials better than ever before. The technology provides a rapid and highly cost-efficient method of supplying tailored solutions to both raw material suppliers and product manufacturers. Haydale supplies the most appropriate feedstock, and the process has been independently verified by the National Physical Laboratory in the UK.

Many advantages

The process's key advantages include the following:

- **Enhanced surface engineering**: The functionalisation process allows the addition of specific chemical groups, which provides greater dispersion and compatibility between different matrices and nanomaterials. It can also remove non-crystalline structures (impurities) from the host material.

- **No acid treatment:** The process does not utilise chemical acid treatments, which adds processing steps that often cause damage and can degrade the functional performance, structural integrity and mechanical strength of the final product, while adding significant costs.

- **Relevant and adaptable for all markets:** The process can be adopted across a multitude of target markets, such as inks and coatings, polymers and composites, energy, electronics, transport, and an endless list of consumer product markets. Each of these require different material specifications, performance and cost targets for specific applications.

- **Advantaged feedstocks**: Haydale's reactors are able to process many types of 'graphene', each defined by a different set of properties depending on form, average flake size, number of layers and the chemical groups existing on the flake surface.

Functionalisation increased to include amines in 2017

During 2017, Haydale completed several key research and development projects to enhance its capabilities and product offerings. It made significant investments into capital equipment, leveraged its team's knowledge base to enhance the HT60 plasma reactors' performance, and yielded increased functionalisation levels to improve the concentration of bonded functional groups. The ability to now offer enhanced functionalisation, including amines, means functionalisation levels can be tailored to further improve the dispersion characteristics of nanomaterials in a wider range of matrices. This has resulted in some significant graphene-related sales contracts being secured and delivered.

Haydale has also been working with its key OEM, to plan and design the next generation of HDPlas™ reactors, which will provide the ability to meet commercial volumes.

Following the sale of an HT60 reactor to the Centre for Process Innovation (CPI) in 2015, CPI continues to assist Haydale to be at the forefront of graphene-enhanced development in a range of applications. Haydale and CPI have developed filter technology for oil/water separation, desalination and industrial waste water, the evaluation of which will continue during the current financial year.

The businesses

Two SBUs established in 2017

In July 2017, the group established two sales-oriented SBUs: Advanced Materials (AMAT) and Resins, Polymers and Composites (RPC).

AMAT

AMAT focuses on two business areas – ceramics and coatings & ink.

Ceramics, manufactured in the US, is focused on marketing several products around its ability to manufacture SiC micro-fibres. SiC is the hardest ceramic material. It has excellent thermal conductivity and low thermal expansion, and is very resistant to acids. SiC micro-fibre is a very high modulus rigid rod nanotube, which is unbreakable at supplied lengths. It is used in high-performance ceramic cutting tools and wear parts to dramatically enhance fracture toughness, abrasion and wear resistance, as well as dimensional stability. Applications for SiC include scratch-resistant cookware, corrosion barriers for oil and gas pipelines, and cutting tools that manufacture, for example, jet engine turbine blades from solid super alloy billets.

AMAT also includes the newly developed functional inks and pastes business. The group has developed regulatory approved proprietary graphene-based coatings & ink for the print and biomedical sensor markets. The business is initially targeting the $15bn self-monitoring blood glucose device market, of which the supply of ink is estimated to be over $500m alone and, crucially for Haydale, centred around Taiwan, Korea, China and Japan.

RPC

RPC focuses on marketing and selling newly developed graphene-infused carbon-fibre pre-impregnated materials (pre-preg) for a wide range of composite types across many industrial sectors, including **thermoplastics**, e.g. Reinforced Thermoplastic Pipes (RTP) and **thermosets**, e.g. Carbon Fibre and Glass-fibre Reinforced Plastics (GRP).

By adding graphene nanomaterials, these pre-pregs will increase the strength and compression after the impact performance of carbon-fibre reinforced epoxy components. Applications include aerospace, automotive and sports goods, such as bicycle frames and racing boats.

Recent strategic developments

The setting up of two SBUs from July 2017 delivered success and ensured growth in all areas of the global business. However, the dynamic nature of the industries has necessitated an evolution in this approach and demonstrates the company's ability to adapt quickly to changing environments. Consequently, FY19 will see the three regional areas of the USA, the UK (and Europe) and the Far East being brought together as a team under the newly created position of the group's COO.

This change is aimed to facilitate greater cross-selling and accountability across the group. Success has already been seen, with commercial activities on coatings with SiC now in progress in the UK, and graphene initiatives being targeted with major players in the US. Furthermore, the combination of ink expertise in the UK with that in the Taiwan facility is bearing fruit on the technology side.

Key products/markets served

Nanomaterial additives – Aerospace and Automotive industries important

Haydale's product portfolio focuses on developing nanomaterial "additives" that will enhance the quality and performance of traditional products and applications across a wide range of industries. Currently, the most important are the aerospace, automotive printing and cookware industries.

Composites

In the composites area, Haydale has a wide and new range of composite products, including thermoplastics, e.g. Reinforced Thermoplastic Pipes (RTP), and thermosets, e.g. Carbon Fibre and Glass-fibre Reinforced Plastics (GRP).

Applications in the $100bn composite market include aerospace, automotive and sports goods such as bicycle frames and racing boats. Within carbon-fibre composites, Haydale has developed a range of graphene-enhanced carbon-fibre pre-pregs, which deliver improved mechanical, electrical and thermal properties. These materials are the basis for customers to develop cost-effective, tailored carbon-fibre composite pre-pregs for volume manufacture.

In the aerospace industry, collaborating with industrial leaders Airbus, GKN and Cobham, Haydale has developed an electrically conductive carbon-fibre pre-preg that potentially makes aeroplanes, drones and marine structures more resistant to lightning strikes. Furthermore, Haydale has improved the pre-preg's thermal conductivity, thereby increasing manufacturing throughput – an industry-wide issue.

Within the automotive industry, working with BAC Mono, and using graphene in the wheel arches and diffuser body panels of the single seater Mono supercar, has improved mechanical performance and consequent weight reduction. Haydale and BAC are now entering into a technical and commercial partnership agreement, with the aim to further develop and commercialise the use of graphene and other nanomaterials in this performance vehicle.

Printing products

Printing using conductive inks based on Haydale's own graphene formulations opens up major technical innovation and commercial opportunities in electronics, sensors, optical systems and many other areas.

Haydale manufactures products using advanced materials through 3D printing. Graphene-enhanced polylactic acid (PLA) for 3D printing potentially offers benefits, such as excellent first-layer adhesion and increases in the speed of processing (improved strength, stiffness and impact performance), good print quality and surface finish, compatibility with a broad range of printers, and ease of use.

The mechanical, electrical and thermal properties of graphene-enhanced PLA filaments can be tailored to meet the needs of different applications and markets. A range of other graphene-enhanced engineering grade materials for 3D printing are planned to be launched in the future.

SiC materials

SiC materials have a wide range of applicability, from high-performance cutting tools to protective coatings, as well as ceramic and metal matrix composites.

Products include the following:

- **Ceramic cutting tools:** SiC whisker reinforces aluminium oxide to make the hardest cutting tool outside of diamond.

- **Technical ceramics:** Ceramic parts reinforced with SiC excel in operating environments requiring very high temperature stability, fracture resistance, wear resistance and resistance to chemicals.

- **Protective coatings:** The range of SiC materials toughens protective coatings, increasing abrasion and scratch resistance, enhancing thermal conductivity and stability, and extending service life. Applications include non-stick cookware coatings, industrial fluoropolymer coatings, epoxy piping coatings, anti-corrosion for the oil and gas industry and ceramic coatings.

- **Ceramic and metal matrix coatings:** SiC fibre is used as a reinforcement for a variety of ceramic and metal matrix composites, to enhance structural and thermal properties. Within the cookware industry, SiC additives have a unique combination of properties that make them exceptional in scratch-resistant, non-stick cookware coatings.

Competitive strategy

Key strategic objective: accelerate transition of business into sales and marketing organisation

Following strategic acquisitions in 2016, the group has moved from being an R&D-focused business to a business now focused on sales growth through product commercialisation. The group's key strategic objective is to accelerate the transition of the business into a sales and marketing organisation.

While there are multiple companies exploring the commercialisation of graphene, we believe Haydale has a favourable competitive position, with a functionalisation process that is already capable of producing consistent, commercially viable graphene.

We note that Haydale does not actually produce the graphene that it functionalises. The company secures the graphene in the market place according to the quality deemed most apt to produce the functionalised end-product most suitable to enhance the customer's product/material. This should be regarded a key competitive strength.

Competitive standing

	Graphene producer	Key markets	Regions
Haydale	No	Inks, Composites	UK, N.Am, Asia
Applied Graphene	Yes	Coatings, Inks, Composites	UK
Directa Plus	Yes	Textiles	Europe
Versarien	Yes	Composites	UK/Fast East
First Graphene	Yes	Electronics	Far East
Graphene 3D Lab Inc	Yes	Plastics, Composites	N.Am
NanoXplore	Yes	Plastics, Composites	N.Am, Europe
St Jean Carbon	Yes	Diverse with Graphenea	N.Am
Talga Resources	Yes	Diverse	Far East
Vorbeck	No	Electronics	N.Am

Source: Hardman & Co Research

The global graphene industry is significantly fragmented, with many of the industry players striving to solidify their market positions through commercial agreements and collaborations, mergers & acquisitions, and expanding their product portfolios. We expect Haydale to remain an active player.

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Commercial opportunities

Partnerships, collaborations and commercial arrangements with leading global companies:

Haydale has engaged in a number of partnerships, collaborations and other commercial arrangements with leading global companies in its chosen market sectors. These include Huntsman, Graphit Krofmühl and Amiantit/Amiblu.

Huntsman

Haydale continues to work with Huntsman Advanced Materials (Huntsman), a world-leading resin company, to develop graphene-enhanced resins such as Huntsman's market-leading epoxy resin Araldite® in key high-end composite markets, such as Aerospace and Space, focusing initially on thermal conductivity enhancement.

GK

Haydale has an agreement with Graphit Krofmühl (GK), now known as AMG Mining and part of AMG Advanced Metallurgical Group N.V. The collaboration is on the development of new value-added nanomaterial products using the HDPlas® functionalisation process and GK graphitic feedstock material.

As part of the agreement, GK has purchased one R&D reactor (HT60) and one larger capacity reactor (HT200) for use in new R&D and scale-up programmes. GK will also be the 'industrialisation' partner for the commercial volumes of graphene-enhanced resin materials once collaborations become more commercial. These reactors will form the basis for the processing of commercial volumes of material as part of the Haydale supply chain.

Amiantit/Amiblu

Haydale has a joint development agreement with Flowtite Technology AS, the 100%-owned GRP pipe technology subsidiary of Amiantit (which subsequently merged with EU-based Hobas to form Amiblu); it is one of the world's largest GRP pipe companies. The programme is focused on developing the next-generation GRP pipe systems for water and sewerage applications, but the results trial in March did not show the improvements Haydale had hoped for. However, despite Amiblu's internal management changes, arising from the merger, the group is continuing its discussions with the Amiblu R&D team, with a meeting planned in the fourth quarter to discuss next steps.

Haydale also has a number of research collaborations with leading research institutions in the UK. These include The Centre for Process Innovation, National Graphene Institute, The UK Nanosafety Group and The Welsh Centre for Printing and Coating.

CPI

The Centre for Process Innovation (CPI) is a UK-based technology innovation centre. CPI collaborates with universities, SMEs and large corporates to help overcome innovation challenges and develop next-generation products and processes. CPI has purchased a Haydale HT60 plasma reactor for processing graphene and other nanomaterials used in moving development projects to commercial applications.

NGI

The National Graphene Institute (NGI) is the national centre for graphene research in the UK. Haydale has partnered with NGI for the opportunity to work in collaboration with world-leading academics and hundreds of researchers.

The UK Nanosafety Group

The UK Nanosafety Group brings together key experts in the field of nanotechnology and helps to establish links with others working in this rapidly developing field. A core aim of the group is to assist research establishments and academia establishments with their legal obligations with regard to occupational health and safety, and to provide guidance to support improvements to health and safety systems when working with nanomaterials.

WCPC

Haydale collaborates with Swansea University's Welsh Centre for Printing and Coating (WCPC), one of the world's leading centres for research and development in printing, inks and coatings. WCPC is undertaking research and development at the forefront of the fundamental chemistry of nanomaterials, which is feeding directly into Haydale to form the technical basis of many commercial products. This partnership will provide Haydale with a dedicated ink and coating service capability; it will also assist the group in the development and commercialisation of inks and coatings into a wide range of applications.

Haydale now a partner with GEIC

Haydale has recently been selected as one of the core Tier-1 partners of the University of Manchester's recently completed £60m Graphene Engineering Innovation Centre (GEIC).

Haydale will install and commission one of its HT60 plasma reactors into the new facility in Manchester, which functionalises and improves dispersion of graphene and other 2D materials.

The GEIC is expected to be a world centre of excellence for research into commercial graphene applications. As a Tier-1 partner, and with an installed patented plasma reactor, Haydale's technology and people will be closely integrated with this research, and will collaborate to expand the commercial opportunities in graphene.

This collaboration will help develop further functionalisation and applications knowledge across a range of graphene and other 2D materials. It will also add value to potential and existing business partners looking for application-specific enhancements in improving performance across a range of products.

Haydale supplies graphene for world's first graphene skinned plane

Haydale announced, on 1 August 2018, that it had supplied graphene-enhanced pre-preg material for Juno, a three-metre-wide graphene-enhanced composite skinned aircraft, which was revealed as part of the 'Futures Day' at Farnborough Air Show.

The pre-preg material, developed by Haydale, has potential value for fuselage and wing surfaces in larger-scale aero and space applications, especially for the rapidly expanding drone market and, in the longer term, the commercial aerospace sector.

By incorporating functionalised nanoparticles into epoxy resins, the electrical conductivity of fibre-reinforced composites has been improved significantly for lightning-strike protection, thereby achieving a substantial weight savings and removing some manufacturing complexities. It additionally offers de-icing capabilities.

The Juno project, led by UCLAN, has been an ideal demonstration for the viability of the pre-preg material for structural applications and the ability to manufacture components using traditional composite manufacturing methods. Further developments are under way to produce the next iteration of lightning strike protection materials based on these nano carbon-enhanced pre-pregs.

This technology also has performance benefits for a wide range of applications and industries, including large offshore wind turbines, marine, oil and gas, and electronics and control systems.

Haydale has also been involved in developing the unmanned aerial vehicle

Haydale has also worked with the aerospace engineering team at the University of Central Lancashire, Sheffield Advanced Manufacturing Research Centre and the University of Manchester's National Graphene Institute to develop the unmanned aerial vehicle, which also includes graphene batteries and 3D printed parts.

This announcement has highlighted the capability and benefit of using graphene correctly dispersed into composite materials to meet key issues faced by the aerospace industry, such as reducing weight to increase range, defeating lightning strikes and protecting aircraft skins against ice build-up.

Haydale has announced a contract with EIS

Again recently, Haydale has announced a contract with the English Institute for Sport (EIS) on wearable technologies for the 2020 Olympic and Paralympic Games. This follows work on inks over the past year that has been focused on the commercialisation of the patented pressure sensors and graphene-based screen-printable inks. Over the next 12 months, Haydale will continue to focus on bringing innovative and novel printed solutions to the market, and it has invested in a sales team to realise this potential.

Non-regulated markets, such as sporting goods, provide potentially significant short-term revenue opportunities for Haydale. An example of this has been the supply during the year of graphene-enhanced carbon-fibre pre-preg to a high-specification bespoke UK bicycle manufacturer, which has met with some success.

Financial summary

The group's three principal areas of income are currently (i) graphene-enhanced and advanced composite consulting services, (ii) sale of SiC whiskers and fibres, and (iii) long-term graphene-related grant-funded projects.

The group changed its internal reporting system from 1 July 2018 to set up three profit-centric SBUs known as "RPC", "AMAT" & "APAC". For the current financial year and beyond, the group intends to report sales and profits under these three SBUs.

The loss before tax for the year was £6.12m (FY17: £5.64m loss)

The group's total income for the year ended 30 June 2018 (FY18) of £4.23m comprised commercial revenues of £3.40m and grant income of £0.83m. Income in the second half of FY18 suffered from a combination of specific customers requesting to defer shipments of products into the current financial year and longer-than-anticipated lead times by customers to reach commercial volumes – the latter being a common factor across the industry.

The RPC segment increased its commercial revenues in the year to £1.02m, from £0.87m in FY17, while AMAT's revenue increased to £2.39m, from £2.13m in the prior year. RPC's revenues include those generated by the three UK entities, whereas the revenue from AMAT is derived from the group's operations in the US and the Far East.

Importantly, Haydale has stated that it generated more than £1.0m of income from sales of graphene-related products and services in FY18, a figure that we believe is comfortably ahead of its peers.

The group's gross profit (excluding grant-funded project income) was £2.0m, with a gross profit margin of 59% (FY17: 70%). The reduction in the margin was due primarily to a different sales mix from the group's US operations, as it looked to expand the markets for its products.

Total administrative costs increased by around 6% in the year to £8.85m (FY17: £8.35m). Overall R&D spend for the year was £1.05m (FY17: £1.15m), of which £0.88m was expensed during the year. The group's other administrative costs for the year totalled £7.68m (FY17: £7.09m), the increase reflecting the investment in the Far East operations during the year, specifically in Taiwan, and an increase in headcount across the group to 79 (FY17: 70). Overall, the loss before tax for the year was £6.12m (FY17: £5.64m loss).

Order book at 10 September 2018 stood at £5.19m

At the year-end, the group's contracted order book stood at £4.64m (FY17: £5.40m) and, since the year-end, additional long-term orders have been secured, resulting in an order book as at 10 September 2018 of £5.19m, to be delivered over the medium term.

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Profit & Loss

- **Forecast sales:** We forecast underlying growth in the range 20%-25% for 2018/19. For 2017/18, we understand that, already, around 55% of yearly forecast sales have been secured.

- **Gross margin:** The gross margin declined in 2017/18 to 59%, compared with historical levels of 70%, reflecting changes in product mix sales. Our 2018/19 margin assumptions are based on gross margin levels of around 65%, largely reflecting the sales of high-margin SiC products.

- **Grant income**: Grant income should be maintained at £0.86m p.a. over the medium term.

- **Administrative expenses:** These amounted to around £7.7m in 2017/18. Our forecasts, reflecting a tight control of costs, suggest around £8.0m for 2018/19, with small increases over the medium term. R&D expenditure amounted to £0.9m in 2017/18. We see this level of expenditure continuing over the medium term.

- **Tax losses:** The group has tax losses that are available indefinitely for offset against the future taxable profits of the company, amounting to ca.£15.8m. The group currently expects to be able to utilise its US tax losses in the foreseeable future.

Profit & Loss				
Year-end June (£m)	**2017**	**2018**	**2019E**	**2020E**
Sales	**3.00**	**3.40**	**4.04**	**5.98**
COGS	-0.89	-1.40	-1.41	-1.80
Gross profit	**2.11**	**2.00**	**2.63**	**4.19**
Gross margin	**70.2%**	**58.8%**	**65.0%**	**70.0%**
Other (Grant) income	**0.90**	**0.83**	**0.86**	**0.86**
Sales & marketing	0.00	0.00	0.00	0.00
Admin. expenses	-7.09	-7.68	-7.91	-8.15
EBITDA	**-4.27**	**-4.91**	**-4.41**	**-3.08**
Deprec. & Amort.	-0.72	-0.82	-0.90	-0.90
Licensing/Royalties	0.00	0.00	0.00	0.00
Underlying EBIT	**-4.99**	**-5.73**	**-5.31**	**-3.98**
Share-based costs	-0.35	-0.29	-0.29	-0.29
Exceptional items	0.00	0.00	0.00	0.00
Statutory operating profit	**-5.34**	**-6.02**	**-5.60**	**-4.27**
Net financials	-0.30	-0.10	0.12	0.12
Pre-tax profit	**-5.28**	**-5.83**	**-5.19**	**-3.86**
Reported pre-tax	**-5.64**	**-6.12**	**-5.48**	**-4.15**
Tax payable/receivable	0.88	0.85	0.52	0.39
Underlying net income	**-4.40**	**-4.98**	**-4.67**	**-3.48**
Statutory net income	**-4.75**	**-5.27**	**-4.96**	**-3.77**
Underlying basic EPS (p)	**-0.26**	**-22.4**	**-17.2**	**-12.8**
Statutory basic EPS (p)	-0.28	-23.7	-18.2	-13.8
U/l fully-diluted EPS (p)	**-0.26**	**-22.4**	**-17.2**	**-12.8**
Stat. fully-diluted EPS (p)	-0.28	-23.7	-18.2	-13.8
DPS (p)	0.0	0.0	0.0	0.0

Source: Hardman & Co Research

Balance sheet

- **Net cash:** At the end of June 2018, net cash stood at around £4.2m, compared with £0.8m at end-June 2017 and £8.0m at end-December 2017.
- **Cash position:** The cash position reflects the share Placing and Offer in October 2017 of £9.3m (before expenses). The group will see a declining cash position in 2018/19, moving into debt in 2019/20.
- **Debt facilities:** The company expects to be able to increase debt facilities once its new SiC blanks business is up and running in Q3'18/19, secured against the new fixed-asset equipment acquired in order to increase the group's cash balances in 2018/19.

Balance sheet

@ 30 June (£m)	2017	2018	2019E	2020E
Shareholders' funds	8.9	12.5	7.9	4.4
Cumulated goodwill	0.0	0.0	0.0	0.0
Total equity	8.9	12.5	7.9	4.4
Share capital	0.4	0.5	0.5	0.5
Reserves	8.5	12.0	7.3	3.8
Provisions/liabilities	0.0	0.0	0.0	0.0
Deferred tax	0.6	0.1	0.1	0.1
Long-term debt	0.4	0.3	0.3	0.3
Short-term loans	0.9	0.6	0.6	0.6
less: Cash	2.1	5.1	0.7	-2.3
less: Deposits	0.0	0.0	0.0	0.0
Invested capital	**8.6**	**8.5**	**8.2**	**7.7**
Fixed assets	5.1	5.1	5.0	4.8
Intangible assets	2.2	2.1	2.0	1.8
Goodwill	2.1	2.1	2.1	2.1
Inventories	1.2	1.0	1.1	1.2
Trade debtors	*0.8*	*0.7*	*0.7*	*0.8*
Other debtors	*0.5*	*0.4*	*0.4*	*0.4*
Tax credit/liability	*0.3*	*0.5*	*0.5*	*0.5*
Trade creditors	*-2.3*	*-2.2*	*-2.3*	*-2.4*
Other creditors	*-1.2*	*-1.2*	*-1.3*	*-1.3*
Debtors less creditors	-1.9	-1.8	-2.1	-2.1
Invested capital	**8.6**	**8.5**	**8.2**	**7.7**
Net debt	**-0.8**	**-4.2**	**0.2**	**3.2**

Source: Hardman & Co Research

Cashflow

- **Cash flow from operating activities:** Haydale's net cash outflow from operating activities for the year was £6.1m (2017: £5.6m), the principal contributing factor being the loss from operations activities of £6.0m (2017: £5.34m).
- **Capital equipment expenditure:** Expenditure on capital equipment utilised a significant portion of cash during the year, at £0.72m (2016: £0.42m).
- **Future capital expenditure:** Future capital expenditure is in the region of £0.7m in 2018/19E, and no dividend is forecast to be paid in the medium term,
- **Five-year bank loan:** In October 2016, a five-year bank loan of $1.72m (£1.4m) was drawn by Haydale Technologies Inc (HTI), the company's US holding company subsidiary, secured on the fixed assets of HTI and its newly acquired operating subsidiary, Advanced Composite Materials. Haydale expects to draw on this as required.

Cashflow

Year-end June (£m)	2017	2018	2019E	2020E
Trading profit	**-5.0**	**-5.73**	**-5.3**	**-4.0**
Depreciation	0.6	0.65	0.8	0.8
Amortisation	0.2	0.15	0.2	0.2
Working capital	1.4	0.16	0.0	0.0
Other	0.0	0.00	0.0	0.0
Company op. cashflow	**-2.8**	**-4.78**	**-4.4**	**-3.1**
Net interest	0.3	-0.1	0.1	0.1
Tax paid/received	0.4	0.9	0.7	0.4
Operational cashflow	**-2.1**	**-4.0**	**-3.6**	**-2.6**
Capital expenditure	-0.4	-0.7	-0.7	-0.5
Sale of fixed assets	0.0	0.0	0.0	0.0
Free cashflow	**-2.5**	**-4.7**	**-4.4**	**-3.1**
Dividends	0.0	0.0	0.0	0.0
Acquisitions	-0.7	-0.6	0.0	0.0
Disposals	0.0	0.0	0.0	0.0
Other investments	0.0	0.0	0.0	0.0
Cashflow after invests.	**-3.1**	**-5.4**	**-4.4**	**-3.1**
Share repurchases	0.0	0.0	0.0	0.0
Share issues	6.0	8.8	0.0	0.0
Change in net debt	**2.9**	**3.4**	**-4.4**	**-3.1**
Opening net cash	2.6	0.8	4.2	-0.2
Closing net cash	**5.5**	**4.2**	**-0.2**	**-3.2**

Source: Hardman & Co Research

Financial comparisons with peers

Currently, there are only a handful of companies that produce audited financial results. Tabled below are salient financials from the four leading listed European and London quoted graphene companies (including Haydale).

Haydale's financials not unfavourable

The key point to note is that it is necessary to ensure that apples are being compared with apples. Revenues may or may not include grant income, and may not solely include nanomaterial/graphene income.

Gross margins high, with a high number of active customers

Importantly, from a Haydale perspective, we note that gross margins are comparatively high, and that all the peers are operating at an EBITDA loss. Haydale's cash position is currently healthy, and Haydale has a relatively large number of active customers. It also has the highest level of graphene-related sales of the London quoted companies.

Financial comparisons

	Haydale		Directa Plus (Eur m)		Applied Graphene		Versarien	
	Prior FY	Latest FY	Prior FY	Latest FY	Prior FY	Latest FY	Prior FY	Latest FY
Revenue (£m)	3.0	3.4	0.74	0.95	0.25	0.27	5.9	9.0
Total income *	3.9	4.3	0.82	1.23	0.27	0.27	5.9	9.0
Gross margin	70%	59%	75%	80%	in loss	in loss	24%	28%
R&D	1.15	0.85	n.a	n.a	n.a	n.a	0.34	0.27
EBITDA	-4.3	-4.9	-3.7	-3.16	-4.0	-4.0	-1.2	-0.8
Profit after tax	-4.7	-4.5	-4.3	-3.95	-3.1	-4.2	-2.2	-1.6
Cash/cash equivalents	2.1	5.1	10.6	6.93	5.6	11.7	1.4	2.3
Number of active customers	8	>50	16	35	>100	>100	>75	>75
Total number of patents	11	11	14	15	>10	>10	>10	>10

** Includes grant income*

Source: Hardman & Co Research

Valuation

Haydale's valuation is difficult, given the embryonic state of the company and the industry in which it competes. We note that there are only a few quoted companies that can be used to provide comparative valuation metrics. Furthermore, conventional valuation methodologies are not particularly appropriate, given the current lack of earnings. We consider EV/Sales and P/NAV as the most appropriate conventional valuation methodologies to adopt.

Shares could be considered undervalued

While we would stress that the valuation comparables are not that appropriate, we can see that Haydale's shares could be considered as undervalued versus the peer group.

Valuation comparables

Company	Price 52-wk range (lc) High	Price 52-wk range (lc) Low	P/NAV (x)	EV/Sales (x)
Haydale	198	43	3.4	1.9
Applied Graphene	215	35	7.2	34.4
Directa Plus	75	30	5.0	9.6
Versarien	117	13	31.8	23.3
First Graphene	0.22	0.07	9.6	157
Graphene 3D Lab Inc	0.27	0.08	11.0	5.6
NanoXplore	2.32	0.06	958	21.3
Elcora Advanced Materials	0.56	0.13	1.9	n.a
Talga Resources	0.93	0.42	4.8	360

Source: Hardman & Co Research

Furthermore, we believe a DCF valuation methodology is appropriate, notwithstanding its inherent shortcomings. In our DCF model, all future cashflows are estimated and discounted by using an appropriate cost of capital to give their present value. The discount rate used reflects the risk of the cashflows and incorporates an estimate of the time value of money, and the risk premium.

Our base-case assumptions are for a 10% WACC and a 1% terminal value growth rate, both of which are typical values used when valuing other similarly positioned engineering companies.

DCF valuation

(£m)	2018	2019E	2020E	2021E	Terminal
EBITDA	**-4.91**	**-4.41**	**-3.08**	**-1.68**	**4.95**
Tax	0.85	0.52	0.39	0.25	-0.60
NOPAT	**-4.06**	**-3.89**	**-2.70**	**-1.44**	**4.35**
Change in working capital	0.16	-0.03	0.02	0.02	0.03
Capex	-0.72	-0.72	-0.50	-0.40	-0.40
Other asset changes	-0.61	0.00	0.00	0.00	0.00
Free cashflow	**-5.24**	**-4.64**	**-3.18**	**-1.81**	**3.98**
Present val. – free cashflow	**-5.2**	**-4.2**	**-2.6**	**-1.4**	
Cumulative present value	**-5.2**	**-9.5**	**-12.1**	**-13.4**	

Source: Hardman & Co Research

DCF valuation summary	
(£m)	
Present value – forecast FCF	(8.4)
Present value – terminal CF	24.0
Enterprise value	**15.6**
Net cash (debt)	**4.2**
Market cap equity	**19.7**
Market cap equity/share (p)	**72.6**

Source: Hardman & Co Research

DCF sensitivity table

Discount rate	Terminal growth						
	0%	**0.5%**	**1%**	**2%**	**3%**	**4%**	**5%**
8.0%	77.8	83.9	90.9	108.3	132.7	169.2	230.2
8.5%	68.4	73.5	79.4	93.8	113.4	141.8	186.3
9.0%	60.1	64.5	69.5	81.5	97.5	120.0	153.7
9.5%	52.9	56.6	60.9	71.0	84.3	102.3	128.4
10.0%	**46.4**	**49.7**	**53.3**	**61.9**	**73.0**	**87.8**	**108.4**
10.5%	40.7	43.5	46.7	54.0	63.4	75.6	92.2
11.0%	35.6	38.0	40.8	47.1	55.0	65.3	78.9
12.0%	26.8	28.7	30.8	35.6	41.4	48.8	58.2
13.0%	19.6	21.1	22.8	26.4	30.9	36.3	43.0
14.0%	13.7	14.9	16.2	19.1	22.5	26.6	31.6
15.0%	8.8	9.8	10.8	13.1	15.7	18.9	22.7

Source: Hardman & Co Research

Risks

There are a number of potential risks and uncertainties that could have a material impact on the group's performance and could cause results to differ materially from current expectations.

Haydale's management seeks to ensure that overall risk is mitigated by avoiding excessive concentration or exposure to any given geographical or industry segment, or to any individual customer. Market conditions, lead indicators and industry forecasts are monitored for any early warning signs of changes in overall market demand, and measures to exploit opportunities or manage elevated risks are taken as appropriate.

Intellectual Property (IP) risk

The group's success will depend, in part, on its ability to maintain adequate protection of its IP portfolio, covering its manufacturing process and additional processes, products and applications, including in relation to the development of specific functionalisation of graphene and other types of carbon-based nanomaterials for use in particular applications. The IP on which the group's business is based is a combination of granted patents, patent applications and confidential know-how. The group aims to mitigate any risk that any of the group's patents will not be held valid if challenged, or that third parties will claim rights in, or ownership of, the patents and other proprietary rights held by the group through general vigilance and regular international IP searches, as well as monitoring activities and regulations for developments in copyright/IP law and enforcement.

Growth risk

Expansion of the group's business may place additional demands on its management, administrative and technological resources, as well as on its marketing capabilities, and may require additional capital expenditure. The group monitors the additional demands on resources on a regular basis and strengthens resources as necessary. If the group were unable to manage any such expansion effectively, then this could adversely affect the business, development, financial condition, results of operations, prospects, profits, cashflow and reputation of the group.

Competition risk

Haydale operates in an industry where competitive advantage is heavily dependent on technology. It is possible that technological development may reduce the importance of the group's function(s) in the market or render the patents and licences on which it relies redundant. Furthermore, the group's existing products may become obsolete; they may also be superseded by new technologies or changes in customer or end-user requirements.

New competitive products, designs or solutions may enter the market with different benefits or using different technologies, making them equally or more attractive. Competitors may also be able to devote greater resources to the promotion and sale of their products, designs or solutions than the group, which would give them a competitive advantage. The group's current and potential competitors include companies and academic institutions, many of whom have significantly greater financial resources than the group, and management regularly reviews the competitive landscape. There can be no assurance that competitors will not succeed in developing products that are more effective or economic than any developed by the group or that would render the group's products non-competitive or obsolete.

Haydale continually monitors the market in which it operates, and it has the resources to invest in new technology as appropriate.

Financial risks – currency and capital raise

Given the group's increasing international presence, its reported financial performance, especially when comparing with prior periods, is impacted marginally by changes in foreign exchange rates, in particular movements in the £/$ exchange rate. The group takes reasonable steps to minimise the effect of changes in FX rates to its performance and position, however, and strengthening of the £ vs. the $ is likely to have a marginal impact on the group's reported income.

It is possible that the group will need to raise extra capital in the future to develop fully the company's business or to take advantage of future acquisition opportunities. No assurance can be given that any such additional financing will be available or that, if available, it will be so on terms favourable to the group or to the group's shareholders.

Dependence on key personnel

The group's business, development and prospects are dependent upon the continued services and performance of its directors. The experience of the group's personnel helps provide the group with a competitive advantage. The directors believe that the loss of services of any existing key executives, for any reason, or failure to attract and retain necessary additional personnel, could have an adverse impact on the business, development, financial condition, results of operations and prospects of the group.

The impact of Brexit

The UK vote to leave the EU (Brexit) has not had a direct material impact on the group's performance in the current reporting period. However, Brexit is likely to bring uncertainty in the following areas:

- **Materials:** The ability of the group to import graphene and export its products, together with fluctuations in the value of Sterling, may have an impact on the group's operations.
- **Regulations:** The group is subject to the relevant regulations, including materials handling, within the jurisdictions in which it operates, including the EU. Any material adverse changes to the requirement for a UK-based business to adopt additional regulations as a result of Brexit may have a detrimental effect on the group's operations.
- **Grant income:** The group has previously benefited from EU grant funds, specifically the Horizon 2020 Research and Innovation programme. However, the group has, in the last 18 months, offset the loss of access to Horizon 2020 with additional grant awards from Innovate UK.

We are confident that group management will respond to the challenges that Brexit brings.

Management: highly experienced

Board of Directors

The Board of Directors has an extensive background in commercial and financial sectors at senior level and should be regarded as a strong and credible management team.

Recent senior management changes and expansion, including the appointment of Keith Broadbent as COO, should be deemed as positive. They will allow experienced and key personnel to fully concentrate on the principal activities of business development and the monetisation of commercial deals.

David Banks – Interim Executive Chairman

David started a career in stockbroking in Birmingham in 1979, working at Harris, Allday, Lea and Brooks before moving to London and becoming an institutional salesman at Panmure Gordon, where he was acclaimed in the Automotive, Engineering, Aerospace and Motor Distributors sectors. He subsequently became a corporate broker, advising many companies on their corporate structure, strategy, messaging and presentations. He also raised the capital for many of these companies, for IPOs and in secondary fund raises. David joined Haydale as Non-executive Chairman in July 2017, and was appointed Interim Executive Chairman on 5 September 2018.

Keith Broadbent – Chief Operating Officer

Keith joined Haydale in July 2017 as head of its Resins, Polymers and Composites Strategic Business Unit (RPC SBU) and as Managing Director of Haydale Composites Solutions Ltd. Prior to joining Haydale, Keith held a number of senior operational and commercial positions, covering the aerospace, automotive, defence, marine and medical sectors. His experience includes significant multi-site responsibilities in both the UK and internationally. The companies he has worked for include Princess Yachts International, Sunseeker, TT Electronics and, most recently, Ultra Electronics. Keith has demonstrated a strong track record in the delivery of budgets, high-level customer service and enhancing shareholder value. Keith was appointed as the Group's COO on 5 September 2018.

Matt Wood – Chief Financial Officer

Matt is a Chartered Accountant and experienced finance director and corporate finance professional, with a background in advising quoted growth companies for almost 20 years. A former nomad, since 2006, Matt has worked as a finance and non-executive director of AIM companies, and he joined Haydale in early 2014, before its AIM IPO. Matt brings a wealth of experience of plc financial reporting, corporate governance and general board advisory. Matt is an approved person by the Financial Conduct Authority and holds a first-class degree in Economics.

Roger Smith – Executive Director

Roger Smith has over 30 years of experience in building and developing technology-based businesses, having graduated with a degree in Physics. Roger has managed and, as their Managing Director, led two startup businesses to profitable multi-million-pound revenue positions with successful exits. Roger has served as Commercial Director with Bureau Veritas SA, a French industrial services business, and, most recently, as Senior Vice President of Petrofac, a global oilfield services group. Roger was one of the members of the original Haydale Graphene Industries' management team that acquired Haydale Ltd in 2010, and he acted as one of its non-executive directors until July 2017. From July 2017, Roger has been using his background in business development and account management to assist Haydale in accelerating its graphene sales. Roger is Non-Executive Chairman of SRJ Technologies Ltd and a Non-Executive Director of Inductosense Ltd.

Roger Humm – Non-Executive Director

Roger is an experienced Commercial and Finance Director, with extensive knowledge of high-growth technology companies. He brings experience of financial reporting, corporate governance, internal control and risk management from multiple board roles in both public and private companies. He currently acts as Chief Financial Officer at Boxarr Limited and G-Volution Limited, is a Trustee Director of the Oxford Instruments pension scheme and chairs the Investment Committee of the University of Bristol Enterprise Funds. In these roles, he provides general support to management teams to ensure effective performance and good communication with all stakeholders. Roger has previously held corporate, financial and senior management roles with Oxford Instruments plc, both in the UK and USA, including responsibility for corporate development, IP management and establishing a corporate venturing portfolio. Roger gained his BSc in microbiology and virology from Warwick University before qualifying as a chartered accountant with Grant Thornton. He has an MBA from the University of Bath.

Graham Eves – Non-Executive Director

Graham joined GKN plc in 1967, where he spent 13 years operating across multiple overseas jurisdictions, including, for the last five years, setting up and running a special operation for GKN plc's head office in Switzerland. He returned to the UK in 1980 to work in venture capital and establish his own international business consultancy. His main activities covered advising a range of German, North American and Japanese automotive component/technology suppliers, and he co-founded, and was chairman of, an automotive technology company, Mechadyne (now part of KolbenschmidtPierburg AG). Graham is a non-executive director of AB Dynamics plc. He was on the AIM advisory committee of the London Stock Exchange for six years, and he has a Master of Arts degree in Modern and Medieval Languages from the University of Cambridge.

Ray Gibbs – President, Business Development

Ray is a Chartered Accountant, and former Deloitte audit and corporate finance partner, where he worked for nine years. He has spent the last 21 years in industry as CFO or commercial director of high-technology and fast-moving consumer goods businesses, in both the quoted and private arenas, with sales ranging from £0.5m to £500m. He was a former CFO of Chemring Group Plc. Ray is a Board Member of the USA-based National Graphene Association, and is the UK Chairman of the UK and China Joint Working Group on Graphene Standardisation, organised by the BSI Group. Ray was part of the original Haydale Graphene Industries' management team that acquired Haydale Limited in 2010, was its CEO between 2013 and 2018, and was appointed as President, Business Development, on 5 September 2018.

Company activities

The group has operational activities in its six chosen geographies worldwide. We summarise these in the table below.

Company activities

Haydale subsidiary	Location	Principal activities
Haydale Limited	Ammanford, Wales	R&D operation, supporting the RPC SBU, developing ink production capability
Haydale Composite Solutions Limited ("HCS")	Loughborough, England	Principally consulting on advanced composites and elastomers design, R&D and testing specialist, covering the full product development lifecycle
Haydale Technologies (Korea) Limited ("HTK")	Seoul, South Korea	Dedicated sales, servicing the fast-moving Korean, Chinese and Japanese markets
Haydale Technologies (Thailand) Company Limited ("HTT")	Bangkok, Thailand	Provides low-cost, high-value R&D and plasma functionalisation facilities, servicing the APAC region and supporting the Far East sales teams.
Haydale Technologies, Inc. ("HTI")	South Carolina, USA	Haydale Ceramic Technologies (formerly ACM) is HTI's wholly-owned operating subsidiary, which produces and sells novel SiC micro-fibres and whiskers
Haydale Technologies Taiwan Ltd ("HTW")	Kaohsiung, Taiwan	Established in July 2017 as the production facility and technical centre for sales of speciality inks, initially into the biomedical sensor market

Source: Haydale

Company matters

Registration

Haydale is incorporated in the UK with company registration number 7228939.

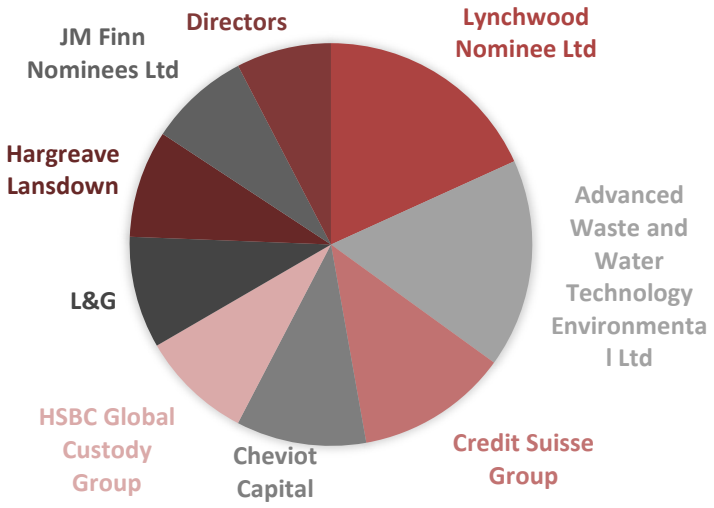
UK headquarters

Clos FFerws, Parc Hendre, Capel Hendre, Ammanford, Carmarthanshire, Wales, SA18 3BL.

Shareholders

At the point of going to press, Haydale has 27.20m Ordinary shares of 2p nominal value in issue. The Board of Directors holds 3.4% of the share capital.

Key shareholders – September 2018



Source: Company reports, RNS announcements

The NOMAD and Broker to the company is Arden Partners.

Share price performance – five-year chart

Source: Eikon Thomson Reuters

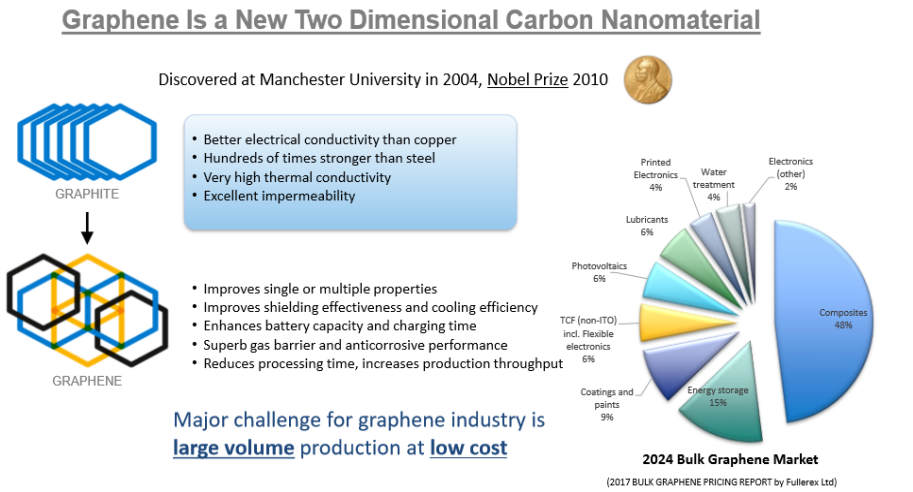
Graphene – background and markets

Background

A 2D carbon nanomaterial

Graphene was first isolated in 2004 by academics in the UK and, since that date, the exploration of the commercial market opportunities for graphene has been researched extensively.

Graphene and its applications

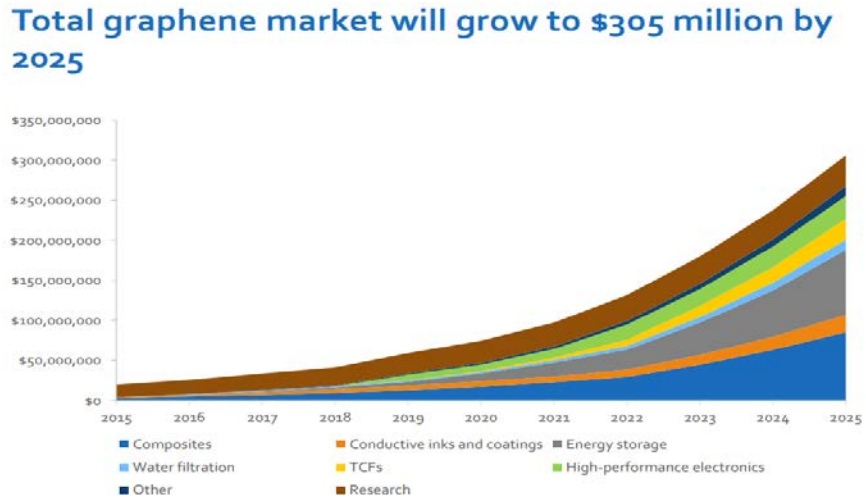


Source: Company reports, Hardman & Co Research

The global market for graphene-based products is projected to grow rapidly

The global market for graphene-based products is projected to grow rapidly, and is expected to reach over $300m in 2022, increasing at a five-year compound annual growth rate (CAGR) of 51.7%.

Graphene market to grow significantly



Source: Company reports, Hardman & Co Research

Graphene – a strong combination of electrical, mechanical and thermal properties

Graphene is a single sheet of carbon atoms arranged in a 2D honeycomb lattice. In its purest form, graphene possesses a strong combination of electrical, mechanical and thermal properties, which gives it the potential to replace existing materials in a wide range of applications and, in the longer term, to enable new applications.

The specific properties of graphene are as follows:

- a surface area of around 2,630 m2 per gram, which can facilitate any chemical process;
- mechanical resistance that is approximately 200 times greater than steel;
- thermal conductivity that is more than twice that of diamond;
- a density equal to half that of aluminium;
- elasticity equal to six times that of steel; and
- very high electrical conductivity, transparency, lightness and flexibility.

When small particles of graphene are used as an additive (mixed into a material) – as little as 2% by weight – this can impart superior strength, lightness and conductivity, or enhance functionality.

Graphene comes in a number of different forms

Graphene comes in a number of different forms, from different processes, with a variety of uses. Basic types of graphene include the following:

- **Single sheet graphene.** This is the purest form for uses in high-frequency electronics and similar applications. It is a single-atom-thick sheet of hexagonally arranged, bonded carbon atoms, either freely suspended or adhered to a substrate. Different qualities are observed when extended to two or three layers, and the cost of production becomes progressively cheaper.
- **Few-layer (FLG) & multi-layer graphene (MLG).** This is a 2D, sheet-like material, either free-standing or a substrate-bound coating of between two and 10 layers, used for composite materials and mechanical reinforcement.
- **Graphene flakes (GNFs).** Production of graphene flakes, usually in solution, is easier than making graphene sheets. They can be made from single-layer flakes that are stacked, and can be made in different shapes, providing a degree of engineering freedom not available with sheets. However, the randomness with which they are made poses issues with the engineering.
- **Graphene quantum dots (GQDs).** A quantum dot (nanoplatelet) is a small, round, disk-shaped particle with similar issues found with GNFs.
- **Graphene oxide (GO).** This is a compound of graphite, hydrogen and oxygen. It is a type of graphene that has been chemically modified by oxidation and exfoliation, but it does not have a lot of applications as a bulk material. Its main use is that it can be reduced to make graphene sheets, but the graphene from rGo contains chemical and structural defects. Nevertheless, it can be suitable for transparent conductive films and composite paper-like materials.
- **Reduced graphene oxide (rGO).** This is GO that has been reductively processed by chemical, thermal or microbial methods to reduce its oxygen content, for uses such as in conductive inks.

Because of the unique characteristics of graphene, there has been significant investment in exploring the potential commercial applications of graphene, and

consequently the graphene market has seen a rapidly rising number of patent applications being filed. Currently, most of the activity in the graphene sector has been focused on the following key areas:

- Composites – adhesives, sealants and high-performing polyester and epoxy resins for enhanced mechanical, thermal, electrical and permeation properties, brake pads and other friction materials.
- Conductive inks and other functionalised coatings, such as anti-corrosion coatings, transparent conducting electronics, biomedical and industrial sensors.
- Elastomers – combination with silicon for heat management and replacement of carbon black in tyres.
- Energy storage – improvements to carbon-based lithium ion batteries and supercapacitors.
- Advanced electronics – replacement for indium tin oxide and use in semi-conductors.
- Smart textiles – thermal and electrical conductivity, barrier properties and wearable electronics.

The market

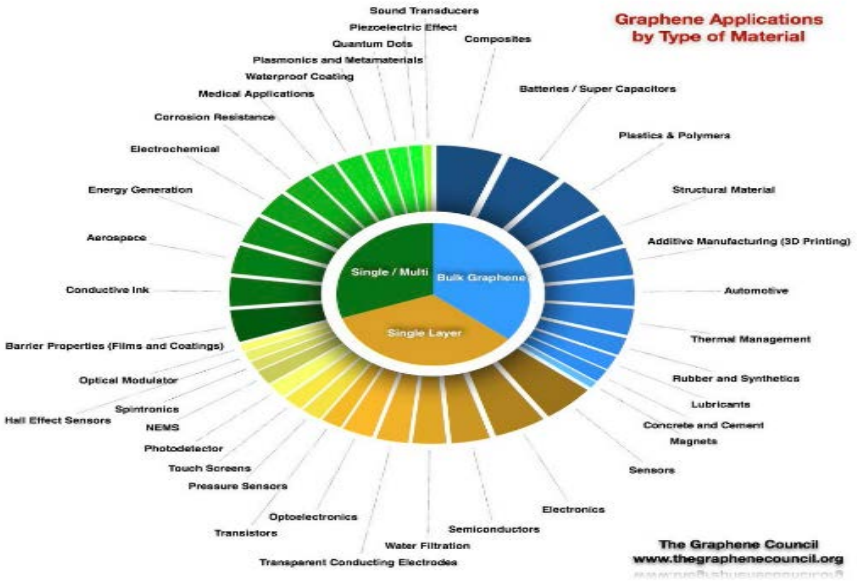
The global market for graphene-based products is estimated at $100m in 2018 and $900m in 2022, increasing at a five-year compound annual growth rate (CAGR) of 51.7%.

IDTechEx, the leading analytic agency in the graphene space, forecasts that more than $100m-worth of graphene-related products will be sold in 2018 for a range of applications, including RFID, smart packaging, supercapacitors, composites, ITO replacement, sensors, logic and memory, and more. Graphene-based composite materials, a category that includes 3D printable materials, are expected to constitute the largest segment of the overall market.

The global market for graphene-based products is projected to grow rapidly, and is expected to reach over $300m in 2022, increasing at a five-year compound annual growth rate (CAGR) of 51.7%.

The major industry sectors for graphene applications are polymer composites, construction materials, lubricants, coatings & inks, energy, electronics, water treatment and metals. However, each of these graphene technologies is at differing levels of technological readiness.

Graphene market



Source: Company reports, Hardman & Co Research

Electronics and Automotive largest markets

The global graphene market can be divided into six end-user segments, including electronics, automotive, aerospace and defence, healthcare, energy, and others such as coating & inks, water filtrations, etc.

Electronics is the most significant end-user segment and accounts for more than 30% of the overall graphene market. The product is widely used in the electronics sector due to its high conductivity and strength. Usage is in touch screens of mobiles and tablets, in making computer circuitry, and as a semiconductor. Graphene is also used in developing mobile phone memory chips. Growing popularity in consumer electronics could be a major factor for the product in the coming years. High growth of the electronics sector in APAC will boost the product demand in this region and will propel the global market in the medium term.

The automotive end-user segment represents almost 20% of the global graphene market. This segment will likely register a CAGR of more than 34% over the medium term. The product is used to manufacture nanocomposites for sensors, smart adhesives and other automobile components. Companies are focusing on developing light-weight vehicles that need lesser amounts of fuel to run. This will augment the global graphene industry in the coming years, as composites made from the product will be extensively used in manufacturing lightweight automobiles.

European graphene market large but APAC market to register strongest growth

The European graphene market accounted for more than 25% of the overall global industry in 2016. Large-scale R&D investments in the product in Europe will positively influence the market's growth. Flourishing end-user industries such as aerospace and defence, energy and healthcare will increase the product demand in the coming years, and will fuel the market growth in Europe.

The APAC graphene market is currently valued at $5.0m for 2016, and is expected to register more than a 34% CAGR over the medium term. High growth in the APAC electronics industry and rising demand for automobiles in the region will drive this market growth. The presence of large graphite mines in China, coupled with

significant ongoing research on the product in Japan, China, India and South Korea, will also contribute to the regional markets growth.

Graphene market, by process

The global graphene market is divided into four major product segments, including graphene oxide, graphene nanoplatelets, mono-layer and bi-layer graphene, and other products, such as few-layer graphene and multi-layer graphene.

Graphene nanoplatelets is currently the major product segment, representing more than 30% of the overall industry. Graphene nanoplatelets exhibit multiple properties, such as high electrical and thermal conductivity, stiffness and surface hardness. Graphene is therefore used in various end-user industries, such as energy transportation, electronics, aerospace & defence, biomedical, etc.

The mono-layer and bi-layer graphene product segment of the global graphene market registered revenue of more than $2.4m in 2016, and is expected register a CAGR of 34.3% over the medium term. Mono-layer graphene can be used as atomic scaffolding to create other materials by interposing the product layers with other compounds. Bi-layer graphene material functions like a semiconductor, and is used in sensors where it provides high sensitivity, good repeatability, fast response and stable specificity. Increasing research & development on this product segment will enhance its applicability in various sectors, which will propel the global market during the forecast period.

Graphene production

Two approaches to making graphene

There are two approaches to making graphene: top-down and bottom-up. Top-down involves starting with graphite or other materials and using exfoliation (peeling) or reduction methods from graphene oxide. Bottom-up involves synthesis of carbon in some form to produce graphene atom by atom.

Graphene – alternative production methods

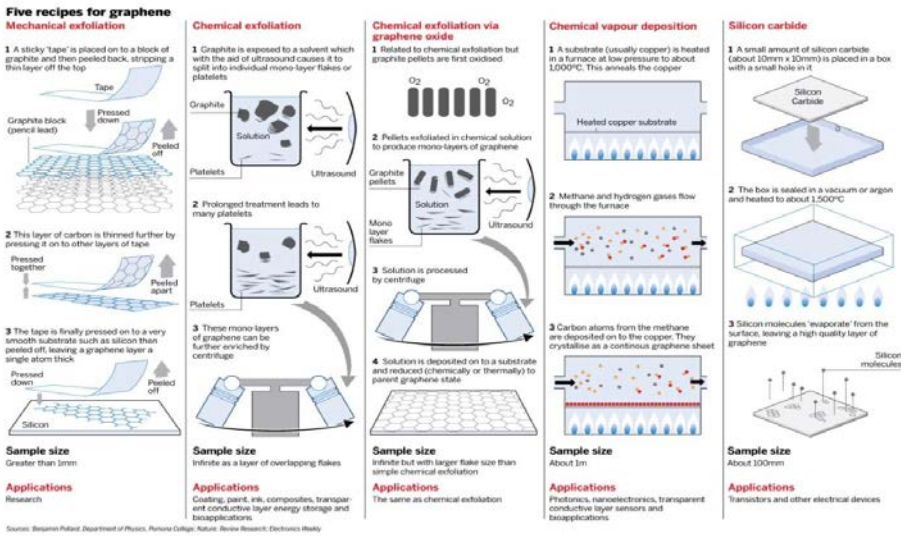
	DESCRIPTION	ADVANTAGES	DISADVANTAGES
Top-down	**Reduced graphene oxide**		
	• Oxidation of graphite • Sonication / heat to separate layers • Reduction to graphene nanoplatelets	• Established process	• Graphite supply chain – concentrated in China • Batch process • Residual graphite • Incomplete reduction
	Liquid phase exfoliation		
	• Graphite in solvent • Sonication to separate layers • Graphene nanoplatelets	• Can be low temperature	• Graphite supply chain – concentrated in China • Batch process • Residual graphite • Toxic solvents
Bottom-up	**Chemical vapour deposition**		
	• Deposition of graphene films onto metal substrates • Film removed from metal substrate • Produces films rather than nanoplatelets • Different end markets to AGM	• Able to produce large films with roll-to-roll approach • High purity with good electrical properties	• Expensive due to need to recover/remove metal substrate • High operating temperature • Low volume of material

Source: Company reports, Hardman & Co Research

Dozens of possible methods of making graphene

There are dozens of possible methods of making graphene, but there is yet to be one proving itself suitable to mass production, particularly of graphene sheets.

Graphene-making method



Source: Company reports, Hardman & Co Research

Graphene functionalisation

Graphene needs to be functionalised before it can be used in applications

Graphene must be in a format that enables its application, i.e. it needs to be functionalised.

Functionalising a material involves adding functional groups on the surface of the material to achieve desired surface properties (such as water-repellent coating or changing the colour). In effect, graphene is 'slippery' and cannot impart its properties to surrounding materials unless functionalised with additional bonds. Functionalising graphene makes it useable in a wide range of applications. It also enables the dispersion of graphene in solutions and enables solution-based production processes.

Covalant bonding – the simplest way to functionalise

Functionalising can be achieved in two ways. The simplest way is the covalent bonding of organic functional groups. There are two main alternatives here. You can start with graphene and form covalent bonds to the C=C bonds, or start with graphene oxide and form the bonds to the oxygen groups. This functionalisation method can be used to enable the dispersion of graphene in organic solvents, to change graphene's properties.

Another useful covalent functionalisation is the attachment of graphene oxide to polymers. In this case, the polymers provide the basic mechanical and morphological characteristics, while the graphene adds electrical conductivity and chemical reactivity, and may make the final material even stronger.

The second functionalisation method is the noncovalent type. This is a promising way to enable the dispersion of graphite in solvents and create monolayer graphene sheets (avoiding stacking). It can also lead to interesting new graphene properties. Graphene-ligand functionalisation could lead to interesting applications, such as hydrogen storage by hydrogen physisorption on graphene sheets. Graphene and nucleobases have been used to design a fast 2D DNA sequencing device.

Graphene composites

Another method of functionalising graphene is to combine it with other materials to create composites, or hybrid materials, thereby capturing its benefits in a material that can be further processed and utilised. Graphene can be combined with metals, polymers and ceramics.

An example of a composite material is a silicon-graphene lithium-ion battery anode. This reportedly increases energy density by 3x and anode capacity by 4x. In another example, a graphene sheet on top of a molybdenum disulphide sheet is said to offer photovoltaic cells that are 1,000x more efficient than silicon-based panels.

Graphene substrates

Graphene can be laid on a substrate to overcome the problem with handling the ultra-thin material. Graphene sheets can be made on substrates such as silicon, copper, nickel and flexible polymers. This graphene can be lifted from the substrate in the final application stage. However, the use of substrates can induce defects in the graphene, via impurities or tears, and these are substantial problems for some graphene formats to overcome.

Graphene pricing

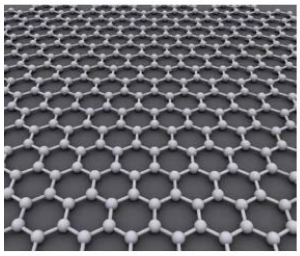
Expensive today – price varies with quality and volume

Graphene pricing

Different qualities mean different pricing

Graphene is a form of carbon consisting of planar sheets which are one atom thick, with the atoms arranged in a honeycomb-shaped lattice.

Price varies with quality and volume



Indicative Prices in US$, order sizes of 100 kg

Graphene (monolayer)	$1,000/kg
Very few layer Graphene (vFLG)	$800/kg
Few layer graphene (FLG)	$300-$400/kg
Multilayer graphene (MLG)	$60-120/kg
Graphene nanoplatelets (GNP)	$30-$50/kg
Graphene oxide	By negotiation

first graphene

Source: Company reports, Hardman & Co Research

Getting an exact price of graphene today is not easy, due to the small volumes available to the market. Indicative pricing from one supplier is $300/gm for single-layer graphene oxide. Another supplier has quoted Euro100 for 250 ml of graphene oxide. However, neither of these have implications for volume.

Future movements in prices – downwards

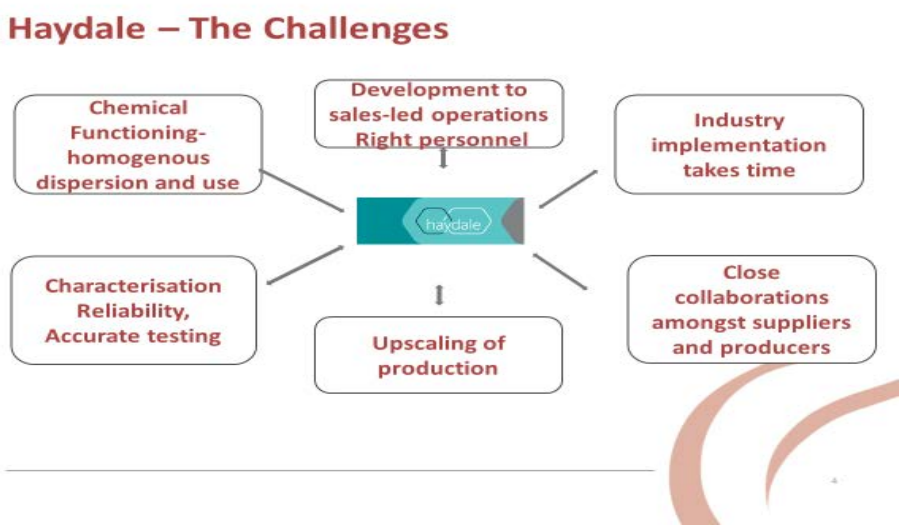
The key point to note is that whatever price you are seeing quoted today, it will not be the price at which commercial quantities will be made available for commercial applications. Almost all graphene production to date has been from small facilities that have been supplying products for research and testing purposes. Future prices will be lower.

Graphene challenges

Graphene is a highly versatile material with enormous potential. However, the graphene industry has faced a number of challenges, and these have delayed the commercialisation pathway and swift adoption of graphene into the market place. These are depicted below:

- the requirement of chemical functionalisation(homogenous dispersion and application);
- the need for reliable, cost-effective, accurate characterisation techniques;
- industry implementation of new products takes time;
- upscaling of graphene production;
- development to sales-led operations – focus and right people.

The challenges



Source: Hardman & Co Research

Standardisation

Material standardisation is key to accelerate the development of graphene-enabled technology and improve the ability to produce graphene in a reliable and repeatable way. Graphene has not had standards – so it is difficult for customers to be assured of the quality and properties of its graphene samples, and of the applications and products they wish to enhance and create.

The University of Manchester and the National Physical Laboratory (NPL) partnered in 2013 to work together on the development of graphene standards, metrology and characterisation, so that they could answer two key questions: What are the characteristics of the produced material? How can it be used and tested to prove it is graphene-enhanced?

First ISO Graphene Standards launched in October 2017

The first ISO Graphene Standards were launched in October 2017. The new international standard, led by the NPL, defines the terminology used to describe the many different forms of graphene and related 2D materials, supporting companies in the testing and validation of the 'wonder material'. This will provide clarity among manufacturers, suppliers, NGOs and academia, helping to unlock new applications, drive down manufacturing costs and open up the industrial-scale use of graphene for applications from next-generation computer chips to smart sensors in clothing. After a rigorous development process involving technical experts from 37 different countries, the standard is now available online, and contains 99 terms and definitions covering the types of 2D materials, material production, material characterisation and material properties.

Many other international and national bodies are looking at replicating these standards to enable their graphene industries to flourish as, today, without them, they are floundering, e.g. China (see interesting development on proposed JV with Versarien for Nanene in manufacturing section below).

Recently, Haydale has announced that the group has partnered with the National Physical Laboratory (NPL) and the National Graphene Institute (NGI) to launch a new graphene characterisation service – for the provision of reliable and consistent product data at the University of Manchester.

The service aims to reassure the industry's commercial partners by increasing the availability of information of the material's properties. By providing this service, Haydale, the NPL and NGI hope to accelerate the commercialisation and industrialisation of graphene in the UK and worldwide.

Full commercialisation – the need for sustainable long-term production sources

Once standards or performance have been demonstrated, the industry wants production volume reality, repeatability and a sustainable long-term source with a 'clean' supply chain for full commercialisation.

Graphene competition

Numerous organisations worldwide

There are numerous organisations worldwide involved in graphene research and production, ranging from university spinouts and other small startups through to large multinational corporations. Competition comes from companies working to directly supply and/or functionalise graphene nanoplatelet products (GNPs), or products incorporating GNPs, to the market.

Strategies focus on consolidating market positions through collaborations

The global graphene industry is significantly fragmented, with many of the industry players striving to solidify their market positions through commercial agreements and collaborations, mergers & acquisitions and expanding their product portfolios.

There is also significant scope for new players to enter the market, and increased competition among industry participants to obtain the majority of patents for graphene application will fuel the rivalry in the global graphene market.

Detailed below is a list of some of the leading competitors in the market place, together with illustrations depicting their competitive position and strategies.

In Europe/the UK, there are around 40 producers. The main competitors to Haydale include Directa Plus, Applied Graphene Materials plc, Versarien, Thomas Swan & Co Limited and Graphene Industries plc.

Directa Plus – possibly the leader in the field

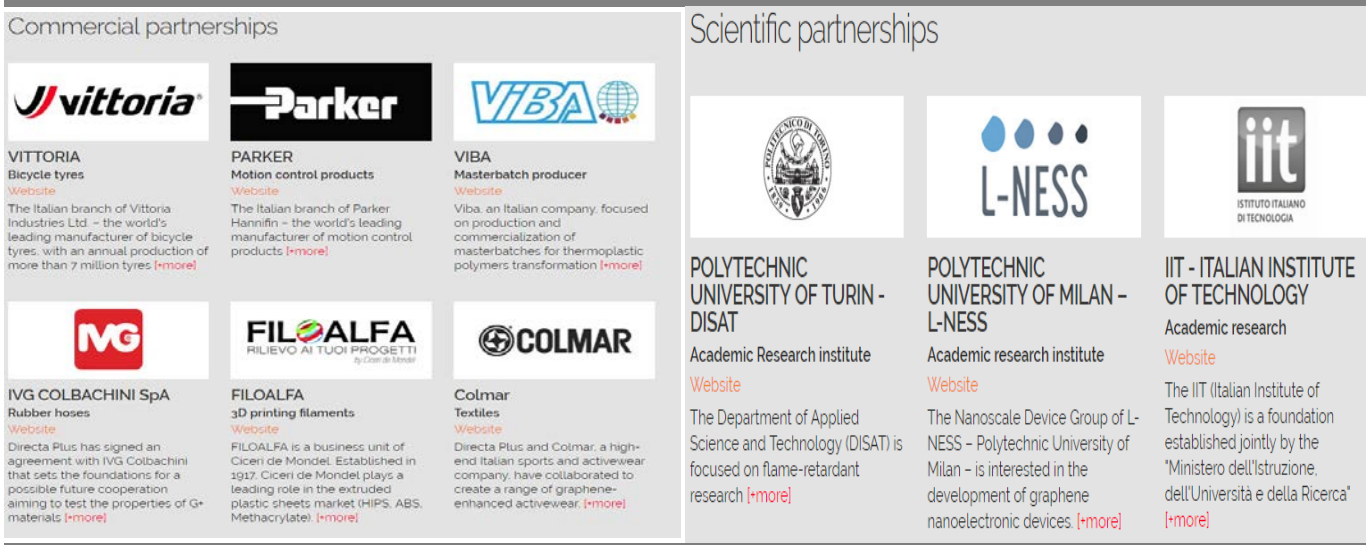
Directa Plus, established in 2005, is one of the largest producers and suppliers of graphene-based products for use in consumer and industrial markets. Directa Plus's graphene-based products are natural, chemical-free and sustainably produced, and are tailored to specific customer requirements for commercial applications, such as smart textiles, tyres, composite materials and environmental solutions. By incorporating Directa Plus's graphene blends, identified by the G+ brand, its customers can enhance the performance of their end-products without significantly increasing their cost.

A patented technology process

The company has a patented technology process, and a portfolio of product and application patents. It produces its graphene-based products at its own factory in Lomazzo, Italy, with a scalable and exportable manufacturing model enabling the set-up of additional production at customer locations to reduce transport costs, waste and time-to-utilisation. Directa Plus partners with customers to enable them to offer the high-performance benefits of graphene in their own products.

Directa Plus now believes it is the leading graphene producer, with at least an 18-24-month lead over competitors, the highest number of commercially available graphene-enhanced products, and with over 35 active customers and a clear commercial lead in textiles. Management believes that the group has industry-leading production and capacity, enabling Directa Plus to produce consistent, certified production at high tonnages and at a price that can satisfy the requirements of large supply chains. Furthermore, management believes that the group offers graphene-based products selling into the textile market that are independently certified as non-irritating and hypoallergenic.

Directa Plus – commercial and scientific collaborations



Source: Directa Plus

Applied Graphene Materials

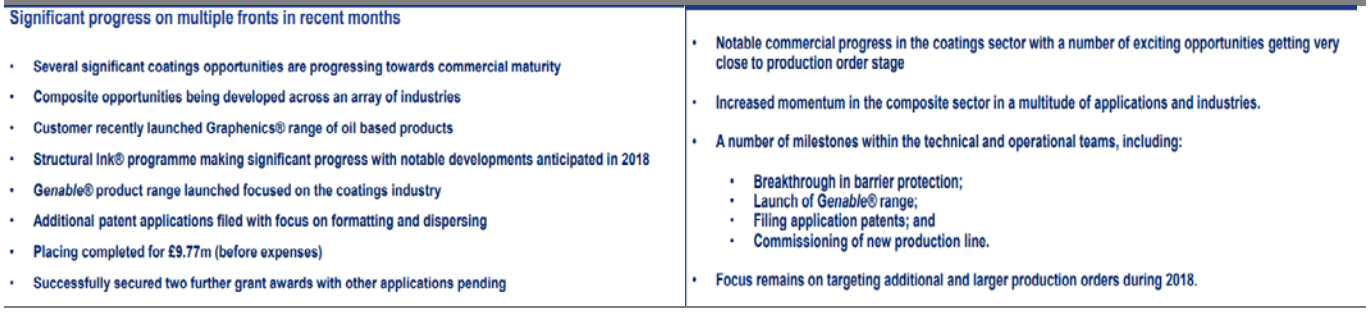
Applied Graphene Materials was founded by Professor Karl Coleman in 2010, with its operations and processes based on technology that he initially developed at the University of Durham. The group is based at the Wilton Site on Teesside and was admitted to AIM in November 2013.

The group has developed proprietary bottom-up processes that are able to produce GNPs using a continuous process. The manufacturing processes are based on sustainable, readily available raw materials, and therefore do not rely on the supply of graphite, unlike a number of other graphene production techniques.

Applied Graphene Materials works in partnership with its customers using its knowledge and expertise to provide bespoke graphene dispersions and formats to deliver enhancements and benefits for a wide range of applications. The company has scaled up its production facility, and is currently engaged with customers across the globe to develop application-specific, graphene-enhanced materials.

The group's strategy focuses on developing collaborations with commercial partners to accelerate adoption of graphene, targeting market leadership based on in-depth knowledge and proprietary processes. The key target sectors are paints and coatings, polymers and composites, and functional materials.

Applied Graphene Materials



Source: Applied Graphene Materials

Versarien

Versarien, founded in 2011, is an advanced engineering materials group with proprietary technology. The group creates engineering solutions for its clients in a diverse range of industries. Versarien has five subsidiaries.

- 2-DTech Ltd, specialises in the supply, characterisation and early-stage development of graphene products.
- Cambridge Graphene Ltd, supplies novel inks based on graphene and related materials, using patented processes, and it develops graphene materials technology for licensing to manufacturers.
- Versarien Technologies has developed an additive process for creating advanced micro-porous metals targeting the thermal management industry, and it supplies extruded aluminium.
- AAC Cyroma Ltd specialises in the supply of vacuum-formed and injection-moulded products to the automotive, construction, utilities and retail industry sectors.
- Total Carbide is a leading manufacturer in sintered tungsten carbide for applications in arduous environments, such as the oil & gas industries.

Versarien – collaborations

Source: Versarien

Versarien has two scalable and patented manufacturing processes for production of its branded products: Nanene (high-quality few-layer graphene nanoplatelets with a low defect ratio and large lateral dimensions) and Graphene Inks (micro-fluidisation). The group's strategic thrust is to further develop strategic collaborations for Nanene and Graphene Inks, as well for further international expansion, especially in China.

Thomas Swan

Thomas Swan & Co is the leader in the manufacture and supply of carbon nanomaterials. In 2014, the group launched Elicarb® Graphene Powder and Elicarb® Graphene Dispersions, which are premium-quality, few-layer GNPs. The group has now extended its graphene product range to include Elicarb® Graphene Electrical Grade Powder and Elicarb® Graphene Materials Grade Powder, providing graphene products that can be accessed by a broad range of industries. Thomas Swan is working in collaboration with Trinity College Dublin to develop a top-down process to produce graphene.

Graphene Industries plc

Graphene Industries plc (Graphenea) is a privately-held company based in Spain, which is focused on the production of high-quality graphene for industrial applications. The company produces single-layer graphene sheets, bi-layer graphene, multi-layer graphene, graphene oxide and other materials – on any substrate the customer provides. The company is also involved with graphene application research. Graphenea is the main graphene supplier for Europe's $1bn graphene flagship project, which was launched in October 2013. In 2015, the company announced plans to construct a new graphene pilot plant in a $2.5m investment.

In North America (around 30 producers), Haydale's competitors include Angstron Materials, Elcora Advanced Materials Corp, Vorbeck Materials Corporation, XG Sciences, NanoXplore, Grafoid and Saint Jean Carbon Saint Jean. Angstrong Materials, Vorbeck and XG Sciences are involved in the commercialisation of graphene technology, using top-down production methods that rely on the exfoliation of mined graphite.

Angstron Materials

Angstron Materials, a subsidiary of Nanotek Instruments, Inc., was founded in 2007 and is based in Dayton, Ohio. The group produces pristine and oxidised nano graphene platelets for the aerospace, energy, defence, automotive and telecommunication markets.

Elcora Advanced Materials Corp

Elcora Advanced Materials Corp was founded in 2011. It has been structured to become a vertically integrated graphite & graphene company that mines, processes, refines and produces both graphite & graphene and end-user graphite & graphene applications. As part of the vertical integration strategy, Elcora is securing high-grade graphite & graphene precursor graphite from operations in Sri Lanka and other countries that are already in production. Elcora has developed a unique low-cost-effective process to make high-quality graphite, graphite products and graphene that are commercially scalable. Graphene Corp, Elcora's graphene subsidiary, has a graphene R&D facility located in Canada that is dedicated to graphene production and application developments. This facility is governed by the North American's laboratory quality standards.

Vorbeck Materials Corporation, Inc., founded in 2006 and licensing its technology from the University of Princeton, is a specialty materials company that manufactures and supplies graphene, primarily for the electronics industry. In October 2012, Vorbeck Materials Corporation, Inc. increased the production capacity of its facility located at Jessup, Maryland to 40 t/a.

XG Sciences, Inc. was founded in 2006 and manufactures and sells GNPs for use in advanced materials and energy applications.

NanoXplore

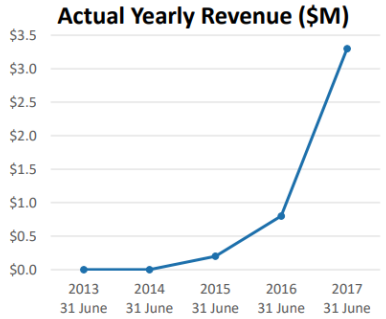
NanoXplore is a manufacturer and supplier of high-volume graphene powder for use in industrial markets, with proprietary and patent-protected graphene production technology (two granted US patents, four pending or provisional patents). The groups employs 100 people, in two production facilities (45,000 sq. ft. in total), one near Montreal and the other in Vallorbe, Switzerland (26,000 sq.ft.).

NanoXplore

NanoXplore Is a Graphene Technology Company

- Largest Canadian producer of graphene and a global graphene market leader
- Low cost manufacturing of graphene- projected cost of $3.6/kg(1) and projected selling price of $10/kg.
- Focused on graphene as an additive to plastic resins - 400 tonnes/year graphene-plastic mixing and compounding line
- Fabricates and sells millions of plastic parts and assemblies per year
- Solid growth trajectory with 4X revenue growth year over year since 2012
- Significant market opportunity with potential graphene and graphene related products market of $2.6B in 2025, growing by 46% CAGR(2)
- Near-term rapid growth opportunity through downstream acquisitions

- ✓ 25 tonnes/year current graphene production capacity
- ✓ 6 patents on graphene production and applications in composites and energy storage.



Source: NanoXplore

NanoXplore has recently announced that it intends to acquire all of the outstanding Sigma common shares and convertible debentures for ca.$9m. The acquisition will allow NanoXplore to incorporate the benefits of graphene to Sigma's existing product lines, and further strengthens our vertically integrated business model. Furthermore, the acquisition is a good opportunity for NanoXplore to develop and sell graphene-enhanced products to the transportation market and grow the overall commercial market for graphene.

Grafoid

Grafoid is a private company based in Canada, which produces graphene on a commercial scale using a proprietary extraction process. The company is also active in high-growth, scalable graphene projects, graphene patents and material applications. Grafoid is collaborating on graphene research with Focus Graphite and is also co-developing graphene-based polymer and non-polymer applications with Rutgets University. In May 2013, the company launched the MesoGraf brand of affordable high-quality graphene materials.

In July 2013, the company raised $3.5m from private investors. In February 2015, Grafoid received a $8.1m CAD grant from the Canadian government. In March 2016, China's Xiamen signed a strategic agreement with Grafoid, and agreed to buy up to 20% of the company.

Saint Jean Carbon Saint Jean

Saint Jean Carbon Saint Jean (SJC) is a publicly traded junior mining exploration company with graphite mining claims on five 100% company-owned properties located in the province of Quebec in Canada. The five properties include the Walker property, a past producing mine, the Wallingford property, the St. Jovite property, and the East Miller and Clot properties. The company also holds the Page graphite property in Ontario. In April 2015, SJC decided to enter the graphene market and signed an agreement with Graphenea to be a distributor in Canada.

Globally – China players numerous

Haydale has numerous other competitors around the globe: 2D Carbon Tech, Dongxu Optoelectronic Technology, Fanglin Minerals, LeaderNano, Nanjing JCNano, Qingdao Huagao Energy Technology in China, The Sixth Element Materials Technology, 2DM Singapore in Singapore, and First Graphene and Talga Resources in Australia.

2D Carbon Tech

2D Carbon Tech was established in China in December 2011 with an aim to develop and produce graphene films. The company is currently offering CVD-produced graphene films on copper, glass, silicon or PET, and also graphene-based touch panels. 2D Carbon Tech's production capacity for graphene films is about 30,000 m2/year. 2D Carbon Tech went public in 2015.

Dongxu Optoelectronic Technology

Dongxu Optoelectronic Technology, a subsidiary of the Tunghsu Group, was established in 1997. Its headquarters and R&D centre are located in Beijing.

The Tunghsu Group, with yearly revenues of over $5bn, has 40 subsidiaries under direct management. The group has now become an industrial investment enterprise, focused on the optoelectronic display and renewable energy industries, while also covering financing, urbanisation and real estate.

In September 2017, Tongshu Optroelectronic announced a new range of graphene-enhance LEDs. These new LEDs reportedly use graphene for heat dissipation and are said to be 75% smaller and 30% lighter compared with the company's regular LEDs. Power saving is around 20%-30%, and the lights also offer better light distribution. Tongshu claims to have installed 200,000 graphene-enhanced LEDs in Beijing and in the Zheziang and Hainan provinces in China. Tunghsu Group has recently released the G-king, a graphene-based battery line, signed agreements with graphene companies (ICN2 included) and invested in several graphene initiatives.

Fanglin Minerals

Fanglin Minerals was established in 1993 to produce and supply magnesite and SiC products and minerals. The company is also producing reduced graphene oxide (r-GO) in a plant that has a yearly capacity of about 200 tons.

LeaderNano

LeaderNano, based in Jiling, China, develops and produces advanced nanomaterials – including graphene, graphene oxide, nitrogen, boron-doped graphene, GNPs and other materials (such as MoS2 and WS2). In January 2015, LeaderNano launched its first graphene production line, which can produce 2-3 tons of graphene powder per year, as part of the first phase of the company's graphene industrial park.

Nanjing JCNano

Nanjing JCNano, based in Nanjing, China, produces and supplies several carbon-based materials, including graphene, graphene oxide, graphite oxide and carboxyl graphene. The company started producing graphene in 2009 using a CVD process.

Qingdao Huagao Energy Technology

Qingdao Huagao Energy Technology (QHET) was established in China to produce graphene materials and develop graphene applications. QHET currently offers several types of graphene and graphene-oxide materials, and is exploring graphene applications in Li-IOn batteries, supercapacitors and semiconductors. The company expects to have an annual production capacity of hundreds of kilograms of single-layer graphene.

The Sixth Element Materials

The Sixth Element Materials Technology (TSE) company, based in Chengzhou, China, is developing and producing graphene flakes, graphene oxide and related materials. The company also owns Wuxi Graphene Film, a CVD-graphene film maker. The Sixth Element Materials launched its graphene-zinc anti-corrosion primer in 2015, together with its partner, Toppen Technology, and the company has since performed extensive testing. TSE notes that the material has now been deployed in China, and has been used to cover several bridges and wind-turbine steel towers. The company says its current graphene-powder production capacity is 100 tons per year, and it plans to increase this to 1,000 tons.

2DM Singapore

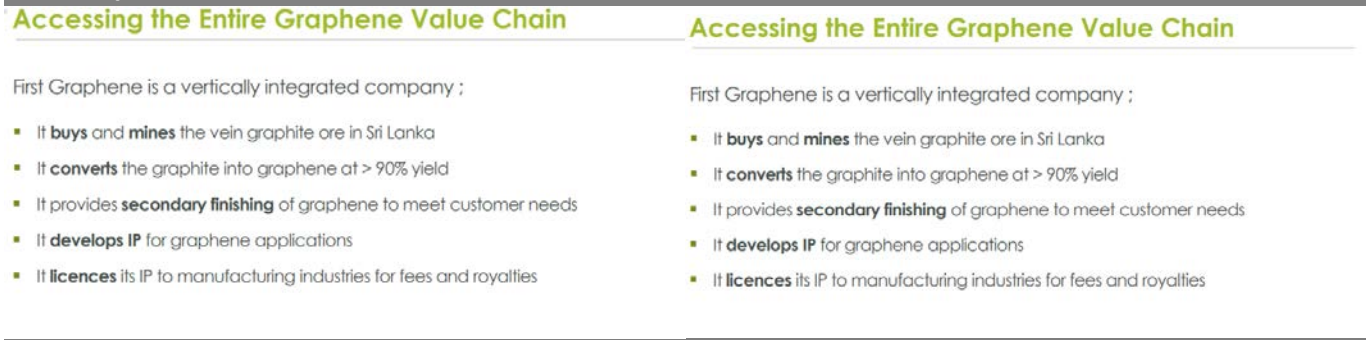
2DM Singapore was founded in 2015 as a spin-off from The Graphene Research Centre at the National University of Singapore. 2DM produces and markets GNPs.

First Graphene

First Graphene (previously First Graphite), a public company trading in the Australian Stock Exchange (ASX: FGR), is a high-quality graphite miner (from its Sri Lankan mine prospects) and a graphene producer. The company uses an electrochemical exfoliation process to produce high-quality graphene from the mined Sri Lankan graphite.

First Graphene has established a commercial graphene production facility for the bulk-scale manufacture of graphene at competitive prices. The company continues to develop graphene-related IP, from which it intends to generate licence and royalty payments. It has collaboration arrangements with four universities, and is at the cutting edge of graphene and 2D-related material developments. Most recently, First Graphene has become a Tier-1 participant in the Graphene Engineering and Innovation Centre (GEIC) of the University of Manchester. First Graphene is working with numerous industry partners for the commercialisation of graphene, and is building a sales book with these industry partners.

First Graphene

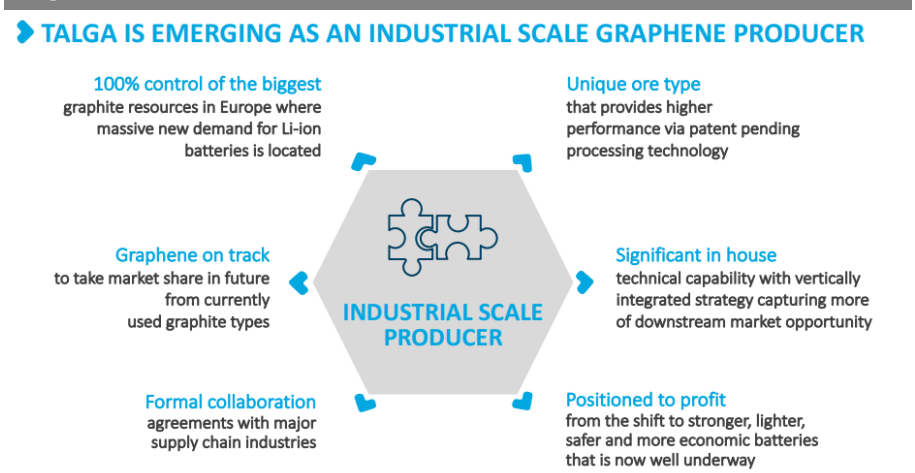


Source: First Graphene

Talga Resources

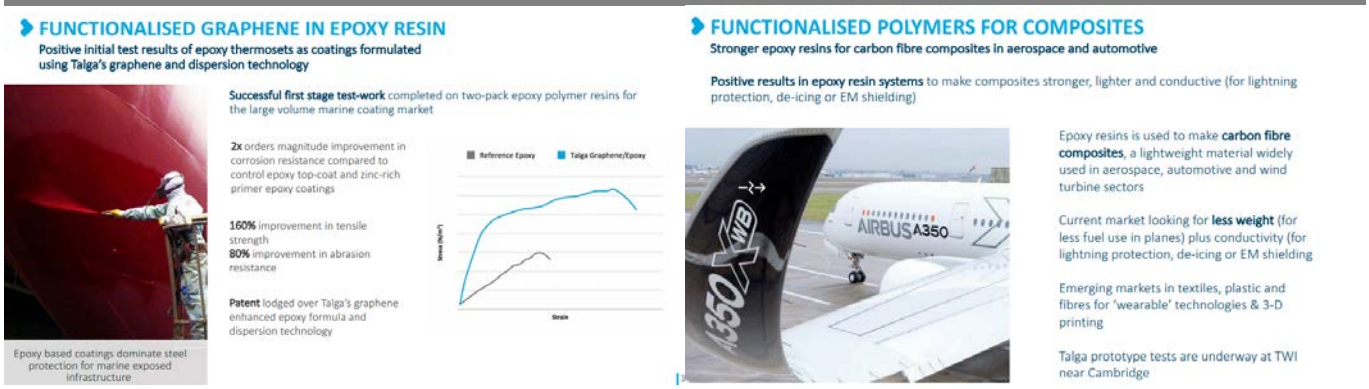
Talga Resources is an advanced material technology company in Australia, functionalising graphene and graphite-enhanced products for the global coatings, battery, construction and carbon composites markets. Talga has good competitive advantages, owing to its 100%-owned high-grade conductive graphite deposits in Sweden, as well as its in-house product development and technology. Joint development and commercial agreements are under way with a range of international corporations.

Talga Resources



Source: Talga Resources

Talga Resources



Source: Talga Resources

Other competitors – other nanomaterials and technologies

Haydale also faces competition from producers of nanomaterials, particularly carbon nanotubes and multi-walled nanotubes, which, in some circumstances, carry similar performance properties to graphene. Known commercial-scale producers of carbon nanotubes include Arkema SA and Nanocyl NV.

Further competition comes in the form of alternative competing technologies working to penetrate the market for similar commercial applications to those on which Haydale is focused.

Glossary

Allotrope: one or more forms of an elementary substance – for example, diamond and graphite are allotropes of carbon.

Bottom-up manufacturing: bottom-up manufacturing of graphene is a commonly used term describing the CVD preparation of synthetic graphene structures.

Characterisation: the measurement of the properties of a material – various types, sizes, shapes and chemical functionality.

CNT: carbon nanotube.

Composite materials: materials comprising discretely different materials, often made from a combination of fibres and resins, which have significantly different properties. By adding graphene to existing resins used in composites, existing qualities can be improved and weights reduced.

Covalently: a chemical bond that involves the sharing of electron pairs between atoms.

CVD: chemical vapour deposition; this is a process whereby a volatile species is deposited or condensed onto a surface substrate.

Disperse: to separate and move apart in different directions without order or regularity.

Exfoliation: the separation of layers of material, typically by chemical, thermal or mechanical mechanisms, when preparing graphene from graphite.

Functionalisation: functionalisation of nanomaterials provides a means by which the surface chemistry of the materials may be modified, which enables them to interact with other materials. (The process Haydale uses to functionalise nanomaterials is patented and configurable, depending on the end-result required. It is dry and environmentally friendly, making Haydale stand out from the competition.)

GNPs or Graphene Nanoplatelets: these are made of between 11 and 100 layers of graphene. Unlike singled-layered graphene, which is manufactured in a laboratory, graphene nanoplatelets can be prepared from mined graphite from multiple sources, including from Sri Lanka, Sweden and Canada.

Graphene: graphene is a flat monolayer (a 2D material) of carbon atoms, arranged in a hexagonal pattern (a honeycomb crystal lattice). The term 'graphene' is generally accepted to apply to materials up to 10 layers' thick.

Graphite: an allotrope of carbon, with an order structure of atoms in a regular hexagonal 2D array weakly bonded with adjacent layers to produce an anisotropic material. It can be either naturally occurring or artificially generated by the heat treatment of appropriate carbon precursors.

HDPlas™: Haydale's patented plasma process for treating carbon materials, as well as other nanomaterials.

Nanomaterial: a material or particle where one of the three dimensions is in the nanometer range (10-9m), but typically less than 100 nanometers.

Nanoparticles: particles of between 1 and 100 nanometers in size.

Nanotube: a cylindrical structure, with a diameter of the order of typically under 2 nanometers (10-9m).

Particle: a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties.

Plasma: plasma is one of the four fundamental states of matter, the others being solids, liquids and gas.

Polymer: a large molecule composed of repeated subunits (monomers).

Precursor: a compound that participates in a chemical reaction and produces another compound.

Substrate: a surface of a material on which a process is conducted and/or used as a support for deposited materials.

2D materials: 2D materials are materials that consist of just a single layer of atoms. Graphene is one of many single-layered materials, many of which have promising applications on their own.

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The fact that Hardman & Co is commissioned to write the research is disclosed in the disclaimer, and the research is widely available.

The full detail is on page 26 of the full directive, which can be accessed here: http://ec.europa.eu/finance/docs/level-2-measures/mifid-delegated-regulation-2016-2031.pdf

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