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Advanced Technologies for Industry – Product Watch

Lightweight Materials

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Section 1

1. Background and objectives of the report

Background

The Product Watch Reports have been developed in the framework of the 'Advanced Technologies for Industry' project and serve to identify and analyse 15 promising advanced technology (AT)-based products and their value chains, with an assessment of the strengths and weaknesses of the EU positioning.

Promising AT-based products can be defined as "*enabling products for the development of goods and services enhancing their overall commercial and social value; embedded by constituent parts that are based on AR/VR, Big Data & Analytics, Blockchain, Cloud, Artificial Intelligence, the Internet of Things (IoT), Mobility, Robotics, Security & Connectivity, Nanotechnology, Micro-nanoelectronics, Industrial Biotechnology, Advanced Materials and/or Photonics; and, but not limited to, produced by Advanced Manufacturing Technologies*".

1.1 Background of this report

Now more than ever before, industrial product development is facing a number of critical challenges, such as the shortage of raw materials and energy resources, and the need to slow the pace of climate change (i.e. to reduce CO_2 emissions). As a result, the concept of sustainability (i.e. material optimisation and energy efficiency) is gaining importance in industrial production. This can be achieved via innovative methods and strategies already applied in early product and production development phases[1]. The use of lightweight materials, i.e. materials that have a comparatively high-strength to weight ratio compared to conventional materials, is one of the key strategies to address these challenges. Lightweight materials lead to weight reduction, which can also reduce fuel consumption[2] in certain applications (e.g. the transportation sector). As carbon dioxide is released to the atmosphere when fossil fuels such as petroleum and coal are burnt, lightweight materials can make a significant contribution to lowering the emission of greenhouse gases.

The lightweight materials market can be divided into three main categories:

1) Lightweight metals and alloys (e.g. high-strength steel, aluminium, magnesium, titanium)

2) Polymer composites (e.g. carbon-fibre reinforced plastics (CFRP), glass-fibre reinforced plastics (GFRP))

3) Polymers (e.g. polycarbonate, polypropylene).

Market research estimates the current value of the global lightweight materials market at about €116.6 bn (in 2019)[3]. This is expected to increase to about €221 bn by 2027 with the compound annual growth rate (CAGR) estimated at 8.3 %[4]. The key driver behind this expected growth is the increasing adoption of lightweight materials across a number of industries, such as the aerospace, automotive and energy sectors, among others.

Application areas

Lightweight materials and construction solutions are already important topics across several industries, most prominently in the automotive, aerospace and aviation industry for several reasons, as elaborated below[5].

[1] Kaspar & Vielhaber, 2017
[2] Tambe, 2020
[3] Reports & Data, 2020
[4] Reports & Data, 2020
[5] GTAI, 2019

The automotive segment has the largest market share of lightweight materials in terms of revenue, reaching €83.45 bn by 2025 at a CAGR of 7.3 %[6]. As the automotive segment dominates the lightweight materials market, it is also the main focus of this report.

0.8 gigatonne CO_{2eq} were emitted by the European road transport sector in 2017, equivalent to 18 % of the total greenhouse gas emissions[7]. Minimising the weight of vehicles and therefore reducing fuel consumption in this sector requires the optimisation of systems-engineering designs and material properties[8]. These expected changes in materials are likely to have a significant impact on the automotive sector: the usage of lightweight materials has the potential to reduce the CO_2 emissions in the automobile industry by up to 20 %. Furthermore, lightweight materials are expected to have the potential to reduce the weight of passenger cars by 50 % and improve their fuel efficiency by around 35 %[9]. The main lightweight materials used in the automobile industry are aluminium, polymers and composites and high-strength steel[10]. The importance of lightweight materials is expected to increase rapidly in this sector, and the share of lightweight materials in car manufacturing is expected to double during the next two decades[11].

The aviation industry is the second dominant segment in the lightweight materials applications market. The main lightweight materials used here include aluminium (around 50 % for structural parts), composites and polymers. Further R&D in lightweight material innovations can significantly improve their application in the aviation industry. The two main drivers for the aviation industry are both cost-related - the need to reduce fuel consumption and to increase passenger/cargo load per flight[12].

Wind turbines for generating energy is a smaller market segment compared to the automotive and aviation market. Nevertheless, applications of lightweight materials are growing rapidly here due to their increasing use in wind turbines, where lightweight materials are used to produce the large rotating blades that transform wind power into rotating energy (and later on into electricity). Currently, glass-fibre reinforced plastics are used as a main structural material for blade production. The increase in the number of wind energy installations may boost the demand for these materials[13].

Lightweight solutions are expected to be taken up by additional industry sectors, such as construction, machinery and equipment due to ongoing developments in new production technologies, digital transformation and Industry 4.0[14].

Global regions

The Asia-Pacific region is the largest global market, with China as the biggest lightweight materials producer in the region. This is due to the presence of a large number of manufacturers and the growing automobile industry here. The emerging energy industry in the developing countries in the Asia-Pacific region is also having a positive impact on the increased use of lightweight materials in this region[15].

North America is the second largest market globally, and the US is the biggest market in this region. Market growth is mostly driven by major car manufacturers in the US and Canada. The presence of renewable energy equipment manufacturers in this region is boosting the demand for lightweight materials as well. It is striking that the strongest focus in lightweight materials R&D in the US has been on the defence sector over the last decade[16].

Europe constitutes the third largest lightweight materials market after Asia-Pacific and North America. The automotive industry is the largest European lightweight materials market, it was estimated to amount to about €55 bn (in 2019)[17]. Germany is the biggest lightweight materials market within Europe, followed by France[18]. The lightweight materials market in Germany is expected to have a CAGR of more than 9.5 % in terms of revenue by 2026[19]. Applications in the automotive industry and additional end-use industries, such as electronics and security equipment, are expected to increase due

[6] Markets and Markets, 2020
[7] Graphical Research, 2020
[8] Taub & Luo, 2015
[9] Grand View Research, 2016a
[10] Grand View Research, 2016a
[11] McKinsey & Company, 2016
[12] McKinsey & Company, 2016
[13] Grand View Research, 2016a
[14] GTAI, 2019
[15] Grand View Research, 2016
[16] Frost & Sullivan, 2017
[17] Market Watch, 2021
[18] Reports & Data, 2020
[19] Graphical Research, 2020

to the presence of major manufacturers, high-level R&D and the automotive industry's growing demand for lightweight materials[20].

Lightweight material groups

With 79.2%, polymers and composites have the largest share in the lightweight materials market **in terms of revenue** (2019)[21]. The global polymers market is expected to reach **€582 bn and the composites market €116 bn by 2025[22]**. Polymers are expected to keep their dominant position on the market with a CAGR of 4.8 %[23] and the composites segment is expected to grow significantly with a CAGR of 7.5 % between 2020 and 2026[24].

Polymers and composites are expected to be increasingly used in car manufacturing (reducing the weight of vehicles in the automotive sector by between 50 and 70 % over the next decade) and also in wind blades and power transmission lines to improve their performance[25]. Furthermore, the exponential rise of the composites segment is additionally driven by the increasing uptake of carbon and glass fibres that are integrated with molten plastics for increased material strength[26].

In terms of volume, high-strength steel has the biggest market share. This segment is also expected to experience the biggest growth in the coming years due to its substitution of traditional steel[27] **and will reach €24 bn by 2023[28]** with a **CAGR of around 12.2 %**. The magnesium market is expected to [29] grow by €4.5 bn by 2025 with a CAGR of 6 % [30] and the aluminium market is predicted to amount to €210 bn by 2026 with a CAGR of 5.7 %[31]. The slowest growth is foreseen for the titanium segment, generating €6.7 bn by 2026 with a CAGR of 4.7 %[32] .

Overall, it is expected that the volume of the lightweight materials market will increase significantly over the next decades, reaching more than €300 bn by 2032 for high-strength steel, aluminium and carbon fibre only[33].

1.2 Objectives of this report

The development of lightweight materials plays an important role in Europe as one of the global industry leaders. Innovative lightweight solutions can further decrease the weight of existing systems in those industries, where lightweight materials have mostly been used until now (i.e. aerospace, automotive construction and wind energy). In addition, these innovative lightweight concepts will enable the production of completely new products with new system properties and new application areas and have an uptake potential in additional sectors[34].

This report aims to provide an overview of the relevant stakeholders on an analytical and empirical base to see how lightweight materials can help EU industry stay ahead of global competitors. The objective is to map the EU lightweight materials industry and its interactions in the value chain, as well as to identify its strengths and weaknesses. Analyses were based on desk research and the expertise of Fraunhofer ISI as well as four external interviews. The report aims to provide relevant stakeholders with a thorough overview of the lightweight materials sector.

[20] Graphical Research, 2020
[21] Reports and Data, 2020
[22] Research and Markets, 2020; Grand View Research, 2020
[23] Research & Markets, 2020
[24] Market Watch, 2021
[25] Grand View Research, 2016a
[26] Market Watch, 2021
[27] Grand View Research, 2016a
[28] Allied Market Research, 2018
[29] Report Linker, 2020
[30] Industry ARC, 2020a
[31] Statista, 2020
[32] Industry ARC, 2020b
[33] McKinsey & Company, 2016
[34] GTAI, 2019

Section 2

2. Value chain analysis

It is very challenging to develop a common value chain for the different lightweight materials included in this report because of their great variety. The value distribution along the value chain of lightweight materials depends on the type of raw material and the purpose and structure of the part to be produced in the subsequent value chain segments. Therefore, the next chapter explores the value chain of lightweight materials at an aggregated level across all the different material groups covered in the report. More detailed insights are provided by including the key actors and the current linkages across the value chain.

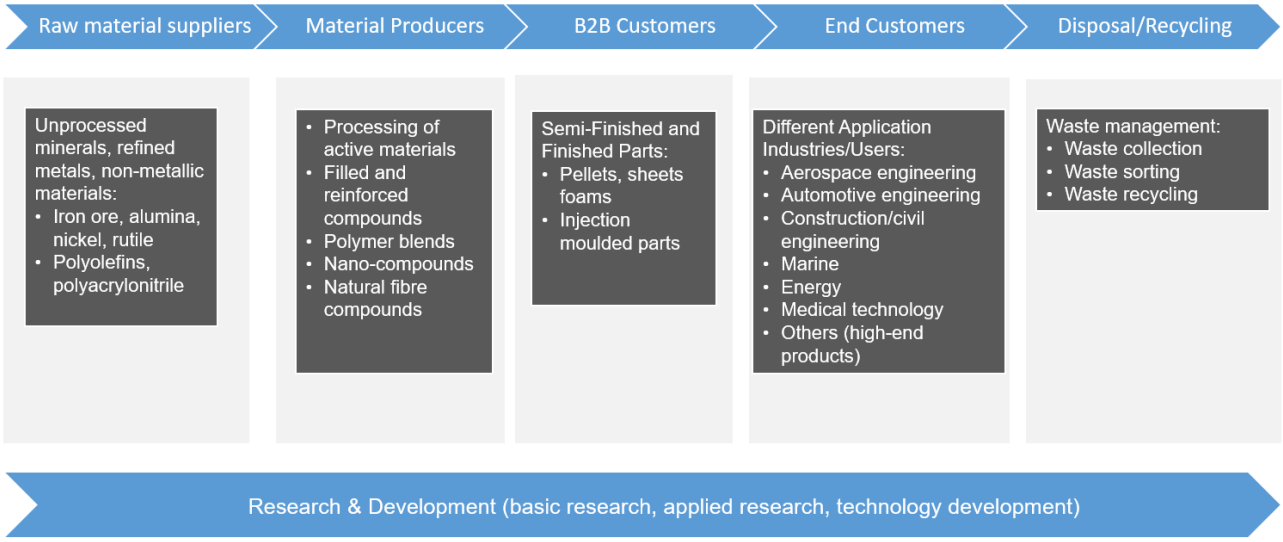
2.1 Value chain structure

The lightweight materials industry is very competitive and consolidated and has high growth potential over the next years due to emission reduction regulations in many industries (especially the automotive industry) and the expansion of renewable energy projects (i.e. wind energy)[35].

Even though lightweight materials have demonstrated clear advantages over non-lightweight materials, the threat of substitutes is still high for lightweight material companies, mostly from traditional steel manufacturers[36]. Many companies still prefer to use steel over lightweight materials in their manufacturing processes due to its cost-efficiency, proven manufacturing methods and well-established supply chain. While lightweight materials demonstrate superior properties compared to steel, availability is still an issue for lightweight materials because of insufficient large-scale production capabilities[37].

Figure 1 depicts the general value chain structure of the sector, which may differ in the case of specific lightweight material groups.

Figure 1: Lightweight materials value chain



Source: Fraunhofer ISI (compiled from secondary sources, industry associations, expert interviews)

The main assumption is that R&D plays a crucial role in the development of lightweight construction solutions for all stages of this value chain, which is indicated accordingly at the bottom of Figure 1.

[35] Reports & Data, 2020
[36] Grand View Research, 2016a
[37] Frost & Sullivan, 2018

Raw material suppliers include the actors that source the raw materials for metal alloys, composites or polymers production (e.g. unprocessed minerals, refined metals and non-metallic materials).

Raw material suppliers provide the input to materials producers, who process active materials (i.e. lightweight metals, polymers and polymeric composite producers). The number of polymers and composite material producers is expected to grow over the next decade due to the increasing use of lightweight materials in the automotive and aviation industries. The lightweight materials manufacturers have established agreements with raw material suppliers. Manufacturing companies are forcefully expanding their control over the value chain by integrating backwards to gain higher control of the supply to end-use industries[38].

Lightweight material manufacturers process the obtained inputs into semi-finished (plastic pellets, sheets, foams) and finished parts (i.e. injection moulded parts, such as different car parts for the automotive industry), which are then ready for the end customers market. The expansion strategies of these actors are mostly application focused, i.e. to maximise the diffusion of lightweight materials[39].

Over the last decades, the lightweight materials industry has consolidated significantly; the largest multinational companies (see examples in Section 2.2.) hold a major share of the market. Consequently, the lightweight materials market is moderately competitive and rather concentrated, with the major leading firms usually covering several lightweight materials value chain steps, while smaller firms may focus on specific steps or regions. The leading lightweight material producers pursue diversification strategies and seek to improve the quality of their products.

The key end-user groups for lightweight materials (especially polymers, composites and aluminium, magnesium and high-strength steel) are automobile and aircraft manufacturers. Other materials, e.g. titanium, are used more in different niche applications (e.g. medical technologies).

2.2 Key actors in the value chain

Globally, across the whole value chain and different material groups, there are around 500 companies active in the lightweight materials market.[40] There is a clear dominance of big multinational companies along the whole value chain and the barriers for new companies to enter the market are relatively high because of strongly established value chains. The market is fragmented in nature, i.e. no single company dominates the market, and the sector has witnessed a number of recent mergers and acquisitions. Reviewing these key actors is essential to understand the value chain of lightweight materials. Focusing on the global lightweight materials market, the main stakeholders relevant for the various segments in the value chain are documented in non-exhaustive tables below by different material categories (i.e. lightweight metals, polymers and composites). A number of key companies are involved in different value chain segments, such as Arcelor Mittal (steel producer), VSMPO-AVISMA (titanium), Shanxi Yinguang Magnesium Industry (magnesium) and Mitsubishi Rayon (carbon-fibre reinforced plastics). These are examples of only a few companies that are active in all steps of the value chain, i.e. from the raw materials of the precursors, the precursors themselves, the carbon fibres to prepregs, and finally carbon-fibre reinforced plastics (Mitsubishi Rayon). It is often not possible to allocate companies to one specific value chain segment only, and each material sector segment has its own unique characteristics. Materials producers are the key players with the largest market share in the lightweight materials sector.

Please see Tables 1 to 6 for an overview of the most relevant companies in the lightweight materials market.

Aluminium

Globally, China accounts for about 56 % of total aluminium production and Europe around 7 %. The 15 aluminium smelters in the EU are located in France, Germany, Greece, the Netherlands, Spain, Romania, Slovakia and Slovenia. The EU27 countries import 50% of their aluminium ingot requirements from Norway, Iceland, Russia, the UAE and Mozambique. The demand for semi-fabricated aluminium depends on packaging and the transport sector (e.g. car production), which has slowed down over recent years[41].

The key European aluminium companies are listed in Table 1. France-based Constellium is the largest advanced aluminium alloys producers in Europe and Norsk Hydro Aluminium (Norway) is one of the biggest aluminium companies worldwide focusing on primary aluminium products (e.g. ingots, billets). These two companies are followed by Amag (Austria), Aludium (Spain) and Alro (Romania) as the key players in Europe, which offer aluminium products and solutions for the automotive, aerospace and packaging markets[42].

[38] Grand View Research, 2016a
[39] Grand View Research, 2016a
[40] Grand View Research, 2016a
[41] European Aluminium, 2020
[42] Al Circle, 2018

Table 1: Key aluminium production companies active in lightweight materials

Company	Product examples	Country	Website
Alcoa Inc.	Alumina, primary aluminium production (billets)	Canada	www.alcoindustrial.com
Aleris International	Aluminium	United States	www.aleris.com
Allegheny Technologies Incorporated	Various lightweight materials	United States	www.atimetals.com
Aluminium Corporation of China	Primary aluminium production	China	www.chalco.com.cn
Amag Austria Metall AG	Primary aluminium, premium cast and rolled products	Austria	www.amag-al4u.com
China Hongqiao Group Ltd.	Aluminium billets	China	www.hongqiaochina.com
Bimo Tech	Aluminium billets	Poland	www.biomotech.pl
Constellium	Advanced aluminium alloys	France	www.constellium.nl
Kaiser Aluminium	Semi-fabricated aluminium products	United States	www.kaiseraluminium.com
KB Alloys	Aluminium alloys	United States	www.kballoys.com
Kobe Aluminium	Aluminium forging and cast rods	Japan	www.kobelco.co.jp
Norsk Hydro Aluminium	Primary aluminium	Norway	www.hydro.com
Novelis Inc.	Aluminium rolling & recycling	United States	www.novelis.com
UC Rusal	Low-carbon aluminium	Russia	www.rusal.ru
Verkhnaya Salda Metallurgical production (VSMPO-AVISMA)	Aluminium pressings	Russia	www.rostec.ru

Source: Fraunhofer ISI (compiled from secondary sources, industry associations, expert interviews)

Magnesium

The global market for magnesium production is dominated by China. In 2018, global magnesium production was around 900 000 tons and 85 % of this came from China. Currently, European-based smelters are unable to compete with low-cost Chinese production. Therefore, the European primary demand depends on Chinese exports[43]. The magnesium market is consolidated and only a few players dominate a major share of the market. The key global and European magnesium manufacturers are listed in Table 2.

Table 2: Key magnesium manufacturing companies active in lightweight materials

Company	Product examples	Country	Website
Allegheny Technologies Incorporated	Various lightweight metals	United States	www.atimetals.com
Amacor	Magnesium alloys	United States	www.amacor.us
ART Metal	Magnesium alloys	France	www.artmetal77.com

[43] CRM Alliance, 2018

Company	Product examples	Country	Website
Shanxi Yinguang Magnesium Industry	Primary magnesium production and processing	China	www.yg-mg.net
Meridian Lightweight Technologies	Magnesium	United States	www.meridian-mag.com
Orjinal Metal Urunleri San Tic AS	Magnesium alloys	Turkey	www.orjinalmetal.com
TDE Srl	Magnesium coil	Italy	www.tde.it
US Magnesium LLC	Metal alloys/magnesium	United States	www.usmagnesium.com

Source: Fraunhofer ISI (compiled from secondary sources, industry associations, expert interviews)

Titanium

The titanium market is consolidated and a few players account for almost 75 % of the market[44]. A Russian company VSMPO-AVISMA is by far the world's largest producer of titanium, titanium ingots, and all types of intermediate titanium alloy products[45]. In Europe, the market leader is a German company, Hermith GmbH, with a broad product portfolio, serving a number of different industries, including the automotive, aerospace, defence and medical sectors[46]. Other key actors include Allegheny Technologies, Sumitomo and ATI International.

Table 3: Key titanium manufacturing companies active in lightweight materials market segment

Company	Product examples	Country	Website
Allegheny Technologies Incorporated	Various lightweight metals, including titanium	United States	www.atimetals.com
Ankuro Int. GmbH	Titanium raw material, castings, final parts	Germany	www.ankuro.de
ATI International	High-strength steel & titanium	United States	www.atimetals.com
Hermith GmbH	Titanium sheets, plates, bars, billets	Germany	www.hermith.com
Precision Castparts Corp	Various lightweight materials	United States	www.precast.com
Sumitomo Titanium Corporation	Titanium sponges and ingots	Japan	www.sumitomocorp.com
Titanium Metals Corporation	Metal alloys/titanium	United States	www.timet.com
Verkhnaya Salda Metallurgical production (VSMPO-AVISMA)	Titanium ingots, intermediate titanium alloy products	Russia	www.rostec.ru

Source: Fraunhofer ISI (compiled from secondary sources, industry associations, expert interviews)

High-strength steel

Luxembourg based ArcelorMittal S.A. is the largest high-strength steel company in Europe and globally. Other key players include Nippon Steel and Sumitomo Metal Corporation. The largest companies have adopted different strategies, such as acquisitions and joint ventures, to increase their market share. At the end of 2019, ArcelorMittal and Nippon Steel acquired an Indian company, Essar Steel, by forming a joint venture in order to increase their market presence in India. Also in 2019, HBIS Group and POSCO

[44] Industry ARC, 2020b
[45] Rostec, 2021
[46] Hermith, 2020

Group set up a joint venture to develop and produce high-strength steel products for the Chinese automotive industry[47].

Table 4: Key steel companies active in lightweight materials

Company	Product examples	Country	Website
ArcelorMittal SA	High-strength steel	Luxembourg	www.arcelormittal.com
ATI International	High-strength steel	United States	www.atimetals.com
HBIS Group	High-strength steel	China	www.hbisco.com
JSW Steel	High-strength steel	India	www.jsw.in
Nippon Steel Corporation	High-strength steel	Japan	www.nipponsteel.com
Nucor Steel	High-strength steel	United States	www.nucor.com
POSCO Group	High-strength steel	South-Korea	www.posco.co.kr
Sandvik Materials Technology	High-strength steel	Sweden	www.materials.sandvik
SSAB AG	High-strength steel	Romania	www.ssabag.ro
Tata Steels Ltd	High-strength steel	India	www.tatasteel.com
Thyssenkrupp AG	High-strength steel	Germany	www.thyssenkrupp.com
U.S. Steel Corporation	High-strength steel	United States	www.ussteel.com
VoestAlpine AG	High-strength steel	Austria	www.voestalpine.com

Source: Fraunhofer ISI (compiled from secondary sources, industry associations, expert interviews) secondary sources, industry associations, expert interviews

Composites

The composite manufacturers dominate the lightweight materials market in terms of revenues due to the large product portfolio of composite materials with high prices. SABIC, Cytec Solvay Group, Owen Corning and Jushi Group are the highest rated companies based on revenue[48].

The market for carbon-fibre reinforced plastics production is dominated by non-European companies. The key players are US suppliers Zoltek and Hexcel, and Japanese suppliers Toho, Toray and Mitsubishi Rayon. The latter is the only carbon fibre manufacturer active in all steps of the value chain, i.e. from the raw materials of the precursors, the precursors themselves, the carbon fibres to prepregs and finally carbon-fibre reinforced plastics[49]. The biggest players in the glass-fibre reinforced plastics market are Owens Corning, Asahi Fibergalss Company and PPG[50]. European and Chinese carbon fibre producers play a less significant role in the value chain[51]. For both carbon-fibre reinforced plastics and glass-fibre reinforced plastics, the transportation industry is the largest end-user market in terms of both value and volume, which can be attributed to their weight and increased fuel efficiency advantages[52].

[47] Fortune Business insights, 2020
[48] Markets and Markets, 2018
[49] Schade, 2017
[50] Markets and Markets, 2018
[51] Schade, 2017
[52] Markets and Markets, 2018

Table 5: Key global composites companies

Company	Product examples	Country	Website
Asahi Fiberglass	Composites (GFRP)	Japan	www.afgc.co.jp
BASF	Polymers and composites	Germany	www.basf.com
Cytec Solvay Group	Plastics & Composites	United States	www.solvay.com
Dolan GmbH	Raw materials (polyacrylonitrile)	Germany	www.dolan-gmbh.de
Dralon	Raw materials	Germany	www.dralon.com
Evonik Industries AG	Composites (CFRP)	Germany	www.evonik.com
Formosa Plastics	Raw materials	United States	www.fpcusa.com
Henkel Corporation	Composites (CFRP)	Germany	www.henkel.com
Hexcel Corporation	Composites (CFRP)	United States	www.hexcel.com
Jushi Group	Composites (GFRP)	China	www.jushi.com
Mitsubishi Rayon Co. Ltd.	Polymers, raw materials	Japan	www.mitsubishichem-hd.co.jp
Owen Corning Corporation	Composites (GFRP)	United States	www.owenscorning.com
Polymir	Raw materials	Belarus	www.polymir.by
PPG Industries	Composites (GFRP)	United States	www.ppg.com
SABIC	Composites & polymers	Saudi Arabia	www.sabic.com
Saint Gobain	Composites (GFRP)	France	www.saint-gobain.com
Zoltek Companies Inc.	Composites & polymers	United States	www.zoltek.com
Toho	Composites & polymers	Japan	www.toho.com
Toray Industries Inc.	Composites & polymers, raw materials	Japan	www.toray.com
UBE	Composites (CFRP)	Japan	www.ube.com
Unichem	Raw materials	Lithuania	www.unichem.org

Source: Fraunhofer ISI (compiled from secondary sources, industry associations, expert interviews)

Polymers

China is currently the biggest market for both polycarbonate and polypropylene.

The biggest global polypropylene producers are Lyondell Basell, Sinopec Group, PetroChina Group and Braskem Group together with a number of smaller companies[53]. Companies with the largest market share for polycarbonates include SABIC, Bayer and Mitsubishi[54].

Table 6: Key companies active in polymers market

Company	Product examples	Country	Website
Asahi Fiberglass	Composites (GFRP)	Japan	www.afgc.co.jp
ARLA	Polycarbonate	Sweden	www.arlaplast.com
Bayer AG	Polymers (polycarbonate)	Germany	www.bayer.com
BASF	Polymers and composites	Germany	www.basf.com
Borealis	Polymers (polypropylene)	Austria	www.borealisgroup.com
Braskem Group	Polymers (polypropylene)	Brazil	www.braskem.com.br
Brett Martin	Polycarbonate	Ireland	www.brettmartin.com
Corplex	Polycarbonate	France	www.corplex.com
Covestro AG	Polymers	Germany	www.covestro.com
Cytec Solvay Group	Plastics & Composites	United States	www.solvay.com
Dott Gallina	Polycarbonate	Italy	www.gallina.it
Dow Automotive	Polymers	United States	www.dow.com
E.I DuPont de Nemours and Company	Polymers	United States	www.dupont.com
Euro-Composites	Polymers	Luxembourg	www.euro-composites.com
Exatec	Polymers	Germany	www.exatec.de
Exolon Group	Polycarbonate, polypropylene	Germany	www.exolongroup.com
ExxonMobil Corporation	Polymers	United States	www.exxonmobil.com
Formosa Plastics Group	Polymers (polypropylene)	Taiwan	www.fpcusa.com
Lanxess	Polymers	Germany	www.lanxess.com
LyondellBasell Industries N.V.	Polymers (polypropylene)	The Netherlands	www.lyondellbasell.com
Mitsubishi Rayon Co. Ltd.	Polymers (polycarbonate)	Japan	www.mitsubishichem-hd.co.jp
Nippon Graphite Fiber Corporation	Polymers	Japan	www.ngfworld.com
PetroChina Group	Polymers (polypropylene)	China	www.petrochina.com.cn
PPG Industries Inc	Polymers	United States	www.ppg.com
SABIC	Polymers (polypropylene, polycarbonate)	Saudi Arabia	www.sabic.com
Sinopec Group	Polymers (polypropylene)	China	www.sinopecgroup.com
SGL Group	Polymers	Germany	www.sglcarbon.com
Solvay	Polymers	Belgium	www.solvay.com
Zoltek Companies Inc.	Polymers	United States	www.zoltek.com

[53] Statista, 2021
[54] Grand View Research, 2016b

Company	Product examples	Country	Website
Toho	Polymers	Japan	www.toho.com
Toray Industries Inc.	Polymers	Japan	www.toray.com

Source: Fraunhofer ISI (compiled from secondary sources, industry associations, expert interviews)

Governing and supporting bodies

The lightweight materials industry is a well-established sub-field of the materials industry as well as an application field of a number of industries. Consequently, there are a number of dedicated European level associations or governing bodies regarding lightweight materials commonly as well as materials specific groups and associations.

Table 7: Governing and supporting bodies

Initiative	Focus	Involved countries	Website
Aachen Center for Integrative Lightweight Production (AZL)	Transformation of lightweight design in mass production	Germany	www.azl.rwth-aachen.de
CFK Valley e.V.	Network of excellence for the fibre reinforced composite value chain	~ 100 German and international members	www.composites-united.com
EPSE	European association of polycarbonate producers	10 companies	www.epse.org
Eurofer	Industry association, 34 members	EU 27	www.eurofer.eu
European Aluminium	Industry association, 80+ member companies	EU 27	www.european-aluminium.eu
European Association for Magnesium e.V.	Supporting research and applied science on magnesium	Germany	www.efm-aalen.de
European Composites Industry Association EuCIA	Representing European national composite associations	EU 27	www.eucia.eu
European Lightweight Association (ELA)	Strengthening position of its members and building a common position in the field	n.a.	www.european-lightweight.com
European Lightweight Cluster Alliance (ELCA)	Strengthening European position in the field of lightweight materials	12 EU Member States	www.elcanetwork.eu

Source: Fraunhofer ISI (compiled from secondary sources, industry associations, expert interviews)

2.3 Linkages along the value chain

Even though the sector is dominated by large multinational lightweight materials producers, the market is still dynamic and offers various opportunities. For example, global composite material suppliers are developing vertically integrated capabilities using mergers with or acquisitions of existing participants. In 2014, Toray (Japan) acquired the second largest manufacturer Zoltek (US), and became the main manufacturer of carbon fibres for the carbon-fibre reinforced plastics market[55]. In 2017, Owens Corning (US) acquired Aslan FRP, and became one of the biggest companies on the glass-fibre reinforced plastics market[56]. European-based aluminium producer Constellium N.V. acquired Wise Metals Intermediate

[55] Schade, 2017
[56] Materials Today, 2017

Holding LLC (US) in 2014 to meet the increasing demand for aluminium on the automotive market[57]. Strengthening supply capabilities and developing successful, cost-effective alternatives that ensure weight savings continue to be the primary points of focus for incumbents[58]. New collaborations can arise as suppliers with lightweight competencies broaden their portfolios to encompass new/additional material groups, such as carbon fibres. There is a high degree of collaboration between actors in the lightweight materials value chain concerning technology developers including universities, R&D centres and major manufacturers. The objective of such collaborations is to improve the materials' properties (e.g. yield strength or strength-to-weight ratio)[59]. Manufacturers are also looking at extending the materials' life cycle with improved recycling methods and more energy-efficient production processes[60].

[57] Constellium, 2015
[58] Frost & Sullivan, 2020
[59] Frost & Sullivan, 2018
[60] Frost & Sullivan, 2018

Section 3

3. Analysis of EU competitive positioning

Overall, Europe has a solid economic base for lightweight materials, as key companies from the value chain have their headquarters in the EU (e.g. ArcerolMittal SA, Bayer AG, Evonik Industries, Henkel Corporation). Since the lightweight materials sector is an established industry, this can be considered a strength as it proves the EU's competitive capacities. Nevertheless, lightweight materials still suffer from the lack of economies of scale. Although there is cross-continental cooperation, inner-European networks are scarce and not strongly established. Moreover, significant international competition with other continents plus uncertainty about end-consumer acceptance makes stronger engagement in lightweight materials a risky endeavour for material producers. Despite this, lightweight materials could help to overcome the limitations of non-lightweight solutions and benefit the whole of society, the environment and the EU economy.

Figure 2: Strengths, opportunities, weaknesses challenges and threats for the lightweight materials value chain

Source: Fraunhofer ISI; Grand View Research (2016)

3.1 Strengths

Scientific basis. The EU has a strong R&D base in lightweight materials and several collaborations exist between different stakeholders (public and private). Furthermore, there are also a number of EU public funding schemes for lightweight materials, which are regarded as one of the key enabling technologies for Europe.

Strong technological competences. The EU possesses strong technological capabilities in lightweight materials, especially Germany, which is the largest market for lightweight materials in Europe and enjoys global recognition for its outstanding automotive industry and engineering excellence[61]. Other European strengths are the necessary infrastructure and know-how in material design and technology to serve new industries. Companies such as ArcerolMittal SA, Bayer AG, Evonik Industries, and Henkel Corporation are among the largest and most important firms in the lightweight materials business. Furthermore, Europe is among the largest markets for lightweight materials worldwide; it was ranked third, behind North America and Asia-Pacific in 2016[62].

Superior material qualities. Lightweight materials represent a significant change in the material mix and improved material qualities besides weight. Promising examples include superior stiffness for high-strength steel or better corrosion resistance and high reflectivity for aluminium alloys.

[61] GTAI, 2019
[62] GTAI, 2019

3.2 Opportunities

New application areas. Lightweight materials offer not only weight savings for existing applications. They are expected to enable the development of completely new products and therefore open the door to completely new applications (e.g. different niche applications, medicine, new production technologies)[63].

Material innovation in the aviation industry. The trend towards the use of innovative lightweight materials along with the rise in manufacturing aircraft in the aviation industry result in increased demand in this market[64]. Many aircraft companies are sponsoring R&D projects focused on using innovative lightweight materials to improve different key aspects in aviation, e.g. aerodynamic efficiency, fuel consumption and noise reduction[65]. However, as the international aviation industry has been massively impacted by the COVID-19 pandemic, a significant decline of the sector is foreseen before its eventual recovery.

Growth in wind project installations. Lightweight materials with high-strength, such as glass-fibre reinforced plastics and carbon-fibre reinforced plastics are expected to replace conventional resins and composites due to their durable and lightweight properties. This is expected to lead to increased demand in the wind installations market[66].

Stringent regulation. Current legislative support aiming to reduce the fuel consumption and CO_2 emissions of vehicles are the key challenges facing automobile manufacturers around the world[67]. Since the introduction of CO_2 targets and resulting penalties, the use of lightweight materials now delivers a monetary benefit as well, which offers lightweight materials manufacturers the opportunity to increase their market share in the respective application industries[68].

3.3 Weaknesses

High cost of lightweight materials. The main factor hampering the deployment of lightweight materials in potential application industries is the cost of materials and processes[69]. All lightweight materials come with higher costs[70]. Alumina, iron ore, nickel, rutile and polyacrylonitrile are the main raw materials used to manufacture lightweight materials. Raw materials and energy are the two largest cost segments in the cost structure of lightweight material manufacturing, representing 20 and 22 % respectively of the overall cost structure. Labour and overhead costs together amount to 29 % of the total cost[71]. Therefore, even though high-strength steel is 20 % lighter than steel, it costs 15 % more. At the same time, the price of high-strength steel is still lower than aluminium, fibre composites and magnesium, and it is therefore used as a lightweight material by automotive OEMs globally[72]. For aluminium, the 40 % weight advantage comes with an additional cost of 30 %. Carbon fibre, which offers the highest weight reduction potential (50 % lighter than steel) costs 570 % more in comparison to the cost of steel today[73]. The current high price of carbon fibres restricts their use to high-end cars in the automotive sector, such as Bugatti, BMW and Ferrari.[74]

Safety and technological constraints. The safety of lightweight vehicles is a major issue, as heavier vehicles have lower fatality rates and are less fragile, resulting in greater crashworthiness[75]. Other key aspects hampering the use of lightweight materials in industry include the existing manufacturing infrastructure, which is not adapted to lightweight materials, and insufficient capacities to produce high volumes of lightweight materials[76]. Mass-scale production of carbon fibre is expected to decrease the cost of the material by up to 70 %, making it significantly more interesting to application industries[77].

3.4 Threats

International competition. Lightweight material companies from the EU face strong international competition from companies from other global regions. The majority of leading companies in the sector

[63] GTAI, 2019
[64] Reports and Data, 2020
[65] Grand View Research, 2016a
[66] Grand View Research, 2016a
[67] Frost & Sullivan, 2018
[68] Frost & Sullivan, 2018
[69] Frost & Sullivan, 2019
[70] Frost & Sullivan, 2017
[71] Grand View Research, 2016a
[72] Markets and Markets, 2020
[73] McKinsey & Company, 2016
[74] Markets and Markets, 2020
[75] BCC Research, 2015
[76] Grand View Research, 2016a
[77] McKinsey & Company, 2016

are based in the United States. In addition to the US, there are also notable activities in China. Asia-Pacific and China, respectively, are the largest and most dynamic global markets for lightweight materials with high-level R&D and manufacturing capacities[78]. Therefore, the trade war between the US and China is likely to have a negative influence on the global supply chain for the lightweight materials market[79].

Price volatility of raw materials such as rutile and iron ore. Unstable prices of certain raw materials is a critical characteristic of mineral markets, and has planning, as well as economic implications for different actors. This kind of price fluctuation can impact the demand on the market[80]. For example, the price of iron ore almost doubled in the second half of 2020[81].

[78] Frost & Sullivan, 2019
[79] Frost & Sullivan, 2019
[80] Bozzo & Guzman, 2020
[81] Hall, 2020

Section 4

4. Conclusions & outlook

4.1 Conclusions

Lightweight materials help to address the major societal challenges of increasing the sustainability of the European economy and meeting the climate targets set by the European Commission and Member States.

The framework conditions surrounding lightweight materials (e.g. emission regulations, material availability and safety requirements for vehicles) are constantly evolving. This applies especially to the automotive sector, which is currently the biggest end-consumer segment for lightweight materials and expected to remain so for years to come. Therefore, it is important for the actors along the whole value chain to collaborate and align their approaches in order to meet the requirements set by the regulators. The lightweight materials industry in the EU features key companies in the overall industrial manufacturing value chain. Therefore, continued solid growth for the lightweight materials industry is likely, considering the significant technological and industrial potential of the EU lightweight materials sector.

Nevertheless, the use of lightweight materials in different fields of application faces a variety of technological and economic challenges. Regarding technology, the need to achieve sufficiently high production at an affordable price remains a crucial goal to make lightweight materials cost-competitive with non-lightweight materials. Consequently, policies could support the development of the lightweight materials market by promoting research and upscaling activities. Furthermore, policy should recognise the important contribution of lightweight materials to meeting the policy goals of reducing CO_2 emissions and tackling resource deficiency in the manufacturing sector.

Moreover, the overall emission footprint of lightweight materials can only be accurately estimated using a life cycle impact assessment that encompasses all the different processing and manufacturing steps. This would provide balanced insights into their benefits and disadvantages for policy making and the development of new regulations.

On the demand side, it is essential to gain the interest and trust of the end-consumer segment. Here, price constraints are a major challenge that the sector needs to overcome, as today's lightweight materials are still too expensive for widespread use in mass-produced goods (i.e. cars). Therefore, research and development are needed to reduce the costs of lightweight materials. Further research is also necessary to improve the recycling properties of lightweight materials and enable their better integration into the existing systems of the end-consumers market (i.e. automotive, aviation, wind turbines etc.). Although lightweight materials obviously promise weight reductions, there are pros and cons to each material that must be taken into account, ranging from cost, availability to material deficiencies.

4.2 Outlook

Overall, lightweight materials have great potential in mobility and energy applications and can contribute to the sustainability transition. In principle, the EU has the potential to become a major hub for lightweight materials production and application, especially in the automotive industry, as it is home to key players in the value chain, especially in the area of R&D and end-user groups (e.g. automotive industry, aviation industry). The CO_2 regulations for vehicles will have a considerable influence on the development of this value chain, as lightweight materials will be increasingly needed in electric cars. Phased in from 2020, the EU fleet-wide average emission target for new cars will be 95 g CO_2/km from 2021[82]. The EU has also set rules for monitoring the CO_2 emissions of new cars. This means that the automotive industry has a clear incentive to use more lightweight materials in its manufacturing processes. However, lightweight material use is only part of a larger systemic transition towards sustainability and should not be considered a silver bullet to solve all the problems associated with current CO_2 emissions and sustainability issues.

[82] European Commission, 2020

4.3 COVID-19 and its impact on lightweight materials

The COVID-19 pandemic has caused major lockdowns in most of the industrial countries in the world. On the lightweight materials market, the resulting supply- and demand-side disruptions are expected to lead to a temporary drop in the overall production of the key application industries (i.e. automotive, aviation and wind) and, hence, in a decreased demand for lightweight materials[83]. Once the pandemic is under control and the situation reverts to normal, however, the industries are expected to return to their pre-pandemic mode and demand for lightweight materials will rise again[84].

[83] Frost & Sullivan, 2020
[84] Reports and Data, 2020

Section 5

5. Annexes

5.1 List of interviewees

Interviewee	Company	Country
Bein, Thilo	Fraunhofer LBF	Germany
Fischer, Alexandre	Shaeffler Bühl	Germany
Scholtz, Patrick	Fraunhofer IPT	Germany
Zhang, Xiaolin	Shaeffler Group China	China

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About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the *Advanced Technologies for Industry* (ATI) project has been set up. It provides policymakers, industry representatives and academia with:

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