EUROPEAN ALUMINIUM

Aluminium Innovation Hub:

Mapping key objectives and R&D challenges along the aluminium value chain

Version 1 – May 2016

EUROPEAN ALUMINIUM

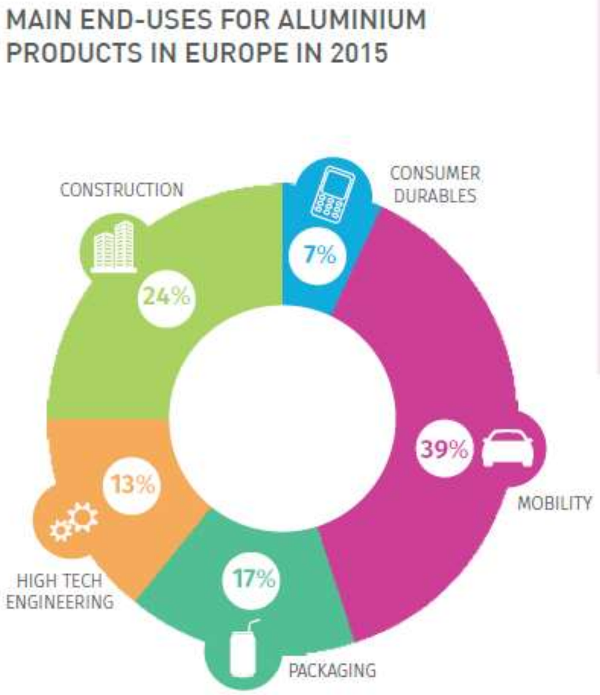
Table of Contents

A key enabler to modern society

Since it was first commercially produced in 1886, aluminium has established itself in an increasing number of applications that improve our daily lives. Its unique properties make it a logical, imaginative, effective and - above all - sustainable solution to many modern challenges. Its high strength-to-weight ratio, durability, formability, conductivity and exceptional barrier properties make it a fundamental part of many aspects of our daily lives. In fact, aluminium is all around us, in essential, functional or decorative roles. We travel in it, we eat and drink from it, make utensils and objects from it and use equipment and appliances made of it every day. Life without aluminium would be quite unthinkable in this day and age.

Today's designers and manufacturers are increasingly excited by aluminium's vast performance and aesthetic potential. This is why they choose it for a wide range of applications in a variety of domains. Various sectors, including transport, building, packaging and engineering are all now reaping the rewards of widespread adoption of aluminium.

Aluminium is now found in a variety of state-of-the-art applications, providing solutions to many current concerns, including sustainability of resources and energy conservation.



Mobility

Aluminium is the natural choice for 21st century transport solutions. It is indispensable to the aviation industry; over two-thirds of the structural weight of the largest commercial aircraft is made up of aluminium alloys. Its lightness improves fuel efficiency, significantly decreasing CO_2 emissions and subsequent environmental impact. **Nowadays, a new passenger vehicle sold on the European market contains on average 150 kg of aluminium, compared to 100 kg in 2000**. The aluminium content in cars is continuing to increase, replacing heavier components made from other materials. Similarly, the latest generations of high-speed trains and ferries deliver optimal performance and energy-efficiency targets by innovative use of lightweight aluminium in numerous applications.

Aluminium's low density, high strength-to-weight ratio, dimensional stability, corrosion-resistance, formability, recyclability and crash resistance is a key driver of lightweight, safe vehicles that contribute significantly to fuel savings and safety in transport.

Construction

The construction sector is also taking advantage of the unique physical, mechanical and structural characteristics of aluminium. This underlines the metal's potential in cutting-edge contemporary design, with a growing emphasis on novel energy-sparing or energy-supplying mechanisms and devices.

Aluminium is deployed in a growing range of building and construction applications. It is the material of choice for curtain walling, window frames and other glazed structures. In addition, rolling blinds, doors, exterior cladding and roofing, suspended ceilings, wall panels and partitions, heating and ventilation equipment, solar shading devices, light reflectors and complete prefabricated buildings all make extensive use of aluminium.

Aluminium offers dimensional stability, high strength-to-weight ratio, corrosion resistance, durability and recyclability. These key assets stimulate the development of products that directly contribute to sustainable buildings, through natural lighting, energy savings, air tightness and energy production through solar heating and photovoltaics.

Packaging

In packaging, aluminium plays a crucial role in preserving foodstuffs, beverages and medicines. This prolongs their shelf life, substantially reducing waste of perishable products. Aluminium fulfils a wide range of roles in packaging. It is used for beverage cans, food and pet food containers, aerosols and tubes. It is also found in numerous other applications including closures, foil trays and lids, capsules, wraps and - along with other packaging materials - as part of laminated foil packs such as blister packs, pouches and drinks cartons.

The unique intrinsic properties of aluminium – high formability, lightweight yet strong, attractive metallic appearance, providing a total barrier to light, gases and moisture and recyclability - make it a preferred packaging material for food and drink.

Engineering and electrical applications

Aluminium is also widely used in engineering, e.g. as framing materials. In particular, it is a key element in the transmission of electricity. High-voltage overhead cables have been made of aluminium for many decades with the combination of light weight and excellent conductivity making it the ideal material.

Aluminium cables are essential in establishing smart electric grid mixes with numerous decentralised renewable energy production units.

Consumer durables and electronics

Aluminium has many domestic uses, particularly in the kitchen. Many day-to-day utensils and kitchen appliances use aluminium, with its excellent heat conductivity – 2.5 higher than steel - making it an ideal component of pots, pans and baking materials.

Manufacturers are also increasingly incorporating aluminium into a variety of electronic equipment, including TVs, tablets, laptops, smartphones. Aluminium casings are light and strong, aesthetic and practical and offering greater robustness and reliability than plastic. Indeed, aluminium is increasingly viewed as an indicator of premium quality in electronic devices.

Apple - lightness and strength: In seeking the perfect balance between lightness and strength, Apple designers and engineers replaced the multiple elements of the device body with a single piece of aluminium; the 'unibody' technology. Since 2008, all MacBooks, iPads and iPhones (since 5th generation) have used all-aluminium bodies.

Aluminium's dimensional stability, light weight, durability, conductivity and recyclability are key assets in making aluminium an ideal material in electronics and consumer durables, particularly in premium products.

Europe as leader in innovation and sustainability

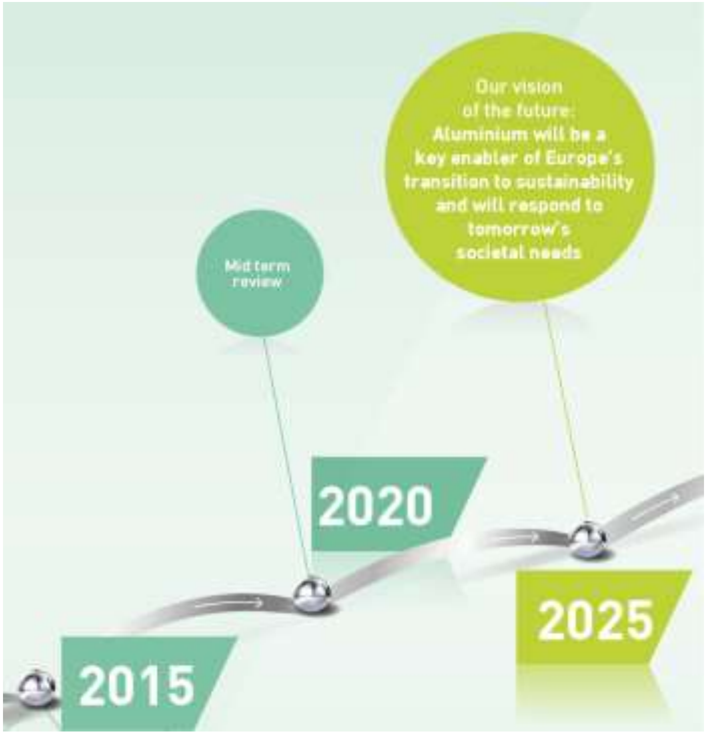
With an annual turnover approaching 40 billion €, the aluminium industry is an important European employer, providing about 250,000 direct jobs and about 750,000 indirect jobs in addition. Aluminium is currently the second most widely used metal in the world. In Europe, per capita use has doubled to around 28kg since 1980. This will continue to grow as its use increases.

There are two principal sources of aluminium; primary production and recycling from process scrap and used aluminium products. This latter route is a vitally important supply source; the European aluminium industry is highly dependent on imports of raw materials from other parts of the world, making recycled material very valuable. This provides Europe with a huge incentive to devise and develop the most resource-efficient aluminium collection and recycling processes and cost-effective technologies to ensure that the industry continues to thrive. In 2015, about nine Mt of aluminium were produced in Europe, of which around 50% originated from recycling.

Although Europe has lost smelting capacity in the last two decades - in the last years, China has become by far the major primary aluminium producer - it remains a major player in terms of new technology and innovation.

Europe is the leader in smelting and manufacturing technologies and equipment, delivering emission levels well below global averages. European plants outperform those anywhere else in the world for productivity. In addition, recycling is widely practised in all key markets, with targets constantly being increased to meet growing sustainability demands. As a result, aluminium that is produced and transformed in Europe demonstrates world-leading sustainability credentials.

To maintain and further develop this leadership in innovation and sustainability, most players along the aluminium value chain - from alumina production to recycling - have recently confirmed their commitment to the 2015 European Aluminium Sustainability Roadmap.



This Roadmap, launched in Brussels in April 2015, supports European Aluminium's Vision 2025 to make aluminium a key enabler of Europe's transition to sustainability in response to the needs of tomorrow's society.

Reaching these sustainability objectives requires coordinated research efforts and innovation along the aluminium value chain. This is why the European aluminium industry has established an Innovation Hub to support its Vision 2025 and to maximise the synergies between the EU innovation agenda and the European Industry RTD efforts.

The Innovation Hub

Initiated in 2015, the Innovation Hub is the European aluminium industry's vehicle to develop joint innovation projects to support its Vision 2025. This collaborative platform is coordinated by European Aluminium, triggering research projects that target important identified technology challenges. To connect our priorities more effectively with the EU innovation agenda and funding opportunities, especially within the Horizon 2020 programme, the European aluminium industry has started engaging in key Public Private Partnerships (PPPs). These include Sustainable Process Industry (SPIRE), Factories of the Future (FoF) and Energy-efficient Buildings (EeB).

Main objectives of the Innovation Hub:

1. Providing a Europe-wide view of technology needs and priorities, focusing on a 2025 horizon.
2. Developing a coherent approach to Research and Technology throughout the aluminium value chain.
3. Providing a single forum to address non-competitive technological issues.
4. Taking a key stakeholder role in the most relevant European PPPs, including Sustainable Process Industry (SPIRE), Factories of the Future (FoF) and Energy-efficient Buildings (EeB).
5. Stimulating networking between the aluminium industry and the R&D community.
6. Initiating and facilitating the development of EU Research and Innovation projects addressing the aluminium value chain.
7. Acting as a key enabler for the European aluminium industry's Sustainability Roadmap Towards 2025 (see annex 2 for more details)

In 2016, the Innovation Hub is directly supported by 12 companies and two market groups of European Aluminium; the Building and the Automotive & Transport groups. The Hub's activities are steered by the Innovation Task Force, with input from the innovation leaders and experts of member companies.

Synergies with Horizon 2020

Horizon 2020 is the largest-ever EU Research and Innovation programme, with nearly €80 billion of funding available over seven years (2014 to 2020). The Innovation Hub has identified significant synergies with the objectives of the Horizon 2020 framework, notably in three areas: Industrial leadership, Societal challenges and Cross-cutting activities.

- **Industrial leadership**

The Leadership in Enabling and Industrial Technologies, with a budget of 13.6 billion €, is part of Horizon 2020 and supports the development of technologies that underpin innovation across a range of sectors. There is a strong focus on developing European industrial capabilities in Key Enabling Technologies (KETs). This part of the programme includes advanced materials, manufacturing and processing, all of which are key areas for the aluminium industry. These activities pursue research and innovation agendas defined by industry and business together with the research community, with an emphasis on leveraging private sector investment. There is a focus on the contribution of Key Enabling Technologies to societal challenges.

- **Societal challenges**

Horizon 2020 reflects the policy priorities of the Europe 2020 strategy, addressing concerns shared by citizens in Europe. This puts societal challenges, with a budget of 30 billion €, at the heart of Horizon 2020, in particular:

1. Health, demographic change and wellbeing
2. Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy
3. **Secure, clean and efficient energy (5.9 billion €)**
4. **Smart, green and integrated transport (6.3 billion €)**
5. **Climate action, environment, resource efficiency and raw materials (3.1 billion €)**
6. Europe in a changing world - inclusive, innovative and reflective societies
7. Secure societies - protecting freedom and security of Europe and its citizens.

The Innovation Hub activities have a clear connection to these societal challenges, especially the three areas addressing energy, transport and resource efficiency.

- **Cross-cutting activities (focus areas)**

Similarly, the aluminium value chain is connected to and contributes to the so-called crosscutting calls on three areas:

(i) **Industry 2020 in the Circular Economy**
(ii) Internet of Things
(iii) **Smart and Sustainable Cities**.

The call 'Industry 2020 in the Circular Economy' aims at boosting economic growth and renewing Europe's industrial capacities in a world of finite resources. It should demonstrate the economic and environmental feasibility of a circular economy while providing a strong impetus for the re-industrialisation of the EU.
Bridging LEIT priorities and Societal Challenges, the call 'Internet of Things' supports combining a range of technologies via the internet, such components, Big Data, cloud or advanced computing and their integration in innovative use cases addressing major societal challenges.
The call 'Smart and Sustainable Cities' brings together cities, industry and citizens to demonstrate the feasibility of developing - and replicating on a larger scale - successful solutions for smart and sustainable cities in Europe.
The calls related to circular economy and sustainable cities are particularly relevant to the aluminium industry.

Objectives of the Industry

Generic objectives

The innovation leaders have identified seven main objectives for supporting the sustainability of aluminium industry and delivering innovative applications and products to the economy and society. These objectives are detailed in Tables 1.A and 1.B. The connection to the Horizon 2020 activity areas is reported in those tables using the following abbreviations:

Abbreviations	H2020 - area
LEIT - Materials	Leadership in Enabling and Industrial Technologies - Advanced materials
LEIT - Processing	Leadership in Enabling and Industrial Technologies - Advanced manufacturing and processing
SC3 -energy	SC3 - Secure, clean and efficient energy
SC4 - transport	SC4 - Smart, green and integrated transport
SC5 – CO_2 and resources	SC5 - Climate action, environment, resource efficiency and raw materials;
FA - Circular	FA - Industry 2020 in the Circular Economy
FA - Cities	FA - Smart and Sustainable Cities

For each industry objective, the most relevant Horizon 2020 areas are highlighted in yellow.

Table 1.A: main objectives of European Aluminium Industry – part A

European Aluminium Industry objectives	Horizon 2020 areas						
	LEIT - Materials	LEIT -Processing	SC3 -energy	SC4 -transport	SC5 – CO_2 & resources	FA - circular	FA - Cities
1. <u>Improve energy efficiency and reduce CO_2 emissions</u> Minimising the energy use and related CO_2 emissions all along the production chain is of key importance to the aluminium industry. Thus developing technologies or aiding implementation of technologies that reduce energy consumption, especially for primary production, is a priority for the European industry. It also contributes to smarter, more flexible electricity consumption patterns.		x	**x**	**x**	x		x
•Develop low-carbon technologies			x		x		
•Contribute to developing smart electricity grids			x				
•Reduce energy use all along the aluminium value chain, e.g. reduce electricity consumption of primary smelters, improve efficiency of extrusion and rolling processes		x					
•Contribute to low-emissions road, rail, sea and air transport				x			
•Contribute to more sustainable buildings							x
2. <u>Improve resource efficiency</u> Ensure that all raw and ancillary materials are used most effectively is vital. Aluminium has the advantage that it is endlessly recyclable. Resource-efficient production covers everything from sourcing of raw material to the end of life of the product once collected for recycling. To be globally competitive, the European aluminium industry needs to be in the forefront in these areas.	x	**x**			**x**	**x**	
•Fully optimise the use of raw materials along the value chain					x	x	
•Optimise scrap quantity and quality in recycling		x					
•Optimise each step of the recycling value chain, including new sorting and melt purification technologies, bottom ashes recovery	x	x				x	
•Reduce process scrap production		x					
3. <u>Reduce environmental impact</u> Controlling and reducing all environmental emissions from processes is already an ongoing objective of the European Aluminium industry. R&D efforts should encourage further reductions in waste emissions, particularly through industrial symbiosis in order to turn waste into resources, in particular solid waste.		x			**x**	x	
•Minimise plant level emissions to air through process design and optimisation and better monitoring		x			x		
•Reduce industrial waste generation		x			x		
•Convert industrial waste into resources through industrial symbiosis		x				x	

Table 1.B: main objectives of European Aluminium Industry – part B

European aluminium industry objectives	Horizon 2020 areas						
	LEIT - Materials	LEIT -Processing	SC3 -energy	SC4 -transport	SC5 – CO_2 & resources	FA - circular	FA - Cities
4. Optimise process technologies Continuous improvement in process technologies is key for efficient production.		**x**			x	x	
•Adapt processes to variations in material sourcing and raw materials quality, e.g. carbon-based materials		x			x	x	
•Develop strategies and tools to improve process optimisation, e.g. control of melt chemistry or control of microstructure along the value chain		x				x	
5. Develop new materials To meet future demand for materials it is important that the European aluminium industry continues to pioneer development of advanced aluminium alloys. In the future, there will also be a need to adapt alloys to account for impurities from recycled material. New predictive tools are also need to simulate the mechanical behaviour of new alloys.	**x**		x	x	x	x	
•Develop new aluminium alloys to better meet customers' demand	x		x	x	x		
•Optimise alloy properties to maximise user benefits	x		x	x	x		
•Develop new alloys addressing new business constraints, e.g. impurities from recycling	x		x	x	x	x	
6. Develop and optimise enabling technologies Promote/develop enabling technologies that promote aluminium solutions in the various markets, e.g. joining of disparate materials.		x	x	x			x
7. Develop the industrial competence, maintain skills and disseminate knowledge Shortage of skilled workers is a genuine threat for many European companies. Collaboration with universities is one way to address this. Participating in collaborative research projects allows the industry to stimulate interest from students and simultaneously strengthen the competence level of its employees.	**x**	**x**					
•Optimise dissemination of R&D results to industry and academia	x	x					
•Widen collaboration and educational partnerships between industry, academia and the broader stakeholder community	x	x					

Process-specific objectives

To convert these overall objectives into more specific goals at process level and associated R&D needs and challenges, the innovation leaders analysed the challenges along the aluminium value chain in depth, ranging from **alumina production[1] up to the key application areas, including recycling aspects**. This document consolidates the contributions from the various industry experts. Such an exercise provides an inventory of specific objectives at process level, combined with potential solutions or innovations that address the related R&D challenges. Experts were also invited to define the priority level, the competitive aspect and the timeframe, as well as whether the R&D challenge identified was incremental or disruptive in character. The consolidated results are reported in the various annexed tables based on the following principles:

- **Priority level**: Very high priority (***) indicates that all experts view this area as high priority. Other priority levels, i.e. high priority (**) or medium priority (*), reflect majority opinion
- **Competitive aspect (reported as "comp." in the table):** 'Y' means that this area is identified as competitive by all experts and would be unsuitable for a project consortium involving several Hub members. 'N' means that this area is viewed by all experts as non-competitive and would be suitable for a project consortium potentially involving several Hub members. 'N/Y' means that there is no unanimity among experts and the competitive character would depend on the exact topic addressed
- **Timeframe:** This is an estimate of the likely period required to reach the objective, assuming that adequate research efforts are dedicated to that research need. Short term is 1-5 years; medium term 5-10 years; long term >10 years.

These classifications, as well as the detailed R&D mapping, can be found in Annex 1. Only the principal outcomes are reported in the following sections based on R&D areas considered as very high or high priority.

Typical life cycle of aluminium products

[1] Given the limited extent of bauxite mining in Europe, this process step was not covered

Alumina production

The principle ore for aluminium is bauxite. Before bauxite can be converted to aluminium, it first needs to be processed in refineries, via electrolysis, into pure aluminium oxide (alumina) using the Bayer chemical process. The aluminium hydroxide is leached from the bauxite using a caustic soda solution, which is then filtered to remove all insoluble particles. The residue of the Bayer process, called "bauxite residue", is managed separately according to industry standards. This constitutes the major by-product of the primary production, with around 600 - 1000 kg of residue per tonne of alumina for European refineries.
The aluminium hydroxide is precipitated from the soda solution then washed and dried; the soda solution is recycled. Calcination (heating with oxygen to a high temperature) then produces the end product - aluminium oxide (Al_2O_3) - a fine-grained white powder.
Producing two tonnes of alumina requires around four tonnes of bauxite, which in turn yields around one tonne of aluminium at the primary smelter.

Main objectives and R&D challenges

The specific objectives are reported in Table A. 1 of Annex 1 and are summarised in the Table 2

Table 2. Main objectives and R&D challenges[2] for the alumina production

Generic objectives	Specific objectives [3]	R&D challenges	Priority level	Comp	Time-frame
Improve energy efficiency and reduce CO_2 emissions	Reduce by 20% the energy use or/and the CO_2 emission of the alumina process	Further optimise leaching and calcination process	***	Y	< 5y
		Develop low-temperature heat recovery technologies	**	Y/N	5-10y
Improve resource efficiency	Use of lower-grade bauxite	Develop bauxite pre-treatment process to reduce transformation costs and residue storage	**	Y/N	5-10y
Optimise process technologies	Increase the life time of the plant	Improve maintenance techniques and durability of materials (e.g. reduce caustic embrittlement).	***	Y/N	5-10y
Reduce environmental impact (air)	Reduce NO_x and particles air emissions	Develop and implement more advanced burner and abatement technologies	**	N	5-10y
Reduce environmental impact (solid waste)	Develop sustainable bauxite residue storage or use of residue	Develop maintenance-free storage solutions	**	N	5-10y
		Use bauxite residue as ingredient of products, e.g. construction products	***	N	5-10y
		Develop technologies to convert bauxite residue into valuable resources, e.g. extracting vital raw materials.	***	N	>10y

[2] Those challenges were partly inspired from the Alumina Roadmap developed by the International Aluminium Institute, updated in 2010

[3] It should be noted that any quantified objective should not be considered as a committed target by the industry but rather as a reasonable objective provided the adequate innovation efforts and resources are allocated to that specific objective. Reduction targets will be very much affected by specific location performance and existing improvement opportunities.

Aluminium refineries are primarily developed and optimised based on the source of their bauxite supply. This is because the origin of the bauxite to a large extent defines its level of reactivity, significantly influencing the performance of the corresponding aluminium refineries. As a result, performance improvements at plant level can only be assessed against a site-specific, rather than a standard European, benchmark. As a result, no European benchmarks exist for this process step.

Improving energy efficiency at the leaching and calcination steps remains a key objective but is viewed as highly competitive, with the exception of the recovery of waste energy from low temperatures sources. Similarly, increasing resource efficiency at the leaching step has also been identified as an important priority but as competitive in most cases. In term of **process optimisation,** increasing the durability of materials and equipment as well as improving maintenance patterns for extending plant lifespan has been identified as a high priority.

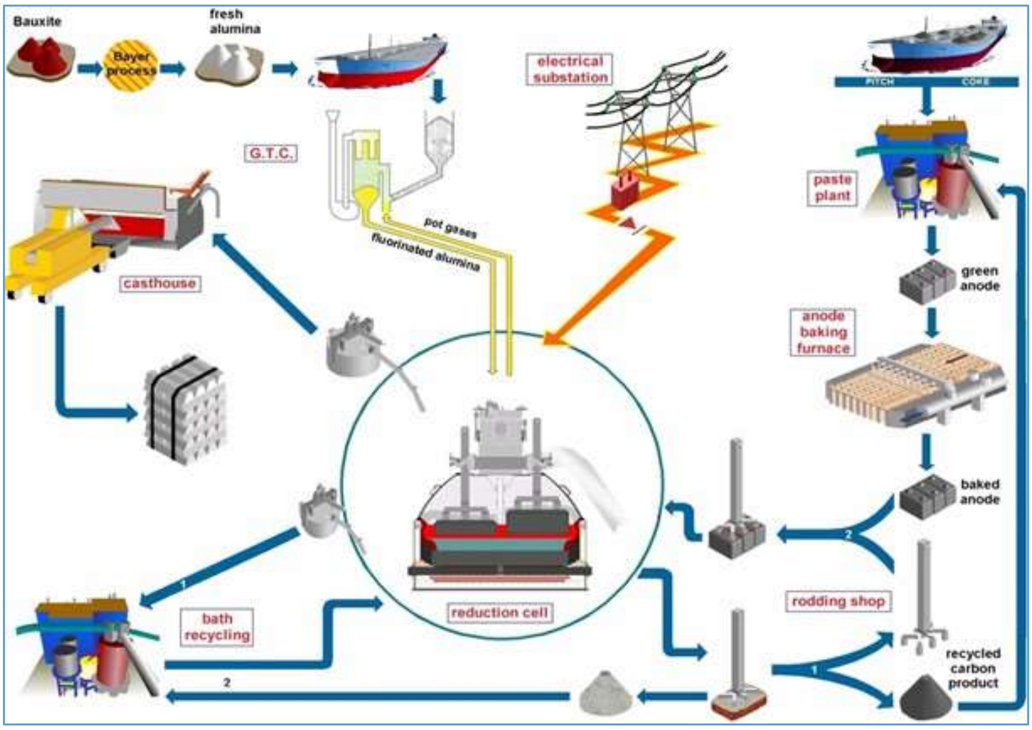
Bauxite residue treatment is also a key priority, and one where the alumina sector is already combining its R&D efforts. Currently, under the European Innovation Partnership on raw materials, two European networks are addressing this issue. These are:

- BRAVO: Bauxite Residue and Aluminium Valorisation Operations (Ireland)
- Mud2metal: Recovery of Critical Metals from the Bauxite Residues (Greece)

These networks are highly active in developing project ideas and proposals as part of the Horizon 2020 framework programme. Hence, any initiative of the Innovation Hub aiming at developing projects relating to bauxite residue issues should be undertaken in coordination with those established networks.

Primary aluminium production

Primary aluminium is produced in reduction plants (or “smelters”), where pure aluminium is extracted from alumina by the Hall-Héroult process. The reduction of alumina into liquid aluminium takes place at around 960 degrees Celsius in a cryolite bath using high intensity direct electrical current. This takes place in electrolytic cells (or “pots”), where carbon cathodes form the bottom of the pot. Carbon anodes are held at the top of the pot and are consumed during the process, reacting with the oxygen coming from the alumina.



Main processes of the primary aluminium production (example applicable for pre-bake technology). (Courtesy: Rio Tinto - Aluminium)

Europe uses mostly pre-bake technology, where carbon anodes are produced from coke and pitch in paste plants and then baked in separate furnaces. Molten aluminium is tapped from the pots at regular intervals and transported to the casthouse, where it is turned into alloys in holding furnaces through the addition of other metals (according to the customer's needs), cleaned of oxides and gases and then cast into ingots. These ingots can take the form of billets for extruded products, slabs for rolled products, or ingots for re-melting, depending on subsequent processing planned.
The diagram below illustrates the main processes involved in the primary aluminium production.

Main objectives and R&D challenges
The main innovation challenges facing the primary aluminium production are set out in Tables A.2 Part A and B in Annex 1. For the objectives considered as competitive, company experts chose not to prioritise them. Therefore, even where these objectives are often intensively addressed through internal research efforts, they are not allocated any priority level in the table. Therefore, the priority objectives reported in Table 3 are those that are viewed as non-competitive or partly non-competitive.

Table 3. Major non-competitive objectives and R&D challenges for primary aluminium production

Generic objectives	Specific Objectives	R&D challenges	Priority level	Comp	Time Frame
Improve energy efficiency and reduce CO_2 emissions	Reduce direct CO_2 equivalent emission	Use of biomass as raw material in anode production – bio-anodes	***	Y/N	5-10y
Optimise process technologies	Develop extended-life pot lining (> 5,000-day life)	Eliminate or improve control of cathode erosion	***	Y/N	5-10y
	Improve alumina dissolution behaviour in the pots	Dissolution mechanisms understanding (behaviour in bath, and alumina characteristics)	***	N	< 5y
Reduce environmental impact (solid waste)	Discover alternative techniques to turn aluminium process waste into usable feedstock/products	Qualify recycled refractory materials obtained from spent pot lining and bake furnaces for possible use (refractories recycling)	**	N	5-10y
		Develop new valorisation options allowing direct reuse for primary processes as feedstock waste in third parties (HSE conditions included)	***	N	< 5y
	Address industry excess salt bath short to mid-term trend	Shared project/evaluation with the bauxite & alumina stream on alumina soda content	***	N	5-10y
Improving overall performance on HSE aspects	Improving the overall performance on Health and Safety	Decrease human exposure to health and safety hazards by improving plant automation and process control	***	N	< 5y

Reducing the electricity consumption of the smelter is a clear key priority but is also a highly competitive area where companies are highly active. The three project examples reported in Annex 3 directly addressing this objective.

In parallel, the **reduction of CO_2 emissions** is also identified as a major priority; the use of alternative or bio-based anodes as possible routes is being investigated.
In terms of **process optimisation**, shifting to more flexible electricity consumption patterns to support the development of renewables-based grid mixes is an important objective. However, such an objective is viewed as competitive and therefore not ranked. Extending the life span of pots and improving understanding and control of the bath chemistry stand out as high priority areas.
Production optimisation should take greater benefit from automation, sensors and IT development, as already used in downstream processes, i.e. product manufacturing.
Reduction of environmental impact should focus on fluoride emissions as well as on solid waste such as Spent Pot Linings (SPL). The handling of these solid waste products in other sectors should then be promoted through cross-sectoral projects and industrial symbiosis.

Semi-fabrication

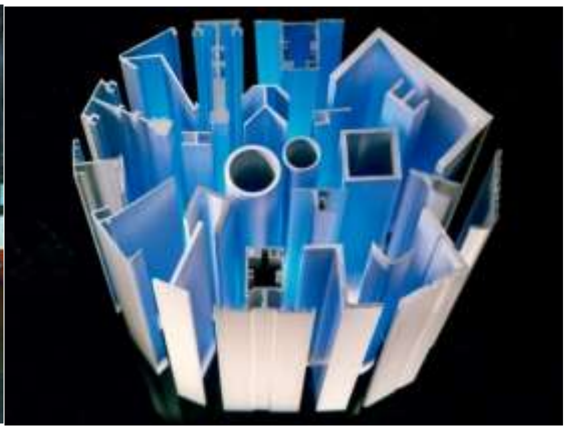
The semi-fabrication stage includes several transformation processes, including product casting, forging, rolling and extrusion. This document will only detail the last two processes, which are the most important for the Innovation Hub members.

Rolling process: Plate, Sheet and foil production

The starting stock for most rolled products is the DC (Direct Chill semi-continuous cast) slabs. These slabs can be over 32 tons in weight, 500 - 600 mm thick, 2,000 mm wide and 9,000 mm long. Before commencing rolling operations, the slab is machined to trim the ends (sawing) and to even the surfaces (scalping).
According to the alloy grade, a thermal treatment of homogenisation may be applied. The DC ingot is then pre-heated, followed by successive passes through a hot rolling mill where it is reduced in thickness to around 4 - 6 mm. Aluminium plates, e.g. thick sheets of 5-100 mm, are also produced via hot rolling only. These are usually converted into components - usually via dry machining - for very specific applications, e.g. aeronautics
The strip from the hot rolling mill is coiled and stored before cold-rolling, which usually takes place in the same site. Cold mills are available in a wide range of types and sizes; some are single-stand, others three-stand and some five-stand. The final thickness of the cold-rolled strip or sheet is usually between 0.2 and 2.0 mm.
Some alloys can be further rolled to produce aluminium foil in varying gauges for a variety of applications, particularly packaging. Foil is available in thicknesses ranging from 5 microns to 200 microns. Aluminium foil can also be produced directly by the continuous strip casting process consisting of casting the molten aluminium directly into a strip that is cold-rolled into a foil. This method is increasingly popular in Europe and now accounts for more than half of current foil production. It is also increasingly used for some sheet production.

Extrusion process

Aluminium profiles are produced by the extrusion process, where a heated ingot is pushed through a shaped die.
The starting material for the aluminium extrusion production is an extrusion ingot (known as a log or billet), which is a cylinder several meters long, typically with a diameter between 20 and 50 cm. The ends (‘tops and tails’) of the billets are usually sawn off at the cast house for direct re-melting. Depending on the presses being used, the billet can be cut into smaller cylindrical pieces before extrusion. Just before extrusion, the billet is pre-heated, usually to around 450 °C - 500 °C. At these temperatures, the flow stress of the aluminium alloys is very low. Applying pressure to one end of the billet, by means of a ram, makes the metal flow through the steel die located at the other end of the container. This creates a cross-section profile defined by the shape of the die. The resulting profile can be used as long lengths or cut into short parts for use in structures, vehicles or components.



Main objectives and R&D challenges

The detailed objectives of the semi fabrication processes are reported in Table A.3, in Annex 1 and priority objectives are reported in Table 4.

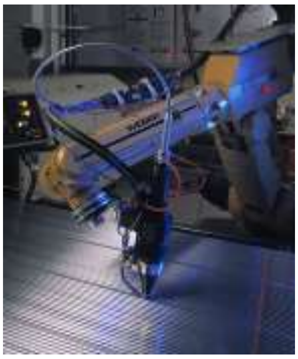
Table 4: Main objectives and R&D challenges for the rolling and extrusion processes

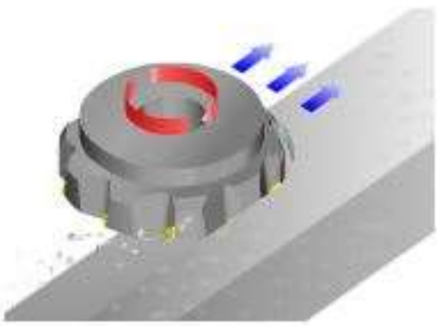
Generic objectives	Specific objectives	R&D challenges	Priority level	Comp	Time-frame
Improve energy efficiency and reduce CO_2 emissions	Reduce thermal energy and electric consumption of furnaces	Optimise further processing route to reduce cycle time and energy consumption e.g. at pre-heating and homogenisation	**	Y/N	< 5y
Optimise processing technologies	Increase fabrication efficiency through better control of the aluminium deformation process and improved tool performances	Maximise tooling life through new surface treatment or new materials for extrusion dies or rolling rolls	**	Y/N	< 5y
	Improve knowledge for more cost effective and robust processing routes	Better understanding of microstructure evolution along the process chain	***	N	5-10y
	Develop modelling capabilities for more cost effective and robust processing routes	Develop real-time predictive modelling tools	***	Y/N	5-10y
	Increase manufacturing efficiency through better monitoring via sensors and measurements	Develop new or improved non-contact sensors and surface inspection devices	**	Y/N	5-10y
New processing routes for more performing products	Use of continuous casting technologies	Develop continuous casting technologies and associated alloys	**	Y/N	5-10y
	Develop further alloy capabilities and performances through non-conventional processes	Develop a cost efficient process routing to make powder-metallurgical products, routed via rolling feedstock, via extrusion feedstock, via net shape manufacturing technologies	**	Y/N	> 10y

Improving energy and resource efficiency has been identified as highly important for semi-fabrication. Optimising processing routes to **reduce cycle time** has been identified as a potentially non-competitive area for initiating a joint project.
The development of more advanced modelling tools to better consider the microstructure evolution along the semi-fabrication chain appears as a key research area for further joint research efforts. These models are considered as non-competitive areas, provided they deliver a toolbox that producers can customise to their specific industrial requirements.
Better understanding and controlling the **interaction between the tool - i.e. rolls or dies - and aluminium** to optimise product quality and maximise tool life has been identified as a significant objective. Further use and development of on-line sensors is also seen as an important goal.
Finally, the **development of new processing routes** is also worthy of further investigation, particularly the use of continuous casting and non-conventional fabrication processes based on powder metallurgy.

Product manufacturing

This section focuses on enabling technologies.. It includes the key transformation steps to convert semi-finished products into final components possibly integrated into complex products such as a passenger car. Enabling technologies are vital applications for original equipment manufacturers (OEMs) in the major markets for aluminium products, their Tier 1 suppliers and their sub-contractors. These are also key 'downstream' technologies for the aluminium industry, allowing the development of innovative solutions through joint R&D efforts with 'aluminium supplier-OEM' along the value chain.





<u>**Main objectives and R&D challenges**</u>
The innovation challenges for the enabling technologies are reported in <u>Table A.4</u> in Annex 1 and summarised in Table 5.
The main goal is to develop **flexible, low-cost and innovative enabling technologies that allow efficient integration of aluminium components, products and solutions into key markets such as automotive, transport, building, packaging or engineering to meet societal demands and customer needs**.
For a number of objectives, it is not possible to precisely define the nature of the competitive character because it depends on the specific topic and solution. For example, addressing the objectives through generic development of new advanced technology concepts and design can be viewed as pre-competitive. At the same time, directly developing a new piece of equipment or a new type of product and implementing the technology with a client is clearly competitive. As a result, many objectives are labelled as N/Y to reflect their mixed character of their competitiveness.
Among the enabling technologies, **forming, machining, joining, product design and surface finishing** appear as the most relevant for aluminium products. In particular, the **joining of dissimilar materials**, e.g. aluminium/steel or aluminium/composite, the **tailoring of surface properties** as well as the prospects of additive manufacturing, are all seen as important research areas.

Numerical modelling, computing and data acquisition are also key elements in developing these enabling technologies. These modelling needs are often transversal in nature, relevant for various processes upstream in the aluminium value chain, e.g. semi-finished product fabrication such as rolling or extrusion.

Additive manufacturing is a disruptive technology, aiming to fabricate complex-shaped and/or multifunctional products. Exploring its implementation in aluminium alloy products covers a wide range of steps including alloy selection, powder or wire fabrication, solidification and - on the enabling side - component design and control.

Skills and knowledge are also seen as essential in securing proper expertise along the product value chain for the efficient integration of aluminium components and products in key markets. Promoting greater understanding of aluminium in educational programmes has also been identified as an important factor in improving aluminium use.

Table 5: Main objectives for enabling technologies

Area	Generic objectives	Specific objectives	Priority level	Comp	Time-frame
Forming	Optimise process technologies	Better control and predict forming behaviour	**	N	5-10y
		Develop further forming technologies	**	Y/N	5-10y
Joining	Optimise process technologies	Develop advanced joining techniques that reduce impact on material properties	**	Y/N	< 5y
		Develop low cost joining techniques for dissimilar materials and hybrid solutions	***	Y/N	5-10y
Machining	Material development	Optimise machining processes for more eco-efficiency			
	Optimise process technologies		**	N	5-10y
Surface & coatings	Reduce environmental impact	Develop alternatives to chromate coatings.	**	Y/N	5-10y
	Optimise process technologies	Develop aluminium product with tailor-made and functionalised surface properties	**	Y/N	5-10y
Additive manufac	New disruptive technologies	Additive manufacturing for tailor-made aluminium products (bulk)	**	Y/N	> 10y
		Additive manufacturing for aluminium products with tailor-made surface properties (surface)	**	Y/N	> 10y
Product Design	Optimise design technologies	Use of numerical methods for analysing and guiding robust and eco-efficient design of products	***	N	< 5y
		Use of predictive modelling tools	**	Y/N	5-10y
		Optimise crash management design	**	Y/N	< 5y
		Optimise design for lightweighting	**	Y/N.	5-10y
All	Skills and knowledge	Secure proper expertise along the product value chain.	**	N	5-10y
	Education	Improve the level of knowledge and expertise in downstream industry and in engineering education	**	N	5-10y

Melting, solidification and recycling

One of aluminium's advantages over competitor materials is its capacity for repeated recycling with high recovery rates without loss of quality. Aluminium recycling offers clear energy and environmental benefits; it requires only around five percent of the energy use and emissions associated with primary production. However, the recycling industry faces technical challenges both in making further efficiency improvements to melting and purification systems and in ensuring a steady and reliable scrap stream.

Most new aluminium scrap, also known as pre-consumer scrap, arrives at the recycling industry directly from product manufacturing. The quality and the nature of the alloy is known; in addition it is often uncoated. This means it can then be melted with little preparation, apart perhaps from baling. Such scrap is usually collected by the so-called re-melters in order to produce new wrought aluminium alloys.

Old aluminium scrap, also called post-consumer scrap, comes into the recycling industry via a very diversified and efficient network of metal merchants and waste management companies equipped with the technology to recover aluminium from vehicles, household goods, etc. This is often performed with heavy equipment such as shredders in parallel with magnetic separators to remove iron; sink-and-float installations or with eddy current installations to separate aluminium from other materials.

Following collection, sorting and preparation, a portion of this 'old' scrap is usually purchased by the so-called refiners and is melted mainly into casting alloys, also known as foundry alloys. Refiners recycle not only scrap from end-of-life aluminium products but also scrap from foundries, turnings, skimmings (dross), etc. A fraction of sorted and prepared scrap is purchased by the aluminium fabrication industry to feed alloy re-melting and casting facilities, ensuring a valuable closed-loop recycling and fabrication process of wrought semi–finished products.

Recyclers use a combination of rotary and reverbatory furnaces that represent about 90% of their furnace technology, while induction technology use is marginal.

The solidification process is closely related to melting and recycling and is also crucial in the aluminium value chain, playing a significant role in the productivity, quality and efficiency of production. Therefore, ingot casting and continuous casting challenges are addressed within this section of the mapping document. However, shape casting is not directly covered in this mapping.

Main objectives and R&D challenges

The main objectives and innovation challenges of recycling, melting and solidification are reported in Table A.5 in Annex 1 and summarised in Table 6.

The **development of affordable sorting technologies** for better separating aluminium scrap from the waste flow as well as potentially separating aluminium scrap into alloy groups appear as a key priority. However, most R&D activities in this area are considered competitive and would not be suitable for joint research project that include several aluminium companies.

Improving **energy efficiency** through better furnace design and technologies and energy recovery is an important objective. **To maximise resource efficiency, decreasing oxidation** during melting process is a major research area.

Melt analysis, purification and control has been identified as a key R&D topic for enlarging the applications and uses of recycled aluminium and for producing new, high-performing alloys based mainly on recycled aluminium.

Developing more energy efficient furnaces, which maximise the metal yield through a better control of the melting conditions, appear as a leading element in a more sustainable recycling sector. The development of sensors and the optimising of process routes to avoid any safety risks, especially related to moisture presence in scrap, are also a major focus.

Table 6: Main objectives and R&D challenges for recycling

Area	Generic objectives	Specific objectives	Priority level	Comp.	Time-frame
Scrap & raw materials	Improve resource efficiency	Generate high quality aluminium scrap flow from contaminated or mixed scrap flows	***	Y/N	< 5y
		Facilitate closed loop recycling within alloy groups	***	Y	5-10y
	Improve process efficiency	Increase performance of raw materials, master alloys, grain refining agents	**	Y/N	< 5y
Melting & solidification	Improve energy efficiency and reduce CO_2 emissions	Reduce the energy consumption of the melting furnace and associates CO_2 emission by 20%	**	Y/N	< 5y
	Improve resource efficiency	Reduce the oxidation rate in refining furnaces by 50%	**	Y/N	< 5y
	Improve resource efficiency	Increase service life of furnaces by 50%	**	Y/N	5-10y
	Optimise process technologies	Increase quality and composition of the melt before casting (analysis)	***	N	< 5y
Products & alloys	Material development	Expand the applications of recycled aluminium by better management of impurities	**	Y/N	5-10y
	Material development	Develop new high performance alloys based mostly on recycled aluminium	**	Y/N	5-10y
Horiz.	Improve safety	Significantly reduce the risk of fire and explosion	**	N	< 5y
	Optimise process technologies	Better control recycled aluminium quality	***	Y	5-10y

Applications

Similarly, innovation leaders have defined the main objectives and R&D challenges for aluminium in its key markets. Those challenges need to be addressed jointly with the final product manufacturers - i.e. OEMs in automotive. Thus, the priority level, the competitive aspect and the timeframe have not been defined. Detailed tables have been developed for mobility, building and packaging applications and are reported in Annex 1.

Mobility

For many years, the largest end-use market for aluminium has been the transport sector.
Heading the list of advantages is aluminium's unique combination of strength and lightness, corrosion resistance, high recyclability, improved safety and design flexibility. Today, aluminium is used in a vast range of transport applications; cars, trucks, buses, coaches, trains, metros, ships, ferries, aircraft and bicycles.
The largest end-use market within the transport sector is now passenger cars. Indeed, the aluminium-based automotive product portfolio has continuously increased and now averages around 150 kg per car. The main driver for aluminium lightweight design is improved fuel consumption, i.e. a reduction of the CO_2 emissions during the service phase of the car. At the same time, the reduced vehicle mass offers significant safety improvements as well as improved driving performance and greater comfort.

Main objectives and R&D challenges

The objectives and challenges are reported in Table A.6 in Annex 1.
The lightweight and crash energy absorbing properties of aluminium make it a key enabler for mobility solutions. Innovation will focus both on finding new applications and on improving existing applications by:

- Developing further lightweight solutions for more energy-efficient mobility
- Continuing to develop light passive safety solutions, also focusing on high strength alloys
- Contributing more to sustainable marine transport, e.g. shipbuilding
- Contributing more to sustainable road and rail transport, e.g. buses, trucks, trains, metros and trams.

Building

Aluminium is widely used in building applications for its superior aesthetics, durability and recyclability. It is an ideal material for framing glazed facades and windows as well for the outdoor skin of buildings. Innovation should leverage this high durability and stability to make it a key enabler for high-performing buildings.

Main objectives and R&D challenges

Those objectives are details in Table A.7 in Annex 1.
In particular, aluminium building products and solutions will contribute to developing more energy-efficient and comfortable new buildings, increase the energy efficiency of Europe's existing building stock through their contribution to smart renovations, for example by:

- Developing intelligent building envelopes contributing to energy efficiency and user comfort
- Developing intelligent multi-functional surface properties for aluminium building components and solutions
- Maximising the production of renewable energy from the building envelope
- Further optimising end-of-life practices to better contribute to the circular economy.

Packaging

Aluminium is a key material for packaging, providing unique solutions for a large variety of applications. Aluminium packaging maximises food and beverage preservation and to the benefits the consumer. Its unique recyclability characteristics has already made aluminium the reference material for beverage cans.

Main objectives and R&D challenges

These objectives are set out in detail in Table A.8 in Annex 1.
R&D efforts should reinforce aluminium's role in packaging and contributing to the circular economy.

- Meeting consumers' needs better
- Developing packaging solutions that minimise food waste
- Developing and promoting optimised collection and sorting technologies for end-of-life aluminium packaging.

Other applications

A research priority is to expand the portfolio of products that can benefit from the lightweight, durable and recyclable properties of aluminium, maximising its contribution to a more sustainable European Society. The various opportunities for applications include:

- Promoting wider use in road infrastructure, e.g. bridges
- Developing greater use in oil and gas engineering
- Developing greater use in heat ventilation and air conditioning (HVAC), electronics, consumer products, etc
- Acting as a key enabler for the transition to smart electricity grid mixes based around renewable energy sources such as windmills and photovoltaic panels.

The innovation stories

To illustrate the nature of the ongoing research projects and recent innovations within the European aluminium industry, Annex 3 features a number of innovation stories provided by the various members of the Innovation Hub. These examples exemplify the innovation potential within the aluminium sector.

The Innovation Hub is not responsible for the performance or achievements reported in the description. The reader is invited to contact the company directly for more information on these innovation stories.

Conclusions

Aluminium is found in an increasingly wide range of state-of-the-art applications, representing a response to many of today's pressing concerns, including sustainability of resources and energy conservation. Today's designers and manufacturers are increasingly aware of aluminium's aesthetic properties and vast potential for improving performance, selecting it for a broad range of applications in a variety of domains. Numerous sectors, including transport, building, packaging and engineering, are now reaping the rewards of these design decisions.

Aluminium is a key enabler for a modern and sustainable European society and a strong driver for the circular economy. It is essential to fully leverage aluminium's attributes in products while minimising the sector's environmental impact. This is the major objective of the Innovation Hub; to reinforce the sustainability and innovation leadership of the European aluminium industry while developing advanced innovative products for a more sustainable Europe.

The Innovation Hub is a collaborative platform coordinated by European Aluminium. It aims to trigger EU research projects within the Horizon 2020 programme, the major EU research funding programme 2014-2020, targeting key identified technology challenges. The Innovation Hub is already engaged in key Public Private Partnerships (PPP) including Sustainable Process Industry (SPIRE), Factories of the Future (FoF), Energy-efficient Buildings (EeB), all of which play a significant role in shaping the work programme and related calls of Horizon 2020.

The mapping of the main objectives of the sector and the detailed analysis at process level aim to provide a holistic overview of the R&D needs along the value chain and to promote coordinated R&D efforts and activities. The objectives of the European aluminium industry are closely aligned with the objectives of Horizon 2020, particularly for the following pillars:

- Industrial leadership in Enabling and Industrial Technologies
- Societal challenges, in particular "SC 3 - Secure, clean and efficient energy"
    - Smart, green and integrated transport
    - Climate action, environment, resource efficiency and raw materials

  Cross-cutting activities (focus areas) with a special focus on "Industry 2020 in the Circular Economy".

The mapping exercise has shown that:

- Energy efficiency is a high priority, especially for alumina and primary production
- Resource efficiency is vital in the recycling sector, where optimising scrap sorting and melting in terms of quantity and quality is essential to fully support the circular economy
- Process and material modelling and sensors are key enablers all along the value chain, particularly at the semi-fabrication and manufacturing stages
- Reducing the environmental impact through industrial symbiosis and by turning waste into resource is highly relevant for addressing the issues of bauxite residue and spent pot linings from primary production
- At the product manufacturing stage, the main objective is to develop flexible, low-cost and innovative enabling technologies to assist the efficient integration of aluminium components, products and solutions. This will be vital in key markets such as automotive, transport, building, packaging and engineering.

In the years to come, the Innovation Hub will specifically promote, initiate and facilitate EU research projects addressing these priority objectives.

Annex 1: Detailed mapping of objectives and R&D challenges along the value chain

Innovation leaders and experts have further analysed the needs along the aluminium value chain, from **alumina production[4] to the key application areas, including recycling aspects**. The following tables set out the consolidated results representing the contribution of numerous aluminium industry experts, who also listed potential solutions or innovations to address the specific objectives. Experts were asked to define the priority level, the competitive character, the timeframe and whether the identified objective was incremental or disruptive in character. These classifications are explained below:

- **Incremental vs. disruptive**: Incremental innovations are associated with significant improvements that can be integrated into existing equipment and installations; disruptive innovations are major technology changes that cannot be integrated into existing installations/plants and/or which require a completely new additional process, e.g. carbon storage
- **Priority level**: Very high priority (***) indicates that all experts view this area as high priority. Other priority levels, e.g. high priority (**) or medium priority (*), reflect majority opinion
- **Competitive aspect (reported as "comp." in the table):** "Y" means that this area is identified as competitive by all experts and would be unsuitable for a project consortium involving several Hub members. "N" means that this area is viewed by all experts as non-competitive and would be suitable for a project consortium potentially involving several Hub members. N/Y means that there is no unanimity among experts and the competitive character would depend on the exact topic addressed
- **Timeframe:** This is an estimate of the likely period required to reach the objective, assuming that adequate research efforts are dedicated to this research need. Short term is 1-5 years; medium term 5-10 years; long term >10 years.

The majority of the objectives and innovation needs listed in this section do not include quantified objectives; these should be principally associated with specific project proposals. Nevertheless, some sections feature quantified objectives. Those should not be considered as committed targets by the industry, but rather as reasonable objectives assuming that adequate innovation efforts and resources are allocated to the specific area.

For **applications-related challenges**, the above classifications are not included, given that key innovation players are also downstream users who did not contribute to the survey.

[4] Considering, the limited activity of bauxite mining in Europe, this process step was not covered

Table A.1: Main R&D Challenges[5] for the alumina production

Generic objectives	Specific objectives [6]	R&D challenges	Type of innovation	Priority level	Comp	Time-frame
Improve energy efficiency and reduce CO_2 emissions	Reduce by 20% the energy use or/and the CO_2 emission of the alumina process	Further optimise leaching, e.g. by increasing performances of slurry heat exchangers or using alternative fuels, and calcination process, e.g. by using cogeneration[7]	Incremental	***	Y	< 5y
		Develop low temperature heat recovery technologies	Incremental/ disruptive	**	Y/N	5-10y
	Reduce drastically the CO_2 emission of the alumina process	Use CO_2 capture technologies, i.e. CCS	Disruptive	*	N	>10y
Improve resource efficiency	Use of lower grade bauxite	Develop bauxite pre-treatment process to reduce transformation costs (soda savings, lower impurity input) and residue storage	Incremental/ disruptive	**	Y/N	5-10y
	Reduce significantly water input, especially in water scarce region	Improve water re-use and/or optimise refining processes requiring substantially less water input, e.g. by 30-50%	Incremental/ disruptive	*	Y	< 5y
	Reduce drastically fresh water input , especially in water scarce region	Implement full water re-use strategy and develop new refining processes requiring substantially less water input, , e.g. 70-80%	Disruptive	*	Y	>10y
	Reduce reagents consumption	Reduce significantly soda consumed, e.g. by 50%, whilst keeping other overall chemical yield and costs steady	Incremental	**	Y	5-10y
Optimise process technologies	Increase productivity	Increase leaching productivity by 20% through higher precipitation yield whilst keeping the same capital cost per production tonne	Incremental	**	Y	5-10y
	Increase the life time of the plant	Improve maintenance techniques and durability of materials and service life of equipment (e.g. reduce caustic embrittlement).	Incremental	***	Y/N	5-10y
Reduce environmental impact (air)	Reduce NOx and particles air emissions	Develop and implement more advanced burner and abatement technologies for NOx and particles emissions reduction	Incremental	**	N	5-10y
Reduce environmental impact (solid waste)	Develop sustainable bauxite residue storage	Develop storage without the need for ongoing management, e.g. by reducing soda and polluting elements content[8]	Incremental/d isruptive	**	N	5-10y
	Use bauxite residue as a by-product or as a resource	Use bauxite residue as ingredient of products, e.g. construction products	Disruptive	***	N	5-10y
	Use bauxite residue as a by-product or as a resource	Develop technologies to convert bauxite residue in valuable resources, e.g. extracting critical raw materials	Disruptive	***	N	>10y

[5] Those challenges were partly inspired by the Alumina Roadmap developed by the International Aluminium Institute and updated in 2010.

[6] It should be noted that any quantified objective should not be viewed as committed targets by the industry, but rather as reasonable objectives assuming that adequate innovation efforts and resources are allocated to the specific area. Reduction targets will be greatly affected by specific location performance and existing improvement opportunities.

[7] Cogeneration is already implemented in some European plants.

[8] Dry disposal with limited control needs is already used in some European plants.

Table A.2: Main objectives and R&D challenges for the primary aluminium production - Part A: Energy efficiency, resource efficiency and process technology optimisation

Generic objectives	Specific Objectives	R&D challenges	Type of Innovation	Priority level	Comp.	Time Frame
Improve energy efficiency and reduce CO_2 emissions	Reduce direct CO_2 equivalent emission	Develop inert anode as alternative to carbon anode (CO_2 emission reduction)	Disruptive	/	Y	> 10y
		Eliminate anode effects occurrences or fugitive PFC emission through better process control (PFC emission reduction)	Incremental	/	Y	< 5y
		CO_2 capture in the flue gases after the gas cleaning facility (through CO_2 concentration)	Disruptive	/	Y	5-10y
		Use of biomass as raw material in anode production – bio-anodes	Disruptive	***	Y/N	5-10y
	Decrease electrolysis process direct energy consumption below 12.5 kWh/kg[9] on new technologies	Improve process control to allow optimised pot operation	Incremental	/	Y	5-10y
		Improve pot materials conductivity to minimise ohmic drop	Incremental	/	Y	< 5y
		Develop economically viable heat recovery on reduction cells and anode bake furnaces and corresponding valorisation options	Incremental	/	Y	< 5y
	Improve energy recovery from electrolytic process and develop valorisation	Develop low grade heat valorisation options applicable in most smelter environment	Disruptive	*	N	5-10y
	Decrease anode bake furnace energy consumption to lower than 1,8 GJ/t of baked anode	Improve anode bake furnace process control	Incremental	/	Y	< 5y
Improve other resource efficiency	Adapt primary aluminium processes to lower grade raw materials	Develop carbon-air burning prevention techniques	Incremental	*	Y/N	5-10y
	Gross / net anode consumption improvement – relevant also to CO_2	Develop new design of anode and cell to maximise anode consumption and reduce anode butts for recycling	Incremental	/	Y	< 5y
Optimise process technologies	Contribute to the deployment of renewable electricity grid mix though new consumption patterns	Increase process flexibility and resilience to power input swings	Disruptive	/	Y	5-10y
		Develop economically viable heat recovery on reduction cells and anode bake furnaces and valorisation options	Incremental	/	Y/N	> 10y
	Develop extended-life pot lining (> 5,000-day life)	Develop advanced refractories for the cell	Incremental	/	Y	5-10y
		Eliminate or improve control of cathode erosion	Incremental	***	Y/N	5-10y
	Improve alumina dissolution behaviour in the pots	Dissolution mechanisms understanding (behaviour in bath, and alumina characteristics)	Incremental	***	N	< 5y

[9] Objective only applicable to new technologies and not on already existing smelters

Table A.2 Main objectives and R&D challenges for the primary aluminium production - Part B: production optimisation (IT) and reduction of environmental impact

Generic objectives	Specific Objectives	R&D challenges	Type of Innovation	Priority level	Comp.	Time Frame
Optimise production in smelters	Develop automation of main smelter operations	Robotics, automated transports, automated tending equipment, etc	Disruptive	/	Y	> 10y
	Increase process productivity	Amperage creep (increase) in existing pot lines and new reduction technologies	Incremental / Disruptive	/	Y	< 5y
	Implement "Factories of the Future" concepts in primary metal plants	Application of on-line continuous smart sensors, data mining, predictive process control, etc	Incremental / Disruptive	/	Y	5-10y
Reduce environmental impact (air emissions)	Improve total fluoride emission	Develop better sensors and measurements approaches for fugitive F emission evaluation	Incremental	*	N/Y	< 5y
		Improve efficiency of scrubbing equipment	Incremental / Disruptive	*	N	< 5y
		Improve pot sealing tightness	Incremental/ Disruptive	/	Y	< 5y
Reduce environmental impact (solid waste)	Discover alternative techniques to turn aluminium process waste into usable feedstock/products.	Qualify recycled refractory materials obtained from spent pot lining and bake furnaces for possible use (refractories recycling).	Incremental	**	N	5-10y
		Develop new valorisation options allowing direct reuse for primary processes as feedstock waste in third parties (HSE conditions included)	Incremental	***	N	< 5y
		Find/develop new valorisation options for contaminated carbon waste	Incremental	*	N	< 5y
	Minimise dross stream in primary casthouse	Valorise alloyed/fluorinated dross from primary casthouse	Incremental	*	N	< 5y
		Develop tapping and liquid metal transfer practices/design improvements allowing lower reoxydation and fluorinated bath contamination	Incremental	*	N	< 5y
	Address industry excess bath short to mid-term trend	Shared project/evaluation with the bauxite & alumina stream on alumina soda content	Incremental	***	N	5-10y
Improving overall performance on HSE aspects	Improving the overall performance on Health and Safety	Decrease human exposure to health and safety hazards by improving plant automation and process control	Incremental	***	N	< 5y

Table A.3: Main objectives and R&D challenges for the semi-fabrication, i.e. rolling and extrusion processes

Generic objectives	Specific objectives	R&D challenges	Increm. /disrupt.	Priority level	Comp	Time-frame
Improve energy efficiency and reduce CO_2 emissions	Reduce thermal energy and electric consumption of furnaces	Optimise further processing route to reduce cycle time and energy consumption e.g. at pre-heating and homogenisation	I	**	Y/N	< 5y
	Reduce further process scrap and maximise productivity	Optimise further processing route to maximise product quality and reduce defects	I	**	Y	< 5y
Optimise processing technologies	Increase fabrication efficiency via a better control of the aluminium deformation process and improved tool performances	Maximise tooling life through new surface treatment or new materials for extrusion dies or rolling rolls, or through a better control of the interaction with the aluminium substrate, e.g. optimised lubrication, alternatives to chromium plating of steel rolls, ensuring high wrought aluminium product flatness, surface quality and process productivity	I	**	Y/N	< 5y
	Improve knowledge for more cost effective and robust processing routes	Acquire a more complete understanding of alloy behaviour including crystallographic texture changes during thermo-mechanical processing	I	***	N	5-10y
		Better understanding of meta-stable phase transformation kinetics and impact on mechanical properties	I	***	N	5-10y
		Better understanding of microstructure under high strain processing conditions (hot rolling, cold rolling and subsequent anneal (if applicable) & direct and indirect extrusion	I	**	N	5-10y
		Better understanding of hardening microstructure at final heat treatment, at further processing at the customer, and ageing in service	I	**	N	5-10y
	Develop modelling capabilities for more cost effective and robust processing routes	Develop real-time, more accurate mechanical process models used for process control or process analysis, integrating microstructural effects such as to accurately predict the macroscopic effects like for instance product shape, temperature distributions, machine responses, etc	I/D	***	Y/N	5-10y
	Increase manufacturing efficiency through better monitoring via sensors and measurements	Develop new or improved non-contact sensors to monitor microstructural features, stress, temperature, dimensions, e.g. for flatness or residual stress control, or the pressure.	I/D	**	Y/N	5-10y
		Develop surface inspection devices for high-speed manufacturing capable of operating in industrial environments	I/D	**	Y/N	< 5y
New processing routes for more performing products	Taylor-made semi-products properties through smarter process production	Develop further extrusion technologies and dies designs, e.g. allowing a combination of thick and thin sections, dimensional accuracy, complex shape and variable sections along the profile	I/D	*	Y	5-10y
		Optimise sustainable finishing and surface treatment operations to facilitate further product manufacturing, e.g. joining	I	**	Y	5-10y
	Develop more efficient extrusion technologies	Develop cost-efficient extrusion process in semi-solid phase.	D	*	Y	5-10y
	Use of continuous casting technologies	Develop continuous casting technologies and associated alloys for a wider product portfolio for more energy and cost efficient production.	D	**	Y/N	5-10y
	Develop further alloy capabilities and performances through non-conventional processes	Develop a cost efficient process routing to make powder-metallurgical products, routed via rolling feedstock, via extrusion feedstock, via net shape manufacturing technologies (metal injection moulding, CIP, HIP), e.g. increase the strength/ductility to weight ratio by using powder metallurgical process routing	D	**	Y/N	> 10y

Table A.4 - Main objectives and R&D challenges for enabling technologies, i.e. product manufacturing

	Generic objectives	Specific objectives	R&D challenges	Type of innov.	Priority level	Comp.	Time-frame
Forming	Optimise process technologies	Better control and predict forming behaviour	Develop further forming models and key materials parameters, e.g. predictive modelling of forming behaviour and limits (alloy constitutive laws, anisotropy, springback, fracture criteria) especially for automotive applications	I	**	N	5-10y
		Develop further forming technologies	Develop forming technologies, e.g. warm stamping or deep drawing technologies to allow the use of higher strength Al alloys in complex, lightweight design	I/D	**	Y/N	5-10y
Joining	Optimise process technologies	Develop advanced joining techniques that reduce impact on material properties	Optimise existing joining technologies, e.g. Friction Stir Welding (FSW) or Linear Friction welding (LFW)	I	**	Y/N	< 5y
		Develop low cost joining techniques for dissimilar materials and hybrid solutions	Develop further mechanical joining, adhesive bonding or FSW for steel/aluminium or aluminium/composite, e.g. GF-reinforcing plastics, and relevant characterisation procedures, e.g. for accelerated corrosion tests	I/D	***	Y/N	5-10y
Machining	Material development	Optimise aluminium alloys properties for machining	Conduct fundamental science and engineering work on the machinability of aluminium alloys, e.g. for alternatives to Pb additions in free machining Al alloys	I	*	Y/N	5-10y
	Optimise process technologies	Optimise machining processes for more eco-efficiency	Develop further machining processes in order to maximise productivity, to reduce environmental impact (e.g. dry machining, enhanced scrap recovery) and ensure the dimensional stability of the product	I	**	N	5-10y
Surface & coatings	Reduce environmental impact	Develop alternatives to chromate coatings.	Develop further low cost innovative Cr-free conversion treatment of aluminium substrate through new eco-friendly reagents and processes	I	**	Y/N	5-10y
	Optimise process technologies	Develop aluminium product with tailor-made and functionalised surface properties	Develop low-cost surface processing techniques and coatings that produce new surface functionalities such as tailored friction, antibacterial properties, aesthetic features, self-cleaning capabilities, etc	I/D	**	Y/N	5-10y
Additive manufa	New disruptive technologies	Additive manufacturing for tailor-made aluminium products (bulk)	Explore and develop affordable additive manufacturing technologies for the customised and/or multifunctional aluminium products	D	**	Y/N	> 10y
		Additive manufacturing for aluminium products with tailor-made surface properties (surface)	Develop affordable additive manufacturing technologies for finishing operations on aluminium products	D	**	Y/N	> 10y
Product Design	Optimise design technologies	Use of numerical methods for analysing and guiding robust and eco-efficient design of products	Develop further modelling tools, e.g. FEM and/or CAD, and materials engineering data to take full profit of Al properties including criteria related to the design for recycling and integrating life cycle assessment tools	I	***	N	< 5y
		Use of predictive modelling tools	Develop further predictive modelling tools better considering relationship between processing-alloy (micro)structure-product property	I	**	Y/N	5-10y
		Optimise design for crash management	Improve numerical models and materials parameters (constitutive laws, fracture criteria) for developing light weight crash management components and systems	I	**	Y/N	< 5y
		Optimise design for lightweighting	Develop further low-cost hybrid solutions for key structural designs in transport, e.g. BIW for passenger cars	I/D	**	Y/N.	5-10y
All	Skills and knowledge	Secure a proper expertise along the product value chain.	Develop tools and data to secure a proper information flow along the product value chain, e.g. translate product requirements into structural and functional requirements, material properties, design rules and test standards	I/D	**	N	5-10y
	Education	Improve the level of knowledge and expertise in downstream industry and in engineering education	Develop channels, sources of easily accessible information and data for supporting the use of aluminium in downstream product development	I	**	N	5-10y

Table A5: Main objectives and R&D challenges for Melting, solidification and recycling

Area	Generic objectives	Specific objectives	R&D challenges	Increm. / disrupt.	Priority level	Comp.	Time-frame
Scrap and raw materials	Improve resource efficiency	Generate high quality aluminium scrap flow from contaminated or mixed scrap flows	Develop further sorting technologies: more efficient, robust and sensitive technologies at affordable-cost, e.g. by using X-ray technologies	I/D	***	Y/N	< 5y
		Facilitate close loop recycling within alloy groups	Develop alloy-based sorting technologies at affordable-cost, e.g. by using X-ray technologies	I/D	***	Y	5-10y
		Increase the aluminium recovery from salt slag by 50%	Develop new mechanical and/or chemical processes for the recovery of salt, aluminium oxides and aluminium metal from salt slag	I	*	Y	5-10y
	Improve process efficiency	Increase performance of raw materials, master alloys, grain refining agents, etc.	Improve their control, quality and effectiveness of in melting and casting	I	**	Y/N	< 5y
Melting and solidification	Improve energy efficiency and reduce CO_2 emissions	Reduce by 20% the energy consumption of the melting furnace and associates CO_2 emission	Further optimise burners' technologies and design of furnaces, use technologies for low temperature energy recovery, use of alternative fuels and/or cogeneration	I	**	Y/N	< 5y
	Improve resource efficiency	Reduce by 50% the oxidation rate in refining furnaces	Develop further salt-based and atmosphere controlling technologies to reduce the production of dross and salt slag while maximising melting yield	I	**	Y/N	< 5y
		Substitute problematic elements, e.g. Beryllium or Lead, in aluminium alloys	Develop a more complete understanding of oxidation mechanisms to identify a non-toxic, non-carcinogenic substitute for Beryllium	I	*	Y/N	5-10y
			Develop Pb-free alloys with similar machinability properties	I	*	Y	< 5y
	Improve resource efficiency	Increase service life of furnaces by 50%	Develop refractories and furnace equipment with longer service life	I	**	Y/N	5-10y
	Optimise process technologies	Increase quality and composition of the melt before casting (analysis)	Develop affordable technology and sensors for real-time chemical analysis and associated process control.	I/D	***	N	< 5y
		Increase quality and composition of the melt before casting (purification)	Develop low-cost process for melt purification including application for possible by-products, e.g. techniques to remove some specific impurities like Mg, Fe, Pb, Li, Si, Ti, etc	I	**	Y	5-10y
		Increase DC ingot/strip quality and casting productivity	Develop slab/strip casting technologies better controlling surface and texture and reducing segregation	I	**	Y	5-10y
Products and alloys	Material development	Expand the applications of recycled aluminium by better use of impurities	Gather more fundamental information on solidification of alloys and develop further models to predict and control microstructure, surface properties, stress, and strain	I	**	Y/N	5-10y
	Material development	Develop new high performance alloys mostly based on recycled aluminium	Gather more fundamental information on solidification of alloys and develop further models to predict the effects of recycling impurities and develop accordingly the recycling value chain	I/D	**	Y/N	5-10y
Horiz.	Improve safety	Reduce significantly the risk of fire and explosion	Develop technologies able to detect moisture presence in scrap lots and avoiding fire in shredders	I	**	N	< 5y
	Optimise process technologies	Better control recycled aluminium quality	Develop real-time sensors to track aluminium scrap and melt composition along the recycling value chain	I	***	Y	5-10y

Table A.6: Main objectives and R&D challenges for mobility

Area	Generic objectives	Specific objectives	R&D challenges
cars	Improve energy efficiency and reduce CO_2 emissions	Further lightweight cars through an optimised use of aluminium solutions	Develop further alloys with higher strength, formability and/or energy absorption capabilities
			Develop BIW concept taking full profit of aluminium properties and attributes
	Optimise process technologies	Reduce cost of aluminium solutions in cars by 20%	Develop further enabling technologies to facilitate aluminium penetration in cars, e.g. joining technologies for dissimilar materials, i.e. between steel and aluminium or between various aluminium alloys
		Expand the applications of aluminium components in transport	Use new manufacturing technologies, e.g. additive or subtractive manufacturing, to develop aluminium components with tailored-based properties
	Improve safety	Improve passive safety of cars	Developing further energy absorbing alloys for developing more-advanced crash management systems
Other applications	Improve safety	Improve passive safety of trucks	Develop new concept and design for crash absorption front end of trucks
		Improve passive safety of other transport means , e.g. trams	Develop new concept and design for crash absorption front and back end of trams or trains
	Improve energy efficiency and reduce CO_2 emissions	Further contribute to a more sustainable water and marine transport	Develop further innovative aluminium concept and use for lightweight and rapid ships, catamarans and ferries
		Further contribute to a more sustainable road a transport	Develop further innovative aluminium concept and use for trucks and trailers to maximise profitability and durability
		Further contribute to a more sustainable rail transport	Develop further innovative aluminium concept and use for metros, trains and coaches to maximise profitability and durability
		Further contribute to a more sustainable air transport	Contribute to the development of more fuel efficient aircraft
Recycling	Resource efficiency	Optimise further the contribution of aluminium to the circular economy at end of life stage of vehicles	Promote and secure the use of smart practices across Europe for the collection and treatment of end of life vehicles using technologies maximising the collection of the aluminium fraction, e.g. use of eddy current combined with flotation processes
	Resource efficiency	Optimise further the contribution of end of life aluminium building products to the circular economy	Develop further smart recycling value chain technologies minimising losses and producing high-value recycled ingot

Table A.7: Main objectives and R&D challenges for buildings

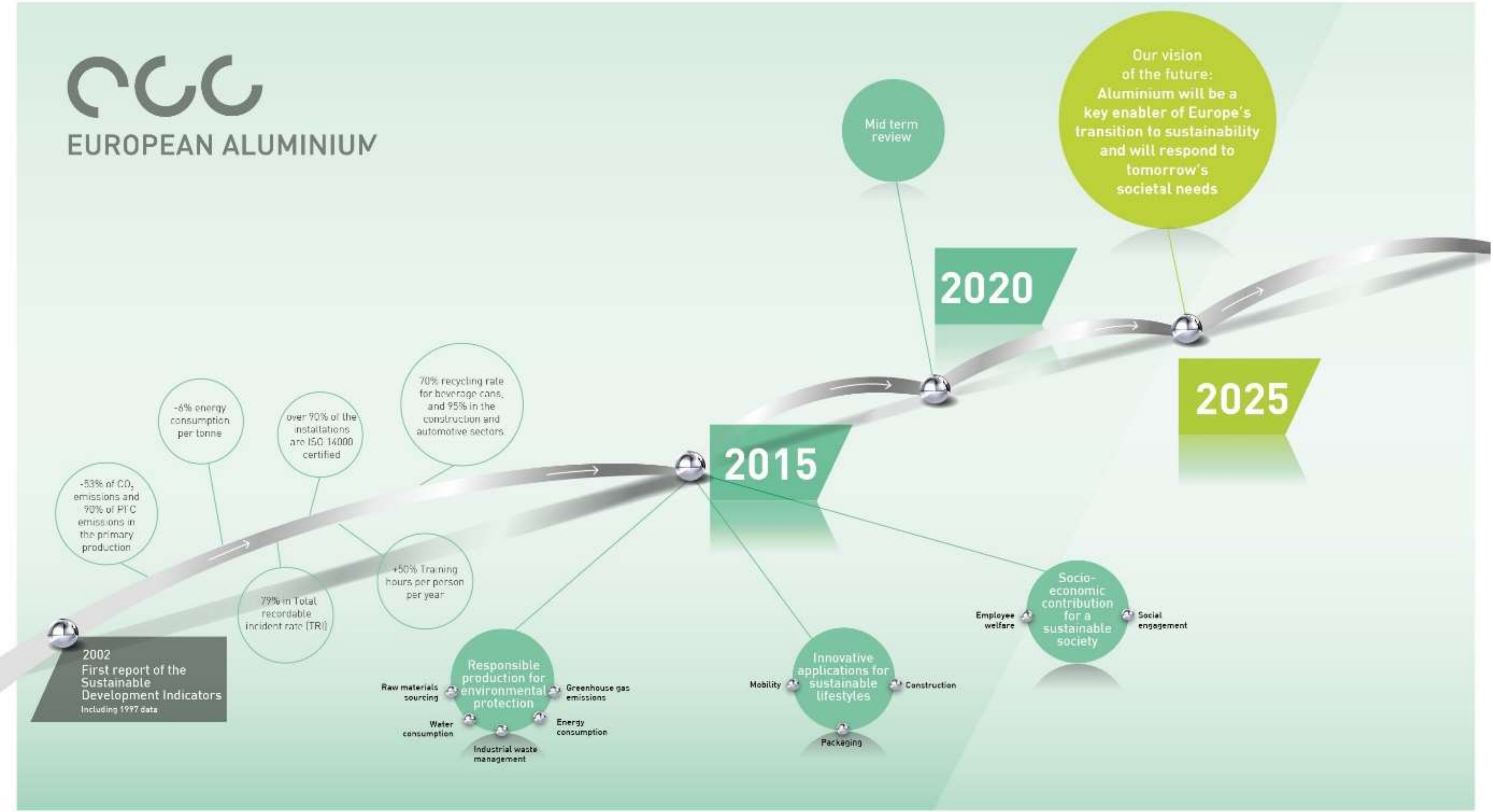
Area	Generic objectives	Specific objectives	R&D challenges
Aluminium frames	Improve energy efficiency and reduce CO_2 emissions	Develop more energy efficient and comfortable buildings	Develop further smart aluminium windows and curtain walling systems, e.g. maximising solar gains and reducing heat losses in cold season while stopping solar gains and heat increase in hot season
		Make the building stock more energy efficient through the intensification of smart renovations	Develop further innovative and affordable window and curtain wall solutions for the renovation market, e.g. promote pre-fabricated and standardised solutions to reduce cost and construction issues
Flat products	Improve energy efficiency and reduce CO_2 emissions	Develop intelligent building envelop contributing to energy efficiency and user comfort	Develop further intelligent aluminium envelop systems, e.g. reflecting or absorbing solar energy during the day in hot season and releasing it at night.
		Contribute to make the building stock more energy efficient through smart renovations	Develop further pre-fabricated, flexible and affordable cladding and roofing solutions for the renovation market
All	Process technology optimisation	Developing intelligent multi-functional surface properties for aluminium building components and solution	Use additive manufacturing to develop new functional aluminium surface properties addressing aspects like maintenance, cleaning, hygiene, heat and electricity production, heat conservation, durability and/or self-healing
All	Improve energy efficiency and reduce CO_2 emissions	Maximise the production of renewable energy from the building envelope	Develop further integrated solar energy collecting systems , e.g. photovoltaics cells in shading devices or and thermal energy collector in roofing systems, in order to contribute to positive energy buildings
End of Life	Resource efficiency	Optimise further the contribution of end of life aluminium building products to the circular economy	Promote and secure the use of smart end of life practices and technologies across Europe at demolition and renovation sites, e.g. using deconstruction practices securing the separate collection of aluminium products
	Resource efficiency	Optimise further the contribution of end of life aluminium building products to the circular economy	Develop smart recycling value chain minimising losses and producing high-value recycled ingot, e.g. development of affordable sorting technologies segregating aluminium alloys family.

Table A.8: Main objectives and R&D challenges for packaging

Area	Generic objectives	Specific objectives	R&D challenges
Product design	Resource efficiency	Reduce food wastage	Develop aluminium or aluminium-containing solutions maximising the packaging function and the food/drink preservation, e.g. maximising shelf life.
		Reduce food consumption and wastage	Develop aluminium or aluminium-containing solutions reducing the food consumption, i.e. consuming what is really needed, and then the food wastage
Recycling	Resource efficiency	Optimise further the contribution of aluminium packaging to the circular economy at its end of life stage	Promote and secure the use of best practices across Europe for the collection and treatment of aluminium packaging, e.g. use latest eddy current technologies, sensor-based or near-infrared sorting systems
		Optimise further the contribution of aluminium packaging to the circular economy at its end of life stage	Develop further smart recycling value chain technologies minimising losses and producing high-value recycled ingot
		Maximise further the contribution of aluminium packaging to the circular economy at its end of life stage	Develop further the recovery of aluminium from bottom ashes issued from incinerators

EUROPEAN ALUMINIUM

Annex 2: Innovation Hub as a key enabler to the Sustainability Roadmap Towards 2025



Roadmap Pillar	Roadmap Sub Pillar	Roadmap Goals	Roadmap Actions	Related Innovation Hub Objectives
Responsible production for environmental protection	Raw materials and sourcing	Source raw materials responsibly, from an environmental, economic and social perspective, promoting traceability best practices	o Contribute to improving the available sourcing and traceability standards o Define a set of core criteria which all members will commit to apply (regardless of the chosen reporting standard)	Improve resource efficiency all along the aluminium value chain
	Water consumption	Identify water scarce areas and develop and implement specific water management programmes in these locations	o Define a common approach to identify water scarce area for industry in cooperation with relevant organisations o Develop sector guidelines on how to develop water management plans to be implemented in the identified water scarce areas	Promote water-saving technologies, especially for the alumina production
	Industrial waste management	Reduce and recycle as much as possible industrial waste, and ban the landfill of recyclable hazardous industrial waste	o Assess the main flows of hazardous wastes in the various segments of the value chain, identifying needs and treatment options, beyond legal requirement o Identify needs for dedicated projects and develop related milestones o Determine and implement solutions, technically and economically feasible, for recycling or minimising waste generation	Turn waste into resource through industrial symbiosis, especially for bauxite residue and Spent Pot Linings (SPL)
	Energy consumption	Reduce industrial energy consumption by 10% per tonne of aluminium produced or transformed in Europe	o Explore the margins for energy-saving of current technologies o Support the development of innovative technologies	Facilitate projects maximising energy efficiency especially through energy recovery
	Greenhouse Gas Emissions	Define together with key stakeholders a pathway towards the realisation of the industry's GHG reduction potential towards 2050	o Engage in demand-side management and capacity mechanisms to improve stability of the energy network etc. o Advance R&D in breakthrough low-carbon production technologies and pilot advanced smelting technologies, to reduce the direct emissions	Facilitate projects maximising CO_2 reduction, e.g. through renewable carbon sourcing, more use of renewable energy or better energy efficiency
Socio-Economic contribution for a sustainable society	Employee welfare	Establish programmes to attract and safeguard competence, ensure proper working conditions and secure employee development and diversity at all levels.	o Develop core criteria for technical, behavioural and managerial training programmeso Promote exchange of best practices amongst members with a view to develop the knowledge base and safeguarding working conditions	Promote aluminium skills and knowledge along the value chain
	Employee welfare	European Aluminium and its members will define set of core ethical values for all members to subscribe	o Identify a core set of criteria, based on established global best practices, which all members will subscribe to, covering employees and contractors	
	Safety	Maintain the highest Health and Safety standards aiming to safely send workers back to their homes after the working day and cutting the TRI by 50%	o Maintain a regular collection and distribution of health and safety statistics, including leading indicators and areas for improvement o Ensure the exchange of best practices, maintaining the Safety Solution Competition to encourage and award improvements across the value chain	Promote projects addressing key safety issues, e.g. water explosion in recycling

Roadmap Pillar	Roadmap Sub Pillar	Roadmap Goals	Roadmap Actions	Related Innovation Hub Objectives
Innovative applications for sustainable lifestyles	Mobility	By virtue of its lightweight, crash energy absorptive and fully recyclable characteristics, aluminium shall enable Europe's transition to low-carbon and safe mobility, representing the material of choice for design engineers of the future	○ Develop, implement and monitor progress of aluminium recycling for the automotive industry, considering design for dismantling and recycling of aluminium parts and maximising the quantity & quality of recovered aluminium scrap ○ Facilitate the manufacture of even more fuel efficient vehicles by engaging in EU research projects ○ Promote the use of aluminium in cars, trucks, buses, tramways etc. ○ Reduce energy consumption and CO2 emissions in transportation by advocating for improved vehicle efficiency standards, better and harmonized labelling and higher visibility and awareness of the weight of vehicles	Initiate and facilitate EU projects addressing those key applications. Hence, the innovation Hub will be a key enabler to reach the sustainability goals defined for the main application areas of aluminium.
	Buildings	By virtue of its high durability, design flexibility, lightweight and fully recyclable characteristics, aluminium shall be an essential component of energy efficient and sustainable buildings, both in residential and commercial sectors	○ Develop, implement and monitor progress of aluminium recycling for the building industry, investigating the relevance of design for dismantling and recycling of aluminium products and maximising the quantity & quality of recovered aluminium scrap ○ Facilitate the development of new solutions further enhancing buildings' energy efficiency, durability, comfort, safety and low maintenance requirements by engaging in EU research projects ○ Address the durability of aluminium product's performance and its adaptation to climate change and ways of living with increasingly flexible solutions ○ Provide learning tools for the next generation of design engineers/architects & guide customers to optimised performance through the use of aluminium products ○ Feed knowledge into European legislation, standards and testings' harmonization processes	
	Packaging	By virtue of its high formability, lightweight, attractive metallic look, total barrier to light, gases, moisture and infinite recyclability, aluminium shall be one of the preferred packaging materials for food and drinks manufacturers, consumers and recyclers	○ Contribute to achieving a 75% recycling rate of beverage cans by 2015 and 80% by 2020, focusing on 'out of home' consumption ○ Contribute to phasing out landfill of recyclable consumer packaging waste by 2025, improving quality and quantity of recycled material by improving the collection-sorting-recycling processes ○ Develop guidelines for post-consumer recycling of aluminium packaging waste ○ Promote the advantages of the various aluminium packaging items towards customers, end-consumers and future generations, in cooperation with canmakers and aluminium foil producers	

Annex 3: Innovation stories

Disclaimer: The following innovation and project stories have been provided by the various members of the Innovation Hub. The Hub is not responsible for the performance or achievements reported in the description. The reader is invited to contact the companies involved directly for further information.

Industry level

Better assessing sustainability in the process industry: SAMT project
SAMT is a Horizon 2020 project, funded by the European Union. It began in 2015 and will be delivered by a consortium of ten partners from different process industries, including the cement, oil, metal, water, waste and chemical industries. The SAMT objective is to review and recommend methods used to evaluate sustainability in the process industry, in particular focusing on energy and resource efficiency. Project partners have ambition goal of producing a strategy for implementing best practices across different sectors of the process industry, increasing its sustainability and competitiveness.
More info at: http://www.spire2030.eu/samt/

Alumina process

ENEXAL: Novel Technologies for enhanced Energy and Exergy efficiencies in Primary Aluminium Production Industry.

Aluminium of Greece coordinated this EU project (FP7, 2010-2014), which aimed at demonstrating the potential of using electric arc furnaces (EAF) in the aluminium industry to treat bauxite residue or to produce aluminium from alumina more efficiently. Two year-long experimental campaigns in Aluminium of Greece have shown the possibility of efficiently producing pig iron and mineral wool from Bauxite residue. In addition, a method for direct Al-Si alloy production from alumina and silica in an electric arc furnace was developed. The production of solid (nano powder) aluminium from alumina in a prototype solar furnace was also demonstrated by a partner. These R&D results will be further leveraged in the ongoing and future activities related to Mud2metal consortium.

Primary production (smelters)

Project: Rio Tinto's Horizon 2020 AGRAL (Advanced Green Aluminium) Inert anode project

AGRAL (Advanced Green Aluminium) Inert anode project is part of the Horizon 2020-SILC-II-2014 programme and was launched on 1 May 2015 (duration 36 months).

The project aims at developing the manufacturing technologies for a specific anodic material, which has previously shown, at lab scale, outstanding properties in high temperature and corrosive media of the aluminium electrolysis. This new material will be tested for two applications; in aluminium production for the manufacturing of an inert anode up to industrial scale and in hydrogen and fuel cell application.

More info: http://www.agral-project.com/

Project: Hydro's project of industrialising more energy-efficient production technology at Karmoy plant

Hydro is currently developing a pilot plant using revolutionary new electrolysis production technology that can significantly reduce energy consumption compared to existing production technologies. The pilot plant, currently under development, is planned to have a capacity of 75,000 tons of primary aluminium per year and will begin production in 2017. Hydro aims to reduce consumption to below 12.3 MWh/ton, compared to the current average of more than 14 MWh/tonne, i.e. a saving of more than 10% electricity.

Picture : Hydro's Karmoy plant

Project: Rio Tinto's APXe Technology Development

In cooperation with an international University Network, Rio Tinto has developed a unique suite of inter-connected models able to simulate the full behaviour of the Electrolysis Cell and to deliver optimised designs. These specific designs have been successfully tested at the Saint Jean de Maurienne (France) piloting facility.

The APXe prototype cells in St Jean de Maurienne are now operating in a range of 500 to 520 kA with energy consumption as low as 12.3 kWh/kg, achieving - for the first time in the industry - a simultaneous benchmark for energy consumption and productivity. The object of the next stage of development of these high amperage and low energy cells is to achieve 12.0 kWh/kg or less by 2016. APXe has already been selected as the technology of choice for a potential greenfield smelter in Asia.

Picture: APXe smelting cell

Semi-fabrication

Innovation: Alcoa's Micromill™

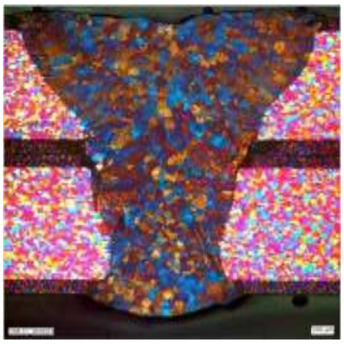
Alcoa's innovative new Micromill™ rolling technology makes the most advanced aluminium sheet currently on the market. It reduces the time needed to transform molten metal into aluminium coil from 20 days to 20 minutes while using 50% less energy than traditional rolling processes. The coil is then used in a wide variety of products, from car bodies to cladding and insulation in construction. The automotive alloy produced by Micromill™ is 40% more malleable and 30% stronger than other aluminium sheets; car parts made with the material will be twice as formable and 30% lighter than parts made from high-strength steel.

More info: http://www.alcoa.com/global/en/innovation/alcoa_micromill.asp

Product manufacturing

Innovation: Novelis' Advanz™ Fusion s200

Novelis' Advanz™ Fusion s200 is an innovation in welding processes, making welding three times quicker than present. Not only do car manufacturers benefit from greater flexibility and ease of welding, but they also reduce their joining costs from €1/m (for conventional aluminium) to €0.3/m. The Advanz™ Fusion s200 also delivers significant time savings for car manufacturers. Moreover, the material also has allows greater scope for joining errors, accepting larger gaps and wider speed ranges, reducing costs on retooling.



Picture: Microstructure of a welding join using Novelis' Advanz™ Fusion s200

Recycling

Innovation: Constellium integrates Linde's Oxy-fuel technology

Following a long-term partnership with Linde in the area of energy-efficient re-melting technologies, Constellium has successfully integrated Linde's oxy-fuel technology in its recycling and melting activities. By using lower temperatures, the innovative technology consumes significantly less energy and increases the productivity of aluminium melting plants.

It has been implemented successfully in half of the furnaces at Constellium's plant in Neuf-Brisach, France, with the other two to be replaced by the end of 2016. Small burners using oxy-fuel technology have also enabled productivity increases in Constellium's Technology Center, C-TEC.

Mobility

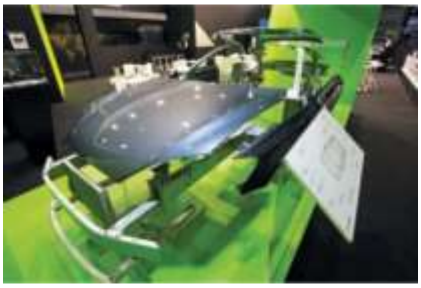
Project: Novelis / Jaguar Land Rover REALCAR (REcycled ALuminium CAR)

As part of a multi-stakeholder partnership with initial grant funding from Innovate UK, Novelis and JLR worked together to launch REALCAR (REcycled ALuminium CAR). This long-term project, launched in 2008, aimed at creating a closed-loop production model using production scrap and working towards the capacity to recycle automobiles at the end of their lives, while meeting the specifications for the auto industry.

Together, the two companies have created a new automotive aluminium alloy that accepts increasing amounts of recycled aluminium automotive scrap. The newly-developed alloy is now used in the Jaguar XE and XJ.

JLR also invested £6.2 million to ensure that press shop metal scrap could be segregated into separate metals, with separated aluminium alloys returned directly to Novelis. This created a Closed-Loop Value Chain (CLVC), returning increasing volumes of segregated high-quality scrap from JLR press shops directly to Novelis, rather than entering the general scrap market.

Innovation: A new skin material to reduce weight of complex automotive parts



Constellium's SURFALEX® HF is a revolutionary aluminium highly formable skin material for complex automotive parts. It provides significantly improved formability in terms of deep drawing, hole expansion and stretch-forming ability with no compromise in strength, hemming performance and surface appearance. By providing a lightweight alternative to steel for car part manufacturers, SURFALEX® HF also reduces CO_2 emissions. In recognition of its visionary innovation in the field of transport and automotive manufacturing, the International OEM Advisory Board nominated Surfalex® HF for the "AEE Innovation Star 2015" at the Automotive Engineering Expo 2015.

Innovation: High-strength technology for safer vehicles

In close collaboration with its automotive customers, Constellium has developed a new high-strength aluminium Crash Management System (CMS) technology, designed for the front and the rear of vehicles. This enhances structural protection in the event of a collision. The product is stronger (10%), lighter (15%) and safer than products currently on the market, while remaining cost-efficient. The new-generation CMS combines the properties of formability, corrosion resistance, energy absorption and recyclability with high-strength mechanical performance.

More info: www.constellium.com/markets/automotive/crash-management-systems

Innovation: Structurlite®, a new high-strength aluminium alloy for automotive applications

In close cooperation with automotive OEMs, Aleris has developed Structurlite® 400, a new high-strength aluminium alloy. Structurlite® 400 enables OEMs to replace high-strength steel in roof beams and door stile support structures with aluminium, thereby ensuring they meet the increasingly demanding weight-limit requirements of the future.

Structurlite® offers customers a step-change improvement in yield strength, including excellent welding properties, lower spring-back after forming, significantly improved cold workability and deep drawing of simple geometries.

Innovation: Longer propulsion time and zero emissions

In cooperation with Phinergy and HEIG-VD University, Alcoa has created an aluminium-air battery that is powering zero-emissions electric boats. The battery will be commercialised for use in other applications, including electric cars and stationary energy.

The boat's battery contains 15kg of aluminium, which provides around 25 hours of propulsion time. The significance of this is clear when compared to navigation without the aluminium-air range extender; only 5 hours.

The battery uses air and water to unlock the energy stored in aluminium. Each kilogramme of aluminium provides approximately 4kWh electricity. The technology allows an energy density that surpasses conventional battery technologies and creates vehicles with travel distances, purchase prices and life-cycle costs comparable to fossil-fuel powered vehicles.

More info: www.alcoa.com/car_truck/en/news/releases/2014_electric_boat.asp

Aerospace

Innovation: NASA's choice for stronger and lighter spacecrafts

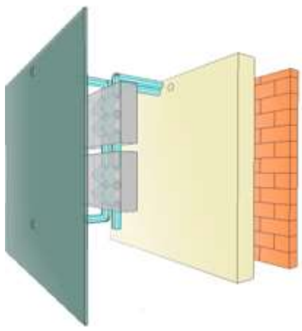
Constellium's AIRWARE® aerospace technology provides low-density alloys that are stiffer and stronger, offering excellent mechanical properties to ensure high performance during the demanding launch and landing phases of space missions. At the same time, the lower density assists the ascent of spacecrafts to outer space.

AIRWARE® contributed to a successful first exploration Flight Test (EFT-1) case of NASA's Orion Spacecraft built by Lockheed-Martin.

Together with AIRWARE® 2050, Constellium's specific aerospace Al 2219-T87 will also feature in the main primary structure of Exploration Mission 1 (EM-1), which will be the Orion's second planned unmanned test flight.

Building

Project: European Aluminium's and Elval Colour's E2VENT



Supported by the EU's Horizon 2020 programme, the E2VENT project is developing a revolutionary heat recovery system that aims to reduce energy use by 40% through using ventilated façade and heat capture from the ventilation air.
When combined with natural lighting strategies and insulation thickness adapted to the building, the energy target will be less than 25 kWh/m2 year (excluding appliances). The project is still at an early phase and will run until mid 2018.

More info: www.e2vent.eu

Innovation: Alcoa's Ecoclean™

Alcoa's new self-cleaning wall cladding is revolutionising building maintenance. An eco-friendly and cost-efficient innovation, the cladding breaks up harmful organisms such as algae and mosses, as well as intrusive odours or industrial emissions and car fumes.
Not only does this mean that the wall and surrounding air are always clean, it also gives the cladding itself a much longer life span, thereby reduces building maintenance costs.
This is the first time that the groundbreaking HYDROTECT technology, which provides the cleaning process, has been integrated directly into the coating of aluminium sheets. Previously, it was only available as a spray or for rollers.
More info: www.alcoa.com/bcs/aap_eastman/ecoclean/en/home.asp

Packaging

Innovation: A lighter and innovative solution for aerosols with reduced environmental footprint

Constellium has launched Aeral™, a new aluminium solution designed for the production of aerosol containers using the Drawn and Ironed (D&I) technology currently used to produce beverage cans. Aeral™ allows a minimum of 30% weight savings compared to traditional impact extruded containers while maintaining the same level of performance in terms of high ductility and resistance to pressure. This innovation will dramatically reduce the environmental footprint of aerosol containers and radically change the aerosol market.

More info

Other applications

A pioneer in lighter, stronger smartphone technology

Alcoa's Power Plate™ is an innovative, aerospace-grade aluminium alloy that is stronger and harder. It is perfect for a variety of uses, including smartphones.
The Power Plate™ alloy is stronger and lighter than other smartphone materials, enabling manufacturers to create slimmer, corrosion-resistant and more lightweight products.
The market for smartphones with metal frames is growing rapidly. Samsung's Galaxy S6 was the first in its range to use an aluminium frame.

EUROPEAN ALUMINIUM

Members of the Innovation Hub

List of main contributors:

Company	Contacts
Alcoa	Carlos Gago & Francesca Stevens
Aleris	Philippe Meyer & Thom Hermens
Alro	Dan Dumitrescu, Iulian Dobra & Iliev Sorin
Aluminium of Greece	Asterios Delipastas & Thymis Balomenos
AMAG	Werner Fragner
Assan Aluminium	Yavuz Arkun & Murat Dündar
Automotive & Transport MG	Patrik Ragnarsson
Building MG	Bernard Gilmont
Constellium	Bruno Dubost
ELVAL	Kimon Daniilidis & Marina Latsa
Hydro	Trond Furu, Jürgen Hirsch & Georg Rombach
Novelis	Axel Foerderreuther
Rio Tinto – Aluminium Group	Jean-Michel Jolas
Sapa	Jan Strid

More info:

Christian Leroy
Consultant Innovation & LCA
innovation@european-aluminium.eu
Phone +32 2 775 63 57
Mobile +32 478 45 90 16