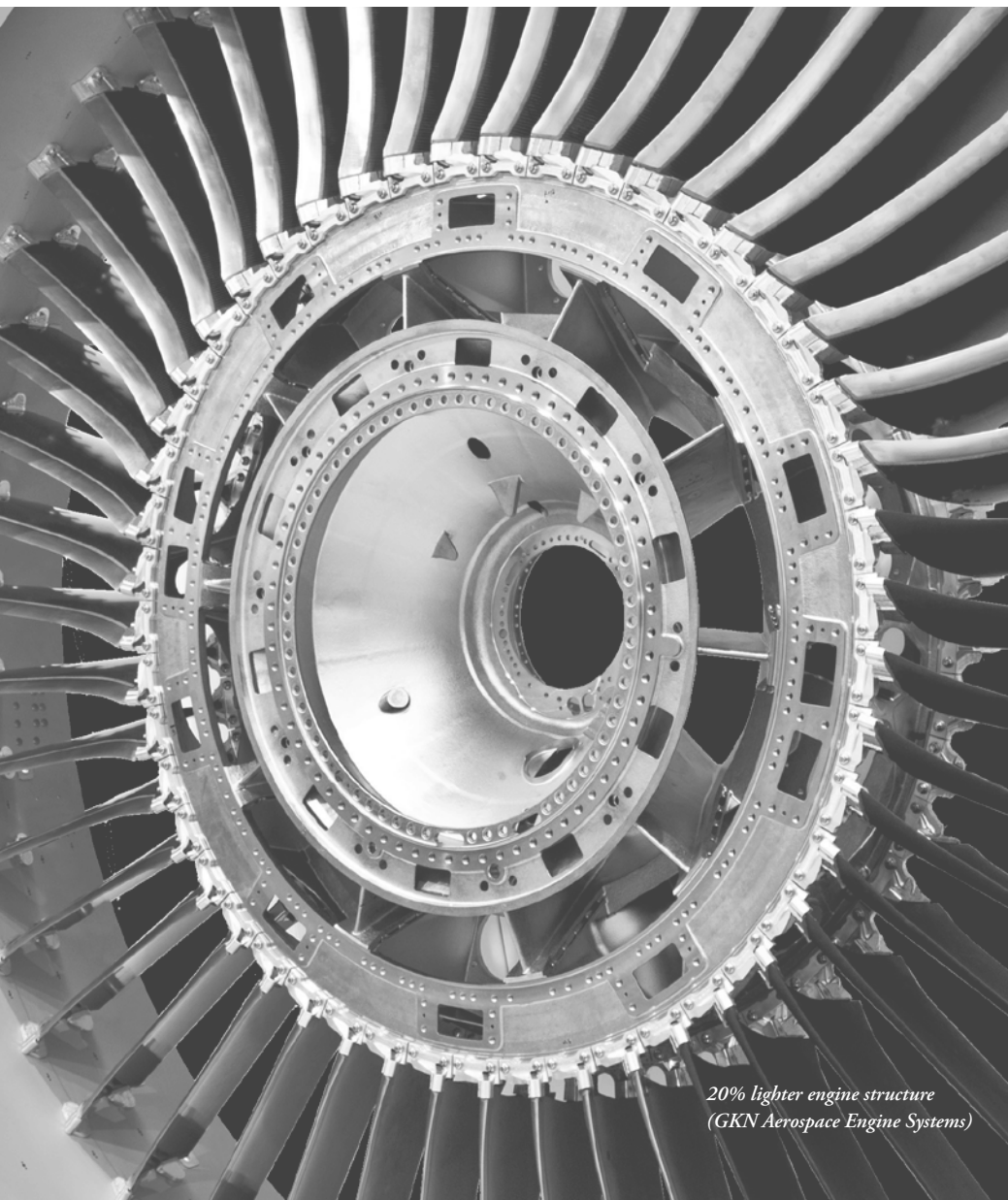


Lightweight solutions strengthen Swedish competitiveness and growth

– for a sustainable society 🌍

Strategic research and innovation agenda for lightweight

2017 – 2037



20% lighter engine structure
(GKN Aerospace Engine Systems)

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HERE WE GO; AN UPDATED ROADMAP FOR LIGHTWEIGHT

Sweden's ability to develop world leading expertise within lightweight technologies is crucial when it comes to maintaining our industrial competitiveness in the future. In 2013 we developed our first lightweight agenda, and after having evaluated the journey so far we are now ready to present an updated roadmap for 2017 - 2037.

This new cross-industry lightweight agenda presents ways in which Sweden can develop new technologies and innovations to drive sustainable growth and tackle the most important challenges facing society. We identify the basic requirements in addition to the areas in which Sweden needs to become even better in order to ensure that our investments result in competitive, lightweight and sustainable products.

Our vision for the country is "Lightweight solutions strengthen Swedish competitiveness and growth for a more sustainable society". By this, we mean that our technologies and solutions will have a decisive impact on Swedish competitiveness and contribute to a sustainable society.

We extend a warm welcome to any organisation that would like to contribute to and benefit from these lightweight investments. LIGHTer manages and coordinates multi-organisational projects and investments within the lightweight area. You can find the latest news about on-going research and development projects, network meetings, training events and more at www.lighterarena.se

Giving Lightweight-Sweden a boost!

Today, Sweden is equipped with a solid base for coordinating lightweight development that is absolutely crucial to the future competitiveness of our industries. In a short amount of time we have managed to gather together a great deal of organisations within a creative and productive network focused on lightweight development. Our ambition is of course to bring in even more companies, universities, colleges, institutes and other organisations as time goes on. We have demonstrated the advantages that are inherent to cross-industry development. Our model for success is to promote collaboration across several technical disciplines and along the entire value chain.

Several significant development lines are being driven by the challenging environmental goals that the world's industries need to face up to at the moment. Trends such as simulation, flexible manufacturing methods and new bio-based materials are all closely linked to lightweight products. Additionally, Sweden's new industrialisation strategy places focus on areas such as digitisation, sustainable production, workforce education and test environments, which supports even more investment in lightweight development.

This agenda presents ways in which we together can give Lightweight-Sweden a boost and thereby overcome huge societal challenges relating to the environment, growth and innovation efficiency. Some of these improvement areas will be of particular importance over the coming years:

Bridging the gap between strategic research and the industry's development

Sweden needs to launch even more projects that seek to develop new innovative approaches to weight challenges. Today, we are not running enough so-called 'high risk projects' which allow senior researchers and product developers from within the industry to collaborate together. In order to bridge the gap, Swedish industries and universities need to find the right working methods and inspiration for numerous additional high risk projects. For this purpose, our research network provides a solid base for the systematic generation of ideas. Put simply, what we need is more technological leaps forward!

Strengthening the whole value chain – from global industries to SMEs

The whole value chain needs to get involved. That's a prerequisite if we in Sweden are going to succeed in our new industrialisation goals and in generating economic growth. In order to strengthen many small and medium-sized enterprises (SME) within the field of lightweight development, we need to work hard at developing our regional nodes; and to make spaces for frontier crossers that can spread knowledge between companies, universities and institutes. We also believe that it is necessary to adapt our models for collaboration so that smaller companies participating in long-term research and development projects can concentrate on the aspects of the project that they are most suited to benefit, and from which they themselves can extract the most value. This kind of approach will benefit both SMEs in addition to larger organisations within the project, and will increase synergy as well.

Taking a holistic approach to test and demo facilities

Sweden needs to take a holistic approach when it comes to the conditions for test and demo facilities; and to implement a comprehensive investment. Carrying out demonstrations is a prerequisite for any new technology that will be used to generate new businesses and projects with strong environmental credentials. Just like many of the country's other innovation areas, lightweight has a great need for test and demonstration environments that can strengthen the entire value chain. We plan to work together with other strategic innovation programmes in order to find new opportunities and solutions at regional, national and international levels.

THE VALUE OF LIGHTWEIGHT

The need for lighter products stems from the major global challenges facing us today. The world's growing population must learn to share our planet's finite resources while agreeing on effective environmental measures. Developing lighter products with a life cycle perspective is a self-evident route towards reduced resource requirements and higher levels of energy efficiency.

Within the transport industry, companies are fast approaching deadlines for global environmental requirements, which means that lighter products will very soon become imperative in order to remain on the market. The demand for lightweight increases even more when we start talking about the powertrains of the future within products such as electric cars, for example.

The benefit of weight reductions and energy savings

The benefits of weight reductions and energy savings are also evident in a range of other industries, such as the energy sector with its wind turbines and insulators; the construction and infrastructure sector with its pre-designed building elements and reinforcement materials; the engineering industry with its tools and robots; and the medical industry with its prosthetics and other aids. At the same time, efforts within the materials industry to develop specialised materials such as high-strength steel or thin re-inforced composites are becoming an increasingly important prerequisite for product manufacturers that wish to reduce the weight of their final products.

We estimate that at least half of Sweden's exports¹⁾

depend on the development of lightweight solutions, considering that the transport, electronics, machinery, iron and steel, metal, forestry and furniture sectors already use lightweight technologies to gain a competitive edge, or to establish niches with growth potential. Similarly, if we look at the largest export companies in Sweden²⁾, we can conclude that at least eight of the ten leading firms compete in markets that require lighter products.

GDP depends on industry specialisation

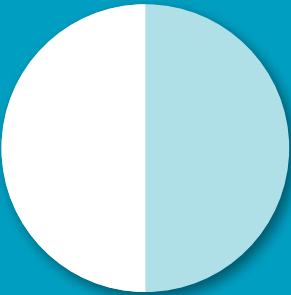
Sweden's GDP is also dependent on high levels of specialisation within the country's manufacturing industry. A whole 30% of the country's GDP relates to welding or products that are in some way joined together³⁾ – a domain that is directly influenced by new advanced lightweight technologies.

The value of lightweight is also high when viewed from an employment perspective. Of the twenty largest industrial employers, 40% include lightweight as one of their key focus areas⁴⁾. In other words, Sweden's investments in lightweight technology are absolutely crucial if the country is to reach its environmental goals, strengthen its competitiveness and create jobs on home turf.

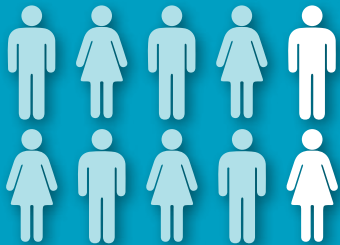
Global environmental goals mean that lighter products are imperative in order to remain on the market.

1) Statistics Sweden (SCB), commodity areas share of total exports Jan-March 2016.
2) Nordic Netproducts AB, largestcompanies.se, the largest export companies.
3) The Swedish Welding Commission (Svetskommissionen), Roadmap 2015.
4) Nordic Netproducts AB, largestcompanies.se, the largest employers in the home country.

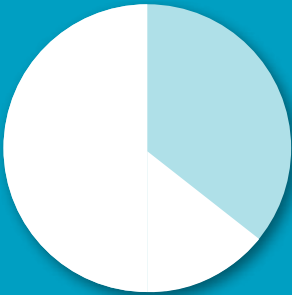
The Industrial Lightweight Business



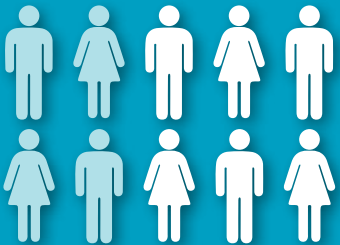
More than 50% of Sweden's total exports correspond to lightweight products



8 out of Sweden's ten largest export companies are dependent upon lightweight solutions



30% of Sweden's GDP stems from welding and welded products



4 out of Sweden's ten largest employers have lightweight as one of their key focus areas

THE SWEDISH LIGHTWEIGHT LANDSCAPE IS GROWING

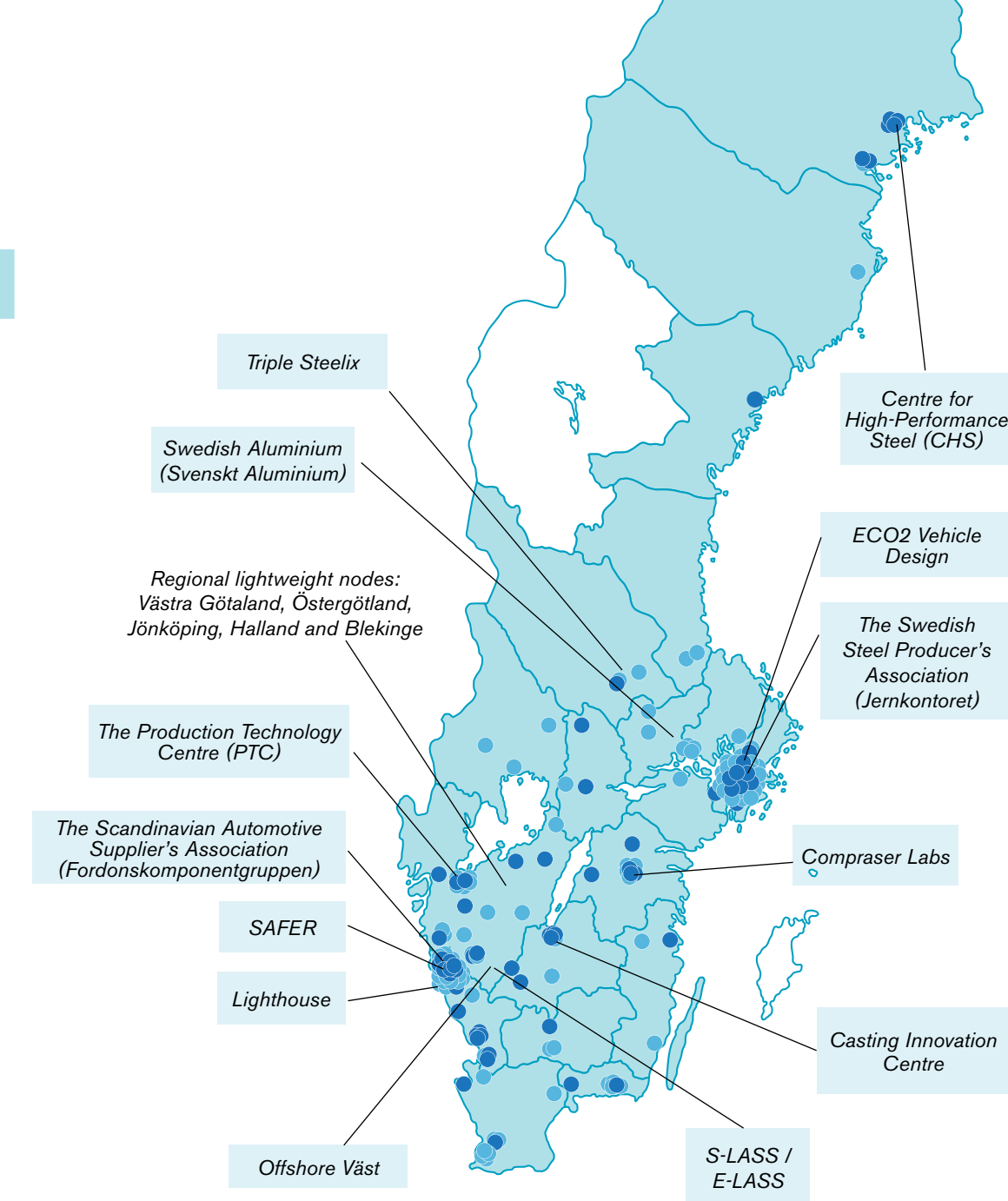
The national cross-industry lightweight arena, LIGHTer, today offers a hub for Swedish competency and technical development within lightweight. Our ambition is to coordinate Sweden's lightweight investments in a way that allows businesses, universities and institutes to really benefit from one another in a truly cross-industrial manner. As an industrial nation, Sweden needs to maximise the result of every last penny that is invested into innovation.

Swedish research and development within the lightweight area is driven at regional, national and international levels by public and internal investments in companies, universities and institutes, in addition to other kinds of organisations as well. The image to the right shows participants that are active within LIGHTer (members and stakeholders) as well as some of the research centres that work with lightweight as a part of their operations. We describe it as 'the Swedish Lightweight Landscape.'

Between 2014 and 2016, 131 organisations took part in our industry-based development project (financed by the Strategic Innovation Programme Lightweight). Around 300 organisations in total shared their lightweight experiences through their participation in our conferences, workshops, training events and projects. The strategic innovation programme Lightweight and LIGHTer currently have activities, participants and networks in 19 of Sweden's 21 counties. Five regions are involved and investing in the construction of regional lightweight nodes. Many of the country's industrial research centres also have lightweight high on their agendas. The Swedish lightweight landscape is growing.

The Strategic Innovation Programme Lightweight and LIGHTer currently have activities, participants and networks in 19 of Sweden's 21 counties.

Dark blue dot: LIGHTer members
Light blue dot: LIGHTer stakeholders



FUTURE DEMANDS FOR LIGHTWEIGHT

The transport industry, which accounts for almost a fifth of global emissions of greenhouse gases, plays a central role in worldwide efforts to improve the environment. Each mode of transport carries out its operations with regards to national and international requirements and visions, all of which require lighter vehicles and marine vessels. Many other sectors have lightweight requirements within environment and health, economics or technology.



LIGHT AND HEAVY VEHICLES

Europe has introduced the toughest emission limits for passenger cars in the world. EU law requires car manufacturers to ensure that their car fleets emit no more than 95 grams of CO₂ per kilometre by 2020 at the latest. For freight vehicles, the European Road Transport Advisory Council (ERTRAC) has set targets for 2030 that represent a 40% reduction in CO₂ emissions per tonne of cargo per kilometre (relative to 2010).

AVIATION

Within the aviation industry, the Advisory Council for Aeronautics Research in Europe (ACARE) has set targets for 2050 that represent a 75% reduction in emissions of CO₂ and a 90% reduction of nitrogen oxide compared with the levels recorded in 2000. In practice, that means that the aviation industry needs to achieve weight reductions in plane and engine components of at least 10% every tenth year.

MARINE VESSELS

The EU's roadmap¹⁾ to a single European transport area sets the goal of reaching a 40% reduction in CO₂ emissions from shipping traffic by 2050, compared with levels in the year 2005. This measure, together with the ban on marine oil within the so-called SECA area issued by the UN's marine organisation²⁾, mean there is a real need to quickly move towards lighter vessel constructions with reduced fuel requirements and an increased payload. Depending on the availability of fuel with a low sulfur content, these regulations will likely be tightened up on a global level by 2020 and at the latest by 2025.

INFRASTRUCTURE

The long-term strategies of the Swedish Transport Administration (Trafikverket) include energy consumption as a functional requirement in the procurement of infrastructure. For the construction industry, this now involves competing with lightweight designs that reduce the environmental impact, handling costs and, as a result, life-cycle costs as a whole.

OTHER SECTORS


The development of lightweight technologies is also being boosted by major economic and technological incentives as well as working environment requirements. Lightweight solutions are being used to create products that are easier to use and cheaper to transport, handle and repair. These driving forces are clearly evident within sectors such as energy, engineering, construction, automation, etc.

1. The EU's white paper 'Roadmap to a single European transport area – Towards a competitive and resource efficient transport system,' 2011. www.transportstyrelsen.se


2. The SECA area (Sulfur Emission Control Area) is comprised of the Baltic Sea, the North Sea, the English channel and North America and concerns the control of sulfur emissions. Valid from January 1st 2015 IMO (International Maritime Organisation)

LIGHTWEIGHT CASE STUDIES


The Swedish Transport Administration (Trafikverket), Chalmers and WSP

 30% LIGHTER ROAD BRIDGE MADE FROM FIBRE-REINFORCED PLASTIC


Road bridges made from fibre-reinforced plastic weigh just 30% of a road bridge built from steel and concrete. They can be pre-manufactured and installed within very short periods of time, and they also have low maintenance requirements – two factors which mean big savings of both time and money. The first bridges made entirely from fibre-reinforced plastics in the country are currently at the planning and design stage.

 **GKN Aerospace Sweden**
10% LIGHTER ENGINE STRUCTURES


Sweden, Europe and the USA have all established long-term goals for air transport emissions. Emission requirements mean that engine structures need to become around 10% lighter every ten years. The key to achieving further weight reductions is to combine both existing and new material forms and alloys into complex structures without allowing the joints to increase the weight and while also ensuring that the combination does not compromise the properties.

 **Envirotainer Engineering**
30% LIGHTER AIR CARGO CONTAINERS


Weight reduction requirements for the aviation industry entail the need to reduce the weight of temperature-controlled air cargo containers. Envirotainer Engineering has made clever material choices in order to produce innovative solutions that reduce the weight of several functions. By using light sandwich-structured composites the company has been able to increase the robustness and insulation of its containers without increasing their weight. This has in turn led to a chain of weight reductions across a range of components, such as batteries, compressors and cooling systems, amongst other things.

Sapa
 20-50% LIGHTER LOAD-BEARING PANELS, SHIPPING/OFFSHORE

The demand for low-sulphur ship fuel is hastening the development of both alternative fuels and lighter constructions. Sapa has developed a new concept for large load-bearing panels made from aluminium profiles, which can reduce weight by around 20-50%. This weight reduction can then be used to achieve either higher load weights or reduced energy usage. The concept is now used by US and French navies, in addition to others.

 **Husqvarna**
USER-FRIENDLY MACHINES

For the Swedish outdoor power product manufacturer Husqvarna, it is important to be able to construct and manufacture products that are as light as possible, but which still deliver a top class performance. Many of their products are carried around by users all day, and so the company is looking at new materials that reduce the weight of both engines and cutting components.

Volvo Car Group
 70% LIGHTER USING FIBRE-REINFORCED PLASTIC COMPOSITE

The demand for lighter cars is increasing dramatically, especially in the EU, and weight reductions achieved using today's ultra high-strength steel and other metal materials are simply not producing sufficient results. Studies into the components of loudspeaker mounting in doors shows that a weight reduction of 70% can be achieved by using carbon fibre-reinforced polymer instead of steel. The same approach can also lead to weight reductions of up to 60% in roofing sheets. Reduced costs, better virtual methods and industrial manufacturing processes are some of the challenges that require solutions. It is also necessary to increase the usage of aluminium in bodies and exteriors as well.

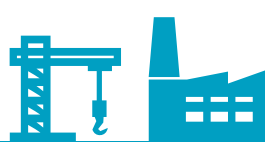
Energy efficiency
is now a functional
requirement for new
bridges and roads.

Global trends



Within the aviation industry, economic and environmental requirements forms an extremely strong incentive. What appear to be small weight reductions are able to have a significant environmental impact, particularly given that standardised aeroplane models are sold all over the world. By reducing the weight of just one aeroplane engine component by 30 kg, CO₂ emissions from a single aeroplane can be reduced by around 400 tonnes across its life cycle¹⁾.

The maritime and wind power industries are also heavily focused on lightweight. Studies on weight-reducing composite materials in marine vessels have shown that the payback period can be as short as just three years, depending on the precise application in each case.²⁾




Halving the weight of an electric car results in reduced energy consumption and much greater driving distances between charging points.

The development of lightweight structures in Europe is largely driven by major manufacturers within the transport sector. The demand for new drive cycles for cars with lower exhaust emissions increases the need for lightweight developments in new hybrid and electric vehicles with longer ranges. Halving the weight of an electric car results in reduced energy consumption and much greater driving distances between charging points.

The offshore, infrastructure and construction sectors are other important areas with a need for lightweight solutions in order to simplify the handling of materials within superstructures and repair tasks, and also in order to solve stability problems that can occur when building at great heights. Key questions in relation to lightweight include the consequences for sustainability and corrosion in addition to fire safety regulations.

1) Analysis, GKN Aerospace Sweden
2) The EU's LASS project



More and more products are manufactured via processes that join together different materials, and the need for competency within the field of multi-material construction is only going to keep growing.

Increased competency in high-performance steel and light metals

For several decades industries in both Europe and the USA have worked with high-strength steel and light materials. Press hardening of high-strength steel is one example of the kinds of methods that are spreading across the world, as they reduce weight and increases motor vehicle safety. This is an area in which Sweden has played a leading role. The USA has contributed significantly towards increasing the usage of aluminium as a lightweight material. New knowledge and new processes are constantly increasing our ability to manufacture larger and lighter steel and metal components that result in quality improvements.

Cost hunt in the composite area

Significant research initiatives in the area of composites are being conducted in several countries around the world. Japan, for example, together with the world's largest carbon fibre composite manufacturers, is investing heavily in efforts to reduce the cost of materials by half. The goal is to showcase demonstrations from several industrial sectors in tandem with the Olympic Games in Tokyo 2020.

In the UK, a national strategy for the composite area has been developed, resulting in a government investment of £25 million in a new industrial centre (Catapult), in addition to other efforts. According to the latest strategy documents published in the UK (2016), the ultimate goal is to achieve a growth of £10 billion by 2030 within the composite area. Similarly, Germany is investing in the construction of industrial research centres in composite materials.

The right material in the right place

Germany and the UK are among the leading countries in research on mixed materials and joining. The goal is to reduce weight by using the right material in the right place. German heavy vehicle manufacturers have made significant progress when it comes to lightweight solutions using mixed materials, and several different joining methods are used today on the production line. At a global level, however, the industry is still rather traditional in its approach to joining methods, even if the trend is nonetheless clear. More and more products are manufactured via processes that join together different materials, and the need for competency within the field of multi-material construction is only going to keep growing.

3D within many industries

Additive manufacturing, also known as 3D printing, is a new technology that is spreading across the globe within many industries. Right now, the technology is advancing so quickly that it is difficult to keep up with new research. In total there are already around 2,500 manufacturing units for additive manufacturing in the world. Poly-Shape in France is a key player when it comes to polymer, and Siemens in the Swedish town of Finspång has established a comprehensive metal printing production line.

Additive manufacturing means that manufacturing principles are changing. It is possible to add materials right where they are needed, rather than to work at removing materials from where they are not required. This opens the doors to new products, new structures, new designs and new material solutions. And new lightweight opportunities are created as well.

Swedish competitiveness is driven by the industry's ability to quickly develop products and processes in a set timeframe.

Industrie 4.0

There is also a huge initiative in the USA and Europe focused on manufacturing technology and the digitisation of product development and industry capabilities which in Germany is known by the name Industrie 4.0. It is not specifically focused on light-weight investments, but Industrie 4.0 nonetheless enables the use of new materials, processes and constructions that result in lighter products.

Expert production can grow on the home front

Sweden's competitiveness is directed to a large degree by the industry's ability to remain at the forefront while simultaneously developing products and production technologies using digitisation and automatisaton processes. It is also increasingly important to develop smart business models based around technology. In other words, we can grow our rate of expert production on the home front if we manage to develop products and processes quickly enough. Huge global investments in lightweight speak for themselves. Sweden must continue to coordinate its resources, develop critical components of the value chain and create a wide span of several competency areas.

One of Sweden's Areas of Advance, which can be future-proofed through cross-industry investments, is steel and metal products and their associated production processes. Creating lighter structures by mixing materials and joining them together, and by finding new innovative solutions, is one of the areas that is moving most quickly, and which Swedish industries need to keep up with.

Constructions made from composite materials are also a clear development area. Today, there are a few companies with truly expert competencies within the

area of composites, but now we need a broader range of multiple clusters. The biggest production companies in Sweden are the key to seriously strengthening the value chain and initiating high volume production of products made from composite materials in the country.

The hope that the Swedish forestry industry would soon be able to launch lignin carbon fibre composites has been very high, but unfortunately development has been slow. One of the challenges has been scaling up the process into full-scale industrial production. An interesting archetype can be found in the Oakridge National Laboratory in Tennessee, USA, where researchers have access to a production facility and can develop the final stage right before the commercial production of bio-based carbon fibres.

Achieving a broad usage of composites alongside other lightweight materials within Swedish production facilities also requires more investment in efforts to reach agreements pertaining to construction and material standards. Without standards it becomes in principle impossible to keep in line with the legal and regulatory requirements in shorter development projects, which in turn makes it difficult for new materials to break into the market.

Global megatrends

Global megatrends such as digitisation and advancements within manufacturing technology can very quickly have an impact upon the degree of competitiveness between various countries and organisations. Those which find themselves at the forefront will have completely new opportunities to produce lighter products.

In order to keep up with the strong global megatrends, several initiatives relating to additive manufacturing were established in Sweden in the year 2016.



Emma Larsson,
Jönköping University (JU) Solar Team

We are facing huge societal challenges

Following on from the UN’s global sustainability goals, Sweden is working on 16 environmental quality objectives which give structure to the country’s environmental work.

The lightweight agenda faces up to society's main challenges by steering itself towards challenging goals relating to the environment, growth and innovation efficiency. We see lightweight as a huge generator of possibilities that will help us reach goals on both national and international levels.

Following on from the UN’s global sustainability goals, Sweden is working on 16 environmental quality objectives which give structure to the country’s environmental work. Lightweight development directly impacts several of these objectives, such as Reduced Climate Impact, Clean Air and Natural Acidification Only.

In the spring of 2016, the Swedish government presented a strategy for new industrialisation, which placed focus on four areas: digitisation, sustainable production, competency development and test environments. All highly relevant areas in terms of further strengthening lightweight development in Sweden.

The Juncker commission has also positioned both energy efficiency and circular economy as central areas within its 10 political priorities for the European Union.

For industries such as road vehicles and aviation, the EU has set high environmental objectives which drive demand on the markets. The European Road Transport Research Advisory (ERTRAC) has for example established goals in its research agenda that aim to achieve a 40% reduction of CO₂ emissions per tonne of load per kilometre by 2030 compared with levels in 2010.

Flightpath 2050 is Europe’s vision for the aviation industry and includes goals which seek to achieve a 75% reduction in CO₂ emissions per passenger-kilometre and 90% reductions in nitrogen oxide emissions.

Vision and Impact Goals for our lightweight agenda are presented on the next page.

VISION AND IMPACT GOALS

“Lightweight solutions strengthen Swedish competitiveness and growth for a more sustainable society.”

| Environment | Growth | Innovation efficiency |
|---|--|---|
| Swedish lightweight products & services reach end customers. | Swedish lightweight solutions create growth in the economy. | Creative structures for research and innovation give a greater return per krona invested. |
| • More than 75% of lightweight technologies (materials, products and services) that are developed as part of the lightweight agenda are industrialised. | | |
| • Swedish industrial companies meet or exceed national and international environmental targets linked to lightweight solutions. • Thanks to world-class expertise within lightweight solutions, Sweden has a strong international profile when it comes to energy and the environment. | • Swedish lightweight exports are increasing by more than 10% annually. • 5–10 Swedish start-up companies within lightweight technology have developed into established global companies. • 100% increase in the number of engineers and researchers with degrees in lightweight technologies. | • More than 50% of Sweden's lightweight innovations are based on cross-industry technological development. • Doubled staff mobility within lightweight between industry and academy/institutes (every 10 years). |



SMART INDUSTRY
Sweden's new industrialisation strategy places focus on digitisation, sustainable production, competency development and test environments.



SWEDEN 2030
By 2030, Sweden must have a vehicle fleet that is completely fossil-fuel free.

16.

ENVIRONMENTAL QUALITY OBJECTIVES
Sweden has 16 environmental quality objectives which give structure to the country's environmental work.

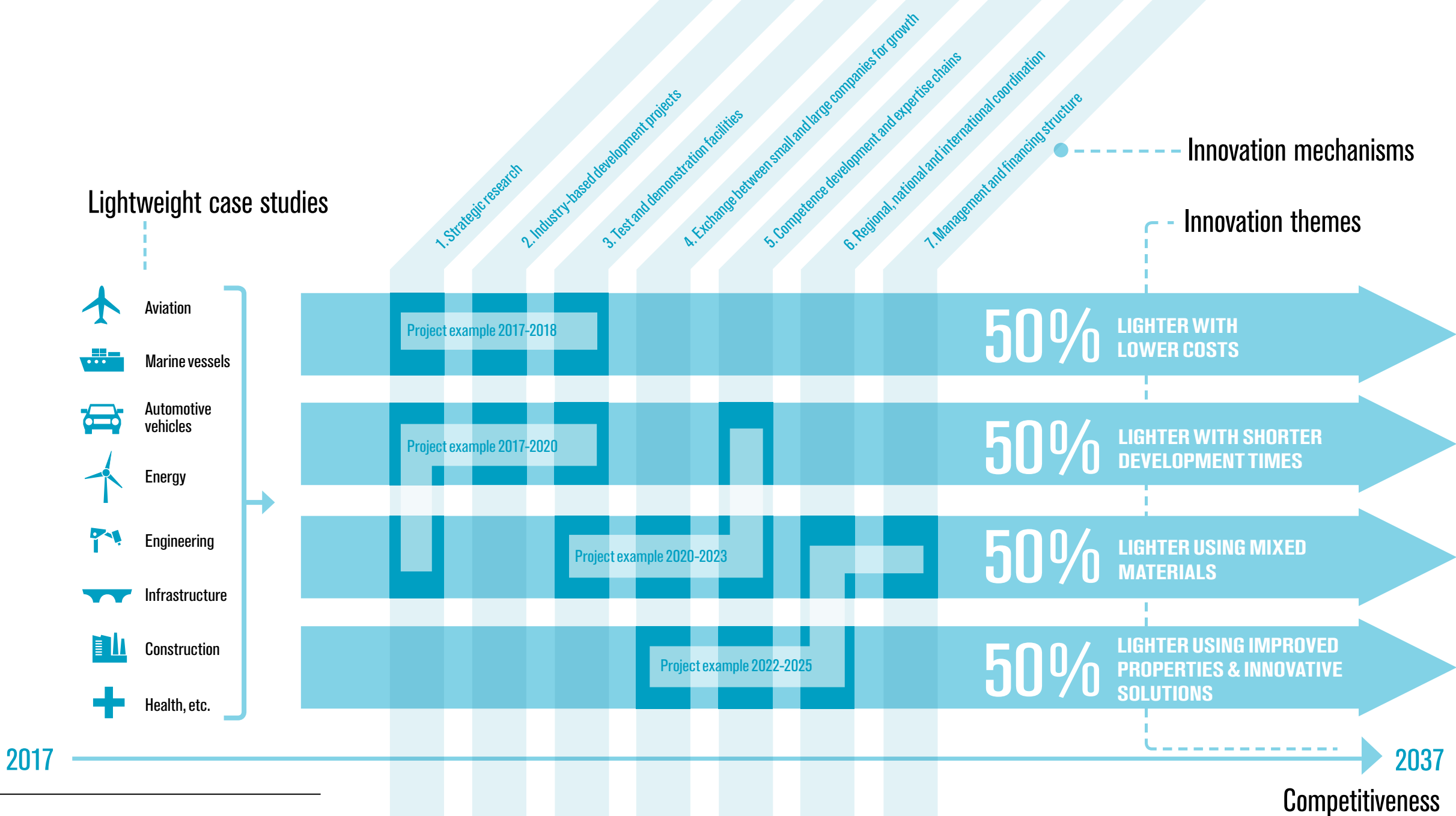
THE LIGHTWEIGHT AGENDA

Our national lightweight agenda is structured around the need for Swedish industries to develop lighter products. The lightweight case studies we look at here reflect the needs of certain competitive areas, but they are also representative of similar needs in a range of other sectors.

Our analysis has given us four distinct innovation themes. Using these themes, we are able to link together and define projects and areas of research enabling us to work towards our goals. As might be expected, a single project can contribute towards development within several themes. Each innovation theme also entails a comprehensive objective that challenges us and leads us to make the most of each project's innovation potential. Percentages refer to levels and should not be interpreted as exact figures.

So what needs to be done and how do we want to work? We describe this in seven innovation mechanisms that we consider to be absolutely critical in order to succeed. Our experience from lightweight work over the last few years has helped us to trim and develop these mechanisms. We know what works and what we need to do more of. One such example is our method for sustainability support which we are going to successively integrate into all of our projects.

Together, these innovation mechanisms boost Lightweight-Sweden, creating a better environment, increasing competitiveness and generating growth.



INNOVATION THEMES:

50% LIGHTER WITH LOWER COSTS

50% LIGHTER WITH SHORTER DEVELOPMENT TIMES

50% LIGHTER USING MIXED MATERIALS

50% LIGHTER USING IMPROVED PROPERTIES & INNOVATIVE SOLUTIONS

2037

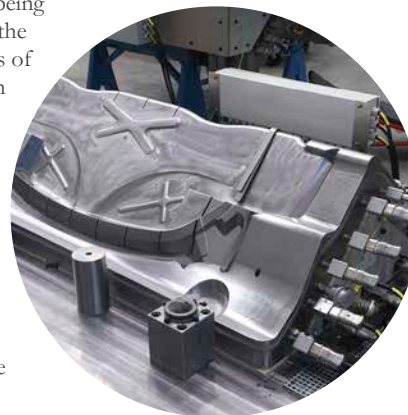
50% LIGHTER WITH LOWER COSTS

Many companies are currently working towards more effective manufacturing processes in order to introduce new lighter materials and innovative solutions at the right cost. Our objective for development investments within the theme is to halve the weight at a lower price so that the costs of lightweight solutions do not limit the introduction of commercial products.

Significant trends right now include replacing carbon steel with aluminium, sandwich material or high-strength steel; using composite materials for entire products or for product parts and developing more sustainable methods. That is to say, using as little material and energy as possible in the manufacturing process (net-shape for complex geometries) and generating possibilities for the recycling of materials.

When it comes to the manufacturing of composite structures, Swedish industries have made some important advances. Within automotive vehicles and aviation, high volume production of composite materials in selected components has been established, although development needs to be accelerated over the next few years. There is also an increased interest in bio-based composites.

New additive manufacturing processes are being introduced quickly within industries across the whole world. This method offers high levels of flexibility when it comes to the construction of components and it generates completely new opportunities to produce geometries that are optimised for lightweight. But for additive manufacturing to break through on a wide scale within Sweden and in a way that generates cost-saving volume production, more investment into development is needed. The manufacturing process needs to be made more effective and new methods for quality verification are required.



New press tool for composite components on a large scale (AP&T).

50% LIGHTER WITH SHORTER DEVELOPMENT TIMES

The demand for short and reliable time frames for product development is high across all global markets. Technologies and development methods must therefore be verified before they are introduced into a business project, ensuring that incisive development work can be carried out without significant setbacks further down the line. One important contributing factor towards that is the development and use of virtual methods wherever possible.

The objective of the innovation theme is to reduce weights by half without causing the development time for lightweight solutions to delay the introduction of commercial products into the market.

That means it is necessary to develop the virtual tool box in parallel with the physical one, amongst other things. Another important aspect is to implement a basic understanding of virtual methods in order to be able to move technologies between products, product sizes and industries.

For example, the testing of tomorrow's composite cars needs to be possible through simulation in the same effective way as it is at present for today's cars. Another area that requires development is the industry's ability to simulate the effect of manufacturing processes and tool shapes on the quality of finished products. For example, geometric tolerancing at the component manufacturing stage; or material quality during the forming and hardening of a composite or metal component.

Methods that are quickly expanding, such as additive manufacturing, also require new virtual methods so that they may be of use in industries with high quality requirements and short product development times.

New manufacturing processes and new test and demo methods may also be a good route towards the faster development of new product solutions or the detailed verification of simulation models. In order to accelerate the development of lighter products on a broad front it is therefore necessary to more quickly offer qualified material data and to create standards for new materials.



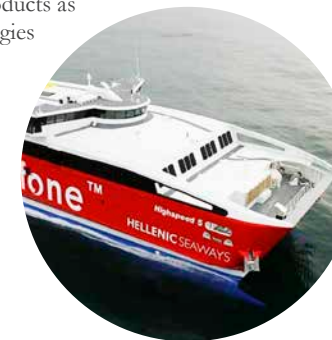
Bengt Nilsson, Lamera and Ann Segerborg-Fick,
Swedish Institute of Agricultural and
Environmental Engineering (JTI).

50% LIGHTER USING MIXED MATERIALS

The ability to use the right material in the right place in a construction is a clear innovation theme for weight reduction. The objective of our innovation theme is to halve the weight by managing to combine different materials while also achieving an optimum performance.

Interest in multi-material construction and joining technologies has accelerated in recent years. Swedish industries have a significant need for more innovative joining methods and the challenge right now is to find structural solutions that can handle different levels of thermal expansion, galvanic corrosion, etc. The problem becomes clearer when working with such a range of different materials such as aluminium, steel and polymer composite; or when two steel alloys with different characteristics must be joined together. When doing so, it is important not to lose product properties during the joining process.

One key to success is to use reliable calculation methods which can indicate the service lives of joined materials. There is also a huge need for automatised joining processes which offer increased precision and production rates. Joining also plays an important role at the final stage for products as it facilitates dismantling, or other strategies for reuse and recycling.



Load-bearing lightweight panels (Sapa).

50% LIGHTER THROUGH IMPROVED PROPERTIES & INNOVATIVE SOLUTIONS

There are a number of approaches creating lighter structures and it is therefore increasingly important to work at an overreaching systematic level. By attaining improved material properties it may be possible to reduce the wall thickness of a component or to redistribute material into more adequate places. There are also other non-mechanical properties that can help to lower weight, such as abrasion or corrosion resistance.

Combined or innovative functions within the mechanical structure (so-called multi-functionality) can also be used to reduce system weight. Multi-functional materials can have optical or electrical functions that can reduce the need for heavy devices or other components, for example.

Our innovation theme objective is to reduce weight by half through the use of improved properties and new innovative solutions.

Metallic materials such as steel, cast iron and aluminium, as well as composites and sandwich materials, have tremendous potential as lightweight materials. That relates to the improvement of the material's properties, but also development of the manufacturing process and component solutions. Sweden needs to strengthen its research and development work in new innovative solutions that can lead to large steps forward in the lightweight area.



Hybrix™, a sandwich material for lightweight panels (Lamera).

INNOVATION MECHANISMS:

STRATEGIC RESEARCH

In order to continuously strengthen our lightweight competitiveness, Sweden must conduct world-leading research within a small number of carefully selected areas. It requires strong research groups to coordinate and be given the opportunity to carry out cutting-edge research into those areas that support the industrialisation of new and lighter products across a period of at least twenty years.

Performance management and continuity can be achieved by connecting this strategic research to our long-term innovation themes. Our strategic research is focused on fundamental issues and methods that can be used across industries and that can be refined in our industry-driven projects, before subsequently being verified in test and demonstration facilities.

Lightweight research, which is coordinated at present by LIGHTer, involves several of Sweden's universities and colleges in addition to research institutes that are active within current technical disciplines. Young researchers have been engaged to drive excellent long-term research. Together we have managed to successfully create a national network that involves both the industry as well as senior researchers and PhD students. In parallel with this, a highly regarded graduate network is also being run, which is known as the LIGHTer PhD Network, and which is comprised of around 50 PhD students from across the country. Our first international conference also marked the launch of a larger international collaboration which will be developed over the coming years.

Thus far, our focus has been on initiating strategic research within the area of material modelling; one of the competency areas that is most crucial for the success of lightweight. Experience so far has taught us, however, that the research project often requires the

input of several technical disciplines in order to match our innovation themes and achieve the desired result. For that reason the scope of our research area going forward will need to be extended so that it includes complementing competencies from several Swedish universities.

We also need to work in a structured fashion with new innovative approaches in order to produce more technological advancements. Today, very few so-called high risk projects with the potential for high returns are being run. These can produce radical new ideas or research data that is then developed into industrial applications. The challenge is to create a natural process that takes ideas from the research stage and develops them into industrial break-through projects. One possibility that we are looking at is to further develop idea generation within our research network and connect this together with product developers from the industry within LIGHTer's technology group.

In order to achieve world-class results in lightweight technology we must continue to increase the number of senior researchers within the lightweight area as a whole. In the same way, senior researchers also have a responsibility to transfer mature technologies to the industry. We also see many advantages in strengthening the research and development work in cooperation with several strategic innovation programmes.

We must increase the number of senior researchers within the lightweight area.

INDUSTRY-BASED DEVELOPMENT PROJECTS

Before August 2016, the lightweight strategic innovation programme had set up just over 30 projects based upon the industry's needs. The projects will form a bridge to quicker product development and commercialisation, both for companies with end products and companies that deliver materials, manufacturing processes or services.

Our ambition is to strengthen several industries and supplier levels at the same time. This has proven to be challenging at the technology readiness level (TRL), at which point the industry's development requirements become much more specific. When it comes to cross-industry collaboration, applications quite simply require more work, more time and a large network. But those who have taken the chance and invested their energy and the over-reaching competencies that are needed have been able to show good project results.

The Strategic Innovation Programmes within lightweight and aviation have tested out a completely new cooperation concept that has resulted in five 'success stories' within the field of automatised composite manufacturing. When 'multi-use' projects work out, they multiply the effect of innovation investments. The conclusion we can draw from this is that we should continue to work across industries in our development projects, but that we should also open up to industry-specific projects in cases where the results can be applied across several industries.

As we have mentioned before, it is also necessary for Sweden to launch more projects that work with new innovative approaches towards weight challenges. In order to bridge the gap between strategic research

and development projects, Swedish industries and universities need to find the right working methods and inspiration for several more high risk projects.

That Sweden invests seriously in test and demo facilities is also crucial if industry-based projects are going to deliver their full effect; that is to say, that the technology will result in new businesses and concrete environmental improvements as quickly as possible.



30% lighter air cargo containers (Envirotainer Engineering).

5 success stories: Strategic collaboration within lightweight composites

Triple Use was a cross-industry collaborative project between several industries divided into four different parts. The project resulted in demonstrators and test facilities for competitive composite manufacturing:

- Flying lightweight - GKN Aerospace automatises processes for carbon fibre components
- Working effectively with composites - Saab reduces production costs by 15%
- New press tool - Volvo Cars reduces component weight by 80%
- The composite bridges of the future – high sustainability and reduced maintenance

Behind the development project and the cooperation concept stand two of Sweden's strategic innovation programmes: Innovair and Lightweight. Read more at lighterarena.se

TEST AND DEMONSTRATION FACILITIES

Within the government’s new industrialisation strategy one of the four focus areas is known as Testbed Sweden. The idea is that ‘Sweden must promote cooperation between universities, colleges and industries when it comes to research.’ For the lightweight area, a bigger and more comprehensive investment in test and demo facilities is absolutely crucial if Swedish industry is to keep up with the rest of the world.

The global trend is that technology development and verification processes increasingly takes place in test and demo facilities before business-based product development begins. This is a way to minimise risks to the business and to create synergy across the entire value chain and between various industries. Both the UK and Germany have established very high test and demo capabilities within research, institutes and universities. This is something that Sweden must do as well, by providing greatly increased resources for similar production verification of technologies and solutions.

Several of our industry-based projects have successfully carried out demonstrations in existing facilities and shown the value of working all the way up to the testing stage within a relevant environment. But it has been difficult to scale up test and demo facilities for lightweight in Sweden, mostly due to a lack both of resources and of the right methods for establishment and operation.

The relationships between those conducting research and the industry needs to be strengthened and investments need to be systematic rather than fragmented. We need cooperation that reaches across from low TRL levels up to the verification and test stages (TRL 5-6). That would create completely new conditions for the commercialisation of new technologies, and would also make the Swedish innovation flow considerably more effective.

Over the next few years we therefore plan on strengthening our facilities, in part by developing demonstrators within several projects and partly by developing the test and demo facilities that are necessary for Swedish lightweight development. We also need to increase our international collaboration and find ways to make use of exchanges within the advanced test and demo facilities that are found in market-leading countries. More quality test and demo environments also increase the potential for cooperation between Sweden’s strategic innovation areas, and create a good development environment for PhD and undergraduate students.

15% lighter cog wheels (Höganäs).



EXCHANGE BETWEEN SMALL AND LARGE COMPANIES FOR GROWTH

Sweden must become better at taking advantage of the innovation potential offered by our small and mid-size companies, and we must generate cooperation with larger companies in order to benefit from our combined expertise. We have identified four measures/tools that strengthen collaboration: process and prototype checks, ‘first customer,’ the certification of new industries and frontier crossers. Over the next few years we need to intensify our investment in regional nodes, amongst other things. That way we have the chance to combine regional knowledge about the needs of companies with national expertise in the right areas.

We also believe that it is necessary to adapt our models for collaboration so that smaller companies participating in long-term research and development projects can concentrate on the aspects of the project that they are most suited to benefit, and from which they themselves can extract the most value. Such an approach will benefit both SMEs in addition to large organisations within the project, while also increasing synergy.

For larger organisations, this means that the choice of participants can be made later on at a stage when it is easier to match needs with suppliers and thereby facilitate the launch of long-term projects. The goal is to strengthen growth across the whole supplier chain in a resource-efficient manner.

Over the next few years we need to intensify our activities, by focusing more on our regional nodes, in addition to other things.

COMPETENCE DEVELOPMENT AND EXPERTISE CHAINS

Swedish industries have large competency gaps within the lightweight area. Beyond strengthening competencies within a range of different technical disciplines, we need to build up cross-functional structures and multidisciplinary competencies in order to develop new innovative lightweight solutions.

Thus far we have worked on offering ‘lightweight diplomas’ and industry courses for people who already work within the industry. In order to quickly spread new technologies, all industry-based development projects have similarly taken on the task of contributing to the range of courses on offer. The challenge going forward is that we must reach many various individuals who work in areas related to lightweight. Amongst other things, we plan on taking advantage of our regional nodes in order to allow more people to have the opportunity to participate and increase collaboration with others in order to find the right set-up for educational courses. Seminars and networks that deal with specific issues are in demand and many educational courses should be offered via digital channels.

Our PhD student network, The LIGHTer PhD Network, has developed into another important channel for the transfer of competencies which we plan on continuing to stimulate. So far 34 PhD candidates have taken part in our graduate courses and exchanged experiences through network meetings and fieldwork within various companies in the industry. Our assessment is that within a ten year period a large number of new PhD students will be required in order to create a sustainable long-term network that is seriously able to contribute towards increasing Swedish innovation power within lightweight technologies.

We also need to strengthen the expertise chains within the lightweight field area using so-called frontier crossers. By that we refer to individuals who build networks by being active in more than one organisation and by spreading competencies and results through their work. Frontier crossers can operate between small and large companies, SMEs and institutes, and between universities and institutes. The first frontier crossers are currently out in companies and our ambition is to develop the concept so that it becomes as effective as it possibly can.



Optimal design using high-strength steel (Volvo Cars Group)

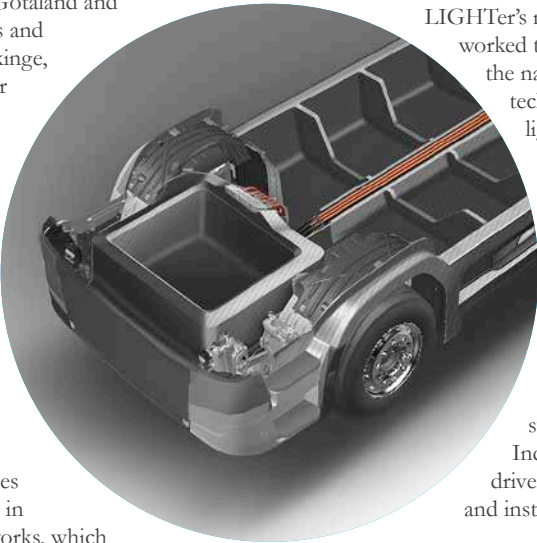
REGIONAL, NATIONAL & INTERNATIONAL COORDINATION

Cross-industry collaboration is one of our vital areas. It is an area that the entire world of Swedish development needs to improve in. That will allow us to achieve lightweight excellence in a cost efficient manner. We have come along way in our work building up regional lightweight nodes in order to strengthen the entire supplier chain. The Swedish counties of Västra Götaland and Småland now have functioning lightweight nodes and discussions are also being driven in Halland, Blekinge, Östergötland and Norbotten, in addition to other places.

Sweden also needs strong structures at a national level for competency and technology development within the field of lightweight, and to find the right ways to collaborate. We are working hard to generate continuous collaboration using public finances, industry specific organisations and other strategic innovation programmes such as SIP Metalliska Material, SIP Innovair, SIP Garfen, SIP RE:Source, SIP Produktion 2030 and the forestry industry's SIP Bioinnovation.

Researchers at academies, institutes and companies are already active within several EU programmes in addition to other research programmes and networks, which of course can be developed even further. Our cross-industry network increases the potential to face up to societal challenges that are outlined in various documents such as, for example, the Horizon 2020 European Framework Programme. We will continue to actively work and attempt to generate influence so that several further outlines and themes place focus on lightweight. We are also working hard to establish our international lightweight conference as the leading cross-industry lightweight conference in Europe.

Conceptual truck chassis in carbon fibre-reinforced polymer (Scania).



MANAGEMENT AND FINANCING STRUCTURE

A sustainable and cohesive management with powerful resources is a prerequisite for generating success within lightweight. Government agencies, industry, academia and institutes must together invest heavily in time and money to genuinely leave an industrial footprint.

LIGHTer's management, members and stakeholders have worked together to show that we have the ability to be the national node that is needed in order to drive technology and competency development within lightweight. Our assessment is that this type of coordination is needed from the entire lightweight industry to reach the objectives we have set out.

One of the management's most important tasks is to take responsibility for managing the portfolio of development projects and the growth-promoting initiatives within lightweight. Our management also works to assess needs, coordinate resources, monitor synergies and identify opportunities around us. Individual projects and initiatives, however, are driven by project managers from industry, academia and institutes.

We have built up a national cross-industry lightweight arena that is widely anchored across many industry branches, system suppliers and subcontractors, including academia, institutes, trade associations and more. That is an achievement we are proud of. We will continue our work in close collaboration with government agencies. The big task facing us now is to use cross-industry collaboration to generate growth and competitiveness in the Swedish industry as part of a sustainable solution to shared environmental and climate challenges.

LIGHTer

A national and cross-industry lightweight arena

LIGHTer creates an effective structure for the development of technologies, test environments and individuals. Individuals with unique, multi-disciplinary abilities to create lightweight products. We are an arena for collaboration between companies, research institutes, academies, industry associations, local authorities, regions and government agencies. Our goal is to effectively increase competitiveness for Swedish industry.

Lightweight SIP

Lightweight Strategic Innovation Programme

LIGHTer has been entrusted with leading and developing the Lightweight Strategic Innovation Programme. In Spring 2013 Vinnova, the Swedish Energy Agency and the Swedish Research Council (Formas) established the first five strategic innovation programmes, of which lightweight was one. 16 programmes have been set up in total. The motive behind our programme is to make lightweight one of Sweden's Areas of Advance.

The Lightweight Strategic Innovation Programme is a long-term investment that builds upon the strategic research and development agenda for lightweight. Stage 2 runs from 2017 to 2019.



Our recommendations

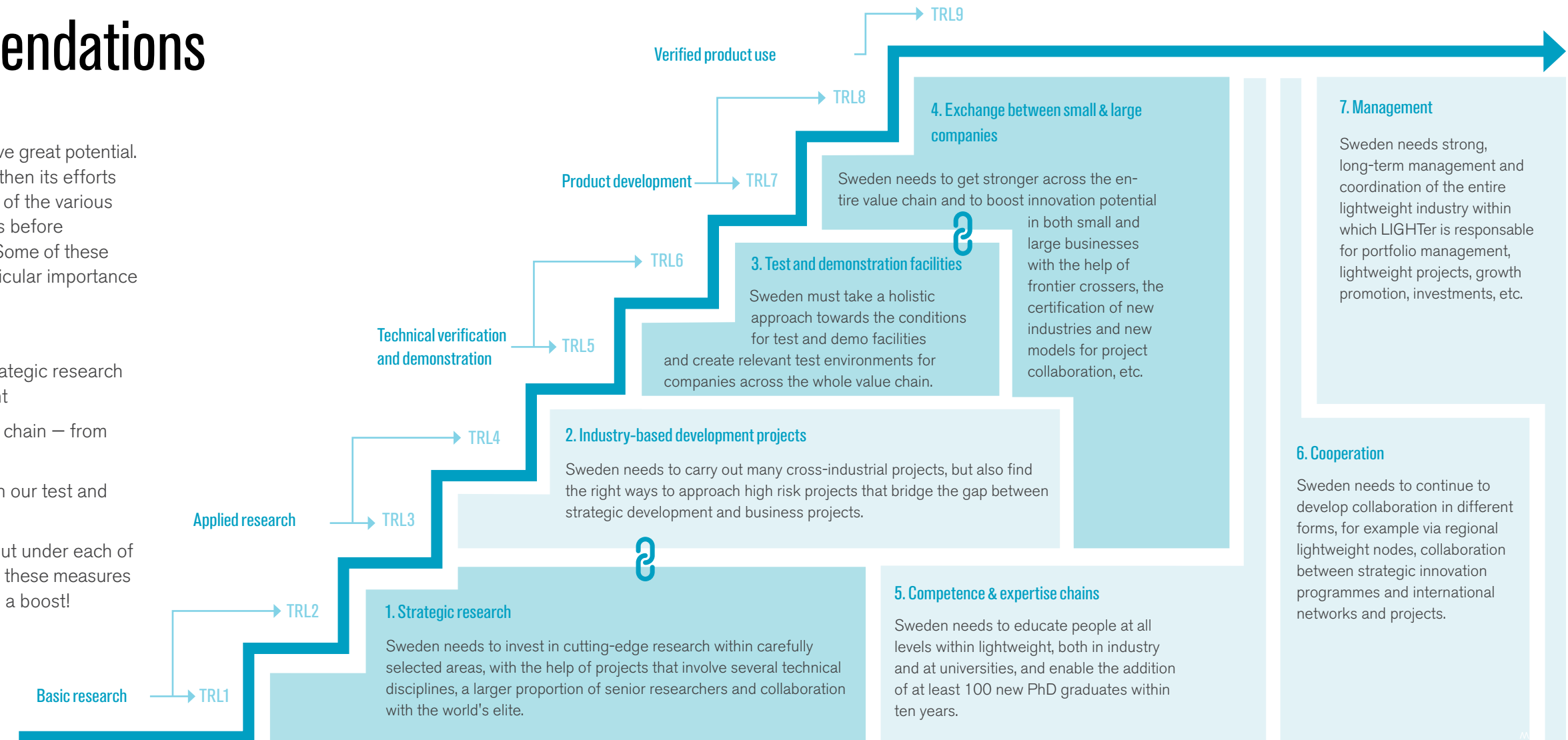
Lighter products and solutions have great potential. To succeed, Sweden must strengthen its efforts up the TRL ladder¹⁾; i.e. across all of the various stages new technology must pass before being launched onto the market. Some of these improvement areas will be of particular importance over the coming years.

We need:

- To bridge the gap between strategic research and the industry's development
- To strengthen the whole value chain – from global industries to SMEs
- To reach complete activation in our test and demo facilities.

Together with the measures set out under each of our seven innovation mechanisms, these measures will give Swedish competitiveness a boost!

¹⁾ TRL (Technology readiness level)





Huge support for the lightweight agenda

When we launched the first version of our lightweight agenda three years ago, more than 100 organisations took part in the job and the majority of them formally expressed their support for the agenda. Between 2014 and 2016, 131 organisations took part in our industry-based development project (financed by the Strategic Innovation Programme Lightweight) and a total of around 300 organisations shared their experiences with lightweight technologies by participating in our conferences, workshops, training events and projects.

This second version of the lightweight agenda has been developed by a workgroup with representatives from the industry, academia and institutes. Discussions have been carried out across several open seminars and the agenda has been anchored in the management of LIGHTer. The following organisations have formally expressed their support for the lightweight agenda and/or are members of LIGHTer.

| | | | |
|-------------------------------|-----------------------------|--------------------------------|-------------------------------|
| SparOs AB | Exova Materials Technology | LEB Casting Technology | Swedish Waterjet Lab |
| ABB Robotics | The Scandinavian Automotive | Lightness by Design | Swedish Composite Association |
| ADC of Sweden | Supplier's Association | Linköping University | (Svensk Kompositförening) |
| Altair Engineering | (Fordonskomponentgruppen) | Ljungby Komposit | Swedish Foundry Association |
| AP&T Sweden | FlexProp | Ljunghäll Group | (Svenska Gjuteriföreningen) |
| Arsizio | FS Dynamics Sweden | Luleå University of Technology | Swedish Aluminium |
| Autokaross i Floby | Gestamp HardTech | Lund University Faculty of | (Svenskt Aluminium) |
| Benteler Engineering Services | GKN Aerospace Engine | Engineering | Swedish Marine Technology |
| Biteam | Systems Sweden | Macromould Modell & Form | Forum (Svenskt marintekniskt |
| Broödena Bourghardt | HBG Teknopress | Marstrom Composite | forum) |
| Bulten Sweden | Husqvarna | Midnight Composites | Swerea |
| Business Region Göteborg | Höganäs | Modul-System HH | Swerea IVF |
| (BRG) | University of Borås | N. Sundin Dockstavarvet | Swerea KIMAB |
| C Lindhe Xtend | Halmstad University | Nolato Goöta | Swerea MEFOS |
| CAE Value | University of Skövde | Nordic Aircraft | Swerea SICOMP |
| Case 5 | University West | Oxeon | Swerea SWECAST |
| Chalmers University of | Ikea | Polymercentrum Sverige | Swedish Welding Commission |
| Technology | Indexator | ProfilGruppen | (Svetskommissionen) |
| Compraser Labs | Innolite Design | Ruuki Sverige, part of SSAB | Talent Plastics Göteborg |
| Design Limit Sweden | Innovatum | Saab | The School of Engineering, |
| Devex Mekatronik | Inventia | Safeman | Jönköping University |
| DIAB International/CCG | Ionbond Sweden | Sandvik Coromant | Triple Steelix/The Swedish |
| Duroc Special Steel | IUC Olofström | Sapa Technology | Steel Producers' Association |
| DYNAmore Nordic | Swedish Institute for Agri- | Scania CV | (Jernkontroet) |
| EELCEE | cultural and Environmental | Semcon Sweden | Winfloor |
| Elitkomposit | Engineering (JTI) | Technical Research Institute | Volvo Cars Group |
| Engel Sweden | Kockums Industrier | of Sweden | Volvo Technology |
| Envirocontainer Engineering | Konsult AB Trifol | SSAB | WSP Sverige |
| ESI – Scandinavia / Efield | KTH Royal Institute of | Stena Recycling International | Västra Götaland Region |
| Essve Tech | Technology | SwedFoam Development | Örebro University |
| Examec Group | Lamera | | |



LIGHTer

A national cross-industry lightweight arena, www.lighterarena.se

Industry, institute and academia have all participated via LIGHTer in the production of this strategic research and innovation agenda for lightweight. HOSTED BY SWEREA
Strategic research and innovation agenda for lightweight (version 2)