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European Green Cars Initiative

Public-Private Partnership

Multi-annual roadmap and long-term strategy

Prepared by the EGCI Ad-hoc Industrial Advisory Group

Research & Innovation policy

EUROPEAN COMMISSION

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2011

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Transport

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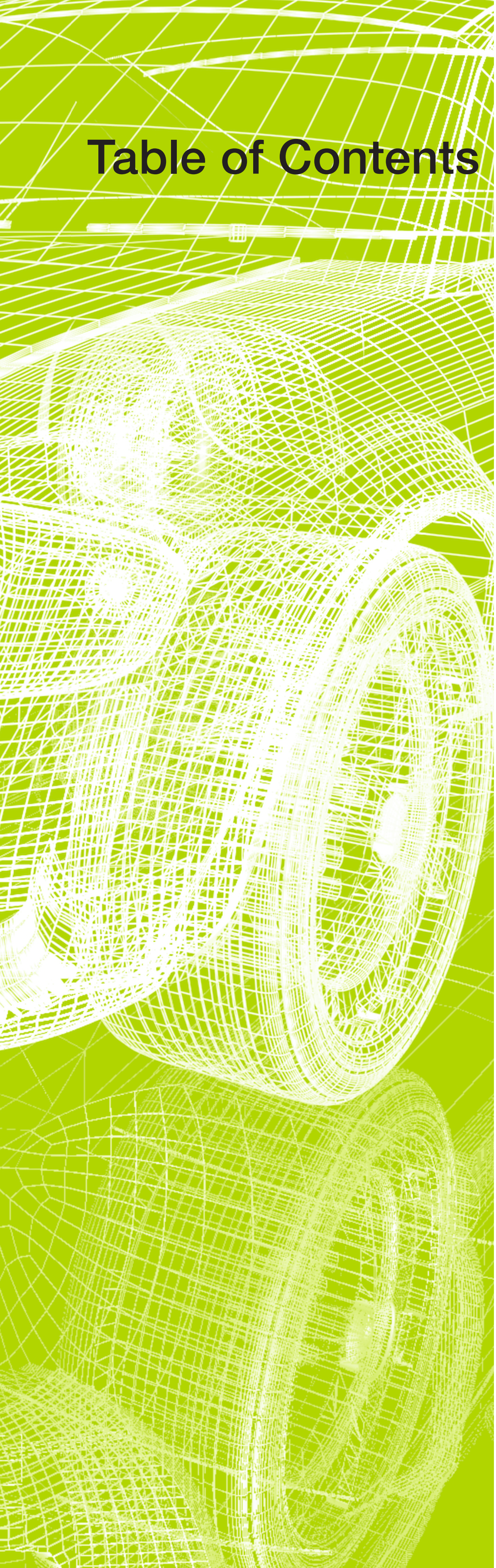


The European Green Cars Initiative

The European Green Cars Initiative (EGCI) is one of the three Public-Private Partnerships (PPPs) launched by the European Economic Recovery Plan, which was announced by the President of the European Commission (EC) on 26 November 2008[1]. The other PPPs of the Recovery Plan are Energy Efficient Buildings and Factories of the Future. The automotive sector was selected with the building and manufacturing sectors due to the severe impact of the crisis on their activities, combined with the high potential for green growth. The objective of the PPP EGCI is to support Research & Development (R&D) on technologies and systems that are able to bring breakthroughs in the goal of Europe to achieve a safe and reliable, green Road Transport System, using renewable energy sources. Apart from loans provided through the European Investment Bank (EIB), the PPP European Green Cars Initiative makes available for the period 2010-2013 a total of EUR 1 billion through R&D projects set up jointly by the EC, industry and research partners, and the European Union (EU) Member States.

In 2010, support for European research projects under the EGCI started with the first calls for proposals (with a total indicative EC budget of EUR 108 million) published in July 2009. A total of 30 projects were selected for funding, with a focus on electrification of road transport, including research on Electric Vehicles (EVs), batteries, hybrid technologies and integration of EVs into smart electricity grids. In July 2010, a second round of calls was published, covering three major R&D pillars: research on electric and hybrid vehicles, research for heavy-duty (HD) vehicles based on Internal Combustion Engines (ICEs) and research on logistics and co-modality. Ten proposals were selected for a total EC contribution of EUR 31million. In addition to this funding of research projects, the EIB continues the implementation of the European Clean Transport Facility as a contribution to the EGCI. Until now, EUR 8.2 billion in loans have been approved for the automotive sector under this scheme.

For more information see http://www.green-cars-initiative.eu

Introduction

Growing societal concerns about the detrimental effects of fossil fuel-based road transport on world climate, air quality, environmental heritage and energy security are calling for fundamental paradigm shifts. The future benchmarks of road transport concern the highest energy efficiency, decarbonisation of energy carriers used in transport and an overall optimised performance of personal mobility and goods transport. Meeting these ambitious goals requires breakthrough developments in a wide variety of technology fields ranging from the production, storage and distribution of energy, to the overall efficient use of any kind of energy carrier in the car, new vehicle concepts and architectures, novel Information and Communication Technology (ICT) solutions and services, to the management of mobility and logistics. Accelerated innovation will be based on joint agreements of the involved economic sectors and the public authorities on short, medium and long-term goals. To ensure a competitive edge for Europe in the field of clean and energy-efficient vehicles, the PPP European Green Cars Initiative is presenting the document at hand.

This strategic multi-annual roadmap is aimed at defining the R&D objectives to be achieved by the PPP EGCI. It has been prepared by the Ad-hoc Industrial Advisory Group, a forum for discussions about the content of the EGCI between the involved industries and the EC services. The members are industry representatives from four European Technology Platforms[2], ERTRAC (European Road Transport Research Advisory Council[3]), EPoSS (European Technology Platform on Smart Systems Integration[4]), SmartGrids (European Technology Platform for the Electricity Networks of the Future[5]), and EIRAC (European Intermodal Research Advisory Council[6]). This unique cooperation between different industrial sectors reflects the importance of the integrated approach, which has to be adopted in order to achieve the ambitious objectives of the initiative. Also, taking a system approach to transport by addressing systemic challenges such as decarbonisation, is in line with the White Paper on the European Transport Policy issued by the European Commission on 28 March 2011[7]. It also reflects the approach taken by the EC in its Communication on a European strategy for clean and energy-efficient vehicles, published on 28 April 2010[8].

When looking to attain a more efficient Road Transport System as a whole, major challenges appear and call for breakthrough developments in a variety of technology fields. The EGCI roadmap comprises three pillars: electrification of road transport, long-distance transport and logistics and co-modality. These three pillars represent the key areas to achieve energy efficiency improvements, carbon dioxide (CO_2) emission reductions and reliable logistics and mobility. At the same time, they represent important opportunities for Europe to turn its outstanding knowledge base in the field of clean and energy-efficient vehicles and transport solutions into innovations bringing substantial environmental and socio-economic benefits. European industrial sectors must develop the next generation of vehicles and mobility solutions, taking care of the environmental impacts of transport with a life-cycle approach (including vehicle recycling and re-use), and adopt a system approach to address mobility needs.

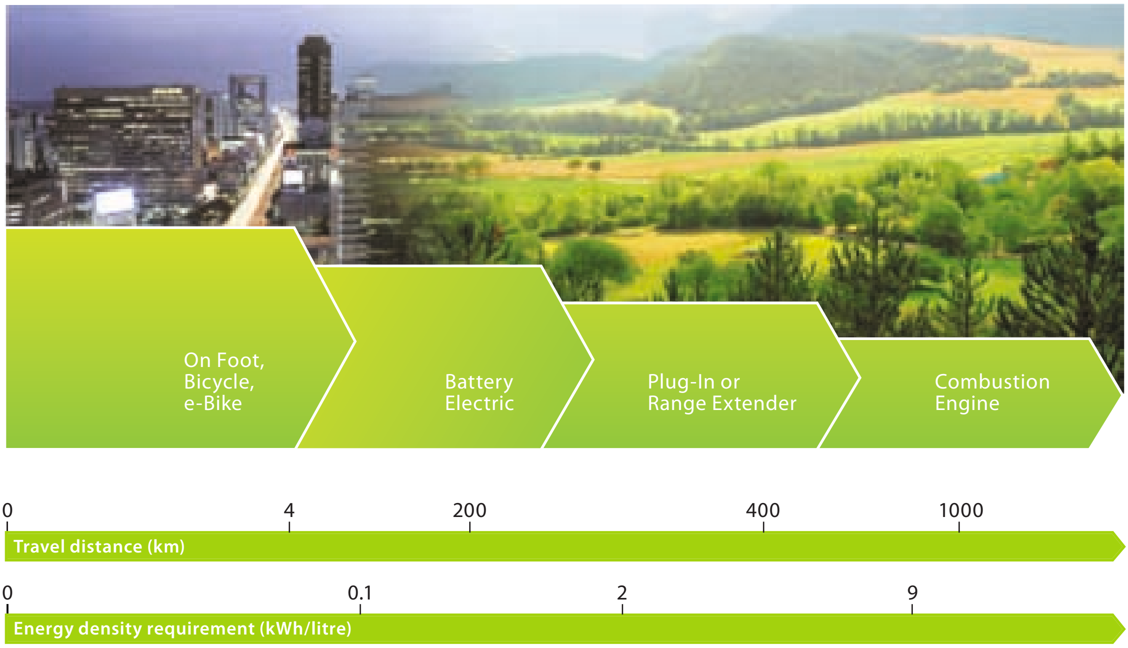


Figure 1: Mobility solutions for both urban and long-distance travel.
Source: ERTRAC Strategic Research Agenda 2010[3].
Taking a system approach to the Road Transport System, the development of a diversity of powertrains is needed to meet the mobility demands of passengers and freight for both urban and long-distance transport.

The electrification of road transport is of specific importance in the context of growing urbanisation in Europe, especially considering the high potential of electrified mobility for climate protection, resources management and air quality. The electrification includes the development of Full Electric Vehicles (FEVs) specifically designed for use in the urban environment (typical daily range of 50 km), as well as Plug-in Hybrids (PHEVs) and vehicles equipped with a range extender, capable of longer trips within and between cities. Electrification represents therefore a great potential to be seized by Europe's automotive and energy industries, requiring the coordinated effort of these sectors, in partnership with public authorities. At stake is the global competitiveness of Europe, and considering the great share of these sectors to EU employment, it represents a unique opportunity to achieve the objective of smart, sustainable and inclusive growth defined in 2010 by the EC in the Europe 2020 Strategy[9]. Turning such innovative vehicles into viable products ready to deliver to mass markets requires significant technological innovations addressing a series of major challenges, including: cheap, safe and high-performance energy storage, Vehicle-to-Grid (V2G) interfaces, thermal management, advanced drive train control, robustness and safety as well as seamless integration into the transport system. Together with these technological innovations, future generations of vehicles require efforts in the area of component standardisation, sub-systems modularisation and new manufacturing requirements. Costs reduction and ability to respond to demands variations will be key driving forces towards success in mass market uptake. In this respect, the EGCI and Factories of the Future PPPs have interesting interactions to develop, in particular for integrated product-process approaches and new materials aspects, with the objective of sustainable high-performance manufacturing of the next generation of vehicles. Underlining the legitimacy of PPPs for this matter, the electrification of road transport additionally requires careful demand-side measures and timely regulatory frameworks, for which a shared knowledge of the expectations and the challenges are of high value. In partnership with industry, the EC and EU Member States have with these measures key policy tools able to act as a leverage effect towards mass market uptake.

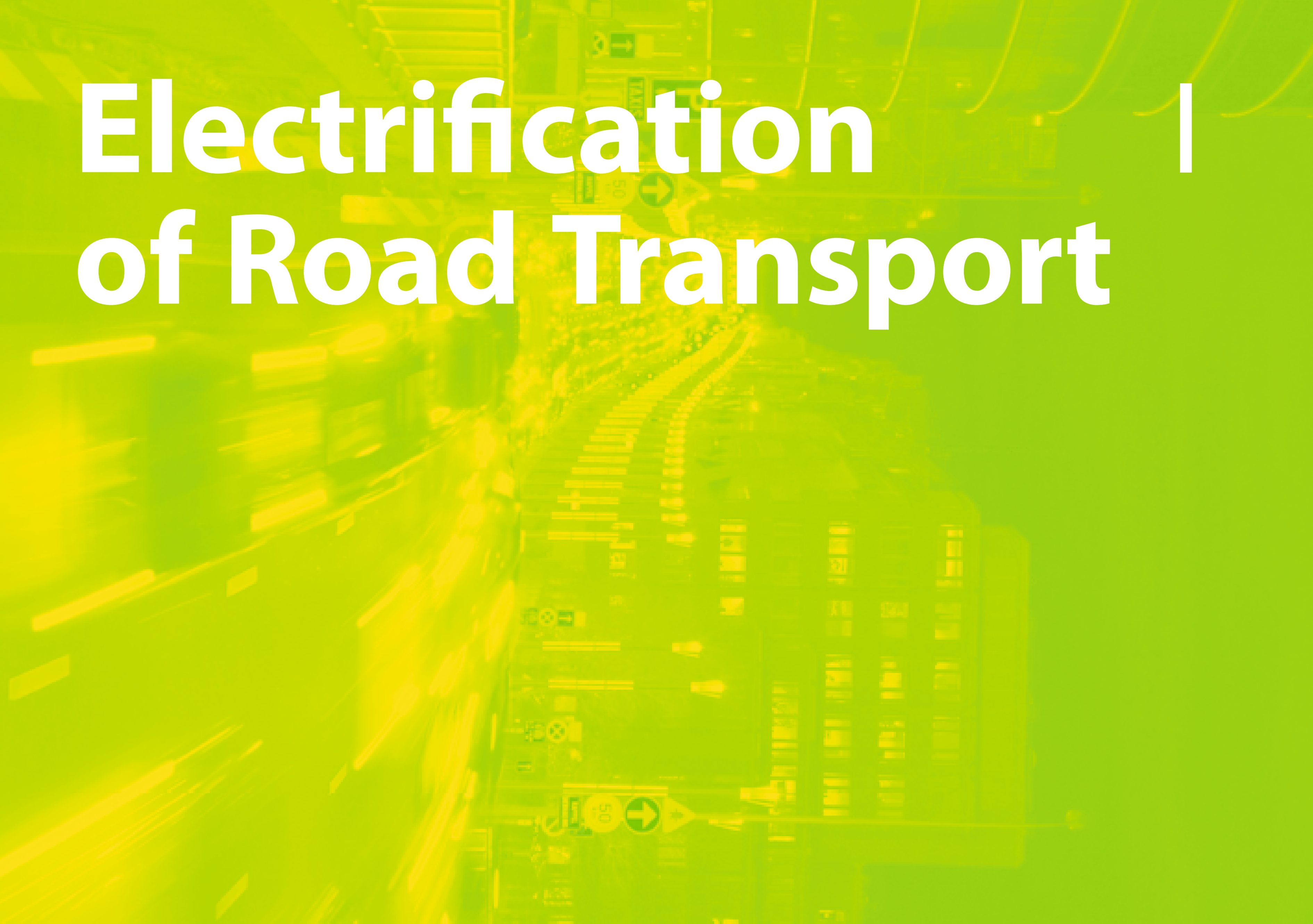
While the electrification of passenger cars and light-duty (LD) vehicles is predicted to increase over the following decades and to be implemented progressively in our cities, powertrains of HD vehicles necessary for long-distance transport are expected to remain based on ICE. Although the powertrains of the commercial vehicles are already very optimised towards fuel efficiency, the predicted increase in goods transport demand necessitates that new technologies are investigated in order to compensate for the overall increase of fuel consumption and its effect on the carbon footprint of freight transport. These efforts towards more energy-efficient trucks must cover three main areas of R&D: vehicle efficiency, driveline efficiency and driver efficiency. And for electrification, timely developments are also necessary in the view of demonstration, production, market introduction and regulatory frameworks. At the same time, CO_2 emissions from freight transport can be further reduced through measures to optimise the use patterns of vehicles and logistics schemes in general.

Indeed, an optimised use of transport resources and infrastructures has the capacity to optimise the performances of the transport system as a whole, bringing more efficiency in the areas of traffic fluidity, transport services reliability, safety and security, cost reduction and, of upmost importance, reduced carbon footprint. An important opportunity for the European industry is therefore represented by the development of integrated services and business models complementing transport modes and building cooperation among the actors of the logistics chains. In close link with the R&D performed on commercial vehicles, research and innovation is needed on this pillar in order to achieve efficient door-to-door logistics, with goods being shipped seamlessly across modes and networks thanks to ICT solutions, cooperative business practices, co-modal transfer hubs and an extended standardisation of freight carriers in terms of dimension and modularisation. Here as well, the regulatory framework will be of high importance to support the deployment of innovative solutions.

By addressing the challenges of clean and energy-efficient vehicles and mobility, this document presents the multi-annual roadmaps defining sets of priority topics for each of the three strategic pillars of the PPP EGCI. By including milestones with a medium to long-term vision, this document prepared by the EGCI Ad-hoc Industrial Advisory Group also aims at providing EC services with a strategic framework and recommendations for future developments in European research policies and programmes.

Electrification of Road Transport

I



1. Introduction

Electrified mobility is currently given top priority in the US, Japan, China, Korea and EU. Announcements of dedicated national programmes are legion. Similarly, there is a proliferation of qualitative position papers and reports, while several automotive company executives have contributed to raise the general expectations through announcing the imminent mass production of EVs. The move from conventional combustion-based mobility to more electric or full electric mobility poses many questions with answers depending on a multitude of interdependent parameters. The matter is quite complex and because of that, when treated only in qualitative terms, gives rise to controversy that may slow down decision-making processes. The aim of this roadmap is to help quantify the differences between conventional and new technologies in terms of the much cited aspects of energy and resource security, climate change, public health, freedom of mobility and economic growth, and to suggest actions that will create an impact on these. Therefore, in the first instance electric vehicles are assessed in comparison with internal combustion engined vehicles taking into account:

- Primary energy savings
- Cuts in greenhouse gas (GHG) emissions
- Reduction of noxious emissions
- Range and speed
- Cost of technology and constraints on raw materials.

Furthermore, based on surveys among major European companies from the automotive and energy value chains, milestones for implementation of the new technologies are set and required actions are indicated in terms of content and timing.

Electrification of road transport generally can refer to vehicles of many kinds including bikes, scooters, passenger cars, delivery vans and vehicles for public transport. In this roadmap the focus is put on passenger cars, and the term EV means all kinds of vehicles that provide at least 50 km of pure battery-electric range such as pure EVs, EVs equipped with a range extender, and PHEVs, which may provide potential beyond the transition phase, e.g. when combined with biofuels.

This first part of the multi-annual roadmap and long-term strategy, has been prepared by a task force team of members of the European Technology Platforms ERTRAC, EPoSS and SmartGrids led by the chairman of ERTRAC. It complements a 2009 Joint ERTRAC/EPoSS Strategy Paper 'The Electrification Approach to Urban Mobility and Transport[10]' that points out the needs in terms of R&D and demonstration for a smarter, greener, safer and more competitive road transport system. The authors expect that the EC and the Member States will refer to this report as a common industry position when setting priorities and timing actions towards the electrification of mobility and transport as a system.

2. Benefits and Challenges of the Electric Vehicle

Primary energy savings
(aiming at energy security)

Due to the EU's growing dependency on primary energy sources this parameter is very likely to be the most motivating one. In the EU, 73% of all oil (and about 30% of all primary energy) is consumed by the transport sector[11]. Biofuels and natural gas are making an important contribution to fuel security, however just a small fraction.

To quantify the technological evolution that makes electric mobility appealing, we take as a reference an ideal vehicle whose energy consumption depends only on mass, aerodynamic drag (frontal area and drag coefficient (C_x)) and tyre/road rolling resistance. In reality, the amount of energy consumed strongly depends on the typology of the powertrain, the chosen cycle and the energy needed for cooling or heating. To compare the EV and the ICE we take as a reference a mid-size vehicle (1 300 kg) with aerodynamic factor of 0.7 m^2, conventional rolling resistance tyres and an ideal powertrain with 100% efficiency, thus consuming 120 Wh/km[12] over the New European Driving Cycle (NEDC).

Combustion engines made in Europe are among the most economical in the world. Their efficiencies can reach up to 0.45, however varying with speed and load. From the well to the tank, it takes 8% to 12% of the energy in extracted oil to refine it into diesel or gasoline. Taking into account real driving cycles and a typical transmission efficiency of the order of 0.9 the overall well-to-wheel (WTW) efficiency of modern powertrains can be set in the range of 0.16 to 0.23[13, 14]. These values already include the most advanced innovations in fuel and transmission controls. Hence, in reality the consumption of primary energy is between 522 Wh/km and 750 Wh/km.

Year	Power Plant Efficiency	Grid Efficiency	Inverter AC/DC Efficiency	Battery Efficiency (Slow Charge)	Power Electrical Efficiency (DC/DC, AC/DC)	Motor and Magnetic Gear Efficiency	Energy Consumption Ideal mid-size car Wh/km*	Total Consumption of Primary Energy Wh/km*
1998 Range 20km*	0.39	0.88	0.85	0.70	0.85	0.65-0.70	120	987-1064 7% Regenerative braking
2008 Range 150 km	0.45	0.93	0.90	0.90	0.90	0.80-0.86	120	457-492 15% Regenerative braking
2008 Range 150 km	Renewable Energy only	0.93	0.90	0.90	0.90	0.80-0.86	120	205-221 15% Regenerative braking
2008 Range 600 km	WTW Powertrain efficiency of a conventional Internal Combustion Engine car in reality: 0.16-0.23						120	522-750 10% micro-mild hybrid

Table 1: Evolution of primary energy consumption of Electric Vehicles and comparison to conventional powertrain.
*Energy needed to move an ideal mid-sized vehicle in the NEDC.
*Reduced battery weight.
*Cars smaller than the reference vehicle may have less energy consumption.

The peak efficiency of an electrical motor can achieve 0.95 at defined power and torque values[15]. It may drop to below 0.6 in extreme cases, but for a large range of power and torque the average efficiency can be kept at above 0.9. Thus the electrical powertrain can be designed intrinsically less sensitive to the characteristics of the driving cycle, particularly when using more than one motor. The overall combined efficiency of power switches, DC/DC and AC/DC inverters can reach 0.9, whilst that of motors and gears depends on the chosen driving cycle with typical values ranging from 0.8 in cases of large demands of power and torque to 0.86 for smoother cycles. In conclusion, the modern electrical powertrain can ensure efficiencies in the range of 0.72 to 0.77 from the battery via power electronics to the wheel. For the electrical car, the assessment of WTW efficiency has to include on the well-to-socket side efficiency of the generation and load losses at distribution point of electricity. In most EU Member States the average efficiency of power plants is 0.45[16, 17], while that of the power grid can reach up to 0.93. Thus considering the whole chain of current conversion efficiencies (power plants, electrical grid, AC/DC inverter, energy-power storage systems in slow charge/discharge modes, power electronics, electrical motors), the WTW efficiency of the electrical powertrain can be stated to range from 0.24 to 0.26, i.e. the consumption of primary energy for the reference vehicle is between 457 Wh/km and 492 Wh/km (Table 1).

A comparison with the situation 10 years ago shows that in the last decade technological evolutions have radically changed the impact of the EV on primary energy consumption: from about 30% higher primary energy consumption compared with the ICE in 1998 to about 25% energy savings in 2008. These figures do not yet take into account the potential for energy harvesting, e.g. by modern, low-cost on-board Photovoltaic (PV) technology. The growing fraction of renewable energy in the EU electricity mix will increasingly enable convergence of CO_2-neutral primary energy sources with electric mobility.

Year	Power	Grid Efficiency	Inverter AC/DC Efficiency	Battery Efficiency (Slow Charge)	Power Electrical Efficiency (DC/DC, AC/DC)	Motor and Magnetic Gear Efficiency	Energy Consumption Ideal mid-size car Wh/Km*	Total Consumption of Primary Energy Wh/Km*
2008 Range 150 km	0.42	0.80	0.90	0.80	0.90	0.80-0.86	120	641-689 15% Regenerative Braking
2008 Range 150 km	Renewable Energy only	0.93	0.90	0.80	0.90	0.80-0.86	120	235-219 15% Regenerative Braking
2008 Range 600 km	WTW Powertrain efficiency of a conventional Internal Combustion Engine car in reality: 0.16-0.23						120	750-522 10% mild hybrid

Table 2: Primary energy consumption with reduced power plant and grid efficiencies as well as fast charge mode.
*Energy needed to move an ideal mid-size vehicle in NEDC.
*Cars smaller than the reference vehicle may have less energy consumption.

The WTW assessments also show that introduction of EVs is less advantageous in countries with power plants and grids with efficiencies below average or when used in the fast charge mode with maximum efficiencies reaching no more than 0.8 in a low state of charge of the battery (Table 2). In those cases, priority should be given to modernising the sectors of energy production and distribution. Moreover, for both primary energy savings and longer battery lifetime, slow charge should be suggested as best practice until next generation batteries can ensure high efficiency under accelerated charging conditions.

Clearly, the convergence of Renewable Energies (RE) and electrified mobility appears the most appealing. Emerging awareness of climate change and pragmatic economical reasons will motivate the driver of the EV to ask for 'clean electrons', which commonly means electricity from RE sources. The EU-27 is paving the way for RE to achieve over 60% of new power installations soon[18] with the goal that new installations of RE could reach 90% before 2020.

On highways, full hybrids, due to their higher weight, have higher consumption than conventional ICEs, but hybridisation of conventional (mainly) large and mid-sized ICEs can be considered a first step towards energy efficiency through electrification as it allows energy savings up to 25% to 35% in urban cycles[19]. Its implementation on a large scale will thus help to comply with CO_2 emissions targets for cars in the EU for 2012/2015[20]. Thus, in the next five years a number of hybrid systems from micro to full hybrids will emerge. At the same time, lighter and smaller FEVs will be developed requiring, from the battery to the wheel on the NEDC, even significantly less energy than the reference car considered here.

Comparison of various powertrain types in terms of primary energy savings requires life-cycle assessment (LCA). In this sense, it has to be noted that the manufacturing of a conventional ICE car consumes an amount of fossil fuels approximately equivalent to twice the car's final weight, amounting to something like 18% to 20% of the total fuel consumption during its lifetime[19, 21, 22, 23]. The manufacturing of FEVs will require about the same energy (1 500 MJ/kWh of Li-ion battery) as the production of conventional ICE vehicles, if the full production chain is taken into account[24, 25]. On the contrary, production of full hybrids requires more energy than either conventional cars or FEVs. Further studies are foreseen to quantify the primary energy needed to produce the different vehicle architectures.

Generally speaking, the path to low-cost electrification is complex and involves new approaches to vehicle and powertrain design as well as a shift to co-modality including a change of consumers' attitudes towards sustainability, environment and alternative powertrains. Integration of EVs in the transport system therefore is necessary to create customer acceptance.

Cut in GHG emissions
(preventing climate change)

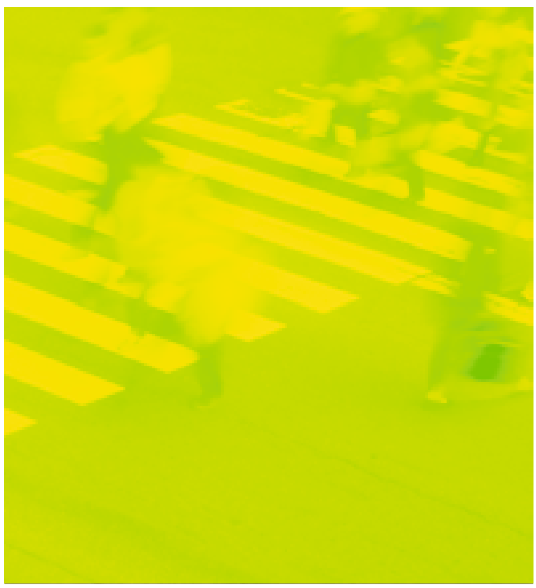
Vehicle emissions are contributing to the increased concentration of gases that lead to climate change. In order of significance, the principal GHGs associated with road transport are CO_2 and methane (CH_4). In the EU the transport sector creates 26% of all GHG emissions due to human activities[9, 26]. Although these are only 4% of the total GHG emissions, they accumulate in the atmosphere because the ecosystem is unable to compensate for them at the same rate since human activities have changed in the last century. Furthermore, the transport sector is the fastest growing source of GHGs, and over 85% of the total from transport are due to CO_2 emissions from road vehicles. Therefore, they are considered a major sector to attack for limitation of GHG emissions[26].

The differences between conventional mobility based on ICEs and EVs in terms of CO_2 emissions are summarised in Table 3. The factor of almost 1.5 between the two (for the EU mix) roughly reflects the ratio of energy efficiencies described in Table 1. Considering the electricity production mix of some of the major EU countries, it is evident that EVs may lead to a considerable reduction of CO_2 emissions.

Again, the impact would not be the same everywhere; for instance in a country where most of the electricity is produced by burning coal, there would be only minor GHG emissions benefit from EV introduction. The largest reduction is associated with the use of RE with the lowest values for EVs achieved, e.g. in the emerging 'carbon-free communities', where the electricity is entirely produced by wind, water, PV, geothermal energy, biomass or animal waste. However, in a vision where most new power installations will be REs, EVs are considered a way towards a radical reduction of GHG emissions. Deployment of EVs may even help to extend the use of RE if it is targeted at captive fleets in areas close to an abundant supply of stochastic renewable electricity.

Vehicle Type	Well to Tank (Batteries)	Tank (Batteries) to Wheels	Total CO_2 emissions
Conventional ICE car	25-35	120-180	145-215*
Electric Vehicle 27% nuclear, 20% renewable, 53% fossil (EU-27 mix 2010)	85-105	0	85-105
Electric Vehicle 11% nuclear, 20% renewable, 69% fossil (EU Italian mix 2010)	120-140	0	120-140
Electric Vehicle 75% nuclear, 20% renewable, 5% fossil (French mix 2010)	20-25	0	20-25
Electric Vehicle 30% photovoltaic on board, 60% other renewable , 10% fossil	18-22	0	18-22
Electric Vehicle 50% photovoltaic, 50% wind (Carbon-free communities)	8 5km per kwh and 40 g/kWh	0	8

Table 3: Comparison of WTW CO_2 emissions* for conventional ICE vehicles and EVs in relation to the electricity mix. Note: EU-27 electricity from renewables > 40% by 2020[18]: 14% hydro (now), 14-16% wind as projected by EWEA[18], 12% PV as projected by EPIA[18], 5% biomass+waste+geothermal electricity.
* CO^2 in g/km/NEDC WTW for the vehicle and LCA for the e-Energy source.
* For some compact ICE cars smaller than the reference considered vehicle, the total WTW CO_2 emissions are as low as 100 g/km.



Reduction of noxious emissions
(raising public health)

Road transport remains the main source of many local noxious emissions including benzene, 1,3-butadiene, carbon monoxide (CO), nitrogen oxides (NO_x) and Particulate Matter (PM). Within urban areas, the percentage of contribution due to road transport is particularly high. There is a growing body of evidence linking vehicle pollutants to severe health effects such as respiratory and cardio-pulmonary diseases and lung cancer. In general, according to the World Health Organization (WHO), emissions from car exhausts are responsible for more deaths than road accidents. EVs can contribute to the elimination of the side effects which are due to hydrocarbon combustion in conventional vehicles, provided that they don't occur during power generation. Some emissions, e.g. due to tyre/road abrasion, however remain.

Road traffic is known to be the most important contributor to urban noise levels, which usually exceed the WHO guidelines and cause major health problems. The noise of EVs is limited to rolling resistance and air drag; however, the effects on road safety caused by low noise levels have rarely been studied so far and need to be further investigated.

Range and speed
(freedom of mobility and the need of fuels)

A mid-sized EV in use for urban mobility will be designed such that it can be operated for most of the day from a single charge. On the contrary, on a highway or more generally at velocities higher than 120 km/h, energy consumption depends mostly on the speed rather than on the distance covered. As a consequence, due to the limitations imposed by affordable costs and the timing of recharge, the use of a fuel-based range extender will remain necessary until the next generation of much more advanced battery technology becomes available. To cover the full spectrum of mobility needs, whether the vehicle is a full, split, mild, micro or a serial hybrid, the use of high-energy density liquid or gaseous fuels will remain necessary without alternatives on the mid-term horizon[7]. At the same time, micro-hybridisation of conventional mid and large-size vehicles will continue and expand on a broad scale.

A need for research is hence foreseen in the direction of integration of compact and efficient ICEs and electrical motors, as well as in advanced fuel cells, e.g. as a range extender. Higher consumption of fossil fuels in emerging economies is likely to hamper biofuel output at global level. The search for new routes to new fuels is therefore of paramount importance in view of the ever increasing gap between demand and supply of oil. Further achievement should be encouraged towards novel biofuels derived from algae grown with biowaste nutrients and novel synthetic fuels, assigning a priority to solutions that minimise the use of land and fresh water.

It is however worthwhile to note that most of the mobility needs in European cities can be satisfied by pure mid-sized EVs as average mileage is almost always below 100 km per day at low speed.

Cost of technology and constraints on raw materials
(EU security)

The cost and supply constraints of the battery pack are acknowledged to be the most limiting factors for wide-scale introduction of EVs. Making a detailed analysis of the raw materials used in the current state-of-the-art Li-ion technology, their selling price may be expected to reach affordable values at below EUR 200 per kWh in the mid term[25, 26, 27, 28]. Learning effects due to large-scale productions and further optimisation of the cell structure would very likely lead to more desirable price levels in a few years, but the automobile user is asking for much more than just lower costs. Progress has been dynamic in terms of design of light-weight chassis, powerful and efficient drive trains, aerodynamic shapes and sophisticated computer controllers. However, the same statement cannot be made for battery technology.

Substantial reservations persist about the long-term performance of Li-ion batteries under the extreme heat, cold, humidity and vibration conditions that automobiles have to endure on a daily basis (if these are not compensated for by appropriate protection measures). For instance, the lifetime of a battery is halved every 10 degrees of temperature increase, which requires complex and expensive temperature conditioning including either expensive liquid or forced air cooling of the overall battery compartment.

Manufacturers and suppliers will accelerate their efforts to build demonstration fleets of high value products using available Li-ion battery systems, but production volumes will remain small until enough hard performance data are gathered to justify the widespread commercialisation of the technology. As a consequence, large format Li-ion battery supplies will be constrained for several years by inadequate manufacturing capacity, which in its turn influences the rate of cost reduction. Considering the size of the plants recently announced to specifically produce batteries for EVs, it can be deduced that the European production volume will not be sufficient to cover the expected demand of the automotive industry.

Batteries will not be available in adequate volumes during the regulatory compliance period and even insufficiently proven Li-ion batteries will be subject to daunting cost and supply constraints. In a nutshell, cost and supply constraints will leave the booming hybrid electric vehicle (HEV) and EV markets in a critical state of flux for several years.

The second large source of uncertainty is related to the availability of reliable and diversified supply of metals, e.g. copper and permanent magnets that are necessary to ensure high efficiency and high-power density (compact) electrical motors. While at a research level several solutions are pursued, it seems there is no viable industrial alternative to Neodymium Iron Boron (NdFeB) for at least another decade. The move from few and critical sources of oil to a likely even more critical single source of permanent magnets should urgently address the development of both new high-efficiency motors using a limited amount of permanent magnets and completely new motor designs. Just as with batteries, the production of low-cost, efficient and compact motors using permanent magnet technology will not be available in adequate volumes and will be subjected to supply constraints for several years.

The issues of batteries, motors and the scarcity of crucial materials severely threaten the large-scale introduction of electrified vehicles as they are pushing back the enormous and crucial economic and environmental benefits that EVs can provide.

3. General Expectations

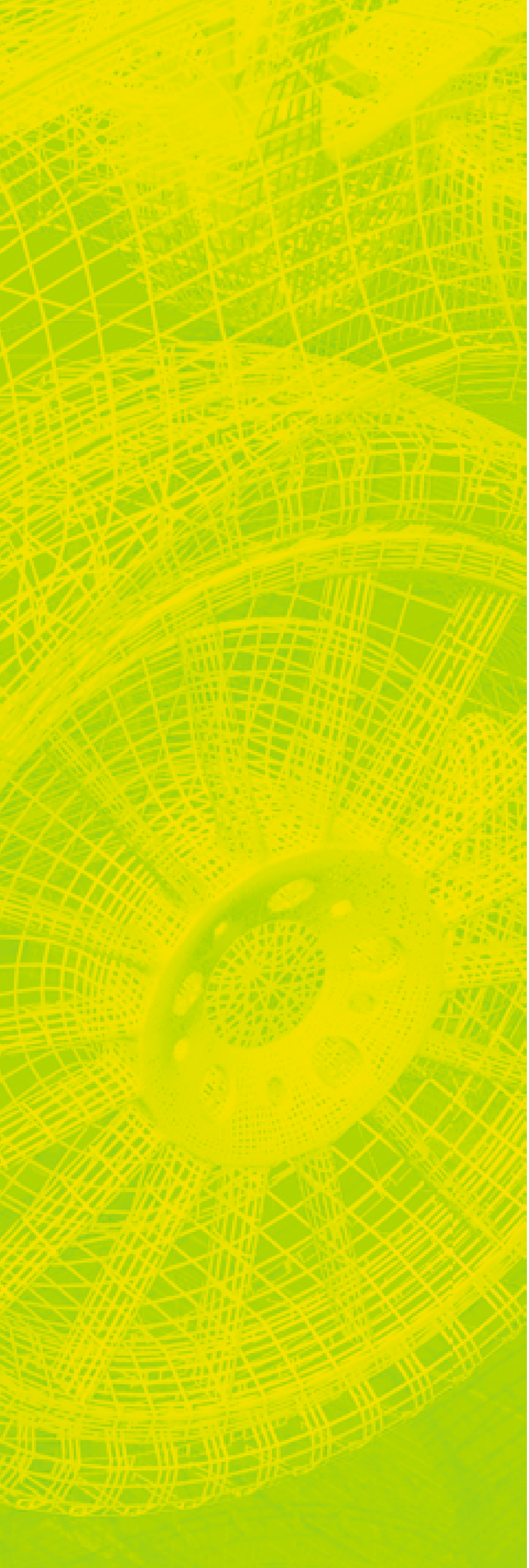
Public perception of the move towards the electrification of road transport is affected by a multitude of motivations like climate protection, primary energy savings and public health. At the same time, there are also concerns including high investment costs and scarcity of raw materials. However, it is the growing awareness that the underlying technology has gained a sufficient level of maturity that is pushing and pulling towards a quick change.

From one side users are asking for EVs well beyond what the Original Equipment Manufacturers (OEMs) can deliver, on the other side spread of unsafe vehicles, bad practices and inefficient infrastructures should be avoided. The number of people living in urban areas has recently surpassed the rest of the world population and everywhere the tendency is to avoid the urbanisation of new lands while remodelling the urban area by introducing new concepts of mobility.

To understand the potential current driving factors for the future market of EVs we consider the following EU data:

- 80% of Europeans live in cities:
  - 16 cities have much more than 1 million people
  - 70 cities have a population ranging from 800 000 to 1 million people
  - more than 1 000 cities have a population above 100 000 people
- From 7% to 10% of all Europeans live in areas or aggregations of houses that can potentially be transformed into 'carbon-free communities' in a few years (because of the current rate of growth of RE)
- 17% of vehicles are purchased by public administrations in the EU.

Several cities have already started the experimental use of EVs in their fleets, and many others are asking for vehicles in order to do the same. All major cities would be willing to be part of demonstration programmes and are ready to buy EVs rather than conventional cars. Because most charging stations will be located within municipal urban areas, some administrations could be tempted to manage the EV infrastructure – public paid recharging stations to generate a profit from both EVs and PHEVs. At the same time, all medium-size or large cities will soon have the problem of preparing the needed infrastructure and none of them wants to be the last. If an EV were to be sold at a price not more than 25% to 30% above what is asked for a conventional car, it is very likely that the majority of the vehicles purchased by public administrations would be electrified. It can be estimated that public administrations alone would currently demand more than 500 000 EVs per year in Europe.



4. Timing for Development and Implementation

In response to the above mentioned public expectations, the industries involved have combined their knowledge and experience in order to assess what benefits of the EV can be achieved by when, and what actions will be required to master the challenges of electrified mobility on a large scale. The setting of milestones refers to different scenarios (passenger cars, vans and buses) and considers six major technology fields:

- Energy storage systems
- Drive train technologies
- Vehicle system integration
- Grid integration
- Safety systems
- Integration into the transport system.

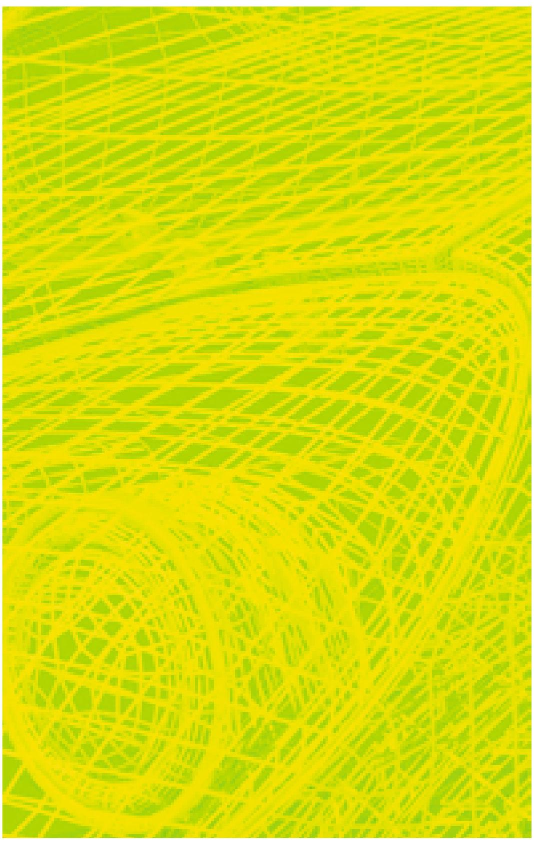
In many cases, further R&D is needed before the phase of market introduction. Furthermore, there is a need for at least Europe-wide standards to ensure interoperability. And the timing of respective measures requires horizontal coordination across the various technology fields.

Example: grid integration

The need for a coherence of R&D activities, business development and regulatory measures across various disciplines and sectors can exemplarily be described for the topic of grid integration of the EV. For EVs, no expensive infrastructures like that which would be needed to deliver and store hydrogen are required. However even for the most simple case, that is the conventional home plug, controlled uni-directional charging is desirable, and to take advantage of the full potential of an EV, a bi-directional smart charging V2G capability may be aimed at in the longer term. This will be based on an appropriate interface allowing the exchange of both electricity and data between the vehicle and the grid. Furthermore, the interaction of the EV with the grid is an issue involving the car owner, energy providers, grid operators, public authorities (at state, regional and city levels) and utilities, all calling for a positive business case.

A large-scale implementation of grid integration requires the definition of safety standards at the charging station as well as regulations to avoid undesired effects when connected to the grid[29]. Bi-directional charging or V2G will rather be a second step as the timing to get the infrastructure ready will critically depend on the speed with which the standards and regulations come into force, and on the availability of the required smart grids technology and the necessary investments. In this sense, experimentation with large fleets appears necessary so that enough data and experience on best practices could be collected prior to implementation.

With the electrification of road transport we are facing a disruptive technology objective that will be backed by massive investments all over the world. Thus major European companies agreed to jointly discuss their strategies and expectations for the largest and most demanding application, i.e. urban mobility, from which other applications will follow. They have developed dedicated roadmaps describing the milestones as well as the actions that will have to be taken in order to turn the move towards electrification into opportunities for Europe.



5. Milestones

As a kernel for the roadmaps, a scenario for passenger cars based on two technology paths was considered, and which can be expected to develop at a comparable pace:

- The PHEV providing 50 km pure electric range, having an energy consumption of about 200 Wh/km as well as same comfort and same safety as a conventional car. A price of additional EUR 2 000 per unit appears to be acceptable.

- The EV providing 100 km pure electric range, seating four passengers, having an energy consumption of 200 Wh/km, smart (and in the long run bi-directional) charging capabilities, same comfort and same safety, at reasonably comparable cost of ownership.

Separate roadmaps may be developed for buses, delivery vans and light duty trucks (i.e. modes of transport being responsible for high levels of noise, CO_2 and noxious emissions), two-wheelers, hybrid and conventional powertrains (which have an enabling role for electrified mobility), HD freight transport (where efficiency gains may rather be expected from smart logistics than from electrification) as well as for road infrastructures. Over the course of the next 10 years, the following three milestones, related to the electrification of passenger cars, can be identified (Figure 2).

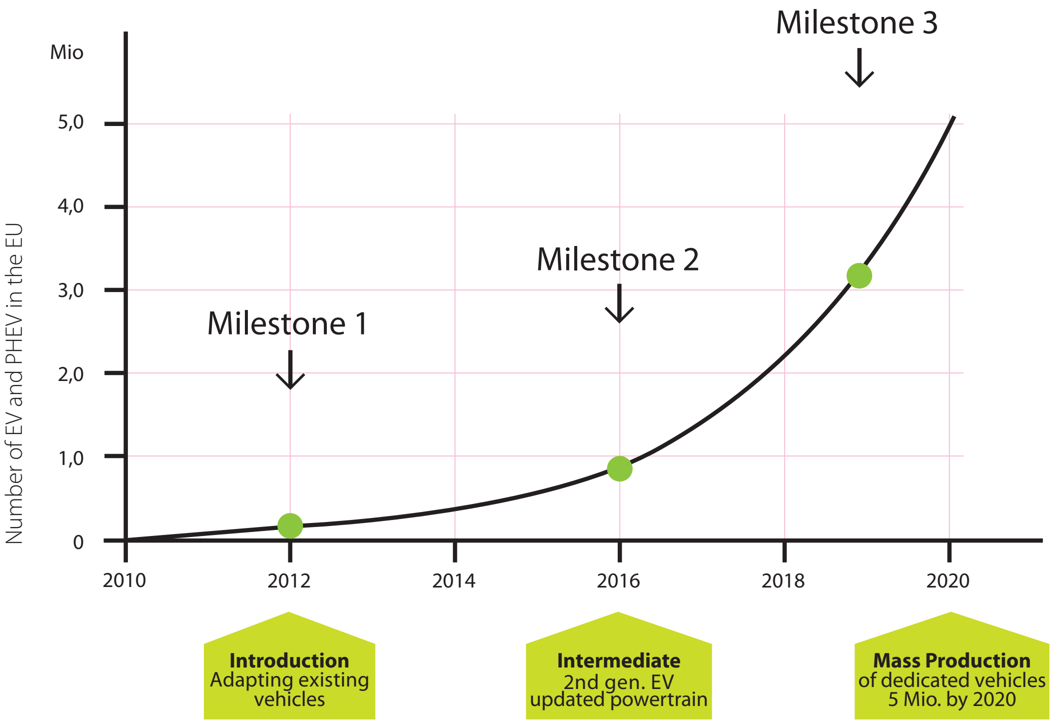


Figure 2: Milestones of the European industry roadmap for electrification of road transport.

Milestone 1: Introduction (2012)

The first step of implementation of electrified mobility will be based on the adaptation and conversion of existing vehicles into PHEVs and EVs. Beyond demonstration and field operational tests, first fleets may evolve for niche applications, e.g. taxis, car sharing systems, delivery services and other captive fleets. Standards for safety, data communication and billing will be developed, along with testing activities and actions for raising public acceptance. At the same time, major breakthroughs can be expected in terms of the understanding of underlying technologies and principles.

Milestone 2: Intermediate (2016)

It is expected that the base technologies for a dedicated second generation EV providing efficiency gains for all consumers, advanced system integration and high-performance energy storage systems will become available at the intermediate time scale. At the same time, an enlarged charging infrastructure allowing dissemination over various cities and regions will develop.

Milestone 3: Mass Production (2018-20)

In about 10 years from today, mass production of dedicated PHEVs and EVs will be fully established in Europe. In particular, batteries, which are the most crucial component, have to be available providing about tripled life time and energy density at about 30% of today's cost, and highly integrated and cheap electrical motors need to be on the market in large quantities. This will make the vehicles sellable without subsidies. The infrastructure for grid integration is expected to provide advanced levels of convenience though contactless and (given the availability of appropriate power lines and batteries) quick charging at high efficiencies. Bi-directional charging will be an interesting option for fleet applications.

The industries involved agree that eventually, after 10 years, the goal of an accumulated 5 million pure EVs and PHEVs on Europe's roads may be achieved. Table 4 summarises the detailed description of the milestones in terms of energy storage systems, drive train technologies, system integration solutions, grid infrastructures, safety systems and road infrastructures as given by the involved companies and organisations from the ERTRAC, EPoSS and SmartGrids platforms.

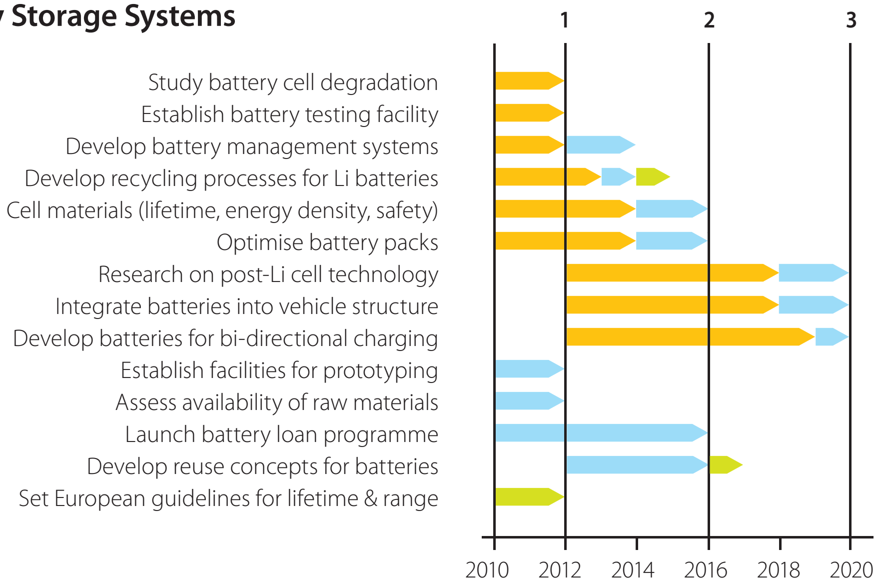
Technology Field	Milestone 1	Milestone 2	Milestone 3
Energy Storage Systems	Full understanding and proper management of all relevant parameters for safety, performance, lifetime.	Manufacturing of long life, safe and cheap energy storage systems with advanced energy and power density.	Availability of batteries providing tripled energy density, tripled lifetime at 20-30% of 2009 cost and matching V2G.
Drive Train Technologies	Availability of drive train components optimised for efficient use and recovery of energy.	Manufacturing of range extenders & update of electric motors for optimised use of materials and functionality.	Implementation of powertrain systems providing unlimited range at sharply reduced emissions.
Vehicle System Integration	Solutions for safe, robust and energy efficient interplay of powertrain and energy storage systems.	Optimised control of energy flows based on hard-and hard-and software for the electrical architecture.	Novel platform based in overall improved system integration.
Grid Integration	Charging adaptive to both user and grid needs.	Charging at enhanced speed.	Quick, convenient and smart charging with bi-directional capabilities.
Safety Systems	EVs (tested and inspected) meeting (new) safety standards at same levels as conventional cars.	Implementation of solutions for all safety issues specific to mass use of the EV and road transport based on it.	Maximum exploitation of active safety measures for EVs.
Transport System Integration	Road infrastructures and communication tools encouraging the use of EVs.	Full integration of EVs with other modes of transport.	Automated driving based on active safety systems and car-to-x communication.

Table 4: Detailed description of the milestones of the European industry roadmap for electrification of road transport.

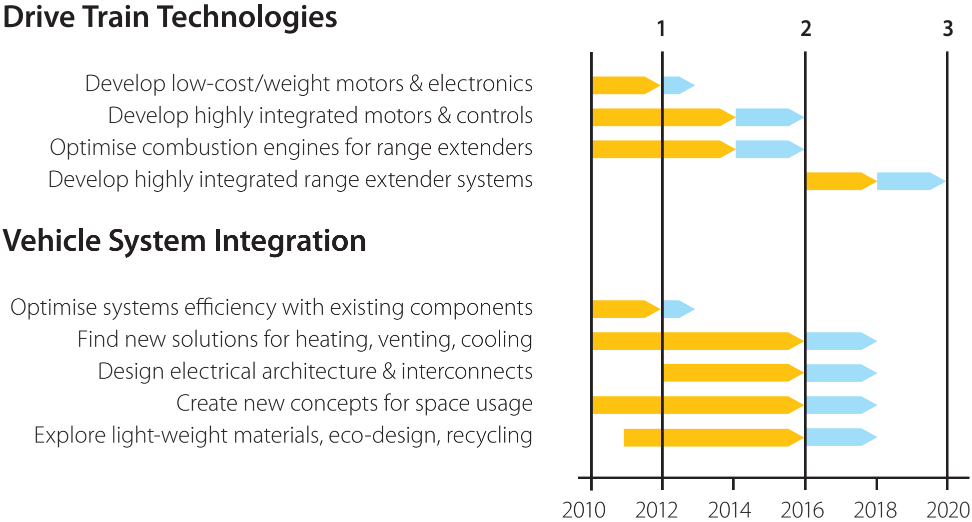
Following the definition of milestones (Table 4), the involved companies and organisations from the automotive and energy sectors agreed on actions to be taken in order to achieve the stated objectives. Considering phases of R&D, production and market introduction as well as the establishment of regulatory frameworks, dedicated roadmaps were drafted that indicate what has to be done when for a well-timed move of Europe towards the electrification of road transport. Focus topics were based on the above mentioned priorities of Energy Storage Systems, Drive Train Technologies, Vehicle System Integration, Grid Integration, Safety Systems and Integration into the Transport System as a whole (see Chapter 6: Roadmaps).

6. Roadmaps

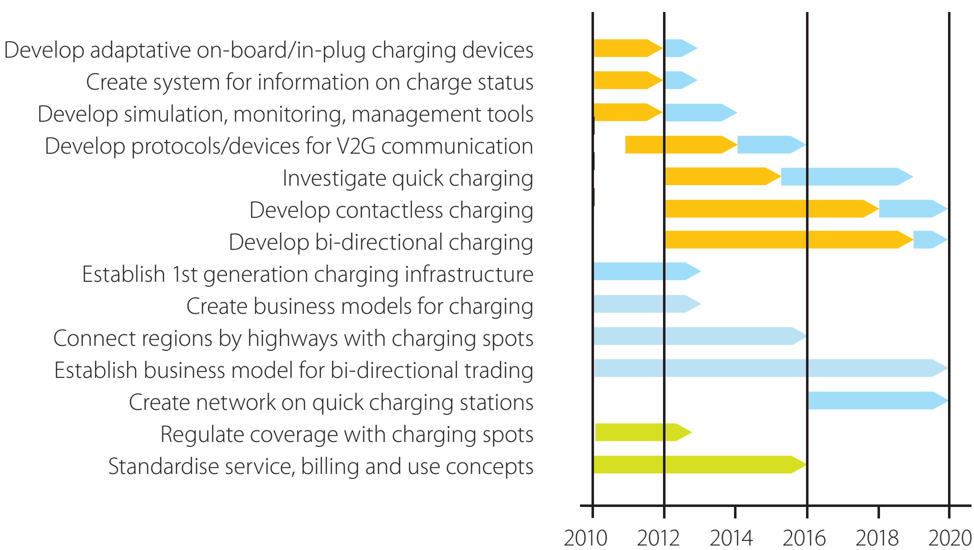
Energy Storage Systems



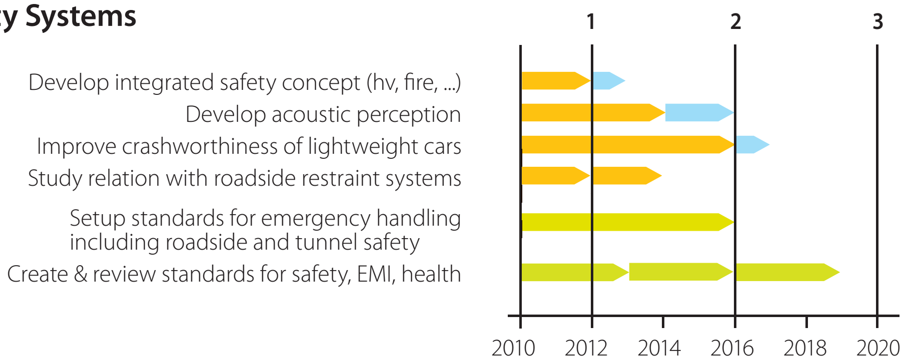
Drive Train Technologies



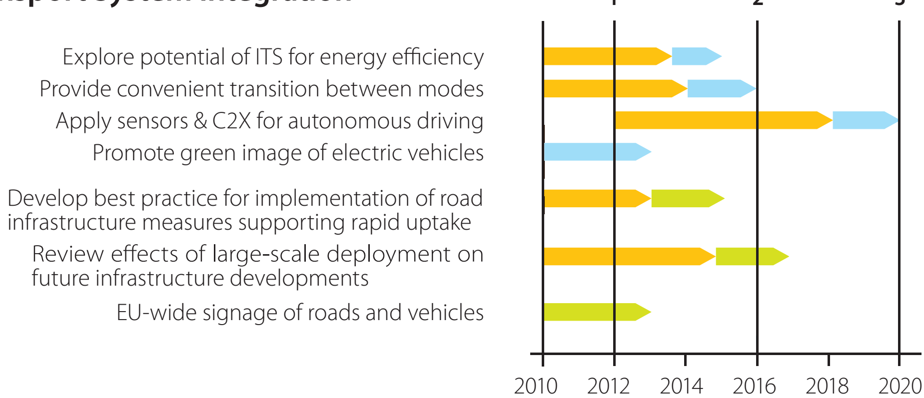
Grid Integration



Safety Systems



Transport System Integration



7. Recommendations

Based on the indications given in the roadmaps, recommendations can be made on how and when the research needs for the EGCI should be covered by objectives of the respective work programmes of the Seventh Framework Programme (FP7) (Figure 3).

Figure 3: Suggested coverage of R&D topics by years and calls of the FP7 work programmes of the EGCI (white box: match of programme and R&D need; green box: suggested objective in respective year).

NMP: 'Nanosciences, Nanotechnologies, Materials and new Production' Technologies (Directorate General Research and Innovation).
SST: 'Sustainable Surface Transport' (Directorate-General Research and Innovation).
ICT: 'Information & Communication Technologies' (Directorate-General Information Society and Media).
ENV: 'Environment' (Directorate-General Research and Innovation).
MOVE: 'Transport' (Directorate-General Mobility and Transport).

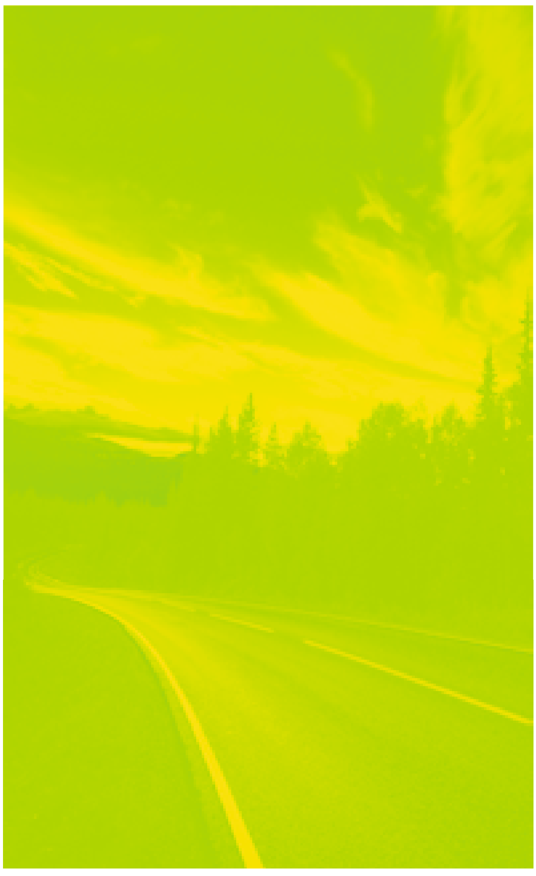
Modes of implementation should include the funding of focussed industrial and academic R&D projects (STREPS: Specific Targeted Research Projects). Furthermore, a multitude of horizontal challenges (e.g. grid integration, transport system integration) will require large scale actions like Integrated Projects (IPs) and Field Operational Tests. Moreover, there is a significant need for coordination among the sectors that are coming together in the new value chains of the EV. Eventually, industry, utilities, infrastructure providers, academia and public authorities at European and Member States level should join their efforts in specific PPPs and joint programmes horizontally covering all aspects of electromobility, the involved industrial sectors and their interconnections. Moreover, the results of all projects of the EGCI should be thoroughly benchmarked according to their industrial and scientific impact.

In relation to coordination with other ongoing related initiatives, the work already done by the European Electricity Grid Initiative (EEGI) under the Strategic Energy Technology Plan (SET-Plan[30]) is acknowledged. Under this initiative, grid operators have recently published a Roadmap 2010-2018[31] that already identifies a functional project that addresses the network changes needed to host large-scale penetration of EVs in Europe, with proposals to implement extended electricity recharge infrastructure in order to guarantee the easy, secure and flexible recharging of EVs. Good coordination and exchange of information between both initiatives must be ensured.

8. International Collaboration

The authors of this roadmap recommend a close cooperation of the PPP European Green Cars Initiative with international partners in the domain of the full electric vehicle (FEV). Based on their experiences and assessments, the following actions are considered of utmost importance:

- To join the Annexes of the Hybrid and Electric Vehicle Implementing Agreement and other working groups of the International Energy Agency
- To establish and manage contacts with China
- To link the EV communities in the US and Europe
- To initiate joint EU-Japanese Programme Activities for the EVs
- To support R&D and demonstration of electric mobility in megacities, e.g. in Brazil
- To actively participate in major international conferences and events.



Long-Distance Trucks

II

1. Introduction

The economic development and competitiveness of Europe depends on an effective and efficient transport and logistics system. The mobility of people and the flow of goods to, from and within Europe must be cost efficient and at the same time safe and environmentally sustainable. Increasing globalisation and competition in most sectors further emphasise the importance of a competitive European transport system. The importance of the European transport system is stressed in the European Commission's Communication on 'A sustainable future for transport'[32] stating that 7% of European gross domestic product (GDP) and 5% of employment can be attributed to the transport industry at large.

Despite efforts during the last decade to decouple GDP growth from freight transport, demand for freight transport increased by 2.7%, whereas GDP increased by 2.5%. This should be compared with passenger transport that grew at a pace of 1.7% during the same period[32]. The European transport sector is not yet on a sustainable path in several respects. Transportation is responsible for the major part of the increase in oil consumption during the last three decades, a trend that is expected to increase. In the EU, the environmental footprint of transport corresponds to 23.8% of GHGs and 27.9% of CO_2. As the sector is 97% dependent on fossil fuels, the environmental concerns are well aligned with efforts to improve energy security[32]. Hence, the entire transport sector, and particularly road freight transport by trucks and lorries, has been focused on as a main policy area where further environmental and overall efficiency improvements are critical for the sustainable future of European transport.

To ensure sustainability and global acceptance, the future commercial transportation requires the development of systems that reduce dependence on oil and minimise the emission of GHGs. Today, the transport sector accounts for 58% of the global oil consumption and approximately 20% of the global, energy-related, emissions of GHGs. The whole transport system needs to be restructured and reorganised. Transport emanates from needs of private citizens, business and public organisations to get goods and employees moving within selected geographic locations. To accomplish this, a number of modes with their individual infrastructures and traffic operations are available. For each mode there are different types of sub-modes with separate and common infrastructures and traffic operations. Between and within the modes there are hubs making it possible to consolidate and change mode for the transport 'packages'. Furthermore, transport and traffic 'packages', carriers, vehicles, drivers, flows, infrastructures etc. are connected to a varying degree through wireless communication infrastructures. Transport operations are planned and managed with different cycle times from months to real time. The transport system as a whole is gradually becoming more effective but there is an untapped potential for improvement. Furthermore, its sustainability, safety and reliability must be improved. A significant amount of these requirements will need new business concepts and new technologies as well as pan-European standards and regulations developed in public-private collaboration.

Examples of new concepts, also found in the ERTRAC Scenario document[33], are for instance the 'Green Corridor' concept that could be introduced and used for highly-populated multimodal corridors in Europe by 2030. The criteria for access to these corridors could be related to new vehicle concepts, performance and transport efficiency. In the road part of these corridors, more transport and energy-efficient vehicles could possibly be coupled electronically into convoys that are 'platooning'. Thereby, the throughput of trucks and goods, safety and energy consumption per load unit (volume, weight) could be higher compared to present highways. Trucks and trailers would need to be optimised for the load carried so that the speed can be harmonised. Emissions would fall, and the levels would depend on the increased throughput, reduction of congestion and the fuel efficiency of complete vehicle concepts. On average, CO_2 emissions could be 25% lower in a corridor, compared with the overall average vehicle emissions.

In 2030, tri-modal land hubs could provide fast trans-shipment of people and goods between rail, inland waterways and road services. Conventional inland terminals, such as those existing today, will still be operating, serving regional traffic and local distribution. At these sites, fast but cost-effective 'horizontal' trans-shipment could take place, including the loading and discharge of trains and barges for inland waterways. Small lifting equipment could be used for loading trucks, when needed for short hauls. Dual-container loading facilities could be provided, both 'horizontal', i.e. making use of automatic shuttles rolling on and off the vessels, and 'vertical', using batteries of container cranes in parallel loading several containers at the same time. A standard loading unit would have been agreed on worldwide and would be used globally, as well as Radio-Frequency Identification (RFID) technology (an ICT protocol that can be used for the remote tracking and tracing of freight consignments).

A network of inter-modal transfer points of various sizes and degrees of reach would facilitate the seamless transfer of cargo between the backbone of interconnecting multi-modal corridors and the regional networks. Automatic locking on container castings and tray castings, in combination with the automatic positioning of the train at the loading floor, would be standard, as would enhanced communication technology, to enable cargo and pallets to remotely communicate their status, and smart dust providing physical security for loading units. For delivery trucks, this would also enhance road security for cargo and drivers. Transport of goods for delivery to local shops or customers would become autonomous.

The system would be further enhanced by efficient information usage and driver support systems (vehicles will be fully 'connected' and able to communicate with each other as well as with the road operator, transport planner etc.) and by the development of strategically located, advanced hubs for both inter-modal transfer and the transfer between urban and non-urban freight transport.

2. General Expectations and Approaches for Road Transport Improvement

All transport modes are needed to work in seamless coordination due to capacity limitations. ERTRAC has recently issued scenarios and objectives for road-based transport proposing that, with the combined commitment and assumption of responsibility by all stakeholders concerned, transport efficiency should become 50% more efficient by 2030 compared with today. This target is translated into three main areas and a number of indicators with corresponding guiding objectives as shown in Table 5 below.

The mission of '50% more efficient Road Transport' is articulated in leading indicators on Decarbonisation, Reliability and Safety. Each indicator is furnished by a guiding objective for 2030 either indicating the improvement versus a 2010 baseline, indicated with '+' or '-' sign or an absolute level as is the case with 'Share of Renewables'.

A number of important research, innovation and policy challenges, that will contribute towards these targets and gain from a pan-European approach, have been identified.

'...transport efficiency should become 50% more efficient by 2030 compared with today...'

	Indicator	**Guiding objective for 2030**
Decarbonisation	Energy efficiency: urban passenger	+80 %
	Energy efficiency: long-distance Freight	+40 %
	Share of Renewables	Biofuels: **25%,** electricity: **5 %**
Reliability	Reliability of transport times	+50 %
	Urban accessibility	Preserve / improve where possible
Safety	Accidents with fatalities and severe injuries	-60 %
	Cargo lost to theft and damage	-70 %

Table 5: Summary of guiding objectives of ERTRAC's 'Strategic Research Agenda aiming at a 50% more efficient Road Transport System by 2030[3]'.

This second part of the multi-annual roadmap and long-term strategy aims to address primarily long-distance trucks, whereas aspects relating to co-modality & logistics are covered in the third part. Correspondingly, a number of cross-cutting issues exist and are treated in both parts from different perspectives, in particular Green Corridors & hubs, city logistics and intelligent logistics solutions.

Today many bottlenecks in road, rail, sea and air transportation 'infrastructure' exist where it is not possible to create new links. The concept of Green Corridors is aimed at addressing this problem by, amongst others, increasing capacity through different means requiring a system approach involving vehicle and trailer manufacturers, road and ICT infrastructures, logistics operators etc. Other resources that should be made more effective are co- and intra-modal hubs. By co-utilisation between different forwarders and faster transfer times, land resources can be freed up. In both cases vehicles, load carriers and switching equipments must be optimised to work in these new physical environments.

In general, full vehicles supporting consolidation of freight loads enable the highest level of transport effectiveness and also the fewest number of freight movements to be achieved, thus reducing congestion. However, the need for rapid delivery and short-stock piling times makes it sometimes difficult to fill or use large vehicles. This situation can be improved significantly by implementing intelligent logistics solutions including the optimisation of e-Freight initiatives and the concept of bundling freight flows controlled by goods operators, which necessitates common platforms for information and business exchange. Research, innovation and policy development to adequately address this issue is required, in addition to focussing attention on business models, service platforms and databases, ICT and protocols, modularised goods carriers and vehicles etc.

Following this approach has important implications for both vehicles and infrastructures. While respecting the limitations on vehicle size given by the road infrastructure, it should be possible to tailor vehicles and load carriers for a better match with the goods transport assignment. Correspondingly, focussed research on the layout and design of vehicles that are optimised for a more specific mission profile and better overall efficiency is required.

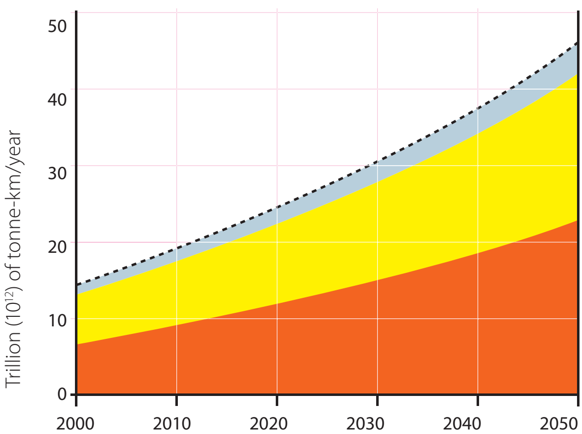
Moreover, a significant part of long-distance transport using heavy trucks is associated with connecting to customers in urban areas. In this context, city logistics issues are a crucial part of the overall picture. Usually hubs at the city periphery are used as switching points for goods, with concepts based on tailoring vehicles and goods carriers to facilitate movement within city environments to load and unload at local consolidation centres. An interesting concept to be developed further in this context is the extension of Green Corridors into the urban environments. In the longer term it should be possible to convert large trucks into smaller vehicles, and vice versa, and to use electric propulsion while moving within the city provided an adequate infrastructure is available (e.g. for battery charging etc.).

Current interest regarding electricity as the energy carrier, especially for cars operating in urban areas, will be explored also with respect to commercial vehicles. Electrification will open up the opportunity for a transfer to sustainable energy sources such as wind, hydro, solar and biomass. Limited energy storage capacity and energy transfer speed will require considerable investments in the whole energy supply infrastructure. For long-distance trucks, a broad approach aiming at developing sustainable trucks that can run on onboard fuels but also have opportunities to attach to available grid sources along the roads is under way. The partial electrification of certain drive train systems will assist in this development. It is important to emphasise, however, that CO_2-neutral liquid fuels and combustion engines are the basic energy conversion concepts for the foreseeable future.

As indicated in Table 5, approximately half of the forecast improvement in the efficiency of long-distance freight must be provided by increased energy efficiency of the vehicle itself. Improved driver support systems and logistics and infrastructure should also contribute significantly to improvements in efficiency. Furthermore, considerable improvements for long-distance trucks are expected in the area of safety, reducing accidents and fatalities.

3. Challenges and Prospects for Long-Distance Truck Innovation

In the 2006 mid-term review of the 2001 Transport White Paper of the EC[34], goods transports in Europe are projected to increase 50% between 2000 and 2020. Regardless of the future scenarios chosen to meet this challenge it is evident that goods transports on European roads will have to absorb the lion's share of the increasing transport demand.



	Average Annual Growth Rates 2000-2030	2000-2050
Total	2,5%	2,3%
Medium-Duty Trucks	3,0%	2,7%
Freight Rail	2,3%	2,2%
Heavy-Duty Trucks	2,7%	2,4%

Figure 4: Predicted transport demand.
Source: WBCSD (2004): Mobility 2030: Meeting the challenges to sustainability[35].

Modal shift from road to rail, short sea shipping and inland waterways are of course put forward as a more sustainable alternative but the potential is intensely debated and limited at best, compared to the potential for energy efficiency improvements in the Road Transport System. Modal shift indications can be found in studies of the UK situation that showed that the road share could decrease 14% (tonne-km) to 2050. Studies in Sweden have indicated

the potential to move freight from road to rail and sea to around 10%[36, 37]. Efficient use of incentives may stimulate the use of innovative logistics solutions such as e-Freight, online load and capacity-sharing platforms. Considering the projected increase in transport demand, Europe will probably continue to rely on long-distance trucks to maintain a competitive transport system.

A key factor for the transport sector is to be flexible enough to adapt to possible changes in the transport patterns. Logistics will be much more complex and flexible due to new trading partners, due to increasing integration of order and production process with transport and delivery and due to changing transport corridors, e.g. road and rail transport between Asia and Europe.

Road transport accounts for about 75%[38] of goods transport today, and continues to develop rapidly, not least because of its transport and quality characteristics.

One major challenge in road transport is congestion. This will be addressed in different ways. There is for instance the concept of Green Corridors, which among others aims to improve the safe and clean usage of transport infrastructures. In principle it can be applied in both inter-urban and urban environments. This concept will put a strong demand on the development of more effective vehicles, standardised load carriers and supporting Intelligent Transport Systems (ITS)/ICT systems.

The potential for increasing energy efficiency and safety of long-distance trucks is structured into three main areas in which timely R&D, demonstration, production, market introduction and regulatory framework development are pointed out in a roadmap format.

Vehicle Efficiency

Areas vital to the truck OEM industry to be addressed include new smart concepts such as modular load-carriers and innovative complete vehicle solutions (including the trailer) contributing to adaptable, tailored, efficient and seamless transport.

Overall transport efficiency also benefits from vehicle optimised aerodynamic design, reduced rolling resistance and internal friction, lighter truck and trailer concept and efficiently designed and controlled auxiliaries.

Areas important for increasing the efficiency of the truck and its operation are, for example, optimised vehicle specifications that better tailor truck and trailer components, weight and length of vehicle combinations, increased level of modularity and innovation in the trailer market, e.g. the uptake of lightweight, high-volume low-bed trailers and also more efficient operation of the truck by the driver.

Vehicle concepts and technologies for research:

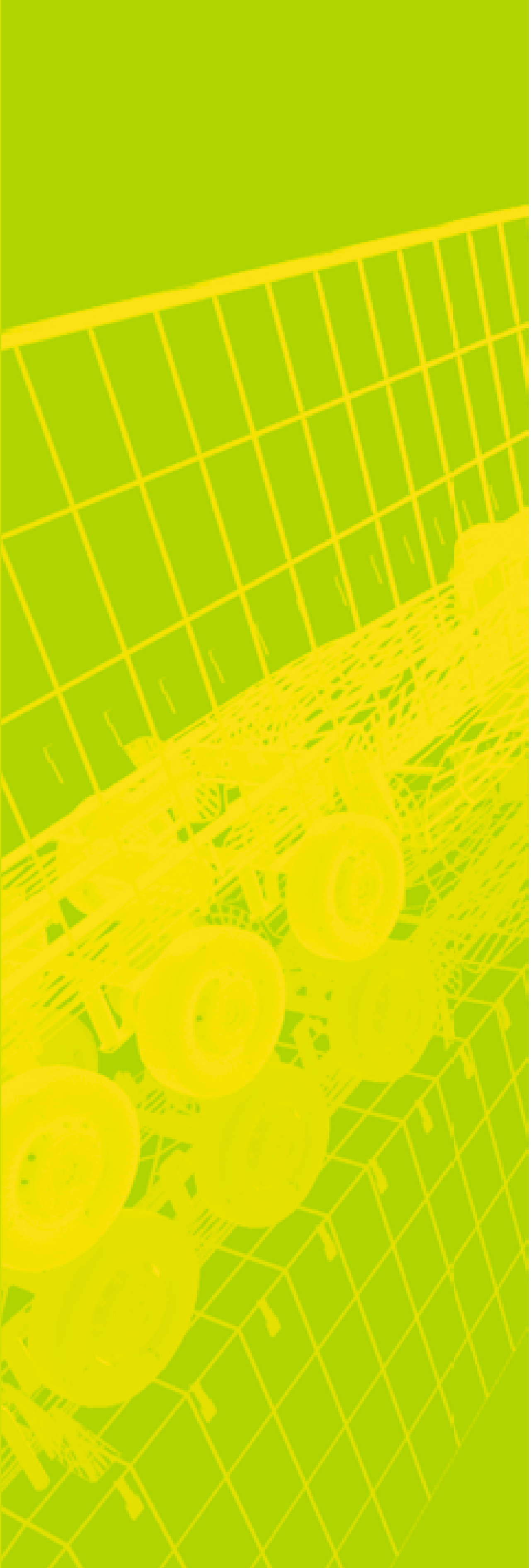
- The safe and intelligent truck
- Matching vehicle to operation
- Design dimensions for optimised load capacity
- Aerodynamics
- Low rolling resistance
- Energy management and efficient auxiliaries
- Advanced materials and design.

The safe and intelligent truck

To be fully integrated into the transport system, vehicles will have to be smart enough to 'sense' their surroundings and navigate through traffic safely and efficiently, while providing their occupants and cargo comfort and convenience. The vehicle will be a 'node on the Internet', and will be 'online' with other vehicles (vehicle to vehicle (V2V)), with the transport infrastructure (vehicle to infrastructure (V2I)), and with homes, businesses and other sources (V2X). When online, the vehicle will assist the driver by offering automated responses to developing traffic and operational situations, leading to increased efficiency, safety and enhanced quality of service.

Matching vehicle to operation

As freight transport operators are likely to require even more flexibility in the future, accessibility to a set of tailored vehicles or to vehicles able to adapt their operation is crucial. Today, single vehicles are often used for many different tasks, often inefficiently. Trucks built to carry 40 tonnes will often only carry 20 tonnes because they are carrying low density goods and are full on volume not mass. In these cases a large quantity of 'dead' weight is transported, therefore the vehicle load carrying ability would need to be 'upsized' to the absolutely maximum volume but 'downsized' both from a structural mass and powertrain point of view. Research, as well as internationally agreed and harmonised standards, are needed to determine present load factors/fill rates to make data collection cost efficient and unambiguous and to agree on realistic targets.



An optimised match of vehicles to the tasks will contribute to improving the efficiency of transport. For the operator to be able to adapt to changing operational conditions it is important to look at aspects such as access to the vehicle that best matches the needs and/or vehicle adaptation strategies to freight/cargo composition (weight, volume, shape, sensibility etc.) and to its operational environment, for example efficient transition between long-distance transport and urban delivery. The vehicle needs to be flexible with regard to powertrain capabilities and chassis design and to the freight modules composition, set up and weight (e.g. flexible tyre sizes). The vehicle needs to have upsize/downsize capability optimising payload.

Innovative leasing solutions that could be offered to transporters, so that vehicles can be leased (short, medium, long-term), and towing units can be switched on a given trip in line with their customers' requirements, according to capacity and engine power needs, will be explored.

An increased level of modularisation of freight modules is crucial for freight inter-modality and efficiency. Common standards need to be agreed to and implemented for the design and dimensions of freight modules (goods containers) in order to optimise the inter-modal vehicle. Automated operation and coupling/decoupling of freight modules as well as built-in intelligence, e.g. cargo on-board monitoring, tracking and distribution, are interesting areas for research. Inter-modal shipping involves the movement of freight by multiple modes, preferably in a single freight module (container). The freight modules have to be flexible enough to fit all modes and handling, loading and unloading need to be efficient and flexible. In other words, a level of increased operational flexibility is needed to be able to implement an efficient inter-modal transport system.

Ensuring smooth, safe and swift trans-shipment between modes could remove an important bottleneck in inter-modal transport chains and an obstacle to an increased share for inter-modal/combined transport.

Design dimensions for optimised load capacity

The use of internationally agreed modular concepts for pallets, swap-bodies, containers etc. will result in increased efficiency of transport in general and road transport in particular. Standardised load modules give high flexibility and an opportunity to standardise vehicles that are adaptable to different situations, and to use optimised combinations.

The use of modular concepts throughout Europe could have a positive effect on transport efficiency and on the environment, and could also support inter-modality. Initiatives to agree on standards and to facilitate the implementation of modular concepts in which industry, authorities and policymakers collaborate, are vital. In order to support the setting of this regulatory framework, extensive impact assessments will have to be performed, taking into consideration the whole transportation system and analysing the impacts on the environment, on safety and on mobility aspects (e.g. congestion, user acceptance etc.).

According to McKinnon and Piecyk[36], we can expect several developments over the next 40 years, promoting consolidation of freight loads into larger and heavier consignments to make better use of vehicle capacity.

To meet these expectations, vehicle design needs to be optimised. Important research areas are: mapping and predicting how many different types of loads are carried by trucks on the road, impact and consequences of road vehicle mass and dimension on transport efficiency, modal split, infrastructure capacity, safety, traffic generation etc., strategies to optimise pay load, chassis control (braking, handling, traction) and modular vehicle architecture.

Aerodynamics

Aerodynamic drag is an important loss factor for long-distance highway freight, and is a key target to reduce for optimising complete vehicle efficiency. Vehicle aerodynamics can be optimised by changing the design with regard to shape, contour and minimised total front area. Reduced aerodynamic drag shows a near linear effect on fuel consumption[39].

As a first step towards true optimisation of the aerodynamic design of trucks, it is essential to study and identify best practices in order to enable standardised methodologies for aerodynamic simulation and analysis to be defined, referring also to other sectors of industry where finely-tuned aerodynamic analysis is critical (aeronautics, performance cars etc.).

Tractor and trailer is the most common configuration in Europe. Only optimising the tractor, or trailer, will not result in any major gain; it is by investigating the whole system that a significant impact can be made. Seeking both increased transport capacity and reduced carbon footprint, aerodynamic solutions have shown great potential[40]. Robustness for different speeds and conditions combined with adaptive configurations and control of the whole vehicle will have a big impact. Front geometry for optimised cooling, better safety and minimised drag, tractor-trailer air-gap control, coupled with rear-end solutions and aerodynamic side-skirts covering wheels have all shown to reduce drag significantly. New aerodynamic solutions should, however, not compromise operational efficiency of cargo handling. Integrated solutions need to be developed.

Platooning or convoying (V2V control and communication) could contribute to increased transport efficiency due to reduced aerodynamic drag and reduced contribution to road congestion, but must be assessed against safety concerns, dedicated new infrastructure requirements and costs.

Low rolling resistance and low friction

Reducing friction, in all parts of the long-distance truck, has a direct impact on fuel economy and vehicle lifetime productivity. New roller bearing concepts, along with novel lubricants, are necessary. New simulation techniques will guide on how to reduce friction even more. Combining coatings with low viscosity lubricants will substantially reduce hydrodynamic friction losses. The whole powertrain and axle parasitic losses should be decreased. Cost efficiency can be maintained by smartly designing for and using low friction-coated bushings to replace lubricated bearings. Lubricants will also be developed and tailored for new driveline concepts.

The use of advanced tyres with extreme low rolling resistance will make an important contribution to improved complete vehicle efficiency. Future work should thus include the development of technology prototype tyres and wheel units for testing and minimising rolling resistance. By adding improvements in tyre-vehicle interaction fuel savings of up to 10% might be achieved. To reach these goals potential target conflicts (wet/winter performance, mileage, robustness, cost etc.) will have to be overcome. Different transportation needs could also require different wheel radii for minimising rolling resistance; for example, volume load benefits from large diameter wheels, whereas maximum laden vehicles benefit from smaller diameter wider wheels. This means matching vehicle to mission to be configurable or adaptive.

Intelligent solutions such as tyre pressure monitoring systems, or adaptive tyre pressure systems, along with information to the driver on tyre condition (age, mileage, wear, damage, temperature), for example via radio-frequency tags or sensors, could further improve tyre performance.

Energy management and efficient auxiliaries

Auxiliaries include water pump, oil pump engine fan, air compressor, active steering, A/C compressor, pneumatic system, defroster/heater/air conditioning, Waste heat recovery (WHR) systems. The objective is to optimise and control all these sub-systems in order to get a balance between mission performance and energy consumption. This can only be done efficiently in real time if all units are electrified and systematically controlled in a complete energy-balancing system. The power supply to the trailer and the control of electrically or hydraulically powered outputs are also to be included in the control loop. The vehicle should be able to be self-aware of the current configuration and situation, in order to be efficient and not to overload the operator or driver. All this can only be introduced with a distributed electrical architecture aiming for as few energy conversions as possible, for better energy efficiency. The path is to go fully electrified with auxiliaries – especially with the advent of electric hybrid powertrains. Higher voltage components (some as 'simple' as Bi-Xe headlights) can increase efficiency and benefit from certain hybrid technology. Other lights, interior and exterior, should also be changed to LED's or other lean alternatives.

Idling can make up for a significant part of the workday for certain vehicles; loading, unloading, or when the driver is sleeping or resting. The cab is a work place and also a resting place, so good insulation (lightweight, recyclable, noise insulation, heat and cold resistance) will also contribute.

An efficient Auxiliary Power Unit (APU) is vital. Energy storing and charging must be solved for highest impact of an electrical system. An alternative based on fuel-cells could be a solution. Energy management aims at optimising the performance and synergies for cooling performance and optimised control of all electrified auxiliaries.

The actual transport situation, i.e. type of mission, route, traffic situation, possible charging possibilities etc., should be taken into account for a complete energy management system. This includes situation sensing and adaptation. Examples are:

- Optimisation of all configurable vehicle parameters depending on the actual mission
- Energy balancing including efficient electrical power generation, conversion and distribution to different systems
- Energy recovering/scavenging/harvesting
- Optimisation of external energy, e.g. quick energy charging stations.

WHR systems and APUs can provide a secondary (back-up) source of electrical generation for emergency and safety reasons, auxiliary load powering, and generally as an additional source of electrical generation and efficiency to increase idling efficiency.

The local control strategy must be optimised while taking the overall energy management into account and balancing local and complete energy storage.

APUs are important when reducing idling energy consumption. Centralised management of all components and sub-systems will play an important role in energy management and control.

Advanced materials and design

A light weight truck has many advantages like increased payload capacity (increasing energy efficiency) less fuel consumption (especially for start-stop situation), reduced road wear (per tonne transported goods). However, this is a challenge that needs to find an optimum balance between demand and requirement – safety is not to be neglected, nor production cost. As a Heavy-Goods Vehicle (HGV) is most likely to have a life of several hundreds of thousands of kilometres, durability is a key element.

For a truck cab, new light weight designs and materials have many possibilities: improving aerodynamics for the hood, and if present, roof and air deflectors. The weight-reduced cab will also be optimised with regard to manufacturability, structural integration, durability and safety. Lessons and synergies from the passenger car industry are increasing and are being transferred not only to trucks, but also to buses and other heavy equipment. Similar approaches will be adopted for the chassis and trailer structures.

Being a place of work, the importance of the interior design of the vehicle must not be overlooked. New solutions for thermal, acoustic and vibration comfort must be sought by improving the design of the cab interior and its sub-systems, including the seat, controls and heating, ventilating and air conditioning (HVAC) system, and through the development of multifunctional materials. The use of advanced materials and innovative technologies could also lead to weight reduction in addition to improving the real and perceived comfort which will also lead to improved safety through enhanced driver performance.

In this context, the development of materials as an enabler must not be underestimated. As regards the structure of the vehicle, the trend must be first to design 'smart' with existing traditional materials, like steel, ultra-high strength steels, magnesium, aluminium etc., low-weight alloys, and then to turn to low-cost composites for certain structures (roof, panels etc.) and finally to use the extreme weight-saving properties of carbon fibre-reinforced plastics for certain key elements.

The development of nanotechnologies will have a significant impact on future manufacturing and designing of components – the 'nano' era will make it possible to tailor material properties for specific applications; high stiffness and high damping in the same material, for example. Nano-reinforced (thermo-) plastic matrices will also make it possible for more rational manufacturing processes.

When considering novel materials, one must maintain a rational view on the benefit, from a Life-Cycle Assessment (LCA) perspective, or cradle-to-cradle analysis. This means that before the introduction of new materials, the life of the product must be analysed, for instance compared with steel - from manufacturing, via usage, to recycling and 'rebirth'. The key here is to find the most effective solution for increased transport efficiency and lowered energy consumption, in both laden and empty conditions.

Coupled to mass optimisation are the noise and vibration issues – higher speeds produce more aerodynamic noise, lower speeds with more acceleration result in higher engine and transmission noise. Tyre-road interaction also plays an important role for speeds over 50 km/h. Noise from auxiliary systems should also be examined and reduced, as well as noise from lifting equipment, reversing signals and door slamming which are relevant for urban (night-time) deliveries. Smart solutions should reduce weight and noise, without compromising safety or productivity. Nano-material reinforced composites have shown potential in this direction – also making possible tailoring properties like damping and stiffness. Tyre noise is a challenge, as friction, noise and rolling resistance could all pose conflicting demands on the material. Nanotechnology will also be of importance here.

Driveline Efficiency

The driveline, with its energy conversion and transmission of power, is crucial for obtaining a fuel-efficient vehicle. A systematic search for energy-efficiency savings based on driveline topologies control approaches as well as new sub-systems, components and technologies is the main road forward. The opportunities in an increased usage of biomass–based fuels, assisting the move to a sustainable transport sector, need to be explored further. Full electrification of long-distance trucks seems unlikely, at least for the foreseeable future relying on an onboard battery, due to limited storage/range and long charging times of batteries. However, a portion of the driveline has to be electrified or hydraulic solutions may be used, e.g. to save and re-utilise braking energy. In the long term, technologies for continuous/discontinuous transfer of electricity from the infrastructure to the vehicle should be explored.

In addition to high reliability, which is a pre-requisite in the engineering of long-distance trucks, a powerful driving force today is the customer requirement for increasingly fuel-efficient vehicles to reduce operational cost. Historically, HD diesel engines have had a history of continuous improvement of fuel efficiency that, however, has been offset on limited occasions by the introduction of stricter emission regulations. After the introduction of tighter emission levels, continued improvement through R&D has allowed the positive trend in fuel efficiency to resume. The need for R&D is thus even more important to the future achievement of practical and cost-effective sustainable transport concepts.

As a long-term goal it is envisioned that improvements in the powertrain area can contribute to a decrease in fuel consumption by 20%. Since diesel-powered commercial vehicles already have very high efficiency, this level of reduction in fuel consumption is not an easy task. It requires considerable technical advances and an integrated approach to reach the desired result. For long-haul trucks, a possible route is to combine highly efficient engines, advanced transmissions and mild hybridisation optimised within an integrated system; these technologies are expected to provide a considerable reduction in fuel consumption and hence in the emission of GHGs, supported also by the use of sustainable biofuels chains.

New generation drivetrains:

- Future powertrain concepts and complete system integration
- Advanced combustion and after-treatment
- Waste heat recovery
- Advanced powertrain control
- Alternative and multi-fuel capabilities
- Friction
- Hybrid powertrain
- Innovative high-efficiency conversion.

Future powertrain concepts and system integration

While electrification of the powertrain is envisioned to have increased importance for passenger car vehicles within the next decades, powertrains for HD, long-haul trucks are expected to be based on ICEs for the foreseeable future. However, technology development that enables recovery of both brake and heat energy will be needed. Hybridisation, including brake recovery, is anticipated to play a major role for HD engines with the degree of hybridisation depending on the development of, amongst others, battery technology. In other cases hydraulic systems can be used that do not depend on battery technology and can also recover brake energy. For certain applications in an urban environment, which is not in focus here, i.e. service and delivery vehicles, full hybridisation and/or EVs, might be expected in the future.

Engine downsizing has a significant potential to further reduce fuel consumption, especially in combination with integration of hybrid systems for boosting the power of acceleration and starting of HD trucks on a hill. This approach also has a reduced emission potential, due to the reduced transient behaviour period of the truck engine.

The general development to increase transport efficiency may alter vehicle size and weight, which affect the torque and power needed from the powertrain. The powertrain system needs to be appropriately sized and optimised according to the application. Further developments of major subsystems such as the turbo charging system, thermal management for the after-treatment system and the selective catalytic reduction (SCR) system will be key enablers for flexible powertrains.

Biofuel blendings influence fuel quality and developments are needed to adapt the combustion and the after-treatment system. Low carbon fossil fuels such as natural gas, already widely used in urban areas for HD applications such as urban buses and garbage collection vehicles, could also play a significant role in the reduction of oil dependency in the Medium-Duty (MD) and HD transportation sector, considering the opportunities presented by liquefied natural gas (LNG) technology and the significant potential to produce bio-methane via biomass conversion. Correspondingly, highly efficient methane HD engine platforms have to be developed, enabling performance equivalent to diesel to be attained while ensuring a quasi-zero pollutants emission level.

The above mentioned factors do all affect the requirements put on the complete powertrain system for long-haul applications. It will thus be necessary to analyse and substantiate these trends to find optimal future engine sizes. Different levels of hybridisation will also affect the sizing and the constraints put on the engine.

Advanced combustion and after-treatment

The main form of energy conversion for long-haul powertrain solutions will be internal combustion of hydrocarbon fuels for the foreseeable future. The diesel process is very efficient and emissions are expected to reach sustainable levels with the Euro VI regulation. However, the combustion process and in particular the diesel engine and after-treatment system as a whole can still be improved to obtain more favourable fuel-efficiency.

Important research needs cover:

- Efficient combustion and clean combustion
- Advanced injection strategies
- Advanced closed loop control
- Combustion modes with high thermal efficiency (e.g. partially premixed combustion (PPC))
- Reduced thermal losses
- Highly efficient and integrated EATS system
- Advanced SCR systems (e.g. new catalytic materials)
- Advanced diesel particulate filter (DPF) systems.

Waste Heat Recovery

Although improvements in the combustion and after-treatment system will lead to lower exhaust temperatures, a substantial amount of energy is still contained in the exhaust. Efficient recovery of this exhaust energy is of crucial importance to reach a substantial improvement of fuel economy. A further development of Rankine WHR systems, and in particular the associated components, is of high importance. Future research should also include investigation of more advanced WHR systems based on Rankine cycles or other advanced technologies. The integration of WHR systems with different degrees of hybridisation is also crucial. Important research needs include:

- Rankine cycles (organic/non-organic)
- Advanced system and heat exchanger design
- Development of expander systems
- Cooling system and integration on vehicle
- Thermo-electric WHR
- Advanced solutions.

Advanced control

A complete integration of the entire driveline will be a crucial factor in achieving a major improvement in fuel efficiency. The full benefit of this integration will be available only if advanced control is employed.

Advanced control is a key enabler for integration of the entire driveline providing means for high-efficiency, low-emission combustion and a co-optimisation of the combustion and after-treatment system. Important research needs are closed loop control (cycle-to-cycle, in-cycle) technologies and the development of advanced and reliable sensors. To ensure optimal operation for various fuel blends in terms of emissions and fuel consumptions, sensor and advanced control technology will be of crucial importance.

A full integration of WHR systems and different levels of hybridisation will be subject to developments in advanced control.

Alternative and multi-fuel capabilities

Future long-haul powertrain systems will have to be tolerant to blends of diesel and biofuels complying with upcoming regulations. The development of fuel quality-tolerant combustion and after-treatment systems will be key issues. Advanced control and sensor technology will be a major enabler to reach these goals. One of the most important development needs in the utilisation of alternative fuels is to maintain, and in the best of cases exceed, the energy conversion efficiency possible with traditional fossil diesel combustion. This is especially important for non-diesel fuels, where other combustion processes, such as Homogeneous Charge Compression Ignition (HCCI) or flame propagation, need to be applied. Engine efficiency is highly dependent on the injection tuning, which in turn is dependent on fuel quality, and especially the oxygen content when biofuels are used. Therefore, a cycle-to-cycle closed loop optimisation for the fuel currently combusted is important. Utilisation of sensor systems that enable direct or indirect measurement of fuel or combustion quality may then be the enabling component/system to achieve high biofuel flexibility. These types of sensors systems are also important to adjust the after-treatment conditioning parameters to maintain durability and total system efficiency.

It is also envisioned that multi-fuel capabilities will become more important. The availability of natural or bio-gas might increase on certain markets. Further research on multi-fuel systems including advanced combustion modes and improved after-treatment solutions should be the focus.

Friction

Measures to lower engine friction have the potential to give major efficiency gains. Future research should focus on new technologies, materials, oils and bearings.

Hybrid powertrain

Future long-haul powertrains will include a certain degree of hybridisation. Battery cost and weight will probably be a limiting factor for the foreseeable future. Upcoming research should include cost-efficient and advanced start/stop capabilities and brake energy recovery. Smart energy management and advanced systems for hotel mode are also crucial topics.

In certain applications hydraulic systems can be used for hybrid concepts. This has the advantage of being independent from battery development as hydraulic components are rugged, reliable and do not need basic research efforts.

However, to reach a substantial improvement in fuel efficiency, the use of at least mild hybrid systems will be critical. A full integration of the powertrain with the hybrid system including WHR, after-treatment and control is paramount.

Several steps of energy-efficiency and cost-reduction actions may be applied for an engine dedicated to be operated in combination with a full hybrid powertrain. A key element in cost and performance is electric energy storage systems where development in the passenger car market will be an enabler to achieve the volumes necessary. Requirements for engine transient operation will be reduced significantly, enabling for engine simplifications and efficiency improvement. This is also valid for after-treatment solutions. Special attention needs to be taken on how to start and stop the engine in an efficient, silent and durable way. The engine system needs to deliver high efficiency in the defined hybrid driving modes, which may differ considerably depending on the type of hybrid application, i.e. the degree of parallel or serial set up.

It is unlikely that full electric, long-haul vehicles will be a reality if the targets in the electrification roadmap on the energy storage systems are not widely met. An alternative solution to be investigated may be a system that transmits energy to long-distance vehicles during travel.

Innovative high-efficiency energy conversion

Work on novel breakthrough technologies is essential to reach a drastic and long-term reduction in CO_2 for long-haul applications. These technologies should go beyond the current limitations and boundaries of today's state of the art. They should either stretch thermal efficiency limits, use new energy conversion principles or use new combinations of those technologies. New solutions in this area could be enablers for an further essential step in CO_2 reduction beyond the technology development mentioned above. Further research actions within the area of efficient drivelines for long-zhaul should thus include activities of a long-term nature. For these breakthrough technologies to be developed and deployed, R&D should begin in the near term.

Driver Efficiency

Driving behaviour has great impact on the quantity of emissions as a function of fuel consumption. Therefore, the behaviour of drivers is a critical factor that has great impact on emissions. By combining cooperative systems using V2I communication, there is the potential for a fuel saving of 20%[41].

Driving behaviour is a key issue for eco-driving/fuel-efficient driving. Today, eco-driving can result in 10% to 12% fuel savings with the use of Driver Coaching Systems (DCS). DCS are technologies supporting drivers and fleet managers to improve fuel efficiency. The DCS on the market today are based on technologies that register information from the vehicles. Information can be displayed directly to the driver while or can be configured as post-trip reports to support fuel-efficient driving. With this information fleet managers can take measures to improve fuel efficiency in the fleet, e.g. by supporting the drivers to improve their eco-driving.

The next generation of DCS is believed to have a potential fuel saving of 20% and will be characterised by a systems perspective combining cooperative systems using V2I communication. Further research is however needed in the area of driver compliance and automated DCS reducing the impact of individual compliance, if the full potential of DCS is to be reached.

4. Milestones

	Milestone 1: 2015 Market 2018-2020	Milestone 2: 2020 Market 2023-2025	Milestone 3: 2025 Market 2028-2030
Target (includes fuels)	+15% tonne-km/kwh, 10% biofuel share + 20% tonne-km/gCO_2	+30% tonne-km/kwh, 15% biofuel share + 45% tonne-km/gCO_2	+40% tonne-km/kwh, 25% biofuel share + 60% tonne-km/gCO_2
Vehicle concept	**Optimised truck** *Cross links to Green Corridors, hubs, etc.*	**Tailored truck** *Cross links to freight bundling, city logistics, etc.*	**Sustainable truck** *Cross links to electrification, biofuels, etc.*
Main elements	Vehicle dedicated to Green Corridors, load & capacity sharing logistics platforms, advanced combustion & after-treatment, driver eco-support, electrification auxiliaries, low rolling resistance tyres & TMPS, advanced safety equipment (LDWS, AEBS).	Tailored truck, modular design, advanced wheel units, ultra-light structures, hybrid powertrain, energy optimised down-sized/ right-sized powertrain.	Convertible vehicles, adaptive aerodynamics, load factor and weight control, grid charging.
Vehicle Efficiency	**Milestone 1: 2015 Optimised truck**	**Milestone 2: 2020 Tailored truck**	**Milestone 3: 2025 Sustainable truck**
The safe and intelligent truck	Robust communication, sensors and data fusion.	e-Horizon-based vehicle control. e-Freight-enabled vehicle.	Semi self-operated vehicle.
Matching vehicle to operation	Optimised vehicle parameters for efficient transport operation. More flexible vehicle leasing concepts.	Vehicle fully adapted to its operation and freight. Modularity. Inter-modal efficiency.	Vehicle that can convert between long and short distance.

(continued on page 43)

	Milestone 1: 2015 Optimised truck	Milestone 2: 2020 Tailored truck	Milestone 3: 2025 Sustainable truck
Design dimensions for optimised load capacity	Vehicle optimised for Green Corridors.	Vehicle optimised for all infrastructure.	Efficient transformable truck. Load factor and weight control.
Aerodynamics	Aerodynamically efficient complete vehicle (tractor and trailer), 7% drag reduction.	Improved aerodynamics, more flexible directives, new vehicle combinations, 13% drag reduction.	Adaptable exterior geometry, suspension, air gap and speed control, 20% drag reduction.
Low rolling resistance	New tyre materials and tread patterns. Optimal use of super single and other wheel combinations. Individual wheel control, 10% rolling resistance reduction, TPMS.	Optimised wheel units, material composition and adaptive tyre pressure. New low friction nano-materials. Wheel hub units. 15% parasitic loss reduction. Intelligent tyre management and communication to driver (RFID).	Advanced wheel multi-functional control. Monitoring and control of all parasitic rolling losses on vehicle. 20% reduction friction losses.
Energy management & efficient auxiliaries	All major auxiliaries electrified. Cooling system optimised and integrated.	Optimised integrated auxiliary systems regarding energy efficiency. Situation sensing and adaption. Efficiency up >20%.	e-Horizon data for optimal overall control and performance. All electrical systems integrated and energy optimised.
Advanced materials and design	Systematic re-design and material optimisation. Both traditional and novel composites. 5-10% weight reduction.	Novel materials optimally used through multi-disciplinary optimisation. Multi-functional materials. Lower weight and better performance.	Significant weight reduction, integrated design of components in optimal material. Nano-materials with multi-functional properties enabling >20% weight reduction.

(continued on page 44)

Driveline Efficiency	Milestone 1: 2015 Optimised truck	Milestone 2: 2020 Tailored truck	Milestone 3: 2025 Sustainable truck
Future powertrain concepts & complete system integration	Mild hybrid low-speed, narrow-band engine with braking energy recovery. Transmission system with predictive gear ratio management and advanced turbo system.	Distributed powertrains for tailored truck applications. Engine downsizing with exhaust heat energy recovery. High peak cylinder pressure and variable valve actuation.	Advanced hybrid concept with range extender.
Advanced combustion and after-treatment	Advanced injection with closed loop functionality.	Non-precious metal catalytic materials and PM sensors.	Advanced combustion modes (e.g. PPC) combined with advanced combustion cycles.
Waste heat recovery	Development of optimised heat recovery cycles such as Rankine.	Advanced heat recovery systems.	Highly efficient thermoelectric systems.
Advanced control	Closed loop control cycle-to-cycle.	Closed loop in-cycle control and advanced and reliable sensors. e-Horizon.	Auto-calibration engine control and durability predictive control.
Alternative and multi-fuel capabilities	Fuel sensor and bio-diesel tolerant engine Low carbon gaseous fuel engines, including LNG option.	Multi-fuel combustion.	Multi-mode combustion.
Friction	New low-friction coatings.	Optimised low-friction concepts utilising nano-structured surfaces and lubricants.	

(continued on page 45)

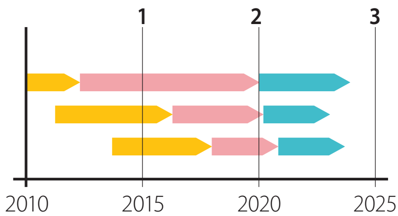
	Milestone 1: 2015 Optimised truck	Milestone 2: 2020 Tailored truck	Milestone 3: 2025 Sustainable truck
Hybrid powertrain	Mild hybrid concept.	Full hybrid concepts combining cost-efficient energy storage solutions. Advanced systems for hotel mode. Advanced design of power electronics.	Novel concepts based on continuous or intermittently transferred electricity from grid.
Innovative high-efficiency energy conversion	Understanding of ultimate boundaries in combustion with ultra-high efficiency.	Concepts based on research to stretch thermal efficiency limits.	New highly efficient energy conversion principle.
Driver Efficiency	**Milestone 1: 2015 Optimised truck**	**Milestone 2: 2020 Tailored truck**	**Milestone 3: 2025 Sustainable truck**
Driver support systems	Eco support, next generation ADAS, improved route planning.	Automated eco-driving cooperative safety systems.	Semi-automated driving.
Freight handling	e-Freight, paperless transport, Internet load & capacity-sharing platforms.	Load factor monitoring and weight control.	Automated carrier operation and loading.

Table 6: Detailed description of the milestones of the European industry for long-distance trucks.

5. Roadmaps

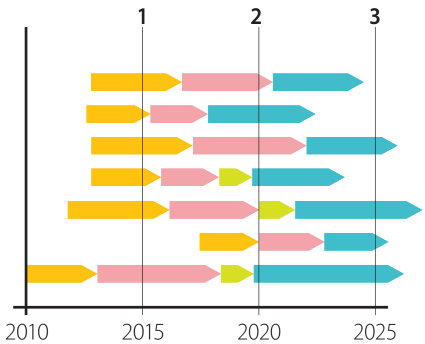
The Safe and Intelligent Truck

Intelligent transport system (ITS)
Driver support systems
Cargo and driver security systems



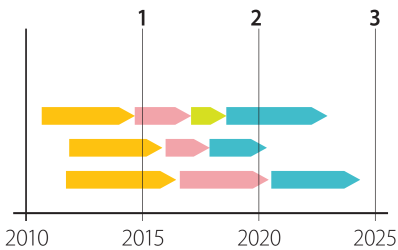
Matching Vehicle to Operation

Vehicle adaptation strategies
Develop flexibility in vehicle powertrain capabilities
Develop built-in flexibility in chassis+vehicle design
Optimise modularity for freight modules
Optimised loading and load control technologies
Automated operation+freight module (de)coupling
Develop inter-modal optimised vehicle



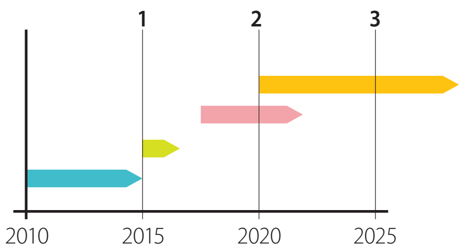
Design Dimensions for Optimised Load Capacity

Optimised road vehicle mass and dimensions
Optimisation chassis control
Develop modules vehicle architecture



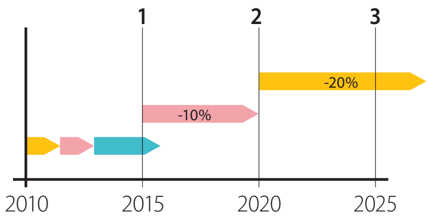
Aerodynamics

Adaptative aerodynamics
Vehicle controlled aerodynamics
Vehicle maximum dimensions
Complete vehicle aerodynamics



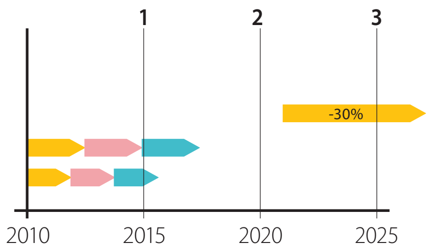
Low Rolling Resistance

Hub motors for adaptative control
Optimised wheel units for low rolling resistance
Low rolling resistance tyres



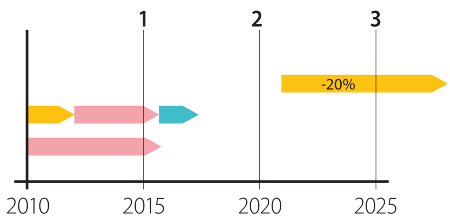
Energy Management & Efficient Auxiliairies

Situation sensing, forward looking (incl. e-Horizon)
Control+optimisation of complete energy system
Electrification of major components



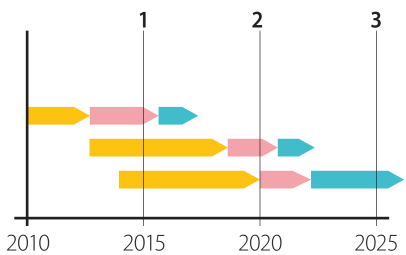
Advanced Materials & Design

Multi-functional nano-materials design
Optimised structures+novel materials incl. LCA
Designing for low weight



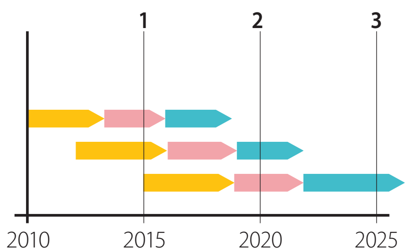
Future Powertrain Concepts and System Integration

Engine resizing/speeding
Distributed powertrains for tailored truck application
Advanced electrified powertrain concepts with range extender



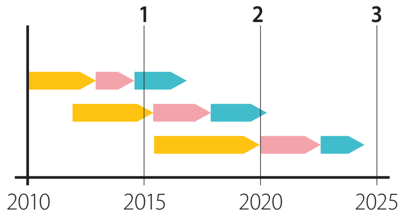
Advanced Combustion and After-treatment

Advanced injection, turbo charging, integrated EATS
Novel combustion modes with highly efficient EATS
Non-precious metal catalytic systems



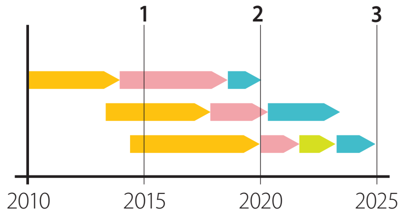
Waste Heat Recovery

Rankine systems
Advanced heat recovery technologies
Highly efficient thermoelectric systems



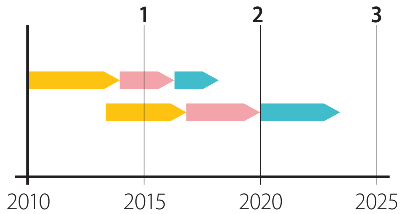
Advanced Control

Closed loop control (cycle-to-cycle, in-cycle)
Predictive control (incl. full electronic Horizon)
Adaptative control and auto calibration



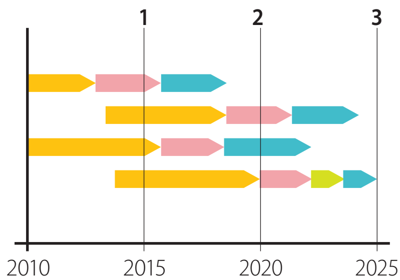
Friction

New low-friction coatings
Optimised low-friction concepts utilising nano-structured surfaces and lubricants



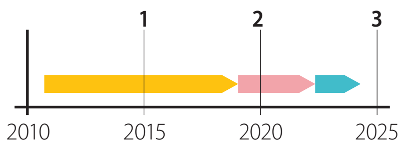
Hybrid Powertrain

Mild hybrid concepts
Full hybrid concepts with cost-efficient, robust design
Advanced systems for hotel mode
Novel concepts based on continuous or intermittently transferred electricity from the grid



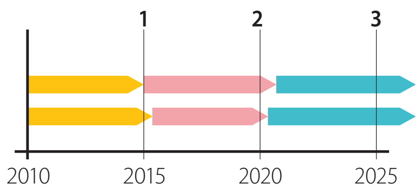
Innovative High Efficiency Energy Conversion

New energy conversion principle



Driver Efficiency

Develop driver support systems
Freight handling



6. Recommendations

A further breakdown on how to address research needs in various FP7/FP8 work programmes will be delivered after consultation.

Preliminary Themes 2012:

Efficient trucks for long-distance transport

- Complete vehicle energy management:
  - Complete vehicle energy management
  - Optimised power management and distribution
  - Electrification of auxiliaries
  - Cab insulation.
- Vehicle technologies for long-distance transport:
  - Advanced vehicle aerodynamics
  - Extreme low rolling resistance tyres.
- Driver efficiency for long-distance transport:
  - Driver support (eco-driving / driver coaching)
  - Efficient work environment (handling / cab interior / alertness).

Preliminary Themes 2013:

Optimised trucks for green road freight corridors

- Configurable and tailored trucks:
  - Optimised trucks for transport mission
  - Configurable truck-carrier and vehicle concepts
  - Energy-tailored driveline, right-sizing.
- Vehicle technologies for long-distance transport:
  - Green Corridor traffic safety (active safety systems and platooning)
  - Green Corridor cargo and driver security.
- Efficient drivelines for long-distance transport:
  - Alternatives and multi-fuels capabilities.

Preliminary Themes 2014

- Complete vehicle system integration:
  - Total truck-trailer architecture
  - Advanced materials
  - Distributed driveline including high level of hybridisation.
- Efficient drivelines for long-distance transport:
  - Innovative high-efficiency energy conversion
  - Friction.

III

Logistics and Co-Modality

Abstract

For the common European market to function smoothly there is a need for an integrated, green and efficient transport system that allows the free movement of goods and people within, into and out of, EU territory. This is vital for economic growth, European cohesion and the well-being of its citizens. An integrated transport system clearly calls for harmonisation of rules and interoperability of networks.

In order to reach these goals, research will be needed on innovative infrastructures (e.g. Forever Open Road, energy-neutral or energy-generating motorways), on new organisational concepts (payload sharing, advanced logistics, supply chain management and e-Freight) and methods of working related to their introduction and on innovative vehicle technologies (such as modular vans and lorries, electric and diesel-electric vehicles).

In addition, further research is needed on the measurement of transport impact on society, especially the development of consensus on the measurement framework for a transport and logistics environmental footprint, and on the measurement of transport and logistics performance.

A series of complementary measures, such as financial incentives, creation of PPPs and an appropriate regulatory framework, are needed to prepare for market take-up. It is important to not only define these measures, but also understand their potential impact and interaction.

This third part of the multi-annual roadmap and long-term strategy of EGCI sets out a three pronged approach, focussed on City Mobility, Green Hubs & Green Corridors and improved logistics control in combination with e-Freight solutions, with the aim to improve the overall efficiency, and substantially reduce the carbon footprint of the European transport system.

The benefits and challenges of an approach, that is not purely technological but rather organisational in nature, and new ways of doing business are described. Milestones are identified and roadmaps defined that highlight the steps to be taken to achieve the desired objectives.

This third part of the roadmap is based on the consensus among the participants of EIRAC. Its purpose is to stimulate the debate about the multi-annual implementation of the European Green Cars Initiative from the perspective of the opportunities that co-modality and logistics can offer, also looking at the social and political acceptance by citizens, authorities and business itself. In particular, new organisational concepts of doing business, i.e. night deliveries through EVs, opening hours of terminals in Green Corridors where around the clock eco-liners may be used etc.

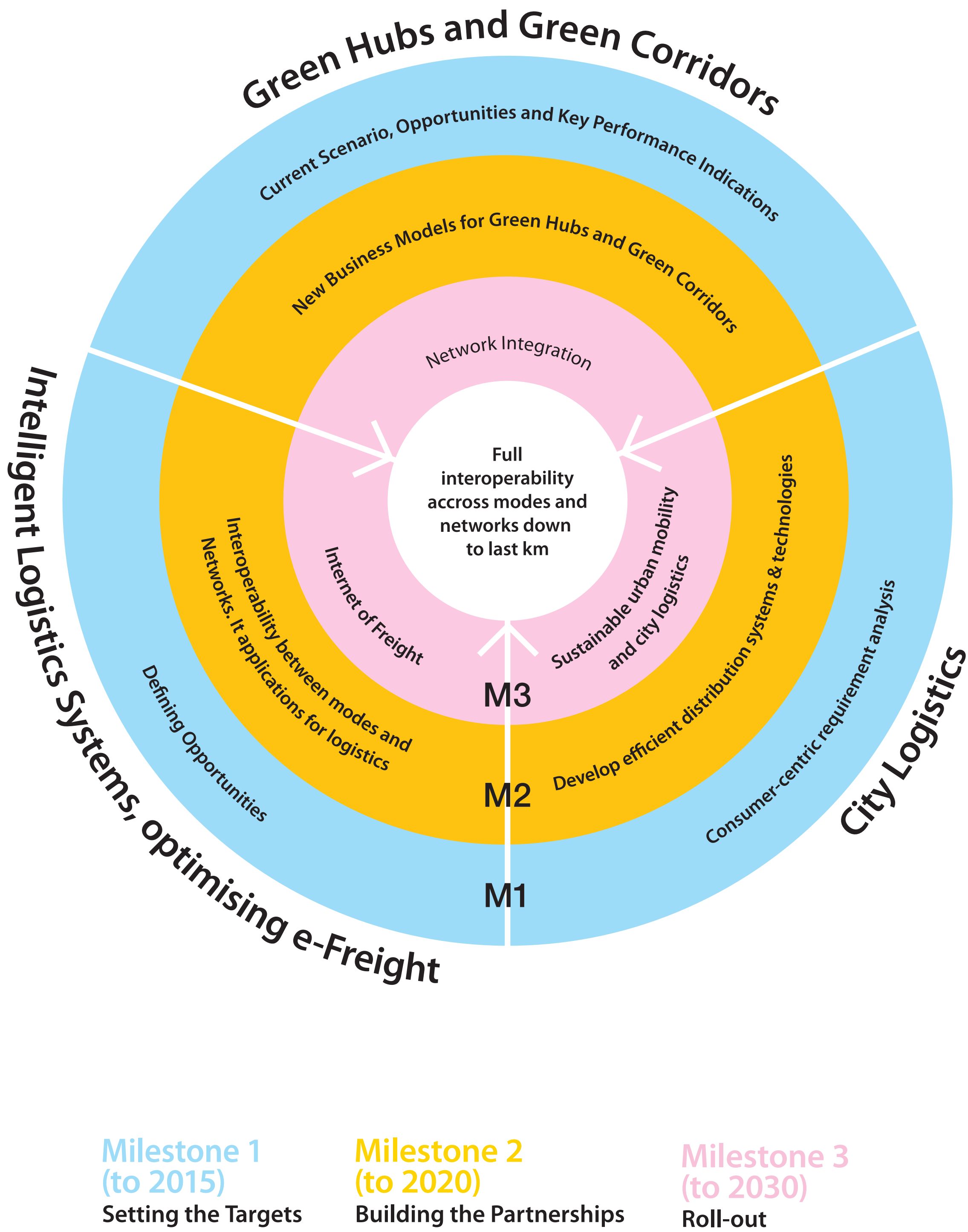


Figure 5: Illustration and summary of the European industry roadmap for logistics and co-modality.

1. Introduction

The demand for freight transport, both over long distances as well as in the urban environment, is growing continuously; road haulage is taking the lion's share of the market.

Nevertheless, today's European transport system is still inefficient. For road haulage on average 24% of goods vehicles in Europe run empty. The other lorries are only partially loaded and have an average load capacity of only 57%. Eliminating, or at least drastically reducing, this inefficiency is a major challenge for policymakers and the transport industry alike. A 30% increase in efficiency would create an estimated economic value of EUR 22 billion for the transportation industry. The current state of empty running in Europe is illustrated in Figure 6.

As a result of the expected growth of transportation in and around Europe, transport emissions, especially of CO_2, are also a continuing concern for policy makers and practitioners. While more and more stringent rules are put forward (Euro 4, Euro 5 for trucks), transport will remain one of the main contributors to emissions. This is illustrated on figure 7.

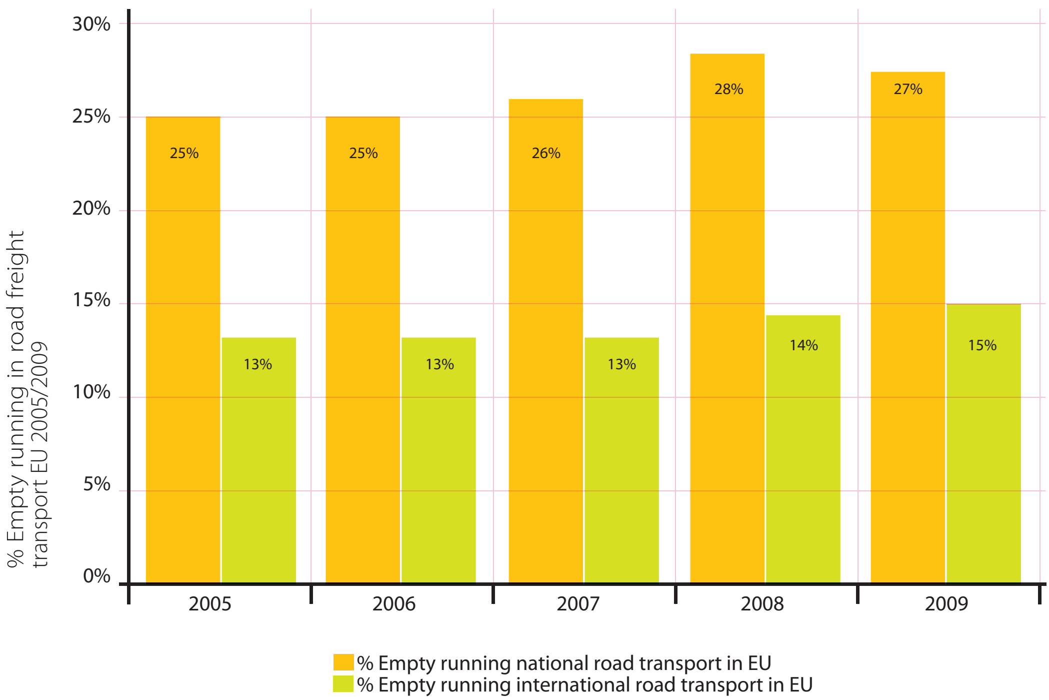


Figure 6: Empty running in the EU.
Source: EUROSTAT website statistics 2010.

Finally, road congestion is generally increasing around Europe. This is connected with the concentration of economic activities, around cities and other clusters of activities (ports, industrial zones). Currently, 60% to 70% of the European population lives in and around urban areas, and this will increase. In addition, 85% of gross domestic product (GDP) is generated in urban areas. As a result, urban areas bear the major burden of traffic congestion and other negative effects of transport, such as pollution, noise and vibration. A further complexity in mobility in urban regions is that freight and people use largely the same infrastructure.

There are very few concrete figures available on the degree of congestion in Europe, apart from a few statistics : 7 500 km of roads are blocked by traffic jams, and the traffic congestion adds 6% to the EU fuel bill, total delay in London's urban centre was 2.3 minute/km before, and 1.8 minute/km after the introduction of the congestion charge.

Against this background, the EC has stressed the need to improve levels of accessibility and mobility for citizens and freight in urban areas especially given the clear deteriorations in congestion, safety and quality of air in major cities. An integrated approach to transport planning has to be taken that treats freight and citizen mobility simultaneously. This road map focuses on nodes in the transport system where the negative effects of transportation are the most poignant, but looks for solutions at both creating more efficient nodes and forging better connections between nodes.

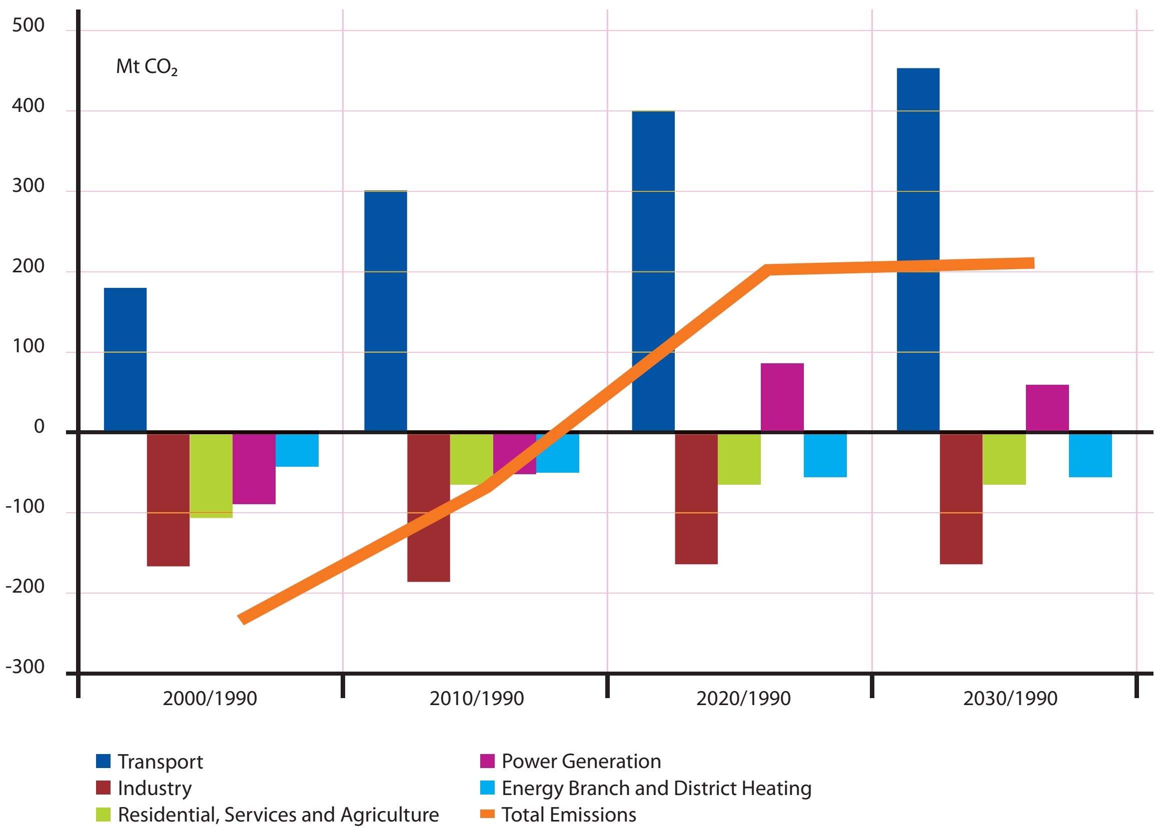


Figure 7: Change of CO_2 emissions since 1990.
Source: Report of the European Commission, 2008[42].

The European Commission, in its mid-term review of the Common Transport Policy White Paper [34], highlighted the need for improved logistics and co-modality (the use of different modes in combination to obtain a sustainable utilisation of resources) in the overall transport system. Logistics/co-modal transport coordination is a specific capability that will enable and facilitate the solutions required to improve the quality of the European transport system that can be measured by levels of performance, congestion and pollution. The development of this capability is the underlying goal of this roadmap.

The targets to measure the impact of this roadmap are:

1. Transport efficiency, as measured by average load factor, km or % empty running of trucks, utilisation rates of terminals and cargo handling facilities; current level: average load factor of 57%

2. Transport emission, as measured by CO_2, NO_x, SO_x and small particles; current level: 270 million tonnes of CO_2 emission (2010 projection Tremove data)

3. Congestion, as measured by average time loss, average traffic jam length and time; current level: 7 500 km of roads congested in Europe.

In order to most effectively tackle the key issues related to co-modality, a three-pronged approach should be taken addressing:

- City logistics
- Concentration of long-distance freight traffic in major (green) hubs and along (green) corridors (which link the hubs)
- Intelligent logistics solutions reflecting the optimisation of e-Freight initiatives.

This third part of the document collates input from major Commission policy initiatives starting with the Mid-Term Review of the Transport White Paper (through Freight Logistics Action Plan, e-Freight, the ITS Action Plan and the TEN-T Programme[43]) and it seeks to integrate and to prepare for a market roll-out the results of a whole series of previously funded EU projects at European level which are relevant to the three subject areas. These include Freightwise, e-Freight, INTEGRITY, Smart-CM, Euridice, Citylog, BESTUFS etc (see Appendix).

2. Benefits and Challenges

City logistics

City logistics can be defined as follows:
- Transport and logistics activities in geographically concentrated and densely populated areas
- The organisation required to move large amounts and different sized volumes of parcels or goods.

City logistics addresses the movement of freight distribution in urban areas, improving the efficiency of urban freight transportation, reducing traffic congestion and mitigating environmental impacts. The principle challenge is to be able to treat these simultaneously. In addition, last mile transport in small volumes is currently largely unprofitable, which is a bottleneck for innovation.

Key elements to take into consideration:
- By 2020, 70% to 80% of the European population will live in urban areas
- Urban freight represents 10% to 15% of vehicle equivalent kilometres travelled on city streets and 2% to 5% of the employed urban workforce
- In all, 3% to 5% of urban land is devoted to freight transport and logistics
- A city not only receives goods, but also ships them: outgoing freight represents 20% to 25% of truck-kilometres in urban areas, incoming freight 40% to 50%, and the rest originates from, and is delivered within, the city
- Transport companies providing urban freight services are generally very small. In Europe, 85% of short-distance truck companies have less than five employees
- Every year, EUR 100 billion, or 1% of the EU GDP, are lost to the European economy as a result of delays and pollution related to urban traffic
- Urban traffic is responsible for 40% of CO_2 emissions and 70% of other pollutants arising from road transport.

EVs are considered to be the most suitable solution for the operating conditions of urban freight while ensuring low noise level and no local environmental impact. No real industrial developments have been made by vehicle manufacturers due to strong economical pressure by operators. Public funding is therefore necessary to fill the gap towards economical viability of this sector.

The main targets for improvement of city logistics are the following:
- improve **load factors** and cost levels of last-mile delivery
- reduce **CO_2 emissions** as well as other emissions from city logistics in urban areas
- remove **congestion**, delay and time loss due to freight transport in urban areas.

As a first step, more extensive measurement of the problems, bottlenecks and transport system performance is required. Currently, no clear statistics on the extent of congestion and its consequences are available for metropolitan areas in Europe. This work should build on the many previous efforts in this field, such as those by CIVITAS[44], BESTUFS[45] etc.

The way to achieve these targets is to reduce the number of truck movements while maintaining a sufficient level of product availability for demand of citizens. The introduction of innovative EVs, modular vans etc. will enable new transportation and distribution concepts to be deployed. They should lead to fewer trips, reduced congestion, improved safety and improved economics (for all the actors involved). The key factor will be that cities throughout the EU will develop standardised technical solutions avoiding the fragmentation or customisation of systems that, in general, has been detrimental to urban transport.

It is recommended to rapidly develop a pilot project with the aim of demonstrating logistic solutions with EV applications for optimising urban logistics efficiency to better manage transport flows and reduce environmental impacts (noise, CO_2 emissions and pollutants) in urban areas.

The demonstration could contain the following elements:
- Demonstration of urban and logistics solutions with electric vehicle fleets with the aim of validating the feasibility of logistic solutions on the basis of electric vehicle applications leading to better efficiency of transport flows and reduction of environmental impacts (noise, CO_2 emissions and pollutants) in urban areas.
- Assessment of these logistics solutions based on electric vehicle fleets compared with existing solutions (city planning, ITS systems, distribution centres and their link with long-distance transport networks, different modes, bundling of flows, sharing knowledge).
- Assessment of public acceptance of demonstrated new delivery systems.

- Assessment on urban transport and delivery market such as size of deliveries, frequencies, vehicle types used (including consumers' cars).
- Assessment of the impact on energy and environment.

Eventually, the work on improving city logistics will have to move from projects in selected cities to an overall European approach. Benchmarking, and project and impact comparison are important steps in this process. In addition, the development of a European solution to urban freight transport needs to incorporate promising and proven solutions, a vision on the comparability and specificity of cities, and a definition of the role of European regulation.

Green hubs and Green Corridors

This domain covers the development of efficient interfaces in the transport system, or 'green hubs'. Efficiency in this context is defined as high operational performance, effective use of resources, limited impact on the surroundings and the environment. The approach to develop hubs according to this ambition has two dimensions:

- the improvement of the hub itself, focusing on operational improvements, reduction of energy use of processes in the hub, etc.
- relieving the hubs of temporary or geographically concentrated pressures by connecting the hubs with each other.

The latter approach is also included in this domain, through the development of 'Green Corridors'. This means that the connections between the hubs should adhere to the same standard as the green hubs: high operational performance, effective use of resources and limited impact on the surroundings and the environment.

Green Corridors should be conceived as long-distance freight transport corridors between major hubs both within Europe and between Europe and other parts of the world. Green Corridors are not a parallel or competing set of transport corridors but rather mark a holistic approach to European transport policy. They bring together the objectives of reducing emissions, increasing energy efficiency, efficiently combining various transport modes (with the right level of innovation in each of these modes) and supporting the competitiveness of European industry and transport.

The focus is on enabling the choice of environmentally-friendly modes and transport technology, while not jeopardising the need for an efficient transport operation. It is the aim in this corridor concept to concentrate technological innovations on specified routes where the flows are 'captive' and that this technology can be managed effectively and efficiently. In addition to the 'hard' physical infrastructure (such as roads, inland waterway infrastructure, rail tracks, ports and terminals), 'soft' infrastructure will also play a role in the Green Corridor concept. For example, smart traffic management systems will reduce congestion and the distance travelled due to better route planning, which in turn should contribute to less pollution.

The Green Corridor concept has strong links with the business sector, in particular with logistics services. They are driven by an optimised use of all transport modes and network planning based on existing and forecast traffic flows. If the business sector is to utilise Green Corridors, the latter will have to be at least as efficient as other transport corridors.

Various studies have demonstrated that eco-driving and aerodynamics of vehicles can reduce fuel consumption by over 10%. Collaborative planning can allow for a reduction of empty running and improve load utilisation on all modes of transport. Therefore, the development of Green Corridors should also involve the evolution and assessment of new business models based on collaborative arrangements across partners in supply chains and due to the experimentation of innovative approaches in the regulatory framework of transport. Given that corridors and hubs also involve infrastructure, the explicit development of new models of Public-Private Partnerships (PPPs), in which not only the investment but also the level of innovation is made part of the partnership, need to be considered as ways to achieve green hubs and Green Corridors.

The main targets are to:

- improve **load factors** and the balanced use of modes of transport across the European freight transport system
- reduce **CO_2 emissions** as well as other emissions, and energy use in green hubs and corridors
- remove **congestion**, delay and time loss in and around the green hubs.

As a first step, more extensive measurement of the problems, bottlenecks and transport system performance is required, as well as the development of a vision on the definition of green hubs and Green Corridors. One of the main challenges is to select the candidates for green hubs and corridors, as well as develop a method of selection that is appropriate in the European context.

Furthermore, new coordination and control mechanisms are required to guide the balance between transport modes from the green hubs. These mechanisms can build on current state of the art in information and decision sciences, where new allocations and governance mechanisms are being developed in wholly different contexts, such as agricultural auctions, packet routing in telecom networks, and so on. Apart from a measureable 'green performance' this type of capability will be a main characteristic of green hubs.

Further challenges are:

- continuous innovation in equipment design and deployment
- improved integration with hinterland transport technology and infrastructures
- organisational innovation to achieve optimum performance
- defining the appropriate investment (e.g. via the revised TEN-T Programme) to remove infrastructure constraints around transfer nodes.

The final step in the development of green hubs and corridors is the integration of initiatives across Europe into one comprehensive coherent network of green hubs and corridors. Ideally, most, if not all, of the TEN-T core network should be covered by a network of Green Corridors. This requires standardisation of approaches, as well as consensus on the definition and measurement of the level of 'greenness'. In addition, networking will go hand in hand with the proliferation of technology development. Therefore, knowledge sharing, benchmarking and co-design are important pre-requisites for European networking.

Intelligent logistics systems

Optimising the use of e-Freight initiatives

Existing infrastructure and vehicles can be used more efficiently by developing sophisticated logistic chains and networks, which use advanced information and communication technologies (ICT). While the foremost imperatives of introducing such logistics chains are to reduce costs and to maximise benefits, it is also essential to manage the degree of co-modality, the environmental footprint of transportation activities, the efficiency of the use of transport modes, and the negative effects of transportation. This management requires data that needs to be generated to a much larger extent than is currently the case. Efficient supply chain management or intelligent logistics systems therefore have a two-fold bonus: security and carbon footprint reduction.

The provision and generation of information from transport activities that can be used to better plan and coordinate other transport activities requires substantial new solutions in information management, data processing, real time planning, data capture technology and monitoring and evaluation, both by businesses and by authorities. There is also an important connection to the development of Single Window Platforms, which are expected to play an increasingly important role in the future efficiency and sustainability of freight. This is a key area in the EU Freight Logistics Action Plan. More effective provision of information will not only, for instance, match loads to capacity more efficiently, but information availability will also enable government agencies (customs, police etc.) to improve their performance in supervising business activities, increase their hit-rates and remove administrative burden and bottlenecks.

The main targets are to:

- improve **load factors** across the European freight transport system due to the use of better and more timely information on freight supply and demand
- reduce **CO_2 emissions** as well as other emissions, due to better measurement, and more appropriate performance-based regulation
- remove **congestion**, delay and time loss in and around the green hubs, due to improved information provision to transport operators.

As a first step, the further development of e-Freight initiatives leading to the integration of information across supply chains and logistics systems is required. This also entails carrying the standardisation of messages and documents further, and developing the level of 'informatisation' of transport operators and transport service providers, as well as of relevant authorities. This will also facilitate further system integration with port community systems, and other private global data platforms such as GT Nexus[46], while achieving user friendliness and interoperability.

Another important development is to standardise the measurement frameworks on transport performance, environmental footprint and negative transport effects and, more importantly, develop ways to supply these measurement frameworks with actual, real time data feeds obtained from ongoing transport and logistics operations. A further challenge is to develop a regulatory framework in which partners in the supply chain are allowed to exchange and share information between and amongst existing shared information or supply chain management networks, without facing immediate claims of violating anti-trust regulation or other impediments.

Finally, integration e-Freight initiatives at the European level are required to reap the full benefits and achieve real progress on the targets specified above. This requires not only a push on information technology (IT) investments and choices for the right architectures, standards and approaches, but also the explicit recognition of the similarities and differences in the governance and government supervision of logistics activities across Europe.

The creation of improved supply chain operations will have great repercussions for the demand for service quality and volume of transport systems. With the advent of RFID and similar identification technology in the supply chain, the development of intelligent cargo systems at the European level is within reach. In addition, possibilities for horizontal collaboration between shippers and increasing responsiveness needs will drive shippers increasingly to develop hybrid distribution channels. A major advantage of these channels is that they allow further bundling of freight among firms. However, this efficiency gain will only materialise if shipper and carrier information systems are sufficiently interconnected and interoperable. This extends the e-Freight roadmap towards synchronisation of transportation, inventory and production schedules among firms.

3. General Expectations

The current trend is that customers and shippers no longer think in terms of the ways or means by which commodities reach their destination – their principle concern is where the goods arrive and when.

The ambition is for physical transport flows, supported by efficient information-sharing networks that are:

- **Seamless**: barriers to modal exchange at nodes are minimised
- **Reliable**: deliveries are punctual and commodities are undamaged
- **Available**: door-to-door services are provided 24/7, Europe-wide
- **Accessible**: customers deal with one-stop shops / single entry points
- **Secure**: commodities reach their intended destinations securely, and no intrusions are possible
- **Sustainable**: built to last, striking the right balance between environmental impact, cost to the customer and meeting societal needs
- **Accountable**: customers have a contract with one party responsible for performance during transport;
- **Affordable**: in the position to offer competitive prices to customers and sufficient profits to operators and investors
- **Transparent**: all stakeholders understand the relation between public costs and market prices (per infrastructure / slot / facility / commodity).

Increasing levels of congestion will place mounting pressure on mobility services, particularly in large urban areas. This will give rise to comprehensive, integrated service concepts and business models that complement existing modes, and for which the dominant factor will be extensive cooperation among the various actors in the chain.

The dominance of high levels of customer service (short lead times, short product life cycles, individualisation of consumers, high levels of customer service in a larger EU) over transport cost (low share of overall product delivery cost) has led shippers and service providers to focus on product and service delivery (and thus enhancing the customer experience) rather than on the efficiency of the transport systems. Solution deployed by shippers and service providers alike are specific, and do not take sufficient advantages of economies of scale. Breakthroughs in efficiency increase and decarbonisation can only be attained if horizontal collaboration is facilitated. This will be based on advances in IT and supply chain management, and needs to be facilitated by a proper legal framework, especially in the area of anti-trust.

Cooperation and collaboration are both needed to optimise the movement of goods and people to better reflect the actual demand for mobility services including public transport. Models and service solutions will be introduced to support innovative business practices, route planning regimes and efficient trans-shipment of goods (in particular over the 'last mile') and people, among modes and networks. Again, ICT and a better knowledge of transport demand will play a major role in these developments, as will the trend towards extended standardisation for freight carriers in terms of dimensions and modularisations.

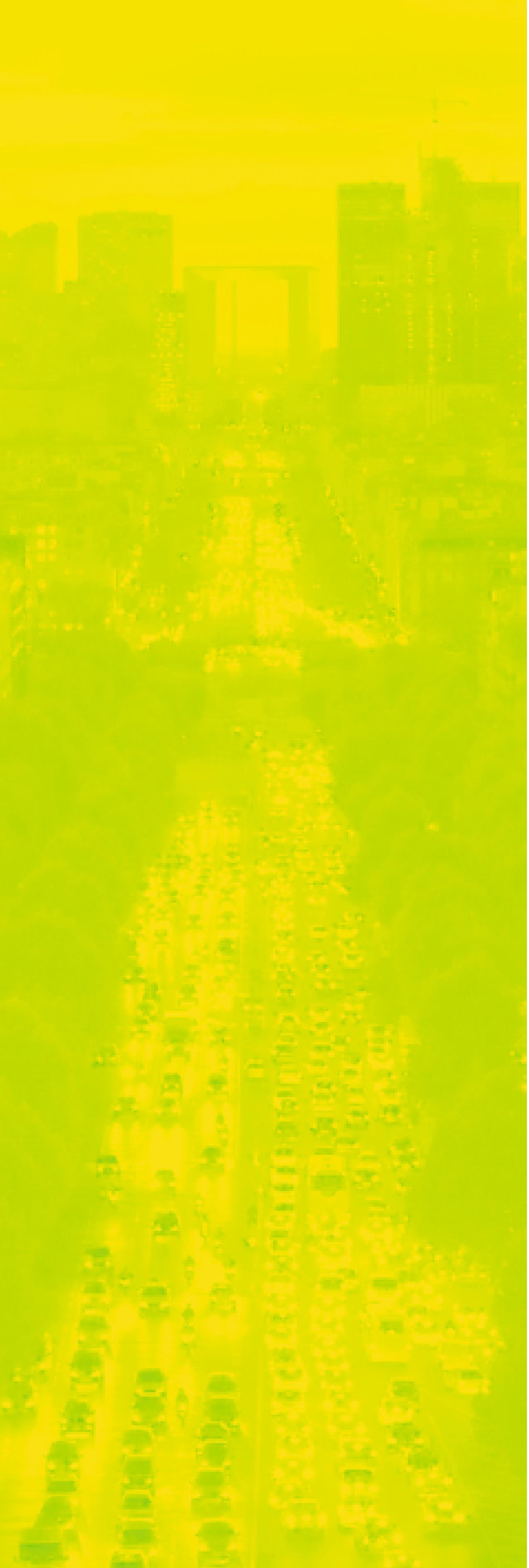
Industry and authorities will agree in a timely fashion on basic requirements, such as standardisation, in view of the deployment process that will be in place, so that incompatible solutions, which would create new barriers for the functioning of the Internal Market, would be avoided.

The regulatory framework will be adapted to enable the effective implementation of innovations. Standardisation and regulations should be in place by 2020 to such an extent that authorities and industry can invest in solutions that can be rolled out directly to the market.

It is important to realise that transport is not an independent phenomenon, but is by and large a result of choices in the design of the entire supply and delivery network. Hence, spatial policies in the Member States have a substantial effect on eventual transport flows. In the long term, towards 2025 and beyond, it is therefore crucial that a coherent vision is developed that aligns spatial policies with the resulting transport requirements. Trans-European network planning needs to precede the developments in markets and investments in manufacturing and distribution resources. Research is needed that will tell how to better predict and influence flows of transport by spatial policies. Expectations from targets specified above are presented in table 7 below.

	2015	2020	2025
Transport efficiency: load factors	65%	75%	85%
Environmental footprint: carbon emissions	230 million tonne (-/- 15%)	200 million tonne (-/- 25%)	162 million tonne (-/- 40%)
Negative effects: congestion	6 500 km (-/- 15%)	5 600 km (-/- 25%)	4 500km (-/- 40%)

Table 7 : Logistics and co-modality roadmaps : targets and expectations.



4. Milestones

A great deal of research has been carried out, and is still ongoing, in the domains of City Logistics, Green Hubs & Green Corridors and Supply Chain Management.

Further research is still needed, as is also the case for the Electrification of Road Transport and Long-Distance Truck themes of the European Green Cars Initiative (EGCI).

There are already sufficient solutions that have been developed to, at least, be able to draw up an effective implementation plan that will help focus efforts on future needs to meet the general expectations.

Therefore, for all three domains, the same milestones are proposed:

Milestone 1 (to 2015):
Setting the targets and picking the low-hanging fruit

Focus is on setting and agreeing to targets, assessment and evaluation methodologies, identification of standardisation and harmonisation requirements, in relation to all relevant research work already in existence.

Milestone 2 (to 2020):
Building the partnerships

Redesign long-distance freight and city mobility concepts, redesign the policy and regulatory framework, building partnerships and drafting corresponding financial investment and exploitation plans.

Milestone 3 (to 2030):
Roll-out

The roll-out of Europe-wide applications (developed along the lines above).

	Milestone 1: Setting the targets, picking low-hanging fruit	**Milestone 2: Building the partnerships**	**Milestone 3: Roll-out**
City Logistics	Developing profound knowledge of the trends in city logistics and models of the underlying processes, as well as a pervasive analysis of consumer needs and behaviour in metropolitan areas. Understanding of the criteria and indicators for measuring the sustainability and performance of city logistics. Comparative city logistics research and developing show cases for adoption across Europe. Pilot project for logistic solutions with EVs.	Efficient distribution systems and technologies, based on a holistic approach for sustainable urban mobility and city logistics. Modular loading units and systems of transfer (including 'zero emission' vehicles) for city logistics. Interoperable soft and hard infrastructure for city logistics and standardisation of equipment and systems for city logistics. Establishment of technical standards for the use of loading units and therefore of transfer equipment.	Implementing the European way to sustainable urban mobility and city logistics, recognising the similarities and differences among European cities.
Green Hubs & Green Corridors	Current scenario, opportunities and Key Performance Indicators. • Developing a vision on the dimensions and capabilities of green hubs and corridors. • Developing a common European measurement system for green logistics.	New business models for Green Hubs & Green Corridors. • Integration of hubs and corridors. Developing the mechanisms for balancing the use of modes in hubs and on corridors (linking information availability with logistics coordination).	Network integration • Integrating hubs and corridors across Europe. Acknowledged European and international standards for green logistics. Achieving seamless modular integration of solutions for green hubs and corridors.

(continued on page 64)

	• **Technologies.** Vehicular technologies (i.e., ITS-enabled convoy driving, modular vehicles, fast freight trains, unmanned and driverless vehicles). Energy storage, smart grids, energy efficient transhipment technologies. • **Identification of Green Corridors and hubs.** Exploring new technologies and solutions, such as overnight electric convoys, self-organising stacking systems and transport, platooning, capacity allocations mechanisms. Blueprint of EU network of hubs enabling use of sustainable transport solutions including appropriate location, number and capacity of transfer nodes. • **Sustainability footprint of logistics transport chain.** Adequate pricing and investment rules for the transport sector. Stimulation of technological development that supports sustainable solutions (launched in call 2010). Address increasing customer need for understanding the footprint (Life Cycle Assessment) of their supply chains.	• **Business models for green hubs and corridors.** New pricing schemes, new services, new capabilities.	Information sharing and technology diffusion, co-design on green logistics. Models for ongoing consensus building.

(continued on page 65)

	Milestone 1: Setting the targets, picking low-hanging fruit	Milestone 2: Building the partnerships	Milestone 3: Roll-out
Intelligent Logistics Systems, optimising e-Freight	Defining opportunities. • Information community development for green logistics in cities, hubs and corridors. Developing information system adoption and interoperability among logistics operators and service providers. Connecting green hubs and cities with long-distance trucking in Green Corridors. Exploring interconnectivity of existing freight information systems, community platforms and global visibility systems. • New legal and regulatory framework. Simplified documentation processes based on common set of terms that can be used electronically.	Interoperability between modes and Networks. IT applications for logistics. • Paperless and electronic flow of information. IT solutions to enable information share and exchange for logistics, used for both planning execution, and invoicing of logistics services. Exploring use of real time data feeds for footprint measurement, statistics collection and government supervision. • Horizontal collaboration. Integration of e-Freight initiatives across modes and hubs. Developing low-cost, low-barrier interface solutions for information system integration.	Internet of freight. • Large demonstration projects. Connecting port community systems across Europe. Integrating vehicle tracking solutions for truck, inland barging and rail. Integrating cargo, vehicle and loading unit tracking in supply chains.

Table 8 : Detailed description of the milestones of the European industry roadmap for logistics and co-modality.

5. Roadmaps

Setting Targets

Building Partnerships

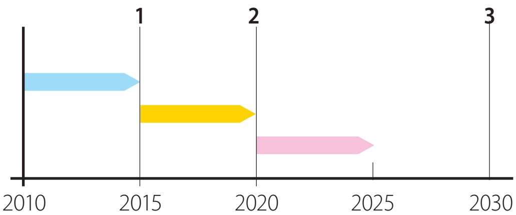
Roll-out

City Logistics

Consumer centred analysis

Efficient distribution systems and technologies

European sustainable urban mobility

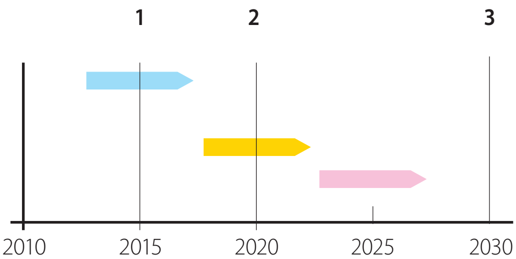


Green Hubs & Green Corridors

Current scenario, opportunities and key performance indicators

New business world for Green Corridors

Network integration

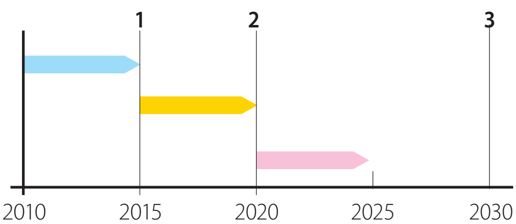


Supply Chain Management

Define opportunities

Interoperability between modes & networks, IT applications for logistics

e-Freight



6. Recommendations

The above milestones and roadmaps must be developed in common upstream with EU transport policies and other industrial initiatives. In addition they must be carried forward through PPPs, particularly through Innovation Partnerships, to ensure that the measures are put in place.

The White Paper on the European Transport Policy, published in 2011[7], will lead to a further and in-depth debate about verifiable targets and solutions that will be fundamental for the first milestone definition of these roadmaps' main three domains.

The review of the Seventh Framework Programme (FP7) will simultaneously enable the research and innovation activities to achieve the EGCI mission more efficiently.

As stressed in Transport Research Arena (TRA) 2010, more innovation and roll-out at large European scale will be needed.

Most relevant are the following:

- The Mid-Term Review of the 2001 Transport White Paper[34] in which the expression 'co-modality' was introduced to signify optimal use of all modes of transport singly and in combination.

- The Freight Logistics Action Plan[47] launched by the EC, amongst a number of policy initiatives, to help Europe address its current and future challenges relies on co-modality and on advanced technology to ensure a competitive freight transport system whilst promoting environmental sustainability. The Freight Logistics Action Plan focuses on quality and efficiency for the movement of goods, as well as on ensuring that freight-related information travels easily between modes.

These objectives can be reached primarily through e-Freight[48] solutions aiding collaboration among all stakeholders involved in freight transport chains. Part of the action plan is establishing synergies with related policies such as e-Maritime.

- The ITS Action Plan Oct 2008: 'ITS tools constitute a core enabler for the management of such logistic chains, notably in maintaining a paperless information trail in the management of the physical flow of goods (e-Freight) '.

- The e-Customs initiative introduced by Decision No 70/2008/CE. The e-Customs vision for 'electronic declarations as a rule', interoperable national computer systems and single window solutions will facilitate information exchange on cargo movements. In the context of the European e-Customs and the Modernised Customs Code programme, Single Windows are foreseen.

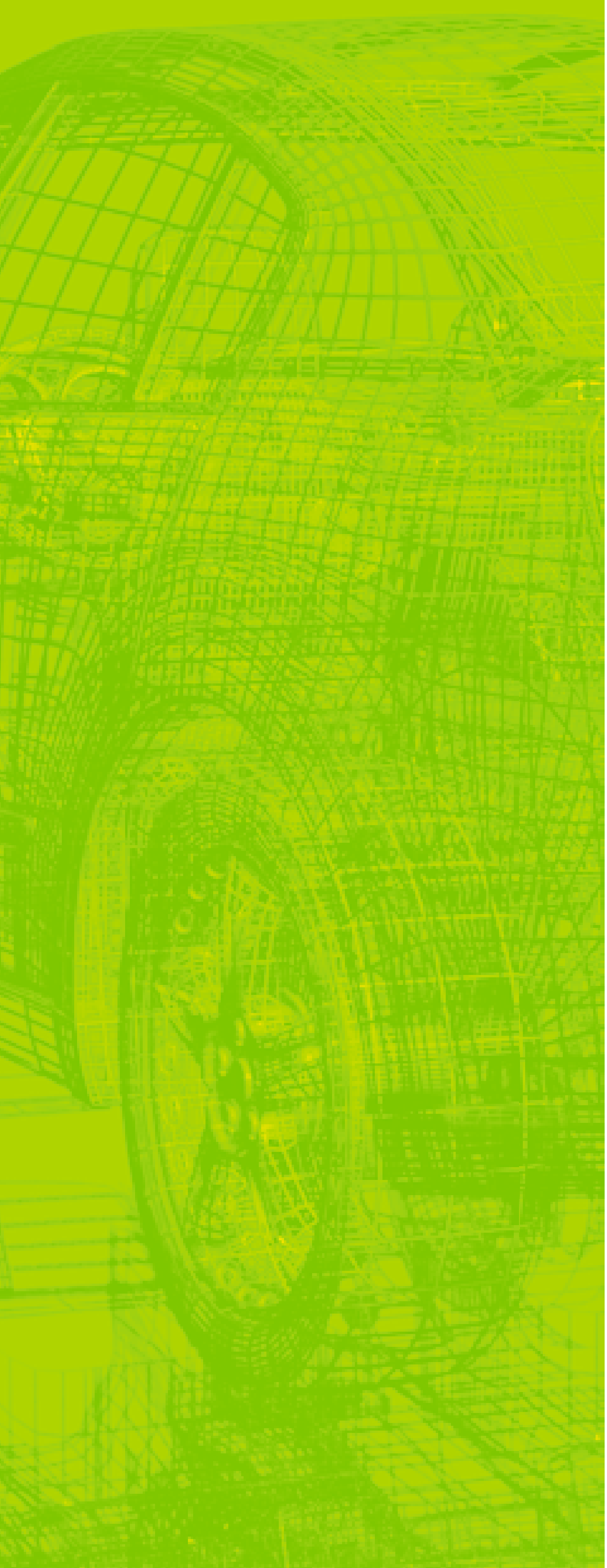
- Directive 2009/17/EC, in the framework of the Third Maritime Safety package, amending Directive 2002/59/EC for establishing a Community vessel traffic monitoring and information system (the 'VTM Directive'). One of the main objectives of the amended Directive is to guarantee that all Member States will be interconnected via the Community maritime information exchange system SafeSeaNet (SSN) in order to obtain a complete overview of the movements of ships and dangerous or polluting cargoes in European waters. The integrated maritime transport strategy opens new horizons for SSN as a core platform to support 'upgraded EU maritime transport information management. '

- Communication and action plan with a view to establishing a European maritime transport space without barriers COM(2009) 10. Short-term actions include 'simplification of customs formalities for vessels only sailing between EU ports' and 'clarification of the use of IMO/FAL harmonised forms through a proposal to the European Parliament and the Council for a directive replacing Directive 2002/6/EC on reporting formalities for ships arriving in and/or departing from ports of the Member States of the Community.' Further, the Commission is preparing measures for 'National Single Windows' (systems that allow traders to lodge information with a single body to meet all import or export-related regulatory requirements).

- The development of the European Border Surveillance System (EUROSUR), which foresees the gradual creation of a common information sharing environment for the EU maritime domain. EUROSUR, focussing initially on the southern and eastern external borders of the EU, suggests to Member States a roadmap for gradually developing a common technical framework to support Member States' authorities in reaching full situational awareness over the coming years. EUROSUR is closely related to the 'integration of maritime surveillance activities' as described in the Commission document COM(2009) 538 'Towards the integration of maritime surveillance: a common information sharing environment for the EU maritime domain'.

- The e-Maritime initiative aimed at fostering the use of advanced information technologies for working and doing business in the maritime transport sector. The e-Maritime initiative will be proposing a Framework Directive and other policy measures.

- The TEN-T programme aimed at developing an efficient trans-European transport network (TEN-T) to support the re-launched Lisbon strategy for competitiveness and employment in Europe. The TEN-T programme is the main instrument for EU financing of transport infrastructure developments across all modes including Motorways of the Sea which invariably rely on advanced ICT integration technologies.



Appendix

Public-Private Activities

GS1

GS1 is a global organisation dedicated to the design and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally and across sectors. The GS1 system of standards is the most widely used supply chain standards system in the world.

GS1 has established the GS1 Logistics Forum (LF) where retailers, manufacturers, material suppliers and logistic service providers are represented. The mission of the LF is to lead development and drive the implementation of the GS1 Logistics Solutions to gain business benefits for global supply chains by fostering interoperability between the partners to overcome barriers of scalability and achieve visibility. The LF has already developed the first version of what is called the Logistics Interoperability Model (LIM) Version 1 and the first version of the Business Requirements Analysis Document (BRAD) For Transport Management. This initiative is backed by industry. Cooperation has already been established.

PEPPOL

EU Member States have expressed a political will to change public procurement significantly. The Manchester ministerial declaration of 24 November 2005 for example defines that 'by 2010 all public administrations across Europe will have the capability of carrying out 100% of their procurement electronically and at least 50% of public procurement above the EU public procurement threshold will be carried out electronically.' The PEPPOL (Pan-European Public eProcurement On-Line) project is strongly supporting this target.

The broader vision of PEPPOL is that any company (including small and medium-sized enterprises (SMEs)) in the EU can communicate electronically with any EU governmental institution for all procurement processes. The objective of the PEPPOL project is to set up a pan-European pilot solution that, conjointly with existing national solutions, facilitates EU-wide interoperable public eProcurement.

PEPPOL limits itself to the situation where the purchaser orders (e-Ordering) a product from the manufacturer and the manufacturer invoices the purchaser (e-Invoicing); See the upper part of the figure that follows.

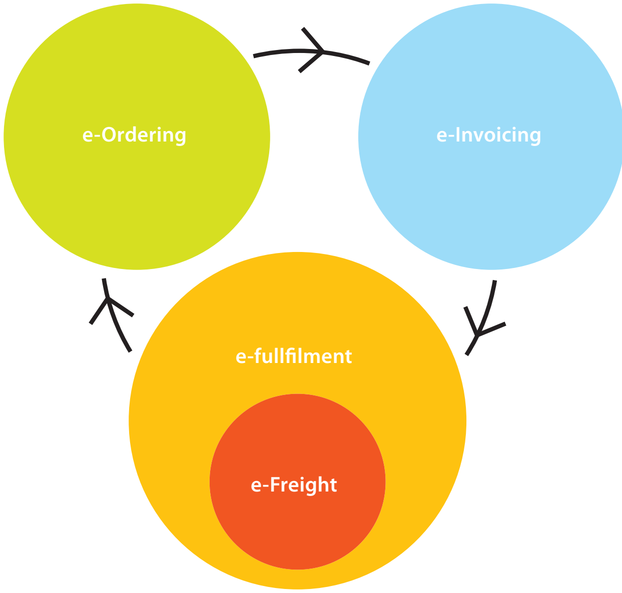


Figure 8 : Exploiting the full potential of PEPPOL.

To ensure that the product is efficiently delivered to the purchaser, the loop needs to be closed (e-Fullfilment, which includes e-Freight). The proposed framework should be supporting public procurement to exploit the full potential of PEPPOL.

Mode-Based Initiatives

ITS

The Action Plan for the Deployment of ITS in Europe dealing with road transport and interfaces to other modes was completed in 2008.

RIS

Directive 2005/44/EC of the European Parliament and of the Council of 7 September 2005 on harmonised river information services (RIS) on inland waterways in the Community (Official Journal L 255, 30.9.2005) sets the stage for traffic management on inland waterways in Europe. RISING is a FP7 project aiming at improving the competitiveness of door-to-door transport chains involving inland waterway transport and utilising RIS to achieve this.

TAF/TSI

The Directive 2001-16 asks railway stakeholders to specify the interoperability constituents for: infrastructure, energy, control and command and signalling, traffic operation and management, rolling stock, maintenance and telematics applications for passenger and freight services. The latter has been further specified in the TAF/TSI (Technical Specifications for Interoperability for Telematic Applications For Freight). The TAF/TAS message specification has been completed and implementation has started.

The EU e-Maritime initiative

The EU e-Maritime initiative is aimed at fostering the use of advanced information technologies for working and doing business in the maritime transport sector. However, the ultimate goal of the EU e-Maritime initiative is to make maritime transport more efficient, safer and environmentally friendlier by improved information use, knowledge creation, facilitation of business collaboration and supports to cope with externalities. The EU e-Maritime initiative also aims at improving life at sea by providing Internet-based services for mariners, thus raising the attractiveness of the seafaring professions.

IATA
IATA has its own e-Freight initiative and is in the business of deploying the concept.

Standardisation

Following organisations contribute to the development of freight standards:
CEN
UN/CEFACT
UBL/OASIS
US Department of transportation:
The Electronic Freight Management initiative (See http://ops.fhwa.dot.gov/freight/intermodal/efmi/index.htm).

Relevant EU Projects

Freightwise
Freightwise[49] was an EU-funded project under the Sixth Framework Programme (FP6) for Research and Development (R&D) that was completed in April 2010. Freightwise built on (and contributed to) ARKTRANS[50], developing a simple, standard framework for information exchange in transport that may be implemented at a very low cost.

e-Freight[51]
e-Freight may be considered a continuation of Freightwise and will provide an e-Freight platform supporting the design, development, deployment and maintenance of e-Freight Solutions, which will be validated in business cases and pilots involving representatives from all relevant stakeholders in surface transport, including large and small businesses and authorities. e-Freight deals with Framework, Single Transport Document and Single Window.

Integrity
Integrity is a project intending to significantly improve the reliability and predictability of door-to-door container chains. The kernel of the project is the development of the so-called Shared Intermodal Container Information System (SICIS) allowing authorised companies and authorities to access planning and status information of selected transports. A framework is required to facilitate interaction between the SICIS and the stakeholders.

Smart-CM

Smart-CM[52] aims to make trade and transport more efficient, secure, visible and competitive across the world in a global inter-modal context, working along with existing initiatives such as that of AEO and the Green Lanes implementation. Smart-CM will provide a simple - transparent - neutral - easy-to-handle solution for the interaction between public administrations (primarily customs) and the market players involved in the container transport chain management and administration business. This interaction mentioned in the previous paragraph will require a framework for interaction and interoperability.

SmartFreight

The Smartfreight project wants to make urban freight transport more efficient, environmentally friendly and safe by answering to challenges related to traffic management, freight distribution management, and a better coordination between the two. The main aim of Smartfreight is therefore to specify, implement and evaluate information and communication technology (ICT) solutions that integrate urban traffic management systems with the management of freight and logistics in urban areas. The actual transport operations carried out by freight distribution vehicles will be controlled and supported by means of wireless communication infrastructure and onboard and on-cargo equipment.

Euridice

Euridice is an EU-FP7 project funded through DG INFSO (Information Society and Media Directorate-General). Euridice concentrates on using smart tags RFID etc., combined with a fixed and mobile web services infrastructure, to facilitate direct interaction between cargo items (individual packages) and between cargo items, load units (pallets, containers etc.), vehicles and infrastructure. Euridice requires a framework to facilitate such interactions.

The term 'intelligent cargo' refers to cargo items that are equipped with active RFID tags[53]. Such tags typically contain at least two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, and other specialised functions. The second is an antenna for receiving and transmitting the signal. An active RFID tag contains a battery and can process and transmit signals autonomously.

RISING

RISING[54] is a FP7 project aimed at improving the competitiveness of door-to-door transport chains involving inland waterway transport and utilising RIS to achieve this. RISING builds on the results of Freightwise.

DiSCwise

DG Enterprise has commissioned a study aiming at 'assisting SMEs to participate in global digital supply chains in the transport and logistics sectors in the single market by (…) providing standard architectures.'

EasyWay

EasyWay is a project under the EU TEN-T budget where 21 European Member States, through their road operators as partners, cooperate on the establishment of Core European Services for European travellers and hauliers. The project shall be seen as the Member States' response to the requirements of the EU ITS Action Plan. Services are mainly related to road traffic and transport, but include interfaces to other modes and the exchange of information at modal shift points. A specific area within EasyWay is dedicated to freight and logistics services.

SuperGreen

A new EU project entitled 'Supporting EU's Freight Transport Logistics Action Plan on Green Corridors Issues' was started on 15 January 2010. The three-year project is a Coordinated Action supported by the European Commission (DG MOVE, (Mobility and Transport)) in the context of the FP7. The purpose of the project is to promote the development of European freight logistics in an environmentally friendly manner. Environmental factors play an increasing role in all transport modes, and holistic approaches are needed to identify 'win-win' solutions.

BeLogic

Started in 2008, the project aims at developing benchmarking and KPI concepts and solutions.

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Acronyms, abbreviations & symbols

AC/DC	Alternating Current/Direct Current
ADAS	Advanced Driver Assistance System
AEBS	Advanced Emergency Braking System
APU	Auxiliary Power Unit
C2X	Communication between cars or car to any other source
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CONCAWE	CONservation of Clean Air and Water in Europe
C_x	Drag coefficient
DCS	Driver Coaching Systems
DPF	Diesel Particulate Filter
EATS	Exhaust After-Treatment System
EC	European Commission
EEGI	European Electricity Grid Initiative
EGCI	European Green Cars Initiative
EIB	European Investment Bank
EIRAC	European Intermodal Research Advisory Council
EMI	Electromagnetic Interference
EPIA	European Photovoltaic Industry Association
EPoSS	European Technology Platform on Smart Systems Integration
ERTRAC	European Road Transport Research Advisory Council
EU	European Union
EUROSUR	European Border Surveillance System
EV	Electric Vehicle
EWEA	European Wind Energy Association
FEV	Full Electric Vehicle
FP7	Seventh Framework Programme
GDP	Gross Domestic Product
GHG	Greenhouse gas
HCCI	Homogeneous Charge Compression Ignition
HD	Heavy-Duty
HEV	Hybrid Electric Vehicle
HGV	Heavy-Goods Vehicle
HVAC	Heating Ventilating and Air Conditioning
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IP	Integrated Project
ITS	Intelligent Transport Systems
JRC	Joint Research Centre
KPI	Key Performance Indicator
LCA	Life-Cycle Assessment
LDWS	Lane Departure Warning System

LED	Light-Emitting Diode
LF	Logistics Forum
Li	Lithium
LNG	Liquefied Natural Gas
MD	Medium-Duty
NdFeB	Neodymium Iron Boron
NEDC	New European Driving Cycle
NO_x	Nitrogen Oxides
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrids Electric Vehicle
PM	Particulate Matter
PPC	Partially Premixed Combustion
PPP	Public-Private Partnership
PV	Photovoltaic
R&D	Research and Development
RE	Renewable Energy
RFID	Radio-Frequently Identification
SCR	Selective Catalytic Reduction
SmartGrids	European Technology Platform for the Electricity Networks of the Future
SO_x	Sulphur oxides
STREP	Specific Targeted Research Project
TAF	Technical Applications for Freight
TRA	Transport Research Arena
TSI	Technical Specification for Interoperability
TPMS	Tyre Pressure Monitoring System
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrasctucture
V2G	Vehicle-to-Grid
V2X	Vehicle-to-any other source
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organisation
WHR	Waste Heat Recovery
WTW	Well-to-Wheel
Xe	Xenon

European Commission

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The European Green Cars Initiative (EGCI) is a Public-Private Partnership (PPP) part of the European Economic Recovery Plan launched in November 2008. The objective of the EGCI is to support Research and Development (R&D) on technologies and systems that are able to bring breakthroughs in the goal of Europe to achieve a greener road transport system, safe and reliable and using renewable energy sources. The PPP EGCI makes available during the period 2010-13 a total of EUR 1 billion through R&D projects set up jointly by the European Commission, industry and research partners and the EU Member States.

The strategic multi-annual roadmap that is presented in this document defines the R&D objectives to be achieved by the EGCI. It has been prepared by the Ad-hoc Industrial Advisory Group, which gathers experts from the industries involved and represents four European Technology Platforms: ERTRAC (European Road Transport Research Advisory Council), EPoSS (European Technology Platform on Smart Systems Integration), SmartGrids (European Technology Platform for the Electricity Networks of the Future) and EIRAC (European Intermodal Research Advisory Council).

Since accelerated innovation will be based on agreements of the sectors involved and the public authorities on short, medium and long-term goals, this multi-annual roadmap provides the EGCI PPP with prioritised R&D needs, jointly with recommendations on production, market uptake and regulatory framework conditions. It is structured in three pillars: electrification of road transport, long-distance transport and logistics and co-modality.

Prepared by the EGCI Ad-hoc Industrial Advisory Group

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