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Lightweight construction in Austria

Status quo, trends, and policy options for the Austrian and European light-weight community, with a focus on mobility

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Executive Summary

Lightweight construction, as a set of cross-sectional technologies, has the potential to contribute to several challenges, which are prevalent now and in the near future. Starting from the mobility sector, which has traditionally been a key driver for innovation for lightweighting, it has the potential to contribute to resource and energy efficiency in a broad set of sectors and locations as long as it does not contradict, i.e., complies with the principles of a circular economy.

This study investigates lightweight construction in Austria. For that purpose, we identify relevant actors in Austria, show the economic significance of the lightweight construction sector, and present the development of applied research projects in different lightweight relevant technology fields supported by the Austrian R&D agency FFG. Subsequently, we present the research and development potentials for Austrian companies as well as the strengths, weaknesses, opportunities and risks of lightweight construction in Austria. We finally set the Austrian lightweight construction 'sector' in an international context, based on Horizon research funding data, a comprehensive overview of lightweight topics at international congresses, and an investigation of the importance of lightweight construction at the strategic level in selected countries.

Status quo and trends in Austria

Many actors are located in the east of Austria, especially in Upper Austria and Styria. However, depending on the thematic field, specialised actors can be found in all other federal provinces. Regional and supra-regional initiatives and clusters with different foci support their development (automotive, aerospace, mechatronic, plastic). Only one of these shows an explicit lightweight focus per se. These initiatives facilitate networking for the benefit of their members, i.e. knowledge exchange, increased visibility, and in some cases defining concrete research needs and initiating respective projects. The lightweight construction communities are well networked within their thematic fields, but the various networks are poorly interconnected, which hinders interdisciplinary exchange.

The impact in terms of value added and jobs secured of lightweight construction is considerable and might be comparable or even greater than the value added of sectors like mechanical engineering. However, there are hardly any relevant studies available to back this up. For a cross cutting theme like this, the results are sensitive to the definition of lightweight construction used, which has an implication for the economic sectors considered.

The importance of lightweight construction in research and development has certainly increased over time. Although focal points can be identified in the areas of industrial manufacturing, material engineering as well as in surface transport and technologies, overall lightweight construction is a cross-cutting issue in research and development. This is reflected in the many different subject areas and sectors that carry out lightweight construction projects. International research and development took place primarily with German partners.

Concerning future fields of research and applications, particular high priority is given to digitalisation and sustainability, including the principles of a circular economy, which apply to the whole life cycle, ranging from materials development, manufacturing (joining technology), production processes (3-D printing), use and recycling.

Globally, there is a high growth potential for lightweight construction. This is due to the ongoing new developments in the area of materials, as well as the versatile applicability in many different industries. The main drivers from a sectorial viewpoint, both globally and in Austria, are the mobility (air, road, rail) and the energy sectors, but also other industries are of relevance. From a societal viewpoint, important drivers should be the reduction of greenhouse gases and the reduction of material throughput in our society. The combination with technology development in the recyclability and reusability of lightweight materials achieves resource savings to contribute to the transformation towards a circular economy.

Lightweight construction in a European and global context

Lightweight construction activities are present in all European countries, but only Sweden and Germany have taken a clear political position on lightweight construction, as these countries have formulated explicit lightweight strategies. Other countries often integrate lightweight construction in other strategies. While Germany developed its strategy (2021)

in a participatory process and focuses strongly on sustainability and digitalisation, the Swedish lightweight strategy, which was first published 2013, focuses in particular on the UNs sustainability goals. Operational measures support both strategies. In Germany, for example, the central public contact points and the Lightweight Construction Technology Transfer Programme (TTP LB) push for the implementation of measures; in Sweden, the LIGHTer network is the central hub, which announces calls within the framework of the strategic innovation programmes.

Similarly, few explicit lightweight construction conferences approach the topic in a holistic way. However, lightweight construction often plays a role at other specialist conferences and events.

Furthermore, the European Lightweight Association (ELA), the European Lightweight Cluster Alliance (ELCA), Composite United (CU) and the European Lightweighting Network (ELN) already established a wide supraregional / international network.

Value chains in the automotive and aerospace sectors are important driving actors for lightweight construction, whereby Austria primarily acts as a supplier. Additional impetus comes from the energy sector, the construction industry, medical technology and sports equipment. The most important countries in Europe are Germany, France, Spain, Italy and the UK, which are also the countries with the most Horizon 2020 projects in lightweight construction. Scandinavian (here especially Sweden) and Benelux countries are also rather active in European research projects and therefore potential partners for Austria. Outside Europe, lightweight hotspots are in South America, the USA (Michigan and Ohio), Canada, South Korea, Japan and China.

Strengths, weaknesses, opportunities, threads

One of Austria's strengths is its compact and well-connected lightweight construction community along certain topics or sectors. Austria has also strengths in research (material sciences) and in economic application as a niche player and hidden champion.

Specific weaknesses of lightweight construction are primarily in technologies such as production processes, which currently still incur comparatively high costs. The fragmented communities (networks) and the relatively small number of lightweight construction actors can be interpreted as other weaknesses.

There are a number of opportunities and possibilities to push lightweight construction further. There is large potential in additive manufacturing (especially 3D printing), in developing more sustainable lightweight materials and more recyclable composite materials.

However, it is also important to recognise certain risks. Due to its broad applicability, it is challenging to facilitate knowledge and technology transfer between sectors and disciplines. There is also a risk that lightweight construction will remain limited to small-scale solutions if it is not integrated in holistic solutions. As an example, cars have become bigger and heavier over the past decades, despite lighter components. Finally, increasing competition and technological complexity can potentially overwhelm small players (e.g. SMEs) in particular.

Recommendations

Austria should continue to pursue the topic of lightweight construction at the strategic level. There are two potential scenarios: Austria develops its own lightweight construction strategy in the medium term, whereby it can follow the international examples of Germany and Sweden. Alternatively, lightweight construction can be integrated more consistently into existing strategies and measures.

Further recommendations aim to increase the visibility of lightweight construction, to improve networking among the actors, especially supra-regionally and transdisciplinary, and to bring together or unite existing networks and initiatives on a European level.

As such, the promotion of international exchange is essential. This study provides an overview of possible interesting candidates, their strategic orientation, industries, and participation in networks and funding programmes.

Improved promotion of research and development of sustainable solutions at all levels (materials, processes, applications) plays an important part. The integration of sustainability criteria in R&D research could also indirectly support lightweight construction and the application of lightweight construction methods (weight reduction, material savings, and functional integration). Furthermore, access to funding at lower TRL levels, especially in areas with high relevance for the circular economy need to be supported. Systematic monitoring of research and development could further support the identification of research topics as well as the dissemination of research results.

For funding programmes, matchmaking opportunities represent an important aspect, especially in the run-up to international programmes. European funding opportunities should be considered more strongly (an example could be to implement a H2020 project along the lines of the current AMULET project).

To counter the shortage of skilled workers and to expand expertise and knowledge, the possibilities of international cooperation should be further explored, especially in masters and doctoral studies with specific international competence centres with high relevance for the Austrian lightweight industry and research foci.

In summary, we need not only send the right signals to the community consisting of industry, research organisations, and intermediaries like cluster and funding organisations. We need to intensify our research and development efforts to enhance and redirect development paths, if they have not adhered to these principles in the past. But this alone is not enough. Funding agencies need to adapt their selection criteria for research proposals to incorporate these new priorities.

Finally, even more important is the correction of relative price structures of lightweight construction solutions adhering to the circular economy paradigm vis-a-vis other solutions, which are less beneficial for societal development goals. This addresses the internalisation of external costs (environmental, social, and economic), for which the socio-ecological tax reform (including a carbon tax) of the year 2022 is only a first step. By internalising external costs even further, lightweight construction solutions will become more competitive on the market place, and will simultaneously ensure that the solutions are developed in the right direction.

1 Introduction

Lightweight construction and applications

Against the background of dwindling resources and a simultaneously growing global demand for mobility, sustainability, prosperity and comfort, lightweight construction is more important today than ever before.

Lightweight construction plays an important role in various sectors. In the recent past, lightweight construction has come back into focus against the backdrop of advancing urbanisation. The goal in the construction industry is to build thinner and lighter with the same or greater strength. To achieve this goal, new lightweight materials are needed, among other things. Lightweight construction is also of significant importance in the mobility sector. Compliance with the increasingly stringent emissions standards and the increase in the range of electric cars are drivers for lightweight construction solutions. Today, many sectors such as aerospace, marine, energy, medical technology and others are facing similar pressures. Unlike the vehicle industry, where lightweight construction is well established, there is still considerable potential for the application of lightweight materials and methods in such sectors.

Improvements in energy efficiency are likely to remain at the top of environmental policy agendas for the near future. However, there is a growing political recognition, that environmental, research, technology, and innovation (RTI) policy need to move beyond energy efficiency to meet the challenges Europe is facing today. In particular, an aggravating scarcity of material resources, challenges in waste management, and increasing greenhouse gas emissions associated with the production and consumption of goods demand rapid improvements in material efficiency alongside advancements in the energy domain (Hertwich et al., 2020). In response to these emerging needs, the Austrian federal government has declared the Circular Economy as a priority field for RTI policy, launching several new initiatives and embedding material efficiency requirements in existing funding pro-

grammes (Ecker et al., 2022). Recently, the government has published the Circular Economy Strategy 2022, which defines the reduction of resource consumption, the increase of resource productivity, the increase of circularity rate and the reduction of private household consumption as main goals. Against this background, the goals of lightweight construction as a method (resource efficiency and optimization) are in high alignment with the strategic goals of the circular economy. Due to the objectives of the European Green Deal (which aims to reduce greenhouse gas emissions by 2030 and achieve climate neutrality by 2050) lightweight construction has great potential for reducing CO_2 in the mobility sector.

This new context brings the "economical" benefits back into focus but poses also new challenges for lightweight construction. As a means to reduce the mass of product components, lightweight construction intuitively contributes to cutting down the demand for material resources. If such improvements are implemented to enable larger or heavier products, as has been the case for modern vehicles, for example, lightweight construction could also contribute to lower levels of material efficiency in production and consumption. Furthermore, lightweighting may negatively affect the environment when alternative lightweight materials are associated with more emission-intensive extraction and manufacturing processes and when the methods implemented to reduce weight impair the recyclability of materials.

The potential of significant synergies and trade-offs between energy and material efficiency calls for concerted efforts and public policy to maximise societal benefits from lightweight construction technologies.

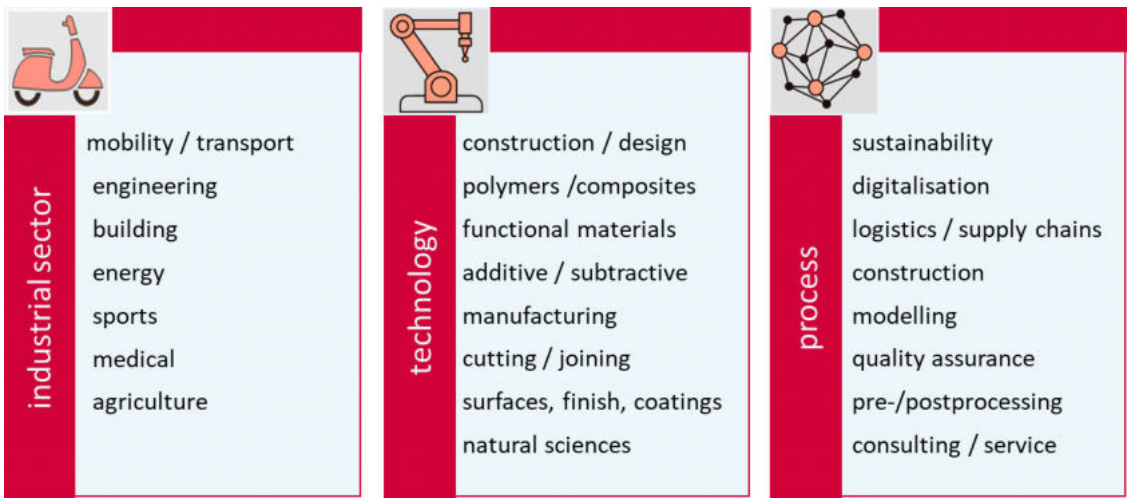
Lightweight construction as a cross-sectional technology

The terms "lightweight construction" or "lightweighting" describe a design or construction method that reduces the weight of a product component, but not necessarily the weight of the whole product, while retaining its functionality. Therefore, material should only be used in the places where it is needed. The mere substitution of a heavy material by a lighter one is the preferred approach when it comes to the weight-related optimisation of

components. In practice, this approach is challenging because, in addition to the availability of alternative materials and higher manufacturing costs (Singer 2012) the alternative materials have to be integrated constructively into the components, for example. Alternatively, engineers may thus focus on load-compatible design and the processes that accompany it. Lightweight construction is therefore not defined exclusively by the material, but encompasses holistic design including bionic applications modelled on nature.

Lightweight construction has a distinct cross-sectional character and is anchored in diverse technologies and industries (see Figure 1). This cross-sectional character manifests itself in the use of a wide range of tools and methods of simulation, testing, automation, and functional integration. Furthermore, lightweight construction may be an enabler of other technologies such as digitalisation, which may benefit from the integration of functionality in lightweight components (e.g. fiber-optic sensors in fiber-reinforced composites). Research, development, and production of lightweight components are increasingly complex, however, requiring a strong knowledge base as well as a well-functioning technology-transfer system.

Figure 1: The three pillars of lightweight construction



Source: Topics and focal points at international conferences related to lightweight construction. Own representation iit.

Today's challenges of lightweight construction

Lightweight solutions can contribute to economic, ecological, and societal benefits, if it is done the right way. Lightweight construction has the potential to be very innovative across several technology fields and sectors and thus strengthen the competitiveness on a broad scale. Within the mobility sector, lighter vehicles require less energy and emit less CO_2. The reduction in mass leads to less resource consumption and therefore decreases the demand of (rare) resources. In certain fields of application, lightweight construction can also lead to very direct societal benefits, as for example in medical engineering (e.g., prostheses). In other fields, lightweight construction is the prerequisite for the application of alternative propulsion systems such as hydrogen use in aircrafts (e.g. lighter tanks and fuel cell systems).

Despite the use of new and more efficient materials and design concepts, the weight of some modern vehicles has increased considerably. This is due to high safety and comfort standards. The economic goal is still to increase efficiency on the material side, where significant improvements towards extreme lightweight construction are still possible. The current major challenges for manufacturers along the entire value chain are material availability, reliability of large-scale production-processes and, finally yet importantly, reaching cost reductions for being able to compete in the mass market. This is also the reason why, at present, high-performance lightweight construction solutions do not generally find their way into the mass market, but are limited to special applications with high quality standards like in aerospace, car racing, and luxury sports cars.

Lightweight construction is coming into political focus (again) across countries due to advancing climate change and the scarcity of resources. Lightweight technologies offer theoretically large potentials for reducing energy consumption and resource savings.

However, the advantages of lightweight construction can only be realised if the production and recycling of the materials or assemblies are also sustainable and economical. Today's lightweight construction solutions still show strong deficits in this respect, as the problems with the recycling of composite materials show. Therefore, the development of new and sustainable lightweight construction solutions requires the inclusion of the entire value chain from the procurement of raw materials to the end of use and beyond. In this

context, the interaction of different design philosophies and technologies offers opportunities. However, this requires an intensive transfer of knowledge beyond the boundaries of disciplines, technologies and presupposes the willingness to learn from each other. The focus of lightweighting needs to be on sustainable, affordable and intelligent lightweight construction. Only this way, lightweight construction will contribute positively to the further development of society.

2 Status quo and trends in Austria

2.1 Organisations engaged in lightweight construction

Austrian companies and research organisations actively engaged in lightweight construction cover a wide range of competencies and economic sectors, ranging from material engineering to manufacturing and production technologies. To identify all companies and research institutions active in lightweight construction in Austria is a challenge due to the wide range of applications. Lightweight construction understood as an activity (creating a concept, manufacturing a component, etc.) with the intention to make something lighter, has application potentials across almost all economic sectors.

One approach is to identify networks, clusters and initiatives with high relevance and that implement certain activities (networking, studies, workshops, conferences, etc.) with a focus on lightweight construction. There are a number of clusters in Austria, in which lightweight construction is at least one of its foci. Their priority of lightweight construction within those clusters varies, however, depending on their thematic orientation. The special focus of this study lies on the mobility sector, but taking into consideration the high cross-sectional character of the topic. This focus was also decisive for the identification of lightweight clusters. The following table provides an overview of the most important clusters, their thematic orientation and the number of their members.

Table 1: Cluster organisations, platforms and initiatives related to lightweight construction in Austria

Name	Organisational structure	Thematic focus	Members
A2LT	Joint initiative of the automotive, mechatronic-, and plastics clusters, ACstyria and the industry division of the WKOÖ	material-independent lightweight construction, cross-sectoral and transregional	18
A3PS	Agency in the form of a public-private partnership, founded by the BMK	Alternative propulsion systems and fuels	28
AAI - Austrian Aeronautics Industries Group	Non-profit organisation and privately financed via membership fees	Aeronautics	35
ACstyria	Privately owned, founded in 1995 by companies from the mobility industry	Automotive, rail systems, aerospace	ca. 320
Additive Manufacturing Austria	Non-profit-organisation, supported by the BMK	Additive manufacturing platform. No thematic focus on lightweight construction, but the technology offers a range of possibilities to create new lightweight components	73
Automotive cluster, mechatronics cluster, plastics cluster of Upper Austria	Part of the publicly funded business upper Austria	These clusters are cross-industry networks supporting cooperation between companies within the respective sectors	Automotive: 277 Mechatronics: 301 Plastics: 422
Cluster Mechatronics Tirol	Cluster of the Standortagentur Tirol GmbH	Among others: lightweight construction and new materials	ca. 100
Composite United (CU) Austria	Independent association, headed by representatives of companies	Fibre composite materials	20

	and research institutions		
Holzcluster Steiermark	Cluster, shareholders are SFG and ProHolz	Focuses on the wood value chain, including R&D in lightweight construc-tion	155
Smart Textiles Platform Aus-tria	V-trion Gmbh is the sponsoring or-ganisation of the platform	The platform has no specific light-weight focus, V-trion conducts research projects related to lightweight	80
Plastics-Cluster Bur-genland	Initiative of the Burgenland Econom-ic Chamber	Plastics, no specific focus	20
Plattform für Luft- und Raumfahrt (Platform for aerospace)	Plattform of the business agency of Lower Austria	Aerospace in combination with sus-tainable materials and digitalisation	-

Sources: Websites of the cluster organisations[1]

A2LT and Composite United (CU) Austria are clusters with a specific focus on lightweight construction. The thematic focus of A2LT is independent of materials, cross-sectoral and transregional. The main goals of A2LT are to build-up competence, increase the visibility of its members, and support the development and commercialisation of solutions and products, and networking with other, including European, initiatives. In the "Roadmap to Sustainable, Affordable and Smart Lightweighting" A2LT defines its positions as follows: promoting lightweight technologies, accelerating technology transfer, optimising funding programmes, defining specific R&D priorities, strengthening international networking, and establishing design for repair/reuse/recycling. As a materials-independent cluster, its 18 member organisations have thematic foci in metals, plastics, textiles and hybrid materials.

[1] https://www.standort-tirol.at/cluster-partners/tyrolean-clusters/cluster-mechatronics-tirol#key-areas , https://www.a3ps.at/ , https://acstyria.com/ , https://www.a2lt.at/ , https://composites-united.com/cluster/cu-austria/ , https://www.smart-textiles-platform.com/ , https://www.holzcluster-steiermark.at/ ; 18.8.2022

Cluster members have competences in materials development, materials and component testing, simulation, product development and design, joining techniques, manufacturing & production, recycling and life-cycle analysis.

CU Austria focuses on carbon-fibre-reinforced-plastics (CFRP) and is included in the network of Composite United with members in Germany, Austria and Switzerland. The Austrian network of composite united is rather small but offers access the German CU network and its partners.

A3PS is a public-private-partnership and has 28 member organisations. The goals of the strategic platform are the promotion of R&D in the field of advanced propulsion systems and energy carriers, to build up common competence and to accelerate market launches. The platform addresses lightweight construction in the “Austrian Roadmap for Sustainable Mobility” (Nöst et al., 2022) and the “A3PS Position Paper R&D Demand 2021+” (Nöst et al., 2021). Lightweight design and materials are explicitly addressed in the advanced vehicle concepts working group. Lightweight construction is understood as a crosscutting technology, which contributes to the reduction in energy consumption through weight reduction of vehicles and is also relevant for future, new propulsion systems and their components. For example, lightweight construction is considered as relevant for all types of hybrid powertrains, e.g., for engine design as well as for transmission and axle drives. Lightweight construction in mobility can be achieved via different approaches. New high-strength materials and new lightweighting alloys offer opportunities for weight reduction, but must also be evaluated in terms of their recycle and reuse capabilities. Fibre-reinforced-plastics, aluminium, magnesium, and composites will become increasingly important (Nöst et al., 2021).

The mobility cluster ACstyria comprises the fields automotive, railway systems as well as aerospace. The core service of the cluster is the networking and support of Styrian companies along the entire value chain. Lightweight construction is perceived by the cluster as cross-sectoral, and is an important topic for cluster members in the automotive and aerospace sectors, but is rather a marginal topic in railway systems. Together with A2LT the cluster organizes the lightweight day once a year. In 2022, the lightweight day was held in

Spielberg, Styria. The cluster tries to increase the visibility of its members and tries to attract stakeholders from abroad to visit Austrian companies.

Although most companies and research organisations active in lightweight constructions are based in Upper Austria and Styria, there are also lightweight initiatives in other regions. In Tyrol, the Cluster Mechtronics Tirol regards lightweight construction as one of the key technologies with high potential to increase resource efficiency. The cluster offers workshops, information and events on the topic of lightweight construction.

The smart textiles platform Austria is a network of 80 companies and research organisations and has no dedicated lightweight focus. V-trion, as one of its sponsoring organisations conducts various research projects related to smart textiles and acknowledges lightweight as a potential field of future applications of textile technologies.

In the Burgenland region, the plastics cluster consists of 20 member organisations. The main activities of the cluster are networking and the implementation of R&D projects. The cluster explicitly addresses the topics sustainability and circular economy.

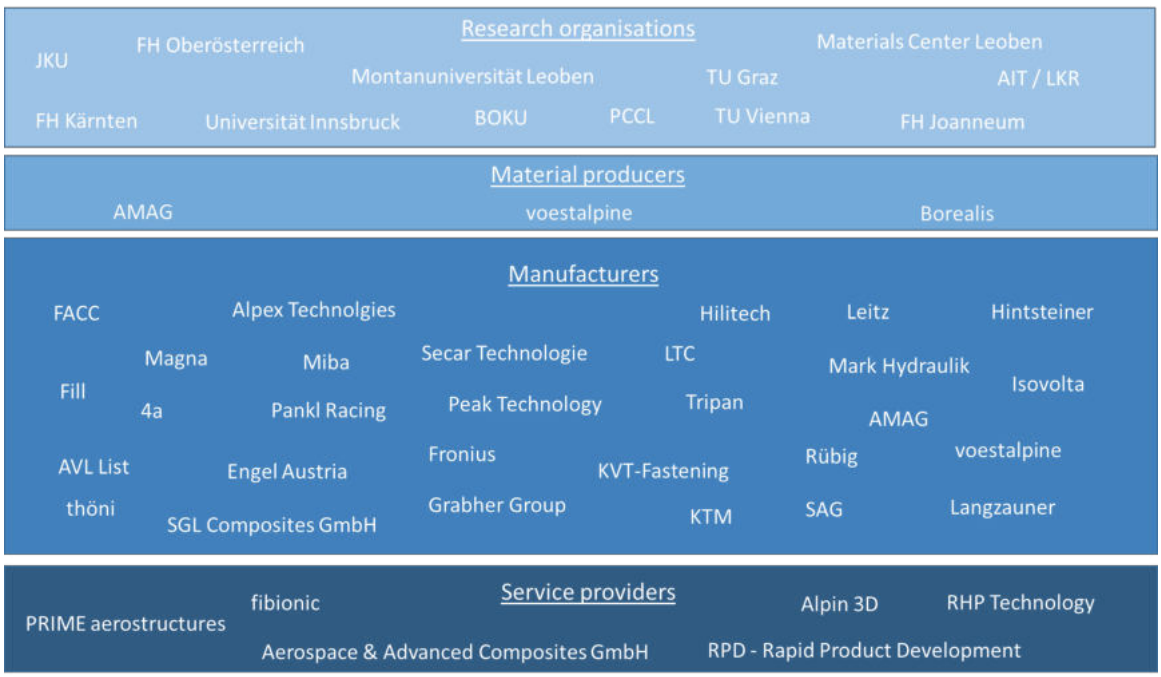
The AAI (based in Vienna) and the Platform for aerospace (based in Lower Austria) are two initiatives with focus on aerospace. The AAI facilitates information exchange, marketing and networking between its members and towards national bodies as well as towards international industries. The platform's main goal is to support technology transfer between industry, research and education.

There is a regular and well-functioning exchange between A2LT, CU Austria, A3PS and AC-styria. Interview partners however also commented on some aspects that could be improved. Due to the regional anchoring of the clusters, the cooperation patterns are also more regionally oriented. Some interview partners noted in this regard that an exchange platform of all relevant lightweight construction networks (e.g. including other regional agencies such as the Mechatronic Cluster in Tyrol or the Smart Textiles Initiative in Vorarlberg) is currently lacking.

The members of the individual clusters can mainly be assigned to the mobility and production sectors. Overall, the number of companies organised in clusters with a strong focus on lightweight construction in Austria is relatively modest and thematically diverse. The

same applies to the research institutions. The Johannes Kepler University, the Vienna University of Technology, the Graz University of Technology, the University of Leoben, the Upper Austrian University of Applied Sciences (Wels) and the University of Innsbruck are particularly worthy of mentioning. The research foci are mainly on materials research, but also on design and conception. The Austrian University of Applied Sciences Research offers the Bachelor Study “Lightweight Design and Composite Materials”. Research related to the possibilities of 3D-printing for lightweight construction is also conducted on the University of Applied Science Carinthia, which also offers a master's programme “Lightweight Engineering “. The Austrian Institute of Technology is one of the most important non-university research organisations and owner of the competence unit “Light Metals Technologies Ranshofen”. The research organisation has strong competences in the development of high-quality light metal alloys, sustainable processing methods and functionally integrated lightweight components. In the region of Styria, the Materials Center Leoben (MCL) and the Polymer Competence Center Leoben (PCCL) both have research areas (composite materials) related to lightweight construction.

Figure 2: Main actors in lightweight construction in Austria



Source: Austrian Institute for SME Research

Based on the analysis above, discussions with cluster representatives as well as companies and research organisations, the lightweight construction community can be characterised as well networked within their respective subject areas (e.g. plastics, metals, automotive, aerospace). They represent regional clusters, which are partly also well networked across regions and subject areas. Still, they represent businesses and research organisation on a regional scale, and some other networks are not integrated much into the core of active cluster representations. This hinders partly cross-disciplinary and domain-specific knowledge and technology transfer, and lessens the leverage of Austrian organisations towards international representation, cooperation and their contribution to a future-proof, sustainable R&D and industrial landscape.

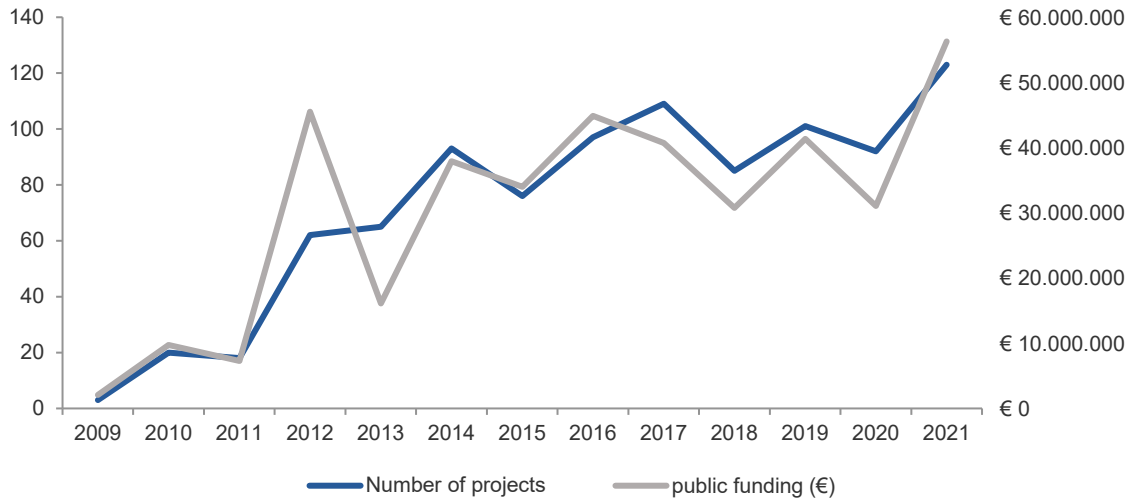
The following chapter sheds some light on the characteristics of lightweight R&D projects and its actors that had been funded largely as industrial research projects between 2009 and 2021.

2.2 Lightweighting in applied research and development as a cross-cutting theme

Especially when it comes to research and development, only a few organisations focus heavily on research and developing in new lightweight solutions. Most of those organisations are related to the aerospace sector or act as suppliers in the automotive sector. New products or solutions are often developed for a premium market segment (e.g. sport cars, aircrafts), as weight and quality are of higher priority than in the mass market, where costs often limit the use of new lightweight solutions.

Based on an analysis of projects funded by the Austrian Research Promotion Agency (FFG), the number of publicly funded R&D projects related to lightweight increased from 2009 to 2021. During this period, the yearly amount of funds given to organisations who conducted R&D projects related to lightweight also increased considerably, as seen in the figure below.

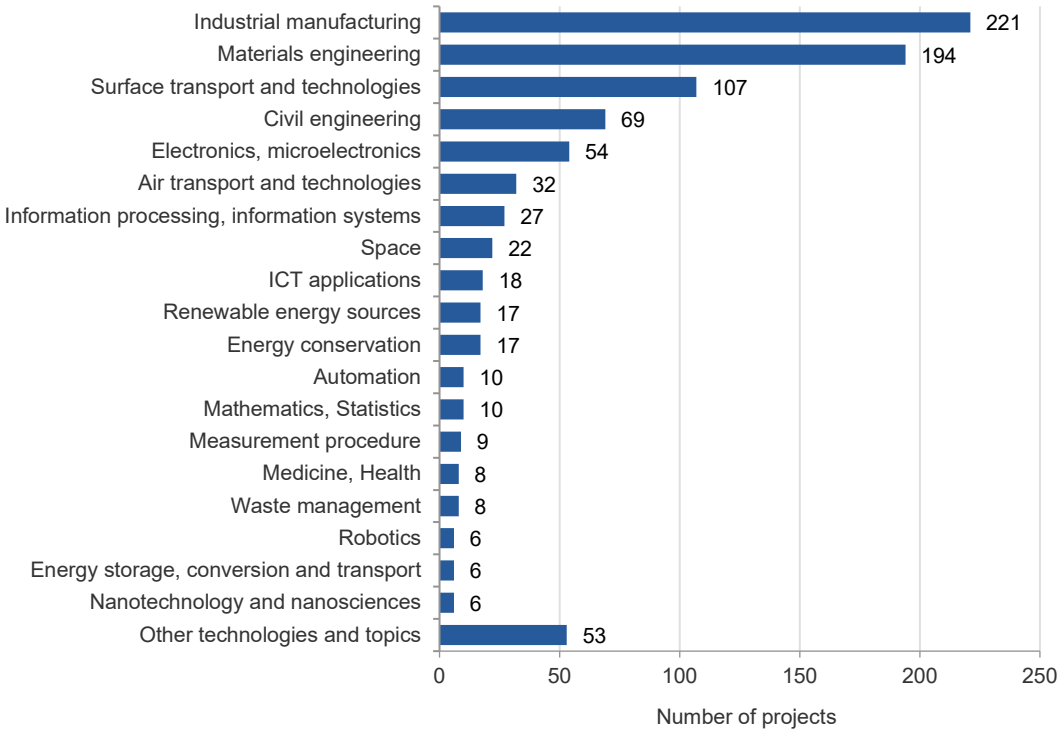
Figure 3: Number of lightweight R&D-projects funded by the FFG and funds received by organisations, 2009 - 2021



Source: FFG, Austrian Institute for SME Research; n=945 projects

The definition of lightweight projects is based on a text analysis of titles, abstracts and whole project applications, which was searched for a set of terms agreed with thematic specialists, with different languages and spellings. Thus, it is not possible to exclude false positives or negatives completely, but it certainly gives a good impression of developments. It also shows that lightweight construction is indeed a cross-sectional theme. For example, there are several lightweight-relevant topics covered within these R&D projects, as shown below. Based on the subject index codes (SIC) that each R&D-project is tagged with by the FGG, the most relevant topics for lightweight construction in Austria between 2009 and 2021 had been industrial manufacturing, materials engineering, and surface transport and technologies. The fourth most mentioned category civil engineering also includes technical services for the construction sector.

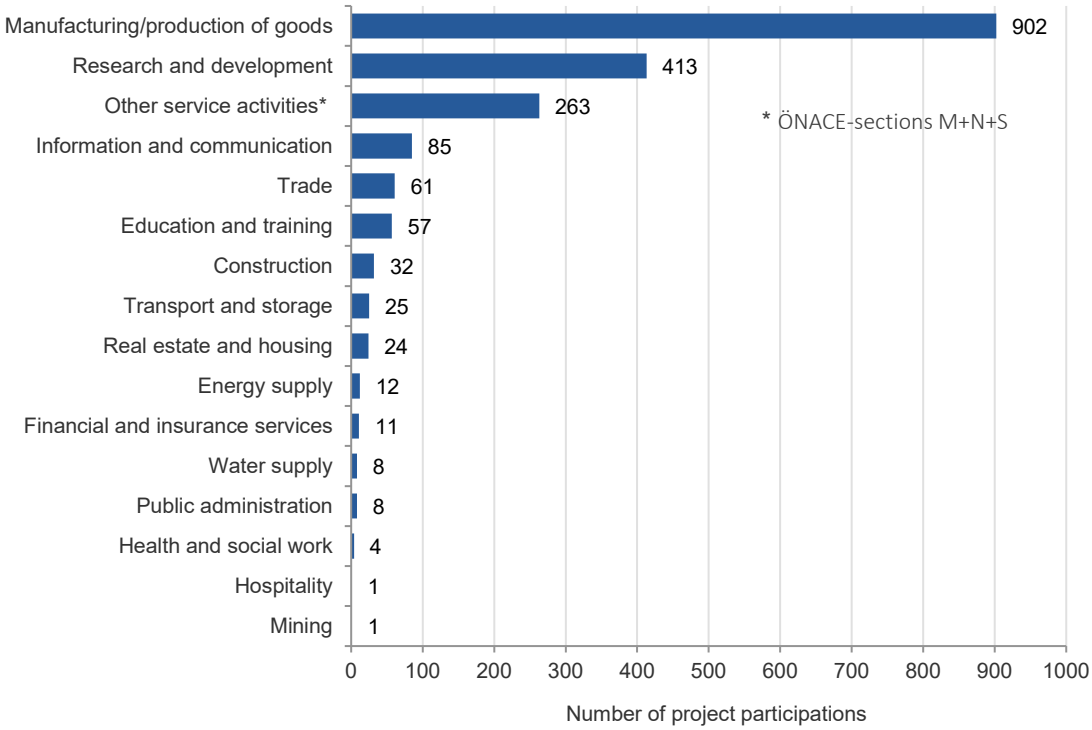
Figure 4: Distribution of lightweight R&D research projects funded by the FFG between 2009 and 2021 according to primary topics (Subject Index Codes)



Source: FFG, Austrian Institute for SME Research; n=894 projects (51 projects could not be assigned a SIC)

A similar picture emerges when we look at the economic sectors that received funding for R&D projects during 2009-2021. Most companies can be assigned to manufacturing / production of goods, followed by research and development and other services activities. This highlights that most of the funded R&D activities (by the FFG) in Austria are related to industry and may have a high economic exploitation potential.

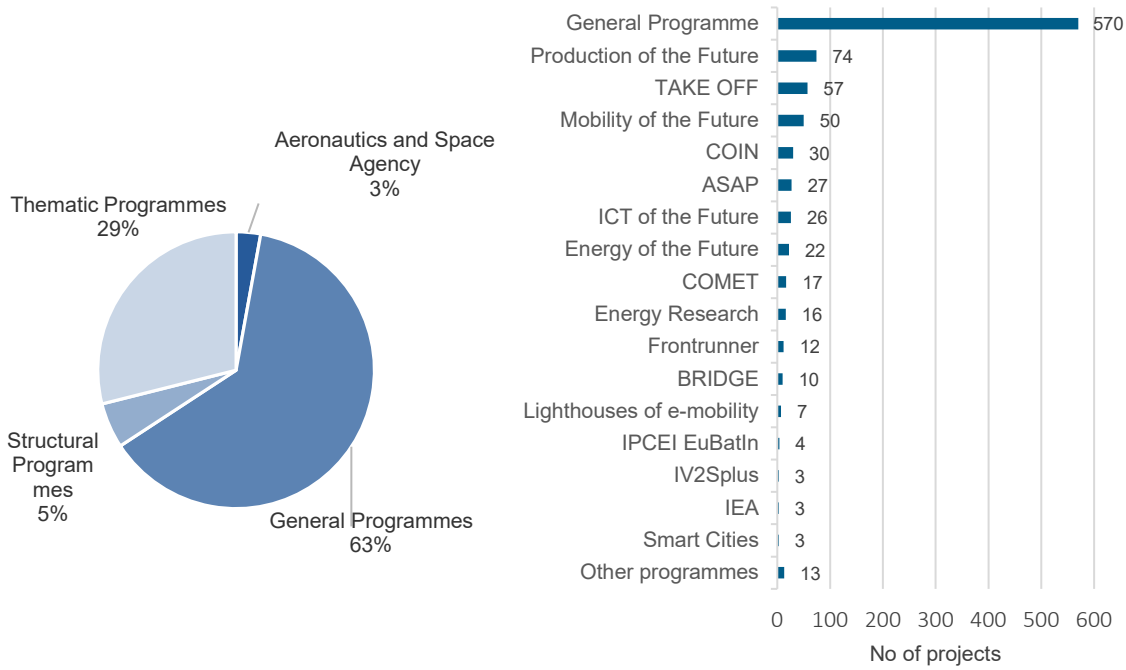
Figure 5: Distribution of funded companies with lightweight R&D projects by the FFG between 2009 and 2021, according to their ÖNACE 2008 classification



Source: FFG, Austrian Institute for SME Research; n= 1.906 project participations (574 research participants are excluded)

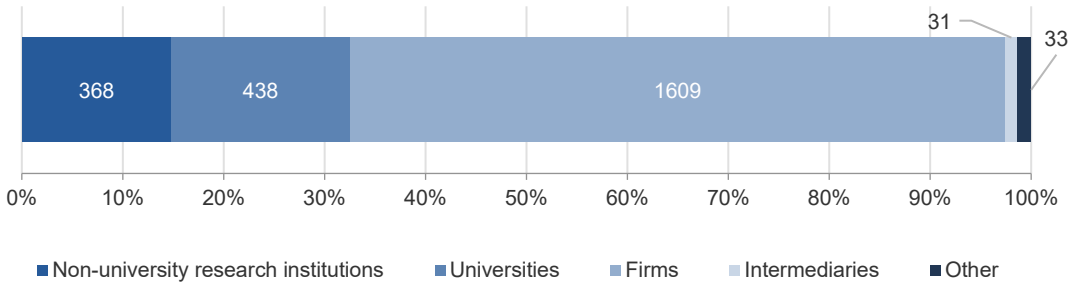
The large share of firms among the funded organisations supports this assumption. Many R&D projects were funded under the thematically open FFG instrument “General Programme”. This specific instrument is tailored towards funding R&D projects in companies, whereas in thematic programmes (in areas such as mobility, aerospace or production technology) research institutes are also eligible for funding in cooperative projects.

Figure 6: Distribution of funded projects by the FFG according to programme areas (left) and funding programmes (right)



Source: FFG, Austrian Institute for SME Research; n=944 R&D projects

Figure 7: Types of organisations funded in lightweight research projects by the FFG, 2009 – 2021 (multiple counting of organisations)

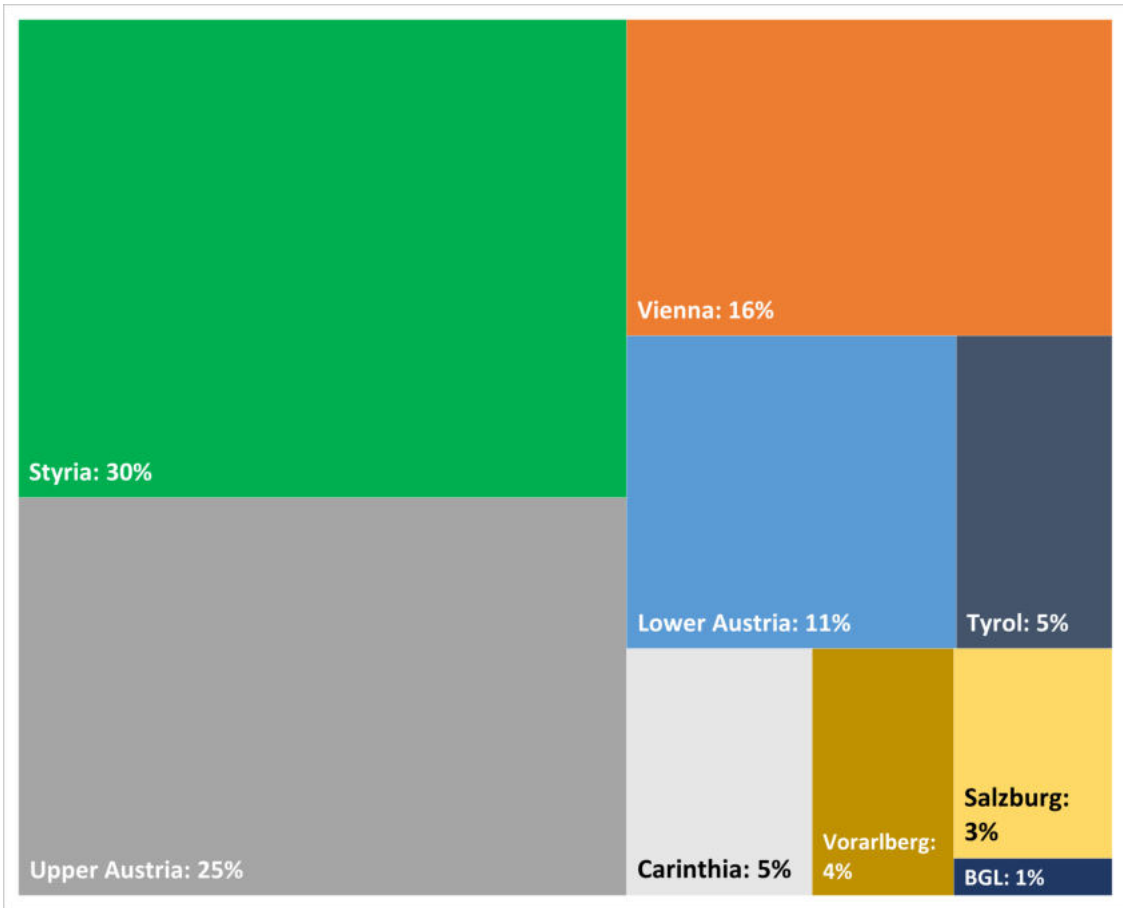


Source: FFG, Austrian Institute for SME Research; n=2.479 project participations

The figure below shows the regional distribution of funded organisations with R&D projects related to lightweight between 2009 and 2021. Most organisations are located in Styria or Upper Austria, which are the regions where most actors related to lightweight

construction activities have company sites. The TU Graz and the Montanuniversität Leoben, two universities active in the field of lightweight research, are located in Styria as well as many manufacturing firms. The same applies to Upper Austria, which has historically a strong industry and also has established research institutions like the University of Applied Science Upper Austria, which offers a study in lightweight design and composite materials. It is also worth mentioning, that the share of SMEs conducting R&D projects is relatively low. The share of large companies among all project participations between 2009 and 2021 is 54%, while the share of medium enterprises is 15% and the share of small enterprises is 31% respectively.

Figure 8: Regional distribution of organisations that conducted lightweight R&D projects funded by the FFG, 2009 – 2021 (multiple counting of organisations)

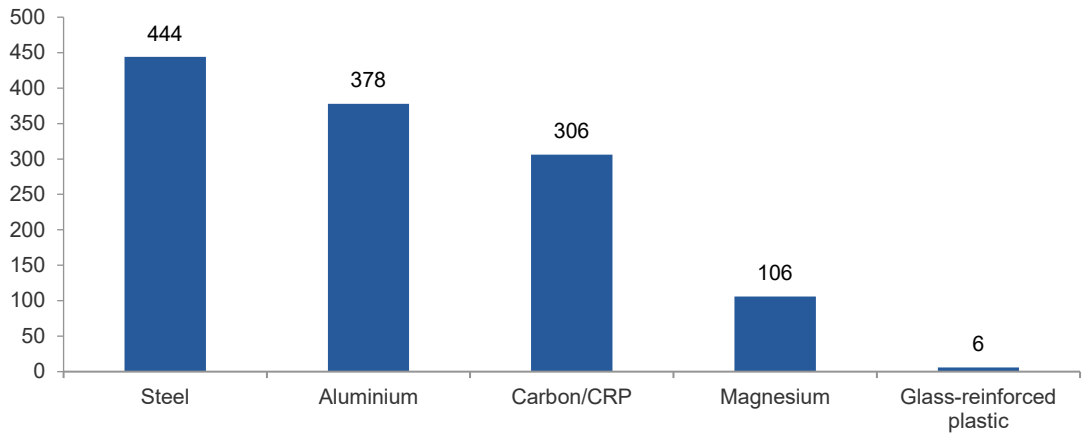


Source: FFG, Austrian Institute for SME Research; n=2.277 project participations (not included are 204 participations of foreign organisations); BGL = Burgenland

Based on the analysis of FFG data, more than 1,000 different actors have engaged in occasional projects with lightweight relevance over the years. But only a few major players conduct lightweight R&D-projects on a regular basis. There are 67 organisations (companies and research institutions) that conducted five or more funded R&D-projects between 2009 and 2021. This includes most of the actors involved in lightweight construction initiatives and clusters as well as other relevant actors we came across in the course of our research for this study. Between 2009 and 2021, 15 organisations conducted 20 or more funded research projects related to lightweight construction.

Funded lightweight projects were also screened for the extent to which different lightweight materials were mentioned in the project title, abstract or proposal.

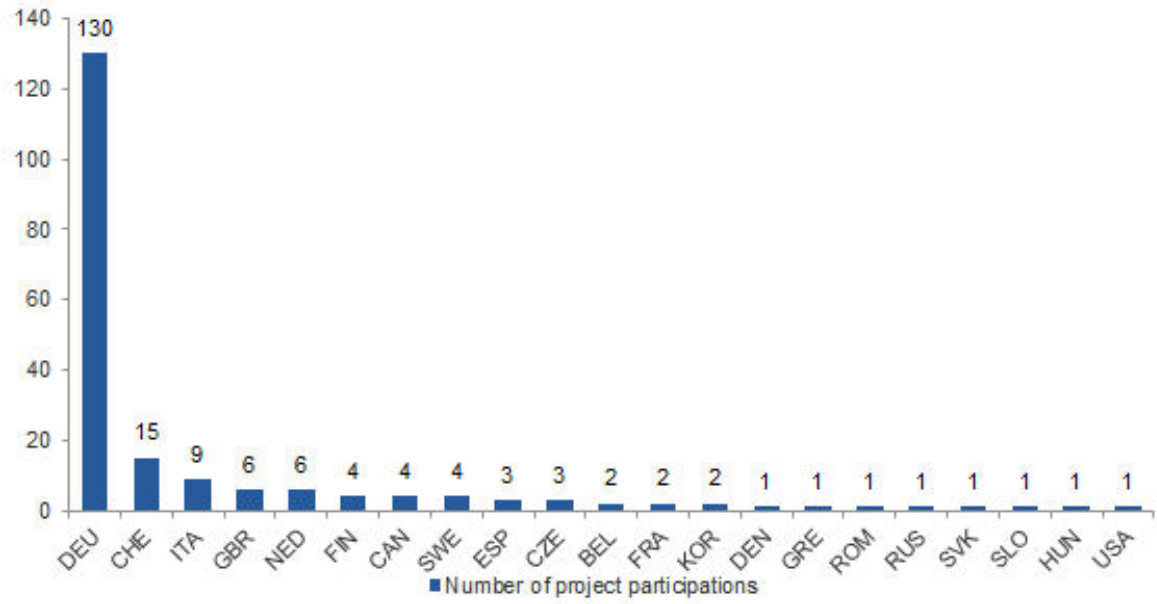
Figure 9: Lightweight materials referred to in R&D projects funded by the FFG, 2009 – 2021



Source: FFG, Austrian Institute for SME Research; n=944 R&D projects; multiple references per project possible

It is noteworthy that most R&D projects can be assigned to lightweight metal construction, whereby the reference to steel, which is not usually considered a classic lightweight material, is particularly striking.

Figure 10: R&D lightweight project participants in the FFG Portfolio from abroad, 2009-2021



Source: FFG, Austrian Institute for SME Research; n=198 R&D project participations; multiple references per participant possible

Within the FFG funding portfolio, transnational cooperations with international partners are also eligible for funding to a certain extent (up to 20 % of project costs). German partners are by far the most frequent collaborators in lightweight research projects, which shows that the general intense relationships with German stakeholders along value chains is also true for lightweight construction. There are also partnerships between cluster organisations on the regional level, like for example between Baden-Württemberg and Upper Austria, offering their member organisations access to lightweight constructions networks and enabling collaboration opportunities. The second most frequent partners are from Switzerland, followed by Italy, Great Britain and The Netherlands. The overall participation of foreign research partners over the period 2009-2021 is rather low however. Out of 944 projects, foreign partners participated only in 61 projects (ca. 6 % of all projects). Foreign partners tend to be involved in projects with more participations, which can be attributed to the fact that foreign organisations often participate in the COMET programme.

Table: 2 R&D lightweight collaborations with European regions

Regions	Project topics	Types of foreign organisations involved	Project participations
Stuttgart	Energy-storage, -conversion and -transport, environment, materials technology	Companies (7), other (1)	8
Munich	Measurement methods, environment, materials technology	Companies	7
Berlin	ICT, renewable energy sources, environment, materials technology	Companies (4), research organisations (3)	7
Darmstadt	Industrial manufacturing, environment	Companies (2), research organisations (3)	5
Ingolstadt	Surface traffic and technologies, environment, materials technology	Companies	5
Bozen	Renewable energy sources, Other technologies	Companies (2), research organisations (1), intermediaries (1)	4
Dresden	Robotics, environment, materials technology	Companies (3), research organisations (1)	4
Tampere	Nano technologies, environment, materials technology	Companies (1), research organisations (2)	3
Schwäbisch Gmünd	Energy Savings, industrial manufacturing, materials technology	Companies	3
Sempach	Surface traffic and technologies, construction technology, materials technology	Companies	3

Source: FFG, Austrian Institute for SME Research; Regions with the highest project participations; n=200 R&D project participations; multiple references per participant possible

In addition to the funding instruments of the FGG, there are other public support options in Austria in which research topics in lightweight construction can be addressed. These include the Christian Doppler Laboratories (CD Laboratories) with involvement of universi-

ties, and Josef Ressel Centres (JR-Centres) which are set up at universities of applied sciences. Both have a duration period of maximum seven years and are co-financed by the public sector and industry. CD labs conduct application-oriented basic research and are therefore prior to the classic industrial and experimental development in the mid-range TRLs, on which large parts of the FFG portfolio concentrates. Four CD laboratories with an obvious connection to lightweight construction have been funded to date, two of which are still in operation at the time of writing this report: the "CD Laboratory for the design of high-performance alloys using thermo-mechanical process technology" at Graz University of Technology and the "CD Laboratory for Advanced Aluminium Alloys" at the University of Leoben. On the lower TRL levels, the Austrian Science Fund (FWF) offers a number of different programmes to support basic research. However, funded projects in the field of lightweight construction are comparatively rare. As a query of the project database shows, a search for "lightweight construction" in the period 2009 to 2021 only leads to a total of 21 hits[2].A study from Stadlbauer (2012) analysed the inventor and publication density of light construction material topics (wood, metal, and plastic) in Austrian and European regions based on European patent applications, Patent Cooperation Treaty (PCT) applications and scientific publications of the previous 10 years. Within Austria and in relation to the number of inhabitants of the respective province, Upper Austria had the most patent applications overall. Vienna had the most publications in relation to the number of inhabitants. In an international comparison, the German regions dominated in terms of patent applications in relation to the number of inhabitants for the material topics of wood, metal and plastics, led by Rheinhessen-Pfalz, Darmstadt, Düsseldorf and Karlsruhe. In terms of publications relative to the number of inhabitants, the top 3 regions were in France (Champagne-Ardenne, Midi-Pyrenees) and Germany (Darmstadt). Recent analyses show that Austria is comparatively innovative in terms of patents potentially relevant to lightweight construction. Austria's shares of worldwide patents (period 2012-2021) for

[2] Four hits when searching for „Leichtbau“, and 17 hits when searching for „lightweight“. https://pf.fwf.ac.at/de/wissenschaft-konkret/project-finder/?search%5Bwhat%5D=&search%5Bscience_discipline_id%5D=&search%5Bpromotion_category_id%5D=&extended=1 , 12.12.2022

glass composites, wood composites, foams, plastic composites and metal composites are higher than Austria's share of global GDP.[3]

The descriptive analysis confirms that lightweight construction can be considered a cross-sectional technology in research and development that is relevant in many different disciplines and sectors. Most lightweight construction projects in Austria can be assigned to the topics of industrial production, material development and mobility. There is no systematic screening of results from basic research, mostly funded by the FWF Austrian Science Fund, for its potential for future lightweight construction.

2.3 Research potentials and fields of application

Lightweight construction is considered to be a set of key enabling technologies of high relevance to the mobility sector for achieving its emission reduction goals. As there is a huge demand for research and technology development in materials, design as well as production technology, lightweight construction is also a highly innovative but also highly competitive field.

Considering the demands derived from the Green Deal and the circular economy, as well as the past and current research portfolio for lightweighting, further research and development is needed along all segments of the value chain of lightweight construction. Various strategy documents formulate the need for research in lightweight construction.

The Research and Technology Centre for Resource-Efficient Lightweight Structures for Electromobility (FOREL) published a guideline (Gaude et al., 2020) for resource efficient lightweight construction. The guide provides an overview of current and future development steps in the form of a roadmap and defines very specific research needs along the topics of lightweight construction technology, joining technology, recycling and predictive

[3] Press conference on 01 September 2022 in Vienna on "Leichtbau ist ökonomisches Schwergewicht und Schlüssel für den Klimaschutz. Studie zeigt erstmals wirtschaftliche Bedeutung von Leichtbau-Technologien in Österreich." (Lightweight construction is economic heavyweight and key to climate protection. Study shows economic importance of lightweight technologies in Austria for the first time)

capability. Developments in the areas of materials, technology and design up to 2030 and beyond are presented along these topics. For future development of lightweight solutions, current industrial developments should be considered, like the adaptation of automated production to different batch sizes, flexibility with regard to the modularity of components as well as the greater use of recycled materials. Digital technologies such as the use of artificial intelligence (AI) can support the planning and design of lightweight components (e.g. best combination of materials for the respective area of application). AI could also be used in the future for the purpose of a life cycle assessment (LCA). In this context, it is also important to collect digital data on products and components along their entire life cycle. In any case, joining technology and recycling must also be taken into account. In joining technology, the challenges are, on the one hand, to find optimised solutions for the respective lightweight structure and, on the other hand, to maintain a certain independence of materials and adaptability, and to enable the recycling or reuse of components. The high potential in the development of new lightweight materials is accompanied by major challenges in recycling. Due to the increasing diversity of materials, the recycling effort could increase, creating a need for adaptive recycling routes. Design decisions, for example, will increasingly require considerations regarding the recyclability and reusability of lightweight components. Cascade use, i.e., reuse (e.g. second use) or at best the recovery of the raw materials used, will also gain in importance. Gaude et al. (2020) define forecasting as another relevant topic. In addition to the development of simulation models, for example to determine material combinations or process parameters, the availability of data (standardised material characterisation, material maps ...) and interfaces, but also computing power play a role here. The authors emphasise the importance of sustainability in terms of increased efficiency and transparency of the production process. In addition to weight reduction, the increase in the degree of automation and the integration function are increasingly important reasons for the use of lightweight solutions in the future.

In the Materials Manifesto 2030 (AMI2030, 2022b), lightweight materials are considered as one field of application with relevance for policies like the European Green Deal and others. Its field of application differs slightly dependent on the economic sector, with its value for climate contribution (e.g. through the reduction of CO_2) mentioned across all

sectors (health and medicine, sustainable construction, new energy, sustainable transportation, etc.). Therefore, the main innovation needs for lightweight materials are solid-based dispersions, lightweight construction and design for hybrid structures, substitution of fossil lightweight materials by using renewable materials, design-for-circularity, and tailored fabrication processes (e.g. additive manufacturing). The AMI 2030 Roadmap (2022a) also defines material challenges and priority areas. In the transport sector (land vehicles, ships, aircrafts) these priority areas are: develop new materials (better durability, reduction of energy consumption, lifecycle performance), develop technologies to enable multi-functionality and multi-materials, improve production processes, high precision non-destructive inspection techniques for zero defects components, and advanced material models and simulation tools.

In the automotive sector, lightweight construction is seen as one solution among others to address current challenges like digitalisation, automation, safety, electrification and sustainability (EARPA, 2020). Future research fields are the implementation of materials that fulfil circular economy principles, the development of bio-based materials, a better understanding and managing of material and structural properties, predictive modelling and simulation, a life cycle database for materials and products as well as repair concepts.

Additionally, sustainability can be increased through design processes that consider sustainability criteria, which for example also include joining technologies. As electric cars are between 10 and 30 percent heavier than conventional vehicles, lightweight construction is a key concept to achieve range extension and the reduction of energy consumption (EARPA, 2020). Another research topic with high future potential for advanced propulsion technologies is additive manufacturing (especially 3D-printing technologies). Research is necessary to enable cheaper and faster additive manufacturing with a higher throughput. According to the Nöst et al. (2021), research is required in construction based lightweight design, material based lightweight design as well as production based lightweight design. Lightweight construction may currently not be of top political priority in the automotive sector as there are challenges to develop new propulsion systems that can fulfil the emission reduction requirements, but lightweight components are an important and integral part of future vehicles and powertrain systems. Furthermore, the community represented

by A3PS is aware of the challenges posed by lightweight materials in terms of sustainability. For example, further research is needed to increase the recycling rations of polymers metals and light metals (EARPA, 2020). Digitalisation could enable the development of lightweight solutions through feeding back data from product use in the product development, through virtual validation, verification and homologation, the use of AI (e.g. machine learning) for material and product development and impact assessment, and a seamless supply chain management (EARPA, 2020).

Market potentials for Austria were primarily derived from the interviews with experts. For example, the Austrian industry has demonstrated expertise in the recycling of lightweight construction materials (e.g. aluminium) in certain sectors, and this expertise could be further developed. Austria could take on a pioneering role against the backdrop of securing raw material value chains. Challenges are seen on both ends, the development of cost-effective recycling materials and securing a sufficient amount of waste as an input-source for being able to cover the demand.

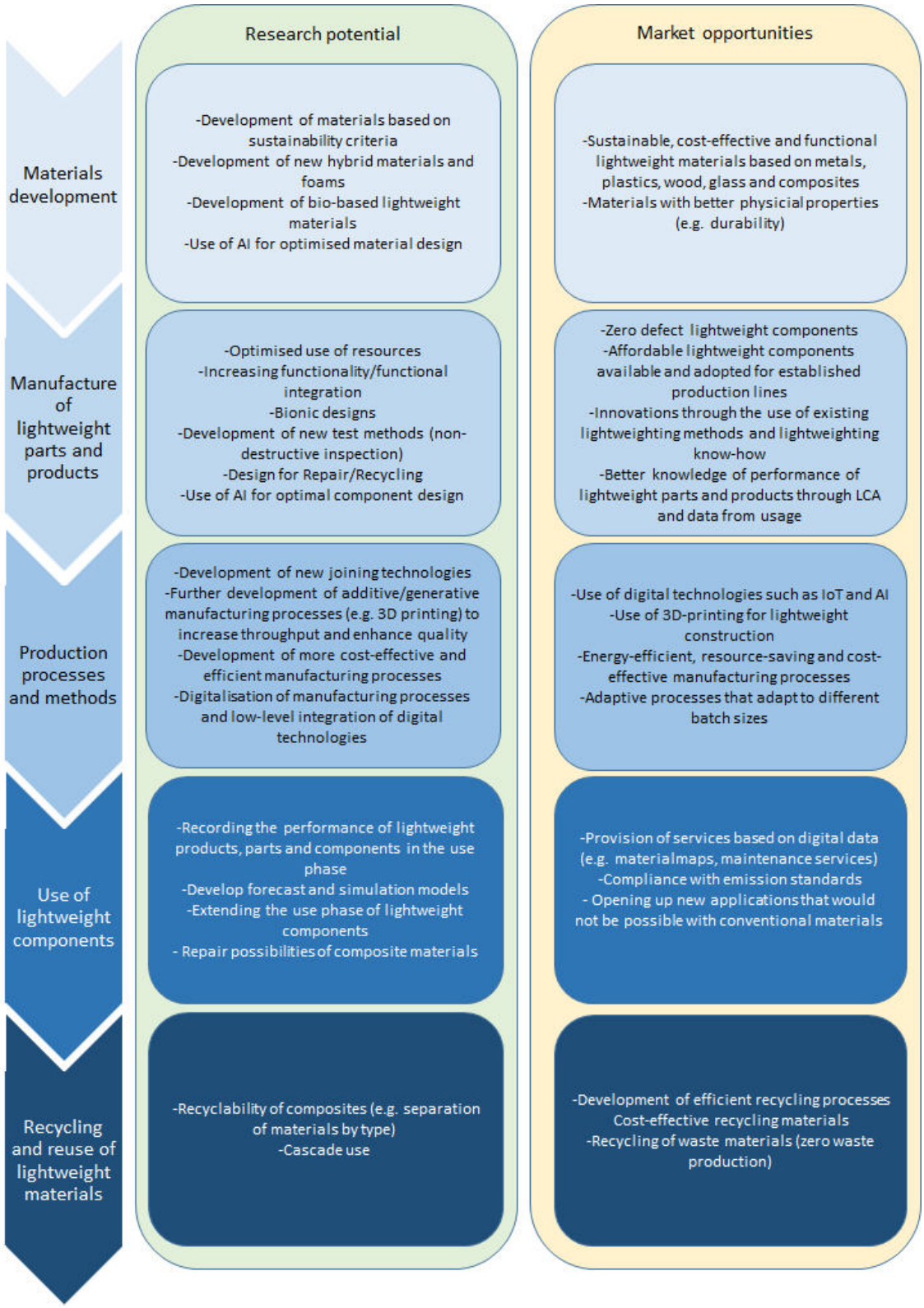
Most of the interviewees point to the high potential of lightweight construction as a cross-sectional technology and thus many different fields of application. Although the focus of this study was on the mobility sector, lightweight construction methods can also be applied in other areas to lower their resource use. For example, as pointed out in Figure 4, a number of research projects have already been carried out in civil engineering. In the construction sector, applications in the construction sector are rather rare, yet have potential, for example, as a construction method for wind turbines.

Austria has high competences and industrial capacities in the automotive, the heavy-duty vehicle construction and in the aerospace sector, but also in other economic sectors and industries such as construction and medical technology.

For applications, particularly high potential for lightweight construction is seen in the weight reduction of electric vehicles, for drones and air taxis, in the development of wind turbines (rotor blades), and in the development of medical products.

Representatives of companies point to the need for greater automation and scaling of lightweight construction in order to be able to offer the most cost-effective lightweight solutions on the market.

Figure 11: Research potentials and market opportunities of lightweight construction



Source: Literature and expert interviews, Austrian Institute for SME Research

2.4 Economic impact

Lightweight as a cross-cutting technology has considerable economic potential in many economic sectors. Lightweight solutions can be used in a variety of ways in a wide range of industries and applications. Thus, an assessment of the economic effects of lightweight construction is associated with some challenges.

The largest global markets for lightweight materials are the Asia-Pacific region, North America and Europe. Within Europe, Germany is the biggest lightweight materials market, followed by France. The global market value of lightweight materials (such as lightweight metals and alloys, polymer composites and polymers) is expected to increase to € 221 bn by 2027, compared to the market value of € 117 bn in 2019 (Fischer, 2021). Overall, lightweight materials have a considerable growth potential in the near future in Europe and Austria. In Austria and Switzerland for example, production of composite materials nearly doubled from 2020 to 2021. Production of composites in Europe increased by 18% from 2020 to 2021, which was higher than the growth of the composite world market (11%). The growth of thermoplastics increased by 25% and the growth of thermosets increased by 10%.

Key industries that boost the global growth of lightweight materials are automotive, aerospace, energy sectors and other industry sectors such as construction, and machinery and equipment. Important lightweight materials are lightweight metals and alloys (e.g. aluminium, magnesium, but also titanium and high-strength steel), polymer composites (e.g. carbon fibre as well as glass fibre reinforced plastics, CFRP and GFRP) and polymers (e.g. polycarbonate and polypropylene). The turnover of all lightweight material markets is expected to grow in the coming years. Interestingly, within the lightweight materials groups, the strongest growth is expected for steel in the next years, due to new steel grades/types being developed and the substitution of traditional steel (Fischer 2021). In addition, new steel based lightweight sandwich and laminate materials are being developed (Gauß et al., 2022). Another reason for the strong growth potential of steel is that most processes and manufacturing methods as well as supply-chains are well established. With regard to aluminium, the upcycling of high-performance alloys from scraps for reuse in applications

could be further developed (Gauß et al., 2022). The large-scale production of fibre-reinforced polymers is limited by high costs and a lack of understanding of the material properties. Therefore, innovative production processes, the development of bio-based fibres, joining technologies and multi-materials are among others important fields for further research (Gauß et al., 2022).

Most materials markets are dominated by Asian countries, where most of the materials production takes place (e.g. China for aluminium, magnesium and polymers, Japan and the USA for composites). In Europe, many important industrial players are based in Germany. There are also important European players based in Austria in the lightweight material categories high-strength steel (voestalpine), aluminium (AMAG) and polymers (Borealis).

In terms of applications, lightweight materials are of essential importance in the aerospace sector; therefore, this is the primary field of applications for lightweight construction. Due to the expected replacement of older and less fuel-efficient aircrafts in the next 20 years, the expected quantity of lightweight materials used in aeronautical structures may reach around 500.000 tons (AMI2030a, 2022).

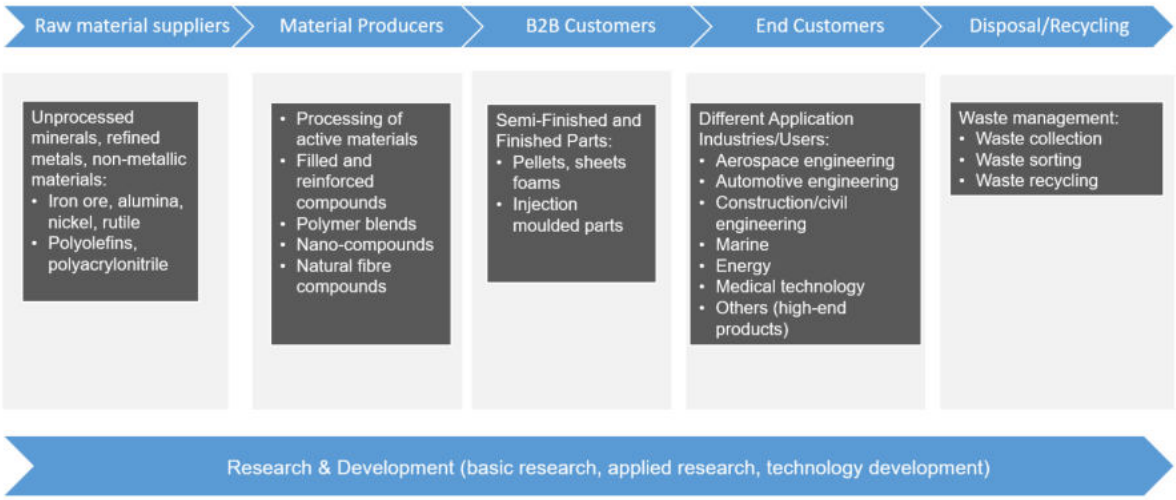
The automotive sector however, has the largest share of lightweight materials in terms of revenue. In 2025, the revenue of lightweight materials in the automotive sector is estimated to reach more than € 83 bn (Fischer, 2021). The importance of the transport sector for lightweight construction is also highlighted by Reiland et al. (2019, p.10), who estimate that 90% of total lightweight materials are used in the automotive sector. Regarding the use of composites in Europe most are used in transport (53%) and construction, infrastructure (19%), and electronics (18%). In both, the aerospace and the automotive sector, the reduction of CO_2 emissions and the increase of fuel/energy efficiency are key drivers for the application of lightweight materials. In e-mobility, there will be an increasing need not only for batteries and fuel cells but also for lightweight traction motors for cars, e-bikes, scooters and heavy-duty transport (Bobba et al., 2020).

In the energy sector, potentials for the increasing use of lightweight materials are wind turbines (rotating blades), and in other industry sectors new production technologies (e.g. additive manufacturing, new moulding processes) broaden the field of application for

lightweight construction. Some experts interviewed in this study also highlighted the potential of lightweight construction in medical engineering, for example in the manufacture of prostheses.

In recent years, the resilience of industrial value chains as well as their sustainability has increasingly become a focus of attention. This is partly due to the measures against the COVID 19 pandemic and its effects on global logistics, but also due to the growing importance of emission reduction measures at all stages of the value chain, from mining to material production, utilisation and recycling. Lightweight solutions have the potential to transform value chains, but are also embedded in established production cycles that are difficult to change due to path dependencies.

Figure 12: The value chain of lightweight materials



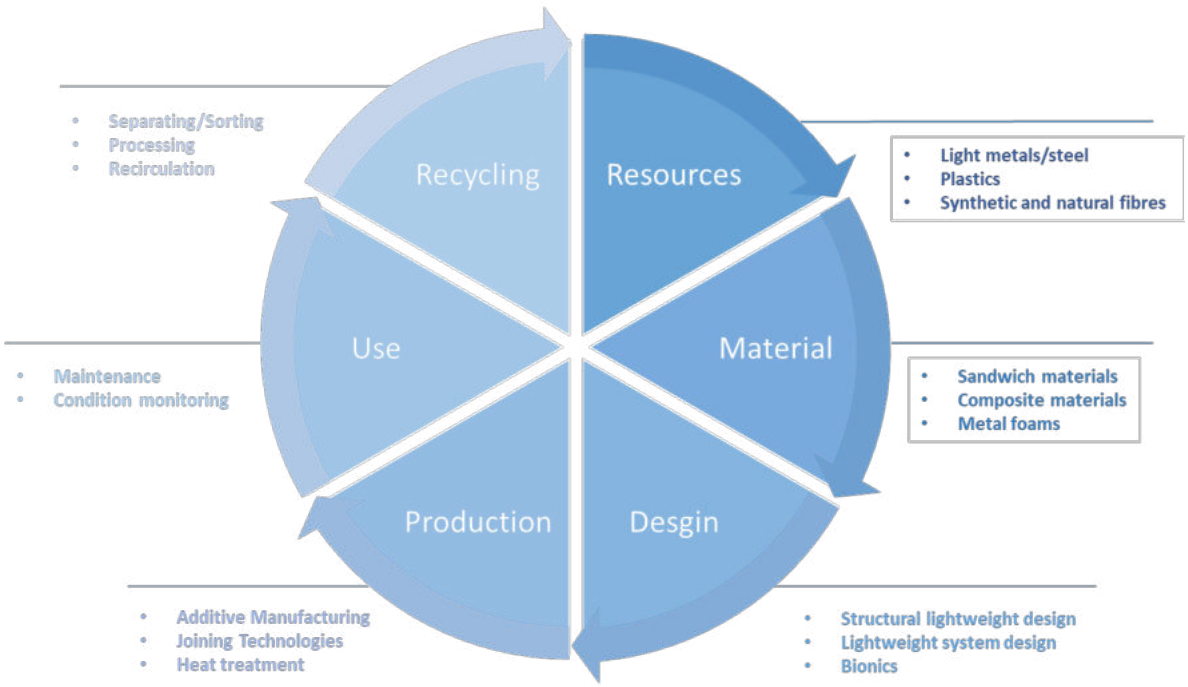
Source: Fischer (2021).

A German study from 2014 examined the value creation potential in lightweight construction with a focus on Baden-Württemberg (Stroka et al., 2014). In this study, value creation potentials were investigated separately for different processes (RTM, SCM) and lightweight metal construction. The study examined the respective value-added shares along the value chain of materials (semi-finished product production, component, finishing/reworking, and assembly) and the types of costs incurred in the production of the component. All three processes have in common that the highest value-added shares are already

incurred in the production of the materials and semi-finished products. This however, could change in the future when sustainability criteria are introduced and the ecological effects of lightweight solutions (like resource efficiency and lower CO_2 emissions in the use phase) during the whole product life cycle are taken into account. The study further investigates the obstacles and motives for lightweight construction, but does not analyse the economic impact of lightweight in terms of value creation of employment.

The following figure illustrates the lightweight construction value chain from a life cycle perspective and shows examples of topics within each stage of a lightweight product.

Figure 13: Value chain of lightweight construction



Source: Kadi, Laubstein, Seifert, & Worrack (2021), adapted by Austrian Institute for SME Research

A recent study analysed the economic impact of lightweight construction in Austria. The author used a top-down approach based on official statistical data and assessment of experts to estimate different model-scenarios for value added and employment effects of lightweight construction. As lightweight construction is cross-sectional, it comprises many economic sectors such as manufacturing, energy, construction, mining and forestry.

Therefore, its overall value-added and employment effect are considerable in comparison to the gross-value-added and total employment in Austria.

According to this (non-published) study, lightweight construction in Austria generated in 2019 direct value added of € 9.4 bn and secured 77,400 jobs. Based on this calculation, the value added created of lightweight construction is greater than the value added of the mechanical engineering sector. Every euro generated in lightweight construction triggers a further 0.74 euros of value added in the upstream and downstream value chain throughout Austria. In total, almost 16.4 billion euros could be attributed to lightweight construction, which secured 186,000 jobs (A2LT, 2022, p. 2-6).

The economic impact of lightweight construction in Austria is considerable. One limitation needs to be considered, though. Estimates are based on expert assessments because no commonly accepted definition of lightweight construction exists as of today. Not least due to the two mega-trends that industry and mobility needs to become climate-neutral by implementing circular economy principles (incl. weight reduction / material replacement) AND the digitalisation of processes, components and products, the market value of lightweight construction will very likely increase in the near and distant future.

3 Lightweight construction in a European and global context

Lightweight construction, both as a technology and in the sense of a design philosophy, is increasingly becoming the focus of attention in politics, research and business in Europe, but is also confirmed by representatives of international networks. Against the background of the European Green Deal[4], which envisages a reduction of net greenhouse gas

[4] Cf.: Europäischer Grüner Deal – Erster klimaneutraler Kontinent werden. See: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_de (15.09.2022)

emissions by at least 55 % by 2030, as well as current economic crises and political upheavals, concepts that save resources and simplify processes are rapidly gaining in importance. Approaches to solutions very often have references to lightweight construction, even if they are not (yet) necessarily linked with this term. The following characterisation of lightweight construction provides an insight into the development of lightweight construction in the regions of Europe and shows possible points of contact for cooperation with Austria. Nevertheless, due to the diversity and cross-sectional character of lightweight construction, the international status of lightweight construction cannot be presented in full within this study. The presentation therefore makes no claim to be complete, but captures the most important (policy) trends and networks.

Central industries and OEMs

The automotive and aerospace industries are important drivers of developments in lightweight construction, especially in the European context. The international supply chains established for major European carmakers (e.g. Volkswagen Group, BMW, Mercedes Benz Group, Volvo, Stellantis) or aircraft manufacturers (e.g. Airbus) form a basis for value chains involving thousands of subcontractors from all over Europe and beyond.

The need for lightweight solutions is also increasing in the production of wind turbines. The top nine manufacturers of wind turbines in 2022 are[5]: GE Renewable Energy (Germany), Goldwind (China), Vestas (Denmark), Enviosion (China), Siemens Gamesa (Spain), Mingyang Shanghai Electric (China), Windey (China), CRRC (China) and Sany (China). Interview partners in this study were very much in favour of strengthening the European value chains, given the economic potential and the political context in which we find us now.

In the building industry, lightweight construction is once again coming into focus. The shortage of raw materials and the associated reduction of resources is the actual driver for lightweight construction innovations. Large potentials are expected from a transfer of

[5] Cf.: Windenergie-Hersteller: Ranking 2020, national & international. Windbranche.de. See: https://www.windbranche.de/wirtschaft/unternehmen/hersteller-ranking. (15.09.2022)

knowledge from industries that are already strong in lightweight construction to the building sector. This does not only apply to the construction of prefabricated houses. In the future, lightweight construction also promises solutions for urban concepts such as the greening of facades und roofs[6], the construction of greenhouses and light construction halls.[7]

Medical technology and the production of prostheses make up a smaller, albeit not insignificant share. For example, manufacturers of prostheses are mainly located in Germany, Switzerland, Austria, Poland, Hungary and Taiwan.[8]

Another segment relevant to lightweight construction is the sports equipment sector. The website https://www.fitnessgeraete.org/marken/ lists almost 100 manufacturers of fitness equipment for the German-speaking market, which corresponds to a considerable market: In 2019 - before the corona pandemic - the turnover of the fitness equipment industry in Germany alone was around 11.66 billion euros.[9]

3.1 Visibility of lightweight construction

More or less pronounced lightweight construction activities can be observed in all European countries. These are becoming visible in particular through networking but are also increasingly moving into political consciousness. However, final strategies and concepts

[6] Cf.: Dachbegrünung Leichtdach. Der schlanke Gründachaufbau für Dächer mit geringen statischen Reserven (0-5°). Optigrün. See: https://www.optigruen.de/systemloesungen/leichtdach/leichtdach. (15.09.2022).

[7] Cf.: Leichtbauhallen: Bauweisen, Preise und Anbieter im Vergleich. Comobau. See: https://www.comobau.de/leichtbauhallen. (15.09.2022)

[8] Cf.: Prothese. Hersteller, Händler, Lieferanten. Industrystock.com ; See: https://www.industrystock.de/de/unternehmen/Medizintechnik/Prothetik/Prothese- (15.09.2022)

[9] Cf.: Der deutsche Fitnessmarkt 2020. Deloitte, Sports Business Group https://www2.deloitte.com/de/de/pages/consumer-business/articles/deutscher-fitnessmarkt-studie.html (15.09.2022)

for the promotion of lightweight construction can so far only be found in Germany and Sweden. Other countries are believed to have strategies in development. However, lightweight construction is often integrated into other strategies: France, for example, has so-called "acceleration strategies for innovation" (linked to the Programme for Investment in the Future; PIA4)[10], which include fields of application in lightweight construction. The focus is on industrial promotion, mobility and space travel as well as sustainable urban construction.

In the past, established conferences and symposia explicitly addressed specific sectors or materials, but for some years now there have been the first events that address lightweight construction holistically, i.e., across all sectors and technologies. With an international audience, these include LightCon[11] in Hanover, which took place for the first time in 2022, and the older LIGHTer International Conference[12] in Gotheburg. The Norwegian LightMAT[13] in Trondheim also focuses on a broad spectrum of lightweight construction themes, with a focus on various materials. In addition, there are few regional events in the German-speaking countries that present lightweight construction in its entirety (see profiles for sample countries).

[10] Cf.: Stratégies d'accélération pour l'innovation. Gouvernement.fr. See: https://www.gouvernement.fr/strategies-d-acceleration-pour-l-innovation. (15.09.2022)

[11] The international congress fair presents lightweight construction solutions for a variety of user industries across materials and technologies. In around 40 lectures, companies and science present the latest developments. In parallel, more than 30 products are exhibited. Cf.: LightCon. New congress fair for lightweight construction. See: https://www.lightcon.info/de/. (15.09.2022)

[12] The International Conference is open to all sectors and technologies. A declared aim of the conference is to promote international networking and the initiation of cooperation as well as the transfer of knowledge between science and industry. Cf.: LIGHTer International Conference 2022. See: https://lighter.nu/en/event/lighter-international-conference-2022. (15.09.2022).

[13] The International Conference on Light Materials - Science and Technology LIGHTMat addresses processes and applications in the context of lightweight construction. Special topic in 2023 was Sustainable and innovative metal processing. Cf.: 5th International Conference on Light Materials - Science and Technology. LightMAT 2023. See: https://dgm.de/lightmat/2023/. (15.09.2022).

Much more frequent are technology- or sector-specific events that (indirectly) address the topic of lightweight construction. Despite the fact that the focus is elsewhere, some of them are generally considered to be "suitable for providing lightweight construction with a stage (also internationally)". The technology-specific events include, in particular, JEC World[14] in Paris, which is considered the world's largest trade fair for lightweight and, with its open-sector focus on composites and their applications, attracted around 43,500 trade visitors from 112 countries in 2019. Conferences and congresses with an international audience and a focus on scientific exchange on composites and polymers are held mainly in Spanish-speaking countries. These include the Congreso Nacional de Materiales[15] (CNMAT 2022) in Ciudad Real and the Latin American Polymer Symposium/ Ibero American Polymer Congress[16] (GEP-SLAP2022) in San Sebastian. The International Materials Research Congress[17] (IMRC) is held annually in Cancun, Mexico. This is organised bilaterally by the US Materials Research Society (MRS) and the Mexican Sociedad Mexicana de Materiales (SMMater) and is also attended by international representatives from Europe. Further conferences with a technology-specific focus can be found in the profiles of the selected countries. The following events are also worth mentioning:

- International Congress on Welding, Additive Manufacturing and Non-Destructive Testing[18] (ICWAM 2019) in Metz, France

[14] Cf.: JEC World. The leading International Composite Show. See: https://www.jec-world.events/de/about-jec-world/. (16.09.2022).

[15] Cf.: Congreso Nacional de Materiales (CNMAT 2022). See: https://cnmat2022.com/. (16.09.2022)

[16] Cf.: LatinAmerican Polymer Symposium/ IberoAmerican Polymer Congress (GEP-SLAP 2022). See: https://www.gep-slap2020.eu/home. (16.09.2022)

[17] Cf.: International Materials Research Congress (IMRC). See: https://mrs.org/joint-meetings/xxx-international-materials-research-congress. (16.09.2022)

[18] Cf.: International Congress on Welding, Additive Manufacturing and Non-Destructive Testing (ICWAM 2019). See: https://icwam.com/ (16.09.2022)

- International Conference on Advanced Manufacturing and Materials[19] (ICAMM) in London, Great Britain
- Congresso Brasileiro de Cerâmica[20] (CBC) in Águas de Lindóia, Brasil
- Canadian international conference on composites[21] (CANCOM) in Fredericton, Canada
- Carbon Fiber in Knoxville and Materials Science & Engineering in Houston; Polymers in Los Angeles, all USA
- Annual World Congress of Advanced Materials[22] (AMMM) in Fukuoka, Japan

Industry-specific events usually address lightweight construction only indirectly. Then, in particular, applications of lightweight construction are presented without it being explicitly emphasised. The world's most important trade fairs related to automobility and transport include:

- IAA Mobility [23]und IAA Transportation[24] in Hannover, Germany
- Geneva International Motor Show[25] (GIMS) in Genf, Switzerland (in 2023 in Doha, Qatar due to the pandemic)
- North American International Auto Show[26] in Detroit, USA

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[19] Cf.: International Conference on Advanced Manufacturing and Materials (ICAMM). See: http://www.icamm.org/. (16.09.2022)

[20] Cf.: Congresso Brasileiro de Cerâmica (CBC). See: https://www.metallum.com.br/65cbc/. (16.09.2022)

[21] Cf.: Canadian international conference on composites (CANCOM). See: https://www.cancom2022.ca/. (16.09.2022)

[22] Cf.: 4th international conference on Advances in Materials, Mechanical and Manufacturing (AMMM 2022). See: http://www.ammm.org/. (16.09.2022)

[23] The key topics for 2023 are Connected, Autonomous, Sustainable, Urban and Rural Mobility, Circular Economy, Digital Innovations and Smart City Infrastructure. Cf.: Experience Connected Mobility. IAA MOBILITY 2023. See: https://www.iaa-mobility.com/de/aussteller/iaa-mobility-2023. (16.09.2022)

[24] Cf.: People and goods on the move. IAA TRANSPORTATION 2022. See: https://iaa-transportation.com/de. (16.09.2022)

[25] Cf.: Geneva international Motor Show GIMS. See: https://www.gims.swiss/de. (16.09.2022)

[26] Cf.: The future is designed in Detroid. North American International Detroid Auto Show. See: https://www.naias.com/.(16.09.2022)

- Automotive Lightweight Technology Expo within the Automotive World Show[27] in Tokyo, Japan

The latest developments in the aerospace industry show, among other things, the:

- International Air Show[28] (ILA) in Schönefeld, Berlin, Germany
- Paris Air Show[29] in Paris and Aeromat[30] in Toulouse, France
- Farnborough International Airshow[31] (FIA) in Farnborough, Great Britain
- EAA AirVenture[32] in Oshkosh, USA
- Dubai Air Show[33]

Rail transport is presented at the International Trade Fair for Transport Technology[34] (InnoTrans) in Berlin.

Wind power trade fairs are:

- WindEurope[35] in Copenhagen, Denmark
- HUSUM WIND[36] in Husum, Germany

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27 Cf.: 15th Aitomotive World 2023. Advenced Automotive Technology Show. See: https://www.automotive-world.jp/tokyo/en-gb.html. (16.09.2022)

28 Cf.: Pioneering Aerospace. ILA Berlin 2022. See: https://www.ila-berlin.de/de. (16.09.2022)

29 Cf.: Paris Air Show 2023. See: https://www.siae.fr/en/. (16.09.2022)

30 Cf.: International Business Convention for the Aerospace Industry. Aeromat 2022. See: https://toulouse.bciaerospace.com/en/. (16.09.2022)

31 Cf.: Pioneer the future. Discover the future of aerospace at the world's leading airshow. See: https://www.farnboroughairshow.com/. (16.09.2022)

32 EAA AirVenture. See: https://www.eaa.org/airventure/. (16.09.2022).

33 Cf.: The Centre of Aerospace, Strategy and Inspiration. Dubai Air Show. See: https://www.dubaiairshow.aero/. (16.09.2022)

34 The following focal points are adressed: Railway Technology, Railway Infrastructure, Public Transport, Interiors und Tunnel Construction. Cf.: The future of Mobility. InnoTrans 2022. See: https://www.innotrans.de/de/ (16.09.2022)

35 Cf.: WindEurope 2023. See: https://windeurope.org/annual2023/ (16.09.2022)

36 Cf.: HUSUM WIND – Transforming Energy. See: https://husumwind.com/. (16.09.2022)

- WindEnergy[37] in Hamburg, Germany
- Offshore WINDPOWER: Conference and Exhibition[38] in Rhode Island, USA

The list of events shows that lightweight construction as an explicit, holistic topic has received little attention so far. This has only begun to change in recent years. The lightweight construction landscape is rather fragmented and is still mainly addressed indirectly. Large events usually take place in countries where the corresponding industry is strong or where a large, internationally active company is located. Nevertheless, these conferences are seen as suitable stages for presenting lightweight construction as such. According to statements made in interviews, the conferences offer the opportunity to present lightweight solutions for the respective industry. If the focus is on the aspect of lightweight construction, a unique selling point can be emphasised in differentiation from other products.

3.2 European networks

A small number of international networks already exist in Europe with the aim of exchange and international cooperation. These are distinguished by supraregional / international cooperation from so-called clusters[39], whose aim is regional strengthening and organisation along value chains or on the basis of common location factors. Most of the international networks are associations of regionally/nationally active clusters or networks that are an association of companies and research institutions. The driving actors are usually active in the networks on a "voluntary" or part-time basis. The degree of networking,

[37] Cf.: Wind Energy Hamburg. The global and offshore event. See: https://www.windenergyhamburg.com/. (16.09.2022)

[38] Cf.: Offshore WINDPOWER 2022. ACP (cleanpower.org). See: https://cleanpower.org/events/offshore-windpower-2022/. (16.09.2022)

[39] A compilation of the most important national/regional clusters for selected countries can be found in the Profiles for European partner countries in the appendix.

the variety of actions and the success of the network depend on their commitment. In addition to the ELN, the most important European networks include the three smaller networks ELA, ELCA and CU.

European Lightweight Association (ELA)

The European Lightweight Association[40] was founded in 2020 by A2LT (Austria), the Hightech Zentrum Aargau (Switzerland) and Bayern Innovativ GmbH and Leichtbau BW GmbH (both Germany).[41] Currently, eight networks/clusters from five European countries are represented in the ELA with the Netherlands and Spain as additional countries. The aim of the association of local lightweight construction networks is to promote cross-border exchange and strengthen access to customers, technologies and best-practice examples. In this way, the ELA aims to further strengthen the visibility of lightweight construction, to demonstrate the possibilities of lightweight construction in relation to the Green Deal as well as the innovative power of lightweight construction.[42]

European Lightweight Clusters Alliance (ELCA)

Founded in 2013 by stakeholders from the chemical and automotive sectors, the European Lightweight Clusters Alliance[43] (ELCA) network originally aimed to develop sustainable composites, especially for the chemical industry. New members were admitted in 2019. According to the web presence, the ELCA

[40] Cf.: European Lightweight Association. A network of lightweight networks. See: https://www.european-lightweight.com/start. (16.09.2022)

[41] https://www.leichtbauwelt.de/leichtbau-start-frei-fuer-das-europaeische-netzwerk-ela/ (28.09.2022)

[42] https://www.bayern-innovativ.de/de/seite/europaeisches-netzwerk-leichtbau-gestartet (22.09.2022)

[43] Cf.: Strengthening European leadership in the field of lightweight materials and technologies. elca. See: https://elcanetwork.eu/. (22.09.2022)

now appears as an open-sector and cross-sectionally oriented European lightweight network with members from currently eleven nations.[44] The fundamental goal of the network is to strengthen and expand European technological competence in lightweight construction. In addition to pure materials, related areas such as manufacturing, design and digitalisation are also of great interest.

European Lightweighting Network (ELN)

The European Lightweighting Network (ELN) is a politically initiated network driven by Sweden, Germany and Austria. However, there are already expressions of interest from other countries. The network is in the start-up phase and does not yet have an online presence or official partners.

According to the interviews with international representatives, the ELN aims to bring together political actors within Europe on the topic of lightweight construction and thus promotes the development of lightweight construction. Although the focus is on the cross-sectoral and cross-technological character of lightweight construction, the emphasis is currently still on the aviation, automotive and production sectors due to the strong community.

Composites United e.V. (CU)

Composites United e.V. emerged from the associations Carbon Composites e.V. and CFK Valley e.V. and is concerned with fibre-based multi-material lightweight construction. Composites United e.V.[45] currently has around 350 members. Around 90 % of the members come from Germany, Austria or Switzerland. Organisationally, the network is divided into six regional and four

[44] Germany, UK, France, Italy, Spain, Portugal, Sweden, Norway, Poland, Slovenia and Hungary

[45] Cf.: CU. See: https://composites-united.com/. (22.09.2022)

specialist CU clusters[46] with more than 40 downstream working groups. Composites United e.V. has representative offices ("CFK Valleys") in India, South Korea, Japan and China. Further contacts to similarly structured networks exist, among others, in a large number of European countries as well as in Canada and the USA, in Russia and Egypt as well as in Turkey and Oman.

3.3 International funding of R&D in lightweight construction

There are a number of funding programmes for European research organisations and industry, which are financed by the European funds and by national budgets. The most important and globally largest funding programme is the European Framework Programme for Research and Innovation, currently known as Horizon Europe (see below). In addition, there are tried and tested networking initiatives that broker international partnerships, but where the funds are provided from budgets of the participating countries or regions. The main programmes are EUREKA and ERA-NET. Eureka is a platform for brokering partnerships and networks between companies and, if required, research institutions that are both open-topic and based on thematic clusters. The programme is divided into the following project types: classic network projects, cluster projects, Eurostars and Globalstars projects (see below for details). The initiative to strengthen the common European research area, ERA.NET, on the other hand, is aimed more at research institutions working on cross-border topics. M-ERA-NET[47] has a special focus on materials science and engineering and is coordinated by the Austrian Research Promotion Agency (FFG). Accordingly, Eureka addresses the higher Technology Readiness Levels (TRL) 5 to 7, while M-ERA-NET focuses on the lower TRLs 1-5.

[46] CU Construction, CU Ceramic Composites for Special Applications in Industry, CU Lightweight Construction Research and the Leading-Edge Cluster MAI Carbon

[47] Cf.: Welcome to M-ERA.NET. See.: https://m-era.net/ (29.11.2022)

In both initiatives, bilateral calls are published, with the respective countries evaluating their own applications and funding the sub-projects from national programmes. Funding for Austrian partners is provided through the basic programmes.

Only a few countries have national funding programmes that also fund foreign partners up to a certain amount if the need for collaboration is given and the demand cannot be met in the own country.

Most national funding programmes address lightweight construction only indirectly in the context of sector or technology-specific programmes. On the one hand, this is due to the fact that the "hype" around lightweight construction has somewhat died down over the last decade. On the other hand, issues specific to lightweight construction are covered by other priorities. Because lightweight construction is cross-sectional, such projects can also be funded in these contexts. However, more basic questions important for the development of lightweight construction itself is usually less possible, such as developing completely new materials and composites.

Funding programmes that focus holistically and explicitly on lightweight construction have so far only existed in Germany and Sweden and are nationally oriented. The German Technology Transfer Programme for Lightweight Construction[48] (TTP LB) of the Federal Ministry of Economics and Climate Protection promotes innovative lightweight construction projects cross-sectionally and interdisciplinary. The budget is currently 73 million euros per year and is available to German small and medium-sized enterprises. Similarly, in the context of the Swedish Lightweight Construction Network LIGHTer[49], multi-year research and innovation projects as well as feasibility studies and SME projects are (co-)financed under the SIP LIGHTer programme. Funding is provided for innovations to reduce weight and/or raise the TRL. Other aspects are the reduction of costs, the acceleration of the development process, the development and improvement of mixed material solutions and

[48] Cf.: Artikel Schlüsseltechnologien. Technologietransferprogramm Leichtbau. See: https://www.bmwk.de/Redaktion/DE/Artikel/Technologie/technologietransfer-programm-leichtbau.html.; Richtlinie: https://www.bmwk.de/Redaktion/DE/Downloads/B/bekanntmachung-foerderung-ttp-lb.pdf?__blob=publicationFile&v=4. (22.09.2022)

[49] Cf.: LIGHTer. Calls for Funding. See: https://lighter.nu/en/calls-funding. (22.09.2022)

improved material properties, innovative features as well as the sustainability of the products and processes related to the life cycle. For the last point, a sustainability analysis is already required when submitting the application.

International funding programmes are generally considered to be complex and personnel-intensive in the application phase and therefore expensive. This is often a hurdle. The high communication effort in the implementation phase is also rated as costly, especially when it comes to consortia with many partners from many different countries. But once you have been successful (especially in Horizon Europe), these kinds of projects are generally seen to be worthwhile by project participants.

Horizon 2020 and Horizon Europe

The most important and globally largest funding programme is Horizon. Horizon 2020[50] was the European Commission's research and innovation framework programme for the period 2014 - 2020. The budget came from EU funds and amounted to almost 80 billion euros. The successor programme Horizon Europe, with a budget of over 95 billion euros, covers the period 2021 to 2027. In addition to strengthening Europe's scientific excellence and innovative strength, the programme specifically addresses industrial competitiveness and - in the new edition from 2021 - also the strengthening of the European area as a unit. The funds for Horizon projects are provided by the European Commission.

The CORDIS database lists all projects funded under the programme. Under the keyword "lightweight", 574 projects are filed for the period 2014 to 08/2022. These are additionally labelled according to the "Fields of Science" and "Domain of Application".

[50] Cf.: What was Horizon 2020. European Commission. See https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en#what-was-horizon-2020. (22.09.2022)

Table 3: Number of Horizon 2020 projects in general and related to lightweight construction in selected countries (2014-9/2022)

	Total Horizon 2020 projects	Total lightweight projects in Horizon 2020	Lightweight projects led by respective country	Projects with Austria
Austria	3.277	90	23	--
Germany	9.910	274	62	12
Switzerland	3.883	90	19	1
Belgium	5.074	134	26	7
Netherlands	6.165	124	21	1
Luxembourg	538	18	0	1
Denmark	2.901	59	13	3
Finland	2.239	61	16	1
Norway	2.037	43	8	1
Sweden	3.401	82	13	5
France	7.988	200	47	5
Italy	7.881	222	66	10
Spain	8.801	250	93	10
United Kingdom	10.490	247	83	3
Czechia	1.395	44	1	2
Poland	1.949	64	5	1
Hungary	1.142	27	3	3

Source: CORDIS database, September 2022; projects with the keyword ‘lightweight’ in in the search function of CORDIS database. Filters: Collection - Projects; Programme – Horizon 2020; Organisation Country

With 274 participations, the largest number of projects under the keyword "lightweight" is carried out in Germany. Spain, the UK, Italy and France have 200 or more participations. Austria positioned itself in the solid upper midfield with 90 project participations, which is a considerable success given its size. The Scandinavian countries have fewer participations

(between 43 and 82), Belgium and the Netherlands somewhat more (134 and 124 respectively). In Eastern Europe, Poland stands out with 64 participations, compared to the Czech Republic and Hungary.

Spain has the highest activity in leading the consortia with 93 lightweight projects, followed by the UK with 83. This corresponds to a percentage share of 17.5 and 15.6 percent of all projects labelled with the term lightweight (total 532 projects). Germany and Italy each lead around 10 percent of lightweight construction projects. Austria, similarly to Belgium and the Netherlands, Switzerland and the four Scandinavian countries, leads between 4.5 and 1.5 percent of the funded projects. Eastern European countries, on the other hand, are at only 1 per cent or significantly below with one to a maximum of 5 projects in the lead.

Collaborations with European partners are especially carried out with Germany, Spain, Belgium and the UK. Scandinavian countries and the countries of Eastern Europe, on the other hand, are less frequently involved in joint projects. This can be attributed, among other things, to the overall lower participation rate in Horizon projects in general. Measured against the size of the countries, there is development potential in the field of lightweight construction in these countries.

Figure 14 shows the thematic distribution of projects based on the designated "Fields of Science". Austria's focus is on mechanical engineering and electrical, electronic, and information engineering. These "Fields of Science", together with materials engineering, are pronounced in almost all active countries. Austrian additional strengths: natural sciences, especially in the chemical and physical sciences Medical and health sciences, transport and agricultural sciences are underrepresented in almost all countries compared to engineering as a thematic field. Projects with a biological and biotechnological background are also strongly underrepresented - especially with regard to bio-based products. The latter one shows some weaknesses concerning the development of alternative, bio-based materials, which can be one of the solutions under the circular economy paradigm.

Figure 14: Thematic distribution of Horizon 2020 projects based on the designated "Fields of Sciences" for selected countries

	AUSTRIA	GERMANY	BELGIUM	DENMARK	FINLAND	NORWAY	SWEDEN	FRANCE	ITALY	SPAIN	UK	CZECHIA	HUNG
TOTAL NUMBER OF PROJECTS IN LEAD	**23**	**62**	**19**	**26**	**21**	**13**	**16**	**8**	**13**	**47**	**66**	**93**	**83**	**1**	**3**
engineering and technology															
mechanical engineering	0,30	0,18	0,05	0,15	0,19	0,23	0,19		0,23	0,43	0,17	0,25	0,19		
electrical, electronic, information eng.	0,30	0,27	0,11	0,35	0,38	0,23	0,25	0,13	0,31	0,19	0,45	0,30	0,19	1,00	0,33
materials engineering	0,17	0,26	0,11	0,19	0,24	0,31	0,19		0,15	0,21	0,15	0,26	0,23		
nanotechnology	0,09					0,08			0,15	0,02		0,06	0,04		
civil engineering		0,02	0,11	0,04	0,10		0,13			0,02	0,05	0,04	0,05		
environmental engineering		0,13	0,05	0,04		0,08	0,06	0,25	0,08	0,11	0,08	0,06	0,07		
industrial biotechnology												0,01			
other engineering and technologies		0,02								0,02					
natural sciences															
computer and information sciences	0,26	0,35	0,16	0,35	0,29	0,62	0,44	0,38	0,38	0,26	0,38	0,28	0,23		
biological sciences	0,04	0,02			0,10						0,03	0,01	0,10		
chemical sciences	0,35	0,11	0,05	0,12	0,10	0,15		0,38	0,15	0,15	0,14	0,14	0,11	1,00	0,33
physical sciences	0,26	0,03		0,27	0,10	0,15	0,06		0,08	0,19	0,11	0,08	0,23	1,00	0,33
earth related environmental sciences	0,09	0,02	0,05		0,14	0,08	0,06	0,13		0,09	0,06	0,04	0,07		
mathematics		0,03		0,04		0,08			0,15	0,15	0,08	0,04	0,06		
medical and health sciences															
clinical medicine	0,13	0,06		0,04				0,25	0,15	0,06	0,08	0,14			
basic medicine	0,04										0,06	0,06	0,02		
health sciences			0,05	0,04			0,06	0,13			0,02	0,02	0,02		
medical biotechnology											0,05	0,02	0,01		
other medical sciences											0,02	0,01			
transport															
electric vehicles	0,09	0,03	0,16				0,19			0,02	0,02	0,04	0,01		
freight transport	0,04			0,04									0,01		
public transport	0,04		0,05				0,06			0,02					
navigation systems											0,02	0,01			
agricultural sciences															
veterinary sciences	0,04	0,02	0,05	0,08	0,05	0,08	0,06				0,02	0,02	0,05		
agriculture, forestry, and fisheries		0,05	0,05				0,06			0,02	0,05	0,01	0,01		
horticulture		0,02	0,00								0,00		0,00		

Score: number of projects in the thematic field / number of all projects. The total number of projects is shown in the top line. Score = 1 if all projects can be assigned to one "Field of Science" and >1 if this is not the case. Dark green shading for Score = 1, white for Score = O. Source: CORDIS database, September 2022.

Figure 15 shows the distribution of projects across the "Domains of Application". According to this, most projects were carried out in the application field of industrial technologies. Spain and Germany lead the way with 52 and 48 projects respectively, followed by Italy, France and the UK. Austria also has the highest number of projects in this application field.

Almost 50 projects were carried out in the application field of transport and mobility. Austria was involved in 10 of these projects and is thus in the middle of the field between the lightweighting core countries and the small active countries.

Figure 15: Distribution of “Domains of Application” for Lightweighting projects in Horizon 2020 for selected countries.

	industrial technologies	fundamental research	transport and mobility	health	society	security	climate change and environment	energy
Total Number	**80**	**27**	**49**	**36**	**27**	**19**	**39**	**29**
AUSTRIA	14	8	10	11	7	5	9	6
GERMANY	48	19	20	24	18	11	27	20
SWITZERLAND	15	7	8	13	12	5	10	6
BELGIUM	19	12	13	12	11	8	14	10
NETHERLANDS	24	10	15	13	11	13	17	8
LUXEMBOURG	1	0	3	1	2	4	3	2
DENMARK	14	9	8	6	8	3	10	5
FINLAND	9	5	8	7	5	1	5	3
NORWAY	9	6	5	6	3	2	5	5
SWEDEN	18	10	11	13	6	2	7	4
FRANCE	35	14	15	16	20	7	19	14
ITALY	40	16	21	24	18	9	18	14
SPAIN	52	20	28	27	20	14	25	21
UK	32	19	18	23	15	8	20	16
CZECHIA	7	3	5	3	2	1	5	3
POLAND	14	4	5	5	6	3	6	4
HUNGARY	8	3	5	3	3	2	3	8

The total number of projects of respective “Domain of Application” is shown in the top line. Dark green shading for highest value = 52, white for lowest value = O. Source: CORDIS database, November 2022

Example of a networking project within the Horizon 2020 programme: AMULET

The Horizon project "Advanced Materials and Manufacturing Technologies united for Lightweight" (AMULET[51]) is an example of a networking project in Europe. The countries involved through clusters and networks are signalling their willingness to network as well as to engage in cross-sectoral exchange. The project has a total volume of almost 5 million euros and is largely financed from the INDUSTRIAL LEADERSHIP - Innovation in SMEs budget.

The project aims to strengthen cross-regional and cross-sectoral knowledge exchange in the automotive, aerospace, energy and construction sectors. The consortium of 15 partners, led by POLYMERIS (France), consists of national clusters and networks related to

[51] Cf: Advanced Materials and Manufacturing Technologies united for Lightweight. Projektbeschreibung. See: https://cordis.europa.eu/project/id/101005435/de. (23.09.2022)

composites (polymers, ceramics and light alloys) from Germany, Belgium, Spain, Italy, Norway, Poland, Czech Republic, Hungary and Slovenia.

The implementation[52] of the project includes two calls with matchmaking events to form consortia. In the second phase, up to 50 consortia can submit feasibility studies, of which 13 will be selected for the demonstration phase. After completion of the demonstration phase, the companies will be supported in commercialising their lightweight solutions. In phases 2 to 4, in addition to technical training and B2B coaching, the consortia also receive financial support: €23,000 in phase 2, €80,000 in phase 3 and €17,000 in phase 4.

M-ERA.NET

The ERA.NET[53] network within the Horizon 2020 programme serves to coordinate national and regional funding programmes in Europe. The programme is very broadly based. In addition to technological focal points, humanities co-operations are also possible.[54]

The aim is to realise a transnational European Research Area (ERA), in which the participating countries support their own actors with funds from national research programmes.

Within ERA.NET exists the M-ERA.NET[55] network, which is specifically geared towards materials and battery technologies. The projects initiated by this network focus not only on the development of new products and processes, but also on establishing recycling and increasing energy efficiency.

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[52] Cf.: Project Information. ELCA: See: https://elcanetwork.eu/wp-content/uploads/2022/05/amulet_flyer_eng-final.pdf. (23.09.2022)

[53] Cf.: Funding and tender opportunities: ERA-NETs. European Commission. See:https://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/era-net_en.htm. (22.09.2022)

[54] Topics: Digitisation and Broadband, Energy Transition, Europe and International Affairs, Society and Security, Cooperation and Research Infrastructure, Life Sciences and Health, People, Skills and Gender, Mobility Transition, Production and Materials, Space and Aeronautics, other topics. Cf.: ERA-NET. FFG. See: https://www.ffg.at/programm/era-net. (22.09.2022)

[55] Cf. Welcome to M-ERA.NET. See: https://m-era.net/. (22.09.2022)

The current third phase of the network was started in 2012. There are 50 public organisations from 36 countries[56] represented. Figure 16 shows the number of participations of selected countries and their respective priorities for the years 2019 to 2021. Germany is the most active partner in this programme with a total of 103 participations, followed by Poland with 72 and Spain with 50 participations. Austria has a similar number of participations (between 36 and 22 participations) as France, Belgium, the Czech Republic, Spain and Norway. It is striking that almost all participating countries are implementing projects in the thematic field of "Functional Materials". Together with Hungary, Austria is one of the few exceptions, but like Switzerland and Canada, it shows strengths in the thematic field of "Materials for Additive Manufacturing".

[56] 25 EU member states, 5 associated countries and 6 non-European organisations

Figure 16: Thematic distribution of M.ERA-NET projects based on lightweight key areas for selected countries for the years 2019-2021.

	AUSTRIA	GERMANY	SWITZERLAND	BELGIUM	NETHERLANDS	LUXEMBURG	DENMARK	FINLAND	NORWAY	SWEDEN	FRANCE	ITALY	SPAIN	UK	CZECHIA	POLAND	HUNGARY	BRASIL	MEXICO	USA	CANADA	JAPAN	SOUTH KOREA
NUMBER OF PARTICIPATIONS BY YEAR																							
2019	5	24	3	2	1	5	0	0	0	0	9	6	13	0	11	29	1	1	0	0	2	0	2
2020	9	32	3	7	0	3	0	0	3	0	14	0	11	0	12	23	0	2	0	0	4	0	0
2021	20	47	2	16	0	5	9	3	19	22	13	0	26	0	11	20	3	3	0	0	3	1	0
TOTAL NUMBER	**34**	**103**	**8**	**25**	**1**	**13**	**9**	**3**	**22**	**22**	**36**	**6**	**50**	**0**	**34**	**72**	**4**	**6**	**0**	**0**	**9**	**1**	**2**
SCORE (TOTAL PARTICIPATION/NUMBER OF PARTICIPANTS BY FOCUS)																							
Additive Manufacturing for the Construction Technology Applications	0,18	0,02		0,04		0,08				0,09	0,08		0,04			0,03	0,25						
Functional materials		0,31	0,63	0,28	1,00	0,23	0,44	0,33	0,59	0,41	0,53	0,67	0,52		0,24	0,28		0,67			0,22	1,00	1,00
High performance composites	0,21	0,06		0,08		0,23				0,09	0,14		0,08		0,09	0,29	0,50						
Innovative surfaces, coatings and interfaces	0,26	0,33		0,28		0,15	0,11	0,67	0,14	0,27	0,17		0,26		0,44	0,11	0,25				0,44		
Materials for Additive Manufacturing	0,35	0,15	0,38	0,08						0,00	0,03		0,06		0,09	0,17					0,33		
Modeling for materials engineering + processing		0,05		0,12		0,31	0,22		0,09	0,14	0,06		0,02		0,12	0,04		0,17					
Advanced material-based technologies in health applications		0,09		0,12			0,22		0,09			0,33	0,02		0,03	0,07		0,17					

Score: number of participations in the thematic field / total number of participation (2019-2021). Score = 1 if all projects can be assigned to one lightweight key area and >1 if this is not the case. Dark green shading for Score = 1, white for Score = O. Source: https://m-era.net/joint-calls, September 2022.

30 funding agencies from 22 European and 4 non-European countries are participating in the current call[57], which started in 2022. The funding volume for the projects, which are expected to start in February 2023, amounts to approx. 25 million €.

The following topics are addressed:

- Materials for energy
- Innovative surfaces, coatings and interfaces

[57] Cf.: Joint call 2022. Announcement of the M-ERA.NET Call 2022. See: https://www.m-era.net/joint-calls/joint-call-2022 (30.11.2022)

- High performance composites
- Functional materials
- New strategies for advanced material-based technologies for health applications
- Materials for electronics

EUREKA

EUREKA[58] is a funding initiative founded in 1985 to initiate and implement application-oriented, international research and development projects. The focus is on the R&D of close-to-market products, processes or services. Accordingly, the range of topics is more limited compared to ERA-NET[59]. Currently, 47 countries are members of the funding initiative. The primary goals of the initiative are to network financial and technical resources in Europe and to facilitate coordinated access to funding. The initiative addresses both international networks for concrete projects and long-term, internationally staffed clusters that make these possible. The initiative is open to all topics. Support is provided for application-oriented projects in the civil sector.

Unlike classic funding programmes, the initiative does not have its own budget to support the networks and clusters. Instead, the cooperation partners have to apply for corresponding funding within the framework of national programmes, the Eurostars funding programme or finance the activities themselves. Access to information on funding institutions within the framework of EUREKA is provided on its website.

There are several funding streams within EUREKA:

EUREKA network projects

[58] Cf.: Eureka. Innovation beyond borders. See: https://www.eurekanetwork.org/. (22.09.2022)

59 Topics: Digitisation and broadband, energy transition, Europe and international affairs, innovative and competitive companies, cooperation and research infrastructure, circular economy, production and materials, quantum research and technology, open topics, space and aviation, other topics. Cf.: Eureka-Cluster. Internationale Industrie-Initiativen. FFG. See: https://www.ffg.at/europa/eureka/cluster. (22.09.2022)

Eureka network projects can generally be submitted on an ongoing basis; they are evaluated and funded nationally. In addition, there are three to four calls for proposals per year with EUREKA member countries or associated partner countries.

EUREKA Eurostars

With Eurostars, a tailor-made funding programme has been available to R&D-performing SMEs since 2007. The successor programme Eurostars-3, a joint funding programme of more than 30 EUREKA member countries and the European Union, has been running since 2021.

EUREKA Globalstars

Globalstars is a funding instrument of the EUREKA network, which offers the opportunity to conduct calls for proposals with countries outside the network. In open calls, companies can submit Globalstars projects as part of a consortium.

EUREKA clusters

EUREKA clusters are industry-driven initiatives that focus on technology areas of strategic interest for (pre-)competitive research and development. Their aim is to promote the development of new products and applications through networking and to strengthen the European economy on the global market.

Austria participates financially in the Eurostars and Globalstars programme. Actors from Austria are also involved in all five clusters with funding provided:

- CELTIC-NEXT – Cluster for Next-Generation Communications
- EUROGIA2030 – Cluster for Sustainable Energy Solution
- ITEA 4 – Cluster for Software Innovation
- SMART – Cluster for Advanced Manufacturing
- Xecs – Cluster for Electronics Components and Systems and Applications

EUREKA SMART[60] is related to lightweight construction, as it focuses on the cross-sectoral promotion of research, development and innovation projects in advanced manufacturing. Another 15 countries[61] are involved in the cluster with national funding provided.

3.4 National lightweight construction strategies and contact points

The countries Germany and Sweden have elaborated national strategies to promote lightweight construction.

The German “Leichtbaustrategie für den Industriestandort Deutschland[62]” was published in January 2021 by the Federal Ministry for Economic Affairs and Energy, BMWi (now Federal Ministry for Economic Affairs and Climate Action, BMWK). It aims to "establish Germany as an economically successful (international) lightweight supplier for innovative lightweight technologies and lightweight solutions" and is primarily aimed at small and medium-sized enterprises. It was developed in a participatory process within the “Initiative Leichtbau”[63] with 350 experts from different sectors. The strategy presents eight sets of measures, planned (public) activities, and their intended effects. The overarching goals of the measures are on sustainability and digitalisation, as well as suitable funding policy framework conditions. The strategy addresses networks and public relations, technology transfer through standardisation and harmonisation, as well as education and training.

The annex to the strategy presents selected funding programmes and support measures. These include the Lightweight Construction Technology Transfer Programme (TTP LB),

[60] Cf.: EUREKA SMART advanced manufacturing. See: https://www.smarteureka.com/. (22.09.2022)

[61] Belgium (Flanders), Czech Republic, Finland, France, Hungary, Ireland, Luxembourg, Portugal, Slovenia, Spain, Sweden, Switzerland, Turkey and Canada, South Korea

[62] Cf.: Leichtbaustrategie für den Industriestandort Deutschland. Bundesministerium für Wirtscgaft und Energie (BMWi) 2021. See: See: https://www.bmwk.de/Redaktion/DE/Publikationen/Technologie/leichtbaustrategie.pdf?__blob=publicationFile&v=10. (22.09.2022)

[63] Cf.: Initiative Leichtbau. Nationaler und internationaler Netzwerkknotenpunkt des Mittelstandes. See: https://www.bmwk.de/Redaktion/DE/Publikationen/Industrie/flyer-initiative-leichtbau.html. (22.09.2022)

which was established specifically to promote lightweight construction and is endowed with around 70 million euros per year. The goals of the programme, which is open to all sectors, are:[64]

- Taking lightweight construction into widespread use
- Identification and establishment of new application areas and technologies
- Transfer through networking of the players in the field of lightweight construction
- Interdisciplinary transfer through digitalisation
- Contribution to achieving sustainability and climate goals by closing cycles, holistic balancing and high-quality recycling

There are central public contact points that carry out networking and public relations work related to lightweight construction. Unlike clusters or industry-led networks, these are sector and technology-unspecific and act as neutral intermediaries between industry and science.

The "Initiative Leichtbau"[65] was launched by the Federal Ministry for Economic Affairs and Climate Action and serves to bundle activities related to lightweight construction in Germany. For this purpose, a Lightweight Construction Office (Geschäftsstelle Leichtbau) was established as a hub for national and international networks. This is currently being implemented by Innos GmbH and organises the strategic instruments: Leichtbauatlas, Forum

[64] Cf.: Bekanntmachung zur Förderung von Forschung, Entwicklung und Innovation im Rahmen des Technologietransfer-Programms Leichtbau (TTP LB). Bundesministerium für Wirtschaft und Energie (BMWi) 2020. See: https://www.bmwk.de/Redaktion/DE/Downloads/B/bekanntmachung-foerderung-ttp-lb.pdf?__blob=publicationFile&v=4. (22.09.2022)

[65] Cf.: Artikel Schlüsseltechnologien. Leichtbau. Bundesministerium für Wirtschaft und Klima. See: https://www.bmwk.de/Redaktion/DE/Dossier/leichtbau.html. (22.09.2022) and Flyer Initiative Leichtbau. Nationaler und internationaler Netzwerkknotenpunkt des Mittelstandes, BMWK. See: https://www.bmwk.de/Redaktion/DE/Downloads/F/flyer-initiative-leichtbau-210518.pdf?__blob=publicationFile&v=6 , (22.09.2022)

Leichtbau, the Strategy Advisory Board of the Lightweight Construction Initiative (Strategiebeirat der Initiative Leichtbau) as well as the annual meeting of politics, industry and research "Lightweighting Summit".

The most active and largest contact point with a wide network of research institutions and companies is the state-owned agency Leichtbau BW[66] in Baden-Württemberg. The eight-member, publicly funded team offers a wide range of services related to lightweight construction, funding programmes, networking and events.

The Swedish lightweight strategy[67] entitled "Lightweight solutions strengthen Swedish competitiveness and growth - for a more sustainable world" was first published in 2013 as the "Strategic research and innovation agenda for lightweight" and has in 2020 been updated for the third time. It is much more comprehensive and detailed than the German lightweight strategy. The strategy covers several decades up to currently the year 2039. The third version of the agenda refers in detail to the years 2020 to 2022 and focuses in particular on sustainability and the UN's sustainability goals. The strategy, which is open to all sectors and technologies, takes a multidisciplinary look at the entire TRL scale. In the current period, particular focus is being placed on electromobility, artificial intelligence, multifunctional applications and sustainability. Projects within the framework of the strategy are funded through various strategic innovation programmes (SIPs), with calls announced via the central website of the LIGHTer network. Specific to lightweight construction is the Strategic Innovation Programme Lightweight (SIP Lightweight), which is a strategic investment programme explicitly designed to ensure the implementation of the agenda.

[66] Cf.: Hier beginnt die Leichtbaurevolution. Baden-Württemberg macht sich stark. Leichtbau BW. See: https://www.leichtbau-bw.de/start.html , (22.09.2022)

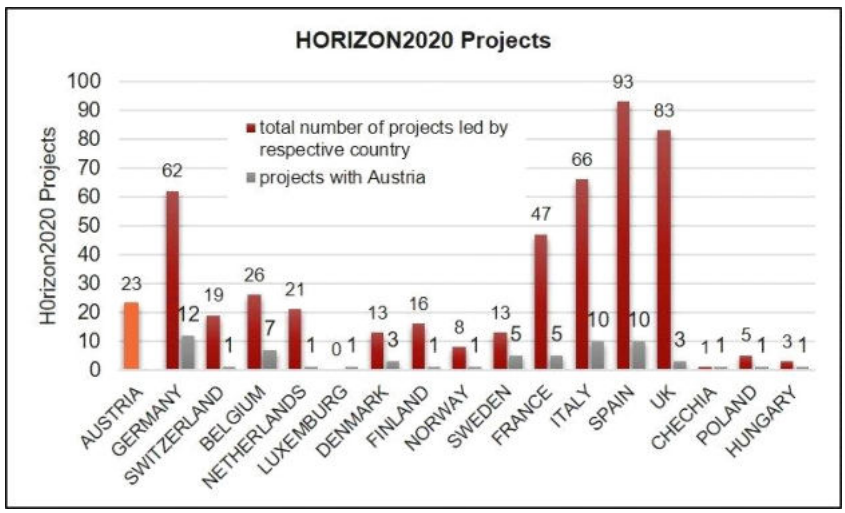
[67] Cf. Cf.: Lightweight solutions strengthen Swedish competitiveness and growth - for a more sustainable world. LIGHTer. See: https://lighter.nu/sites/default/files/2019-12/191108_lattviktsagenda_2019_eng.pdf. (22.09.2022)

The central hub of the lightweight construction programme is the LIGHTer network[68]. Within the network, projects are initiated and carried out, publications are published, experts receive further training and (international) events are organised for networking and exchange. The network is supervised by the state-run research institute RISE[69].

3.5 Lightweight construction hotspots in Europe

The topic of lightweight construction is attracting increasing attention throughout Europe. European regions and individual countries can be distinguished from each other in their lightweight construction activities based on networks and participation in programmes.

Figure 17: Project participations in the Horizon 2020 programme (2014-2022)

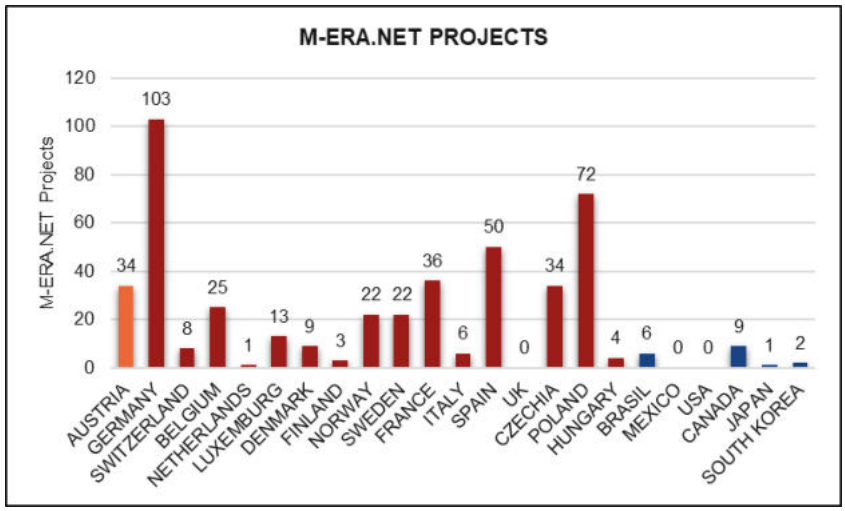


Source: CORDIS Database, own representation iit. Projects with the keyword 'lightweight' in in the search function of CORDIS database. Filters: Collection: Projects; Programme Horizon 2020; Organisation Country. Orange bar: Austria; red bar: Europe; blue bar: non-European countries.

[68] Cf.: This is LIGHTer. See: https://lighter.nu/en/menu/lighter. (22.09.2022)

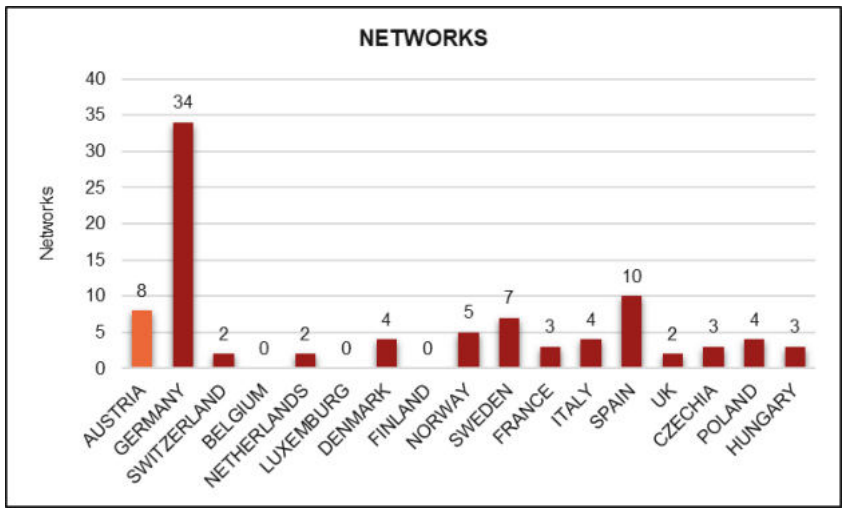
[69] Cf.: Competitiveness and sustainable transition grounded in science. RISE. See: https://www.ri.se/en. (22.09.2022)

Figure 18: Project participations in the M.ERA-NET programme (2019-2021)



Source: M-ERA.NET Database, September 2022. Own representation iit. Orange bar: Austria; red bar: Europe; blue bar: non-European countries.

Figure 19: Networks in the ELCA database (until September 2022)



Source: ELCA Database, own representation iit. September 2022. Orange bar: Austria; red bar: Europe; blue bar: non-European countries. Source: see annex on methodology.

Strong participation activities can be seen in particular in countries that have a traditionally strong automotive or aerospace industry on the one hand and a high number of universities and non-university research institutions on the other due to their size. These include Germany, France, Spain, Italy and the UK. In these countries, lightweight construction is strongly represented in research and development, which is reflected in the number of projects funded through the EU's Horizon 2020 programme. These countries are

generally regarded as core countries for lightweight construction. They are perceived as drivers in the field of lightweight construction but are also considered to be not the easiest partners to engage with because of their already extensive activities and networks - at least in the initiation phase of proposals and projects. This was also confirmed in the focus group. Countries with strong research infrastructures can meet their needs themselves (often within an institute) and are therefore not dependent on cooperation partners abroad. The question then arises as to the added value that the partner from abroad can contribute.

Austria cooperated in Horizon 2020 projects with many countries (grey bars in Figure 17 above). In projects led by Austrian actors, Germany, Spain and Italy were particularly frequent partners (12 / 10 / 10 cooperations respectively). Comparably frequent partners were also Belgium and (7 cooperations) as well as France (5 cooperations).

In addition to the major drivers, there are several other countries in Europe that are actively addressing lightweight construction. In many countries, especially in Eastern Europe, lightweight construction is still in the early stages of establishment but indicates a promising development. Within Europe, the following regions can be distinguished, which were mentioned in the interviews as hot spots or interesting partners.

German speaking countries: Germany and Switzerland

Germany is the most active European country with 34 networks listed in the ESCA database[70]. With 274 Horizon 2020 projects, Germany is involved in the most projects with the keyword lightweight construction (2014-2022). Of these, German organisations are leading 62. With 103 participations, this is also where most M-ERA.NET projects were initiated or carried out in the past three years. The high numbers indicate a pronounced sensitivity for the use and presence of the term lightweight construction. This is also reflected in the large number of small and large conferences and events that not only address lightweight construction in a sector-specific or technology-specific way, but also address it holistically.

[70] The European Secretariat for Cluster Analysis (ESCA). See: https://cluster-analysis.org/. (22.09.2022)

Lightweight construction receives political attention from the Federal Ministry for Economic Affairs and Climate, which publishes its own lightweight construction strategy and finances a suitable funding programme with the Technology Transfer Programme for Lightweight Construction (TTP LB) (see extended profile in chapter 6.1). Germany is consistently mentioned as an interesting partner for R&D cooperation.

Austria's neighbour Switzerland is also considered an interesting partner for research projects in the field of lightweight construction, not least because of the close cultural base, but also the long traditions of industrial relations and the strong interactions in the scientific world. Although Switzerland does not (yet) have its own lightweight construction strategy, it has a political and thematic presence in international lightweight construction networks. Actors from Switzerland participate in projects in the Horizon 2020 and M-ERA.NET programmes (see profile in chapter 6.1).

Scandinavia: Sweden, Norway, Finland and Denmark

Lightweight construction is increasingly present in Scandinavia. However, the intensity of activities and the foci vary between the countries. The most comprehensive activities are taking place in Sweden (see profile in chapter 6.1). The country is the second European nation with a lightweight construction strategy. This is embedded in a network that supports not only the holistic promotion of lightweight construction projects but also the education and training of scientific specialists. Sweden is regarded as an internationally active country with participation in international networks and thus stands out from the other Scandinavian countries, with only nationally active lightweight construction-related networks. Sweden is involved in 82 lightweight projects und is leading 13 of them. Norway, Finland and Denmark are each involved in 43, 61 and 59 Horizon 2020 projects, leading 8, 16 and 13 of them respectively. Finland and Norway are also partner countries in the Horizon 2020 network project AMULET, from which an interest in future international exchange can be derived. Sweden and Norway in particular are actively participating in M-ERA.NET projects.

Benelux countries: Belgium, Netherlands and Luxembourg

Belgium and the Netherlands in particular are often considered interesting partners for cooperation projects with Austria. They are each involved in 134 and 124 Horizon 2020 projects, leading 26 and 21 of them. According to interview partners, both countries signal interest in international (political) exchange. The Netherlands is a partner in the European Lightweight Association with the RAI Automotive Industry NL cluster. Belgium (see profile in chapter 6.1) participates in the Horizon 2020 network project AMULET and is active in the M-ERA.NET programme with 25 participations. Both countries are still at the beginning of establishing topics in lightweight construction but will establish their economic focus in the field of engineering science and in the provision of chemical products. In all three BeNeLux countries, there is both interest and development potential. This is also shown by the presentation of the countries at JEC World in Paris: all three countries had their own pavilions (Belgium even had two) with 8 (Luxembourg), 16 (Netherlands) and 17 (Belgium) exhibiting companies. The advantage of these comparatively small countries compared to the established lightweight countries is a more flexible interaction when initiating projects.

Eastern Europe: Poland, Czech Republic and Hungary

From the Eastern European countries, lightweight construction has so far primarily raised a specific interest in Poland, Hungary and the Czech Republic. Their actors have taken the lead in a few projects in the Horizon 2020 programme. In contrast, the total number of participations is about in the same range as in the Scandinavian countries (64, 44, 27). With 72 projects, Poland has the second highest number of participations in the M-ERA.NET programme in the past three years and is mentioned as a recommendable partner for further cooperation (see profile in chapter 6.1). With 34 projects, the Czech Republic is also in the same order of magnitude as the large lightweight countries such as Spain and France. All three countries signal a great interest in international networking through their participation in the Horizon 2020 network project AMULET, and thus show their willingness to establish networks.

Lightweight construction hotspots outside of Europe

Sector or technology-specific hotspots on a global scale can be found, for example, in South American countries, where lightweight construction is experiencing strong growth and international interest in collaboration is certainly expressed. So far, this is primarily of a "regional nature" and takes the form of knowledge transfer between South American countries. Brazil, for example, has bilateral projects with Bolivia and Peru. Brazilian actors are also involved in M-ERA.NET- Projects[71] with six participations. Further funds are made available within the framework of CORNET[72].

Mexico maintains a strong knowledge exchange, especially joint conferences focusing on composites, both with countries in the Americas and - certainly due to the common language - with Spain.

The USA is considered a hot spot for automotive engineering, especially in the states of Michigan and Ohio. Except for the Ohio (battery) and Michigan (automotive) regions, the USA was not mentioned by any of the interview partners as an interesting or suitable partner.

Canada is considered an interesting partner by many players. The Ontario region is considered a focal point. The Great Lakes Automotive Manufacturing Cluster is one of the world's largest clusters for automotive manufacturing and parts suppliers worldwide. The Canadian Association for Composite Structures and Materials[73] (CACSMA) is also important. CACSMA is a network of individuals and companies along the entire value chain whose goal is to improve applications for composite structures and materials. The Baden-

[71] Founding by São Paulo Research Foundation (FAPESP). See: https://fapesp.br/en , (22.09.2022)

[72] Funding by EMBRAPII – Empresa Brasileira de Pesquisa e Inovação Industrial. See: https://embrapii.org.br/en/ and FAPESP – Fundação de Amparo à Pesquisa do Estado de São Paulo

[73] Cf.: Canadian Association for Composite Structures and Materials. See: http://cacsma.ca/ , (22.09.2022)

Württemberg state agency Leichtbau BW puts Canada at the centre of international efforts for lightweight cooperations. Canadian actors are involved in M-ERA.NET[74] as well as CORNET[75] projects.

Strong activities are also shown by countries in Asia, primarily South Korea, Japan and China. South Korea and Japan are involved in M-ERA.NET projects, among others. The Japanese New Energy and Industrial Technology Development Organization (NEDO) provides funding for CORNET projects. Despite the interesting lightweight construction activities, international cooperation between companies is often judged to be more difficult, not least due to cultural differences. According to the statements of interview partners, it takes a long time to build up trust. Economic interests also differ occasionally.

4 SWOT analysis for lightweight construction in Austria

The following overview provides a summary of the strengths, weaknesses, opportunities and threads for lightweight construction in Austria based on the different information sources and methodological instruments implemented during this study, as summarized in the Annex. The reasoning behind the different judgements in the SWOT are discussed in more detail below.

[74] Funding by The Advanced Materials Research and Innovation Hub PRIMA Québec. See: https://www.prima.ca/en/ (22.09.2022)

[75] Funding by Ministère de l'Économie, de la Science et de l'Innovation

Figure 20: SWOT analysis for lightweight construction in Austria

	Strengths	Weaknesses
Austrian Lightweight Community	Successful niche players and hidden champions Strong innovative capacities not only from larger companies, but also SMEs and start-ups Strong economic impact of lightweight construction in Austria Players along the entire value chain, from research and materials development to manufacturing Active lightweight construction 'community' that is well networked within the different thematic fields Lobbying opportunities via regional clusters New, specialized post-secondary degree programmes in lightweight construction in addition to established master's degrees Highly qualified engineers Broad set of funding opportunities and funding of foreign partners is possible in the FFG portfolio Regular events with focus on lightweight construction ***Recommended activities addressing these strengths:*** • Integrate existing structures in building up European networks • Implement lightweight construction on a strategic level, either through developing a lightweight strategy or integration lightweight in existing strategies • Further strengthen cross-disciplinary knowledge and technology transfer through targeted workshops / conference sessions / expanding and promoting existing project databases (e.g. FFG project database, FWF database)	Too few major players, OEMs and manufacturers of products Shortage of skilled workers; Lightweight construction could be given greater consideration in apprenticeship trainings Relatively hard to access thematic funding programmes for explicit lightweight topics Current technologies allow only for limited mass production and/or expensive production of lightweight components Community somewhat fragmented by regions and themes ***Recommended activities addressing these weaknesses:*** • Implement a national lightweight platform (example: LIGHTer in Sweden) • Set activities to increase education and training opportunities (e.g. masters / PhD programmes in cooperation with foreign research centres / universities) and promote existing instruments (e.g. Talents programme) • Access increased funding opportunities at the European level with targeted partners
	Opportunities	**Threads**

Context and international Environment	Lightweight construction as a cross-sectoral technology offers many application opportunities in areas of strengths of Austrian players: mobility including aerospace, energy technology, logistics, medical technology, sporting goods, construction Increasing demand for lightweight solutions, especially in sectors such as aviation, energy (wind power), (e-)mobility, railways, construction, and sporting goods Austria can build on an established knowledge base in new manufacturing processes (incl. 3D printing) and material sciences/materials engineering Continuous development of innovative/new materials; hybrid lightweight construction and composite materials Recyclable lightweight components and resource-saving solutions as new R&D fields and lightweight applications Awareness that a transition towards a circular economy is needed within the community Policy makers use the momentum to foster innovation activities by setting up thematic missions that include lightweight construction ***Recommended activities addressing these opportunities:*** • Introduce sustainability criteria in funding programmes, which will in turn support lightweight research and investments • Focus lightweight research on solutions that contribute to societal and ecological challenges • Strengthen innovation dynamics by improving interdisciplinary exchange (e.g. digital technologies in lightweight construction or others concerning resource use and materials across networks and sectors/applications)	Lack of interdisciplinarity and holistic solutions lead to incremental innovations. Thus, danger of small-scale solutions that do not advance the transformation of the European economy and the competitiveness on a global scale Current price regimes (externalities) discourage the development of highly innovative lightweight solutions Not considering the overall effects of the final product cradle-to-grave may lead to rebound effects Not harnessing the potential of interdisciplinary knowledge and technology transfer by too little networking Dependence on foreign OEMs as a potential lock-in effect because of conservative attitudes and certification standards for products Rising competition from overseas (Asia, USA, but also South America in selected application areas) Path dependencies through long innovation and investment cycles (e.g. aerospace, rail) in design and input materials limit innovation opportunities Increasing complexity in lightweight construction might overwhelm SMEs and discourage innovation Companies and research institutions might not be able to keep up with the technological development cycles due to little funding Rebound effects, emission-intensity and poor recyclability lead to conflicts with circular economy and climate protection agendas Due to continuous high costs, lightweight construction in automotive might be of relevance only in the premium segment High investments needed for starting a business with focus on lightweight construction ***Recommended activities addressing these threads:***

	• Active participation in standardization processes offer the opportunity to positively influence the world market with European quality standards • Focus on resilient value chains with a potentially higher share of European resourcing • Expand networks (across materials and applications) by including currently underrepresented sectors • Create opportunities for knowledge-intensive start-ups due to more radical solutions needed for a circular economy	• Ensure that training and education facilities use up-to-date content to facilitate quick incorporation of circular economy principles for lightweight development (design, materials, business models, etc.) • Make funding instruments more accessible for lightweight solutions • Enhance accessibility of R&D funding for radical lightweight solutions in the lower TRL levels • Reduce transaction costs for SMEs and startups with the help of a competence landscapes, matchmaking options, and networking events • Ensure the development in the right direction on a broader scale through the support of a sizeable ecological tax reform

Source: Consortium, based on literature, secondary data, interviews, focus group, and participatory observation at a networking event

Strength and weaknesses

The domestic core lightweight construction community is of manageable size, which facilitates intensive exchange between actors. Good networking in the community within the different fields is perceived as a key strength by many of the interviewees.

The innovative strength of smaller companies and start-ups was positively emphasised. Firms are often able to position themselves as successful niche players and sometimes even as hidden champions. The various clusters in Austria (including the automotive cluster) also offer good lobbying opportunities for lightweight construction activities. One of Austria's strengths is its versatility, as it has expertise in a range of lightweight materials (metal, plastic, wood) as well as production.

The biggest weakness of lightweight materials is its costs, as interview partners repeatedly emphasise. Also, according to Fischer (2021)[76], high-strength steel is 20 % lighter than steel but also 15 % more expensive. Steel is still the cheapest lightweight material, compared to aluminium (40 % lighter but 30 % more expensive), and carbon fibre (50 % lighter but 570 % more expensive). Therefore, lightweight steel is used by automotive OEMs around the world, while carbon fibres are often used only in premium or high-end cars. As new mass-scale production opportunities are developed, the cost of materials could decrease by up to 70 % in case of carbon fibres (ibid.) To make lightweight construction more profitable, further developments in production technologies are necessary, both in the already established joining techniques, in the development of new processes, and in the combination of different processes (e.g. joining techniques and 3D printing).

Austria has been able to position itself successfully on the international market with its expertise and know-how of the engineers working the field, thus highlighted as a key strength. This is specially the case in metal and plastics processing as well as in mechanical engineering and toolmaking. The domestic training system in general and new university of applied sciences courses in Upper Austria and Carinthia are considered beneficial in order to keep the knowledge of local engineers at a high level. However, in some interviews, the lack of skilled workers (post-secondary graduates as well as trained apprentices) was highlighted as a major weakness. In addition, it was noted that the current number of students and graduates within Austria is not sufficient to even come close to meeting the domestic demand for skilled workers in lightweight construction.

In several conversations, the well-functioning exchange within and between organisations was praised. For example, successful knowledge transfer in certain materials sectors was mentioned as well as the transfer between sectors (aeronautics to automotive) or within the certain product lines (e.g. from sports cars to everyday cars). However, it was criticised in this context that the transfer from research to industry sometimes requires a great deal of patience: The steps from basic research to series production are a tremendous financial

[76] https://ati.ec.europa.eu/sites/default/files/2021-06/Product%20Watch%20Lightweight%20Materials.pdf , 09.12.2022

burden for companies. This is the reason why it remains challenging to find industrial partners for joint research projects for research institutions, which is close to impossible for projects below the TRL of around five.

As far as networks and cooperation opportunities are concerned, the manageable size of the domestic lightweight construction community is perceived as an advantage: the stakeholders know each other and are largely well connected nationally; research cooperations sometimes also arise in the networks. The materials conferences and lightweight construction conferences held in Austria are also positively highlighted.

But there is still room for improvement. Stakeholders are well connected in thematic subareas (e.g. composite lightweight construction), but less well connected between thematic fields or between regions.

It was criticized is several discussions that small-scale, regional thinking and the lack of supra-regional clusters and (research) institutions prevents Austrian stakeholders from becoming internationally more competitive. This needs to be broken up.

This is also reflected in the prevalent perception that Austria is not yet sufficiently recognised as an important lightweight construction player in other countries and that international networking should be expanded.

In some cases, the lack of output from networks and R&D cooperations was also criticized: Members/participants could not benefit directly from networking events - meetings were sometimes seen as entertaining rather than as productive sessions. Business delegations and network events were sometimes experienced as merely show programs without any added value.

Several interviewees identified a structural problem: mainly large companies are well networked, while smaller and medium-sized companies often lack the time and human resources for networking and cooperation. In addition, the desire for easy access to clear-cut information about relevant contacts within the field of lightweight was expressed.

With regard to Austria as a location, the innovative capabilities of companies and research institutions are highlighted as a particular strength. The automotive lobby in Austria (and Europe) plays an active, important role as it also takes up lightweight construction issues.

Although lightweight construction may not be of top priority right now when compared to other research and development areas like new propulsion systems.

Nevertheless, domestic lightweight players face strong competition from foreign research institutes (MIT, Cambridge) and international industries (such as car manufacturers in other countries). Frontrunners (especially those in aeronautics) tend to be located in other countries such as the Netherlands, the UK and the USA.

The strengths of domestic lightweight construction companies in manufacturing and production lie primarily in semi-finished products and joining technology. Some respondents identify strengths in both, materials production and downstream manufacturing, with the driving forces being the mobility and aerospace sectors.

However, the fact that no major OEMs are located in Austria is identified to be a disadvantage, because this means that companies are always Tier 1 or Tier 2. In addition, the fact that many producers are located in Asia is seen as unfavourable.

Potential is recognized in Austrian companies positioning themselves more broadly in various application areas of lightweight construction technologies.

The general funding landscape in Austria is praised as a strength. The funding opportunities for foreign cooperation partners are also mentioned positively. Research and development in lightweight are increasingly becoming important for Austrian companies and research organisations, as shown in chapter 2.

The European research network M-ERA-Net is perceived as a principally interesting instrument that supports transnational collaborations. However, it is considered unfavourable that the level of funding varies from country to country, and the administration costs are high compared to national funding programmes. This results either in the judgement that some question the cost-benefit ratio and thus do not participate in the programme. Others try to reduce the transaction costs by specialising in this support scheme.

It is criticized more generally that research funding is often heavily oversubscribed also in the FFG portfolio. Unrealized project applications may result in the loss of employees and thus knowhow. The need for holistic approaches to increase the beneficial effects of lightweight solutions may require the costly redesign of established processes and the

thoughtful remodelling of products. This usually exceeds typical funding volumes of national programmes.

However, national funding organisations are not the only source of funding for innovation projects. One interviewee in particular argued that, for example, joint ventures between SMEs and bigger companies can offer greater funding opportunities (due to higher volumes and longer project duration) and may even lead to stronger commercialization efforts.

Horizon Europe projects in particular are seen by some interviewees as not well fitting for lightweight projects. The requirements (with regard to include partners from different EU countries to increase chances of funding and high administration costs) are perceived as having a potential negative effect on project outcomes.

Opportunities and threats

The changing context of environmental and RTI policy, as set out in the introduction to this report, creates multiple **opportunities** and risks for the lightweight industry. Despite steady improvements in energy efficiency at an average rate of 1.1 %, Austria failed to meet national energy reduction targets for 2020 (BMK, 2022). The new target to cut energy demand by 2030 by 9 % compared to 2022, as agreed by EU member states, will require an acceleration of energy efficiency improvements (ibid.). The intensification of efforts in energy efficiency could reinforce the need for lightweight solutions in the mobility sector.

In automotive applications, there is strong evidence that energy savings that can be achieved through weight reductions can overcompensate for the higher energy intensity of lightweight construction in extraction and manufacturing. However, the ratio can also be reversed under some circumstances, leading to higher energy and greenhouse gas emissions from a product life cycle perspective. Instead of a one-size-fits-all approach, the results of life cycle analyses thus call for a differentiated approach that considers vehicle type as well as the selection and origin of lightweight materials (Gonçalves, Monteiro, & Iten, 2022; Wolfram et al., 2021). For example, the potential for reductions in greenhouse

gas emissions is likely to be significantly higher for internal combustion engine vehicles than for hybrid electric and battery electric vehicles (Luk et al., 2018).

Some interviewees highlighted that lightweight construction will become more important for e-mobility in the future. When electronic cars and new propulsion technologies are well established, producers will likely try to increase range by means of weight reduction. Furthermore, the environmental performance of lightweighting is highly sensitive to the regional energy mix and rate of secondary materials in manufacturing (Wolfram et al., 2021; Gonçalves et al., 2022). The opportunities and threats for the lightweight industry of the energy transition in mobility are thus tightly linked to trends in electromobility, the pace of change towards renewable energy, and the growth of markets for secondary lightweight materials. As energy markets and costs of energy sources recently have come into the public focus, implications for lightweight construction are also likely. Rising energy costs may lead to a re-evaluation of profitability of manufacturing processes, due to the different levels of energy required in the production of lightweight materials.

The experts consulted in this study expect increasing demand for lightweight solutions in relation to resource conservation and the use of renewable, biodegradable resources. In general terms, lightweighting of product components is – as opposed to downsizing at the product level – not a priority area for material efficiency (Hertwich et al., 2020). Lightweight construction is consequently largely absent from existing discourses and policy documents on the Circular Economy and Bioeconomy. Historically, the application of lightweight technologies has often even been co-dependent with increasing product sizes: the latter increasing demand for lightweight construction to compensate for higher energy requirements in use and the former reducing costs that can be re-invested in the form of additional product features (Kawajiri et al., 2020). Such rebound effects and co-dependencies undermine climate and Circular Economy policies and could thus pose a threat to lightweight industries in the medium to long term. Manufacturers with lightweight solutions that offer improvements in both energy and material efficiency across the product life cycle could, on the other hand, gain significant competitive advantages.

Austria is generally well positioned and can continue to establish itself in the areas of energy, mobility and industry in the future, provided that sufficient funding is made available. For example, Austria has a good starting position in additive manufacturing; the industry just needs to become a stronger user of this technology. Especially SMEs could profit from this new manufacturing method, as it requires less logistics than traditional manufacturing.

The general prospects for the future are considered to be particularly promising because lightweight construction as a cross-sectional technology offers a large number of possible applications in Austrian players' core areas of strength. In addition, an increasing demand for lightweight solutions - especially in sectors such as aviation, energy (wind power), e-mobility (weight reduction), sustainability (e.g. through resource conservation) and construction based on renewable resources (incl. industrial bioeconomy) is expected. Furthermore, demographic change makes lightweight construction in the healthcare sector indispensable: on the one hand with regard to the mobility of physically impaired persons (e.g. wheelchairs), on the other hand aging workers are dependent on lightweight construction solutions. But also, applications in sports technologies have been increasing over the years and there are past and future areas of relevance in the building sector (for bridge structures, prefabricated houses, etc.).

The Covid-19 pandemic and the war in Ukraine have brought the resilience of value chains into focus. In this context, innovative lightweight construction solutions offer high potential through resource savings, substitution and recycling, also in terms of sustainability. Resource savings and material substitution are particularly relevant when using raw materials that are not produced within Europe and have to be imported in high proportions from third countries. Recycling was mentioned by a particularly large number of interviewees as a promising business area because recycled materials are currently still more expensive and therefore less attractive than primary raw materials; they are also subject to intensive materials testing. Political requirements (mandatory re-use quotas) could achieve significant progress in this respect. In the context of sustainability, the topic of design for repair is often seen as an important and promising field for development for the future.

Lightweight construction has considerable research, development and innovation potential (see chapter 2.3). With regard to Austria's areas of strength, such as material sciences, 3D printing and the established supplier industry, there is a high innovation dynamic: : on the one hand, manufacturing processes are constantly being (further) advanced or optimized (e.g. additive manufacturing or 3-D printing), on the other hand, there is a constant development of innovative materials and new types of materials; here, hybrid lightweight construction and composite materials are recognized as particularly promising. Innovations are also seen in connection with digitalization (for example, in the area of function integration or smart materials).

As far as wood applications are concerned, there is still considerable potential for improvement, as wood is currently still a niche material in the lightweight construction sector - despite the fact that the raw material, the expertise and the relevant companies are all available locally. But even experts from aerospace research see potential. Although it is less likely that future aeroplane structures will be built again with wood, it is very likely (and partly already in place) that inner parts of aeroplanes (in cockpits, etc.) will be built with wood or wood composites with more traditional structural materials).

Despite the many opportunities, the interviews also revealed some **risks** associated with domestic lightweight construction activities.

The demand for lightweight solutions and the priority given to lightweight construction varies from sector to sector. While they are considered as essential in mobility applications such as vehicle technologies (especially in aviation), for example, they are of secondary importance in other industries like medicine and construction. In other sectors, the benefits of lightweight construction may be even less obvious and innovation potentials may remain unexploited.

Lightweight construction as a pure substitution of materials is hardly effective; instead, greater attention must be paid to the overall concept and total weight of vehicles. This requires sometimes enormously high costs associated with the production of materials, the changeover in the production process and in connection with reusability and recyclability. The dependence of Austrian lightweight construction on foreign OEMs is also identified as

a risk, as well as the strong competition for domestic companies from abroad, especially from Germany (but also from Asia, the USA and other countries).

Moreover, positive network effects are difficult to sustain over the longer term when the community is fragmented (formed primarily on the basis of the used materials). Further expansion of networks (open to all materials) and inclusion of sectors such as the construction industry and medical technology, which have so far been underrepresented in lightweight construction networks, would be a possible approach here.

A challenge especially for SMEs is the increasing complexity of lightweight solution due to raising technological pressures (functional integration) as well as regulatory pressures (meeting sustainability requirements - which are initiated by policies but are in the meantime also expressed by OEMs) and potential customers. On the one hand, new requirements may overwhelm SMEs, as they may not have the financial means to comply and therefore refrain from innovation activities. On the other hand, they may not be able to keep up with the rapid technological development cycles due to wrong foci or lack of funding options. To increase innovation activities and the likelihood of successful innovations as well as to sustain a high level of innovation activities, some support measures for SMEs might be necessary. To refrain from innovation is not only a risk for SMEs: as far as path dependencies in design and input materials are concerned, the lack of willingness to tackle holistic solutions/redesigns is also identified as risk.

One major challenge for lightweight construction is, especially in the automotive sector, that multi-materials are currently hardly or not recyclable (yet) and are therefore largely at odds with current efforts to move toward a circular economy. Consumer preferences can also stand in the way of lightweight construction goals: Consumers feel safer in heavier cars, and they have preferences for roomier and more comfortable cars. The latter example highlights that lightweight construction will of course not be able to solve the big picture of a circular economy and climate neutrality on its own. There are important societal processes that will make a huge difference, but lightweight construction can make a critical contribution towards fulfilling some of the prerequisites of a circular economy, if it is done the right way.

5 The way forward

Weight reductions and miniaturisation are major achievements in lightweight construction. However, its contributions have not yet reached its full potential because the overall design and sustainability criteria have not yet been sufficiently taken into account in the design, R&D, and implementation of lightweight solutions. Nevertheless, sustainability criteria can have an impact in two ways: On the one hand, they define requirements for lightweight construction solutions. On the other hand, they define criteria for lightweight solutions, which lead to certain materials (such as carbon fibres) being replaced by others. The focus of future lightweight construction needs to be on the overall design, resource-efficiency along the entire product life cycle and the substitution of greenhouse gas-intensive and critical resources. Only if this is implemented successfully and cost-efficiently, and so partly reaching mass production, then Europe will succeed to be competitive vis-a-vis the other global players and lightweight construction can make a meaningful contribution to societal wellbeing.

The 'new paradigms', the Green Deal and the circular economy can support the political awareness of lightweight construction in this respect. If it is done the right way, lightweight construction can become an essential pillar of a circular economy and thus rise in the political perception. Lightweighting has the potential to contribute to several narratives and strategies important for the future development of Europe. Lightweight structures decrease the weight of vehicles and thus increase their range, thereby helping to achieve the CO_2 reduction targets of the Green Deal. Lightweight production methods require less material than conventional production methods. The increase of efficiency and the reduction of material and resource consumption fit into the European and Austrian circular economy strategies. Lightweight construction also offers economic opportunities, as the development, design and production of lightweight components usually requires specific knowledge and depends on highly skilled workforce and highly innovative companies. This opens up opportunities for companies in high-wage countries like Austria, especially for new lightweight solutions in the premium segment, but also in the conventional

markets by replacing critical resource use with easily and cheaply available resources. In the latter case, it does not always have to be the best available solution, but it might suffice to develop a good-enough solution for the purpose. Lightweight solutions are applicable in many different economic sectors and still offer great innovation potential (see chapter 2.3).

For this happening, it is important to get the framework conditions right. The following conclusions and recommendations (in red) address the relevant issues arising from the discussions in this report.

National developments

How large is the value added and how many jobs are there in the lightweight construction sector in Austria?

Many actors profit economically from lightweight construction. According to a recent study[77], the direct value creation effects of lightweight construction are estimated at around € 9.4 billion for 2019. Due to upstream and downstream value creation steps, the total effects on value creation are estimated to be at around € 16.4 billion. Lightweight construction also secures around 77,400 jobs directly in the relevant sectors and another 108,000 in other economic sectors.

Which organisations are active in lightweight construction in Austria, which actors conduct R&D or are active in research projects and what are their thematic foci?

More than 1,000 different organisations conducted publicly funded research projects between 2009 and 2021.[78] Only 60-70 of them, however, conducted lightweight research projects on a regular basis.[79] The thematic focus of the lightweight research projects is

[77] https://www.biz-up.at/fileadmin/user_upload/BizupWebsite/2022/News/Q3/PK_A2LT_Studie_FINAL.pdf , 12.12.2022

[78] Funded by the FFG

[79] For this purpose, we set as a criterion the implementation of five or more lightweight construction projects participations in the period 2009-2021. An activity of the companies identified in this way in the area of lightweight construction also seems plausible with regard to their respective business fields.

mainly on industrial manufacturing, materials engineering and surface transport. The analysis also showed that lightweight construction is cross-sectional, and the research and application fields are correspondingly broad and diverse. It should be noted at this point that the analysis only covers the lightweight construction projects funded by the FFG. Research projects funded by companies themselves, for example, could not be taken into account. Concrete recommendations for research projects for specific mobility applications (Nöst et al., 2021; Gude, 2020; EARPA, 2020) or materials (AMI2030, 2022b) have already been developed. Ecological sustainability and the greater inclusion of digital technologies will play a decisive role in future research projects. Digital technologies can increase resource efficiency in lightweight construction and thereby contribute to sustainability goals. The integration of functions, the increasing importance of material cycles and supply chains, the reduction of manufacturing costs through automation and efficiency increases span a broad field of research and development needs.

Recommendation: Future calls for proposals should focus on areas in which the ecological and societal benefits of lightweight solutions appear to be greatest or where the need for solutions to master societal and ecological challenges are highest. Therefore, Austria should pursue a thematic approach for lightweight construction that includes the most important sectors (industry, mobility, energy, medical engineering, and sports equipment) and technology fields (material sciences, production technologies, joining technologies, digital technologies) and targets the SDGs of the UN. For orientation, consult the analysis of future research potentials and fields of application in chapter 2.3.

Where are the market opportunities for the Austrian supplier industry and for providers of development services for foreign customers?

There is a high economic potential for lightweight construction in Austria, but also a high potential for companies to learn from the expertise and specific processes of lightweight construction through knowledge and technology transfer. Due to Austria's areas of strengths, there are opportunities in material development, process technology (e.g. joining techniques, 3D printing) as well as the recycling or reuse of lightweight components and materials, which OEMs are increasingly demanding. These fields offer points of contact for international partners. The expertise of Austrian research institutions in material

development and the strengths in semi-finished products and in the area of joining technology can be pointed out especially for the initiation of transnational cooperation projects. Due to the high innovation dynamics in Austria and the well-trained specialists, this position does not appear to be at risk in the medium term, which in turn could also attract foreign companies to invest into lightweight construction projects.

Global developments

What are the thematic hotspots in the global development of lightweight technologies and what are their development perspectives?

Lightweight construction, in its diversity and not least due to its cross-sectional nature, is a topic in almost all industrial nations - even if usually not discussed under this term. Due to dwindling resources and the need to reduce energy consumption, lightweight construction is increasingly becoming the focus of research institutions, companies and, to some extent, politicians. Globally, Europe, Asia, North and South America are important for lightweight construction.

Within Europe, Germany, Spain, France, Italy and the UK are the countries with comprehensive industries and many specialised research organisations. Germany and Sweden address lightweight construction in a holistic context and not just in a specific sector or technology, and therefore have a special role. Projects focus largely on functional materials and innovative surfaces for various applications. The BeNeLux countries show many lightweight construction activities in international projects and are well represented in bilateral projects, especially addressing functional materials and innovative surfaces. In Luxembourg, there is a focus on modelling for materials engineering and processing. The Eastern European countries are still in an early phase of developing their lightweight construction potentials. In addition to functional materials and innovative surfaces, high-performance composites (Poland and Hungary) and additive manufacturing (Hungary) are also being developed.

China, South Korea and Japan belong to the most active countries in lightweight construction in Asia with a wide range of technologies. India takes on a special role: its focus in

R&D is on raw materials that occur exclusively in this country. This limits potential bilateral partnerships.

Lightweight construction in Canada and the USA focuses on mobility and automotive construction as well as civil and military aviation technologies. Nevertheless, there are also lightweight construction links to other sectors and with a variety of technologies - not least due to the size of these countries.

South America specialises in the development of materials, especially plastics and composites. There are good partnerships between Central American countries and Spain, which, in addition to the thematic focus, is also due to the common language.

What are the central industries driving the further development of lightweight technologies in and outside Europe?

Historically, lightweight construction started as a promising avenue of research and development for fulfilling mobility needs more efficiently. The focus was on reducing heavy materials and thus, costs. The automotive and aerospace industries will continue to be important drivers of development in lightweight construction, although the thematic focus is currently shifting towards sustainability and especially the circular economy.

Asia is currently the most important market for aluminium, magnesium, and polymers (Fischer, 2021). Within Europe, many of the most important industrial players are located in Germany. However, depending on the lightweight materials, there are also key players in Norway (aluminium), Netherlands (polymers), or Luxembourg (high-strength steel), for example (ibid.).

The need for lightweight solutions is also increasing in the production of wind turbines, being an explicit growth market. Six out of the top nine manufacturers of wind turbines are from China, with the remaining in Germany, Denmark, and Spain. European stakeholders will likely strengthen their presence over the coming years; this will be possible by investing in lightweight research and the further digitalisation of production.

The transfer of knowledge from industries already strong in lightweight construction to the construction sector represents another important opportunity. This does not only apply to the construction of prefabricated houses. In the future, lightweight construction also promises solutions for urban concepts such as the design of public spaces, the greening of facades, the construction of greenhouses or small buildings, etc.

Medical technology and the production of prostheses make up a smaller, albeit not insignificant, share.

Another segment relevant to lightweight construction in Austria is the sports equipment sector. These companies are very active in research and development.

Due to the different stages of establishment of lightweight construction and the different thematic foci of the individual countries and regions, it is not possible to make a general recommendation for intensifying international cooperation with specific countries. Instead, it very much depends on the topic and the industry in specific countries, and how Austrian stakeholders can relate to this.

Recommendation: The choice of possible international partners should be made based on the objectives and the thematic priorities announced, as well as with reference to the available funding programmes. The country profiles in the Appendix provide an overview of the strengths of suitable partner countries.

Which other relevant EU countries have national lightweight construction strategies and what conclusions can be drawn from these strategies for the preparation of an Austrian lightweight construction strategy?

To date, only Sweden and Germany have national lightweight construction strategies. Both view lightweight construction in a holistic way.

The Swedish strategy is very long-term and is updated at regular intervals. Priorities are set for specific periods. In addition to economic aspects, it also includes social and ecological criteria derived from the UN's sustainability goals as the basis. Behind the strategy is a network at national scale that, in addition to information diffusion and events, also implements trainings of experts. A well-structured website informs the community (partly in

English) about the strategy, milestones, relevant activities like events, calls in funding programmes, etc.

The German lightweight construction strategy has currently a strong focus on the economy. It contains eight bundles of measures, their intended effects and planned activities. The German ministries are currently updating the strategy to go beyond the sole focus on the economy. Unlike in Sweden, there is no single network in Germany that shapes the activities around lightweight construction. The office set up by the Federal Ministry of Economics and Climate Protection coordinates the country's political activities, but also has a clear political focus. In addition, there are several other specific or regional networks. Leichtbau BW provides the best overview, whereby this focuses on Baden-Württemberg. There is no central website in Germany that disseminates information on the topic of lightweight construction in a sector- and technology-neutral manner without being limited to one region.

Recommendation: The development of a lightweight construction strategy for Austria is cost and time intensive, not least because of its cross-sectional character. Although it seems worthwhile due to the challenges ahead and the knowledge and technology diffusion potentials across sectors, one needs to consider that there are already other, domain-specific and up-to-date strategies in place (aerospace, mobility, circular economy, etc.). Thus, there seem to be two potential avenues ahead: Either invest in a separate strategy or invest in a less in-depth process, bringing together stakeholders from different sectors to facilitate knowledge and technology transfer, but supporting the goals derived from the other strategies already in place. How lightweight feeds into the goals of other strategies needs to be shown clearly also at the lightweight website for orientation.

Following the avenue of a strategy, an approach modelled on the lightweight construction initiative in Germany could be implemented, where experts from all sectors were involved in a bottom-up process. This should clearly go beyond the mobility sector and be designed in a cross-departmental way. We can learn from the Swedish strategy its foundation on the SDGs, which could potentially also lead to synergies for collaboration with Swedish partners.

International context of Austrian lightweight activities

Which transnational cooperations exist at regional and national levels and how can these be perceived in the context of other lightweight construction R&D activities?

Most transnational R&D cooperations take place with Germany, both at the national and regional levels. The reason for this lies in strong economic but also cultural ties with Germany. The participation of foreign partners in lightweight construction R&D projects in the FFG portfolio could still be improved, but this is also the case with Austrian partners contributing to pre-competitive research projects in Germany, with the "Industrielle Gemeinschaftsforschung" (IGF) as a good example, or the programme "Zentrales Innovationsprogramm Mittelstand" (ZIM) for classic R&D cooperation projects. The CORDIS data in chapter 3.4 provides insights in the remaining international cooperation portfolio.

Interview partners emphasise the importance of transnational cooperation in lightweight construction. Big companies find it easier to access foreign partners through their already established networks. SMEs and research institutions expressed a need for support services to find corresponding partners for lightweight projects because they are, due to their cross-thematic nature, less easily identifiable. This is also reflected in the fact that large enterprises account for more than half of the participations in FFG research projects (see chapter 2.2). It is also criticised by interviewees that suitable funding programmes for, e.g. joint research projects with foreign universities are relatively hard to access. The Horizon programme is extremely selective and national, thematic programmes are getting increasingly oversubscribed. In comparison to other topics, some of the lightweight themes seem to have a harder time to succeed. It is not clear yet, inhowfar this will change in the future, when lightweight construction research increasingly follows the circular economy principles.

Recommendation: Intensify partner-matching activities for lightweight projects for SMEs in the European and national programmes, partly for higher TRL levels, and partly for lower TRL levels for more radical innovations.

Cooperation between universities and universities of applied sciences would be another possibility for international cooperation. Here, one could tie in with existing structures in

other countries (e.g. the PhD-network of the Swedish LIGHTer initiative), for example, to offer graduates of universities of applied sciences further research activities in lightweight construction. Existing PhD study opportunities at universities (e.g. at the Johannes Kepler University Linz) could also benefit from such network, especially if these cooperations also offer opportunities for project funding.

Recommendation: Explore possible collaborations within the framework of doctoral studies in the field of lightweight construction, especially for universities of applied sciences. Ideally, such activities are embedded in existing funding opportunities in the respective countries, in Austria for example the FFG or the Christian Doppler Research Association (CDG). An international PhD day within the framework of an international conference (established in the ELN network, for example) could facilitate early exchange and thus, international cooperation in the future.

How are the actors positioned in the international environment with regard to their thematic foci, what are Austria's strengths and weaknesses?

The strengths of Austrian's lightweight community lie in its expertise in material sciences and materials engineering. In addition, the narrower lightweight construction community in Austria is well networked and there are tertiary education opportunities in lightweight construction. Players active in lightweight construction are at several stages along the value chain, which offers potential for cooperation. Austria can also position itself internationally within its areas of strengths in accordance with its size, as shown by evaluations of patents or approved Horizon 2020 and M-ERA.NET projects. At the political level, Sweden and Germany have led the way with lightweight construction strategies. Germany in particular has additionally underpinned its strategic intentions financially with the establishment of the TTP LB programme. The fact that most European countries do not have any lightweight construction strategies also shows that lightweight construction per se plays a rather subordinate role as a topic for political strategies. This is also reflected in strategies in the thematic field of sustainability that hardly take lightweight construction into account, of which the Austrian circular economy strategy is only the most recent example.

Austria is a niche market for lightweight construction, which is why international cooperation at the strategic level is particularly important. Austria is therefore called upon to position itself accordingly. In doing so, an approach should be pursued that builds on what already exists and jointly defines strategic priorities and collaboration potential with Austria's most important partner countries, and nurture new ones like described in this report. Visibility of lightweight solutions, with a focus on their potential for solving challenges such as the European climate targets, should be increased both at national and international levels and corresponding platforms and networks should be further developed and established.

Recommendation: A comparable central information site like in Sweden is recommended for Austria to bring structure to the community, enhance information diffusion and create visibility for lightweight construction in the country and beyond. It is self-explanatory, that this needs to be well hosted and kept up to date for being able to benefit its members and send the right signals internationally.

The SWOT analysis in chapter 4 gives a concise overview of strengths and weaknesses and how to overcome them.

Recommendation: Austria should try to reduce its weaknesses by supporting exchange between all relevant actors, cross-sectoral and material-independent. Exchange at an international level is of utmost importance. The current activities under the ELN are a useful first step at the political level. These "high-level" activities will need substantial support from intermediaries (clusters, networks) and other main stakeholders to facilitate the integration of organisations active in lightweight construction into a European network. An "umbrella approach" should be pursued to build on existing network structures, common interests, and a common representation.

Partnerships are an important tool to position lightweight construction as a strategic topic and to open channels for knowledge and technology transfer, but they should also be backed up with corresponding activities.

Recommendation: A sensible way of strengthening existing partnerships and establishing new contacts is to initiate international, i.e. Horizon projects, which could be modelled

along the Horizon 2020 project AMULET, this time initiated by or at least with contributions from Austria. This should be based on a broad, holistic understanding of lightweight construction, for example with a view to expanding strategic value chains in Europe and the circular economy.

What are the promising future market and application potentials of lightweight construction in Austria?

Summarising the discussion in this report (see chapter 2.3, figure 11), promising future market applications and potentials of lightweight construction in Austria are distributed. For example, applications in the development or recyclable materials, design for reuse, implementation of cost-efficient recycling technologies, technology transfer from core lightweight construction sectors to various fields of applications, and in increasing automation processes in manufacturing. In terms of applications, drones, wind turbines, and weight reduction in e-vehicles are promising future market opportunities, above many others.

How should Austria position itself towards RTI in lightweight construction, what are the relevant research topics and what are the most promising areas of application?

Relevant research topics cover the entire value chain, from materials development and the manufacture of components and products to production processes and recycling or reusability. Therefore, Austria should pursue a thematic approach, including all sectors and technology fields, and based on the potential for lightweight construction to contribute to the UN SDGs. For example, in the area of sustainability, there is particularly great potential for lightweight construction applications in the energy savings resulting from weight reduction as well as material savings through lightweight designs.

Due to the high availability of possible private RTI-financing partners (e.g. along companies' supply and customer networks), public funding programmes should additionally focus on preventing potential lock-in effects due to path-dependencies and support an entrepreneurship friendly environment. Support for start-ups will need further attention, however, as business activities based on lightweight construction usually require relatively high investments.

Recommendation: Activities that lower transaction costs for SMEs and start-ups should be improved, e.g. competence landscapes, matchmaking options, networking events with a clear purpose, etc.

Recommendation: Focus on sustainable materials, energy-efficient production processes, and recycling / re-use capabilities of lightweight components. Another important research field is the integration of functionality. This could be achieved in various ways, with support of new digital technologies (AI, simulation models, etc.).

Recommendation: Facilitate exchange between lightweight "frontrunners" and "newcomers". One sector that offers huge but still underdeveloped potential is the construction sector. This could be achieved though the creation of a national platform, increased networking and low-threshold funding opportunities.

Recommendation: Focus on additive manufacturing as one of the topics with high potential for lightweight construction in Austria. One advantage of this technology is its cross-sectional applicability, therefore enabling the design and creation of new lightweight components for, among others, aviation, automotive, medical technology, sports equipment.

Networking / cooperation and public support

How to better leverage synergies from the cooperation of complementary partners from the manufacturing industry, development service providers and research institutions as well as foreign partners?

Due to the convergence of different trends, such as digitalisation and sustainability, also the field of lightweight construction is becoming increasingly complex. A constant exchange between different disciplines and across industries facilitates knowledge transfer and opens up new research and development opportunities in lightweight construction. Due to the broad field of application, it is important that lightweight construction solutions are implemented in open-topic research funding programmes. With a view to the future, however, it also makes sense to specify topics to drive development in lightweight

construction. These can be topics that directly promote lightweight construction (e.g. substitution of problematic materials and composites, resource savings) as well as topics that indirectly promote lightweight construction (e.g. joining technologies).

Recommendation: Calls for tenders in R&D funding programmes need to take sustainability / circular economy criteria into account. The aim is to favour the development of lightweight solutions in different application areas, e.g. through specifications such as minimal resource use and in compliance with the objectives of corresponding Austrian strategies and action plans (e.g. circular economy strategy, R&D strategy, national energy and climate plan).

Recommendation: Rework apprenticeship trainings to meet the needs of interdisciplinary lightweight construction. Build on the successful examples and broaden the opportunities for graduate education immediately relevant for lightweight construction to meet the growing needs by industry.

Which other intervention and support measures might also be useful to support innovation processes in the field of lightweight construction and to promote synergies from the cooperation of manufacturing companies, development service providers, research institutions and transnational R&D cooperation?

Given the prevalent issues of climate change, higher consciousness towards the sourcing of resources and building sustainable value chains, there is a need for more radical solutions. This necessitates increased research along the entire R&D value chain, from the (substitution of) raw materials to design principles, to component and product development to the use phase of lightweight components and further use (cascade use) or reprocessing. However, R&D for lightweight solutions are currently pursued with different support instruments, of which only a few are targeting the lower TRL levels.

Recommendation: Enhance the accessibility of R&D funding in the lower TRL levels (oriented basic research, industrial research) for lightweight topics with high economic significance in Austria and with an urgent need for action against the backdrop of the circular economy paradigm.

Useful formats for this kind of research are not that easy to access. The Austrian Science Fund is not accessible for engineering questions, even if they are at a truly basic research stage. Within the FFG-Portfolio, smaller projects can be leveraged through the support instrument 'Sondierungsprojekte' in several thematic programmes, or the bottom-up format Bridge (financing a PhD candidate). The remaining portfolio necessitates contributions by industry, which shifts the focus already into higher TRL levels (starting from around 5) for them to be interested to contribute. Useful formats are here the Christian-Doppler Laboratories, Josef-Ressel-Centres, or some of the COMET Centres and projects for somewhat larger endeavours. Horizon Europe projects can be of high value, but also coming with high transaction costs.

We could also not identify much systematic screening of results from basic research for their potential applicability for lightweight applications. This is actually also true for results from other FFG projects, of which a considerable share has transfer potential, as can be learned from the yearly FFG impact monitoring (Kofler et al., various years). The data in chapter 2.2 shows that there are a considerable number of research projects with relevance to lightweight construction. A more systematic gathering of research projects and research results could facilitate access to information as well as the identification of relevant research trends.

Recommendation: Intensify the systematic monitoring of results from basic and applied research for their potential applicability for lightweight solutions in different domains, and ensure their easy accessibility via webpages (project databases of FFG, FWF, CDG, etc.) and in networking events (see the SWOT analysis in chapter 4).

How could the establishment of a European lightweight construction network be supported with the involvement of national networks?

We see in Austria relatively well-developed regional cluster networks, which still show uneven activity levels at national and international levels depending on the relative strength of its industrial and R&D base in the region. All of them are strongly connected to their regional enterprise and R&D structures. With A2LT, Austria has also a material-independent, cross-sector and transregionally networked platform with a specific focus on lightweight

construction. There is also a regular exchange between ACstyria, A3PS and CU, and a core lightweight construction community has formed between these initiatives and their members. However, there are also other clusters and platforms such as the Mechatronics Cluster in Tyrol or the newly formed aerospace platform Ecoplus in Lower Austria, where closer links could be beneficial. All these clusters focus at varying degrees on lightweight construction and cover diverse and sometimes overlapping topics and sectors, where the differentiation is on the represented regions. We applaud these activities. As a next step in the evolution, we can identify a need for action at a supranational level with a significant public good share, which justifies activities partly financed from the taxpayer. This judgement is based on the insights, on the one hand, that lightweight construction is currently entering a need for more radical innovations to comply with the circular economy paradigm. Thus, we need new combinations of knowledge and technology transfer across disciplines, materials and applications, which are not easy to exploit. On the other hand, a new industrial policy is taking afoot in Europe proposing structural transformations to keep larger parts of key value chains in Europe and an increased sensitivity towards managing critical resources. With that in mind, it is recommendable to invest in a European network (with a strategic global orientation)

- with a higher visibility of the critical role of lightweight solutions for a circular economy
- where the demands for lightweight construction implementation can be voiced
- where interdisciplinary knowledge and technology exchange can be enhanced beyond the often domain specific information exchanged at trade fairs, and partly even at academic conferences.

This can only work by including the existing intermediaries, i.e. clusters, in developing the structures and its implementation, and modelling it along the lines of the German “Geschäftsstelle Leichtbau” or the Swedish “RISE network”. Austria is in a good starting position, with the existing cluster structures and the overarching platform (A2LT), and with the Austrian public sector having taken up the initiative started by Sweden and Germany to develop a ‘European Lightweight Network’. This would mean, for once, that Austria is an

early mover on this topic, which was not often the case historically (Kaufmann et al., 2021).

Recommendation: Building on already existing initiatives on the regional, national and European levels, support with other European countries a lightweight construction platform and mirror its organisational structure largely at the national level for being able to contribute and interact effectively.

Which EU countries would be suitable for launching transnational R&D tenders? Which options for implementation and which instruments are suitable for such tenders?

Projects with European partners were often preferred to transatlantic projects or projects with Asian partners, especially by interview partners from industry or clusters. They are considered easier to initiate, largely due to cultural differences (especially in Asia, where it takes a long time to build trust). On the other hand, academia sees some advantages of support structures in other continents, where e.g. doctoral students come for three years fully financed by study-abroad programmes from South America or the U.S.

Many countries in Europe are suitable partner countries, each with their own regional characteristics and thus relevant for different parts of the Austrian lightweight stakeholders. Hence, there is a distinction between strong lightweight countries and the emerging, smaller countries. Scandinavia, BeNeLux and Eastern Europe are more dependent on cooperation partners than the large countries with a diverse research landscape on their own. Access via bilateral programmes has proven successful, demonstrated by the number of projects within the framework of M-ERA.NET and - even if there has been no specific focus on lightweight construction so far - EUREKA. This should be maintained, although the transaction costs of initiating and running these kinds of projects are a constant reminder that administrative demands should be kept at a reasonable level, which is particularly difficult for designs with bilateral financing and review requirements. This is the reason, why some stakeholders focus on these kinds of projects to leverage some transaction cost savings, or they do not engage at all because they judge these projects to have a less favourable input-output relationship.

Horizon 2020 and Horizon Europe projects are particularly recommended for high-performance companies and research institutions. These give high visibility and significant collaboration potentials, and thus, are important for being perceived as an important player in the community.

Irrespective of participation in research programmes and projects, the visibility of the Austrian lightweight construction community on the international market needs to be ensured. Taking on a leading role for developing the European network gives already high visibility. Beyond that, participation in conferences and events promotes international exchange and presents Austria as a potential partner. A role model could here be the Polish community, which has entered into a strategic partnership with the Lightweight Construction Alliance in Saxony and is considered a likely partner country for the next LightCon.

6 Annex

6.1 Profiles for European partner countries with high potential

Europe is seen as a driver for the further development of lightweight construction. In addition to many industry and technology focal points, lightweight construction is addressed in Europe in a more holistic context. The diversity of lightweight construction activities is based on existing networks and established cross-border cooperation between research and industry as well as between countries, for example in the transnational value chains of Airbus and VW. Europe has research and development as well as production facilities and sales markets for lightweight products. The advantages for cooperation within Europe are seen in comparatively short transport routes and supply chains. The assessment is supplemented by already existing positive experiences in research cooperations as well as the solid data protection law. Nevertheless, there are certainly global potentials to be harnessed from cooperations beyond Europe. Though, the following seven profiles describe selected countries of the European hotspot regions mentioned under chapter 3.3, which are the more prevalent cooperation partners on a broader scale.

Germany

Leichtbau	
economy, industry, export	**central economic sectors in general** • motor vehicle industry and parts • engineering industry • chemical industry • electrical industry **specific to lightweight construction** • mechanical engineering • aerospace • automotive, traffic engineering, transport technology, storage technologies • medical technology

	• wind power and maritime • sports equipment **most exported industrial goods** • chemical products
strategic orientation with reference to lightweight construction	Germany has a lightweight construction strategy. This was developed by the Federal Ministry for Economic Affairs and Climate Action. The Federal Government is currently working on transforming the strategy, which was published in 2021, into a cross-ministerial strategy. **Conferences organised in Germany** Conferences with a holistic lightweight approach • LightCon: International Convention for Lightweight Solutions (Hannover)/ Composites United e.V. / www.lightcon.info • Technologietag Leichtbau (Stuttgart) / Landesagentur LeichtbauBW www.leichtbau-technologietag.de • Internationales Dresdner Leichtbausymposium (Dresden) / TU Dresden www.leichtbausymposium.de Conferences with specific industry or technology focus • International Conference on Bio-based Materials, Köln • Composites Europe, Stuttgart • Fachkongress Composite Simulation, online / Allianz Faserbasierte Werkstoffe www.composite-simulation.de • Formnext für additive Fertigung und industriellen 3D-Druck, Frankfurt https://formnext.mesago.com/events/de.html • HUSUM Wind 2019 • Osnabrücker Leichtbautage für Landmaschinentechnik, Osnabrück https://oslt.de • Symposium Leichtbau im urbanen System, Stuttgart / Leichtbau BW • Leichtbau-Gipfel der Automobil-Industrie, Würzburg • Werkstoffsymposium, Wolfsburg / www.werkstoff-symposium.de • Internationales Stuttgarter Symposium Automobil- und Motorentechnik, Stuttgart www.fkfs-veranstaltungen.de/veranstaltungen/stuttgarter-symposium
Visibility and (international) topic presence	**participation in international networks (and *who)** • European Lightweight Association (ELA): * Bayern Innovativ, Dr. Nicole de Boer * Leichtbau BW, Dr. Wolfgang Seeliger * Center of Maritime Technologies GmbH (CMT), Matthias Krause • European Lightweight Clusters Alliance * Fraunhofer Lightweight Design Alliance / Fraunhofer Research Field Lightweight Construction (Chemnitz, Freiburg)

	* MERGE Cluster of Excellence (TU Chemnitz) * Automotive Supplier Network Saxony (AMZ, Chemnitz) • European Lightweight Network * Founding partners of the network
	Participation in international conferences, including contribution and topics • Sweden (LIGHTer International Conference) with the focus on Multi-functional Materials, Battery, Circular Lightweight, Lightweight Vehicles and Material Applications • Spain (GEP-SLAP2022) as part of the Scientific Advisory Committee, as Keynote Speaker and with lectures in Advances in polymer synthesis and characterization; in rheology, processing, additive manufacturing and polymers for biomedical applications and nanomedicine • Spain (EASN) part of the International Scientific Committee • Poland (Komposyty Expo) as exhibitor with products in the field of additives and modifiers; R&D services; sandwich panels and fibres • Norway (LightMat2023) part of Programm Committee • USA (Materials Science & Engineering, Houston and Polymers, L.A.) as experts for materials/ polymers • Mexico (IMRC2022) with the focus on Nanoscience and Nanotechnology, Materials for Energy Conversion, Storage, and Harvesting, Materials Processing and Design, Organic and Hybrid Materials: Experimental and Computational Analysis, Bioapplications and Biomaterials, Smart Textiles, and Wearables
Participation in funding programmes and research priorities	**research focal points in Horizon** • Electrical, elecronical and informatical engineering, especially computer information • Material engineering, especially functional materials • Innovative surfaces **research focal points in M-ERA.NET** • functional materials • innovative surfaces **research focal points in EUREKA** • CELTIC-NEXT – Cluster for Next-Generation Communications • ITEA 4 - Cluster for Software Innovation • Xecs – Cluster for Electronics Components and Systems and Applications
cooperation with Austria	• participations in Horizon -projects coordinated by Austria: 9
promotion of lightweight construction	**participation in international funding programmes** • Horizon (2014-2021): coordination of 62 projects • Horizon-Project AMULET • * Technical University of Chemnitz

	• M-ERA.NET: participation in 103 projects • EUREKA: 3 Clusters / Eurostars / Globalstars / Network projects **national promotion programmes with lightweight construction reference** • Zentrales Innovationsprogramm Mittelstand (ZIM), incl. international networks https://www.zim.de/ZIM/Navigation/DE/Infothek/UeberZIM/ueber-zim.html • KMU-innovativ (ProMat_KMU) https://www.bmbf.de/bmbf/de/forschung/innovativer-mittelstand/kmu-innovativ/kmu-innovativ_node • Technologietransferprogramm Leichtbau (TTP LB) • Industrielle Gemeinschaftsforschung (IGF) **funding sources** • BMBF (Federal Ministry of Education and Research) • BMWK (Federal Ministry for Economic Affairs and Climate Action) • SMWK Sachsen (Saxon State Ministry for Science, Culture and Tourism) - only province explicitly financing lightweight projects • BAFA (Federal Office for Economic Affairs and Export Control)
national and regional clusters	**COMPOSITES UNITED** • Composites United e.V. • CU Nord • CU West • CU Ost • CU BW • CU Leichtbauforschung • CU Bau • Ceramic Composites **MECH. ENGINEERING** • Kompetenznetz Verfahrenstechnik Pro3 • Metallverarbeitungscluster Waldeck-Frankenberg • ICM Institut Chemnitzer Maschinen- und Anlagenbau e.V. • Cluster Mechatronik & Automation • Kompetenznetzwerk Mechatronik in Ostbayern
	MATERIALS • Cluster Neue Werkstoffe • Materials Valley e.V • Carbon Composites e.V • Kunststoffinstitut Lüdenscheid • Kunststoff-Netzwerk Franken e.V. • Institut für Kunststoffverarbeitung • smart³ | materials - solutions - growth • MetallDialog Heilbronn • KunststoffDIAL **AUTOMOTIVE** • Cluster Automotive Bayern • automotive thüringen e.V. • automotive BW • automotive Nordwest • aen – automotive. engineering. network e. V.
summary	Germany is the country with the most comprehensive lightweight construction activities in Europe and is also referred to as the core country for lightweight construction. Germany is very committed to research and development, with

	many different (fragmented) subsidies available. These are the primary drivers for the establishment of lightweight construction in this country. Germany is considered a suitable and interesting partner country for Austria. Lightweight construction, especially with a focus on fibre composites, is treated as a cross-sectional topic. There are regional focal points in • Southern Germany, especially Baden-Württemberg (automotive industry) • Northern Germany, region around Hamburg and Stade (aviation) • in the Braunschweig region (automotive industry, VW) • Saxony, especially Dresden and Leipzig (fibre composites)

Italy

costruzione leggera	
economy, industry, export	**central economic sectors in general** • structural engineering and building construction • civil engineering and infrastructure • renewable energies • automotive industry and automotive parts • mechanical and plant engineering • medical technology, recycling and waste disposal industry **specific to lightweight construction** • robotic • produciton • industry • mechatronic **most exported industrial goods** • machines
strategic orientation with reference to lightweight construction	Italy does not have a lightweight construction strategy. **conferences organised in Italy** • Conference on Steels in Cars and Trucks, Mailand
visibility and (international) topic presence	**participation in international networks (and *who)** • European Lightweight Clusters Alliance * Mechatronics and Motoristics Clust-ER (MECH, Emilia-Romagna)
	participation in international conferences, including contribution and topics

	• Spain (GEP-SLAP2022 und EASN) • Mexico (IMRC2022) especially in the thematic fields of Nanoscience and Nanotechnology; Smart Textiles and Wearables • Poland (Komposyt-Expo) as exhibitor in the subject area of machines and tools
research priorities	**research focal points in Horizon** • Electrical, elecronical and informatical engineering, especially electronics • Computer and Information **research focal points in M-ERA.NET** • functional materials • technologies in health applications **research focal points in EUREKA** • no cluster participation in EUREKA
cooperation with Austria	• participations in Horizon-projects coordinated by Austria: 2
the country's relationship to mobility	**participation in international funding programmes** • Horizon (2014-2021): coordination of 66 projects • Horizon-Project AMULET * Cluster Meccatronica e Motoristica * Italian Technological District for the Engineering of Polymeric and Composite Materials and Structures • M-ERA.NET: participation in 6 projects • EUREKA: Eurostars **funding sources** • MUR (Ministry of Higher Education and Research) • Regione Calabria • Ministero dell'Istruzione (Ministry of Education, EUREKA): https://www.miur.gov.it/
national and regional clusters	**national clusters with focus on lightweight construction** • MESAP - Meccatronica e Sistemi Avanzati di Produzione (robotocs) • AFIL (industry) • COMET (components, plastic and metal production) • Clust-ER MECH (mechatronics)
summary	Italy is a strong driver with reference to lightweight construction and with a strong thematic focus. The term itself plays a subordinate role. The north of Italy is characterised by the automotive industry. In the Emilia-Romana region around Bologna, a corresponding centre has formed. At the

	University of Bologna, subjects related to lightweight construction and automobility are taught (Corso Stylist Engineering, Corso Automotive Engineering, Master in Advanced Automotive (Electronic) Engineering): https://www.motorvalley.it/en/partner/bologna-university

Spain

construcción ligera	
economy, industry, export	**central economic sectors in general** • building construction • civil engineering and infrastructure • chemical industry • renewable energies • automotive industry and automotive parts • mechanical engineering and plant construction **specific to lightweight construction** • automotive • railway • metal and steel • plastic and advanced materials • light battery • wind power **most exported industrial goods** • chemical products
strategic orientation with reference to lightweight construction	Spain does not have a lightweight construction strategy. **conferences organised in Spain** • CNMAT 2022: Congreso Nacional de Materiales (Cuidad Real) https://cnmat2022.com • GEP-SLAP2022: LatinAmerican Polymer Symposium and IberoAmerican Polymer (San Sebastian) https://www.gep-slap2020.eu • EASN: International Conference on Innovation in Aviation & Space for opening New Horizons (Barcelona) https://easnconference.eu • ASIDIC 2019: Aerospace Structural Impact Dynamics International Conference (Madrid) https://asidiconference.org/

Visibility and (international) topic presence	**participation in international networks (and *who)** • European Lightweight Association(ELA) * Cluster Metal Industry of Asturias (MetaIndustry4), Jose Ramón Natal * Automotive Industry Cluster of Catalonia (CIAC, Cluster da la Industria d´Automocio de Catalunya), M. Teresa Tous Tendero • European Lightweight Clusters Alliance * Advanced Materials Cluster of Catalonia (MAV) • European Lightweight Network * candidate for the network
	participation in international conferences, including contribution and topics • USA (Materials Science & Engineering, Houston) as material experts • Mexico (IMRC2022) with the focus on nanoscience and nanotechnology; materials for energy conversion; storage and harvesting; materials for sustainability and environmental applications; materials processing and design; experimental and computational analysis; bioapplications and biomaterials; smart textiles and wearables
research priorities	**research focal points in Horizon** • electrical, elecronical and informatical engineering • mechanical engineering **research focal points in M-ERA.NET** • functional materials • innovative surfaces **research focal points in EUREKA** • CELTIC-NEXT – Cluster for Next-generation communications • EUROGIA2030 – Cluster for Sustainable energy solution • ITEA 4 – Cluster for Software innovation • SMART – Cluster for Advanced manufacturing • Xecs – Cluster for Electronics Components and Systems and Applications
cooperation with Austria	• participations in Horizon -projects coordinated by Austria: 8
promotion of lightweight construction	**participation in international funding programmes (and *who)** • Horizon (2014-2021): coordination of 93 projects • Horizon-Project AMULET * Associacio Cluster de Materials Avancats de Catalunya * Bax Innovation Consulting SL • M-ERA.NET: participation in 50 projects • EUREKA: 5 Clusters/ Eurostars / Globalstars / Network Projects

	funding sources • AEI (Agencia Estatal De Investigación) • CDTI (Centre for the Development of Industrial Technology), https://www.cdti.es/index.asp (EUREKA; Claster SMART) • IDEA (Agencia de Innovación y Desarrollo de Andalucía, Andalusia) • IDEPA (Agencia de Desarrollo Económico del Principado de Asturias, Asturia) • Innobasque (Basque Country) • ICE (Instituto para la Competitividad Empresarial, Castilla+Leon) • fmi+d (Madrid)
national and regional clusters	**national clusters with focus on lightweight construction** autotomive industry clusters: • CEAGA • AVIA Clúster de Automoción de la Comunitat Valenciana (• AEI Automoción de la Rioja • FaCyl (also: additive manufacturing) • CIAC (also: lightweight battery) other clusters: • MAFEX Asociación Ferroviaria Española (railway) • Clúster de Materials Avançats de Catalunya (advanced materials) • Polo del Acero (steel) • Advanced Manufacturing Cluster of Metal Industry in Asturias MetaIndustry (metal) • VALMETAL (metal, mechanics)
summary	Spain is a strong lightweight construction player in europe. The industrially strong north-east of Spain, and in particular the region of Catalonia, is a regional hot spot. The regions of Andalusia, Castilla y Leon, Madrid and Andalusia are also active, especially in promoting research and development. The technological focus is on material development.

Belgium

construction légère	
economy, industry, export	**central economic sectors in general** • chemical industry • renewable energies • automotive industry and automotive parts • mechanical engineering and plant construction

	• recycling and waste disposal industry **specific to lightweight construction** • no specific sectors **most exported industrial goods** • chemical products
strategic orientation with reference to lightweight construction	Belgium does not have a lightweight construction strategy. **conferences organised in Belgium** • no conferences organised in Belgium
Visibility and (international) topic presence	**participation in international networks** • no participatins known
	participation in international conferences, including contribution and topics • Mexico: IMRC2022 with a focus on nanoscience and nanotechnology, materials for sustainability and environmental applications
research priorities	**research focal points in Horizon** • electrical, elecronical and informatical engineering • computer and Information • physics **research focal points in M-ERA.NET** • functional materials • innovative surfaces **research focal points in EUREKA** • Cluster ITEA 4 (Brusseles, Flanders) – Software innovation • Cluster SMART (Flanders) – Advenced Manufacturing • Xecs (Flanders) - Electronics Components and Systems and Applications
cooperation with Austria	• participations in Horizon -projects coordinated by Austria: 5
promotion of lightweight construction	**participation in international funding programmes (and *who)** • Horizon (2014-2021): coordination of 26 projects • Horizon Project AMULET * Flanders Make • M-ERA.NET: participation in 25 projects • EUREKA * Brussels: 1 Cluster / Eurostars

	* Flanders: 3 Cluster / Eurostars / Globalstars / Network Projects * Wallonia: Eurostars / Globalstars / Network Projects **funding sources** • FWO (Research Foundation – Flanders) • HERMESFUND/VLAIO (Fund for Innovation and Entrepreneurship. Flanders Agency for Innovation and entrepreneurship) • FNRS (Fund for Scientific Research) • SPW (Service Public de Wallonie, Direction générale Opérationnelle Economie) • VLAIO – Agentschap Innoveren & Ondernemen (EUREKA, Cluster SMART) https://www.vlaio.be/nl/vlaio-netwerk/flanders-innovation-entrepreneurship (FLanders)
national and regional clusters	**national clusters with focus on lightweight construction** • no national cluster known
summary	Belgium, like the Netherlands, is named as a hot spot region for lightweight construction in Europe. Compared to the strong lightweight construction nations such as Spain, Germany or France, Belgium is only at the beginning of a strategic orientation of the topic area. This is reflected in the low presence of the lightweight construction topic at conferences and the lack of clusters and networks. At the same time, Belgium is a partner in all funding programmes and in the Amulet project.

Sweden

lätt konstruktion	
economy, industry, export	**central economic sectors in general** • structural engineering and building construction • civil engineering and infrastructure • renewable energies • automotive industry and automotive parts • mechanical and plant engineering • recycling and waste disposal industry **specific to lightweight construction** • railway • automation • hybrid component **most exported industrial goods**

	• machines
strategic orientation with reference to lightweight construction	Sweden has a lightweight construction strategy: “Lightweight solutions strengthen Swedish competitiveness and growth”. This gives the Swedish innovation system a thematic focus, especially with regard to the development of recovery methods. The strategy has emerged from a network and is linked to a funding programme and an extensive education programme for young professionals. **conferences organised in Sweden** • LIGHTer International Conference 2022, Göteborg / Network LIGHTer https://lighter.nu/en/event/lighter-international-conference-2022 • ICERT 2018: International Conference on Epoxy and Resins Technology, Stockholm und Helsinki
Visibility and (international) topic presence	**participation in international networks (and *who)** • European Lightweight Clusters Alliance * LIGHTer • European Lightweight Network * founding partner
	participation in international conferences, including contribution and topics • Austria (Wiener Motorensymposium) with a lecture on "Cast iron as light as aluminium" • Spain (GEP-SLAP2022) with a lecture on “Polymers for energy and smart applications”
research priorities	**research focal points in Horizon** • electrical, elecronical and informatical engineering • mechanical engineering • computer and information **research focal points in M-ERA.NET** • functional materials • innovative surfaces **research focal points in EUREKA** • CELTIC-NEXT – Cluster for Next-Generation Communications • ITEA 4 – Cluster for Software Innovation • SMART – Cluster for Advanced Manufacturing • Xecs – Cluster for Electronics Components and Systems and Applications
cooperation with Austria	• participations in Horizon -projects coordinated by Austria: 3

promotion of lightweight construction	**participation in international funding programmes** • Horizon (2014-2021): coordination of 13 projects • M-ERA.NET: participation in 22 projects • EUREKA: 4 Cluster / Eurostars / Globalstars **funding sources** • Vinnova, Sweden's innovation agency / https://www.vinnova.se/en/
national and regional clusters	**national clusters with focus on lightweight construction** • Automation Småland (Automation) • Automation Region (Automation) • Järnvägsklustret (Railway) • IUC Syd AB (Industry/ Digital) • TTC (Hybrid Component) • Sustainable Steel Region (Steel) • Techtank Advanced Engineering Alliance (Industry)
summary	Sweden is considered a hot spot region in Europe. The country's national lightweight construction strategy is holistic, sector- and technology-neutral. Behind the strategy is an entire network (LIGHTer) including an education and promotion programme. No regions or specific focal points have been identified. Sweden is seen as an attractive partner for Austria.

Switzerland

Leichtbau, construzione leggera, construction légère	
economy, industry, export	**central economic sectors in general** • building construction • civil engineering and infrastructure • chemical industry • renewable energies • automotive industry and automotive parts • mechanical engineering and plant construction **specific to lightweight construction** • composites • materials • nanotechnologies **most exported industrial goods** • chemical products

strategic orientation with reference to lightweight construction	Switzerland does not yet have a lightweight construction strategy or specific program. However, there are indications that work is being done on the corresponding development. The promotion of lightweight construction projects takes place indirectly through programmes of the Federal Office for Energy and Environment and Innosuisse, the federal applied research funding agency. **conferences organised in Switzerland** • there are no conferences organised in Switzerland
visibility and (international) topic presence	**participation in international networks (and *who)** • European Lightweight Association (ELA) * Hightech Zentrum Aargau, Leendert den Haan
	participation in international conferences, including contribution and topics • Sweden (LIGHTer) with the focus on Fossil Free Transportations, Battery, Circular Lightweight and Fibre Composites • Mexico (IMRC2022) in the thematic area Nanoscience and Nanotechnology, Bioapplications and Biomaterials, Smart Textiles and Wearables • Poland (Komposyty-Expo) as exhibitor in the thematic area paints, coatings, resins and gels
research priorities	**research focal points in Horizon** • no special focal points **research focal points in M-ERA.NET** • functional materials • materials for additive manufacturing functional materials **research focal points in EUREKA** • CELTIC-NEXT – Cluster for Next-Generation Communications • EUROGIA2030 – Cluster for Sustainable Energy Solution • ITEA 4 – Cluster for Software Innovation • SMART – Cluster for Advanced Manufacturing • Xecs – Cluster for Electronics Components and Systems and Applications **focal points of applied patents** • lightweight construction • sports equipment mechanical engineering
cooperation with Austria	• participations in Horizon -projects coordinated by Austria: 1
promotion of lightweight construction	**participation in international funding programmes** • Horizon (2014-2021): coordination of 9 projects • Horizon Project AMULET: no participation • M-ERA.NET: participation in 8 projects

	• EUREKA: 5 Clusters / Eurostars / Globalstars / Network projects **national promotion programmes with lightweight construction reference** • An overview of funding programmes, target groups and thematic priorities can be found on the website of the Swiss National Science Foundation: https://snf.ch/en/A7fep1IPxz1XezVS/page/find-funding-scheme?category=&page=2 • Information on funding opportunities with international partners can be found on the Innosuisse webpage: https://www.inno-suisse.guide/#/guide/international-partner **funding sources** • DETEC (Federal Department of the Environment, Transport, Energy and Communications – M-ERA.NET) • SFOE (Swiss Federal Office of Energy - CORNET) • Innosuisse - Swiss Innovation Agency (EUREKA, Cluster SMART)
national and regional clusters	**national clusters with focus on lightweight construction** • CU Switzerland • Swiss Materials
summary	Switzerland is considered particularly active in the cross-cutting topic of lightweight construction and as a hotspot in Europe. Switzerland appears to be a suitable and interesting partner for cooperation with Austria. There is a well-connected lightweight community in the country. Special focus areas include hydrogen and nano and materials technology. In the canton Aargau, there is a focus on power plant construction.

Poland

lekka konstrukcja, budowa lekka	
economy, industry, export	**central economic sectors in general** • structural engineering und building construction • civil engineering and infrastructure • mechanical and plant engineering • automotive industry and automotive parts • chemical industry • medical technology • recycling and waste disposal industry **specific to lightweight construction** • automotive and advanced manufacturing (to mobility) • environment technologies • aluminium and metal

	• composites **most exported industrial goods** • electrical engineering products
strategic orientation with reference to lightweight construction	Poland does not have a lightweight construction strategy. **conferences organised in Poland** • Komposyty-EXPO (Międzynarodowe Targi Materiałów, Technologii i Wyrobów Kompozytowych), Cracow • Click-Watch-Talk Komposyty-EXPO (Online-Konferenz) • Cracow Tech Week, Cracow
visibility and (international) topic presence	**participation in international networks (and *who)** • European Lightweight Clusters Alliance * Bydgoszcz Industrial Cluster Tool Valley
	participation in international conferences, including contribution and topics • Spanien (EASN) as part of the International Scientific Committee • USA (Materials Science & Engineering, Houston und Polymers, L.A.) as Materials / Polymers Experts • Mexico (IMRC2022) with the focus on Nanoscience and Nanotechnology; Materials Processing and Design • Germany (Dresdner Leichtbausymposium) with lectures, among others on climate-friendly vehicles
research priorities	**research focal points in Horizon** • electrical, elecronical and informatical engineering • mechanical engineering • computer and information **research focal points in M-ERA.NET** • functional materials • high performance composites **research focal points in EUREKA** • EUROGIA2030 – Cluster for Sustainable energy solutions • Xecs – Cluster for Electronics Components and Systems and Applications **focal points of applied patents** • lightweight construction technologies • materials engineering
cooperation with Austria	• participations in Horizon-projects coordinated by Austria: 1

Promotion of lightweight construction	**Participation in international funding programmes** • Horizon (2014-2021): coordination of 5 projects • Horizon Project AMULET * Bydgoszcz Industrial Cluster * Fundingbox Accelerator Sp. Z O.O. • M-ERA.NET: participation in 72 projects • EUREKA: 2 Cluster / Eurostars / Globalstars / Network Projects **funding sources** • NCBR: Narodowego Centrum Badań i Rozwoju / The National Centre for Research and Development • NCN: Narodowe Centrum Nauki / National Science Centre
national and regional clusters	**national clusters with focus on lightweight construction** • Silesia Automotive & Advanced Manufacturing (Automotive and Advanced Manufacturing) • Radomski Klaster Metalowy (metals) • Polish Aluminium Cluster (aluminium) • KOM (aluminium) • PKTK: Polish Cluster of Composite Technologies (composite) • BSCC: Baltic Sea & Space Cluster
summary	The presence of lightweight construction is growing in Poland. In general, there is a "rising community" in the country related to lightweight construction, especially with regard to composites. The drivers are the Polish composite clusters. There are strong efforts towards networking and exchange. The Polish community is already working with lightweight construction players in eastern Germany and is being discussed as a partner country for LightCon 2023 in Hannover. Particularly active regions are Cracow, Silesia, Pomorskie. Main topics are plastics, metal, recycling. Special applications are light aircraft and yachts.

6.2 Methodology

International networks

Interviews were conducted with four representatives of international networks using target group-specific guidelines:

- European Lightweight Association (ELA)
- European Lightweight Network (ELN)
- European Lightweight Cluster Alliance (ELCA)

- Composites United (CU)

The interviews were conducted online by two members of the project team. The interviews were recorded with the consent of the interviewee and recorded in writing. The relevant network with its goals and activities, the international status quo of lightweight construction (Europe and worldwide), including national/regional hotspots and focal points as well as the funding landscape and visibility of the topic were addressed (see interview guidelines). The analysis was carried out content-analytically according to Mayring (2002).[80]

Analysis of existing funding and programmes

The funding database CORDIS (for Horizon projects), the funding programme M-ERA.NET and the lightweight construction-specific Horizon project AMULET were analysed applying the following approach.

- The CORDIS[81] database (Community Research and Development Information Service) provides information on the projects funded by the European Union in the EU Framework Programme Horizon. The Horizon 2020 and Horizon Europe programme for the period 2014 to 2022 was used for the study. It was based on all projects with the English-language keyword "lightweight" “light-weight”. The hits were grouped along the coordinating partner countries. A thematic score (number of projects in the thematic field / number of all projects) was used to characterise the countries with regard to the "field of science".
- The European network M-ERA.NET[82] is an association of national and regional funding organisations founded in 2012 with the aim of promoting research and innovation projects related to materials and battery technologies. For the study, the participations were counted by thematic field for all calls/projects in

[80] Cf.: Mayring, Ph. (2002): Einführung in die qualitative Sozialforschung. Eine Anleitung zu qualitativem Denken. Beltz Verlag, Weinheim/ Base

[81] Cf.: Datenbank CORDIS. See: https://cordis.europa.eu/search/en. (23.09.2022)

[82] Cf.: Webauftritt von M-ERA.NET. See: https://m-era.net/ (23.09.2022)

the period 2019-2021 and a thematic score was created for each country (number of projects in the thematic field / number of all projects).

- Advanced Materials & Manufacturing United for LightwEighT (AMULET[83]) is a Horizon 2020 project with an explicit focus on lightweight solutions made of polymers, light metals and ceramics in the automotive, aerospace, energy and construction sectors. The project is funded with around €5 million of EU funding and aims to promote and harness the innovation potential for SMEs through cross-sectoral, international knowledge exchange. In addition to funding demonstration projects, SMEs are supported through technical training and B2B coaching. For the study, the participating countries and the institutions behind them were evaluated.

Analysis of clusters with lightweight construction reference

For the identification and analysis of cluster structures in the national and international context, the analysis results of the European Secretariat for Cluster Analysis[84] (ESCA), which is located at the VDI/VDE-IT, served as a basis. For more than 10 years, national and international cluster initiatives as well as cluster management organisations have been recorded in a specially created database. For the study, cluster initiatives with description elements relevant to lightweight construction were researched and these were supplemented by further online research for the profiles. The cluster name, the country, the web address, the year of foundation, the technological focus and the number of partner organisations were recorded.

Analysis of trade fairs and conferences

The study of conference events as well as participation in conferences - especially in an international or supra-regional context - enables an assessment of the respective interest in the topic of lightweight construction as well as an analysis of the country-specific focal

[83] Cf.: Webauftritt von AMULET. See: https://amulet-h2020.eu/amulet/. (23.09.2022)

[84] Cf.: The European Secretariat for Cluster Analysis (ESCA). See: https://cluster-analysis.org/. (22.09.2022)

points. For this purpose, a desktop search was carried out with the conference and lightweight construction relevant keywords in the languages German, English, Spanish and French and the relevant conferences were screened. The organisers were then recorded and the programmes evaluated with regard to thematic focus and international participation.

To assess the national status quo and its development opportunities, FFG data was analysed. FFG-funded projects were searched by 12 keywords with reference to lightweight in German and English in the title, abstract and proposal of the funded projects from 2009 to the last available values (2022).

Semi-structured Interviews

Between June and September 2022, a total of 22 semi-structured interviews were conducted online via MS Teams with relevant stakeholders and with national representatives from the following institutions:

- 4A MANUFACTURING GMBH
- A2LT
- A3PS
- AC Styria
- ALPEX Technologies GmbH
- AMAG
- AVL List
- Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
- Österreichische Energieagentur
- Economica
- Engel Austria GmbH
- FACC
- Holzcluster Steiermark
- JKU Linz, Institute of Structural Lightweight Design
- Leichtmetallkompetenzzentrum Ranshofen
- MAGNA STEYR Engineering AG & Co KG

- Montanuniversität Leoben; Dep. Kunststofftechnik
- Pankl Racing Systems AG
- Polymer Competence Center Leoben GmbH PCCL
- PRIME aerostructures GmbH
- Secar Technologie GmbH
- TU Graz, Institute of Materials Science, Joining and Forming (aviation)

Findings and conclusions have been presented and discussed in a focus group held on September 26th, 2022. Eight participants attended the 2-hour online workshop to discuss in depth the preliminary hypotheses on the importance of collaborative networks and transnational R&D funding.

6.3 Tables

6.4 Figures

6.5 Abbreviations

AI	Artificial Intelligence
CFRP	Controlled Free Radical Polymerization
CO_2	Carbon Dioxide
FFG	Forschungsförderungsgeschellschaft
GDP	Gross Domestic Product
GFRP	Glass Fiber Reinforced Plastic
OEM	Original Equipment Manufacturer
R&D	Research and Development
RTI	Researach, Technology, and Innovation
RTM	Resin Transfer Moulding
SCM	Supply Chain Management
SME	Small and Medium-sized Enterprises
SWOT	Strength, weaknesses, opportunities, and threats

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