Final Report Summary - ENLIGHT (Enhanced Lightweight Design)

Executive Summary:
ENLIGHT advances innovative lightweight & low embodied CO2 materials and their related de-sign, manufacturing & joining capabilities suitable for automotive industry which requires unique levels of affordability, mechanical performance and ecology. The project innovates computer-based as well as experimental validation approaches (and their combinations) to allow for a fast, efficient and reliable design process. ENLIGHT validates the solutions by means of large scale level physical demonstrators to be evaluated experimentally in combination with a full vehicle virtual design and simulation. ENLIGHT has delivered
• highly innovative lightweight / low embedded CO2 materials for their application in medium-volume automotive production,
• design capabilities for affordable medium-volume lightweight EVs,
• manufacturing and joining capabilities for affordable medium-volume lightweight EVs,
• experimental and simulation validation environments to enable rapid & reliable multi-parameter optimization when designing with these new materials,
• LCA and economic analysis taking into account all salient factors,
• 5 conceptual designs and prototype modules (front module, suspension parts, door module, components for the cockpit/firewall section and the floor section) demonstrating the weight savings and manufacturability of composite intensive designs.

Significant weight savings up to 50% compared to commercial products have been achieved. Compared to the ALIVE reference the targeted additional weight savings have been realized for all components. The weight savings have been achieved to a novel conceptual design of the considered structure making use of novel thermoplastic materials either in a pure composite design or in combination with aluminium or steel. The material developed and applied were mostly thermoplastic or thermoset composites. For most modules a bio-based PA 410 reinforced with glass or carbon fibres and an advanced carbon spread tow fabric was used. All materials were characterized to an extent that material models and cards for the FEM-simulation could be derived and implemented in commercial FE-codes. For the assessment and optimization of the module design a full vehicle model was set up. The performance of the modules was evaluated numerically and experimentally ensuring that all requirements are met regarding fatigue, crash and NVH. Besides manufacturing technologies like fast RTM, thermoforming or a hybrid stamp-form/compression molding process were developed allowing a cost-efficient manufacturing of medium-volume production. The manufacturing processes were validated on simplified components or on the parts of the modules. The economic feasibility as well improvements in environmental footprint when using novel composite impact were analysed and validated by means of a LCA and LCC.

Project Context and Objectives:
ENLIGHT aims to advance highly innovative lightweight material technologies for application in structural vehicle parts of future volume produced Electric Vehicles (EVs) along four axes: performance, manufacturability, cost effectiveness and lifecycle footprint. The main target is to develop viable and sustainable solutions for medium production volume EVs destined to reach the market in the next 8-12 years.

Over recent decades, cars have become larger and heavier with every new generation. Vehicle weight has seen an average increase of approximately 16kg per annum. Today medium-sized vehicles are almost twice as heavy as 20 years ago: whereas a 1976 VW Golf GTI weighed 820 kg, in 2006 the equivalent model weighs 1340 kg. The main drivers of such a weight increase have been the improved safety and comfort requirements. Decades of R&D investments from the car industry and its supply chain to tackle this tendency have resulted in a substantially increase in the weight-specific performance of components and assemblies in terms of cost, strength and stiffness. This improved performance per kg has been instrumental in enabling advances in static and dynamic performance (such as body torsional stiffness), better meeting market requirements (such as the competitive price of the vehicle), and complying with and even exceeding the regulatory requirements in terms of crashworthiness, CO2 tailpipe emissions, and end-of-life recyclability.

Each of these considerations applies equally to the EVs which have either recently been released or are due to reach the market over the coming months, also because in practically all cases they represent a derivative of a conventional, Internal Combustion Engine (ICE)-powered model. However the need for weight reduction in future EVs, without unduly compromising performance and safety, is even stronger since additional weight translates into either reduced driving range or in larger, heavier and more
Since additional weight translates into either reduced driving range or in larger, heavier and more expensive batteries (for the same range). However striving for reduced weight as the only objective will not necessarily result in a reduced environmental impact of the EV fleets of the future: Another two key and equally important drivers need to be pursued at the same time, namely affordability and life cycle impact minimization. Affordability is essential since it will allow for larger portion of the total EV fleet to adopt specific light-weighting solutions; and Life Cycle Impact effectively defines the total CO2 impact over the lifetime of the vehicle, including the intrinsic CO2 emitted prior to the use-phase of the vehicle (in terms of raw material extraction, materials production, forming and finishing of the components and the vehicle).

ENLIGHT comprises an integral set of RTD and innovation activities that advance highly innovative technologies on one or more of the key parameters identified above. The aim is to advance both the materials as well as their application in future EVs, enabling both medium term application in premium / niche vehicles (to be introduced to the market around 2020) as well as longer term application in high volume / highly affordable EV (for introduction around 2025). As such ENLIGHT has been defined so as to be completely complementary with respect to the ALIVE project funded under the same call. Despite being complementary and potentially synergetic, the two projects have two main differences: ALIVE focuses on material technologies that might be closer to real industrial uptake for lightweight applications in a timeframe up to 2020 (including ultra-high strength alloys, aluminium and magnesium) while ENLIGHT looks further into the future by addressing those materials that offer even higher potential for lightweight vehicle design and lower CO2 footprint, but require a longer R&D trajectory in order to adequately take all the necessary factors into account (life cycle impact, high production volumes, affordability, performance) in order to ensure true sustainability. Such materials, to be addressed directly by ENLIGHT, are thermoplastics, fibre reinforced plastics, advanced hybrid materials, (renewable) bio-polymers.

Conceivably the European research project SuperLightCar represents the current state-of-the-art with respect to vehicle lightweighting, achieving a 30% reduction in BIW weight with respect to a reference ICE-powered vehicle (VW Golf). However, electric cars are, by their nature, very different in terms of weight distribution from ICE-powered vehicles. Correspondingly, as a reference for ENLIGHT, it is appropriate to consider a recently-launched EV such as the Nissan Leaf. In the graph below the weight breakdown for this vehicle is represented together with the weight reduction targets for each category which have been set for ENLIGHT.

Primarily ENLIGHT targets an ultra-compact four-seated passenger car, which can be scaled up to light duty vehicles (concept of modularity & scalability). A virtual design of the complete vehicle will allow coordinating the interface between the different modules as well as calculating overall weight reduction obtained.

In ENLIGHT each of the principal major weight-incorporating parts of a vehicle will be addressed directly: the body-in-white (demonstrated with a front module and central floor module), hang-on parts (demonstrated with a front door), the chassis (demonstrated with a control arm) and heavier interior components (demonstrated in a cross-car beam). By focusing the activities on determining and verifying directly the greatest weight saving potential for each of these modules from the perspective of true sustainability, the realisation of a complete demonstrator vehicle is remains outside the scope of this project.

The optimal combination of architecture & design, processes and materials requires a systemic technical cost modelling, ensuring sustainable solutions using LCA and accounting for externalities, while taking into account the necessary integration into the manufacturing strategy of each car manufacturer and supplier.

At the same time, new factors such as the availability, source and price stability of materials or the...
At the same time, new factors such as the availability, source and price stability of materials or the competitive international context must be taken into account when selecting the right material strategy.

Scientific and Technological Objectives
ENLIGHT seeks to provide Europe’s automotive industry with highly competitive innovative lightweight / low CO2 material solutions and the necessary capabilities to design, simulate, manufacture and assemble very lightweight, CO2 efficient yet affordable EVs.

As such, the S&T objectives are all directly linked to providing the European automotive industry with a high level of confidence with respect to these technologies, in order to ensure the results find their way into European produced EV (initially mid and premium segments, and subsequently the high-volume / economy segment), without creating any unacceptable risks for European companies and citizens alike.

The specific objectives of the ENLIGHT project are:
• Holistic and integrated conceptual design concerning how the technologies and materials addressed (in combination with materials / forming/joining processes coming from other previous and on-going projects) can be combined into a representative medium-volume EV by around 2020. This design is targeted to have a highly significant additional weight reduction (20%) compared to the targets that are pursued in the complementary ALIVE project; this translates into the medium risk targets for the various sub-systems of a vehicle as listed in Table 1 (the current production Nissan Leaf selected as a reference).
• Depending on the detailed architecture to be adopted (by referring to the activities and results of the activities underway in the ELVA and/or e-light projects), the absolute weight specifications for the demonstrator vehicle to be physically realized will be reconfirmed is underway in order to ensure that such extremely ambitious targets are maintained without unduly compromising performance, crashworthiness and cost.
• Deliver a level of industrial applicability readiness for various next-generation materials tailored for automotive applications, which provide significant weight reduction as well as low intrinsic CO2, a strong potential for part count reduction (integration of part into complex parts with variable wall thickness and tailored an-isotropic stiffness and strength properties) at an affordable cost level and without any negative impact on long term durability, static and dynamic performance, or crashworthiness;
• Develop design capabilities across the automotive ecosystem, leveraging Europe’s highest de-gree of scientific excellence with the creation of automotive-focused design solutions and approaches that fully lever the potential that advanced composites offer in terms of superior component and function integration in comparison to metals;
• Advance simulation capabilities with regard to the micro-mechanical behaviour of the materials addressed, which may exhibit unconventional failure mechanisms, specifically taking into account an-isotropic behaviour;
• Develop thorough, well-quantified LCA knowledge especially on the pre-use-phase CO2 foot-print in combination with the use-phase (tailpipe) CO2 emissions and energy consumption. This data will support also the work on future emission standards and regulations undertaken at European and global levels.
• Advancements in joining technologies towards realistic industrial solutions that can reliably and repetitively join a variety of materials: fibre reinforced thermoplastics with each other, with thermoset composites, with metals (cast and wrought) with full crash loading path functionality under all climate conditions and with full vehicle life reliability.
• Development of high throughput manufacturing technologies for advanced lightweight composite materials in order to bring costs down and achieve economic viability for medium production volumes higher market segment EV.
higher market segment EV.

- Increased reliability in service and improved crashworthiness including protection of vulnerable road users through the application of smart (intelligent) materials and implementation of sensorial functions; enabling the application of next-generation materials in safety-critical parts.

In summary, ENLIGHT advances innovative lightweight & low embodied CO2 materials and their related design, manufacturing & joining capabilities suitable for automotive industry which requires unique levels of affordability, mechanical performance and ecology. The project innovates computer-based as well as experimental validation approaches (and their combinations) to allow for a fast, efficient and reliable design process. ENLIGHT validates the solutions by means of large scale level physical demonstrators to be evaluated experimentally in combination with a full vehicle virtual design and simulation.

Key deliverables of the project include:
- Development of highly innovative lightweight / low embedded CO2 materials for their application in medium-volume automotive production
- Design capabilities for affordable medium-volume lightweight EVs
- Manufacturing and joining capabilities for affordable medium-volume lightweight EVs
- Experimental and simulation validation environments to enable rapid & reliable multi-parameter optimisation loops when designing with these new materials
- LCA and economic analysis to ensure the highest probability of application by 2020, taking into account all salient factors
- Integration of results and coordination of activities with other FP7 and Green Car projects
- Demonstration of the proposed solutions through the realisation of 5 full scale demonstrator modules, covering different distinguishing features of purpose-designed EVs: Front module, Cross-Car Beam, Central floor section, Control Arm as part of the suspension system and Doors.

Project Results:
An extended summary of the main S&T results/findings including figures is attached as *.pdf

The main results of ENLIGHT can be divided into the following categories:
1. Conceptual module design
   - The five considered modules were conceptually designed and validated numerically and experimentally. For this the numerical models were elaborated and implemented in a full vehicle model using validated material cards derived within ENLIGHT. Besides, the modules and sub-components were prototyped for testing and demonstration.

2. Novel lightweight materials
   - Within ENLIGHT novel materials were developed and qualified for automotive applications along the following lines:
     - Thermoplastic and thermoset matrix composites
     - Advanced hybrid materials and
     - Bio-composites and renewables
   - Along with the material development, also respective material models were developed, validated and implemented in commercial software.

3. Manufacturing technologies for composite intense vehicle modules
   - Essential for the large-scale introduction of composites in automotive applications are cost-efficient manufacturing technologies. Thus, various joining and manufacturing technologies have been analysed and adapted for the considered materials and foreseen conceptual design of the modules taking into...
and adapted for the considered materials and foreseen conceptual design of the modules taking into account the cycle timing. Besides also assembly strategies have been analysed.

4. Life-Cycle-Assessment and Life-Cycle-Costing

Finally, the life-cycle impact and life-cycle cost have been analysed. Both are being considered more and more in lightweighting to select the right technology with minimal environmental impact.

1. Conceptual design of the five considered modules

The purpose of the ENLIGHT project is to further reduce the mass of a conventional lightweight automotive body structure (reference: ALIVE aluminum intensive structures) by the means of composite and hybrid material systems. Those offer significant weight saving over an aluminium intensive design but need to be considered already in the conceptual design phase. Due to the nature of the materials not being fully understood prior to the ENLIGHT project commencement, re-designing a whole body structure was seen as a task too big for this project. Instead the ALIVE body structure was used as a basis, but then certain elements of that body structure were chosen to apply composite and hybrid material systems to. The following five modules were considered:

1. Front module – including crash management system, front longitudinal members, front corner node and a stiffness modifiable hood
2. Control arm as part of the suspension system
3. Front door
4. Cross car beam
5. Central floor module

The weight of these modules should be reduced further by 20% compared to the respective component of the ALIVE reference architecture while meeting all requirements with respect to fatigue, crash and NVH. This one realized in an iterative approach. In a first iteration a conceptual design was elaborated using state-of-the-art material data. In consecutive iterations step the properties of the in ENLIGHT considered materials implemented and the design adapted to the final ALIVE reference architecture. The design was virtually validated in a full vehicle model provided by ALIVE which resulted in a final optimization loop to meet all crash requirements. The final design of each module is described below.

1.1 Front module

The front module can be subdivided into four sub-modules and the hood. These sub-modules are a

• Crash management system (crash box, bumper cross member)
• Front longitudinal member
• Strut dome and wheel housing
• Front corner node

In order to save 20% weight compared to the metal intensive light weight structures of the ALIVE project a hybrid design approach was chosen for the front module components. In this approach fibre reinforced thermoplastic composites and metals are combined in order to utilize the advantage properties of both material groups. The chosen composite materials are based on the thermoplastic matrix system EcoPaXX Polyamide 4.10 of DSM. This was selected due to high mechanical values, high chemical resistance and a very low CO2 footprint. In order to realise the major weight reduction of 20% in the highly crash relevant area of the vehicle all composite components of the front module are reinforced by carbon fibres. The composite parts are made of unidirectional (UD) layers of EcoPaXX QXC HC12 that can be combined in various fibre angles to build up tailored laminates.

The final design of the front corner node is composed of two thermoforming carbon fibre reinforced plastic...
The final design of the front corner node is composed of two thermoforming carbon fibre reinforced plastic (CFRP) parts. The upper and the lower component are joined at their flanges and build a closed structure. For the joining of the corner node assembly only adhesive bonding and riveting is used. This structure serves as the structural basis of the corner node, carrying the load in the frontal crash scenarios. The attachment points for engine carrier and chassis subframe are realised by steel brackets which are joined to the composite structure. Due to the application of these metal parts, mounting of the adjacent components is possible by conventional screwing.

The strut dome serves as the main support for the chassis loads of the front suspension system and as a support of the surrounding parts in crash scenarios. It is designed to spread load into the adjacent components, the upper longitudinal, corner node, firewall and structure of the cowl. In the present vehicle a strut brace is applied as well. The developed design integrates the strut dome and wheel housing within one component. The main structure of this subassembly is formed by a ther-moforming CFRP part. In the top area it is reinforced by an aluminium forming part which is bonded to the inner surface of the dome. It is applied in order to reduce the static and dynamic loads in the highly loaded curved area at the top and it ensures stable mounting points for the spring strut. Furthermore, the strut dome is reinforced by a CFRP hat profile at the side. This part supports the load path connecting the corner node with the strut brace and upper adjacent components. This load path in necessary due to occurring loads in the front crash scenarios. Without this reinforcement the front corner travels upwards during the crash which leads to structural failure of the front structure. In order to connect the reinforcement to the strut brace adapter by conventional mechanical fastening methods (screwing), it is closed by an aluminium hat at the upper end.

The crash management system consists of the cross bumper beam and the crash-boxes. In the con-ceptual design a conventional multi-chamber aluminium crash-boxes was combined with a hybrid bumper cross member. The concept is based on a basis metal cross member that is reinforced by a CFRP inlay and a CFRP closing sheet. The reinforcements provide a high bending stiffness and strength, especially in central pole crash scenarios. For this design concept two different variants have been developed, offering different weight saving potentials:

- Variant 1: Design based on steel cross member
- Variant 2: Design based on aluminium cross member

Therefore, the main difference between the parts is given by the basis part, the metal cross member. In variant 1 a high strength steel with a reduced thickness of 1.0 mm is used, for variant 2 a high strength aluminium forming part with a thickness of 2.5 mm is applied. The composite reinforcements are the same in both variants (EcoPaXX QXC HC12). Due to the joining by welding, the material of the towing adapter parts is adapted to the specific concepts.

The general concept of the frontal longitudinal member utilizes a hybrid approach which combines an aluminium outer profile with a CFRP tube inside of the profile. For the CRRP tube a continuous winding process using UD tapes of EcoPaXX QXC HC12 was chosen. The chosen fibre angles are +10/-10° (near to longitudinal direction of the tube). Only two layers of high fibre angle are neces-sary for the first two layers in order to build the base structure of the tube: +85/-85° as base layers, followed by 20 layers with a winding angle of +10/-10°. For failure initialization the rear end of the crash tube has a chamfer.

Simulations showed that it is good to initiate the crushing of the tube at the rear end while the buckling of the aluminium profile starts at the front end. This way it is possible that in the beginning of the axial loading the folding of the aluminium does not affect the crush tube crushing and vice versa.

The final, optimised weight of the above mentioned components resulted in significant weight sav-ings as listed in the following:

Corner node: 108 kg (43% compared to ALIVE)
Corner tube: 10.6 kg (-45% compared to ALIVE)
Strut dome: 5.6 kg (-39% compared to ALIVE)
Crash management system: 3.5 kg / 3.3 kg (-23% / -28% compared to ALIVE)
Longitudinal member: 4.0 kg (-4% compared to ALIVE)

The realised prototypes were crash-tested to validate the design. The testing confirmed the in the simulation predicted behaviour. The prototyping also confirmed the feasibility of the manufacturing approach and the weight saving potential.

Regarding the hood, the final design is a multi-material design using aluminium sheet for the outer hood structure and stiffness modifiable composite for the inner structure. The final hood design has stiffness properties better or comparable to those of the reference hood designs. For the lateral stiffness and torsional stiffness, the performance of the new hood exceeds that of all the other bench-mark designs, while for the longitudinal stiffness it is within 10% of the average reference design values, and it would score as the median across the designs. It is important to note that although a lighter hood designs exist among the reference designs (the Volvo C30 hood), this hood has a significantly smaller surface area due to its distinct slim shape. The apparent weight savings of such a design are however compensated by the increased surface area of the fender covers. The weight of the ENLIGHT hood design (6.5 kg) is 36% lighter than the average of all the reference hood designs. When however only reference hood designs with comparable dimensions and aspect ratios are considered, the average weight saving is 44%.

Through simulation it has also been shown that even if only small areas of the stiffness modifiable material are activated, a good HIC evaluation can still be achieved meeting 5* EuroNCAP rating.

1.2 Control arm as part of the suspension
The control arm connects the wheel to the chassis or the subframe. The design of this part follows certain requirements: a high stiffness and low mass improves the handling performance of the car, while high structural damping is needed for the isolation of road noise from the interior of the car. Thus, two different concepts for a composite control arm were developed within ENLIGHT. One concept focusing on a short fibre reinforced control arm whereas the 2nd concept focused on the integration of shunt damping to increase the NVH behaviour. Thus, the 2nd concept applied a continuous fibre reinforced plastic control arm.

a) Concept 1
The 1st concept is a hybrid component combining a vinyl ester resin reinforced through long (2 inch.) chopped carbon fibers with three inserts made of Aluminium EN-AW 6082 T6. The component has been realized through a manufacturing process called Advanced Sheet Molding Compression (ASMC) that is able to realize geometrical complex parts showing a quasi-isotropic behavior. Besides it becomes easy co-molding metallic inserts or reinforcements, without using bonding or other connection elements. The mass of the part is 1.8 kg which is 50-55% lighter compared with the standard version made of steel. Mechanical testing confirmed that the concept fulfill all static and dynamic requirements. The control arm passed the Longitudinal Static Yield with a reaction force of 1918 daN which is over the target of 1761 daN. Besides, the part passed the Fatigue with Longitudinal Loads (dynamic test) showing a failure at 281.300 cycles which is again over a target of 200.000.

b) Concept 2
The 2nd concept is a CFRP control arm with integrated semi-active vibration damping. For this, the design of a regular Golf V control arm was converted to a CFRP design. The design was optimized for weight, the requirements regarding loads and fatigue as well as for maximizing the vibration attenuation of the integrated piezoelectric shunt damping.
Integrated piezoelectric shunt damping.

Compared to a structure with 1% modal damping, a significant improvement of about 20 dB in the frequency response can be observed in the simulation. The improvement is in the range of a passive tuned mass damper of 1.6 kg. The total weight of this concept with attachments and piezoceramics is about 2.3 kg which 42% reduction in weight but with a much better NVH behavior. The control passed the accelerated fatigue testing without any visible or measurable damage passing representative 100,000 cycles. Also the shunted piezoceramics did no show any degradation. However, the predicted large vibration attenuation could not be validated. Through an experimental modal analysis only 6 dB vibration attenuation could be measured. However, in the prototype a different set-up of the piezoceramics was used which could not be integrated but was bonded to the control arm.

3.1.3 Front door

The front door was designed completely with fibre reinforced plastics. The main structure is composed of the door inner, outer skin, waist rail reinforcement and the intrusion beam. Except the intrusion beam, the door module was designed using predominately thermoplastic composites (with the exception of the hinge and latch reinforcement), which are made up of an EcoPaXX PA410 based matrix, reinforced with carbon fibre spread tows. These tows are then woven to produce a laminate sheet (also known as organo-sheet). For this reason the only manufacturing process that is applicable is to thermo-form the components of the door module. The intrusion beams were manufactured with EcoPaXX PA 410 reinforced with carbon fibres in a continuous winding process. The total weight of these components has been estimated to be 6,1 kg. The overall weight with trimming ad latches weight about 8.5 kg which is 2 kg lighter than the ALIVE reference (-20%). The proto-typed door, which was realised with trimming and latches weights about 6,3 kg which is slightly heavier than estimated. The door was split up into 4 smaller sections allowed the door to be manu-factured in a stamp-forming process from one continuous organo-sheet to demonstrate the feasibility for mass production. The crash-worthiness of the final door design was validated virtually on full vehicle level.

1.4 Cross-car beam

Standard cross-car beams (CCB) are based on steel, characterised by high E-modulus (approx. 210GPa). Within ENLIGHT, a hybrid solution of an CCB was developed starting from an already available geometry based on magnesium. Due to the lower E-modulus of magnesium the design had not the same mechanical performance as its steel counterpart. Thus, a hybrid design by using aluminium and thermoplastic composites introduced and optimised to reach the required first eigenvalue and the overall stiffness of the module. The optimisation led to hybrid design where the introduced thermoplastic parts are mainly concentrated on the passenger side. Additionally metal inserts were introduced. The metal insert holds the steering column, connecting it to the left A-pillar, to the firewall (by means of a nose) and to the central tunnel. The backbone of the passenger side is a CF reinforce-ment that connects the A-pillar on the passenger side to the metal insert on the driver side: the back of the structure is then over-injected with thermoplastic PA410 filled with 50% (weight) short glass fibres in order to create ribs increasing the overall stiffness of the structure and obtain the fastening points of the CCB to the cockpit. The final mass, estimated from CAD, is approx. 5,7k which is a weight saving of 47% compared to the steel reference applied in ALIVE. The mass distribution is the following:

- 3.10kg aluminium insert (steering column area)
- 0.90kg aluminium insert (interfaces to BIW)
- 0.40kg carbon fibre reinforcement
• 0.40kg carbon fibre reinforcement
• 1.30kg PA410 50% weight short glass fibre

However, the final prototype for testing is mainly based on a normal production Mg-based cross car beam, where the portion of passenger side attached to the PAB bracket was substituted by a thermoformed and injection molded part in PA410+50%SGF reinforced with carbon fiber textile. The thermoplastic part was tested and validated in a standard PAB deployment test under different temperatures. The PAB deployment test was chosen since this test was considered since the highest stresses on the CCB occurred during PAB deployment. The test confirmed the design the numerical prediction and the feasibility of the hybrid design. The overall crash-worthiness of the design was again validated virtually using the full vehicle model.

1.5 Lower Floor module

A hybrid lower floor module using the ALIVE BiW as referenced was designed which is composed of a composite floor section, cross beams, perimetral connecting flanges and battery cover, steel seat brackets and plastic battery separators. Within ENLIGHT the focus laid on the composite floor section which consists of the floor pan and front and rear tunnel. These parts were designed using the ENLIGHT material PA410 reinforced with glass fibres.

However, due to changes in the ALIVE references and its impact on the crash performance of the floor section, additional reinforcements needed to be introduced as shown in Figure 15. The reinforcement was realized by increasing the thickness of the floor pan locally and by adding two thermoplastic composite beams in the front part to avoid collapse. The floor pan and both tunnels are foreseen to be manufactured in a stamp-forming process using organo-sheets. The beams are manufactured by the hybrid stamp-form/compression moulding process.

The optimized design weights about 26.6 kg which is 25% less weight than the final ALIVE reference. The floor pan and both tunnels together weight 9.223 kg according the CAD design.

For the prototyping of the floor module the preliminary design was chosen since the final ALIVE design was not available for designing the required tooling. Furthermore, since a very large tooling would have been needed for the floor pan only the front tunnel was realized with ENLIGHT technologies. The floor pan and rear tunnel were manufactured using a vacuum assisted resin injection process. The front tunnel was manufactured using a one step stamp-forming process and GF-PA 410 woven tapes. The final demonstrator overall weight is 10 kg, slightly heavier than estimated.

The torsional stiffness and eigenfrequencies of the front tunnel were measured to validate the numerical model. Both, the results obtained from numerical model used in the full vehicle model as well as the measurements fits nicely together. The crashworthiness was validated again virtually.

2. Novel lightweight materials

A variety of novel lightweight materials were developed, characterised and validated within ENLIGHT. The materials and material systems ranged from thermoplastic and thermoset matrix composites over advanced metal-plastic hybrids to bio-composites and renewables. All considered materials were tested, characterised and listed in a material-data base for use in the design of the modules. The most promising materials like the spread tow weaved textiles and the modified PA 410 reinforced with carbon or glass fibres were directly applied in the ENLIGHT modules.

2.1 Material Development
2.1 Material Development

a) Novel thermoset matrix composites

Three different concepts to achieve a stiffness-variable material were studied. While EP@CF was considered as a reference material at the beginning, it became clear through the presented characterisation methods that even this material has potential regarding stiffness-reduction upon applied current. It could be shown that an application of all proposed active materials for safety systems is feasible, as stiffness-reduction can be achieved within the required time frame using energy systems available in future electric vehicles. The three concepts resulted in 4 proposals for stiffness-modifiable materials with different processing requirements, activation temperatures, efficiencies regarding stiffness-reduction and mechanical properties.

Furthermore, spread tow reinforcements have been considered. The theory behind the reinforcement is to weave with spread tow tapes, rather than with yarns, to get better in- and out-of-plane alignment of the fibres due to parallelisation of the filaments and lower crimp angles and crimp frequencies. The spread tow tapes are subsequently woven into a spread tow fabric. The reinforcement type has proved to combine the good impact behaviour and mechanical strength of a conventional woven reinforcement with the stiffness of a unidirectional reinforcement combining these desirable properties of the different reinforcement types in one material. The process needs to be optimised in terms of fibre type, weave architecture and reinforcement thickness in order to produce a more economical spread tow fabric for the automotive industry. For this development work has been carried out to find a reinforcement suitable for the requirements of the automotive industry. Emphasis has been on low cost while maintaining the beneficial mechanical properties that the spread tow reinforcement structure provides. Mechanical testing has proven the properties are indeed maintained and superior to those of a conventional reinforcement of the same areal weight. The increased tape width (=increased production rate) and the less expensive fiber type used allows for cost to be reduced. The production rate of 50,000 units per annum is estimated to be possible with this reinforcement. The demands for fast cycle times are rather a challenge for the resin manufacturers.

b) Novel thermoplastic composites

Among other a melt impregnation technique for the manufacturing of fully impregnated and consolidated thermoplastic prepregs was developed which provide both low machinery investments and low cycle times at a continuous manufacturing technique. The manufacturing technology is based on the melt impregnation technique. Fibrous material such as unidirectional fibres, fabrics or non-crimp fabrics are pulled through a special melt impregnation device where it is impregnated and consolidated. A special tool was constructed and after tool assembly, laminate manufacturing and optimization will be conducted. The laminate quality has been evaluated and validated by mechanical testing of the specific prepreg laminates. Additionally carbon fibre composite materials based on catalyst-enabled pDCPD (polycyclopentadiene) resins has been developed and characterised. pDCPD resins exhibit better mechanical properties than the composite materials traditionally used. The properties of Carbon-pDCPD are adequate for structural applications. The influence of the resin in laminate properties has been assessed with tensile 90° and in-plane shear tests, and the observed behaviour is better than counterparts produced using epoxy resin. RTM is a suitable process to take advantage of pDCPD composites. Nevertheless, Vacuum Assisted Resin Infusion is an acceptable substitute process for short production series in the future. On the other hand, the resin has not reached the expectation in term of cycle time. According to results, this material will only be suitable whenever cycle times longer than those currently obtained in the automotive industry are acceptable.

Furthermore the processing of spread tow fabric with a thermoplastic matrix has been considered. In this...
Furthermore, the processing of spread tow fabric with a thermoplastic matrix has been considered. In this study, carbon and glass fibre tapes were impregnated before the weaving process. Although the manufacturing process has been developed and improved, there were some interlacing gaps remaining in the fabric due to the stiffness of the tapes. However, this material remains promising because it presents not only the benefit of a spread tow fabric concerning the mechanical properties but also the advantage of the thermoplastic matrix allowing high production rate. This material was used in the manufacturing of some of the demonstrators.

c) Advanced hybrid materials

Hybrid material systems may offer a variety of advantages over mono-material solutions. Several module concepts within ENLIGHT rely on the combination of thermoplastic CFRP with Aluminium alloys. The described hybrids combine high strength, high stiffness and low weight of CFRP structures with the ductile, failsafe behaviour of aluminium. Especially hybrid components with metal joining sections allow the cost-efficient integration of lightweight composites into automotive assembly processes. Within ENLIGHT the feasibility for joining thermoplastic composites based on PA410 with etched aluminium in cycle times less than 60 s has been proven. Experimental studies have shown that an innovative reactive fast-cure adhesive allows for higher bond strengths than a thermoplastic based hot-melt adhesive tested alternatively. However, process parameters have been developed that enable for hybrid manufacturing routes combining aluminium and thermoplastic composite components in a thermal joining procedure. For more innovative components, such as the hybrid CMS, integrated joining during composite thermoforming has been demonstrated as well on a hybrid variant of the front tunnel demonstrator. The hybrid front tunnel production has been supported with aluminium reinforcements including form closure pins.

Furthermore, the integration of piezo-ceramic patches within the layers of a composite was investigated in view of a structure-integrated shunt damping. Simplified coupons of GFRP were equipped with piezoelectric elements for semi-active damping. Different configurations were realized, including application of encapsulated piezo elements (DuraAct) and raw ceramics. During a cyclic fatigue test, the generated voltage of the piezos was measured, which gives indication of the degradation of the electromechanical coupling. At the end of 2 million cycles in a fatigue test, the smart structure exhibited neither significant loss in electric response nor reduced functionality or material deterioration. It turned out that encapsulated elements have a better performance regarding the long term behavior under cyclic loading. For the integration of ceramics the Tailored Fibre Placement (TFP) has been identified for the most suitable manufacturing technology for mass production.

Finally, the potential of metamaterials concept to reduce acoustic transmission has been proven. For the study performed a set of acoustic enclosures making use of resonant structure based metamaterials was designed and produced through additive manufacturing. Prediction of the sensitivity study based on a newly developed unit cell models were compared with the fabricated enclosures. The overall trend was well predicted by the unit cell models and the vibro-acoustic models of the complete enclosures, however, some discrepancies between predicted and measured insertion loss were found. It became apparent that the commercial additive manufacturing process has some limitation, such as high variability in material parameters and a relative large spread in geometric accuracy, which complicates a detailed prediction based on unit cell models. However, the demonstrators clearly uncovered the high potential and flexibility of the proposed metamaterial concept to achieve a strong acoustic insertion loss in a priori tuneable frequency bands. Furthermore, for production processes with less variation on geometric and material parameters, such as injection moulding, the proposed design process shows a high potential to predict the frequency zones of increase insertion loss based on very cheap and fast numerical models.

d) Bio-composites and renewables
Bio-composites and renewables

Regarding bio-based (thermoplastic) matrix, natural/bio-based reinforcement fibers, a project material portfolio has been developed for specific applications such as door inner trim, door reinforcement beam, floor module and cross-car beam. These bio-composites and renewables based on both chopped – compounds - and continuous fiber - composites - reinforcements as well as their initial material and processing behaviour have been made available to support different tasks such as design, simulation and manufacturing.

Compounds were made with a variety of combinations of Polyolefines, bio-based regenerated cellulose fibers and natural fibers as well as with the bio-based polymer PA410 reinforced with chopped carbon fiber. The level of the reinforcement fibers (i.e. fiber wt-%) or additives were modified according to requirements from specific applications. Similarly, Composites were developed in the bio-based polymer PA410 reinforced with either continuous glass or carbon fiber to form a uni-directional tape. These tapes form the basis to build laminates that consist of either stacked plies or stacks of spread-tow woven tapes. Both stacked UD laminated and woven tape based laminated are used in design optimizations of the front module, the floor module, and the door.

Different classes of bio-based materials were developed based on chosen structural and semi-structural applications (a.o. door beam, door frame, floor structural beam). One class of materials consists of chopped carbon fiber PA410, while the other consists of continuous fiber reinforcements in either glass or carbon fiber with the same polymer. Within the developments of chopped carbon fiber compounds, a PA6 variant is included as reference material. When comparing strength and stiffness at room temperature in dry as molded condition between PA410-CF30 and PA6-CF30, it can be concluded that the bio-based PA410-CF30 compound indeed delivers the required structural performance. Different fiber weight fractions are also analysed demonstrating the effect in properties of increasing fiber content from 15wt% up to 50wt%. Depending on the actual design and packaging space of the ribbing in for example the doorframe of floor reinforcement, a choice can be made between these set of compounds. A mass specific comparison indicates an efficient reinforcement effect of these compounds with a fiber weight percentage up to 40wt%. A higher carbon fiber weight percentage did cause issues in fiber breakage and polymer degradation leading to a less efficient reinforcement.

When comparing the developed materials of continuous fiber reinforcements to metals and existing glass and carbon fiber woven fabric reinforced thermoplastic sheets - so-called organo-sheets - , it can be concluded that the developed UD-tapes, and the thereof derived cross-plies (XP) as well as woven tapes (WT) meet expectations. Both absolute and mass specific performance of strength and stiffness demonstrate weight reduction potential over traditional metals as well as organo-sheets making these materials in basis for the structural door and floor panel, as well as front and door beams.

Furthermore novel cellulose reinforced polymers suitable for foaming were developed according to the requirements, e.g. for the interior door trim. The materials developed have been selected for the interior door trim due to good performance/ecoconomy/cost ratio. Compounds with various different cellulose fibre types and lengths as well as cut and milled fibres with different dosing positions, bonding agents and polymers have been produced, characterized and tested. The light weight potential has been explored by reinforcement with regenerated cellulose fibres (density 50% less than glass fibers or talc) of a partially bio-based polymer blend as a matrix material with low density (approx. 0.93 g/cm3), filled with microporous mineral fillers to reduce shrinkage as well as the option of chemical foaming supported by (microencapsulated) blowing agents or physical foaming e.g. by using the MuCell Process. The adapted material, Arbofill 3278, fulfills the technical requirements for an interior door trim, has a bio-based carbon content of >50%, and achieves a moderate cost range of around 3 Euro/kg.
2.2 Material modelling

Along the material development also material models to be used in the FEM-based optimisation of the modules were developed and validated by means of testing on coupon level. Particular all material cards used in the simulations were validated experimentally. The most relevant composite material cards were those for the crash simulation on full vehicle level. The materials cards are built up for the most crash relevant composite materials. These are the fibre reinforced EcoPaXX materials that are used in the body-in-white related modules. The materials cards for the metal materials have been used from the common material database of ENLIGHT and ALIVE. For the implementation of the material models into commercial software, the necessary procedures have been established in the course. Among others, Neo-Hooke, Mooney-Rivlin and Ogden material models used for the analysis of materials containing fibres with a preferable directions were implemented and validated. Additional complementary mathematical aspects have been solved related to the modelling of accurate constitutive equations of hyperelastic material models suitable to be used in biocomposite materials. Besides, a micro-mesomechanical method was developed for the modelling of a Non Crimp Fabric (NCF) composite to allow for the creation of a stiffness changing material. The presented methodology can be utilized to model the macroscopic stiffness response of an impacted beam at various temperatures and loading rates. The simulations show that the softened material reduces its stiffness, and consequently lowers the peak load. Thus, the material concept in the design of a car hood has high potential to result in increased protection of VRUs, by decreasing the deceleration forces experienced by the VRUs upon impact. The finite element model was calibrated for the non-linear shear response, but does not account for any damage development that may occur in the laminate during impact.

3. Manufacturing technologies for composite intense vehicle modules

Within ENLIGHT the following main manufacturing technologies have been considered and adapted to the requirements coming from the conceptual module design:

- Adhesive bonding
- Joining of multi-materials
- High volume RTM processes and
- Manufacturing technologies for hybrid materials like
  o Thermoforming or
  o Sheet molding compound

Beside, assembly strategies for the different considered ENLIGHT modules have been discussed. From these studies technologies have been identified which are suitable to manufacture the considered module design in a medium scale-production. However, not all identified technologies were finally applied to the ENLIGHT demonstrator modules. Some of the technologies were discussed, analysed or developed in a more generic manner in view of general composite manufacturing. For other technologies very costly tooling would have been needed which could not be realised within ENLIGHT. Thus, the developed composite-based ENLIGHT demonstrator modules were build-up partly with alternatively processes which are not foreseen for mass manufacturing or in scaled down processes.

3.1 Adhesive Bonding

Different adhesives and surface preparations for different adherends were evaluated using the single lap joint SLJ. The study included metal-metal as well as metal-plastic joints. Among others, the epoxy
Among other the adhesive bonding of a PA composite (Airborne) bonded to PP biopolymer (Tec-naro) and a PA composite (Airborne) bonded to Aluminum (AMAG) were considered. As adhesive a SIKAPower 498/3 and a DP8005 were used. Although under impact load the joint strength increased for both configurations, the influence on CFRP/Aluminium joints was less significant due to the aluminium yielding. At +80 °C, CFRP/Biopolymer joints are strongly sensitive to strain rate variations due to the high ductility of the DP-8005. For CFRP/Aluminium the strength of SP498/3 is high enough to reach aluminium yielding. At -30 °C the resistance decreases for both configurations and the effect of impact is lower due to the brittle behaviour of the adhesives. When predicting failure of hybrid single lap adhesive joints, the wide variety of possible failure modes is a strong disadvantage. It is needed either to ensure that cohesive failure in the adhesive occurs or develop models that include all possible failures.

3.3 Efficient high volume RTM manufacturing

The usual approach to increase the production rate of RTM has been to reduce resin viscosity, increase the injection pressure and/or add a flow layer. Another possible route is to utilise the so-called injection-compression process, where the resin is injected into a gap formed by partially opened tool and an after-following compression. A big advantage of such a process is the fact that the resin is thus easily infused through the thickness of the laminate, where a drastically reduced resin impregnation distance leads to a more significant reduction of cycle time compared to high-pressure methods or reduction of resin viscosity. Theoretical considerations were combined with an experimental evaluation of the method and it was found that the compaction process takes only a few tens of a second. This is significantly faster than a usual RTM-process which may take about a few minutes. In addition, the trials resulted in a process capable of wetting the normally highly impermeable (and thus difficult to RTM process) TeXtreme fabrics.

3.4 Mass production of thermoplastic composites

Within ENLIGHT a process for continuous winding of thermoplastic composite pipes has been adapted to automotive applications. This process uses an extruded thermoplastic liner as a mandrel for the winding process. Based on this continuous winding technology, a continuous process to produce discrete rectangular profiles has been developed. This Continuous Fibre Placement (CFP) process is based on connected mandrels that move through a series of CFP stations. Each CFP station adds a layer of composite with a certain fibre orientation and consolidates it in-situ. Because the beams are made in a continuous way, the production rate is high, which results in low cost per part. The setup for continuous fibre placement was successfully designed and built and various beams manufactured using materials developed within ENLIGHT. It was proven that the setup can process materials with a melting temperature as high as 340 °C for PEEK. When a bio-based polymer is used like PA410, a composite beam performs much better than a comparable aluminium beam in Life-cycle Analysis (LCA).

3.5 Hybrid TPC process
3.5 Hybrid TPC process
The objective was to manufacture a demonstrator component using a thermoplastic stamp forming process capable of medium to high volume manufacture.

The hybrid TPC process is a non-isothermal, hybrid, stamp-forming/compression-moulding manufacturing route for thermoplastic composites, whereby a continuous aligned-fibre reinforced laminate skin is co-processed with a compatible, flow-formable core material to create a highly integrated structure. The basic process involves preheating the composite laminate to T(m) along with the flow forming material for 180 s, transfer to heated press tool and hold for 60s before demoulding and trimming the flash to complete the part. Use of this technology facilitates optimised processing of the laminate blank using flash edge condition tooling as well as increased reinforcement fibre lengths in the flow-formed material.

This process was adapted and optimise for the thermoplastic composite considered in ENLIGHT. Thermomechanical techniques were used to identify material characteristics to establish an outline set of parameters. Manufactured components were evaluated using a series of mechanical tests with subsequent analysis of performance and process consolidation by means of macro and microstructural techniques. Process viability was established and a demonstrator component was designed and tooling manufactured featuring key aspects of a typical automotive component used for structural applications.

Further development established specific process requirements for the glass and carbon reinforced Ecopaxx 410 material for the actual demonstrator design and a number of full size demonstrator parts have been moulded. Positive indication of part quality have been achieved using qualitative and microstructural assessment techniques.

3.6 Tailored Fibre Placement (TFP)
Tailored Fibre Placement (TFP) is a fibre roving lay-down method for manufacturing 2D semi-finished products. This technique has been analysed for compatibility with the processing approach for the CFRP control arm which combines traditional textiles with unidirectional reinforcements and piezo-active patches. Experimental studies on a preform have shown the general process feasibility for the control arm with an annual series production target of 50,000 vehicles. After manufacturing the two-dimensional reinforcement stack by TFP, the component gets manufactured in a state of the art RTM process. TFP allows the necessary design freedom for a load optimised fibre distribution.

3.7 Direct Thermal Joining of thermoplastic composites
Direct Thermal Joining includes techniques for joining thermoplastics with metals based in short cycle times below 60 s by means of material bonds. Several adhesion mechanisms for joining thermoplastic composite sheets (glass and carbon fibre reinforced PA410) have been studied:

- Natural adhesion of molten PA410 matrix polymer to pre-treated Aluminium surface
- Thermoplastic hot-melt adhesive film
- Fast curing epoxy adhesive film

It has been shown that all variants are capable of establishing solid bonds between the joining partners within less than a minute. Especially the adhesive supported joints show good strength in lap shear tests. However, the resistance against corrosive media needs improvement for structures in weathered vehicle surroundings such as the suspension system.

3.8 Hybrid Thermoforming of thermoplastic composite sheet with aluminium joining
In a hybrid thermoforming process it could be demonstrated that composite structures can be thermoformed while directly joining with aluminium sheet reinforcements. Two joining strategies have been tested:

- Bonding of aluminium sheets to PA matrix polymer with hot-melt adhesive film
- Joining based on adhesion and supported by mechanical interlocking of LKR pins in fibre structure
Joining based on adhesion and supported by mechanical interlocking of LKR pins in fibre structure. Thermoforming tests on front tunnel demonstrators have proven that both joining strategies are feasible. For structural purposes the pin-supported variant is recommended, so that the structural failure potential resulting from defective surface adhesion can be minimised.

4. Life-Cycle-Assessment and Life-Cycle-Costing

ENLIGHT also carried out environmental and economic evaluations of the developed technologies by means of the Life Cycle Assessment (LCA) and Life Cycle Costing approaches to calculate and compare the effects of the introduction of innovative lightweight materials. In particular, LCA analysis was carried out considering the comparison between ENLIGHT and reference solution, and also two different End-of-Life scenarios. The results suggest that, beside a delicate trade-off between use phase and production phase impacts, effective benefits can be achieved from the mass reduction, especially regarding the use phase, and more advanced technologies for post-shredding and recycling materials. Moreover, an overview of the calculation of the vehicles’ recyclability and recoverability with reference to the ISO Standard 22628 is provided; in this sense the main critical aspects were identified and discussed, and a tailored approach for ENLIGHT modules was identified.

4.1 Life-Cycle Assessment

For the Life-Cycle assessment, two different scenarios – current and future - have been selected taking into account both the module design (e.g. materials, joining techniques) and the available technologies for post-shredding treatments. Such management systems were modelled and included in the LCA analysis based on an adaptation of the ISO 22628 standard.

The results from the LCA comparison with the reference parts for each module showed that for those modules where relevant mass reduction is achieved (above the project target) than the benefits obtained in the use phase are significant; in fact, the environmental improvements in terms of GWP (expressed in kg CO2-eq.) were obtained along the whole life cycle and in particular for the use phase. However, LCA outcomes suggest that a delicate trade-off between production phase and use phase impacts exists, indeed the material production phase was found to increase, contributing to the majority of the impact categories for about 60%. This is mostly due to the different materials involved, whose raw materials extraction and processing could require more energy. Concerning manufacturing and assembly processes, they were found negligible if compared with other life cycle phases. The analysis and the comparison of the two End-of-Life scenarios demonstrate that the impacts (in terms of avoided burdens) from the final disposal could influence the overall life cycle impact and the final comparison with the reference solution in a considerable way. Moreover the benefit achieved from advanced post-shredding treatment and materials recycling (both metals and fibre) could be higher than the energy recovery process.

4.2 Life-Cycle Costing

A LCC model was which will be published as a web tool, in order to allow the ENLIGHT partners to remotely access it in an easy way, and experiment with it. The tool allows engineers and module designers to gain an early estimation of the costs related to the manufacturing of an automotive module. Given an initial geometry, the user can test different manufacturing technologies and material combinations, in order to get an estimation of the cost of manufacturing the module in series production. The tool already has some assumptions (vehicle lifetime distance, cost of energy, cost of labour), but it also gives the possibility to the user to change the assumptions, in order to fit the specific situation. Furthermore, the tool allows the
to the user to change the assumptions, in order to fit the specific situation. Furthermore, the tool allows the user to change database values, such as material prices, manufacturing technology energy consumption, etc.

The parameters influencing the final cost for each manufacturing technology vary for each technology. One parameter that seems to have a significant influence on the final cost of manufacturing is labour cost. This is due to the fact that most composite manufacturing technologies are still labour intensive (some to a higher, and some to a lower extend). Related to labour cost, process cycle time seems to highly influence the final cost, as higher cycle times imply higher labour cost attributed per part.

4.3 End-of-Life

The most efficient and effective way to manage the ENLIGHT components and modules at their end-of-life seem to be through the use of post shredding technologies for material sorting and recycling or the use of ASR energy recovery. This is due to the following main aspects:

1. the majority of the considered components are difficult to be dismantled separately (this is the case for the cross-car beam, floor, front module and control arm; only the door, the hood and the wheel housing – the last two ones belonging to the front module - might be disassembled more easily);
2. the majority of these modules are not mono-material, but constitute of a mix of metals (either steel or, more often, aluminium) and thermoplastic or thermoset-matrix composites, often reinforced with carbon fibres.

In order to evaluate other possibilities of a dedicated recycling of components with a considerable amount of plastics and composites before the shredding phase, some advantages and drawbacks (in terms of accessibility for disassembly, weight, economic feasibility, environmental sustainability, and so on...) must be assessed. In particular, concerning the end-of-life management of automotive Carbon Fibre Reinforced Plastic (CFRP), BMW carried out an investigation and demonstrated that the large CFRP parts can be removed by using special tools like excavators (in this case, the fiber length is maintained), whereas all other CFRP parts can be treated in the vehicle shredder. Subsequently, special methods within the post shredding technologies (PST) are likely to be required to separate the CFRP from other shredding fractions. These additional steps in the end-of-life management of a complete vehicle may obviously increase the overall costs and environmental impacts of this life cycle phase.

Potential Impact:

1. Potential Impact

1.1 Strategic Impact

The European Union is still the world’s largest car-producing area and car market, and its automotive industry is vital to Europe’s sustainable development. Europe produces 29% (2010) of the global vehicles [1]. In order to meet the challenges arising from the new markets in Asia and the policies defined worldwide to meet the global demands, the European automotive industry must recognise the worldwide technology trends by incorporating them into their own strategy on the one hand and by driving the market growth on the other hand. Lightweight design, highly efficient engines and efficient use of energy within the vehicles are among the most important global technological trends to be addressed by the European industry.

The ENLIGHT OEM partners jointly produce 54% of the vehicles in the EU-27 countries and 24% of all the vehicles in the world. In this way ENLIGHT ensures an effective direct wide scale impact on the sector through the participating OEMs and their supplier networks. The shortest term target market segment for ENLIGHT is the segment of mid volume (~30,000 units/year) premium vehicles (in 2020), which, selling at a premium price, are more likely to incorporate more costly components / modules into the vehicle.
a premium price, are more likely to incorporate more costly components/modules into the vehicle structure. This will allow for the maturing of advanced composite lightweight technologies in real market vehicles. Further research, know-how from first application experiences and increasing economies of scale will then lead to lower unit costs and make the advanced lightweight technologies economically viable for mass volume electric (and ICE) vehicles in the next generational leap (in 2025), thus leveraging the benefits over the whole EU vehicle fleet.

As summarised in the result section, ENLIGHT achieved a total weight reduction of 50% for the modules considered (front module, control arm, cross-car beam, door, lower floor module). If the ENLIGHT technology is applied consequently applied to the BiW, Hang-on Parts, Chassis and Heavy Interior parts of the Nissan Leaf as benchmark, this would reduce the vehicle weight by 250 kg. Furthermore, in principal, a weight reduction also allows for downsizing of other components such as the battery and powertrain, which are not considered here.

a) ENLIGHT maintained or improved safety in crash situations

Currently used composites based on a thermoset matrix tend to splinter and they are also difficult to mass-produce efficiently and cannot be recycled. Thermoplastic fibre composites can not only be shredded, melted down and reused to produce high quality parts, but they have also been found to perform significantly better in crash tests. When reinforced with textile structures they absorb the forces generated in a collision through viscoelastic deformation of the matrix material – without splintering. As such ENLIGHT mainly considered thermoplastic composites. The obtained results proofed that thermoplastic composite dominated parts exhibit similar or even better crash performance as their metallic counterpart but with much less weight. In addition, ENLIGHT also focused on “active materials”, which will be able to reduce stiffness upon impact thus transforming the stiff car hood into a soft material. With respect to Vulnerable Road Users (VRU) these can be major benefits, limiting substantially the potential inflicted damage in road accidents. The validated simulation of a newly design composite hood with stiffness modifiable composites showed that slightly better HIC values can be reached but with a much lighter structure.

b) ENLIGHT accelerated the introduction of energy efficient battery electric vehicles (BEV) by taking away “range anxiety”

Presently, the attractiveness and efficiency of hybrid and fully electric cars is significantly influenced by the purchase cost and most important by the range of the vehicle, both dominated by the underlying battery technology. Up to now, the cost of EV batteries has ranged from 500 – 1000 € per kWh. Further significant cost reductions are foreseen over the next 10 years with target costs as low as 200 €/kWh. Even the best forecast assumes additional costs for the battery in the order of 5.000€. Additionally, the specific energy (≈ 120 Wh/kg) is rather low, resulting in very heavy battery systems and limiting the range under electric driving conditions down to about 100 – 150 km or even less. To compensate for the additional weight of the battery and to extend the driving range under electric driving conditions the overall vehicle weight must be reduced drastically. The importance of lightweight design increases by reason of the significant influence of the range of electric vehicles [2]. ENLIGHT would result in a considerable weight reduction (of about 250 kg) compared to the present BEVs on the road. Generally, energy consumption of vehicles is due to the physical resistance factors that the vehicle has to overcome during its operation. The resistance factors and thus energy savings by lightweighting vary by vehicle type. The main resistance factors are: Rolling resistance (proportional to mass and rolling friction), Gradient resistance (proportional to mass and gradient), Acceleration resistance (proportional to mass and acceleration) and Aerodynamic resistance (proportional to vehicle dimensions...
With the exception of aerodynamic resistance, all resistance factors for ground vehicles are linearly dependent on the mass of the vehicle. The aerodynamic resistance, however, depends on the dimensions of the vehicle and the square of speed. With the same driving situation and behaviour assumed, the correlation between energy consumption and vehicle weight is therefore linear [3]. A 18% lighter BEV will also be 18% more energy efficient. Of course breaking energy recovery systems can lessen the impact somewhat as between 15% - 40% of the energy can be recuperated in the deceleration process of braking.

Applying this model, ENLIGHT would ceteris paribus augment the range of the BEV substantially (reducing full vehicle weight from 1400 to perhaps 1 150kg), accelerating its acceptance with the general public by taking away the “range anxiety” with potential customers. Once this practical obstacle has been removed, the penetration of FEVs will probably progress very quickly if the right government incentives are put into place (which is most likely to happen).

c) ENLIGHT’s main environmental benefit is greenhouse gas reduction through lower energy consumption taken from the electricity grid, while diminishing the EU’s geopolitical oil dependence.

ENLIGHT lightweighting research is inspired by (and applied to) Electric Vehicles but substantial impact can also be expected on future non-electric drive vehicles and hybrids. One can expect that for ICE vehicles, the allowable cost for lightweighting is lower than that allowed for lightweighting an EV, which means that the typical weight reduction of 250kg in a EV may for a ICE or other non-electric drive vehicle may not reach more than 150kg.

Even then, the impact on European and global CO2 emissions will be large. It has been documented that a 100 kg weight reduction for an ICE vehicle [4] has an estimated direct impact of 8,5 gCO2/km emissions being avoided. Assuming a vehicle life of 150 000 km, the resulting reduction in CO2 per vehicle achieved through full application of the ENLIGHT impact would be: 8,5 * 150 * 150 /100 = 1.912 kg CO2 per vehicle over its lifetime. One can easily perceive the potential impact if taking into account that ENLIGHT partners together are expected to produce by 2020 over 20 million [5] of ICE vehicles worldwide.

For an electric vehicle the CO2 footprint depends on the materials used (production phase) and on the CO2 intensity of the electricity grid (usage phase). If we assume an electricity grid with a CO2 intensity equivalent to 50g CO2/km then a 18% vehicle weight reduction (some 50% in the structure translated to a full vehicle downsizing), would result in a reduction of 9g CO2/km, meaning: 9 * 150 = 1.350kg CO2 per vehicle over its lifetime.

The indirect impact of cost effective lightweight design will be to accelerate the wide acceptance of FEV by the EU market, where the ENLIGHT OEM partners produce more than 50% of the vehicles. To realistically quantify its potential CO2 impact, we consider the phased introduction of advanced lightweight materials into the vehicle market.

- ENLIGHT’s estimated CO2 reduction scenario

In the first wave in 2020, the ENLIGHT lightweighting solutions will mainly be incorporated in premium cars, with a medium production level, estimated conservatively at 30.000 units per year, and aim for a weight reduction from 1200 kg to 950kg. It is estimated that the ENLIGHT carmakers will collectively produce at that time about 300.000 premium EVs. If the partners use the knowledge gained in ENLIGHT to realize an estimated 250 kg reduction in vehicle weight then this would equate to 1.777.703 tons of CO2 emissions that are reduced by ENLIGHT in 2020 car purchases which displace (let’s assume) 150 000 heavier FEVs and 150 000 ICEs.

Assuming also a more modest ENLIGHT impact of 150kg into about expected 960.000 annually produced non-electric drive vehicles in the premium segment by 2020, then ENLIGHT will have made possible a
non-electric drive vehicles in the premium segment by 2020, then ENLIGHT will have made possible a corresponding reduction of 1.835.520 tons of CO2 emissions that are reduced by ENLIGHT in 2020 car purchases if only applied to the ICE vehicles. This will also be the minimum amount of CO2 reduction in the following years, as it is more likely that the production volumes rise.

In a second wave in 2025, the lightweight materials will have further evolved through production experience and state-of-the-art R&D so that they can be incorporated in the mass-market compact cars to realize an estimated (conservative) weight reduction from 900 kg to 800 kg. To these impacts, one can add the impact by means of spin-off applications into trucks and buses produced by various partners in ENLIGHT (such as Volvo, Volkswagen Group, Fiat Group under brands such as MAN, Mercedes-Benz, Volvo Trucks, Scania, Iveco and Renault trucks).

- Impact on reduced fuel dependence

Over the last five years, global oil demand increased by 11% and is expected to increase another 25% by 2030. Almost all of this growth is expected to occur in developing countries, primarily China and India [6]. Meeting demand while factoring in depletion rates will require an additional 64 million barrels per day (mbpd) by 2030 and an investment of $5 trillion. By facilitating the wide-scale introduction of FEV, ENLIGHT will indirectly contribute to a major energy security of the European Union by reducing the amount of imported transport fuel.

Assuming that the first generation of “ENLIGHT premium EVs” will displace 50% of ICE vehicles and 50% heavier EVs, then the projected 300.000 ENLIGHT partner vehicles in 2020 will lead to a fuel reduction of: 50% * 300.000* 8L/100 km * 150.000 = 1.800 106 litres of fuel over the lifetime (of 150 000 km) of the ICE vehicles that will not be produced that way.

ENLIGHT will also foster oil independence in a direct way by spurring the adoption of advanced renewable composites to substitute their oil-based counterparts. Care will be taken to elect bio-sources that do not have a destructive environmental impact such as cotton, which require large quantities of fertilizers, pesticides and water, contrary to natural fibres such as hemp, flax and other.

d) ENLIGHT induces an overall reduction in time-to-market and development costs

The competitiveness of the EU auto industry not only depends on the capabilities of its actors (OEMs, T1 & T2 suppliers, SMEs, research institutes, universities) but also on the quality of the interactions between them. ENLIGHT not only foster the EV capabilities of the actors but also at the same time strengthen collaborative links between them.

First of all, the OEMs first of all will gain new design capabilities with advanced lightweight materials and thus accelerate the adoption (time-to-market) of really innovative materials across the industry. The characterization, simulation and extensive testing of new materials will provide crucial data, which will allow to “virtualize” more and more steps of the development process with new simulation tools. This will minimize costly real world testing, bringing time and costs down in the process.

While the typical development time for a conventional ICE vehicle nowadays is about 2,5 - 3 years because of the use of mature technologies and materials, the development cycle of a new EV is about 4-5 years. Every effort, which reduces this period, will significantly lower the costs and risks for OEMs to embark on advanced lightweight electrical vehicle developments. It is estimated that ENLIGHT will shorten the initial EV development cycle with 3-4 months. In the highly integrated automotive supply chain the competitiveness of the suppliers is key and must be considered as well. Through ENLIGHT the suppliers (DSM, Oxeon, Tecnaro, Airborne, Sispra, Benteler and Marelli) co-develop innovative materials and production processes together with the OEMs, integrating them at an early stage in the advanced EV development process and thus shaving off perhaps another few months from the development cycle.
development process and thus shaving off perhaps another few months from the development cycle.

e) ENLIGHT paves the way to increasing product flexibility
The absence of the ICE with its related powertrain, fuel tank and exhaust system offers in theory greater freedom in design (cfr. ELVA, DELIVER, e-light project) and consequently enables a higher possible degree of modularity. However to be able to make use of this design freedom, automotive designers need to gain confidence in the feasibility of alternative materials, components, function integration and assembly strategies, which can only be founded on thorough experimentation coupled with reliable virtual assessment tools, both of which need to be backed up with convincing examples of how these new technologies, materials and designs may actually work in real, destructive tested assemblies. ENLIGHT delivered exactly these building blocks that designers will need to increase their product flexibility.

f) ENLIGHT promotes the cross fertilization with other sectors where lightweighting is important, such as the aircraft industry.
Europe has a strong position in the application of CFRP in aircraft. Several ENLIGHT partners have substantial experience and business in the aeronautical industry (especially Oxeon and Airborne Composites) which they bring into the ENLIGHT project. Likewise they will also be able to make the reverse technology transfer happen, taking ENLIGHT results and finding applications for them into the aeronautics sector.

g) ENLIGHT operates within the “business” constraints of economic viability and scalability
The project covered the use of lifecycle costing simulation tools, including life cycle costing when assessing materials used in ENLIGHT along with their related processes. This business case analysis will provide a cost-benefit analysis of technologies and their processes, ensuring that the best technologies are utilized in each process in an economically realistic way.

h) ENLIGHT integrated the use of renewables in its lightweighting strategies for reasons of sustainability.
Various ENLIGHT partners have in depth expertise in renewable composites and co-developed modules together with the OEMs, aiming as well for lightweighting as for a reduction of carbon footprint. In most of the realised modules a PA 410 resin was used which is made to 70% from renewable resources and thus have a much lower carbon footprint.

1.2 ENLIGHT impact on EU competitiveness
a) ENLIGHT will contribute to match the external competitive threats, especially from the USA and Japan
A report from Frost & Sullivan [7] states that the global market for materials and chemicals capable of reducing the weight of cars and trucks is set to more than double over the next six years as a result of demanding new fuel-efficiency standards in the EU, US and Japan: the market for automotive lightweighting will climb from $38bn in 2010 to $95.34bn in 2017 – an increase of 150 per cent. An important R&D effort will be necessary in the EU to be competitive against the US and Japan, where important government funded initiatives are under way. With the wide use of renewable materials in the considered modules ENLIGHT strengthened the competitive position of the supplier base of the material suppliers (such as DSM, Tecnaro). They will gain a stronger position in the ecosystem of renewables. This effect will spill over beyond the automotive sector into their other markets like aeronautics, marine & offshore.
b) Additional business impact of ENLIGHT
To quantify additional sales impact for automotive industry in Europe caused by ENLIGHT, the following (of course highly speculative) estimation approach is proposed. It is assumed that the consortium OEMs will have sold 10% more FEVs in 2020 because of the ENLIGHT project, amounting to around additional 30,000 FEVs sold annually. If each of those represents a selling price of some 30,000 euros then this would result in an additional 900 million euros. Of course the same lightweighting of the 300,000 vehicles will also help those vehicles to compete in markets across the world.

c) ENLIGHT exploits potential synergies with other types of environmentally friendly vehicles or the cabs of heavy-duty vehicles
Whereas the vehicle architecture of an EV will be significantly different from a conventional ICE vehicle and even more from a bus or a truck, the advanced light weight material characterization, simulation and testing will be as relevant for these other vehicles as well. In the case of industrial vehicles and buses, a decrease in vehicle weight will result in at least an equivalent increase in payload; since the amount of possible payload often is restricted by the maximum allowed axle weight rather than by the total vehicle weight, an optimized weight saving strategy will in many cases significantly multiply this effect. Altogether, this will result in fewer vehicles on the road, less traffic congestion, and less energy consumption. It is important to note that trucks have usually a very high annual and lifetime mileage. Considering e.g. an articulated truck with an use phase mileage of 1.2 million km, use phase primary energy savings for 100 kg weight reduction turn out to be about 30 GJ [8], which is even higher as estimated for average private ICE passenger cars. The high total savings are mainly due to the very high use phase mileage of articulated trucks. In the case of busses and trucks, other compromises between material choice and manufacturing process might for low volume selected applications be economically feasible at an earlier stage (not necessarily high volume mass production as is the case with mid-level passenger cars). ENLIGHT partner VOLVO alone produces approximately 100,000 trucks and 10,000 buses a year and is thus well placed to capitalize on the acquired know how in the project into its vehicles, as are Volkswagen group and-Fiat Group through their respective truck and bus businesses. The transferability of ENLIGHT technologies e.g. to trucks have been validated within ENLIGHT.

1.3 ENLIGHT impact on EU employment
It is important to acknowledge the dramatic shift of automotive production capacity to BRIC coun-tries, particularly Asia. By 2025 China alone will account for 31% of sales of light vehicles, com-pared to just 3% in 2000. By contrast, the share of TRIAD countries (NAFTA, EU and industrial-ised Eastern Asia) in sales of light vehicles will plummet from 80% in 2000 to just 44% by 2025.
This poses a risk for mature markets. Innovation in the automotive industry tends to result from manufacturing and engineering capabilities. As these capabilities shift to emerging markets, there will be a major impact on jobs. In Europe some 300,000 jobs – one job in eleven – could be lost in automotive manufacturing. At the same time, automotive-related industries such as transportation, retail and other services will create an additional one million jobs, outweighing the loss in manufacturing jobs.
Against this macro-trend it is of paramount importance to maintain the technological lead within Europe with respect to future vehicle technologies, of which FEV technology will be an important part. ENLIGHT is a crucial link to make this technology viable for mass volume production.
Perhaps the most straightforward approach to estimate job impact of ENLIGHT is to relate the ex-pected increased production of EVs to an amount of jobs. With 12.6 million workers now in Europe producing and...
Increased production of EVs to an amount of jobs. With 12.6 million workers now in Europe producing and maintaining and selling 16.9 million vehicles, one could simplify that each 1,34 cars produced equates to one job. Taking the previously calculated impact of ENLIGHT on EV sales as a basis, this would result in ENLIGHT directly contributing to maintaining $30,000 / 1,34 = $22,000$ automotive jobs in Europe (although this is merely a tentative, ‘order of magnitude’ approximation).

1.4 ENLIGHT impact on the education and skills of the workforce
ENLIGHT developed skills regarding design in composite materials, manufacturing with advanced composites and hybrids of those composites combined with lightweight alloys. It also delivered new skills in simulation and testing of such materials in automotive structures. By transferring these skills to large amounts of students and engineers, ENLIGHT will be able to positively impact the available skill set in Europe and thus contribute to Europe being an attractive place to develop and manufacture EV’s. For this a training package have been prepared which can be used by all partners besides their own materials used for education and training.

1.5 ENLIGHT impact on the quality of life
Very lightweight EV will offer low energy consumption, low CO2 impact. These very lightweight EV being designed well will ensure that such EV are still fun to drive, safe to drive and healthy to drive (or be driven around in). The strong lightweighting of EV will accelerate their uptake in many market segments, and this in turn will have a direct positive impact especially on the quality of life in urban environments that today are suffering from excessive amounts of NOx and other unhealthy gases, combined with excessive concentrations of diesel particles. With growing percentages of the population suffering from mild respiratory disease (asthma and similar), any contribution to clean city air will directly affect the 70% of the EU population living in those cities.

Literature:
2.1 Dissemination

As ENLIGHT builds upon the results of several projects and is strongly linked with the ALIVE project, the dissemination activities of ENLIGHT are not a stand-alone affair but rather planned as an integral package closely coordinated with such other projects. With start of the project the so-called SEAM cluster was formed which links the FP7 projects SafeEV, ENLIGHT, ALIVE and MATISSE. Later also the projects EPSILON and Urban-EV were added to this cluster. The SEAM cluster aimed to coordinate the exchange of results and to facilitate common dissemination activities to reach an audience as wide as possible. The SEAM cluster itself was coordinated by a Liaison Team composed of the respective coordinators of the original SEAM projects and CRF and B&W.

The SEAM dissemination strategy was highly linked with the specific dissemination activities of the respective SEAM cluster projects. The main responsibilities of the SEAM were:

a. Coordination of common dissemination / exploitation activities including a final exhibition and a workshop to be organised between the SEAM projects to present the results to the respective target groups envisaged. The event will include a showcase of hardware prototypes that were developed in each project. Organisation is done by B&W in coordination with fka.

b. Establishing the web-pages, their hosting and a content management system allowing each project to add their own content. The SEAM office will also introduce and maintain general cluster web content and send out a 6 monthly e-mail newsletter. Short and snappy articles on the project’s activities and case studies will give a good impression to the different target groups SEAM intends to reach. The newsletter will work with fixed sections to improve recognisability. The newsletter will also allow further extending the project cluster contact database, through the subscription option on the SEAM cluster website. The leaflet as well as the news-letter will be part of the SEAM joint dissemination activities.

c. Design, production and distribution of common flyers and brochures, including a standard SEAM PowerPoint presentation will also be made and updated throughout the cluster as results become available. It will also be amended according to the specific target group and scope of the respective events in question.

d. Coordinating of joint events (workshops, conferences, training courses etc.)

e. Communication of relevant events / information towards all partners involved

f. Collecting / listing all dissemination events of all projects

g. Providing best practices for exploitation activities and coordinate them between the projects

On top of the SEAM strategy ENLIGHT has defined a consistent set of dissemination measures with a clear line of activities for each identified target group. The major part of the targeted audience is the automotive industry as well as its suppliers. In order to effectively communicate with the automotive industry, a proper communication with the industry representative organisations such as EUCAR, CLEPA and EARPA has been established. Communication was ensured by partners of ENLIGHT being also members of the representation organisations. These representative organisations are envisioned as information providers and can forward the projects information to their members. In doing so, a large group of the target audience has been reached through one channel. Additionally, those organisations also coordinate other European projects creating a close link between related projects.

Of course, ENLIGHT targeted audience includes the research community actually performing the road vehicle research, research on smart structures and materials on a wide scope. Researchers in the wider scope of ENLIGHT have a scientific interest in the results of the project. For them it is important to get access to the project results and outcomes. All partners of the consortium participated in forums, workshops and conferences presenting results and discussing ENLIGHT objectives & results with other...
workshops and conferences presenting results and discussing ENLIGHT objectives & results with other participants. These activities also included the publication in relevant national and international magazines.

In detail, the audience targeted for the ENLIGHT dissemination has been defined as follows:

- **Industry automotive and supply industry (research and development departments)**
- **SME’s**
  - SME’s dealing with light weight design and materials, manufacturing technologies and other emerging technologies
  - SME’s in the new member or associated states
- **R&D community (RTO, universities)**
  - R&D groups or institutions dealing with lightweight design, materials, manufacturing, computational mechanics and other relevant technologies
  - other related projects of FP7 / GCI and H 2020
- **undergraduate / graduate students**
- **European and national institutions**
  - European Commission
  - National Contact Points
  - National agencies and ministries
  - Policy makers in national and EU levels
  - Representative organisations such as EUCAR, CLEPA, EARPA, EGVIA or EFFRA
  - Press
  - General public

At the beginning of the project, the basis for a harmonised dissemination approach was laid by

- Establishing a corporate design (logo, template for presentations and flyers, etc...)
- A project website harmonised with the SEAM cluster ([www.project-enlight.eu](http://www.project-enlight.eu)) ([www.seam-cluster.eu](http://www.seam-cluster.eu))
- A general overview presentation to be used by all partners
- Flyers and roll-ups for general dissemination activities

Based on this the following dissemination measures were conducted:

- **a. Newsletter and news on website**
  - Over the duration of the project three newsletters together with the SEAM cluster were distributed by e-mail to more than 200 recipients. The newsletters contained recent publishable results and information on dissemination events. Furthermore, news on results and dissemination events were communicated through the projects websites. On the website also all public deliverables have been made available.

- **b. Scientific and Trade Media Publications**
  - Publications in scientific and general press were one of the main measures to disseminate ENLIGHT results. Particular for the universities and RTOs such publications are important since they are a measure of their scientific quality. Altogether more than 45 scientific publications were made of which 10 are peer-reviewed and 3 PhD theses. Besides, one patent application has been filed and two more under consideration.

- **c. Workshops, Exhibitions and Conferences**
  - Besides publications, ENLIGHT results were presented on conferences, exhibitions and workshops by
Besides publications, ENLIGHT results were presented on conferences, exhibitions and workshops by means of presentations, poster and flyers. Altogether ENLIGHT results were disseminated through more than 45 events, not only to the scientific community but also to industry and policy makers. The ENLIGHT consortium organized two events by themselves, one workshop addressing the lightweight community in Germany and the as public final event at the end of the project.

d. Educational module development
A training package has been prepared at the end of the project which can be used by all partners for internal and external training. The individual lectures combine both, state-of-the-art approaches and recent results from the ENLIGHT project.

2.2 Exploitation
The main measure for exploiting the ENLIGHT results were presenting results to the industry, incorporating them in follow up initiative and mapping business opportunity. Besides, each project partner identified exploitable results which will be communicated and exploited internally in their organization, via their established channels. The impact of this will only be known later in time. The exploitable results by each partner are listed in in this report.
Overall, the ENLIGHT project managed to receive quite some industry attention through e.g. its presence at the Aachen Body Engineering Days 2016 (coupled with the final event) as well as with the workshop organised by LBF in Darmstadt. The presence at JEC and at the EUCAR conference 2016 also draws a lot of industry and policy maker attention.

The SMEs were especially supported for mapping business opportunities as well as funding oppor-tunities for future development. The partner B&W supported among others the SMEs Airborne and SISPRA to map business opportunities for the technologies they were developing in the project: a new automated tape laying process for Airborne and the advanced pDCPD matrix of SISPRA. As a result three follow-up proposals were submitted to the SME instrument NMP-25-2015. Unfortu-nately the proposals failed.
Furthermore, Bax & Willems has developed the “Carbosplash” concept with the aim of showcasing the ENLIGHT research applications in lightweight transportation vehi-ciles while exploring alternative ways of financing such demonstrators. “Carbosplash” is an innova-tive vehicle concept (sports water bicycle with e-drive) with RTM CFRP multi-functional body which was designed, and planned to be launched in the Kickstarter portal.
Furthermore, through the partner B&W ENLIGHT engaged with 11 clusters relevant to automotive composites to present the public insights coming from ENLIGHT and explore the possibility for aligning common interests and joining forces to create a larger support base for the promotion of composites. As a result, the European Lightweight Clusters Alliance emerged (of which LBF and Swerea are partners) which hopes to serve as a virtual open innovation platform by bridging the communication and matchmaking between 7 leading clusters.

List of Websites:
www.project-enlight.eu www.seam-cluster.eu

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