STRIA roadmap on "Vehicle Design & Manufacturing"

September 20, 2016

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1. Executive summary

Over the last fifty years, design and manufacturing of transport vehicles has followed an evolutionary path. Transport vehicles were continuously optimised, mostly in an empirical way, integrating new technologies as well as responding to global mega-trends. Environmental issues were always taken into consideration, but by and large were not the driving force. Yet, design and manufacturing improvements in aircrafts and cars, powered by internal combustion engines, have slashed the fuel burn and emissions per passenger km by more than 80%. While, there is still room for further improvements and higher fuel-burn gains towards counter balancing the annual passenger and freight growth, many of the technologies onboard transport vehicles have reached their maximum potential.

Today, the evolutionary path of car design and manufacturing is already disrupted by the high degree of electrification, digitalization and automation. Maritime and air-transport demonstrated electric and hybrid technologies at small scale, preparing the ground for real transport vehicles in the years to come. Competitiveness of the European industry and emerging flexible and decentralised manufacturing processes will further accelerate those changes. However, cyclicality of the industry development, high fixed cost structure coupled with moderate growth and low profit margins for operators hold back such changes. R&D funding is necessary to accelerate existing and upcoming technology roadmaps. STRIA vehicle design and manufacturing roadmap proposes three key cross-modal research and innovation paths that will enable the achievement of the Energy Union targets, while boosting the European industrial competitiveness.

I. Advancements on Design Tools and Processes - Integrated, multidisciplinary, scientific-based and validated design processes and tools, that make use of high performance computing resources, will allow efficient design, optimization and manufacturing of transport vehicles. New tools and processes will expand the design space offering more environmentally friendly options, substantially decrease the development lead time and maintain or even increase safety and security.

II. Advancements on New Vehicle Concepts and Architectures – Evolutionary and disruptive vehicle concepts that will adopt new technologies, as soon as they are developed, and fully integrate them in the design of the next generation vehicles, providing significant improvements in emissions in all transport sectors. Energy efficiency gains are expected to come not only from components and systems but also from their integration.

III. Circular economy – modular vehicle architecture and remanufacturing, greening industry Greening the primary production and supply chain operations could be achieved by optimizing processes, with digitalization along the value chain enabling modular vehicle architecture and a closed loop approach. There is need for research on innovative end-of-life recovery options, which allows for a shift from traditional recycling to eco-design and eco-manufacturing.

1.1 Scene Setter

A common set of questions/issues to all the seven STRIA roadmaps set the scene towards an integrated approach. Together with the high level documents that describe STRIA, they serve as an excellent scene setter.

1. How the considered technology area can contribute to tackling the **Energy Union** challenges of decarbonisation and energy security?

Vehicle design and manufacturing (VD&M) is one of the three main pillars of the transport system – together with infrastructure and operational procedures. Advances in VD&M have already transformed transportation, more than anything else, over the last 50 years. Aircrafts and cars, powered by internal combustion engines, have slashed the fuel burn and emissions per passenger km by more than 80%. New technologies (e.g. automation, energy storage, and powertrains) in all transport vehicles cannot just replace existing components. Evolutionary and disruptive concepts, designs and architectures are required to integrate those new technologies. The design tools and processes together with the system integration offer big energy efficiency gains. The roadmap also pays particular attention to the complete transport vehicle life cycle management - raw materials, design processes and manufacturing, maintenance and recycling.

2. Where an **integrated approach**; both in terms of integration across sectors as well as integration across technologies is needed? Within each roadmap clarify what "integrated approach" means, which are the concrete R&I implications of such approach and specific requirements

Transport vehicles are complex products made of millions of components. They interact between each other and the infrastructure, and they should comply with the rapidly evolving regulatory framework. The proposed roadmap focuses on three cross-modal integrated R&I paths that will have high impact on the Energy Union targets as well as competitiveness. The integrated development of new generation design tools and processes will enable even higher integration between the supply-chain, industries and universities as well as between design and manufacturing. Synergies between seemingly different vehicles, across their life-cycle will be exploited.

3. Outline the **timeline** of the actions/initiatives. Specify which innovations/solutions could be deployed within 5-7 years. Specify as well the possible bottlenecks/barriers related to the actions/initiatives envisaged.

Civil commercial transport vehicle industry has high fixed cost structure and cyclicality and is coupled with moderate growth and low profit margins for operators. A two-year evolutionary development cycle for the automotive industry is different from a fifteen year one in the aeronautics sector. Deployment of disruptive new technologies, within 5-7 years, that will have substantial impact to the Energy Union is not realistic to be expected from the maritime, aeronautics and rail sector. R&D funding is necessary to accelerate existing and upcoming technology roadmaps. Globalised supply chain, new-entries in the transport vehicle industry, power requirements and available technologies, public acceptance, as well as safety critical issues define completely different timelines between transport modes. The successful introduction of evolutionary and disruptive design and manufacturing technologies will have an impact to public acceptance. While, in the automotive sector visible impact at fleet level is expected within the coming decade, the timeline for aeronautics and marine is towards two to three decades from today.

4. Which are the **roles** of the public (EU, national and local level) and private? Who should do what?

Strategic policy priorities at EU and Member States level should lead to strategic orientation of the forthcoming EU framework programmes. Monitoring and follow-up of the research activities is also expected to be a priority with SETIS and beyond. Linking together scientific outcome from fundamental research conducted under ERC to demonstration activities in JTIs is an important element of the roadmap. Collaboration between EU, National, private and public entities is necessary.

5. What overall **impact in terms of CO2 emission** reduction and use of cleaner energy can be expected by the development and deployment of the considered technology/technology solutions? Specify other relevant impacts resulting from the development and deployment of the considered technology

Associating a specific transport vehicle technology (e.g. novel architectures, manufacturing, automation, system integration and remanufacturing) especially at low TRL, to impact on CO2 reduction at vehicle or fleet level during operations, is a daunting task. Integration certainly plays a very important role. This is the reason why one of the proposed priorities in the VD&M roadmap is to advance further next generation design tools and processes that will allow virtual physically-based integration and virtual manufacturing to be evaluated at very early stages of the process and therefore allow even better optimization of vehicles. Technology evaluators are called to provide good approximations, assessing in detail the impact that results from the development and deployment of considered technologies.

6. Which **gaps** (science, technology, innovation, market, policy, consumer acceptance, user needs) and potential game changers need to be taken into account?

The roadmap identified three specific technological and non-technological areas that need to be accelerated towards transforming the energy and transport system. It is also clear that decisions at product and market level have to be taken by the industry, which solely takes the financial and technological risk. Beyond the three proposed cross-modal R&I paths, the VD&M roadmap identified additional gaps and enabling technologies (e.g. new materials, superconductivity, energy storage devices, vehicle customization and distributed manufacturing).

7. How **policies** driven by demand could contribute to the development and deployment of the considered technology (i.e. public procurement).

Research and innovation are part of the Commission's new Better Regulation framework. The Better Regulation tools also allow identifying cumulative burdens or inefficiencies of EU regulation and assessing impacts on competitiveness, relevant to innovation. In this context, the roadmaps should not contradict other policies and not hinder European competitiveness.

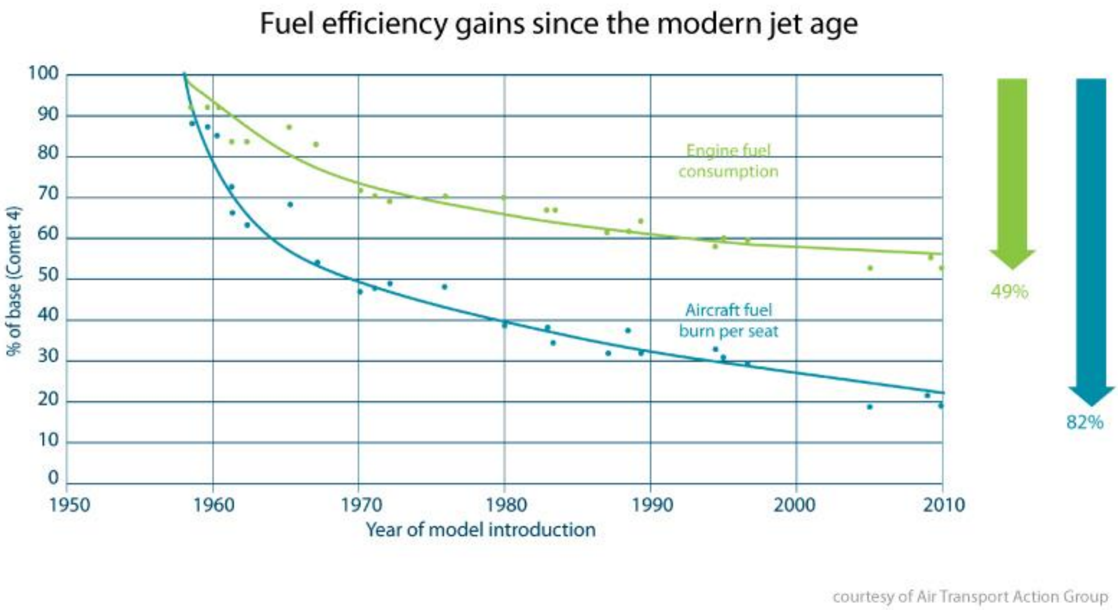
8. Where does the **international cooperation** in R&I represents an added value? how?

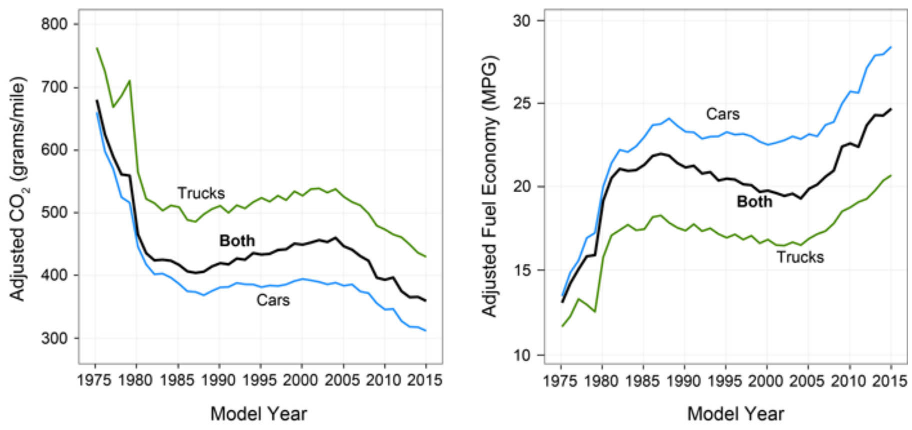
Development of standards is an enabler to today's globalized supply chain. The opportunities of international cooperation in this context should be given high priority. Equally important is data exchange at operational level with high impact to environmental goals (e.g. 4D trajectories for aviation). At this level, circular economy-based design and manufacturing of transport vehicles is an excellent topic that can be addressed at international level.

1.2 Introduction

Civil commercial transport vehicles are designed and manufactured to respond to market needs, which are translated to requirements and are mainly driven by product lifetime cost. Environmental issues were always taken into consideration but by and large were not the driving force. In times of high fuel prices, the development of technologies towards minimizing operating cost (part of which is fuel cost) is directly proportional to CO_2 emissions reduction. Between 2002 and 2013, the fuel prices have almost quadrupled. Less fuel efficient transport vehicles were retired early and replaced with more efficient ones. On the contrary, in periods of low fuel costs, operators usually delay the retirement of older vehicles, as they still remain in the economic zone. The long industry development cycles and high fixed cost structure, common to the design and manufacturing of transport vehicles, justify public intervention and sustained investments in research and development.

Over the last fifty years, design and manufacturing of transport vehicles has followed an evolutionary path. Transport vehicles were continuously optimised, mostly in an empirical way, integrating new technologies as well as responding to global mega-trends. Yet, design and manufacturing improvements in aircrafts and cars, powered by internal combustion engines, have slashed the fuel burn and emissions per passenger km by more than 80% (Figures 1 & 2).





[1]Adjusted CO_2 and fuel economy values reflect real world performance and are not comparable to automaker standards compliance levels. Adjusted CO_2 values are, on average, about 25% higher than the unadjusted, laboratory CO_2 values that form the starting point for GHG standards compliance, and adjusted fuel economy values are about 20% lower, on average, than unadjusted fuel economy values that form the starting point for CAFE standards compliance.

Figure 1 & 2 – Fuel efficiency of jet engines, cars and trucks.

While, there is still room for further improvements and higher fuel-burn gains towards counter balancing the annual passenger and freight growth, many of the technologies onboard transport vehicles have reached their maximum potential. Today, the evolutionary path of car design and manufacturing is already disrupted by the high degree of electrification, digitalization and automation. Maritime and air-transport demonstrated electric and hybrid technologies at small scale, preparing the ground for real transport vehicles in the years to come. Competitiveness of the European industry and emerging flexible and decentralised manufacturing processes will further accelerate those changes. However, cyclicality of the industry development, high fixed cost structure coupled with moderate growth and low profit margins hold back such changes.

The STRIA vehicle design and manufacturing roadmap proposes three key research and innovation paths that will enable the achievement of the Energy Union targets, while boosting the European industrial competitiveness.

I. Advancements on Design Tools and Processes

Continuous reduction of energy demand and environmental footprint, as well as increased passenger comfort, resulted in transport vehicles with high degree of complexity (more than 2 million parts and more than 7 million lines of software code in a modern aircraft). Multidisciplinary interactions between sub-systems and difficulties and uncertainties in the final integration and manufacturing give further rise to unexpected costs and delays.

Collaborative, integrated, multidisciplinary, scientific-based and validated design processes and tools, that make use of high performance computing, will allow efficient design, optimization and manufacturing of transport vehicles. Such advanced computational design tools and processes should seamlessly validate models with physical data from new and updated testing facilities. The collaborative processes should evolve from data-based to model-based exchanges. Uncertainty quantification and visualization of trade-offs should support the integrated capabilities. These tools and processes will expand the design envelope and contribute to new design architectures that will transform the transport system. Europe is world leader and should maintain the leadership.

The initiative will enable Energy Union targets as well as boost the competitiveness of the European transport vehicle integrators, along with their supply chain. Research laboratories and academia should contribute and strongly engage to this initiative.

II. Advancements on New Vehicle Concepts and Architectures

In order to meet EU emission targets, new vehicle concepts and architectures with disruptive new structures, systems and power generation should be developed for all transport sectors. Electric/hybrid concepts and architectures will revolutionise and transform the transport system. Further developments depend on research on power electronics, energy storage devices as well as superconductivity advancements in the medium term. System integration for all transport vehicles is a key enabler.

These new vehicle concepts and architectures will provide significant improvements in emissions in all transport sectors and permit the attainment of ERTRAC, EU Integrated Maritime Policy and Flightpath 2050 energy efficiency and environmental targets.

Research is required to facilitate the changes in vehicle design concepts and architectures while guarantee the same or improved levels of safety and security. Synergies exist between automotive, aeronautics, maritime, rail, space and defence and should be exploited. European supported research is lagging behind in exploiting synergies and integrating knowledge created in different EU research initiatives. Research on design tools and processes as well as vehicle architectures and system integration are excellent pilot topics towards exploiting synergies at European level.

Figure 4. Concept aircraft (Courtesy, Airbus)

III. Circular economy – modular vehicle architecture and remanufacturing, greening industry

In Europe, End-of-Life Vehicles (ELVs) constitute about 8–9 million tonnes of waste per annum, which must be properly managed. The EU regulations provide an ambitious framework for 95% recovery by weight per vehicle in the automotive industry. The appropriate recovery of ELVs allows for both economic and environmental benefits, as for example, remanufacturing of automotive components saves on average 50-80% of energy use, and 85% of material use. The integrated vehicle design and manufacturing process based on the eco-design concept is a key element to contribute to circular economy.

Greening the primary production and supply chain operations could be achieved by optimizing processes, with digitalization along the value chain enabling modular vehicle architecture and a closed loop approach. There is need for research on innovative repair and end-of-life recovery options, which allows for a shift from traditional recycling to more energy efficient remanufacturing. New lightweight and easily recyclable materials are needed, as their industrial implementation will allow for the phasing out of materials which are non-recyclable or difficult to recycle (loss of quality in recovery process). Promoting eco-design is crucial, as it reduces the negative environmental impact and increases energy efficiency in the whole life cycle of the vehicles, as well as enabling reuse (including new second-life applications). New methods of organizing the vehicle design and production process are required, including supporting measures, such as the drafting of standards for assessing product performances and process sustainability.

The shift towards a closed loop approach in the transport industry, particularly in the area of vehicle design and manufacturing will have a significant impact on the reduction of primary energy and primary materials usage. Greening the vehicle manufacturing processes and closing the materials loop in the whole supply chain will improve competitiveness of the European transport industry and will enable meeting Energy Union emissions target.

2. Policy Targets and Objectives

2.1. EU targets for climate protection and energy security

2.1.1. Road transport

Transport emissions accounted for almost one-quarter of the EU's total GHG emissions in 2013. Road transport has the biggest part - almost 73% of all GHG transport emissions. Passenger cars accounted for 60% of all road transport emissions and HDVs for 27%. Emissions from light duty trucks comprise 8.7% of total transport GHGs (and 12% of all road transport GHG emissions) [1]. Since 1990 road transport emissions have increased by almost 17%[2].

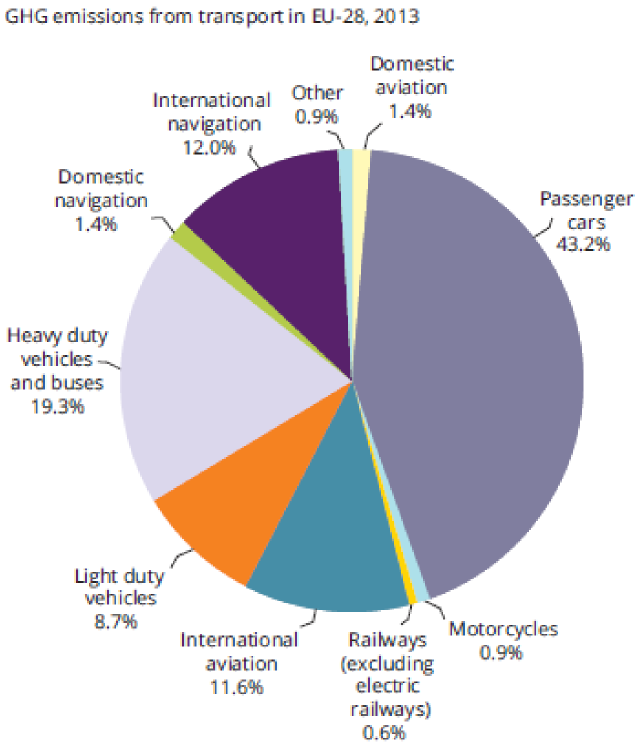


Figure 5. GHG emissions from transport in EU-28 in 2013[3]

Emissions of CO_2 from newly registered vehicles have fallen by 12% and the 2015 target, of 130 g CO_2/km, was met in 2013, two years before the deadline. In 2014, the majority of the car and light commercial vehicles met their CO_2 emission target. Both regulations for passenger cars (EC No 443/2009) and light duty vehicles (EC No 510/2011) seem to be

[1] European Environmental Agency , TERM report, 2015
[2] European Environmental Agency , TERM report, 2015
[3] EEA, 2015e, Annual European Union greenhouse gas inventory 1990–2013 and inventory report 2015, Technical report No 19/2015, European Environment Agency (http://www.eea.europa.eu/publications/ european-union-greenhouse-gas-inventory-2015)

efficient enough[4]. “However, car emissions still need to fall by an additional 23% in order to meet the 2021 target of 95 g CO_2/km.” [5].

Road transport accounts for consumption of almost three-quarters of total energy demand in the EU-28 in 2014. The fraction of road transport fuel that is diesel has continued to increase, and in 2014 is to just over 70%, compared with 52% in 2000, which reflects the increasing dieselisation of Europe's vehicle fleet since that time[6]. The CO_2 emissions are generated in the whole lifecycle of the vehicle. The use phase creates the higher emissions for all sorts of powertrains (cf. Figure 6).

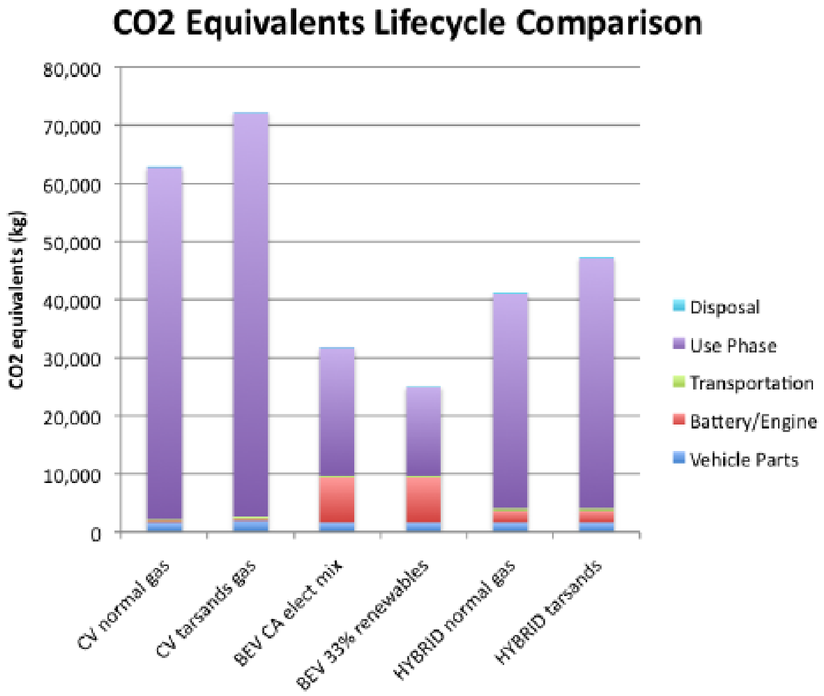


Figure 6. CO_2 equivalents[7]

The 2011 Transport White Paper's decarbonisation targets will not be met unless further ambitious measures are put in place[8].

2.1.2 Waterborne Transport

Maritime transport emits around 1000 million tonnes of CO_2 annually and is responsible for about 2.5% of global greenhouse gas emissions[9] according to the International Maritime

[4] European Environmental Agency , TERM report, 2015
[5] European Environmental Agency , TERM report, 2015
[6] European Environmental Agency , TERM report, 2015
[7] Aguirre, K., Eisenhardt, L., Lim, C., Nelson, B., Norring, A., Slowik, P., & Tu, N. (2012). Lifecycle analysis comparison of a battery electric vehicle and a conventional gasoline vehicle. California Air Resource Board.
[8] European Environmental Agency , TERM report, 2015
[9] http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Greenhouse-Gas-Studies-2014.aspx

Organization. It is important to note however that global NO_x and SO_x emissions from all shipping are much higher and represent about 15% and 13% of global NO_x and SO_x from anthropogenic sources reported in the IPCC.

Maritime CO_2 emissions are projected to increase significantly in the coming decades. Depending on future economic and energy developments, credible scenarios project an increase by 50% to 250% in the period to 2050. Further action on efficiency and emissions can mitigate the emissions growth, although all scenarios but one project emissions in 2050 to be higher than in 2012 (3rd IMO GHG Study). This increase is not compatible with the internationally agreed goal of keeping global temperature increase to below 2°C compared to pre-industrial levels, which requires worldwide emissions to be at least halved from 1990 levels by 2050.

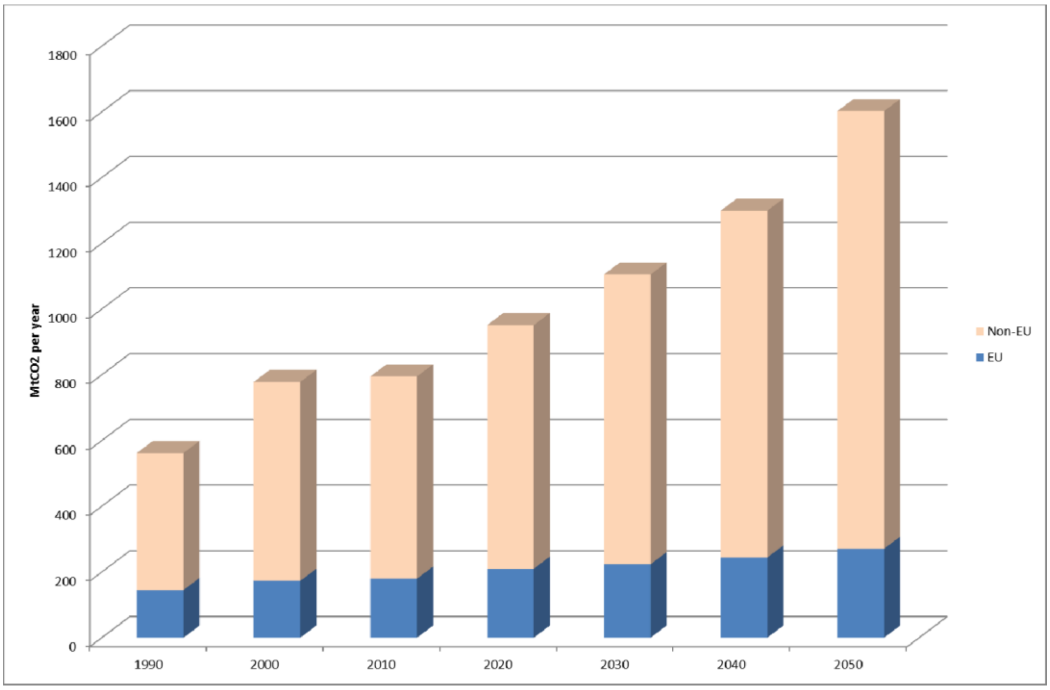


Figure 7. Projected maritime emissions.

2.1.3 Aeronautics

The climate impact of aviation is driven by long-term impacts (several hundreds of years) from CO_2 emissions and shorter-term impacts (several decades) from non-CO_2 emissions that include water vapour, particles and nitrogen oxides (NOx). Based on current understanding, aviation affects climate in three main ways: emissions of CO_2 that results in positive radiative forcing (warming); indirect effects of nitrogen oxide (NO_x) emissions that are partially balanced between warming and cooling; and formation of condensation trails and cirrus clouds whose overall effect is considered to cause warming. Advisory Council for Aviation Research and Innovation in Europe (ACARE)[10], reports that the aviation industry produces around 2% of human-induced CO_2 emissions. This may increase in proportion, as other energy consumers move towards de-carbonisation and as the demand for air-

[10] *Strategic Research & Innovation Agenda*, ACARE Advisory Council for Aviation Research and Innovation in Europe, 2012.

transport continues to increase. The non-CO_2 effects are still poorly understood and carry large uncertainties. Nevertheless, the total radiative forcing from aviation in 2005 was estimated to represent some 3.5% and 4.9% of current anthropogenic forcing, excluding and including cirrus cloud respectively[11].

Besides GHG emissions and noise, “production and assembly of the components of aviation systems consume energy and raw materials. They also require the use of a variety of chemical processes, that give rise to gaseous emissions as well as liquid and solid wastes. Aviation operations consume a wide range of chemicals, for cleaning and washing processes, stripping and repainting of air vehicles as well as de-icing of runways and air vehicles.”[12]

European and International agendas and government offices have set significant targets to reduce the emissions in aeronautics. The European Flightpath 2050[13] sets an overall goal of a 75% reduction in CO_2 emissions per passenger per kilometre over 40 years, while the Strategic Research and Innovation Agenda (SRIA) by ACARE sets targets and baselines for emissions to be achieved in the short-, medium- and long-term with contributions from both technologies and operations:

- “In the short-term, the ACARE goals set out in SRA 2 for 2020, including a 50% reduction in CO_2 emissions per passenger per km, are pursued and met. Many evolutionary technologies are mature near to their maximum potential and disruptive, breakthrough technologies are included in projects.

- The medium-term goal for 2035 coincides with a significant point in the worldwide aircraft fleet renewal cycle and with a generational step change in technologies in service and operational practices. Disruptive technologies are delivered in advance, by or before 2030, to be included in manufacturers’ projects. The enabling technologies, to deliver the Flightpath 2050 performance levels, are initiated. A detailed technology vision is ready by 2035 so that research and development programmes are set in hand from that point forward to deliver at TRL6 early enough to achieve the 75% CO_2 and 90% NO_x reduction goals.

- In the long-term, the results of continuous performance evaluation are used to reorient and redefine research activities and to refine the split of goals between domains. This accounts fully for mature evolutionary technologies and for the emergence of disruptive and radically new technologies.”

These European targets can be compared to those ones of the IATA resolution[14] which is looking for reductions in carbon emissions for a 1.5% average annual fuel efficiency improvement between 2010 and 2020, carbon neutral growth from 2020 onward, and a reduction of 50% in net emissions by 2050 compared to 2005 levels. The performance goals

[11] Lee et.al, Atmospheric Environment 44 (2010) 4678–4734
[12] ACARE SRIA vol.1
[13] *Flightpath 2050 - Europe’s Vision for Aviation*, Report of the High Level Group on Aviation Research
[14] *IATA Resolution on the Implementation of the Aviation “CNG2020” Strategy*, June 2013.

also support meeting and exceeding projected noise and NO_x standards, such as those recommended by ICAO[15].

Similar targets are reported by Air Transport Action Group (ATAG)[16], "the aviation industry collectively agreed in 2008 to the world's first set of sector-specific climate change targets. The industry is already delivering on the first target - to continue to improve fleet fuel efficiency by an average of 1.5% per year until 2020. From 2020, aviation will cap its net carbon emissions while air traffic continues to grow to meet the needs of passengers and economies. By 2050, the industry has committed to reduce its net carbon footprint to 50% below what it was in 2005." This view is illustrated in Figure 8, and according to ATAG these targets can be reached using a range of different efficiency opportunities and by working collaboratively with the support of governments. ATAG presents that the aviation industry has a collective four pillar strategy for reducing its climate change impact: technology, operations, infrastructure and market-based measures.

Also NASA in its Strategic Implementation Plan[17] describes community performance goals for subsonic transports that include specific levels of reduction in energy consumption, emissions of nitrogen oxides (NO_X), and noise.

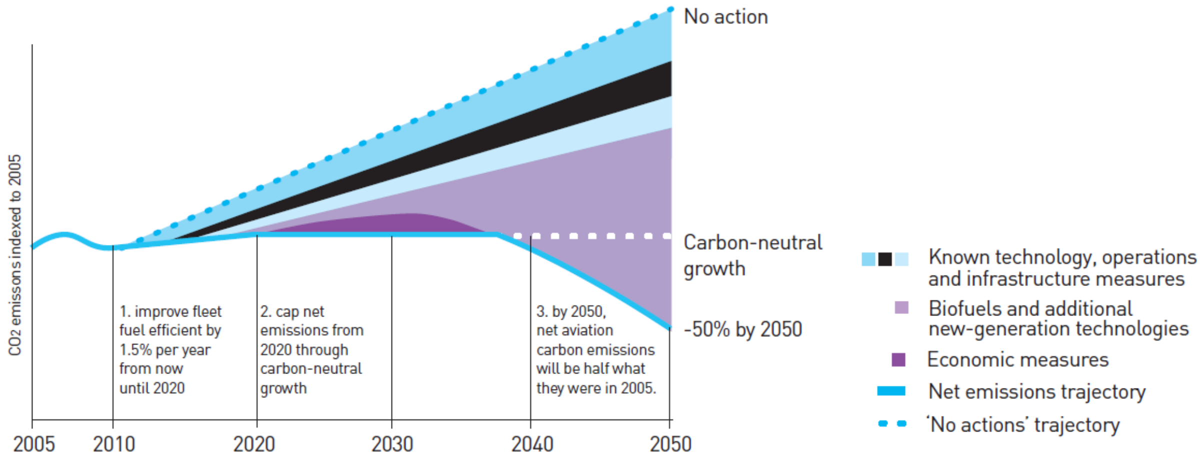


Figure 8. Aeronautics vision for achieving carbon neutrality

Over the last 50 years, the aviation industry has cut fuel consumption and CO_2 emissions by more than 80%, NOx emissions by 90% and noise by 75%, according to ATAG. Despite efficiency improvements, CO_2 emissions from international aviation are projected to be seven times higher in 2050 than in 1990. At the Paris climate conference (COP21), countries agreed to limit climate change to well below 2°C. Without considerable contributions of the aviation sector to global mitigation efforts, this goal cannot be achieved. The aspirational goal of ICAO is to achieve Carbon Neutral Growth from 2020 (CNG 2020) – fig.8. It will be achieved through a basket of measures (Non-market and Market ones):

[15] ICAO Working Paper A38-WP/25, Developments in Civil Aviation and the Environment, July 18, 2013.
[16] *Aviation Benefits Beyond Borders*, Air Transport Action Group, April 2014.
[17] NASA Aeronautics - *Strategic Implementation Plan*, www.nasa.gov, 2013.

- Aircraft Technologies (lighter airframes, higher engine performance, CO2 efficiency standard)
- Operational Improvements (improved ground operations and Air-traffic management)
- Sustainable alternative fuels
- Global market-based measures (GMBM)

European and American studies suggest that evolutionary improvement of aircraft technologies will not be sufficient to achieve international targets in terms of environmental impact reduction. Disruptive key technologies have to be developed together with new approaches for design and manufacturing.

2.2. Issues beyond climate and energy policy

Automotive industry faces two challenges[18]:

- how to make vehicles more fuel efficient, while keeping costs at an acceptable level (technical challenge),
- how to change customer behaviour and preferences and make green vehicles attractive to consumers (societal challenge).

The environmentally friendly cars nowadays have only limited market success. Recently carmakers are not in the position to demand a price premium for applying new technology in order to recover investments in additional R&D. There is not enough market-driven demand (market pull) for energy efficient vehicles and transport services. In EU most of the energy efficient technologies are driven by regulations rather than real demand (technology-push). Relatively low fossil fuel prices didn't encourage customers to buy new types (energy efficient) vehicles or to switch towards energy efficient transport services. The scarcity of the infrastructure for charging electric or fuel cells is discouraging the growth of demand for energy efficient vehicles.

The current mobility patterns and the urban planning still encourage the usage of private vehicles instead of public transport. Aging population might be an important issue because of lower acceptance of new technologies comparing to the younger consumers.

The aviation industry faced in recent years security concerns which overshadowed safety that is record low. Security management systems need to be further developed and standardised. Cyber threats in aviation also pose a considerable risk which is expected to grow. Common use of open standards brings opportunities for interoperability and connectivity, but also cybersecurity vulnerabilities.

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[18] PriceWaterhouseCoopers report "The automotive industry and climate change Framework and dynamics of the CO2 (r)evolution", 2007

2.3. Impacts on competitiveness, growth and job creation

2.3.1. Road transport

The automotive industry plays an important role in European economy. Its competitiveness is crucial to sustain and even increase the over 12 million jobs. Manufacturing accounts for 3 million jobs, sales and maintenance for 4.3 million, and transport for 4.8 million[19]. It constitutes to 4% of the EU's GDP. The EU was traditionally the biggest automotive producer but the last decade brought some changes. Car transport is the dominant mode of passenger transport, although the average distance travelled by car per inhabitant has fallen since 2009, because of economic and changing socio-demographic factors[20].

In the last years the automotive industry is driven by the constant costs –pressure, shift in the consumer markets, and stricter environmental regulations and the circular economy concept. "The aim of the EU's policy in the automotive sector is to establish an internal market for vehicles, ensure a high level of environmental protection and safety, strengthen competitiveness, and provide a stable level playing field for the industry"[21].

Challenges include, high complexity and cost pressure (price-cost gap narrows), decreasing demand for new vehicle in EU and growing competition from Chinese and India manufacturers. In EU there is increasing number of regulations with respect to environmental and safety standards. The pressure on development of new alternative powertrain technologies with lower-emission is a challenge (impulse for disruptive technologies) and burden at the same time, as manufacturers do not know what will be the prevailing technology of the future. The customers search for customized cars which better suit individual preferences. It results in rapidly increasing complexity of operations at the assembly line. The order-to-delivery times (OTD) get longer (up to few months), which discourages potential customers. The new cars sales shift to emerging markets (mainly China, Russia, India and Brazil). The car market in EU and US is saturated and new cars sales are dropping. The fastest growing demand for transport services will be in low income countries (mainly Africa and Asia)[22]. By 2020, emerging markets will generate over two-thirds of the total automotive profit (China will be the leader). The current policy makers impose more and more strict environmental regulations, which results in higher vehicle manufacturing costs. The OEMs manage to keep the 3-4% annual cost cutting goal to keep the pace with new requirements and make some profit margins, but a lot of solutions are not realistically valued by the customers. Moreover, in emerging markets, where most of the new vehicle demand has shifted, such legal restriction driven innovations are not valued. This results in lower competitiveness of EU manufacturers compared to the Asian ones.

[19] (http://ec.europa.eu/growth/sectors/automotive/index_en.htm

[20] European Environmental Agency, TERM report, 2015

[21] http://ec.europa.eu/growth/sectors/automotive/policy-strategy/index_en.htm

[22] Global Transport Scenarios 2050, World Energy Council

2.3.2 Waterborne Transport

Whilst Asia now dominates the world ship building market European Ship Manufacturers have focused on high added-value “special vessels”. These include passenger ships and ferries, cruise ships and working vessels such as offshore support and tugs. These special vessels represent only ~7% of the number of vessels, but Europe has almost 50% of this market sector[23]. This sector also has much higher added value, than most transport vessels, with high degrees of automation and complex propulsion systems.

It is also clear that Asian manufacturers could target these classes of vessels to the detriment of European manufacturing. It is therefore important that the European manufactures move quickly with hybrid type systems to maintain their technology lead in this area.

2.3.3 Aeronautics

Nowadays, Europe has a world-leading position in aeronautics. As reported in the SRIA by ACARE, “over the past 40 years, European aviation has successfully risen to the top of the world rankings, through the combined, coordinated and collective efforts of many European entities, both public and private, major companies, thousands of small and medium-sized enterprises (SMEs), academia and research laboratories. Together they contribute to the global reach and success of European aviation.”

This world-leading position is demonstrated also by the bibliometric data presented by the European Commission[24], based on Scopus database. Aeronautics is one of the fields in which the EU has a world scientific lead (in terms of high-impact). Besides, in aeronautics the EU submits the largest share of patent applications by the Patent Cooperation Treaty (PCT), and is almost on a par with North America. Aeronautics is also one of the sectors in which European countries have the highest intensity of international co-patenting, with an intensity level above the world average.

However, competition is growing not only from established competitors, such as the United States and Canada, but from recently emerged and emerging countries, such as the so called BRICS countries (Brazil, Russia, India, China and South Africa). Besides, new countries as the Gulf States and Southeast Asia are heavily investing in aeronautics. Indeed, government authorities have understood the strategic nature of aviation in terms also of societal benefits and job creation, and support their industries accordingly. This impacts the competition between countries as well as between companies.

As highlighted in the SRIA by ACARE, “even though the global aviation market is increasing in size, Europe must preserve its preeminent position to ensure the continued success and economic contribution of its aviation industry by investing continuously and heavily in key enabling concepts, technologies and systems, but also by developing an adequate policy framework.”

[23] Lloyds shipping 2015

[24] Innovation Union Competitiveness Report 2013, European Commission, 2014.

New aircrafts will be also designed, but aerospace research is a long-term business. Decisions on research and technology development may have consequences on the future of the sector, decades after they have been made. Moving from laboratory to production can take 20 years or longer. So aerospace industries have already chosen their path in design to the mid-2020s and have few decisions left that need to be taken to the mid-2030s. Beyond that, the path is less certain, but the decisions have to be taken in the near future.

3. Baseline and State-of-the-Art

3.1. State of the technology development

3.1.1. Road transport

In Europe the numbers of diesel engines will grow and petrol engines will be less popular[25]. Between 2000 and 2013 the proportion of diesel in energy consumed by road transport increased substantially, as many European governments provided financial incentives to directly or indirectly encourage usage diesel engines[26].

The number of electric vehicles (EVs) has grown only by a minimal proportion (0.07%) of total passenger car fleet[27].

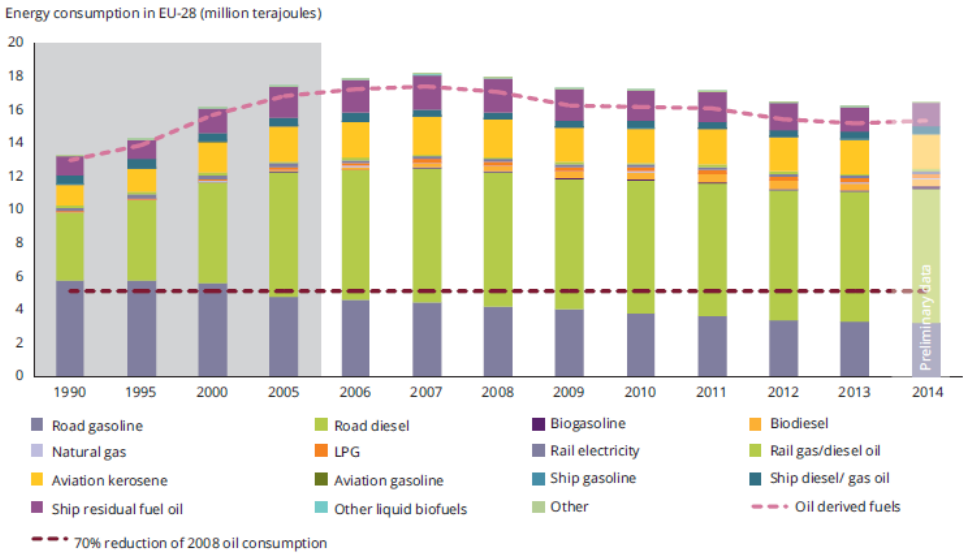

Figure 9. Energy consumption in transport [28].

The fuel efficiency and emission characteristics of LDV have improved between 1990 to 2009, but that positive environmental impact is offset by growing car ownership and

[25] Global Transport Scenarios 2050, World Energy Council
[26] European Environmental Agency , TERM report, 2015
[27] European Environmental Agency , TERM report, 2015
[28] European Environmental Agency , TERM report, 2015

distances travelled. The energy efficiency in EU is mainly driven by regulations rather than by changing real demand patterns. The customers are (and will be) more focused on active safety solutions, infotainment and combined mobility-communication solutions. The easier availability of cheaper alternative power-trains might encourage customers to change their preferences.

"The global transportation sector will face changes resulting from demographics, urbanization, pressure to minimize and dislocate emissions outside urban centres, congestion of aging transport infrastructure and growth in fuel demand"[29]. There will be shift from vehicle ownership to vehicle-usage-services solutions. The new customer segments will appear. The demand for small urban preferably electric cars will grow.

3.1.2 Waterborne Transport

The vast majority of modern vessels rely on some form of diesel engine for their prime propulsive power. The majority of vessels rely on a diesel engine driving a propeller which at first site would seem a simple and efficient system. However, this is only efficient close to a single operating point, which means that ships with a more complex operating cycle can be significantly improved by other technology. The advantage of a hybrid power plant is based on the fact that diesel engines are most efficient when run at around 80% of their maximum capacity. At lower performance levels they use proportionately more fuel, generate higher emissions, require more maintenance and wear out more quickly. Many vessels do not operate at full power most of the time, and this is when it becomes more efficient to shut down the main engine and generate power using a smaller generator that is running on or near the optimal (80%) level. A more flexible alternative is to use batteries as a temporary power source, resulting in zero emission cruising. When the battery level drops the generator starts and recharges them under its own optimal running conditions. The result is that the combination of diesel engine, generators and batteries allows the system to supply the required power more efficiently and cleaner than a conventional diesel system. This system can also permit the use of batteries in ports which can reduce emissions significantly in major port areas. This also requires further grid connection capabilities to allow re-charge as well as the "cold ironing" process.

Hybrid Electric Propulsion systems have been shown to provide both fuels and emission savings in practice with major fuel savings reported for some ship categories and are starting to make significant market penetration for certain vessel categories. This is particularly applicable to vessel categories where the operating cycle is varied and applies to;

- Cruise Ships (penetration of >90% with most using electric pods)
- Ferries
- Working ships such as tugs and offshore support vessels

However, this trend has slowed recently due to the fall in fuel prices.

[29] Global Transport Scenarios 2050, World Energy Council, p. 4

This list also corresponds closely to the class of high added-value ships manufactured in Europe whereas Asia has focused on long distance transport vessels. The latter have a very constant operating cycle and are generally unsuitable for Hybrid where the flexibility and buffering capability permits significant fuel savings. In terms of these categories most new Cruise vessels (around 99%) are Hybrid Electric designs with working ships currently around 33%.

The key technologies of Marine Hybrid Electric Propulsions systems are:

- Compact high efficiency electrical machines
  These machines tend to be direct drive and relatively low speed machines compared with other forms of transport. This is due to restrictions on propeller speeds due to cavitation effects. Also power density tends to be less of an issue although volumetric power densities can be a factor for example for podded applications. However, efficiency is important as in other sectors.
- Highly Integrated power networks
  These are standalone networks but need to be able to operate in all types of operating conditions including on energy storage, hybrid or connected to a land grid for cold ironing for example. This requires complex control and protection designs.
- Advanced power electronic drive systems
  These provide speed control for the motors and are therefore important in complex operating cycles.
- Battery and Electrical Energy Storage
  More and more battery systems are being installed in ships to provide flexibility and control. Advanced battery systems with a good operating lifetime and energy densities are important.
- Advanced system integration
  Many topologies are possible and system integration is becoming a major issue for these classes of ship design.

In addition, switching to LNG as a marine fuel is also likely, as the burning of LNG releases less toxic emissions than conventional fuel oil. Several solutions are available and include complex gas combustion systems. Switching to LNG fuelled engines is expected to contribute to a 95% reduction in SOx emissions, and to a nearly 90% reduction in PM and NOx emissions. One of the major obstacles at present is refuelling, as significant infrastructure investments[30] are still needed for this to become a viable solution. For many companies, LNG does not offer a profitable business model yet, as the higher equipment costs for engines and tanks are not offset by savings in fuel or operating expenses - although this could change with the use of restrictions on the use of low-costs heavy fuel oils. The use of LNG engines is often combined with Hybrid Electric propulsion to give a highly efficient system with lower emissions than traditional ships.

3.1.3. Aeronautics

[30] The US has opened its first LNG bunkering facility in Port Fourchon (Louisiana) in early 2015 and trial refuelling tests have already been carried out.

To be able to reach the EU targets for climate protection and energy security requires ground-breaking changes in future air-vehicle concepts for both the airframe and the propulsion system considering classical and new designs, and at the same time requires new approaches for design and manufacturing.

The application of biofuels is probably that one that has applicability in the near future. Biofuels and renewables will be integrated to address dwindling natural resources. The US Federal Aviation Administration (FAA) has set a goal for the US aviation industry to consume one billion gallons of renewable jet fuel each year from 2018 onwards[31]. This goal is an aggregate of renewable fuel targets for the US Air Force, the US Navy and US commercial aviation. The renewable fuel target for commercial aviation represents 1.7% of predicted total fuel consumption by US airlines in 2018.

Electric propulsion is the more challenging solution for eliminating carbon emission. It has begun with two-seat trainers, but electric or hybrid-electric architectures can be reached in the near future so to power aircraft with fewer than 100 seats. Airbus Group and Siemens have signed a collaboration agreement[32] in the field of hybrid electric propulsion, and have launched a major joint project towards the electrification of aviation with the goal of demonstrating the technical feasibility of various hybrid/electric propulsion systems by 2020.

The applicability to electric propulsion for aircrafts larger than 100 seats will be more difficult, and will definitely require breakthrough technologies. The time horizon is towards the mid of this century. One of the big enablers for electrification is energy storage. Different systems of energy storage will be needed, such as batteries, supercapacitors, multi-functional materials or even more advanced concepts. Hybrid electric aircrafts will possibly use distributed propulsion and larger aircraft using this approach will require superconducting electrical systems to obtain the required power density and efficiency. These systems will require, in turn, cryogenic cooling.

Even if solar power is still far to be a reality especially for commercial aircrafts, and several studies have been already performed regarding how much power an airplane can capture from sunlight, new technologies can be developed to store energy from solar cells, contributing to aircraft electrification.

The development of an electric or a hybrid design will open up completely new design spaces. Many studies[33] have already demonstrated the need to enhance the synergies between the different disciplines such as propulsion, aerodynamics and the structure in order to compensate the negative weight impact of the advanced electrical system integration. Indeed, while deeper investigations together with innovative technology step forwards are requested in terms of power generation and storage, together with more

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[31] Federal Aviation Administration (FAA*). FAA Destination 2025.* Washington, DC. 2011.

[32] http://www.airbusgroup.com/int/en/news-media/press-releases/AirbusGroup/Financial_Communication/2016/04/20160407_Airbus-Group_MoU_Siemens.html, April 2016.

[33] C. Pornet and A.T. Isikveren, “Conceptual Design of Hybrid-Electric Transport Aircraft”, Progress in Aerospace Sciences, 2015; 79: 114-135.

efficient electric motors and ways of transmission, from the aircraft design point of view it is evident that electric propulsion offers to the designers an unique opportunity to explore unconventional configurations that are not attractive when based on conventional propulsion systems. A successfully application of electric propulsion to transport aircrafts requires a rethinking of aircraft configuration and for sure cannot be successful by simply substituting a conventional propulsion system with an electric one.

The majority of today's large civil transports are propelled by high bypass ratio engines characterized by a large fan mechanically connected and driven by low pressure turbines. The largest part of the power produced by the engine is used to rotate the fan to generate the engine thrust. Despite a large by-pass ratio allows to reduce the fuel consumption and the engine noise, it cannot be increased indefinitely due to the increased weight and diameter of the fan.

In a traditional aero turbine engine, the fan and turbine engine are connected by the same shaft and rotate at the same speed except in the case of new geared-box engines. This physical link between the power user and the power producer in the classical aero turbine engine represents at the same time a strong constraint in a disruptive step forward in traditional aircraft propulsion but, at the same time, represents the business case for electric propulsion. By removing the mechanical coupling between torque and speed substituted by an electrical coupling introduce a further design freedom enabling a more advantageous trade between on-design and off-design performances allowing for a practical implementation of the emerging concept of "distributed propulsion" based on the use of multiple small propulsors or engines embedded on the wing or fuselage. The design of this revolutionary airframe/propulsion integration concept could be achieved by connecting multiple propulsors to one or more highly efficient power generator. Turboelectric propulsion offers so the possibility to introduce new aircraft design configuration.

Electric distributed propulsion technology is expected to disrupt the traditional aircraft design paradigms. An important example is the redesign of the wing for optimum efficiency in cruise enabled by distributing propellers along the leading-edge as initiated in the Leading Edge Asynchronous Propellers Technology (LEAPTech) Project by NASA[34]. Indeed, wing design is usually constrained by low-speed where the high lift system has to guarantee an acceptable take-off and landing field performance. Taking advantage of the propeller slip-stream effect on the wing generated by the distributed engines, the low-speed requirement on high-lift devices and wing design could be reduced, in favour of opening the design space for optimum wing design for en-route operations. The advantages in terms of aircraft design impact many other aspects that can leverage the improved performances in a broader range. For example, differential thrust can be used for aircraft control and reducing the size of control surfaces. Moreover, the global safety of the aircraft can be improved since the distributed propulsion system is intrinsically more fault tolerant.

Both considering classical and new aircraft configurations, further research in aircraft structures is needed. The convergence of materials such as composites or new metallic alloys, with new manufacturing techniques as automated fiber placement or 3-D printing, and with advanced computational methods, are changing the manufacturing capabilities of

[34] http://www.jobyaviation.com/LEAPTech/

the airplanes and are increasing their design space. The structures can become monolithic, present adaptive characteristics and offer multifunction with the capability, for example, to storage energy.

The development of electronics already heavily impacted on the progress of aviation. Usually these devices are applied to existing transport systems, but there is an increasing demand of embedded components. In the near future it is expected that new manufacturing methods at nano-micro scale level could produce a relevant impact in terms of miniaturization so that nano-micro sensors and actuators can be embedded into sub-components of transport vehicles or, more challenging, into multi-functional structures. Sensing and data transfer capability, in most of the cases using wireless mode, can improve the control, monitoring and maintenance of transport systems.

The intersection of the research field in structures and of computer sciences has introduced big changes in the design of aerospace vehicles. Computer aided modelling and finite element simulation was the initial enabler. In the near future it should be possible to design the aircrafts in a full 3D model from the beginning to the end of the life cycle. From concept and requirements to architecture will be through design in 3D models with physics based simulations wrapped around them for verification and validation. Manufacturing and integration tests and ultimately sustainment in the field can be more and more performed in a virtual environment.

A larger use of computational analysis and optimization early in the design phase can allow more options to be explored in search of the best solution to the requirements. Consequently, the design time will radically decrease, even if the speed of decision making for design will probably further increase. Besides, increasing automation in engineering and manufacturing will bring down cycle times and cost. The convergence of big data and data analytics will allow having airplanes that are more efficient, safer and require less maintenance.

Modularity and modular architectures are expected to advance further and shift from recycling to remanufacturing.

3.2. Barriers and gaps; as well as success stories

3.2.1. Road transport

The automotive industry faces growing complexity and cost pressure. There is need for more modular solutions. The modularity focus in the design of vehicles allows to speed up return on investment as the new technologies can be use across different brands and models. It helps to provide the financial resources to mount a long term R&D effort and quicker developed prototypes for real life tests. It helps to improve the technology readiness level (TRL scale) and overcome the risks of “death valley” (TRL 4-TRL6). According to the industrial experts[35], “40 % of all investments go into innovations that never make it into the car or are

[35] Olivier Wyman report “2015 car Innovations - A comprehensive study on innovation in the automotive industry”

never produced in sufficient numbers due to a lack of market acceptance, 20 % is for necessary serial development, another 20 % is for innovations that fulfil legal requirements but do not add to a product's distinctiveness, only remaining 20 % represents profitable innovation investment". It means that more financial support from public sector is needed to encourage disruptive energy efficient technologies. There is need for more integration in the supply chain especially with 1st tier suppliers. Lifetime of car models in the past decade in the more advanced countries decreased on average from 8 to almost 4 years. Also, the development time of a new model was shortened from 48 to about 25 months and in 2018 is expected to further reduce the level of 20 months. In order to meet that goal, suppliers must be involved at the very early stage of the vehicle design process. The high costs and low effectiveness of R&D and shorter life cycles of models require that the mega suppliers will take more and more often role of integrators. The main opportunity is to eliminate the inefficiencies along the whole value chain and to achieve economy of scale, quicker elimination of technologies with low market entry potential, avoiding overlapping of R&D work, easier to achieve platforms/modules design. Suppliers will provide more of the value-added content per vehicle.

According to the industry experts[36] the share of regulation-driven new technologies will increase after 2020 up to 60% from current 40%. As the result, OEMs will struggle in prioritizing among differentiating features and customer requirements. Car manufacturers are confronted with the paradox that although customers seem to be willing to drive greener cars, green features play a minimal role in their purchasing decisions[37] (Lane and Potter, 2007). The integration with the suppliers should be achieved by sharing physical and digital resources. There is need for IT solutions that allow safe and efficient exchange of data between different members of the value chain.

The growing complexities of customized vehicles will require a novel approach to the assembly process when building based on global platform. Digitalization will be applied as one of main tools to meet these challenges. The leaders in the sector are dedicated to the concept of Industry 4.0 (networking of the whole value-chain from design to sales services in real time). This means full digitalization, which allows to link man, machine and industrial processes in order to achieve high quality product quicker and more flexible (higher competitiveness). The digitalization creates need for research in short- and mid-term perspective. The average automotive manufacture uses dozens of IT systems along value change. It creates need for research with regard to data compatibility, interchangeability and security (especially regarding digital footprints). There is need for research which focuses on standardization (including data standardization), as it is a key issue to allow such modular approach.

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[36] McKinsey report „The road to 2020 and beyond", 2013.

[37] The adoption of cleaner vehicles in the UK: exploring the consumer attitude-action gap. J Clean Prod 15(11-12):1085-1092

The greening of automotive industry is getting more and more expensive. Although EU manufacturers focused on diesel internal combustion engines (traditional amount of petrol engines is decreasing), they are now making big efforts towards developing further electric vehicles. The hybrid production in EU was not competitive enough comparing to non-EU manufactures (e.g. Toyota). The 2020 target might be reached without introducing disruptive technologies. The OEMs make effort to optimize the conventional ICE-powered vehicles by engine control systems, downsizing, and lightweight or automatic transmissions. In the long-term, in order to achieve the 2011 transport White Paper goals, a big change is necessary.

Important element will be R&D on the various electric powertrain alternatives (especially for growing urban population). Mid-term policy (from 2020 up to 2030) will require transition from ICEs to EVs or augmentation of ICE-based vehicles with electrified powertrain solutions. OEMs will invest more in e-mobility. They will focus mainly on electrical/hybrid powertrains (including batteries), lightweight and aerodynamic technologies. According to World 2050 transport scenarios the traditional ICEs (mainly diesel) will be still dominant. This is also due to the long life of vehicles, making technology change a gradual process.

The application circular economy approach in vehicles design and manufacturing requires actions, as follows:

- research on innovative End-of-Life recovery options and shift from recycling to remanufacturing, which is more energy efficient. According to the Remanufacturing Institute, manufacturers of refurbished products save on average 50-80% of energy use, 86% of water use, and 85% of material use as compared to manufacturing of a new product[38].
- integrated approach to reduce negative environmental impact and increase energy efficiency in the whole life cycle of the vehicles from the design, through production and use phase till recovery (eco-design),
- phasing out of the materials that are not recyclable,
- research in new easy recyclable materials.

Europe, End-of-Life Vehicles (ELVs) constitute about 8–9 million tonnes of waste, that must be properly managed[39]. Directive 2000/53/EC set European targets for vehicle recovery 95% and 85% recycled or reused from 2015. In order to comply with this Directive, vehicle design and manufacturing process must be adjusted. The life cycle analysis (LCA) should be a key concept of research more in the transport sector. The closed loop supply chains are still highly theoretical concept with regards to automotive industry. The recent EU policy focuses on recycling of End-of-Life (EoL) Vehicles, when underestimating other EoL recovery options, especially remanufacturing. For electrically propelled vehicles, the use of decommissioned

[38]http://www.scot-reman.ac.uk/about-remanufacturing/benefits-of-remanufacturing/

[39] Santini, A., Herrmann, C., Passarini, F., Vassura, I., Luger, T., & Morselli, L. (2010). Assessment of Ecodesign potential in reaching new recycling targets. Resources, Conservation and Recycling, 54(12), 1128-1134.

traction batteries in stationary „second life" applications is now being considered. Vehicle LCA studies should embrace uncertainties as an inherent part of LCA and make them explicit in the result. An example of a range based vehicle LCA can be found in Messagie (2014)[40].

A framework based on case studies on Life Cycle Sustainability should be worked out. A typical Life Cycle Sustainability Assessment would combine E(nvironmental)-LCA, S(ocial)-LCA and Life Cycle Cost (LCC) aspects in one multi-criteria assessment (MCA). An eco-efficiency example of combining environmental LCA with a Total Cost of Ownership of different vehicles technologies is explained in Messagie (2013)[41].

Adoption to a Life Cycle Philosophy from the earliest stages of automotive research and development is required to ensure the appropriate selection of technology for lower environmental impacts. Ecodesign should become a standard procedure when designing a vehicle, as it allows to reduce the product's negative impact on the environment at the very early stage. A vehicle should be designed including the largest amount of standardised and recyclable materials, which are properly label to make them easily distinguishable in disassembly and recycling.

The main technological trends in the mid-term horizon 2030 will be electrification of the powertrain, autonomous driving, digitalisation and remanufacturing. Regarding the non-technological trends there is need for innovative approaches to ergonomics at the production line and in the car design for aging drivers and new logistics solutions along the whole value chain.

3.2.3 Aeronautics

The European industry should move faster and adopt faster disruptive new technologies[42]. Nowadays the revolutionary technologies can develop in a fast way, and the length of time that these technologies take for widespread adoption can be really short.

It is expected that there will be a number of new aircraft industries that will spring up, and challenge the traditional and well-established ones. As in the automotive market, that Tesla entered the market that was predominant by heavyweight industries like GM, BMW, Volkswagen and Renault, new industries will also probably enter the aeronautics market, bringing breakthrough concepts, sustainable and environmentally-friendly air-transport.

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40 Messagie, M., Boureima, F., Coosemans, T., Macharis, C., Van Mierlo, J. (2014) A Range-Based Vehicle Life Cycle Assessment Incorporating Variability in the Environmental Assessment of Different Vehicle Technologies and Fuels. ENERGIES Volume: 7 Issue: 3 Pages: 1467-1482

41 Messagie, M., Lebeau, K., Coosemans, T., Macharis, C., Van Mierlo, J. (2013) Environmental and Financial Evaluation of Passenger Vehicle Technologies in Belgium SUSTAINABILITY Volume: 5 Issue: 12 Pages: 5020-5033

42 T. Enders, Airbus – Speech at American Institute of Aeronautics and Astronautics (AIAA), 22 June, 2015, Dallas, Texas, "ARE WE MOVING FAST ENOUGH?"

3.3. Competitiveness of the EU industry

3.3.1. Road transport

There are many uncertainties related to sift in the vehicle design and manufacturing towards decarbonisation and energy efficient technologies. The production on the bigger scale of the electrical vehicles (including EV, PHEV) requires intensive research on new lightweight materials and more efficient batteries. The appearance of the new players might disturb the existing supply chains in the industry and results in loss of work places. Modularisation trend might lead to the growing interest in knock-down kits which might be imported from non-European markets and cause further loss of jobs in EU.

3.3.3 Aeronautics

To keep the world-leading position, EU aeronautical industries will meet a growing competition also from recently emerged and emerging countries. As pointed out in the SRIA by ACARE, it is fundamental to have "a skilled workforce, possessing the quality, skills and motivation to meet the challenges of the future".

To reach this objective, key actions are:

- Europe aeronautical industries should have available, internally or in European research centres and universities, world class capabilities and facilities for research, development, test and validation;
- Talents should be attracted in young age to study STEM disciplines (Science, Technology, Engineering and Mathematics), and in particular should be attracted to careers in aeronautics;
- European Universities should offer courses that closely match the needs of the aeronautical industries, and evolve continuously as the needs of the industries develop;
- Industry should be engaged actively with European students at all levels both motivating their interest in the sector and stimulating innovation and ideas;
- Industry should be committed to lifelong and continuous education through collaboration with universities and research establishments.

4. Strategic Implementation Plan

4.1. Roadmap

The STRIA vehicle design and manufacturing roadmap proposes three key research and innovation paths that will substantially contribute to the achievement of Energy Union targets, while boosting the European industrial competitiveness. These three paths cut across all transport modes and exploit synergies, therefore attaining the maximum added value for public and private funding research.

I. Advancements on Design Tools and Processes
II. Advancements on New Vehicle Concepts and Architectures
III. Circular economy – modular vehicle architecture and remanufacturing, greening industry

4.1.I Advancements on Design Tools and Processes

Action	**Type of action** ***R&I*** ***Deployment*** ***Policy***	**Time frame** ***Short-term (to 2020)*** ***Medium-term (to 2030)*** ***Long-term (to 2050)***	**Priority** ***High*** ***Medium*** ***Low***	**Responsible** ***EC*** ***MS*** ***Cities***
Support research on design tools and processes	R&I	Short-medium term	High	EC
Support disruptive technologies	R&I	Long term	High	EC
Facilitate technology convergence	R&I	Medium term	Medium	EC
Develop strategic testing facilities	R&I	Long term	High	EC
Develop further and exploit better HPC facilities	R&I	Short-medium term	High	EC, MS
Automation in design and manufacturing	R&I	Medium term	High	EC
Develop new multifunctional materials	R&I	Medium term	High	EC
Develop a leading new generation of standards	R&I, Policy	Short-term	Medium	EC, MS
Secure a strong research network	R&I	Short-term	Medium	EC
Develop an agile market for facilitating implementation of disruptive technologies	R&I, Policy	Long term	High	EC
Attract students to technical careers	R&I, Policy	Medium term	High	EC, MS
Enable multi-disciplinary education	R&I, Policy	Short-term	Medium	EC
Incorporate mechanisms for dialogue with the community	Policy, R&I	Short-term	Medium	EC, MS, Cities
Link basic and applied research on Multi-Disciplinary Design Optimization	R&I	Short-term	High	EC, MS
Support Design for Manufacturing and Operations with real industrial pilot cases and scaled demonstrators	R&I	Short-term	High	EC, MS
Support Artificial Intelligence Methods and Big Data analysis - linking evolutionary design and operations	R&I	Short-medium term	High	EC, MS
Support advanced visualization methods and HMI	R&I		High	EC, MS
Support open source European and International computational initiatives	R&I	Short-Medium-Long term	High	EC, MS

Table 1. Strategic implementation plan - Design Tools and Processes

Support research on design tools and processes

Collaborative, integrated, multidisciplinary, scientific-based and validated design processes and tools, that make use of high performance computing, will allow efficient design, optimization and manufacturing of transport vehicles. Such advanced computational design tools and processes should seamlessly validate models with physical data from new and updated testing facilities. The collaborative processes should evolve from data-based to model-based exchanges. Uncertainty quantification and visualization of trade-offs should support the integrated capabilities and the needs of the architects. These tools and processes will expand the design envelope and contribute to new design architectures that will transform the transport system.

Integration of design and manufacturing capabilities will allow substantial reduction of development timescales and costs. The extensive use of advanced simulation tools will enable moving towards virtual design/testing/certification capabilities, with lower costs and faster routes to market for key innovations.

Support disruptive technologies

Research programs in support of disruptive and risky technologies should be adequately promoted. New projects at low TRL with new breakthrough ideas in the field of vehicle design and manufacturing should be supported, even if many of the funded projects will not bring any immediate product. Precisely because they are at high-risk, the research is often not successful. Yet, in most of the cases, the few successful ones develop disruptive technologies and spin-offs in other areas of science and technology.

Facilitate technology convergence

Technology convergence, widely defined as the combination of two or more different technologies in a single device or product, has historically played a major role in technological innovation. The convergence of different disciplines such as propulsion, aerodynamics, structure, as well as the synergies between new materials as composites or new metallic alloys, with new manufacturing techniques as automated fiber placement or 3-D printing, and with advanced computational methods can improve the manufacturing capabilities and increase the vehicle design space.

Develop strategic testing facilities

The EU should provide a Europe-wide testing facility that can support all transport sectors, or different testing facilities for the different sectors organized in a network for the best usability. The EU-supported facilities have to provide open access to EU and MS supported research programs as well as to SMEs, research organizations and universities. The strategic testing facility can allow small companies to effectively participate in this field, encourage new entrants that can act as catalysts in the transport sector, and facilitate cross-fertilization of ideas. The testing facilities, the provided instrumentations and capabilities will continue to evolve in support of the necessary research.

Develop further and exploit better HPC facilities

Open access should be established between EU and MS supported transport research programs as well as SMEs research organizations and universities with EU-supported HPC facilities.

Facilitate automation in design and manufacturing

Automation can facilitate design and especially manufacturing, so to reduce time and cost and to improve quality control and material handling processes. Capitalizing on big data can be a critical tool for realizing improvements in the manufacturing processes where complexity, process variability, and capacity restraints are present.

Support the development of new materials

New materials, such as composites with tailored strength properties and ceramics for high-temperature applications, will continue to replace customary metal structures and components. They will present new capabilities to reduce weight, to decrease manufacturing cost, to enhance production flexibility, to improve vehicle performance, to allow multi-functions and adaptive shape-changing.

Develop a leading new generation of standards

A leading new generation of standards need to be created. They are an important mean for the deployment of new technologies, are fundamental to guarantee the safety of future vehicles with conventional or unconventional architectures, and are needed for new materials.

Secure a strong research network

A strong research network stimulating collaboration of industries with research centers and universities will contribute and strongly engage to reach the Energy Union targets as well as boost the competitiveness of the European transport vehicle industries respect to both established and emerging rivals.

Develop an agile market for facilitating implementation of disruptive technologies

The step from the birth of a revolutionary technology to its implementation is getting shorter, as is the length of time for widespread adoption. Europe should be able to adopt new technologies as soon as they are developed and fully integrate them in the design of the next generation vehicles. Otherwise more agile markets such as Asia may speedily adopt these, penalizing EU competiveness.

Attract students to technical careers

The transport community will engage actively with European students from the earliest age and will be committed to lifelong learning and continuous education thus promoting interest in the sector and stimulating innovation. Courses offered by European Universities will closely match the needs of the transport industry, its research establishments and administrations, and evolve continuously as those needs develop. European Universities should motivate students to pursue graduate studies in the field, so to ensure a steady supply of talent for a first class work force. To attract top talent of European Member States as well as from other parts of the world to study and work in Europe in the transport sector will be seen as exciting, challenging and financially attractive as a work option.

Enable multi-disciplinary education

To be able to develop changes in vehicle design concepts and architectures using hybrid/electric systems, multi-disciplinary competences and education are required. It will facilitate technology advances outside of, as well as within, traditional vehicle disciplines, and will assure continuity through basic research, applied research, development, demonstration and innovation in vehicle design and manufacturing.

Incorporate mechanisms for dialogue with the community

Transport is an integral part of our economy and impacts daily lives. Regular dialogue with the community will grow public concern about environmental sustainability, as well as will allow to lead to transformative innovations responsive to future needs and to realize the community vision. The involvement of the community is important also because nontechnical issues, such as public acceptance, moral decision making, and changes in users roles and tasks, could pose barriers to the applications of the research results into the market. As the transport industry becomes more global, more nations are conducting advanced research in the field and are developing their own industries. Consequently, it is important to engage the community so to understand what the stakeholders believe are priority research areas, and to maintain global leadership for a sector that is highly advanced and anticipated to grow.

4.1.II Advancements on New Vehicle Concepts and Architectures

Action	Type of action ***R&I*** ***Deployment*** ***Policy***	Time frame ***Short-term (to 2020)*** ***Medium-term (to 2030)*** ***Long-term (to 2050)***	Priority ***High*** ***Medium*** ***Low***	Responsible ***EC*** ***MS*** ***Cities***
Support research on new vehicle concepts and architectures.	R&I	Short - automotive Medium - waterborne Medium-Long in aeronautics	High	EC
Support research on electric/hybrid vehicles, systems, system integration and enabling technologies	R&I	Short-automotive Medium-Aeronautics and Warerborne	High	EC
Support power systems validation facility	R&I	Short term	High	EC
Exploit synergies with the power-electronics industry and explore disruptive technologies for heat dissipation	R&I	Short and Medium term	High	EC, MS
Exploit synergies with Space & Defence	R&I	Short-term	High	EC, MS
Ensure and enhance safety & security	R&I, Policy	Short-term	High	EC, MS
Support risk-based certification methodologies	R&I, Policy	Short-medium		
Support relevant standardization groups	R&I, Policy	Short term		
Attract students to technical careers	R&I, Policy	Medium term	High	EC, MS, Cities
Enable multi-disciplinary education	R&I, Policy	Short-term	Medium	EC
Incorporate mechanisms for dialogue with the community	R&I, Policy	Short-term	Medium	EC, MS, Cities

Table 2. Strategic implementation plan - New Vehicle Concepts and Architectures

New vehicle concepts and architectures

In order to meet EU emission targets, new vehicle concepts and architectures with disruptive new structures, systems and power generation should be developed for all transport sectors. System integration for all transport vehicles is a key enabler. Research is required to facilitate the changes in vehicle design concepts and architectures while guarantee the same or improved levels of safety and security. Synergies exist between automotive, aeronautics, maritime, rail, space and defence and should be exploited. European supported research is lagging behind in exploiting synergies and integrating knowledge created in different EU research initiatives. Research on design tools and processes as well as vehicle architectures and system integration are excellent pilot topics towards exploiting synergies at European level.

Electric/hybrid vehicles, systems, system integration and enabling technologies

It is essential that research on hybrid/electric technologies and new architectures is accelerated in the EU. Research and development on relevant enabling technologies (e.g. high power density electric motors and generators, energy storage devices, power electronics) should be timely planned. Basic research on superconducting technologies should be adequately linked with applied research and technology demonstrators.

Support vehicle validation facility

The EU should provide a Europe-wide validation facility that can support all transport sectors, or different testing facilities for the different sectors organized in a network for the best usability. The facilities have to be open to all EU companies, from large companies to supply chain including SMEs, as well as to research organizations and universities. The facility would allow testing of power systems of various sizes and integration with other vehicle systems either using real (scaled) equipment and/or hardware.

This approach can allow small companies to effectively participate in this field, encourage new entrants that can act as catalysts in the transport sector, and facilitate cross-fertilization of ideas. The testing facilities, the provided instrumentations and capabilities will continue to evolve in support of the necessary research. The first stage would be to establish such a facility (site and buildings) and in parallel through wide consultation with industry (including supply chain and SMEs) design and install appropriate facilities. The final stage would be a funding proposal to support research projects within the facility to ensure take up of the approach.

Ensure and enhance safety and security

It is important to ensure that the safety implications of advanced technologies and new vehicle architectures are identified and considered in the development process, so to enhance safety. Technology, training, procedures, evaluation, analysis, testing, and certification should be strengthened and improved to reduce the risk of accidents from all causes in all phases of operation. At the same time, appropriate tools and approaches need to be developed for having crashworthy structures, so to reduce damage and losses in the event of an accident, and guarantee the same or improved safety levels for the new vehicle architectures.

Security concerns overshadowed aviation safety which is record low. Security management systems need to be further developed and standardised. Cyber threats in aviation also pose a considerable risk which is expected to grow. Common use of open standards brings opportunities for interoperability and connectivity, but also cybersecurity vulnerabilities.

Attract students to technical careers

The transport community will engage actively with European students from the earliest age and will be committed to lifelong learning and continuous education thus promoting interest in the sector and stimulating innovation. Courses offered by European Universities will closely match the needs of the transport industry, its research establishments and administrations, and evolve continuously as those needs develop. European Universities should motivate students to pursue graduate studies in the field, so to ensure a steady supply of talent for a first class work force. To attract top talent of European Member States as well as from other parts of the world to study and work in Europe in the transport sector will be seen as exciting, challenging and financially attractive as a work option.

Enable multi-disciplinary education

To be able to develop changes in vehicle design concepts and architectures using hybrid/electric systems, multi-disciplinary competences and education are required. It will facilitate technology advances outside of, as well as within, traditional vehicle disciplines, and will assure continuity through basic research, applied research, development, demonstration and innovation in vehicle design and manufacturing.

Incorporate mechanisms for dialogue with the community

Transport is an integral part of our economy and impacts daily lives. Regular dialogue with the community will grow public concern about environmental sustainability, as well as will allow to lead to transformative innovations responsive to future needs and to realize the community vision. The involvement of the community is important also because nontechnical issues, such as public acceptance, moral decision making, and changes in users roles and tasks, could pose barriers to the applications of the research results into the market.

As the transport industry becomes more global, more nations are conducting advanced research in the field and are developing their own industries. Consequently, it is important to engage the community so to understand what the stakeholders believe are priority research areas, and to maintain global leadership for a sector that is highly advanced and anticipated to grow.

4.1.III. Circular economy – modular vehicle architecture and remanufacturing, greening industry

The table presents the actions which support the initiative: „Circular economy – modular vehicle architecture and remanufacturing, greening industry".

Action	Type of action	Time frame	Priority	Responsible
	R&I Deployment Policy	***Short-term (20) Medium-term (25) Long-term (30+)***	***High Medium Low***	***EC, MS Cities***
Support research on greening the primary production and supply chain operations by innovative tool for optimizing processes, with digitalization along the value chain (including security of data exchange)	R&I	Short term & Medium term	High	EC, MS
Support research on innovative End-of-Life recovery options (shift from traditional recycling to more energy efficient remanufacturing) and new second life applications	R&I (and policy)	Short term & Medium term	High	EC, MS
Support research on new lightweight and easily recyclable materials	R&I (and policy)	Short term & Medium term	High	EC
Promoting eco-design	R&I (and policy)	Short term	High	EC, MS
Drafting of standards for assessing vehicles performances and production process sustainability.	R&I	Short term	Medium	EC
Enable multi-disciplinary education with focus on circular economy challenges	R&I, Policy	Medium	Medium	EC, MS

Table 3. Implementation plan - Circular economy

Greening the primary production and supply chain operations

The vehicles' production is resource-intensive. In order to achieve the Energy Union goals it is important to reduce the resources usage along the whole value chain. It could be achieved by optimizing processes using innovative IT tools and systemic solutions. There is need for better integration of physical and virtual resources on the shop floor and in the whole supply chain. Vehicle manufacturers face growing complexity and cost pressure. There is need for more platform sharing and more modular solutions. The growing complexities of customized vehicles will require a novel approach to the assembly process with building based on global platform. Digitalization can be applied as one of main tools to meet these challenges. The leaders in the sector (like e.g. Mercedes Benz) are dedicated to the concept of Industry 4.0 (networking of the whole value-chain from design to sales services in real time). This means full digitalization, which allows to link man, machine and industrial processes in order to achieve high quality products quicker, more resource efficient and in a more flexible way (higher competitiveness). The smooth, quick and safe exchange of data between integrators and 1st tier suppliers allows eliminating the inefficiencies in materials supplies and changing the vehicles' architecture. The digitalization creates need for research in short- and mid-term perspective. The average automotive manufacture uses dozens of IT systems. It creates need for research with regard to data compatibility, interchangeability and security (especially regarding digital footprints). The digitalization along the value chain will enable modular vehicle's architecture and a closed loop approach (zero waste).

End-of-Life recovery options and new second life applications

Directive 2000/53/EC (the "ELV Directive") on end-of life vehicles aims at making dismantling and recycling of ELVs more environmentally friendly. The EU regulations provide an ambitious framework for 95% recovery by weight per vehicle in the automotive industry. The traditional recycling requires destroying the product, which is not often the optimal way of recovery from an energy efficiency perspective. The recycled materials are already used in the vehicle production but there is need for innovative and more energy efficient methods. The appropriate non-destructive recovery (e.g. remanufacturing) of ELVs allows for both economic and environmental benefits, as for example, remanufacturing of automotive components saves on average 50-80% of energy use, and 85% of material use. The electrification of the vehicles creates need for new methods of electric and hybrid vehicle components recovery. The recovery of the batteries is nowadays very challenging. The development of electrically propelled vehicles requires new methods to ensure the safe handling and high-grade recycling of the batteries (especially for lithium batteries).

There is need for research on the electric and hybrid vehicle's components recovery technologies and new applications for second life of components (e.g. vehicle battery can be reused in house for renewable energy storage).

New lightweight and easily recyclable materials

There is need for research on new lightweight and easily recyclable materials, as their industrial implementation will allow the phasing out of materials which are non-recyclable or difficult to recycle. The existing EU regulations (Directive 2005/64/EC on the type-approval of motor-vehicles with regards to their reusability, recyclability and recoverability; REACH) oblige vehicle manufactures to design and produce vehicles without hazardous substances (in particular lead, mercury, cadmium and hexavalent chromium). The specific exemptions of hazardous substances usage in vehicles are listed in Annex II to the ELV Directive and are subject to regular reviews according to technical and scientific progress. The ELV Directive is consistent with Commission policies on resource efficiency, but may not be adapted to new market conditions and technology development, like electrically propelled vehicles , the trend for lighter vehicles, use of nanomaterials, may affect the manufacturing and treatment of vehicles in the future. [43] The traditional composition of vehicles is changing as new lightweight materials allow better energy efficiency (less fuel consumption) and less GHGs. The complex electronic systems and composite materials create technological challenges in

[43] Ex-post evaluation of certain waste stream Directives - Final report, European Commission – DG Environment, 18 April 2014

maintaining the overall reuse and recovery rates. There is need for new or improved methods of recycling of plastics and nanomaterials (lighter components).

Promoting eco-design

Promoting eco-design is crucial, as it reduces the negative environmental impact and increases energy efficiency in the whole life cycle of the vehicles, as well as enabling reuse (including new second-life applications). Design for recycling or design for remanufacturing is gaining more attention in the industry but there is still room for more actions. The ELV Directive does not explicitly promote eco-design. Vehicle manufacturers could be incentivised to change the design of their vehicle and decrease treatment costs by integrating eco-design[44].

Standards for assessing product performances and process sustainability

The electrification of the vehicles creates a need for new standards for assessment of product and processes. There is lack of transparency to monitor the resources utilization along the vehicle manufacturers' value chains, no standards existing in this field. The existing standards on emissions are very often applied in different way by manufacturers. Drafting new standards is needed

New applications like second-life use of batteries will need new standards in particular.

Multi-disciplinary education with focus on circular economy

Vehicle design and manufacturing is becoming more complex. The integration of circular economy goals into design and manufacturing processes requires cooperation of multidisciplinary teams. There is need for education of engineers that will be able to develop and apply "green" technology outside of traditional vehicle disciplines.

[44] Ex-post evaluation of certain waste stream Directives - Final report, European Commission – DG Environment, 18 April 2014

4.2. Public and private roles

- embedded in the three tables

4.3. Resources and financing

- Planning in time and allocating resources should be done together with MS and industry.

4.4. Potentials for transfer and synergies

The synergies between the transport modes are adequately highlighted in chapter 4.1.

4.5. Recommendations

STRIA vehicle design and manufacturing roadmap proposes three key cross-modal research and innovation paths that will contribute to the achievement of the Energy Union targets, while boosting the European industrial competitiveness.

Vehicle design and manufacturing is overarching to all decision making for all transport modes. The selection and integration of systems, powertrains, architectures and manufacturing processes is part of this process and depends on the mission of the transport vehicle, societal challenges, available technologies, and economics. While industry is leading the path, the roadmap identifies that additional public R&D funding is necessary to accelerate existing (i.e. European technology platforms) and more specific (i.e STRIA) technology roadmaps.

The roadmap exploits synergies and recommends to balance evolutionary and high TRL demonstrations with more disruptive vehicle concepts that will adopt new technologies and integrate them in the design of the next generation vehicles faster, providing significant improvements in emissions for all transport sectors.

The roadmap identifies the need to invest adequately on collaborative, integrated, multidisciplinary, scientific-based and validated new design tools and processes that will expand the design space offering more environmentally friendly options, substantially decrease the development lead time and maintain or even increase safety and security.

The roadmap recommends that particular attention and adequate R&D funding is available for innovative end-of-life recovery options, which allow for a shift from traditional recycling to eco-design and eco-manufacturing.