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Transport Research Market Uptake (Market-up)

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Selected case studies on transport innovation: R&D initiatives and market uptake of results

Lead partner: UA

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- TIS.pt (PORTUGAL) - Co-ordinator
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Foreword

This document corresponds to a summary report of the FP7 Market-up project Deliverable 3.1 – Selected case studies on transport innovation: R&D initiatives and market uptake of results and it was prepared by UA.

This document is set to be Public (PU), and should be referenced as:

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or

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1. Introduction

1.1 Background

Market-up project aims to identify barriers (both social and technical) and drivers for the market uptake of transport research results and, via this identification process, to contribute to the increased role of the transport sector in delivering a low carbon economy, looking forward to tools that enable the achievement of two main goals: a) that research results are uptake by the market and b) that European research supporting covers all actors, including the weakest ones.

The goal of work package 3 is to undertake a detailed assessment of seven cases representing different innovative clusters in the transport sector, based on which an insight analysis of success or failure of policies to stimulate innovation in transport is promoted with the overall goal to obtain a better knowledge on the market uptake of results.

Case studies were chosen based on WP1 analysis, which explains the elements of innovation systems and the analytic approach to describe and improve them. For each case study a review of the current status of innovation and R&D in that specific topic is discussed, and a review of progress is established. The idea is to provide clear examples, easy to communicate, about the uptake of previous R&D activities and establish the link to existing challenges by drawing conclusions from past experiences and provide recommendations to address challenges that are now being faced in these areas. The case studies chosen are listed in chapter 1.3 below.

The case studies aim to collect and generate concrete knowledge on innovative clusters in transport field, in particular: (a) identification of key players (and investors) and their roles, (b) understanding of the policy and institutional setting in which innovation is realised, (c) understanding the financial and funding schemes adopted (European, national, regional, local, other), (d) influence of contextual elements over innovation development, (e) innovative practices in place (policy, operators, users), (f) market structures, (g) barriers and drivers.

In order to facilitate the comparability of results in the various case studies it is important to underline that they share some common elements. Although the work envisages the coverage of various areas and modes within the transport sector, the analysis is focused on the market uptake of innovations that might contribute to a low carbon economy, and whenever possible the case studies will try to look backwards and trace actual developments on R&D and market uptake rather than rely exclusively on expected impacts.

The methodological approach used to reach the goals set out for the work package 3 of the project is described next.

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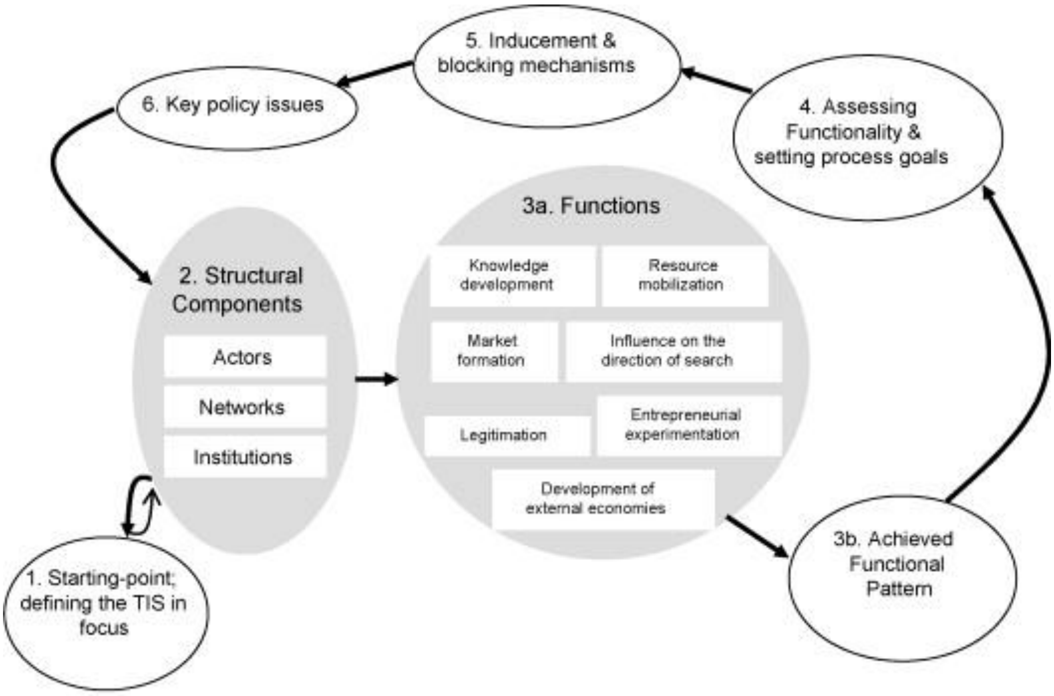
1.2 Methodological approach

The Technological Innovation System (TIS) used in the Market-up project is based on Bergek *et al.* (2008) and includes a set of 6 sub-analyses, called "steps". In the approach an analyst needs to go through 6 steps of the analysis.

"The first step involves setting the starting point for the analysis, i.e. defining the technological innovation system (TIS) in focus. In the second step, we identify the structural components of the TIS (actors, networks and institutions). In the third step, we move from structure to functions. With an analysis of functions, we first desire to describe what is actually going on in the TIS in terms of the seven key processes where we come up with a picture of an "achieved" functional pattern, i.e. a description of how each function is currently filled in the system. The subsequent fourth step is normative; we assess how well the functions are fulfilled and set process goals in terms of a "desired" functional pattern. In the fifth step, we identify mechanisms that either induce (drive) or block a development towards the desirable functional pattern. We can then specify key policy issues related to this inducement and blocking mechanisms; and this is the sixth and final step." [1]

Figure 1: Scheme of Technological Innovation System analysis



Source: Bergek *et al.* (2008)

The analysis itself was not performed in a linear fashion. Market-up partners worked on the scheme in an iterative manner. The TIS analysis steps to complete were the following:

- Step 1: the starting point of analysis: defining the TIS in focus;

[1] Paragraph from Bergek *et al.* (2008).

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- Step 2: identifying the structural components of the TIS
    - 2.1 Actors;
    - 2.2 Networks;
    - 2.3 Institutions;
- Step 3: mapping the functional pattern of the TIS:
    - 3.1 Knowledge development and diffusions;
    - 3.2 Influence on the direction of search;
    - 3.3 Entrepreneurial experimentation;
    - 3.4 Market formation;
    - 3.5 Legitimation;
    - 3.6 Resource mobilization;
    - 3.7 Development of positive externalities;
- Step 4: assessing the functionality of the TIS and setting process goals;
- Step 5: identify inducement and blocking mechanisms;
- Step 6: specify key policy issues.

The analysis steps were completed by filling in the TIS analysis template (see Annex A – Templates). The template is based on the methodology suggested in Bergek *et al.* (2008) and applied in Köhler *et al.* (2010).

The methodology used for TIS analysis of the case studies is in line with the description in the DOW, see Table 1 below.

Table 1: Link between DoW and TIS-methodology

DOW	**Steps in TIS-methodology (Based on Bergek *et al.* (2008))**
a) Identification of key players (and investors) and their roles	2.1, 2.2
b) Understanding of the policy and institutional setting in which innovation is realised	2.3, 4
c) Understanding the financial and funding schemes adapted (European, national, regional, local, other)	3.6
d) Influence of contextual elements over innovation development	3.1, 3.2
e) Innovative practices in place (policy, operator, users)	3.2, 3.3
f) Market structures	3.4
g) Barriers and drivers	5

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1.3 Choice of the case studies

For performing the TIS analysis Market-up partners selected case studies within their area of expertise, see Table 2. The selected cases were identified as a result of the work undertaken in the earlier stages of the project, namely the trends identified in WP1. The cases represent a diversified set of innovative clusters in the transport sector.

It should be mentioned that selection of case studies was done as much as possible in relation to on-going or planned demonstrations of EU and national projects. This also takes into account the important R&D effort that European industry has been devoting to the electric vehicles.

Table 2: The selected case studies

Area of research	Topic of Case study	Partner	
Electromobility	Electromobility	TIS	Road
Alternative motor fuels	Biofuels for surface transport	CLEPA	Rail, road, maritime, inland waterways
Maritime Transport	Deployment of Green Technologies within the Maritime Sector: SO_x Abatement Technology	EMEC	Maritime
Intermodality	Versatile, efficient and longer wagons for Intermodal Transport	UNIZA	Rail
Maritime and Inland waterways	Container transferium	UA	Inland navigation, maritime
Rail	Cargo sprinter	BME	Rail
Aeronautics	Biofuels in aviation	ISI	Air

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2. TIS analysis of the case studies

The selected case studies have been analysed based on the TIS methodology described above. This chapter presents the TIS analyses of the case studies.

2.1 Electromobility

Title	**Electromobility**
Mode	rail ☐, road ☒, air ☐, maritime ☐, inland waterways ☐, intermodal ☐
Partner	TIS.pt

In these last few years an increasing interest in the electric vehicle (EV) has been observed, both by the industry and policy makers. All major vehicle makers or Original Equipment Manufacturers (OEMs) have plans to roll-out new battery electric vehicles (BEVs) or plug-in hybrid electric vehicles (PHEVs) within the next five years. Meanwhile the first mass-produced electric cars have entered selected markets in the middle of 2010 and one was even elected car of the year 2011[2].

Within the policy arena substantial attention has also been placed in EVs, which are generally seen as an important way to meet transport policy challenges related with the sector's energy dependence on oil and related environmental impacts, notably:

- Energy security (e.g. peak oil),
- Climate change/Greenhouse Gas (GHG) emissions and
- Air pollution.

In Europe the electrification of transport (electromobility) is a priority in the Community Research Programme. It also figures prominently in the European Economic Recovery Plan presented in November 2008, within the framework of the Green Car Initiative. The economic crisis seriously hit the car industry in 2008, causing decreasing car sales and raising other new business opportunities. As a reaction to the crisis in the automotive industry an economic stimulus plan was initiated, of which substantial parts are directed towards the electrification of cars. Although these environmental, economic and political issues have given new impetus for the dissemination of EVs, there is still a lot of uncertainty around the technology. Current research puts especial focus on technological feasibility, economic viability and environmental desirability of EVs and often takes the form of vague predictions, scenarios and *ex-ante* evaluations. Therefore, science carries a message of uncertainty to decision makers in business and politics and, via the media, to potential customers. Will the range be sufficient to please customers? Are EVs sufficiently safe? Will alternative business models work? Is political support necessary? And are EVs really 'green'? In order to reduce uncertainty, practical experience with EVs is required. Several show cases with EVs are being carried out to foster the legitimation of the technology.

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[2] http://www.caroftheyear.org/

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Under this framework of uncertainty, it comes as no surprise that many variations of EVs technical solutions are now in the market or pre-market phases, ranging from simple hybrid EVs without a plug-in option to pure battery EVs. In addition to the plug-in option, EVs differ with respect to design of the drive-train and the degree of hybridization. A vast list of options regarding electric vehicles is shown in the Figure 2 below, presenting a synthesis on the specifications of each one.

Figure 2 Synthesis on the specifications of electric vehicles technological variants

Type	Regenerative brakes	Drive only with electric motor	Plug-in battery charging	Gas engine	Examples
Combustion engine vehicle (CEV)	✘	✘	✘	✔	*Hummer, VW Beetle*
Mild hybrid electric vehicle (HEV)	✔	✘	✘	✔	*Honda Civic Hybrid*
Full hybrid electric vehicle (HEV)	✔	✔	✘	✔	*Toyota Prius*
Plug-in hybrid electric vehicle (PHEV)	✔	✔	✔	✔	*BYD F3DM*
Range extended electric vehicle (REV)	✔	✔	✔	✘/✔[1]	*Chevy Volt*
Battery electric vehicle (BEV)	✔	✔	✔	✘	*Nissan LEAF*

Source: Sonnenschein, J (2010)

The concept behind the EVs is rather simple: it has an electric powered engine which uses energy stored in batteries within the vehicle. The energy sources are twofold: the batteries can be plugged in to the grid or regenerative brakes can recover part of the kinetic energy of a moving vehicle. In the case of the regenerative breaking, the motor is used as an electricity generator in the braking process. Depending on the type of power-train, energy from braking operations is "recycled" in different ways.

Then, two main types of hybrid gas-electric power-trains are common: series hybrid and parallel hybrid.

In a series hybrid only the electric motor provides the power to make the wheels turn. Electricity is stored by batteries that are charged by a generator that is driven by an internal combustion engine. In addition the batteries can also be charged by regenerative braking or by plugging the car in. The main advantage of the series hybrid configuration is that the engine for driving the generator is very efficient as it can operate at a constant load, independently of the start-stop-operations of the car. In a parallel hybrid both the engine and the electric motor power the wheels. They are both connected to a transmission. The

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advantage of this configuration is that energy from the engine does not have to be converted into electricity before driving the wheels and, thus, avoids conversion losses. On the other hand, a parallel hybrid is not as efficient as a series hybrid in city traffic with many start-stop-operations. A parallel-hybrid drive-train combines the other two set-ups. Both the gas engine and the electric motor can drive the wheels individually. This is currently the most efficient but also most costly option since two motors, a generator, a big battery pack, and advanced computing equipment are necessary (Friedman, 2003, p. 12).

At this moment where numerous experts and policy makers seem confident that the *car of the future is electric* but where *uncertainty still rules*, this market-up case study will analyse success and failure of policies to stimulate innovation in the field of electromobility. Although one might note that it might be too early to perform such assessment a structured analysis will look into the innovation system and its structural components allowing a better understanding of how innovation can be geared towards improving the changes for massive uptake of electric vehicles.

Step 1: the starting point of analysis: defining the TIS in focus

Several stakeholders and policy makers place high hopes that electric mobility will provide an effective response to the energy problems of the transport sector. Currently the European transport system is nearly fully reliant on oil as energy source, which reserves are finite and prices are instable in the short-term and expected to rise in the long-term. In face of this scenario the discussion about alternative transport fuels and new powertrains has been ongoing for years, with electric vehicles being frequently seen as the most favourable technology in the medium term.

At the political level this discussion has already delivered important results. In 2009 this discussion culminated with the adoption of a European Directive on the promotion of clean and energy efficient vehicles[3], which requires several (public) contracting authorities to take into account lifetime energy and environmental impacts, including energy consumption and emissions of CO2 and of certain pollutants, when purchasing road transport vehicles with the objectives of promoting and stimulating the market for clean and energy-efficient vehicles and improving the contribution of the transport sector to the environment, climate and energy policies of the Community. This Directive reflects the fact European policy makers expect that using vehicles with alternative powertrains and fuels to play an important role in meeting the EU targets to achieve at least a 20 % reduction of greenhouse gases by 2020 compared to 1990, improvement of energy efficiency by 20 %, and a 10 % share of renewable energy in transport in the Community by 2020. This was further recognised in 2011, when the new White Paper on Transport Policy[4] was released which recognises that "*New technologies for vehicles and traffic management will be key to lower transport emissions in the EU as in the rest of the world*" and establish the following important objective:

> *Halve the use of 'conventionally-fuelled' cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO2-free city logistics in major urban centres by 2030.*

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[3] DIRECTIVE 2009/33/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009.

[4] COM(2011) 144 final.

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Although one can certainly note that these policy papers trend to position themselves as technology neutral, it is worth noting the promoting electromobility fits perfectly the achievement of the established targets and objectives since:

- EVs are generally more efficient than internal combustion engines (ICE), providing an opportunity to increase transport fuel efficiency;

- by using electricity from the grid, EVs can potentially use power generated from renewable energy sources, reducing transports' dependency on oil; and

- higher efficiency and use of low carbon (renewable) energy sources contribute to reduce GHG emission by road transport.

Nevertheless the European automobile industry has shown that there is still a lot to be done in the process of moving from EVs formative phase to a growth phase. The automobile industry is in the process of bringing Battery Electric Vehicles (BEVs) to the market, following recent technology advances in batteries, and in response to consumer's willingness to reduce fuel costs and policies for reductions in GHG emissions from automobiles. Still, recent research has pointed out that current HEVs and Plug-in Vehicles have much higher Total Costs of Ownership (TCOs) than conventional powertrains and that battery cost reductions will be a key driver of future vehicle electrification (Bernstein and Ricardo, 2011).

Moreover one should also be aware of the restrictions to use electric powertrains in the next 2-3 decades: as stakeholders pointed out in a workshop on logistics, urban mobility and intermodality in the framework of the Consultation for the Strategic Transport Technologies Plan (STTP), *electric vehicles could be part of the solution for urban mobility but not for long-distance freight transport*.

In addition important considerations on the interests of Original Equipment Manufacturers, who dominate the innovation system, have to be made. These companies, normally very large undertakings, have most of their sales in internal combustion engines (ICEs) vehicles and will therefore be cautious about abandoning them to embrace a new technological solution. Indeed, the automobile industry spends a great deal of money and resources on R&D, which is strongly oriented to maintaining shares of the current and near term market (Leduc, G., *et al*, 2010) Technological developments *within* ICEs have also been relevant, providing important cuts in energy consumption, GHG and air pollutant emissions and improving their 'green' image. Indeed conventional engines can meet 2020 regulatory targets at low cost (Bernstein and Ricardo, 2011).

Given the difficulties identified, the cost differential and the fact OEMs don't necessarily need to offer EVs, the large scale diffusion of BEVs as inherently low carbon vehicles will be dependent on policy support for some time, currently applied through emissions standards, tax reductions and purchase subsidies.

The scenarios are best by considerable uncertainty over technical progress and promotion Policies. It seems possible that electric vehicles will carve themselves a large share of the market in countries with constantly high support policies (e.g.: China, France and the US). However, their market share will presumably be negligible in emerging economies that do not subsidise the technology quite simply because it is too expensive. Without state support, even in ten years' time, the market share of electric vehicles in some countries (e.g. India, or Latin America) will be marginal. Bosch, the world's largest automotive supplier, expects only

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about 3% of the more 100 million sales of passenger cars and light commercial vehicles in 2020 (roughly 70 million in 2010) to be electric[5].

Forecasting beyond 2020 becomes somehow unrealistic, as strong technological progress increases uncertainty to very high levels. But the stage is currently being set so that at least in the passenger car segment driveline electrification will continue to grow beyond the year 2020.

At present and in the years to come, high costs and the state of battery technology development will confine Electromobility to the realm of a niche market. Falling costs are by far the most important prerequisite for leveraging the technology's potential, with research indicating that a breakthrough in battery performance (energy and power density) and cost is necessary to overcome range anxiety and Total Costs of Ownership (TCO) concerns. All other challenges, such as the short driving range, recharging infrastructure and power source, initially pale in comparison to the cost issue. In the long term however, the electric vehicle can at least be expected to enhance the combustion engine, the open question today is to know in what form and extent this will happen.

Step 2: Identifying the structural components of the TIS

The second step focus on the structure of the innovation system for electromobilty, including an identification of the most relevant actors, existing networks and institutions.

The Figure 3 below presents the relevant structural elements of EU's R&D in the automotive sector. It derives from the work of Market-up WP2, in which the most important actors and stakeholders in EU road transport research have been identified.

[5] TIS.pt estimated BEV to represent approximately 3% of all new light passenger cars in Portugal in 2020 and 13% in 2030, under a business-as-usual scenario (which considers Portuguese investment and incentives on electromobility).

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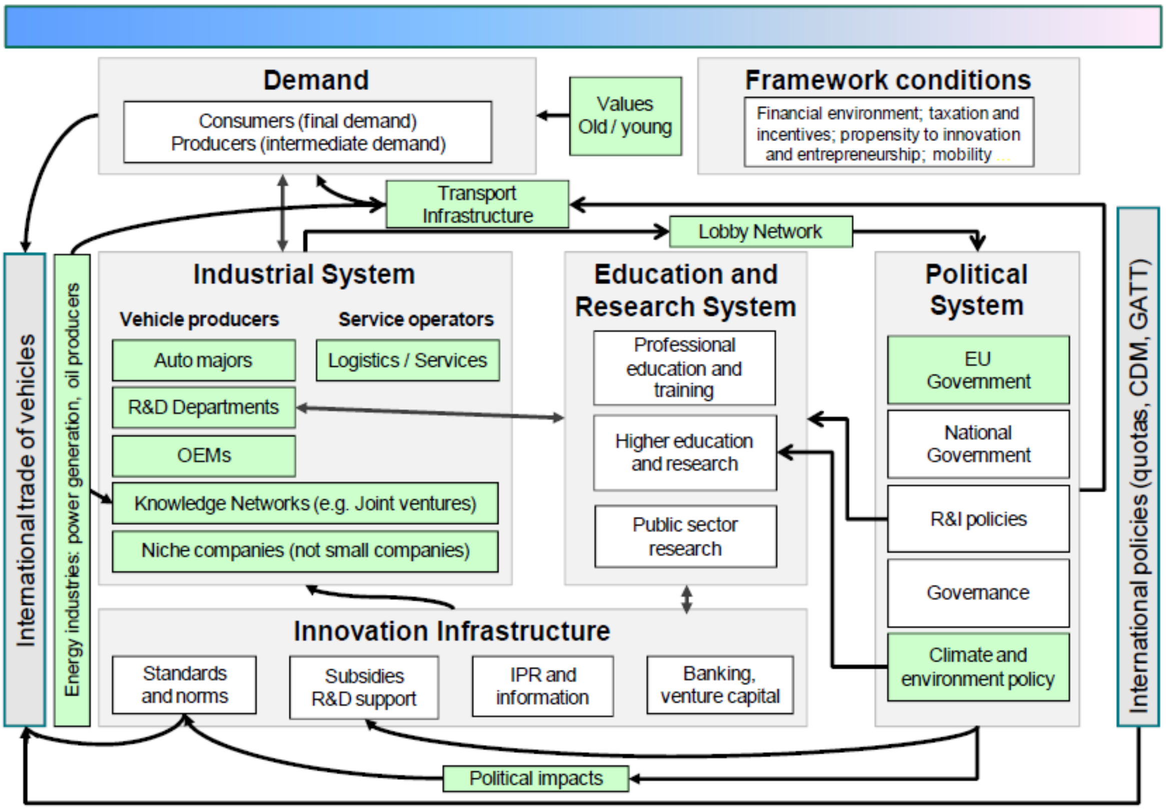
Figure 3: Innovation system in the Automobile Sector



A few aspects should be underlined as particularly important on the specific case of the promotion of Electric Vehicles.

First, the particularly important role of the political system. This aspect was already briefly debated above, when it was noted that the BEV have difficulties to compete with ICE if incentives are not provided by the public sector. One example of such influence is the big challenge that is being posed to OEM's in the EU market, to reduce vehicle's GHG emissions to an absolute average of 120 gCO2eq/km[6] by 2015 and subsequent reduction to 95 gCO2eq/km until 2020. Achieving these objectives is possible with combustion engine, says Peter Gutzmer, responsible for engine systems at Continental. However, the European Regulation provides special incentives for OEMs to achieve these targets by increasing their sales of BEVs. Therefore and to turn possible the above mentioned challenge the E-mobility concept underpins its relevance.

A second aspect worth noting is the particularly important role of knowledge networks / joint ventures and niche companies. OEMs are normally very large companies which normally focus on being at the edge of developing ICEs. Developing EVs normally imply exploiting new areas of knowledge (notably on battery technologies) and new business models, which is generally performed by establishing joint ventures of companies of different backgrounds (such as the joint venture between Volkswagen and VARTA).

[6] Grams of CO2 equivalent is a measure for describing how much global warming a given type and amount of greenhouse gas may cause, using the functionally equivalent amount or concentration of carbon dioxide (CO2) as the reference.

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Indeed, E-mobility will require new collaboration and joint ventures between suppliers and OEM's to control costs. Establishing some partnerships between companies from European countries more evolved in this area:

- Utility companies should get active (they are already very active, for e.g. in Germany), together in cooperation with OEM's they are building and developing sustainable business models.
- From product to service – E-mobility may require a change in the traditional purchase model, offering an opportunity for a longer term OEM/customer relationship.
- Customers buy vehicles – not powertrains: Electric vehicles have to compete on costs, utility, image and lifestyle requirements as well as safety. Though, electric vehicles will require subsidies at the beginning to encourage consumer demand.
- Germany and the UK have a strong automotive ecosystem and players, thus often see them as difficult markets to enter for foreign companies above all without strong automotive references and background. An interdisciplinary approach may often mean long term industry ecosystem commitment starting within the definition/standardization phase and may require a very structured process oriented and documented approach and a special focus on reliability and security.

Nevertheless E-mobility affects many components and parts of the car, thus several commercial areas may benefit from its success. If electric cars are broadly adopted, no matter which kind of new material they use, they will cause a shift in the relative demand growth rate for certain basic materials of conventional cars. Stock market analysts see following developments:

- Demand for aluminium, for example, is likely to increase.
- Copper demand may increase as well due to the high copper content of electric motors used to power the wheels of electric cars.
- Corn relative demand may decrease due to the reduced use of liquid fuels, of which ethanol is a component, and for which corn is an important feedstock.
- Coal and natural gas relative demand may increase due to increased demand for electric power plant output for plug-in electric vehicles (gas being a major energy source of electricity generation).
- Demand for lead may increase due to possible increased use of lead-based batteries in some electric vehicles, but may be relatively flat if other metals are the battery base of choice.
- Lithium relative demand may increase due to the use of lithium in some percentage of electric car battery systems.
- Nickel relative demand may increase due to the use of nickel-based batteries in some percentage of electric car battery systems, but may be relatively flat due to possible preference for other battery materials.
- Oil relative demand may decrease due to lower demand for gasoline for which electricity would be the substitute.
- Platinum relative demand may decrease due to smaller catalytic converters, or due to a lower rate of replacement, as a result of lower average gasoline consumption per driven mile per vehicle.
- Uranium relative demand may increase due to the increased demand for electric power plant output for plug-in electric vehicles (uranium being a significant energy source for electricity generation, particularly in some countries).

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- Zinc relative demand may increase due to the use of zinc-based batteries in some percentage of electric car battery systems, but may be relatively flat due to possible preference for other battery materials.

Whether the future car is full electric, a plug-in hybrid or an improved ICE, it is bound to be made of a variety of materials that have not much left in common with steel.

In fact and for the automotive industry the major challenge posed by E-mobility is the need to prepare for electric vehicles long term market uptake in passenger cars while at the same time securing their own technical edge conventional drives. This harbours both opportunities and risks, depending partly on the position occupied along the automotive value chain. Many products are already covering a large part of the future value chain but this is not the case of battery cell production.

2.1 Actors

Recent research on innovation theory and systems shows that innovation should be understood as a systemic process, rather than a linear one, involving interactions and feedbacks between a large number of actors creating valuable ideas and technologies[7]. The aim of this section is to answer the following question: **who are the most relevant actors in electromobility research?**

As shown in Figure 3, the most relevant actors on electromobility research can be grouped in: industry, research organisations and policy making bodies. For low carbon technologies, there may be less market pull from investors than for other technologies, both because consumer demand for low carbon products may be limited and/or since the costs of GHG emissions are not fully reflected in prices (GHG emissions are an externality). As a result, innovation systems for low carbon technologies have often included a higher degree of intervention from governments than in other technologies, either in technology push, or in market pull, or both. This is illustrated in Figure 4. Note that the investors may, in some cases, be the technology developers themselves, such as in the automotive industry.

[7] EC Economic Policy Committee Working group on R&D, Report on Research and Development, EPC/ECFIN/01/777-EN Final, Brussels, 10 January 2002

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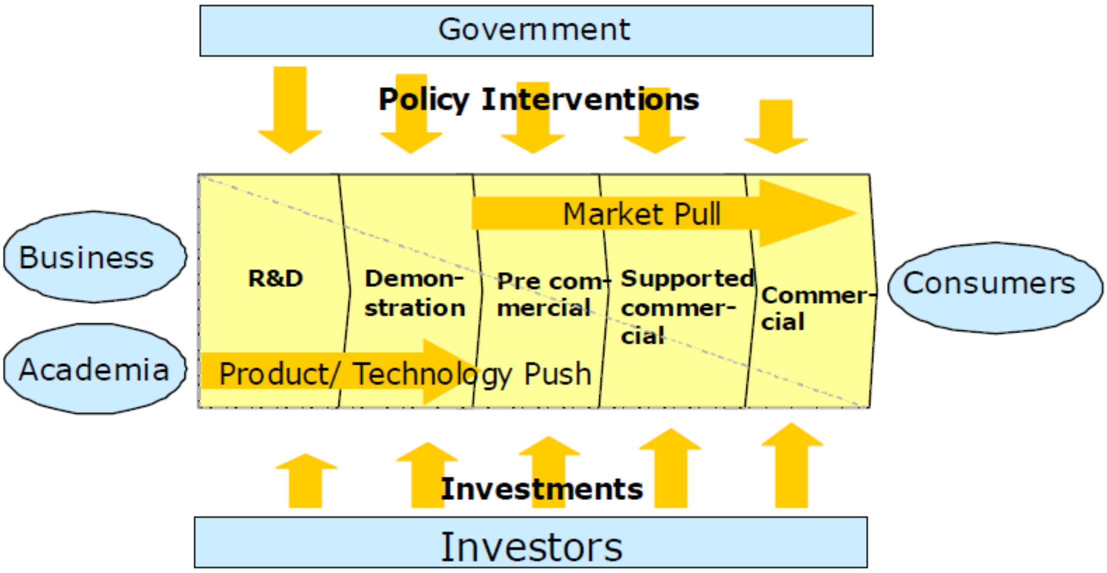
Figure 4 Stages of the innovation chain for low carbon technologies.



Source: adapted from Carbon Trust (2002).

To enable electric vehicle industry to succeed, new kinds of cooperation are needed, especially between the three main groups of actors mentioned above, but also within such groups. These need to go beyond the traditional partnerships between OEM and supplier, and include the players outside the automobile industry, such as utilities or charging station manufacturers. Also a stronger role should be committed to governments, especially in earlier phases.

This can be illustrated by looking at the example of Germany, where the large utility companies have taken a relevant role in e-mobility. There are lot of cooperation between utilities and OEM's, and these partnerships are a kind of drivers on the field, also pushing and controlling the most pilot projects.

Similarly in the UK, many actors are involved in the development of a low carbon surface transport system. These actors are shown in the diagram below.

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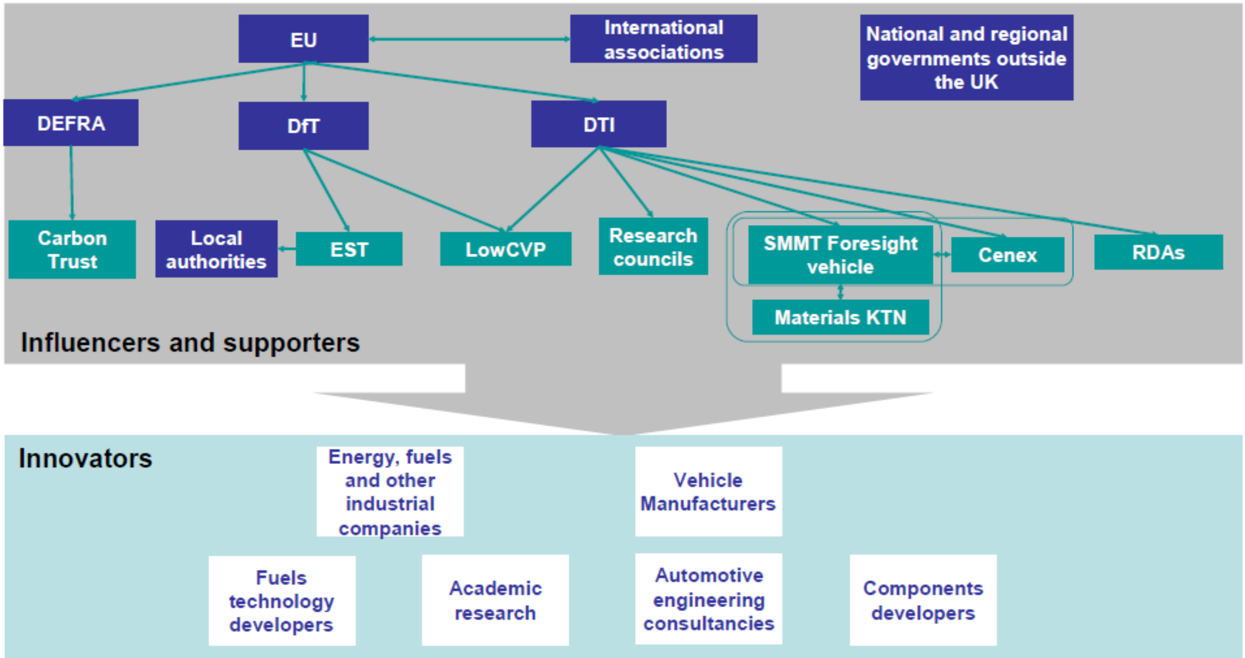
Figure 5 Schematic showing main actors in the low carbon transportation innovation system in the U.K. influencers (in blue) and supporters (in green) affect the innovation of the innovators (in white)[8]



In general the innovation system encompasses those that have influenced, innovated or supported innovators.

Influencers of innovation in the automotive and fuels industry are mostly consumers and policymakers. Consumers play a major part in driving general innovation in the automotive sector providing direct signals to Vehicle Manufactures (OEMs) and creating competitive pressure amongst firms which operate in the same market. The demand signals for low carbon road transport technologies have been weak to date compared with demand for features such as function, image, performance and cost. Private consumers play a lesser part in directly influencing technical innovation in the fuels industry since the product is a "distress purchase" for most with price and convenience being the paramount buying criteria. Fleet purchasers may have a stronger influence on technical innovation in low carbon technology then private consumers. Fleet purchasers are more concern with issues regarding fuel economy (and consequently with lower emissions) as a result on decision making which takes into consideration lifetime fuel costs. In fact choices that are made by OEMs have high impact both on the product quality, safety and environmental standards and fiscal and other instruments relating to their purchase and use. Policies relating to CO2 are set at EU, national and local level. Policymakers also influence the supporters of innovation that will be presented below.

[8] E4tech, A report for the department for transport, "A review of the U.K. innovation system for low carbon road transport technologies" March 2007.

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The Innovators entails all the vehicle and fuel suppliers and their associated supply chains from industrial developers to academic researchers. Innovation occurs globally and pervades rapidly, within regulatory and commercial constraints. Innovation is instigated by OEMs and fuel companies in response to influencers. The automotive industry works with a well-developed network of components suppliers (known by their 'tier' in the supply chain) and tier companies are often called upon to innovate in partnership and on behalf of OEMs.

The OEMs are also served by automotive engineering consultancies, which play an increasing part in powertrain developments. OEMs, components companies and engineering consultancies also take part in consortia with academic research establishments. Although component sourcing is global, there is a tendency for OEMs to work with local partners which means that UK innovators are at some disadvantage compared with their counterparts in Germany, US and Japan in particular. Fuel technology innovation occurs within oil companies, but also, amongst new entrants to the sector, for example specialist energy and biofuels companies and industrial gas companies (for hydrogen).

A wide range of actors support innovation through co-ordination and funding. Coordinators act on behalf of the industry or government to ensure that the sector(s) are strategically focused at regional, national or EU level. Funding is applied to research, development and demonstration to enable technologies to become viable candidates for deployment. In some cases the actors are common to the policymaker and innovator categories – for example oil companies fund academic research and policymakers set research budgets and overall direction.

2.2 Networks

The section above underlined the need for cooperation between different actors on electromobility research. Such conclusion reinforces the role of networks, where such cooperation is based upon.

Networks are constituted by formal and informal links between different actors. Public private partnerships (PPP), project consortia and links between research institutes and industry are some examples for such networks. The most challenging structural components of the TIS are the institutions. While formal institutions, such as regulations and laws, are explicit and can be researched by reviewing documents, informal institutions, such as culture, norms and routines, are usually implicit and just reflected in behaviour (Bergek et al., 2008, p. 413).

To enable electric vehicle industry succeed, new cooperation is required. Electric drive trains are common in other industries, so the basic knowledge for the construction of vehicles with electric power trains is also common. In contrast, advanced Li-ion battery and fuel cell technologies are specialised activities. Therefore, it has been necessary for car manufacturers to enter into agreements with battery and fuel cell specialists. Because of the concentration of car manufacturing and the consequent strong competition between established companies, knowledge sharing happens mainly through limited, explicit alliances – e.g. Daimler-Ballard, Renault-Nissan-NEC, Toyota-Matsushita. Figure 6 illustrates the structure of alliances for electric vehicles.

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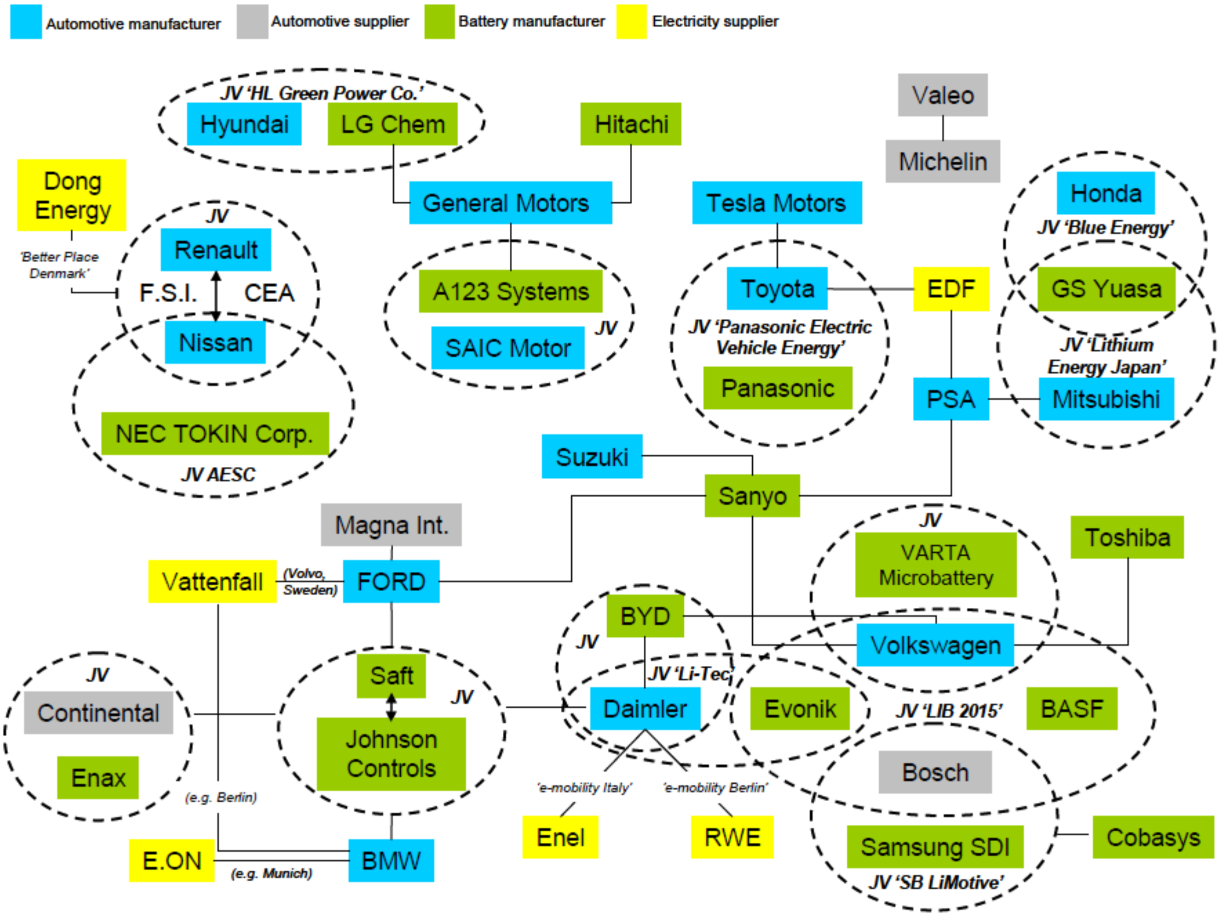
Figure 6: Examples of partnerships worldwide for developing electric vehicles (PHEVs, HEVs, BEVs)



Source: Leduc, G., *et al*. (2010)

In Germany, the big utility companies have taken a relevant role in e-mobility. There is lot of cooperation between utilities and OEM's, and these partnerships are a kind of drivers on the field, also pushing and controlling the most pilot projects.

Some projects and initiatives are examples of the former. In fact partners in the Green eMotion initiative are to accumulate experience with e-mobility in existing and new test regions within Europe and refine the technology. Key issue is the development of European processes, standards and IT solutions that allow customers of electric vehicles an easy and seamless access to charging infrastructure and related services throughout the European Union. Standardization is also the key factor for a fast and cost-efficient European rollout of electromobility.

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The four year long project 'Green emotion' is part of the European Green Cars Initiative, and will be funded under the Seventh Research and Development Framework Programme in order to:

- ✓ compare the twelve on-going regional and national electromobility initiatives in eight different EU Member States,
- ✓ compare the different technology approaches,
- ✓ contribute to the identification of the best solutions for the European market.

The initiative will cover different types of electric vehicles, the development of Smart Grids, innovative Information and Communication Technologies solutions, and urban mobility concepts.

An interoperable platform it is envisaged to be created to enable the different actors to interact and to allow for new high-value transportation services and innovative billing systems. It will contribute to the improvement and development of new and existing standards for electromobility. Green eMotion will demonstrate this interoperable electromobility framework in all participating regions and will thus provide the basis for its replication across Europe.

The partners in the Green eMotion initiative are the industrial companies Alstom, Better Palce, Bosch, IBM, SAP and Siemens, the utilities, Dansk Energi, EDF, Endesa, Enel, ESB, Eurelectric, Iberdrola, RWE and PPC, the automobile manufacturers BMW, Daimler, Micro-Vett, Renault and Nissan, the municipalities Dublin, Cork, Copenhagen, Bornholm, Malmö, Malaga, Rome, Barcelona and Berlin, the universities and research institutions Cartif Cidaut, DTU, ECN, ERSE, Imperial, IREC, LABEIN, and TCD and the technology institutions DTI, FKA and TÜV Nord.

A total of 47 companies and scientific research institutes are involved in the initiative. The initiative focus chiefly on ICT-based charging, control, vehicle navigation and billing infrastructures for various vehicle types and effective business models, services and potential standards that can be developed to fit these infrastructures. This will provide solutions that make electricity production, grids, storage and consumption more intelligent, advance the integration of renewable energies and enable communication, new ways for cooperation across all the links in the supply chain.

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EU funded networks e.g. HyWays have also played an important role in supporting the sharing of knowledge about the new technologies and developing plans/roadmaps for technology development that contribute to developing common expectations for the new technologies. Furthermore, the EU also has ERTRAC, the European Road Transport Research Advisory Council, which has organised many activities around these technologies (Leduc, *et al*, 2010).

In Portugal an ambitious programme to deploy electromobility involved the Government, Local Authorities, R&D Companies, Power Utilities and technology providers. The absence of an OEM is notorious but an agreement was broken with NISSAN, to ensure that EVs would be available in the Portuguese market. An interesting feature of the MOBI.E approach is that it aims to establish an open system, i.e. a framework in which every OEM can potentially enter. The programme is still ongoing, and charging stations for EVs are now common in dozens of Portuguese cities.

In Denmark a different plan was undertaken. The Danish Government is implementing an ambitious EVs programme with the Silicon Valley company, Better Place and Dong Energy, the biggest utility in Denmark. The concept is very different from the approaches in Germany or Portugal as it relies on a new mobility service approach. Instead of charging at home or public stations users will swap batteries in better place stations. Denmark is expected to be the first country to start a program for EV owners that lets them earn money on power they feed to the grid from their charged car batteries. An EV owner could make as much as $10,000 over the life of the car.

What the Portuguese and Danish schemes have in common is also interesting to analyse. In both countries high vehicle registration taxes apply, which allows the Governments to induce an economic incentive for EVs. In addition, both countries combine the fact they are relatively small with a high performance of renewable energy – particularly wind – which could strongly benefit from a widespread capacity to store power in car batteries (one of the problems with renewable energy rely on the capacity to make energy production meet demand).

2.3 Institutions

Government legislation, or the possibility of legislation, specifying emissions standards for vehicles has been the main driver of improvements in environmental performance of vehicles in the past. During this electromobility case study it has been showed that legislation imposing tighter emissions standards for vehicles have an important impact in attaining interest to EVs. Moreover, taking into account the presence of external costs which are not fully reflected in prices, taxation of conventional fuels and vehicles provide very important signals to the markets. These regulations and incentives have certainly contributed to the fact new vehicles are being developed and tested.

An indirect effect has come through legislation and policies in other markets, since products are internationalised in the automotive industry. Japanese government support for electric vehicles led to the development of the Japanese manufacturers' battery hybrid vehicles, in particular the Toyota Prius, which has demonstrated that these cars can be produced and sold in a mass market, with relatively low levels of subsidy vs. conventional vehicles. The US CAFÉ standards and in particular the Californian ZEV standards, have forced the development of low emissions vehicles (Leduc, *et al*, 2010).

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In order to reduce emissions and still allow drivers to have full control of the vehicle improvements on the vehicles' navigation system has being made. This constitutes the strongest norm in the auto industry, however other social norms concerning the definition of social status are being implemented. The later norms are covering better performances and more features in all size categories rather than reductions in costs, fuel use or emissions. In fact and as presented in Bratzel et al, 2010, younger people have a more rational view of the cars as means of transport. They are willing to adopt new forms of service provision such as car sharing. The implication is that the car is being perceived as good that enables the achievement of an objective and not as a property of their own. This fact opens the market for cleaner low emission cars with lower performance in terms of maximum speed.

Step 3: mapping the functional pattern of the TIS

This step constitutes one very important phase of the analytical framework. Seven core functions have been identified (Bergek et al, 2008) and represent archetypes that can be observed in TISs. The functions are not tailored to EV programs, but these functions tend to be similar across different technological innovations. The seven functions that comprises this step are knowledge development and diffusion, Influence on the direction of search, entrepreneurial experimentation, market formation, legitimation, resource mobilization and development of positive externalities. Hereunder it is foreseen to present a short overview on how each of these seven functions may be seen and fit into the electromobility.

To better understand what is being presented above it is required to contextualise a little.

3.1. Knowledge development and diffusion

A lot of data is available for ICEs and technology knowledge for conventional vehicles is widely spread, through training in colleges and universities, as well as within the industry.

For EVs the situation is rather different although there is information that suggests that much more attention is being placed in development knowledge in this field. Although electric drive trains are common in other industries, and the basic knowledge for the construction of vehicles with electric power trains is also common, there is a need to develop several other critical elements, especially to gain confidence from the market. For example, one of the most critical constraints in comparing emissions of ICEs and EVs – while information about fuel economy of ICEs is widely available that same information for EVs is rare and difficult to understand.

The Figure 7 below represents the number of papers published in Web of Science and which work on 'Electric Vehicles'.

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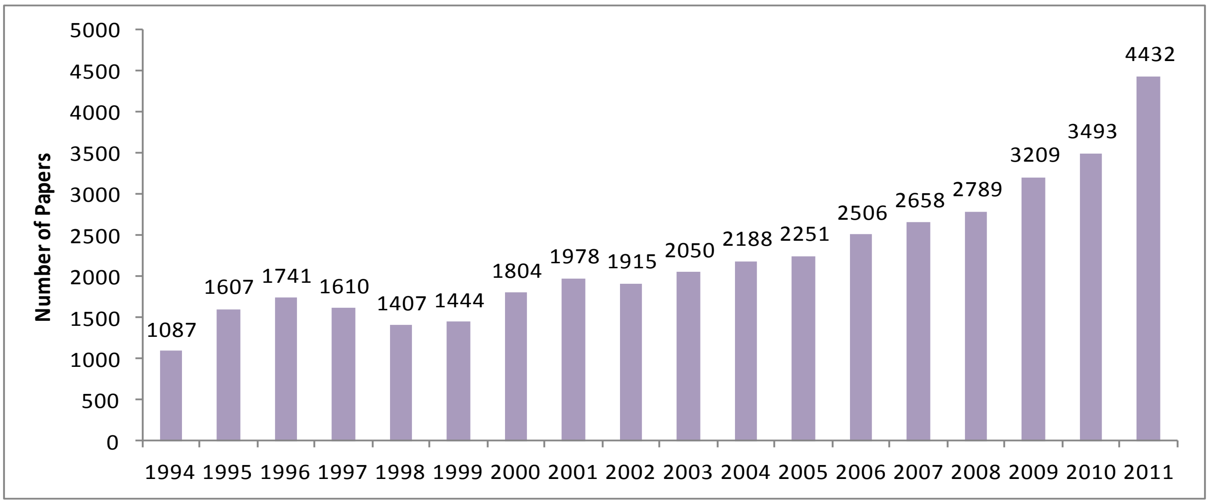
Figure 7: Number of scientific papers published which focus on 'electric vehicles'



The Figure clearly shows a growing trend towards increased knowledge creation in the field of electromobility. It confirms the above-mentioned indications which suggested nearly all major carmakers (OEMs) to be engaged in partnerships to develop electric vehicles. Knowledge creation comes through R&D programmes in industry, universities and research institutes.

However, a challenge that has been pointed out, is the existence of established institutions and the lack of some EV-specific new institutions. EVs have to be fitted in the existing purchasing process of public and private companies, which can cause difficulties and delays (Mollstedt, Interview). A challenge in the standardization process is that different technological solutions have different interests behind them. "If we introduce public charging infrastructure, which is not a large challenge, roaming standards are necessary. And you can already observe big companies [e.g. RWE in Germany] dashing ahead to push their own standards." (Wolters, Interview). Another frequently cited issue is permitting. The rationale behind it is that when the first cars arrive, people, especially in the USA, will need home charging equipment. For this equipment they will need a permit, which might take so long to obtain that the dissemination of EVs is blocked. This scenario is taken very seriously and several cities in the USA have already educated their permitting departments. In the European case studies permitting is not perceived as an issue. The big challenge in the context of permitting will be to supply owners of EVs that live in multi-storey dwellings in densely populated areas with charging infrastructure (Mattila, Interview).

3.2. Influence on the direction of search

It was mentioned above that EVs are expected to play a major role in achieving transport policy objectives. The role of public support to the development and uptake of EVs was also underlined. Accordingly, it comes as no surprise that innovation in this field has been strongly influenced by government policy and policy towards emissions from road vehicles in particular.

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Several examples confirm this observation. The Japanese MITI programme supported the development of batteries and electric power trains, resulting in the early introduction to the market of Japanese battery electric hybrid vehicles to the market, the Toyota Prius in 1997 and the Honda Insight in 1999 (Åhman, 2006). California ZEV legislation is another main policy driver in a large market. New EU legislation (Regulation (EC) No 443/2009) setting CO2 emissions limits on cars from 2012 130g CO2/km requires rapid action from manufacturers (Leduc, *et al*, 2010)

Policy plays a potentially significant role in the innovation system for low carbon road transport since 'climate change is the greatest and widest ranging market failure seen' (Stern Review). Policy can play a role at different points in the innovation system and governments must decide on a balance of interventions ranging from earlier stages to nearer commercialisation.

For the main purpose of this case study we will only introduce the programs and actions that are willing to support the electromobility issue in the European countries. For that purpose some information from UK was gathered. The main UK policies for encouraging innovation in electromobility at the RD&D stage are:

- EU Framework Programme - This is the EU's main method of providing funding for collaborative research and innovation. The programmes aim to strengthen partnerships with teams across Europe to share knowledge, skills and expertise and gives access to new networks, markets and contacts. Framework programmes fund specific research projects, as well as networks of excellence and has a special focus in sustainable transport modes with clean technologies therefore a great emphasis has been allocated and funds provided to projects dealing with environment and energy.
- Foresight Vehicle– A networking organisation for the automotive industry. It is run by the Society of Motor Manufacturers and Traders Ltd (SMMT) and aims to drive forward R&D in this sector. It is organised around 5 technology development areas; engine and powertrain; hybrid, electric and alternatively fuelled vehicles; advanced software, sensors, electronics and telematics; advanced structures and materials; and design and manufacturing process. Originally, Foresight Vehicle received funding, which was allocated between its thematic groups to fund projects that responded to calls from those groups. Foresight Vehicle no longer receives funding for allocation to projects but continues to exist as a network between groups working in different areas of automotive research.
- Energy Technologies Institute – this new initiative will support innovation at the R&D stage through Government funding of up to £500m over 10 years from 2008, matched by industry. Lower carbon transport is planned to be one of the Institute's seven priority areas but more detailed research priorities have not yet been specified.

This situation seems rather representative of the approaches undertaken in other European countries, with the EU-funded research working as a starting point and Government initiatives or industry networks focusing on exploring certain topics.

3.3. Entrepreneurial experimentation

Entrepreneurial experimentation in the specific case of EVs is strongly influenced by two major factors:

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- Since the automobile industry is very concentrated in its manufacturing structure, experimentation is mostly determined by the decisions and strategies of the few auto majors. This means that the auto majors are aware of the R&D strategies of their competition, since there are a small number of large players and there is an imperative to advertise technical progress, since this is an important part of competitive advantage in an oligopoly market. This means that all the auto majors develop a similar small set of future technologies, although the details of the applications differ.
- Because the market penetration of EVs is only possible if an infrastructure to charge the vehicle's batteries is available, a strong involvement between public and private parties is necessary to undertake entrepreneurial experimentation.

In practice this has led to a situation in which most large scale projects to experiment EVs combine large OEMs, large firms from associated areas (e.g. utilities) and policy makers, either at national or local level. For example, in Aachen (Germany) a project named Smart wheels is underway. This project is the vivid entrepreneurial environment and several innovative companies are quite in favour of the EV development in the city. The electric mobility is an issue which is at the top of the agendas where many actors want to be part of the movement. Evidently that the RWTH Aachen University is one of Europe's leading institutions for science and research and a leading automotive engineering institute that plays a core role in the entrepreneurial development. Many researchers bring their expertise to companies or just spin-off their know-how in small start-ups. A physical example of the previous is the fully functional BEV scooter developed at RWTH. One other example is the transfer of knowledge between the Smartlab innovation enterprise which wants to develop models for local utilities in the area of electric mobility (Smartlab, 2010).

In the same way like Aachen, several research institutes in Denver are making appealing EV test market. There are companies that are working on innovative technologies, engine manufacturers and companies that make plug-in conversions.

On the other side in the city of Malmö (Sweden) experimentation regarding EV only takes place with the projects that are being subsidized meaning that this matter is virtual without a real entrance into Malmö's EV system. In fact research institutes do not provide high support for entrepreneurial experimentation around EV's.

3.4. Market formation

The issue of market formation is of major importance for EVs. The new electric and technologies require new delivery infrastructure, which limit diffusion until these infrastructures are provided. This is a significant disadvantage which is limiting EVs to small niche markets (smaller cars, urban areas, etc).

In more practical terms and from the available case studies it can be assumed that the electric market is not at "zero" but it is not far ahead, mainly if we are approaching the segment of family cars. The situation is rather different if we look beyond the cars market, as scooters and pedelecs already have a mature market and the demand for two wheelers is increasing.

In fact and in what concerns the EVs there is still some developments to be done concerning the battery development and those developments are edging the mentioned uncertainties. While research in this area is not conclusive, there is wide agreement on the fact that EVs

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can contribute to the reduction of GHG emissions from transportation through increased efficiency and if the share of renewable energies (or nuclear power) in the electricity mix is high. The impact of motorized vehicles in terms of GHG emissions depends on three factors: the distance driven, the fuel economy, and the life-cycle emissions per unit energy.

For EVs very little data are available, as already mentioned. This is one of the most critical constraints in comparing emissions of ICEs and EVs. Assuming a charging efficiency of around 85%, the plug-to-wheel energy efficiency of a Tesla Roadster is reported to be around 200 Wh/km (Wikipedia contributors, 2010c). Mini states the energy efficiency of the electric Mini with 140 Wh/km (see specs in Mini USA, n.d.). The U.S. DOE test of the Mini-E shows a plug-to-wheel energy consumption of about 165 Wh/km (U.S. Department of Energy, 2009). Nissan claims a battery-to-wheel energy efficiency of 150 Wh/km for its LEAF (Nissan, 2010b). That is the same efficiency that EV expert John Voelcker assumes in his IEEE article "How Green Is My Plug-In?" (Voelcker, 2009, p. 44). Greenpeace expert Wolfgang Lohbeck calculates with less efficient 200-300 Wh/km (Lohbeck, 2010). For this study a plug-to-wheel energy efficiency of about 175 Wh/km shall be assumed for a compact five seater series-production EV.

Li-Ion batteries are not considered to be the "silver bullet that permanently solves all of the world's energy storage problems, but they can certainly make a large contribution for at least several decades". Additional exploration and better batteries can extend the supply with lithium even further (Gaines & Nelson, 2009). For the next five to ten years, when the mass roll-out of EVs is expected to start, the price for Li-Ion batteries is expected to drop.

3.5. Legitimation

This function means the social acceptance of a new technology and the establishment of relevant informal institutions. Different stakeholders within a TIS might come to varying conclusions about the legitimacy of a technology. Perceived legitimacy has a big impact on demand, new legislation and firm behaviour.

Having stated this it will be easily understood that legitimation, as other topics already addressed, hasn't a consensual opinion. In fact it depends largely on the country where it is foreseen to be implemented and the approach used to carry on the awareness raising and acceptance campaigns.

From the research made it is clear that several entities feel that it is too early and thus very risky to be supporting EVs. Some have given an early support in the past to Compressed Natural Gas (CNG), which revealed as noxious procedure because the technology and public acceptance were not mature enough, causing a bad image to the technology which prevails until today. Therefore they fear that if public charging infrastructure is in place and nobody ever uses it that will give EVs bad image.

To avoid the above, in Europe some entities are launching campaigns and demonstration projects. People are invited to use and test electric scooters and pedelecs for this reason the demand for electric two-wheelers is increasing. Thus they feel that public legitimacy for the EVs will be easier to achieve.

The research also revealed that people are keener to have a PHEV than a BEV and the numbers rise when quick charging is available. The population has no doubt that EVs brings environmental benefits and they feel that they will not hesitate to leave ICEs and acquire PHEVs.

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Ernst & Young in 2010 have carried out a survey which shows that in the whole US about 75% consider access to charging stations, price and battery driving range as factors that make them hesitant to buy a PEV. Nevertheless 90% see fuel saving is a favourable factor in the purchase decision.

3.6. Resource mobilization

The automobile industry has access to very extensive resources. Due to the position of the car in modern culture, many people choose to study and take up careers in the industry. Its maturity in the basic technologies has led to the development of an extensive research and education infrastructure. Resources subsume human capital, financial capital and other necessary assets such as infrastructure and complementary products and services, which all seem to be possible to obtain for developing wider market uptake of EVs.

The relevance of resource mobilization is directly connected with the intensity of entrepreneurial activity. When EV projects involve industry partners/automakers, much more financial resources can be mobilized but their financial power can be accompanied by strong interests that might diverge from other project partners.

The market for mobilizing further assets like infrastructure does not appear to be a bottleneck of EV deployment. The market for charging stations steering software and further complementary products is much better developed than the market for EV itself. As long as financial resources are available the necessary assets are available as well.

In what concerns the possibility of charging batteries, from the assessed information that is not a relevant issue because recharging places are available and, if wanted, can be easily acquired to be used at home.

3.7. Development of positive externalities

Research on electromobility has "positive externalities" because there are "spill over" benefits on external parties that are not accounted for in the market". As economic theory suggests under the condition of a positive externality, suppliers and manufacturers will likely under-invest in innovative initiatives to offer BEVs because they are undercompensated for their efforts. Indeed, they will incur in the costs to produce the innovations but some of the benefits will be enjoyed by other entities, since the information from innovation is readily used or adopted by others. This issue needs to be recognised when looking to overall industry R&D efforts in the field of electromobility.

An example of a positive externality arises as the net value of a BEV grows with increased commercialization, also known as a "network effect." This occurs via direct and indirect positive externalities. The BEV market has a network externality because BEVs require a recharging infrastructure. Public charging networks, based on a combination of slow charging and/or fast charging, that are at the same time included into value propositions around home charging or office charging networks can together possibly provide a powerful lock in effect as well as a complementary system. These networks together could create positive externalities and on the other hand also increase the switching costs to other suppliers.

Additional purchases of BEVs give rise to more accompanying infrastructure, which in turn increases the net value of a BEV by improving the availability, performance, and affordability of such infrastructure. The indirect effect occurs as increases in the number of BEVs sold

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presumably leads to increased production, thereby lowering the unit price of BEVs. This effect is premised on the assumption that economies of scale in the PEV supply chain lower unit production costs. Economies of scale have been documented repeatedly in the manufacturing sector, especially at relatively low production volumes. Under these circumstances, firms have an incentive to "free ride" on the efforts of their competitors to attract demand for an innovative vehicle. The inevitability of some network externalities suggests a role for public policy in the early stages of BEV commercialization when infrastructure development is incipient, production volume is low, and unit production costs are highest. This function stresses the systemic nature of a TIS. Experimentation can create legitimation, legitimation helps market formation, and knowledge diffusion might mobilize the resource human capital. The utilization of positive externalities can have different forms, e.g. pooled labour markets, an institutionalized flow of information or the division of specialization labour. Two specific issues that need to be addressed are project authorisation and financing. Permitting and cross-border cooperation must become more efficient and transparent to increase public acceptance and speed up delivery.

The electrification of vehicles is providing a response to numerous challenges facing society and the economy. Two of the aspects of this multidimensional or multifaceted challenge are related to the reduction of negative externalities offered by electric vehicles replacing internal combustion vehicles, while another two are related to the benefit entailed by introducing electric vehicles integrated within the electricity system from renewable energy sources and intelligent electricity supplies, known as 'smart grids', and a further two respond to challenges of a political and industrial nature.

In spite of the growing number of opportunities and positive externalities entailed by the incorporation of green vehicles as a solution for future mobility, the number of challenges to overcome is also high, as is the number of players that must align their interests for this multifaceted challenge to be a success. Financial solutions must be found to meet investment needs– estimated at about one trillion euros for the coming decade of which half will be needed for energy networks alone. Regulated tariffs and congestion charges will have to pay the bulk of these grid investments. However, under the current regulatory framework, all necessary investments will not take place or not as quickly as needed, notably due to the non-commercial positive externalities or the regional or European value-added of some projects, whose direct benefits at national or local level is limited. The slowdown in investment in infrastructure has been further compounded by the recession.

Step 4: assessing the functionality of the TIS and setting process goals

EVs are coming! – That is the belief of most people who has been involved in the development of this topic. However they have not totally arrived due to several hindrances identified throughout this case study. The Table 3 below shows where the most relevant challenges persist.

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Table 3: Assessment of electromobility development across the seven innovation funtions

Function	Assessment
Knowledge development and diffusion	☺
Influence on the direction of search	☺
Entrepreneurial experimentation	😐
Market formation	☹
Legitimation	☹
Resource mobilisation	☺
Development of positive externalities	☺

The perception from the TIS analysis is that the issues of creating the knowledge, direction of search and resource mobilization are not the major barriers to increased market uptake of EVs. Although difficulties persist (for example concerning standardisation or batteries technologies) the most relevant problems occur at entrepreneurial experimentation, market formation and legitimation.

For entrepreneurial experimentation difficulties arise mostly due to the fact the experimentation of EVs require combined efforts between several entities, which normally include policy makers. This suggests that the issues of intellectual property are more difficult to settle (as several entities are involved) and there is high political risk involving investment in this field.

Similarly political risks are relevant in what concerns the market formation. Due to limitations in the technology side EVs are currently present in small niche markets. For those markets it has been possible to find several policy makers that are ready to provide meaningful market creation support mechanisms, notably by reducing taxes or subsidizing electric vehicle acquisitions. However, questions whether such willingness to support EVs will remain when they cover wider markers are increasingly important, as wider market share would necessarily imply that such subsidies and tax cuts would have higher impacts on public accounts. To put it in a simple way: it is easy to find a government willing to subsidy a few thousand vehicles and/or to exempt a short share of the vehicle/fuels market; however is there any government which is willing to exempt a large share of vehicles from acquisition

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taxes? And how will governments finance road infrastructure maintenance of construction if EVs became dominant and fuel taxes go down? These questions might not appear in EVs leaflets and exhibitions but certainly concern both policy makers and industry.

Within the market formation it is also worth noting that results for the base scenario clearly show a growing potential for market diffusion for both PHEV and BEV until 2030. Nevertheless additional policy measures are needed to reduce the actual economic drawbacks of EVs – which suggests why political risks are an important issue. These measures may consider the important differences between private and company cars to promote electric mobility equally towards all actors. However there are some relevant interventions at the city level, company and private level that are remaining in the grey area that that needs further clarification (as mentioned in the previous chapters).

Finally legitimation is also an important issue. Most consumers expect a car to be reliable, easy to use and to last for many years. As a result, for EVs to gain increased market share they need to convince consumers about their reliability and user-friendliness, which is only possible with large scale experimentation projects. Such projects differ from demonstration projects in the sense that experimentation goes beyond driving an EV for a few minutes. If consumers are to buy such vehicles they will need to be comfortable with issues such as charging procedures and have guarantees the vehicles are reliable for their needs, which imply experimenting the vehicle for longer periods of time (a few days/a week).

Step 5: identify inducement and blocking mechanisms

In fact the battery constitutes the highest hurdle for electric vehicles which technology still needs further important developments. Therefore three main questions can be posed: Will the price of batteries go down? Will the energy density of batteries increase? And will a high battery price and low energy density prevent a wide dissemination of EVs?

But before going into these questions some relevant facts have to be addressed, in principle all the elements of an electric vehicle are highly mature industrial products, but not so for the battery, which both converts and stores energy. Thus it has to accomplish with several requirements that have not featured prominently in previous areas of application, such as:

- <u>Safety</u>; due to the lithium-ion batteries currently in use. The metallic lithium ignites when it comes into contact with air and when it exceeds its melting point and cannot be extinguished with water or other foam. There is a high risk that one or more of these events may happen during a traffic accident. In such an event it has to be guaranteed that the entire auto electrical system is discharged instantaneously (high voltage intrinsic safety).
- <u>Runtime</u>; the battery is by far the most expensive part of the electric vehicle, its service life determines the potential length of time the vehicle can be used. A battery should be able to receive approximately 2000 to 3000 charge processes which may correspond to about 300.000km.
- <u>Battery system</u> for an electric vehicle must provide far more power, voltage and energy than necessary in consumer electronics. Consequently the integrated control electronics and the battery thermal management requires must be constructed accordingly.
- <u>Temperature resistance</u>: A lithium ion battery operates optimally at around 35º C. Ambient temperatures below freezing point cause a drastic fall off in performance, and in temperatures above 45ºC the battery ages rapidly. Comprehensively thermal

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management is necessary to keep the battery pack within an optimal temperature range.

In what concerns the price of batteries the U.S. Department of Energy (DOE) expects battery costs to drop by half, by 2015 some batteries even by 70% (U.S. Department of Energy, 2010a, p. 6). While also Deutsche Bank has published similar figures (Deutsche Bank, 2010), some estimates are less optimistic. The energy density of batteries is magnitudes lower than that of carbon fuels. This restricts the range of EVs and increases the weight of the vehicles. Therefore, increasing the energy density is a central research focus. For decades lead-acid (PbA) or nickel metal hydride (NiMH) batteries with their energy densities of about 35 Wh/kg and 65 Wh/kg were the batteries of choice (Chan, 2002, p. 267). The state of the art lithium-ion (Li-Ion) batteries that are used in today's EVs reach an energy density of up to 130 Wh/kg (Tesla Motors, 2010). The energy density of petroleum is 12400 Wh/kg (Chan, 2002, p. 268). Assuming that an electric motor has an efficiency of about 90% and a combustion engine an efficiency of less than 20%, the propulsion energy in one kg Li-Ion battery would be "just" twenty times less than in one kg petroleum. Radically new battery types have the potential to further increase the energy density. One candidate is the lithium-air battery. But this technology is still very immature and it is not likely that it will be introduced to the market within the next 20 years (Rahim, 2010).

As long as the energy density of batteries is significantly lower than the energy density of petroleum debates about the range of EVs will remain. It is far from clear what will happen in the coming decade if there is no new breakthrough in battery technology and the costs of batteries do not drop as much as hoped for. Many important influence factors, such as the oil price, carbon pricing or the development of charging infrastructure, are difficult to foresee.

Besides the batteries two other bottlenecks are being posed to EVs and which are related with safety matters they are the low noise of electric motors and the vehicle weight.

A report of the U.S. National Highway Traffic Safety Administration supports this view by presenting empirical evidence for the higher accident rate of HEVs with pedestrians and bicyclists (NHTSA, 2009, p. 19). However it has to be dully balanced the weight of each aspect. If on the one hand the hazard regarding the low noise emission exists, on the other hand, EVs reduce the air pollutants emission that also has negative health impacts. Furthermore, the "problem" of too quiet EVs appears only at low speeds. At higher speed tire and aerodynamic noise give notice of approaching EVs. Several automakers address the problem of the quietness of EVs at low speeds by adding automatic sound generators (e.g. Nissan, 2010a).

The second safety aspect of EVs is the additional weight of the batteries. These are usually positioned under the floor pan which lowers the centre of gravity of EVs and therewith improves their road holding (see Commuter Cars, n.d.). Because of the higher total weight of EVs they have a longer breaking distance. On the other hand, additional weight brings a safety benefit in accidents since the heavier a car is, the smaller is the change in momentum if it is hit by another vehicle (National Research Council, 2002, p. 71).

In what concerns inducement mechanisms the availability of a wide public charging infrastructure seems to be key, alongside with large scale experimentation projects. On the infrastructure side this needs to be analysed independently from the batteries development: even in case batteries increase their capacity a wide network of charging stations will always

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be key to overcome 'range anxiety'. Regarding the issue of experimentation projects this was addressed above. EVs are a new technology and since buying a vehicle is a long-term financial intensive decision consumers need to be very confident the technology will meet their needs. This can't be achieved with demonstration projects, in which people only ride a car for a few minutes, as people need to be sure that the technology meets their daily/weekly needs (as a minimum).

Step 6: Specify key policy issues

It has been demonstrated that electromobility is still far from being economically viable for mass market, but that in the long term it does offer considerable potential. Governments in many countries and cities can be seen offering support, by proving subsidies and incentives for EVs or with a range of different measures (charging infrastructure construction, tax and fees exemptions, dedicated parking places, etc).

It is interesting to verify that a niche product like batteries for electrical vehicles which does not look like becoming economically competitive at any time in the foreseeable future, and causes high CO2 avoidance costs, should enjoy such prominent political backing and not only in countries with an automotive industry of their own. Such early commitment to promoting a specific technology harbours particularly high (financial) risks for government when no end-date is set for phasing out this support. It is, moreover, the precise opposite of a technologically open-mind state subsidisation policy, because it potentially blocks the way for any better storage technology (such as hydrogen). In principal a critical view can be taken of state support for electromobility in view of the static efficiency of the technology, but this does not alter the fact that it is political reality.

The overriding motives behind the promotion of this technology presumably lie chiefly in the fact that global oil reserves are finite and policy makers wish to embark in good time on transition to the "post oil era" to avoid sudden economic friction. They also hope to make their contribution to combating climate change, even though there are cheaper ways of reducing carbon emissions. With confidence in technological progress (dynamic efficiency), a case could then be made for subsidising what is not yet a competitive technology.

The motives behind political backing vary greatly from one country to another. In nations whose automotive industries are important as jobs providers, support for domestic industry undoubtedly comes into play, even though companies in the various countries have made varying degrees of headway on the development of EVs. When all other automotive nations are promoting the technology, considerations of a level playing field make it difficult for politicians to justify their country being the only one not to join in the "subsidy race".

It is foreseen that electromobility policy can be a prime mover in economies such as China, US, France or Germany, the reasons for this are diverse but one motive is transversal which is related with the plans to promote the technology, and hence local industry. One other motive for encouraging electromobility is the possibility of lowering local noise and pollutant emissions. The carbon reduction argument has particular weight in countries that the technology plays a relevant role even though they do not have their own automotive industry (e.g.: The Netherlands, Denmark, Portugal).

As previously mentioned, support given by governments may be supporting the electromobility through monetary and non-monetary means.

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Among the classic non-monetary incentives to end users to encourage electromobility are privileges for electric vehicles in road traffic (e.g.: the use of bus lanes and special designated parking spaces). From a regulative point of view these kinds of measures are easy; preferential treatment vis-à-vis vehicles with combustion engines can be justified by lower local pollutant and noise emissions. Whilst legal and technical prerequisites must be put in place for this, it should be possible to do so even within a short time frame. Of course this type of privilege will reach its logistical limits as the number of electric vehicles increases, making it likely that its effect will wane in the long run. Privileges for electric vehicles could of course be beefed up by road user charges or even driving bans on conventional passenger vehicles in certain parts of town (e.g.: city centre tolls), which admittedly have a monetary flavour. In the short medium term we consider wide scale regulations of this kind neither appropriate nor political enforceable.

The monetary measures to encourage electromobility comprise the direct subsidisation of car purchases and indirect financial incentives. Additionally, tax amendments could re-weight relative prices in favour of electromobility. Raising the duty on petrol and diesel and simultaneously lowering electricity tax or the levy on renewable energies for users of electric cars, would give electric vehicles an even greater variable cost edge.

In fact the main political goal is to bring as many electric cars as possible to market, then state premiums to buyers are extremely effective. But these are a number of reasons for taking a very critical view of monetary incentives. They represent market intervention in favour of specific technology for which policy makers presently have no way of knowing when it will be able to hold its own in the market without government support. It is true that generous subsidies will help a technology to achieve breakthrough in a narrowly defined market but at the same time there is danger of other options that would be more economical and /or environmental better in long run not getting off the ground.

Nonetheless as it is recognised, subsidies establish perceived “vested rights” that are then always difficult to remove again. But The Commission will make €24.2 million available to partly finance of a cross-European electromobility initiative, such as Green eMotion.

This project brings together 42 partners and its objective is to exchange and develop know-how and experience in selected regions within Europe as well as facilitate the market roll-out of electric vehicles in Europe. Vice-President Siim Kallas, responsible for transport, said: "Transport is current 96% dependent on oil for its energy needs. This is totally unsustainable. The Transport 2050 Roadmap aims to break transport's current oil dependency and allow mobility to grow. We can and we must do both. It can be win-win. But there are major challenges. Transport 2050 calls for a reduction of CO^2 from transport of at least 60% by 2050. At the heart of this strategy is a major shift in cities to the electric vehicles away from cars with conventionally fuelled engines. The level of EU financial support for this e-motion project shows just how serious we are at EU level about achieving these goals. This is a project tackles some of the practical problems and real bottlenecks for cities and companies who want to bring electric vehicles to the market. It is exactly the kind of initiative where European co-operation adds huge value. This is a very promising initiative for the future."

Transport 2050 aims to half the number of conventionally fuelled cars in cities by 2030 and phase them out by 2050.

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2.2 Biofuels for surface transport

Title	**Biofuels for surface transport**
Mode	rail ☒, road ☒, air ☐, maritime ☒, inland waterways ☒, intermodal ☐
Partner	CLEPA

Transport fuel supply today, in particular to the road sector, is dominated by oil, which has proven reserves that are expected to last around 40 more years. The combustion of mineral oil derived fuels gives rise to the CO2 emissions and total CO2 emissions from transport have increased by 24% from 1990 till 2008 (despite the fact that the fuel efficiency of new vehicles has been improving, so that these emit significantly less CO2).

The EU objective is an overall reduction of CO2 emissions of 80-95% by the year 2050 compared to the level of 1990.

In order to achieve this level of reduction a number of alternative fuel options are available today:

- Electric/hydrogen where the electric power is used to directly propel the vehicle;
- Methane from natural gas;
- LPG (liquefied petroleum gas);
- Biofuels (liquids) and synthetic (liquids) fuels based on biomass (including biomethane).

In principle all combinations of the fuels or fuel systems mentioned above are possible to combine and then we arrive at the large family of hybrid vehicles, where the most common variants are electric (power from batteries) motors in combination with some kind of combustion engine.

The electrically driven vehicles can receive the electricity from batteries, fuel cells or overhead lines/third rail. The first variant is the one most widely used today and fuel cell technologies are still at the experimental level, but feeding electrical power into vehicles by lines/rails is widely used today in trains, metro or trolley-buses.

The gas driven vehicles can use methane derived from natural gas or LPG, depending on the technology used in their engines. Both these sources of fuel are however almost as limited, in a long time perspective, as the petroleum based liquid fuels widely used today. They do however emit considerably less CO2 and can therefore be used in order to reduce the GHG (Green House Gases) in the atmosphere.

The biofuels and the synthetic fuels derived from biomass can be used as substitutes for almost all fuels mentioned above, with the exception of electricity. Minor changes in the internal mechanisms of the combustion engines might be needed, but these can easily be introduced in newly manufactured vehicles.

The use of biofuels and synthetic fuels derived from biomass can be divided into three different categories:

- First generation biofuels, where the liquid fuel is derived from crops, animal fats etc.
- Second generation biofuels, where the liquid fuel is derived from wastes and residues

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- Synthetic fuels produced from different feedstock converting biomass to liquid (BTL) or producing Di-Methyl-Ether (DME) directly from biomass

The different transport modes require different options of alternative fuels:

- Road transport can be powered by all the variants mentioned above
- Rail transport is preferably powered by electricity or otherwise by biofuels
- Air transport should be supplied from biomass derived kerosene
- Waterborne transport can utilize all the energy sources mentioned above and also in addition nuclear power for certain applications

Step 1: the starting point of analysis: defining the TIS in focus

The case study on the potential impact and consequences related to an increased use of liquid biofuels as replacement for fossil fuels, is covering all aspects of technological developments and other factors of significant importance such as the changes in land use and the political (sometimes purely philosophical) considerations that are involved.

In view of the huge potential impact in a medium frame (10 to 30 years) time perspective, the following case study has been narrowed down to cover the possibilities that can be found in the extended use of liquid biofuels and liquid synthetic fuels derived from biomass.

The potential of biofuels production from both traditional crops and energy crops is determined by the available area of land. The production of second generation biofuels from wastes and residues is limited by the availability of these materials.

The extent of greenhouse gas emissions saving with biofuels depend on the biofuels pathway. According to Directives 2009/28/EC and 2009/30/EC the CO2 saved from the use of biofuels must be at least 35% of that produced from using fossil fuels. This however does not include the impact of indirect land use change, which has to be addressed according to the legislative mandates in the directives.

An overview of the most common kinds of liquid biofuels is given in the annexed fact sheets on: DME, Ethanol, Liquid synthetic hydrocarbons, FAME (Fatty Acid Methyl Esters) and Methanol.

Step 2: Identifying the structural components of the TIS

2.1 Actors

The array of actors taking part in the analysed technological innovation system related to the research, development, innovation (R, D&I) and the production and use of biofuels is indeed much diversified. The most important actors are with short descriptions listed below, but it must be kept in mind that there are a number of others, that can justify a position in this overview. In order to maintain the possibility to use this document in order to get exactly an overview, the amount of actors described has been intentionally limited.

- The European Automobile Manufacturers Association (ACEA), founded in 1991, represents the interests of the eighteen European car, truck and bus manufacturers at EU level. Its membership consists of the major international automobile companies, working together in an active association to ensure effective communication and negotiation with legislative, commercial, technical, consumer, environmental and other interests. The members of ACEA are competitors in the

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automobile market place and support free and fair competition as a trade policy and a legal concept. ACEA is an Economic Interest Grouping. Its headquarters are based in Brussels and made up of the Secretary General and the Secretariat. In 1995 and 2004, ACEA opened additional offices in Tokyo and Beijing. ACEA has founded a separate entity named EUCAR, which is specifically responsible for questions regarding Research, Development and Innovation (R,D&I) within the activities of the Original Equipment Manufacturers (OEMs), belonging to ACEA.

- The European Association of Automotive Suppliers (CLEPA), founded in 1909, represents CLEPA represents the official voice for the automotive supplier industry and its aim is to further strengthen the position and promote the common interests of one of the most strategic industries in the European and global economy. The over 3000 member companies of CLEPA play a central role in adapting the automotive industry to the sweeping changes brought on by the double processes of globalization and technological development. Automotive suppliers account for about 75% of the vehicle industry's final product value and are responsible for about 50% of the research and development in the sector. The CLEPA mission is to defend and to make the most of this endowment of innovative skills and industrial achievements by initiating activities, which stimulate the successful business growth and development of its members and by rising debate on those topics, which directly impact the future of the automotive industry in general and of the supply chain in particular. CLEPA acts as information network and as the principal negotiation platform between suppliers and institutions. Building on more than 50 years of experience and activity, CLEPA is now recognized as the natural discussion partner on all issues regarding the automotive supply industry by the European Institutions and the United Nations. Within UNECE, CLEPA received formal mandate from MEMA (USA) and JAPIA (Japan) to represent the worldwide suppliers. CLEPA also facilitates constructive dialogue with all relevant parties including vehicle manufacturers (ACEA, JAMA, etc.) and fellow associations in the relevant automotive world markets both in the field of Original Equipment and of the Aftermarket.
- Founded in 2002, European Automotive Research Partners Association (EARPA) is the association of automotive R&D organizations. It brings together the most prominent independent R&D providers in the automotive sector throughout Europe. Its membership counts at present 39 members ranging from large and small commercial organizations to national institutes and universities. EARPA, as the platform of automotive researchers, aims at actively contributing to the European Research Area and the future EU Framework Programmes. In this task, EARPA seeks a close cooperation with the automotive industry, the automotive suppliers, the oil industry as well as the European Institutions and the EU Member States.
- The Community of European Railway and Infrastructure Companies (CER) is the leading European railway organisation. It was founded in 1988 with 12 members and now brings together 77 railway undertakings and infrastructure companies – private and state-owned, large and small. The members come from the European Union, the candidate countries (Croatia, Macedonia and Turkey) as well as from the Western Balkan countries, Norway, and Switzerland. CER is based in Brussels and represents the interests of its members to the European Parliament, Commission and Council of Ministers as well as to other policymakers and transport actors. CER's main focus is to promote a strong rail industry that is essential to the creation of a sustainable transport system which is efficient, effective and environmentally sound.

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- Community of European Shipyards Associations CESA represents the shipbuilding industry from 17 Member States (Belgium, Bulgaria, Croatia, Denmark, Finland, France, Germany, Greece, Italy, Lithuania, The Netherlands, Norway, Poland, Portugal, Romania, Spain and United Kingdom).CESA has a long tradition as representative organization and could look back proudly to decades of fruitful cooperation and constructive dialogue. Starting in 1937 as "International Shipbuilding Conference", it was re-established after the war as "West European Shipbuilders Informal Contacts" and renamed in 1965 to "Association of West European Shipbuilders", AWES. In the 1980ies, AWES established an EC-linking committee, which later on, mainly for administrative reasons, became a separate sister organization under the name of CESA. In 2004, AWES and CESA decided to go back to the initial one-organization structure - the COMMUNITY OF EUROPEAN SHIPYARDS' ASSOCIATIONS or, CESA, which had become a well-established trademark in the maritime world as well as in the predominant field of EC related activities.
- The European Biodiesel Board (EBB), is a nonprofit organization established in January 19997. EBB aims to promote the use of biodiesel in the European Union, at the same time, grouping the major EU biodiesel producers. EBB has the goal to represents its members to the institutions of the European Union and other international organisations, promotes scientific, technological, economic, legal and research activities, collect, analyse and disseminate information, study problems confronted by the biodiesel industry and suggest solutions at economic, political, legal, institutional and technical levels.
- Formed by the merger of UEPA (European Union of Ethanol Producers) and eBIO (European Bioethanol Fuel Association), ePURE represents and supports companies that produce renewable ethanol in the EU for all end-uses, i.e. fuel, potable and industrial uses. ePURE also represents companies that have an interest in ethanol production. The creation of ePURE consolidates the ethanol industry's representation and activities in Brussels and beyond. Currently, ePURE's membership accounts for 80% of the installed renewable ethanol production capacity in Europe.
- Joint Research Centers (JRC) were originally established in 1957. This is the year when the two treaties of Rome were sanctioned: one to establish the European Economic Community (EEC) and one to establish the European Atomic Energy Community (Euratom). The Joint Research Centre was originally established under the Euratom treaty. Euratom’s role is to promote nuclear safety and security in Europe and the JRC has been contributing to this aim with its research activities ever since. The JRC has, however, at the request of its customers, expanded to also embrace other fields important to policy making, such as life sciences, energy, security and consumer protection. It has transformed itself from a purely research-driven organization focusing on nuclear energy to a customer-driven, research-based policy support organization. Today, the JRC is deeply embedded in the European Research Area and the EU legislative process.

The actors mentioned above are represented in Figure 8, mainly under the headings: Industrial System and Innovation Infrastructure.

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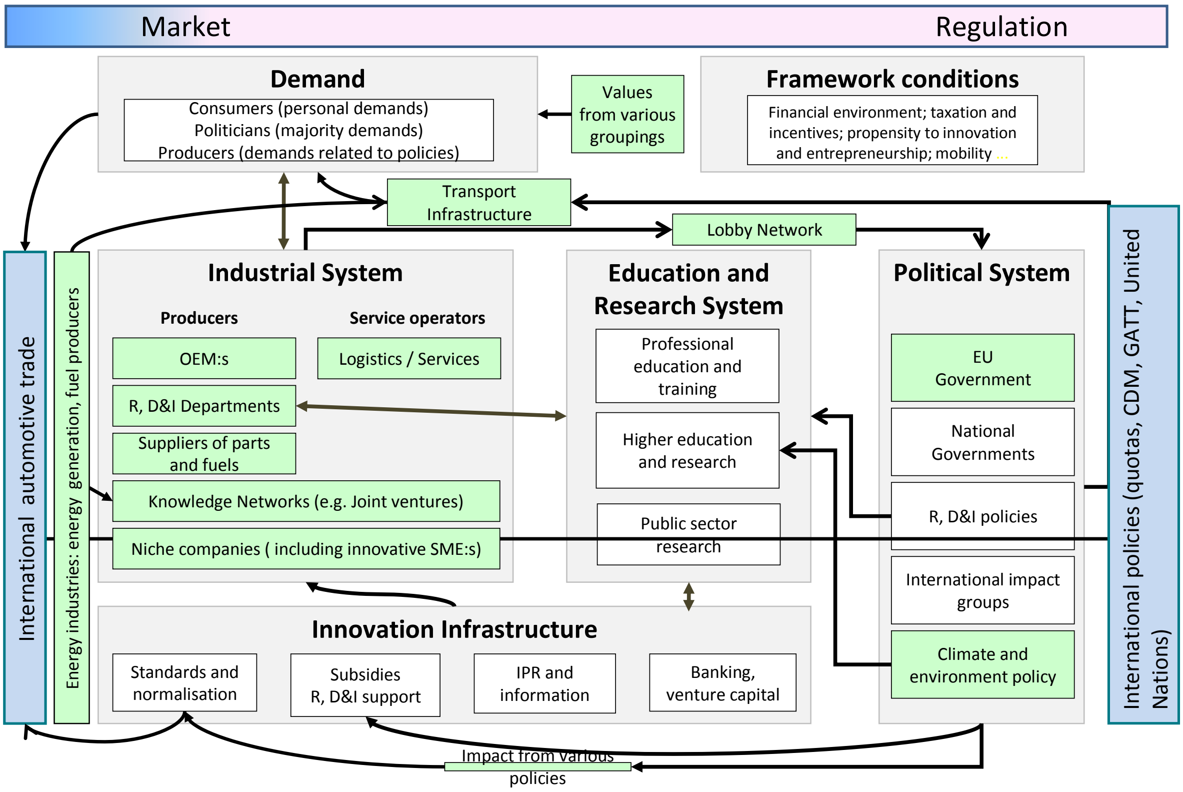
Figure 8: Innovation leading to the production and use of liquid biofuels



2.2 Networks

A number of different networks are active in the area of production and use of biofuels. They are represented in Figure 8 with different headings, but a more detailed description is given here. Just as in the case of actors (see. 2.1), the array of networks is much diversified. The most important networks are with short descriptions listed below, but it must be kept in mind that there are a number of others, that can justify a position in this overview. In order to maintain the possibility to use this document in order to get exactly an overview, the amount of networks described has been intentionally limited. The most influential networks in this area are the European Technology Platforms (ETPs).

- The European Research Transport Research Advisory Council (ERTRAC) is the European Technology Platform (ETP) for Road Transport, recognized and supported by the European Commission.
  ERTRAC has more than 50 members, representing all the actors of the Road Transport System: transport industry, European associations, EU Member States, local authorities, European Commission services, etc. ERTRAC is working on an ambitious program intended to: i) Provide a strategic vision for the Road Transport sector with respect to Research and Development, ii) Define strategies and roadmaps to achieve this vision through the formulation and maintenance of a Strategic Research Agenda (SRA) and Implementation Roadmaps, iii) Stimulate effective

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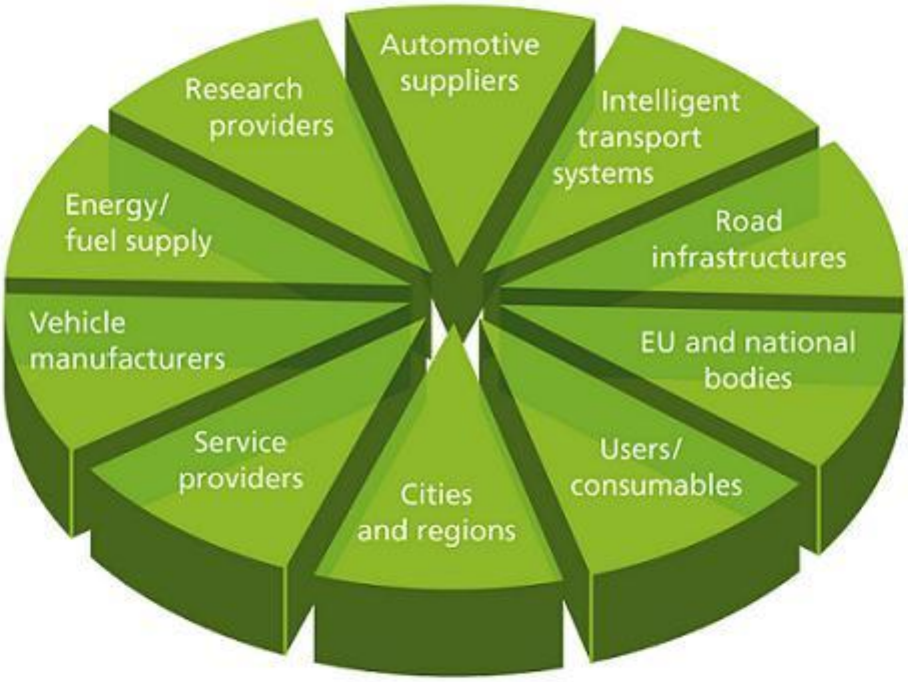
public and private investment in Road Transport Research and Development, iv) Contribute to improving coordination between the European, national, regional public and private R&D activities on Road Transport, v) Enhance the networking and clustering of Europe's Research and Development capacities and, vi) Promote European commitment to Research and technological development, ensuring that Europe remains an attractive region for researchers and, and enhancing the global competitiveness of the transport industries. The members of ERTRAC represent the sectors illustrated below:



- The European Rail Research Advisory Council (ERRAC) was set up in 2001 with the ambitious goal of creating a single European body with both the competence and capability to help revitalize the European rail sector and make it more competitive, by fostering increased innovation and guiding research efforts at European level. Within ERRAC, all major rail stakeholders are gathered. ERRAC comprises of 45 representatives from each of the major European rail research stakeholders: manufacturers, operators, infrastructure managers, the European Commission, EU Member States, academics and users' groups. ERRAC covers all forms of rail transport: from conventional, high speed and freight applications to urban and regional services. Since its start in 2001, ERRAC has produced a number of important and influential documents, such as the Joint Strategy for European rail Research – Vision 2020, the SRRA – Strategic Rail Research Agenda and its 2007 updated version, Suburban and Regional Railways Landscape in Europe, Light Rail and Metro Systems in Europe, Rail Research in Europe, a comparison of the Member States public research programmes with the ERRAC SRRA and others that you can find on the ERRAC web site as well. At present ERRAC carries out a 3 year rail research road mapping project called ERRAC ROADMAP.

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- WATERBORNE TP is an initiative that came forth from the Maritime Industries Forum (MIF) and its R&D committee in 2005 and is making strident efforts to regularly update R&D requirements for European competitiveness, innovation and the meeting of regulations like safety and environment. The stakeholders include EU associations covering deep and short sea shipping, inland waterways, yards, equipment manufacturers, marine leisure industry, research and university institutions, classification societies etc. The so-called stakeholder Support Group is matched by a Mirror Group of government appointed delegates. The WATERBORNE TP is one of the some 30 technology platforms in the EU and where appropriate possibilities for exchanges or other ways of cooperation are investigated. The WATERBORNE published a VISION 2020 paper in 2005, a Strategic Research Agenda in 2006 and an Implementation Plan in 2007. The contents are been used by industry sectors, national R&D programs and not in the last place by the European Commission for defining the outline of and calls under the R&D Framework Programs.
- The European Biofuels Technology Platform (EBTP) is dedicated to contribute to the development of cost-competitive, world-class biofuels technologies, to the creation of a healthy biofuels industry and to accelerate the deployment of sustainable biofuels in the European Union through a process of guidance, prioritization and promotion of research, technology development and industrial demonstration. The EBTP continues to work closely with the European Commission, and has drafted a policy toolkit outlining the measures that are needed to promote the large-scale deployment of advanced sustainable biofuels. The Working Groups of the EBTP will continue to support these initiatives through complementary activities on cost data, sustainability issues, feedstock availability, etc. To provide the wider public with basic information on biofuels technologies and innovative processes being developed, five biofuels fact sheets (see annex of this document) have been drafted.

2.3 Institutions

The general denomination "Institutions" covers a very wide array of political, legal, trade and lobbying organisations. Just as under 2.1 and 2.2 (see above) the picture of relevant institutions is much diversified. The most important institutions are with short descriptions listed below, but it must be kept in mind that there are a number of others, that can justify a position in this overview. In order to maintain the possibility to use this document in order to get exactly an overview, the amount of institutions described has been intentionally limited. The definition given by North (1994) indicates that a study should be concentrated on the constraints, codes of conduct etc. and the enforcement of these structural components, but not focus on the organisations performing this enforcement. In Figure 8, the structure is more directed into indentifying the organisations and groupings, that are responsible for and initiators of these constraints, codes of conduct etc. In the following the latter approach has been mainly used.

- The political constraints regarding the increased use of biofuels for surface transport mainly originates in the political system (see Figure 8). Here a number of important players like the EU Government, the Governments of the member states, the international lobbying and impact groups, can be identified. There are however also several global players influencing the political constraints on the innovation, production and distribution of liquid biofuels like: The United Nations (ultimately through their UN/ECE WP29, responsible for global automotive technical regulations)

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and also the global organisations involved in organizing the impacts from trade unions and employers as well as the various, very powerful global media groups.

- The second category of institutions that influence the constraints and codes of conduct etc. are the organisations involved in the research system. There are many of these directly connected with the actors described under 2.1, but there are also a number (JRC for example) related to players operating under the Political System. This category of institutions are in most cases responsible for the technical possible innovations in the area of liquid biofuels, but they are under constant pressure from the players under the Political System to work in areas of R, D&I, that are politically accepted by the other institutions, because most of the funding for their work is coming from these sources.

Step 3: mapping the functional pattern of the TIS

In this step of the analysis the functional pattern of the technological innovation system is described. The functional parameters shown in Figure 1 are described:

3.1. Knowledge development and diffusion

As mentioned under 2.3, the initiatives for creating new knowledge (through research) about liquid biofuels would normally come from research, development and innovation (R, D&I) policies of the political institutions and also from the corresponding industrial departments. In addition the Education and Research system through its module Higher Education and Research would provide input for the technological possibilities in this area.

This would then normally lead to an evaluation of the technological possibilities and the industrial system and the political system would then start the needed innovation cycle for creating an optimum in the area of liquid biofuels for land transport.

Liquid biofuels do definitely have the potential to limit GHG emission in the land transport sector as long as they all meet the existing sustainability criteria. Higher grades of mixture with fossile liquid fuels might be needed to fulfil the climate and energy targets. Advanced biofuels offer additional benefits and coupling the production of these fuels with Carbon Capture and Storage (CCS) could eventually lead to a net reduction in atmospheric CO2. No significant change in consumer behaviour is needed (driving range, refuelling habits, look and feel of the car).

The description of influence from the market and the political system that partly manipulates and distorts the normal development cycle partly described above is further elaborated in the following parts of this chapter.

3.2. Influence on the direction of search

As described under 3.1 the more normal development cycle of new technologies involving a start-up through basic research followed by applied research, development and thereafter industrialisation through innovation can only be partly recognised in the area of liquid biofuels for land transport.

Like all other fuels biofuels need to meet the sustainability criteria as established in various pieces of legislation as for example EU legislation in force (see Step 1 of this case study), including those biofuels present in the market and future advanced types that might be developed.

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This is in itself a strong influence on the areas to be researched, because it will only lead to positive results if the existing legislation is well adapted to the existing knowledge about total emissions. This can be observed in the present focus, in existing legislation, on the GHG emission, where a more balanced approach involving other dangerous emissions like for example particle emissions, would be preferable.

In addition to the influence described above, the Political System has other measures for influencing these activities. A considerable part of the funding for R, D&I efforts is provided by EU (mainly through various DGs of the EU Commission) and also by the National Governments of the EU member states. This support is of course in itself not a bad way to go, but it requires an extremely good knowledge of the state of the art and future developments in this area.

The influence from various lobbying groups and individual politicians and consumer organisations is also considerable and provides in most cases guidance for the actors inside the political system that are responsible for the legislative measures and funding programs mentioned above. A broad discussion has been taking place on the Indirect impact of Land Use Change (ILUC) with a wide spectrum of contributions put forward within various initiatives. The basic idea that a number of people, mainly in the developing countries, will lack nutrition, because the available land is used for growing crops to be used for driving cars in the developed countries, could be regarded as a reason for grave disagreements, maybe even future national and international unrest (read potential reason for revolutions). This issue should have been addressed within the framework related to the EU directive of the Renewable Energy Directive and the Fuel Quality Directive, but will be addressed in an upcoming legislative proposal to the Council and the Parliament. This issue must be settled before moving to a broad market introduction of higher blend liquid biofuels for land transport.

The present existing and pending legislation, like the EU setting CO2 emission limits and for example the California Zero Emission Vehicle (ZEV) regulations is putting a lot of pressure on the OEMs to introduce rapid measures for reducing these emissions. In this area the increased use of liquid biofuels could present a stop gap measure. The reason is that, as described under 3.1, the increased use of liquid biofuels requires no major investments in distribution networks and can be used as a substitute for fossile fuels without major technical changes in the existing combustion engines. In addition liquid biofuels can be used in all land transport modes like road (light and heavy vehicles) transport, public transport, maritime and railways. The potential expansion for sustainable liquid biofuels is however limited for political reasons (see above) and in order to arrive at a maximum effect of the efforts, they should be allocated to those modes, where few other alternatives exist.

The increased use of liquid biofuels does not automatically mean a dramatic reduction of CO2 emissions (see attached annexes) since the manufacture of some of these fuels can only be performed with a considerable emission of CO2. In addition the use of these liquid biofuels emits considerable CO2, when consumed in combustion engines, but nevertheless they are in most cases more environmentally friendly compared to the use of fossile fuels.

3.3. Entrepreneurial experimentation

The area of liquid biofuels has not received a great deal of attention from the major OEMs and Automotive Suppliers. Instead the interest in experimenting in this can be traced to manufacturers of chemical substances and also to the specific manufacturers in the

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petrochemical area. The patent applications in this area have reached a stable level already in 2005 and no dramatic increases can be foreseen. The definitions of biofuels[9] show that the innovation potential for conventional biofuels technologies is relatively limited. The reason for this is that when all biofuels technologies are addressed, the ones that prove to be sustainable with regard to their social, environmental and economic impact will come out as winners. As mentioned above the biomass feed stocks needs to be addressed. A sound policy framework is needed to address the growing feed stock demand for biofuels, heat and power to and to ensure sustainability of biomass production throughout all these uses.

The uncertainty about which low carbon technology, that will be dominant in future vehicles has, for obvious reasons, hampered the level of innovation in the liquid biofuels area, but the mix of different propulsion systems, that can be foreseen in the future might improve this situation if biofuels are regarded as a stop gap measure for the OEMs, while other systems (fuel cells and batteries) will be replacing other systems at later stages.

3.4. Market formation

The market for liquid biofuels already exists and is today mainly supplied by fossile fuels being used in combustion engines. There is a neighbour market in the combustion engines driven on biogas or natural gas, but this falls outside the scope of this case study.

The normal market mechanisms based on pricing and the balance between supply and demand, are in the case of liquid biofuels for land transport, not applicable. This is partially based on the facts described in the previous parts of this chapter. The influence from the political system under pressure by the opinion of the public (consumers) leads to a very complicated market situation.

The pricing of liquid biofuels compared to the available alternatives in fossile fuels is completely offset by political initiatives involving differentiated taxation, direct R, D&I support guided by varied ambitions to use liquid biofuels either as a stop gap measure to dramatically reduce the emission of GHG in a medium time scenario, or an ambition to introduce new biofuels in a long time perspective.

[9] Conventional Biofuels Technologies include well established processes that are already producing biofuels on a commercial scale. These biofuels, commonly known as first generation, include sugar and starch based ethanol, oil crop based biodiesel and straight vegetable oil, as well as biogas derived through anaerobic digestion. Typical feed stocks used in these processes include sugarcane and sugar beet, starch bearing grains like corn and wheat, oil crops like rape, soybean and oil palm, and in some cases animal fats and used cooking oils.
Advanced biofuels technologies are conventional technologies which are still in the research and development, pilot or demonstration phase, commonly referred to as second or third generation. This category includes hydro treated vegetable oil (HVO), which is based on animal fat and plant oil, as well as biofuels based on lignocellulosic biomass, such as cellulosic ethanol, biomass to liquids (BtL) diesel and bio synthetic gas (bio-SG). The category also includes novel technologies that are mainly in the research and development and pilot stage, such as algae based biofuels and the conversion of sugar into diesel type biofuels using biological or chemical catalysts.

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The various opinions in this area have reached almost religious dimensions when it comes to advocating which way to go in order to solve the problems related to future propulsion of surface transport vehicles. This fact further decreases the influence of the normal market forces and in addition a number of local and national initiatives have been launched in the area, which partly show contradictory opinions about which technology to support and which technology that can receive public funding.

The public support is however of vital importance, when it comes to demonstration projects, which are needed to help the politicians to make the right decisions for future R, D&I efforts covering the use of liquid biofuels.

As has been stated earlier the distribution of liquid biofuels requires relatively small investments in distribution systems. Since these fuels are distributed in liquid form and in many cases are mixable with existing fossile fuels, the acceptance by the market, in this area, presents small problems compared to other future possible energy distributions for propulsion systems.

3.5. Legitimation

The increased use of biofuels for surface transport contains few elements critical to the legitimation of the new practices.

The new fuels fully comply with existing requirements for vehicle fuels for use in EU and when it comes to the fuels under development, these requirements are included in the specifications for the projects developing these fuels.

There is in addition information available both through official sources and through mass media regarding the use and distribution of these fuels and these increases the level of information and knowledge to all users.

3.6. Resource mobilization

The automotive sector has in principle access to considerable R, D&I resources. A large amount of young persons choose to study for and seek work in the automotive sector, because of the special position of the automobile in the modern culture. The technologies used in this branch of industry are in many cases forerunners in many development areas.

The industry also possesses considerable financial resources and has in many cases possibilities to access large amounts of public funding, because of the amount of employment created throughout the industrialised world through this branch.

This means that the automotive industry and all other branches connected with its activities, as for example the fuel producers, are strong in human and financial resources. This area of industry also includes the activities supporting transport as road, rail and canal constructors, maintenance operators, aftermarket products etc. Altogether, the whole area covering surface transport is a most important and dynamic factor in the modern society with possibilities for strong resource mobilisation.

3.7. Development of positive externalities

The fact that liquid biofuels for surface transport have existed for several decades and the market penetration is less than 5% today (compared to fossile fuels), indicates that the customers on the transport side have not exactly embraced this technology.

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There are several reasons for this situation and maybe the most important one is that this TIS is not competitive pricewise to the fossile fuels.

This has however been counteracted by the political system, where several (depending on where in the world this takes place) tax reductions, funding support, reduced investment costs etc. have been introduced in order to increase the use of liquid biofuels.

The minor changes that in most cases have to be introduced in the combustion engines have also added to the reluctance to start using liquid biofuels for propulsion.

During the last decade and in particular the last few years, the situation has dramatically changed and the OEMs now have to comply to regulations that cannot be fulfilled, in a medium time perspective, without increased use of liquid biofuels. This pressure put on the manufacturers have triggered the suppliers, many of them SMEs, to come up with new ideas regarding improved performance with the use of liquid biofuels.

Another factor that has released many ideas about how to streamline distribution and use of liquid biofuels is the fact that an increase in awareness about climate change can be noted, not only among politicians but also among normal consumers.

Step 4: Assessing the functionality of the TIS and setting process goals

The TIS covering the area of liquid biofuels is at present at a stage, where the first generation biofuels (see 3.3) are in limited production and limited use, mainly as additive to fossile fuels. These biofuels are in commercial production and use, but are only economically justifiable when the various national and regional incentives (tax reductions, economical support for purchase of biofuels vehicles etc.) make them compatible.

The second generation biofuels (see 3.3) are under limited development and will, with all probability if sustained funding and support mechanisms at the level required can be received, be developed into commercial products.

This could result in the fact that promising advanced biofuels (mainly generation two and three) could reach commercial production within the next 10 years if it can be proved that they have ability to reach cost and sustainability targets.

The TIS related to liquid biofuels can be compared with the competing technologies in the areas of electrical vehicles with energy supplies from batteries and fuel cells.

The TIS in the area of electrical propulsion has received considerably more funding, support and acceptance than any other comparable technology. The reason for this is partly traceable to the successful introduction of hybrid vehicles, where the electric propulsion is supported by a small combustion engine which is emitting considerable amounts of green house gases (GHG). The reason for the popularity and resulting major support for electric vehicles with battery energy storage can be traced to the fact that this technology can be regarded as a further development of the already existing hybrid vehicles. This line of developments will continue for more than 30 years and finally, with all probability, lead to the introduction of a large amount of various vehicle models mainly for road transport.

The TIS regarding electrical propulsion has also taken another path, where in principle the propulsion system is the same as for the battery electrical vehicles, but with an energy supply based on fuel cells. The fuel cell technologies are receiving even more support than

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other comparable TIS areas, but a break-through resulting in vehicles with this kind of energy supply is foreseen to appear at the earliest 20 – 30 years from now.

The main weakness of the biofuels TIS and the TIS dealing with electrical propulsion, both battery storage and fuel call storage, is that they are not fully competitive with the presently dominant propulsions systems, mainly based on fossile fuels.

This means that none of the new technologies can continue to expand without massive national and international, read through EU, economical support. The most important incentive is however today that the awareness about dangers emanating from the emission of GHG is growing rapidly and this puts strong pressure on the Political System to act. In their eagerness to act many national and international, EU for example, introduce legal measures, which are sometimes contradictory and in many case not based on scientific evidence.

The TIS covering liquid biofuels could lead to a considerable reduction of GHG emissions in a medium time perspective, if it is developed in the right direction. This would require that financial support schemes are linked to the sustainable performance of liquid biofuels, where assurance of more than a 50% reduction of GHG in a life cycle perspective can be reached.

The TIS would also lead to a measure of intensified use of wastes and residues as feedstock for production of the liquid biofuels (see 3.3).

In order to arrive at a socially acceptable production of liquid biofuels the TIS would also have to concentrate on promotion on alignment of biofuels policies with those in related sectors, such as agriculture, forestry and rural development.

It would also be necessary to adopt an overall sustainable land use management system. This system would aim at assurance that all agricultural and forestry land is comprehensively managed in a balanced manner in order to avoid negative indirect land use change.

Step 5: Identify inducement and blocking mechanisms

The customer demands for more environmentally friendly surface transport is slowly growing, but the rate of increase of public awareness in this area is still rather low. Aside from this inducement there is also an indirect inducement introduced by various national governments. This inducement is designed as various tax incentives such as lower automobile tax for selected vehicles.

The main blocking mechanism for a rapid introduction of liquid biofuels for surface transport is however the structure of the industry, mainly the automotive vehicle industry. The TIS in this area is totally dominated by the large OEMs and the technology networks attached and created by the OEMs. It must be regarded as extremely difficult for new alternative networks to be formed in this area and therefore the TIS remains fairly static. The OEMs are in addition devoting a major part of their R, D and I budgets to work in the area of conventional propulsion of motor vehicles and therefore a radical change will have to be forced on these actors.

Some signs showing possibilities for unblocking these mechanisms can however be found in the increased interest in finding new approaches to increased use of liquid biofuels for surface transport. Some evidence for these developments can for example be found in the amount of scientific articles published about this technology area during the last 19 years. In these figures the number of articles for 2012 is for natural reasons (this is written at the end

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of February, 2012) incomplete, but even a modest extrapolation indicates a total all time high for these articles during 2012.

This gives an indication that the interest for developing possible widespread technologies for the use of liquid biofuels for surface transport is increasing and changing social norms could be an important step in an effort to give the customers a more rational attitude towards the purchase and use of means for transport.

The scientific literature is however, for reasons already described, covering the competing areas of electro mobility for surface transport, with more articles than described above for the use of biofuels. This can partly be explained by the fact that funding from, for example FP7 is considerable compared to the corresponding funding for biofuels. This is a strong blocking mechanism for the TIS in question.

Another very strong blocking mechanism is the fact that the different kinds of biofuels are being promoted by different lobbying groups, interested in selling their specific products, instead of concentrating on finding the ultimate biofuels for achieving a medium perspective propulsion solution. The long time solution for propulsion of surface vehicles is with all probability to be found in electro mobility, but as a stop gap measure in order to reduce the emission of GHG, the widespread use of biofuels could have an important role to play.

It is however required that a solid scientific base for decision making is established and that all factors are taken into consideration. The uncontrolled production and use of liquid biofuels can in some cases lead to additional presence of for example CO2 in the atmosphere, because especially forests and also plants of various kinds today stores large amount of this GHG.

The most important inducement for moving in this direction is with all probability to be found in more stringent legislation, which might then make the OEMs move to one kind of liquid biofuels for medium perspective transport solutions and at the same time develop very environmentally sound solutions for long perspective electro mobility.

This requires however that the blocking mechanisms described above are removed and that concentration on one kind of medium time solution is accepted by all actors.

Step 6: Specify key policy issues

The TIS covering the liquid biofuels for surface transport is hampered by the blocking mechanisms described above and their negative impact is not matched by the inducements existing today. In order to arrive at a balanced level of use involving these biofuels a number of policies have to be introduced and a much higher level of awareness regarding the negative effects of emission of GHG has to be achieved.

In order to promote the positive effects and reduce the negative effects described under Step 5 a systematic approach describing the needed policies should be used.

Such an approach can be based on suggesting policies at various levels and then analyse the combined positive effects, which can be found in this material.

- At the top level, the policies from global actors, such as for example the United Nations should aim at massive activities in order to raise awareness among all citizens about the ill effects of use of fossile fuels for surface transport. This would automatically lead to increased demands for more environmentally friendly surface transport.

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- At the level of networks of governments, such as EU and USA for example, policies regarding regulations can play a major role in the movement towards a dramatic reduction of the emission of GHG. These policies should contain elements for removal of the blocking mechanisms described under Step 5. They can be designed as incentives, where the increased use of biofuels is supported by tax reductions and similar measures.
- These actors also have possibilities to establish policies for their support of R, D&I, in order to promote the initiatives that shows potential to considerably reduce the emission of GHG. In order to arrive at optimum results with the limited resources at hand, the basic interaction between increased use of biofuels of various kinds and the emissions of GHG must be established once and for all through scientific methods. The present situation, where various lobbying groups advocate the increased use of their specific biofuels, mainly based on commercial aspects, must be avoided. The same is true for the almost religious efforts to promote specific biofuels with very little scientific background and motivation.
- The national governments are also major R, D&I promoters in these areas and they have similar opportunities to introduce policies supporting positive developments in the area of reduction of GHG through increased use of biofuels. The establishment of the increased use of biofuels as a measure to reduce GHG emission in a medium time perspective and promoting other solutions for a long time perspective should also be made through the introduction of appropriate policies at national levels.
- At the level of various manufacturers in the transport area, for example the OEMs, the creation of the appropriate policies is a responsibility of the manufacturers and this cannot be changed in most of the world today. There are, however other possibilities to influence the creation and contents of these policies and several have already been mentioned under the initial parts of Step 6. The customer demands from a enlightened group of potential purchasers, is a very strong argument in this area. Because of this fact, the awareness activities mentioned above will play a major role in order to arrive at policies, which will promote the reduction of GHG emissions. The other powerful instrument to arrive at developments of policies among manufacturers, which promote new technological structures, is the instrument of regulations. This instrument can be used both at the sub national level of for example EU and USA and at the level of national governments.

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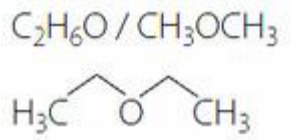
Annexes

Dimethyl ether DME Fact Sheet

Introduction

Dimethyl ether (typically abbreviated as DME), also known as methoxymethane, wood ether, dimethyl oxide or methyl ether, is the simplest ether. It is a colourless, slightly narcotic, non-toxic, highly flammable gas at ambient conditions, but can be handled as a liquid when lightly pressurized. The properties of DME are similar to those of Liquefied Petroleum Gas (LPG).

Molecular Formula



Properties of DME

Molecular mass: 46.07 g/mol

Density at 20°C: 668 kg/cm³

Viscosity at 20°C: 0.15 mPa s

Heating value: 28.4 MJ/kg

Vapour pressure at 20°C: 5100 hPa

Utilization

Substitute for diesel fuel; transportation fuel; power generation fuel; domestic gas

Relevant fuel regulations

EN590 (diesel fuel)

Main feedstocks

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Black liquor, forest products, agricultural by-products, organic waste, energy crops

Scale of Production

Demonstration scale

Costs and GHG Balance

Origin	GHG [g CO_2eq/km]	Production cost [€/GJ]
Waste wood	12	16.8
Farmed wood	16	19.9
Black liquor	7	8.5

Assumes crude oil at 50 US-$/bbl

Production process

DME is primarily produced by converting natural gas, organic waste or biomass to synthesis gas (syngas). The syngas is then converted into DME via a two-step synthesis, first to methanol in the presence of catalyst (usually copper-based), and then by subsequent methanol dehydration in the presence of a different catalyst (for example, silica-alumina) into DME.

The following reactions occur:

$2H_2 + CO \Leftrightarrow CH_3OH$

$2CH_3OH \Leftrightarrow CH_3OCH_3 + H_2O$

$CO + H_2O \Leftrightarrow CO_2 + H_2$

Alternatively, DME can be produced through direct synthesis using a dual-catalyst system which permits both methanol synthesis and dehydration in the same process unit, with no intermediate methanol separation, a procedure that, by eliminating the intermediate methanol synthesis stage, the licensors claim promises efficiency advantages and cost benefits.

Both the one-step and two-step processes are commercially available. DME can also be converted itself into olefins and synthetic hydrocarbons.

State of the Art

Due to its good ignition quality, DME can be used in diesel engines as a substitute for diesel fuel. Compared to diesel DME has a lower viscosity. It is stored under relatively low pressure of 0.5 MPa in the liquid state. Because of this, slight modifications to the engine are necessary, primarily relating to the injection pump and the installation of a pressure tank, similar to that for LPG. Dimethyl ether in diesel engine burns very cleanly with no soot.

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According to the EC Directives 2009/28/EC (RED) and 2009/30/ EC (FQD) dimethyl ether is a biofuel if it is produced from biomass and intended for use as biofuel (in diesel engines). For other purposes (e.g. continuous combustion in boilers), DME can be blended with LPG. As part of the FP7 project BioDME under the leadership of the Volvo Group DME production is being optimized, especially for use as a transport fuel.

The demonstration plant in Piteå, which was put into operation in 2010, is the only gasification plant worldwide producing high-quality synthesis gas based on 100% renewable feedstock. The raw material used is black liquor, a high-energy residual product of chemical paper and pulp manufacture which is usually burnt to recover the spent sulphur.

BioDME plant with DME log truck in foreground © Chemrec 2011

EC-funded projects on DME

See R&D Funding page for further project details

BioDME - Production of DME from Biomass and utilisation as fuel for transport and for industrial use. Funded by 7th Framework Programme and Swedish Energy Agency.

Major stakeholders

Some major DME stakeholders in the EU are listed below:

Volvo Group, Sweden
Chemrec,, Sweden
Haldor Denmark
Preem, Sweden
Total, France
Delphi, Luxembourg
DECHEMAETC, Sweden

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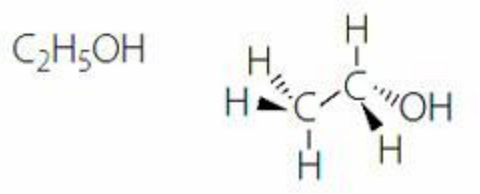
E2.Ethanol fact sheet

Introduction

Ethanol, also known as ethyl alcohol, pure alcohol, grain alcohol, or drinking alcohol, is often abbreviated as EtOH. EtOH is a light alcohol and is a volatile, colourless, flammable liquid with a characteristic odour. EtOH is a versatile solvent and is miscible with water and many organic components. Due to its polar character EtOH can dissolve many ionic compounds. EtOH burns with an almost invisible flame. Ethanol is used as a fuel, alcoholic beverage, as a chemical (e.g. as solvent) or as a feedstock. EtOH is also deliquescent, therefore without proper conditions, it attracts water while stored. Another important feature of EtOH is the formation of an azeotropic mixture with water.

Molecular Formula



Properties of ethanol

Molecular mass: 46.07 g/mol
C (%wt) 52.2
H (%wt) 13.1
O (%wt) 34.7
Density at 20°C: 794 kg/cm^3
Viscosity at 20°C: 1.2 mPa s
Heating value: 26.8 MJ/kg

Utilization
Substitute for petrol; petrol blend component; feedstock for petrol additive ETBE

Relevant fuel regulations
EN 228, EN 15736

Main feedstocks
Sugar and starch from agricultural crops, (sugar cane, cereals, sugar beets); lignocellulosic biomass (forestry residues, agricultural residues, energy crops)

Scale of Production

This project has been funded with support from the European Commission under Seventh Framework Programme (FP7)

Industrial production for first-generation ethanol and pilot-plant/demonstration scale for second generation (cellulosic) ethanol

Costs and GHG Balance

Origin	GHG [g CO_2eq/km]	Production cost [€/GJ]
Sugar beet, pulp to fodder	160	17.1
Farmed wood	156	21.3
Wheat straw	155	26.6

Assumes crude oil at 50 US-$/bbl

Production process

EtOH is a naturally widespread chemical, produced by ripe fruits and by wild yeasts or bacteria through fermentation. Ethanol from biomass, usually referred to as bioethanol, can be produced from any feedstock containing appreciable amounts of sugar or materials that can be converted into sugar. The fermentation of such materials has been known for centuries. The first production of pure EtOH was carried out in the Middle East, where the distillation process was reportedly perfected in the 9th century AD. The word "alcohol", commonly used for EtOH, is said to be derived from Arabic. Today fermentation is still the predominate pathway for EtOH production.

Biomass can also be converted to EtOH via biotechnological and thermochemical pathways.

Biochemical pathways

Most EtOH is produced by fermentation from various sugar and starch materials. The most common raw material are sugar cane and corn, and in temperate climates also sugar beet, wheat or potatoes.

The overall fermentation process starting from glucose is:

$C_6H_{12}O_6 \Leftrightarrow 2\ C_2H_5OH + 2\ CO_2$

Naturally, the underlying biochemical processes are much more complicated. Adapted yeasts, for example Saccharomyces cerevisiae are used and fermentation can be carried out with or without the presence of oxygen. With oxygen some yeasts are prone to respiration, the conversion of sugars to carbon dioxide and water. As EtOH is a toxin, there is a limit to the maximum concentration in the brew produced by the yeasts, some 15 vol.-%, although with specially adapted yeasts up to 20 vol.-% is possible. This results in a high energy demand for EtOH purification by distillation.

In industrial processes an efficiency of about 90 to 95% of theoretical yields can be reached. But, unmodified yeast will only convert sugars with 6 carbon atoms. As sugars with 6 carbon atoms are only a part of the biomass the overall conversion efficiency is much lower. To enable the use of a wider range of biomass components, processes, that also convert sugars with 5 carbon atoms are under development. Larger compounds in biomass must first be broken down into fermentable sugars and lignin which is currently not a candidate feedstock for EtOH.

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Other pathways

Non-biotechnological methods for production of EtOH have been developed. EtOH from chemical conversion routes is called synthetic ethanol. The most common chemical process for EtOH production is the acid-catalyzed hydration of ethylene:

$C_2H_4 + H_20 \Leftrightarrow C_2H_5OH$

Ethylene is obtained from petrochemical feedstocks.Phosphoric acid is mostly used as catalyst. Such production was carried out on an industrial scale in the USA in the 1930s. The ethanol, thus produced, was used industrially, e.g. in solvents, paints and pharmaceuticals. Due to EtOH monopolies imposed by countries such as Germany, chemical ethanol synthesis became less important after the late 1940s.

EtOH can also be produced from synthesis gas through chemical synthesis. In addition certain microorganisms are able to digest synthesis gas to produce Ethanol.

State of the Art

Today huge amounts of EtOH are produced both on an industrial scale and on a small scale. Because of the many methods of EtOH production, statistical data is not always reliable.

Global bioethanol production in 2009 has been estimated at 73,954 Ml. The United States is the leading producer with 40,130 Ml (54%), while Brazil produced 24,900 Ml (34%). The EU-27, with a production of 3,703 Ml (5%), ranks third behind these two majors producers.

The production of EtOH by fermentation is a centuries old process but as with every industrial process it is always under optimisation, especially to improve energy use.

As an alternative to using sugar- and/or starch-based biomass, R&D is focused on advanced processes that use lignocellulosic materials as feedstocks. These processes have the potential to increase variety and quantity of suitable feedstocks including cellulosic and food-processing wastes, corn stovers, and cereal straws as well as dedicated fast-growing plants such as poplar trees and switch-grasses. Moreover, cellulosic feedstocks may be grown on non-arable land (limiting competition with the food-chain) and/or be produced from integrated crops (increasing land availability considerably). Advanced processes include biomass pre-treatment to release cellulose and hemicellulose, hydrolysis to fermentable 5- and 6-carbon sugars, sugar fermentation, thermal conversion of solid residues and non-hydrolysed cellulose, and distillation of ethanol to fuel grade. In order to provide better conversions, new pretreatment schemes and innovative enzymatic processes have been investigated.

Since the early 1980s, many processes for this type of conversion have been tested or developed. One of the more sophisticated solutions is the so-called "lignocellulosic feedstock biorefinery (LCF biorefinery)" which uses lignocellulosic biomass, for example wood from short rotation forestry or energy crops like triticale. Besides EtOH, in theory, a broad range of intermediate chemicals could be produced from a LCF biorefinery.

Today in Europe some pilot or demonstration plants are running or are being commissioned. Due to significant investments in funding by the EU and by industry the technology for production of lignocellulosic biomass to EtOH is available, but market incentives for industrial production are still needed.

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Thanks to its properties, EtOH has a series of technical advantages as a fuel for spark-ignition engines. First, EtOH has a very high octane number. This gives the fuel a strong resistance to knock which translates into the possibility of optimizing the engine by increasing compression ratio and advancing spark. Second, EtOH has a high heat of vaporization, enabling a cooling effect. This enhances the cylinder filling efficiency, partly offsetting its lower energy content per litre. Finally, the presence of oxygen in the ethanol molecule provides a more homogeneous fuel-air mix formation and permits low-temperature combustions with a consequent decrease in unburned or partially burned molecule emissions (HC, CO, and NOx).

Despite these advantages, some negative properties have also to be considered. Firstly, the oxygen content leads to an increase in the fuel volumetric consumption and, due to its ability to oxidize into acetic acid, may cause compatibility issues with some materials used in the engine, such as metals or polymers. Secondly, the high latent heat of vaporization can cause running difficulties in cold conditions, especially cold start. Finally, EtOH leads to azeotropes with light hydrocarbon fractions and can cause volatility issues. It is miscible with water, which can cause demixing issues when blended with hydrocarbons, and implies acetaldehyde emissions.

Applications

E5 ethanol-gasoline blends can generally be used in conventional spark-ignition engines with no technical changes. E10 can be used in the majority of modern car fleets in EU (vehicle owners should check with specific manufacturers), while modern flexi-fuel vehicles (FFV) can run on up to 85% (E85) with just a few modifications during production. The use of alcohol fuels, such as E95, in heavy duty applications is also possible, with some modified buses and trucks already on the market.

EC-funded projects on ethanol

See R&D Funding page for further project details

BIOLYFE - Demonstrating large-scale bioethanol production from lignocellulosic feedstocks

NEMO - Novel high-performance enzymes and micro-organisms for conversion of lignocellulosic biomass to bioethanol

DISCO - Targeted DISCOvery of novel cellulases and hemicellulases and their reaction mechanisms for hydrolysis of lignocellulosic biomass (FP7)

BABETHANOL - New feedstock and innovative transformation process for a more sustainable development and production of lignocellulosic ethanol

PROETHANOL2G - Integration of biology and engineering into an economical and energy-efficient 2G bioethanol biorefinery

HYPE - High efficiency consolidated bioprocess technology for lignocellulosic ethanol

KACELLE - Demonstrating industrial scale second generation bioethanol production – Kalundborg cellulosic ethanol plant

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FIBREETOH - Bioethanol from paper fibres separated from solid waste, MSW

LED - Lignocellulosic ethanol demonstration

Major stakeholders

Some major bioethanol stakeholders in the EU are listed below:

Abengoa Bioenergy, Spain
Tereos, France
CropEnergies, Germany
Cristal Union, France
Agrana Group, Austria
Verbio, Germany
Agroetanol, Sweden
Industria Meridionale Alcolici, Italy
AlcoBioFuel, Belgium
N.prior bioenergy, Germany
Chemtex, Mossi & Ghisolfi Group, Italy
DONG Energy, Denmark

Abengoa Bioenergy, a biofuels subsidiary of the Abengoa group, is the European leader of fuel bioethanol production. In 2008, its production capacity was equal to 780 Ml/yr, 580 of which was distributed on the EU market. In the same year, the French industrial group Tereos registered a total production capacity of 770 Ml/yr while the German group CropEnergies reached a total production capacities of 760 Ml/yr.

3. Fatty Acid Methyl Esters FAME Fact Sheet

Introduction

The physical characteristics of fatty acid esters are quite close to those of fossil diesel fuels. A mixture of different fatty acid methyl esters is commonly referred to as biodiesel, which is a renewable alternative fuel derived from vegetable oils, animal fats or waste cooking oils. Since it has physical

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properties similar to those of conventional diesel, it can be considered as a renewable replacement for conventional petroleum-based diesel fuel. It is also non-toxic and biodegradable.

The EC Directive 2009/30/EC (FQD) allows for a maximum of 7% FAME in diesel fuel (B7). Above this level, suitability of blends requires guarantees by specific car manufacturers, and may be subject to amended servicing schedules (for example, more frequent oil and filter changes). Tests are typically carried out on blends with diesel fuel up to 5-10 %, or at 25-30 % and 100 % pure. Modifications (e.g. seals, piping) may be required for use at 100 % pure. The current use of biodiesel as a transport fuel has not required any significant changes in the distribution system, therefore avoiding expensive infrastructure changes.

Some properties of biodiesel are different from those of fossil diesel and for correct low temperature behaviour and for slowing down oxidation processes biodiesel requires a different set of additives than fossil diesel.

Molecular Formula

$CH_3(CH_2)nCOOCH_3$

Properties of FAME

Specific gravity: 0.88 kg/l
C (%wt) 77
H (%wt) 12
O (%wt) 11
Density @ 20 °C 0.86-0.90 kg/m^3
Lower heating value 33.175 MJ/kg
Kinematic viscosity @ 40 °C 4-6 kPa s

Utilization

Substitute diesel; transportation fuel; power generation fuel

Relevant fuel regulations

EN14214 (Biodiesel specification), EN590

Main feedstocks

Oil seeds (rape, sunflower, soy, palm)

Scale of Production

Industrial scale

Costs and GHG Balance

Production costs for biodiesel from rapeseed oil are based on feedstock prices. In Germany 2007: 24€/GJ, predictions for 2020: 23€/GJ. A GHG reduction of 2.1 kg/l biodiesel is expected. Modelled

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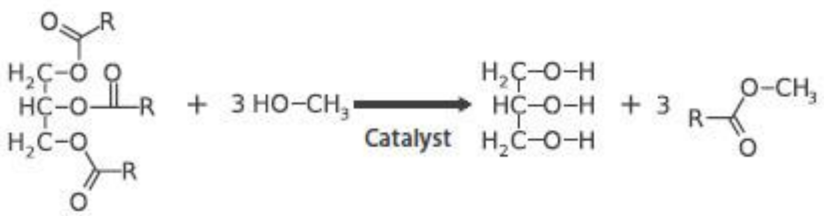
savings of GHG emissions per hectare for 2020 are increasing due to increasing yields and potential increased production processes and energetic uses of residues.

Assumes crude oil at 50 US-$/bbl

Production process

Fatty Acid Methyl Esters are produced from vegetable oils, animal fats or waste cooking oils by transesterification. In the transesterification process a glyceride reacts with an alcohol in the presence of a catalyst, forming a mixture of fatty acids esters and an alcohol. Using triglycerides results in the production of glycerol.

Transesterification is a reversible reaction and is carried out by mixing the reactants. A strong base or a strong acid can be used as a catalyst. At the industrial scale, caustic potash is mostly used. The following reaction occurs:



The production of biodiesel is relatively simple from a technical standpoint, also allowing the construction of small decentralised production units without excessive extra costs. This limits the need to transport raw materials long distances and permits operations to start with modest-sized installations.

Rapeseed, sunflower, soybean, palm oils and spent oils are the most common raw materials being used for the production of biodiesel. Using methanol in the transesterification process has the advantage that the resulting glycerol can be separated simultaneously during the transesterification process. When using ethanol during the process the ethanol needs to be free of water and the oil needs to have a low water content as well to achieve an easy glycerol separation.

The end products of the transesterification process are raw biodiesel and raw glycerol. After a cleaning step biodiesel is produced. The purified glycerol can be used in the food and cosmetic industries, as well as in the oleochemical industry. The glycerol can also be used as a substrate for anaerobic digestion.

State of the Art

Transesterification processes have been used since the establishment of the oleochemical industry. Industrial scale production of biodiesel for use as a transport fuel has taken place in Europe since 1992. To ensure conformity of biodiesel production the standard EN14214 was implemented in Europe. Global biodiesel production in 2009 was 17,929 Ml.

The leading producer is Germany with 2,859 Ml (16%) of biodiesel produced, followed by France with 2,206 Ml (12%) and the United States with 2,060 Ml (11%). The potential market for biodiesel is

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estimated at around 20 EJ by 2050, assuming the development of synthetic biofuel production technologies, using new feedstocks, achieving higher yields and reduced GHG emissions

EC-funded projects on FAME

See R&D Funding page for further project details

ALGFUEL - Biodiesel production from microalgae

ECODIESEL - High efficiency biodiesel plant with minimum GHG emissions for improved FAME production from various raw materials

SUPER METHANOL - Reforming of crude glycerine in supercritical water to produce methanol for re-use in biodiesel plants

InteSusAl - Demonstration of Integrated & Sustainable enclosed raceway and photobioreactor microalgae cultivation with biodiesel production and validation

Major stakeholders

Some of the major biodiesel stakeholders in the EU are listed below:

Diester Industries, France
ADM Biodiesel, Germany
Biopetrol Industries, Switzerland
Verbio, Germany
Cargill, Germany
Ital Green Oil, Italy
Bioenergética Extremeña, Spain
Acciona Energia, Spain
Gate, Germany
Biofuels Corporation, United Kingdom
Novaol, Italy
Natural Energy West, Germany

With the inauguration in 2008 and 2009 of four new facilities and a total of 10 facilities, Diester Industries remains the largest producer of biodiesel in the EU in 2009 with a production capacity of 2,250 Ml/yr, only in France. ADM Biodiesel, a German subsidiary of the American group Archer Daniels Midland (ADM), runs three production plants in Germany with a total production capacity of 1,130 Ml/yr. The American group owns biodiesel plants also in Brazil, India, Indonesia and the United States. Its global production capacity is about 1,700 Ml/yr. The Swiss group Biopetrol Industries is also one of the leaders of the European biodiesel market, its biodiesel production is done in Germany in Schwarzheide (220 Ml/yr) and in Rostock (170 Ml/yr), and since 2008 in the Netherlands in Rotterdam (450 Ml/yr). The German company Verbio is active in both biodiesel and bioethanol markets. It owns two biodiesel production facilities in Germany, in Schwedt (280 Ml/yr) and

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Bitterfeld (230 Ml/yr). According to the EBB (European Biodiesel Board), the production capacity of biodiesel in the EU exceeded 23,500 Ml in 2008, with 276 production facilities.

w4. Methanol from Biomass Fact Sheet

Introduction

Methanol, also known as methyl alcohol, wood alcohol, or wood spirits, is often abbreviated as MeOH. It is the simplest alcohol, and is a light, volatile, colourless, flammable liquid with a distinctive odour. At room temperature it is a polar liquid. MeOH is miscible with water, petrol and many organic solvents. MeOH has a high toxicity in humans. If ingested, as little as 10 ml can cause permanent blindness by destruction of the optic nerve. A fatal dose is typically 100–125 ml.

Molecular Formula

CH_4O

Properties of methanol

Molecular mass: 32 g/mol
Density at 20°C: 0.7918 g/cm³
Viscosity at 20°C: 0.59 mPa s
Heating value: 19.94 MJ/kg
Vapour pressure at 20°C: 13.02 hPa

Utilization

Chemical feedstock, petrol blend component

Relevant fuel regulations

EN 228

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Main feedstocks

Natural gas, coal, biomass

Scale of Production

Industrial scale

Costs and GHG Balance

Origin	GHG [g CO_2eq/km]	Production cost [€/GJ]
Waste wood	18	15.8
Farmed wood	14	18.9
Black liquor	11	8.2

Assumes crude oil at 50 US-$/bbl

Production process

In nature MeOH is produced via anaerobic metabolism by many bacteria. It is also formed as a by-product during the ethanol fermentation process. MeOH also occurs naturally in many plants, especially in fruits.

Historically MeOH was first produced from wood by destructive distillation, as early as 1661 by Robert Boyle

In 1923 the German company BASF introduced industrial MeOH production based on coal gasification. Since then MeOH has grown into one of the largest chemical synthesis feedstocks. Key uses include production of formaldehyde, MTBE/TAME (gasoline components), acetic acid, DME and olefins and direct use as a petrol blend component. Today MeOH is mainly synthesized from natural gas, but also from coal, mainly in China and South Africa. The leading MeOH production processes are the pressurized syntheses developed by ICI and Lurgi. In 2007 the world production of MeOH amounted to 40 million tonnes with a forecast compound annual growth rate of 4.2% for the period 2008-2013 excluding captive production for the methanol-to-olefins (MTO) route.

Biomass can be converted to MeOH via thermochemical and biotechnological pathways as shown in the following diagram.

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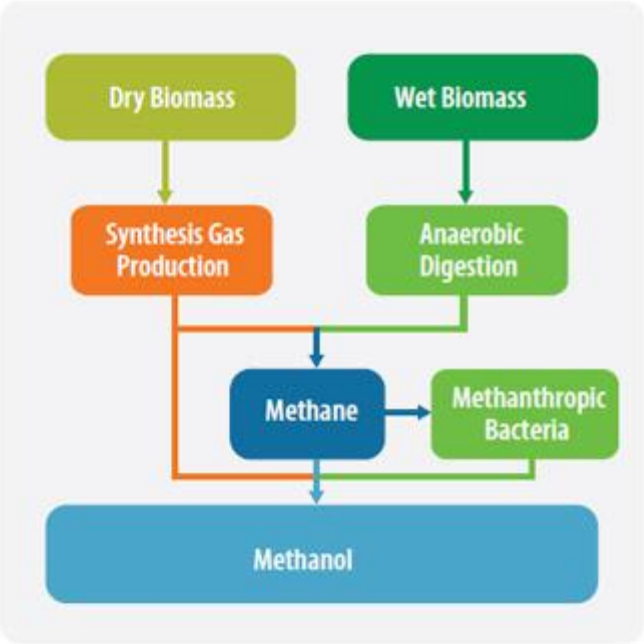

Thermochemical pathways

The thermochemical conversion paths to MeOH are basically the same as for fossil feedstocks, such as coal or natural gas.

The biomass is gasified and the resulting synthesis gas, a mixture of CO, H_2 and CO_2 is adapted to the quality requirements of MeOH synthesis.

During synthesis the following reactions occur:

$CO + 2H_2 \Leftrightarrow CH_3OH$

$CO_2 + 3H_2 \Leftrightarrow CH_3OH + H_20$

$CO_2 + H_2 \Leftrightarrow CO + H_20$

The formation of MeOH is exothermic and is favoured by high pressures and low temperatures. For reasons of process simplification, investment cost reduction and energy consumption reduction, alternatives are under development, which could also be used for MeOH from biomass:

Direct oxidation of Methane: $2CH_4 + O_2 \Leftrightarrow 2CH_3OH$

Liquid-phase oxidation of Methane

Conversion through monohalogenated methanes

Biochemical pathways

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One biochemical route is via methane formation by anaerobic digestion. This process is well developed due to the rise of biogas production from municipal waste or landfill sites.

The biogas has to be cleaned to obtain a gas with high methane content and MeOH is then produced from the methane as described above.

Recently a genuine biochemical route using methanothrophic bacteria has been investigated. For example, bacteria such as *Methylococcus capsulatus* will convert methane to MeOH if methane is the only available resource.

State of the Art

Today methanol from biomass is produced through gasification of glycerine, a by-product of biodiesel production, by BioMCN in the Netherlands. The thermochemical conversion of syngas to methanol is well known from fossil feedstocks and the basic steps are not different for biomass. The main issue faced is the economic feasibility of gasification of biomass at elevated pressures and conditioning of the raw synthesis gas.

In the past there was some small-scale production of methanol from biomass. In 2004 the German company Choren Industries GmbH produced Methanol from wood using its Carbo-V process. In the Chemrec AB pilot plant in Piteå, Sweden about 6 tons per day of methanol is used as an intermediate in the production of BioDME.

While the biochemical route through methanothrophic bacteria is still in a quite early state of development the conversion of biogas to methanol has been proven on bench scale. ZSW has proven that methanol could be produced from biogas at a decentralised level.

Projects on methanol

See R&D Funding page for further project details

SUPER METHANOL - Reforming of crude glycerine in supercritical water to produce methanol for re-use in biodiesel plants (FP7-212180)

MTO/OCP Project - Methanol-to-olefins/olefin cracking process (€45m project funded by Total)

Major stakeholders

Some major methanol stakeholders in the EU are listed below:

Chemrec AB, Sweden
VärmlandsMethanol AB, Sweden
BioMCN B.V., Netherlands
B.T.G. BIOMASS TECHNOLOGY GROUP BV, Netherlands
Choren Industries GmbH, Germany
Karlruhe Institute for Technology (KIT), Germany
ZSW, Germany
DECHEMA, Germany

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Technical University of Vienna, Austria
Technical University of Graz, Austria

e5. Synthetic Hydrocarbons Fact Sheet

Introduction

Hydrocarbons are organic compounds consisting mainly of hydrogen and carbon. There are many sub-groups: paraffins, such as alkanes, alkenes, alkynes, naphthenes, such as cycloalkanes, and aromatics, such as xylene, benzene, as well as many other compounds consisting of hydrogen, carbon, nitrogen, and sulphur. Alkanes are saturated hydrocarbons in which all C-C bonds are single bonds. Alkenes are unsaturated hydrocarbons that have at least one C-C double bond. Cycloalkanes have at least one ring of C-atoms. Aromatics are hydrocarbons that have a C6 ring analogous to that of benzene. Hydrocarbon fuels produced from natural gas, crude oil, or coal are referred to generically as fossil fuels, while those produced from biomass are called biofuels. When the fuels are produced via extensive processing, such as the XtL routes, they are generically called synthetic fuels.

Molecular Formula

C_xH_y (general), C_nH_{2n+2} (alkanes)

Properties of BtL

Density at 20° 0.76 kg/l
Viscosity at 20°C 4mm2/s
Heating value: 44.01 MJ/kg

Utilization

petrol, diesel, aviation fuel, marine fuel

Relevant fuel regulations

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EN 590 (diesel fuel)
ASTM D7566 (50% FT fuel in Jet-A1)

Main feedstocks

Energy crops and trees, agricultural food and feed crops, agricultural crop wastes, wood wastes and residues

Scale of Production

Pilot test stage

Costs and GHG Balance

Production costs in Germany 2007 for BtL was 31 €/GJ with predictions for 2020 at 26 €/GJ. The expected yields per hectare of 4000 l/ha and savings of 2.5 kg CO2/l provide higher GHG reduction per hectare for BtL.

Assumes crude oil at 50 US-$/bbl

Production process

Hydrocarbon fuels are ideal for transportation applications because they have high energy content per volume or mass and since they are mostly liquids they can be easily transported and stored. A wide variety of hydrocarbon components are blended together to make motor fuels according to the specifications appropriate for cars, trucks, non-electric trains, or aeroplanes.

Liquid, synthetic hydrocarbons (XtL) can be used in petrol, diesel, aviation fuel and marine fuels. To what extent depends on their properties, which result from the specific manufacturing process and subsequent downstream processing. XtL is the generic name of synthetic liquid hydrocarbons, for distinguishing between the different raw materials; the abbreviations CtL (Coal to Liquid), GtL (Gas to Liquid) and BtL (Biomass to Liquid) are used. Their utilization as a transportation fuel requires no significant changes to the existing infrastructure and engines, because synthetic hydrocarbons can be processed to fit the specifications. Hence they are often referred to as drop-in fuels.

BtL is produced in a four-step-process:

1. Gasification – to produce raw syngas:

$C_XH_yO_z + AOa \rightarrow CO + H_2 + CO_2$

Exact reactions are multifold, e.g. any sulphur becomes H_2S and COS

2. Syngas conditioning – to achieve correct gas quality:

$CO + H_2O \Leftrightarrow CO_2 + H_2$

and removal of CO_2, and any H_2S and COS

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3. Synthesis via a type Fischer-Tropsch process:

$nCO + 2nH_2 \Leftrightarrow (-CH_2-)n + nH_2O$

or

synthesis via a Methanol-to-Gasoline process:

$CO + 2H_2 \Leftrightarrow CH_3OH$

$nCH_3OH + H_20 \rightarrow n/2\ CH_3\text{-}O\text{-}CH_3 + n/2\ H_2O\ (CH_2)_n + nH_2O$

4. Product preparation to achieve desired properties:

This can range from simple distillation to complex hydroprocessing and distillation. This is followed by preparation of final fuels, which is largely a skilled blending operation,

Generally, the production of BtL has a more favourable energy balance than that of first generation biofuels (i.e. greater levels of GHG reduction). Although biogenic fuels are sometimes referred to as carbon neutral, energy is required for fuel production, as well as transport, cultivation or processing of feedstock (this energy may come from fossil fuels). The EU-funded project BioGrace aims to harmonise calculations of biofuel greenhouse gas emissions, which form part of the sustainability criteria for biofuels within the Renewable Energy Directive (2009/28/EC). A number of schemes for certifying sustainable biofuels have now been approved by the EC.

Hydrotreated vegetable oils (HVO) are produced from vegetable oils or fats via direct hydrogenation (hydrogenolysis). It is possible to use the catalytic processes and catalysts similar to crude oil middle distillate hydro treatment, which is a commercial process. The liquid fuel is comparable to FT fuels.

State of the Art

Currently, there is no large-scale production of BtL fuels in Europe. The research project OPTFUEL, led by the Volkswagen Group, aims at demonstrating the production of BtL-based fuels made from wood and wood residues. In the OPTFUEL project fast growing biomass like willow or poplar are used as feedstock. The development of BTL production technology is still in progress and is not yet competitive.

CHOREN Industries Ltd. developed the so-called Carbo-V process, which is a three-stage gasification process resulting in the production of syngas:

- low temperature gasification
- high temperature gasification
- endothermic entrained bed gasification

After gas conditioning the Fischer-Tropsch process is then used to convert the synthesis gas into a crude product which is further processed using hydrocracking into products such as the automotive fuel SunDiesel™.

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Currently, a pilot plant for a novel process, the so-called bioliq-process, is underway at the Karlsruhe Institute of Technology (KIT). The bioliq pilot plant will cover the process chain required for producing customized fuels from residual biomass, dry straw or wood. Furthermore, the integrated process chain enables production of both fuels and chemicals. The concept combines decentralized production of an energy-rich intermediate product “bioliqSynCrude” and centralized processing into products with final industrial-scale refinement.

In a joint venture with Stora Enso, Neste Oil works on a project to develop BtL technology for the production of synthetic diesel from wood residues. The project will focus on developing new gas cleaning technology and on using Fischer-Tropsch processes to make the biodiesel. VTT Technical Research Centre of Finland will join the two partners to implement the development phase and commercialize the technology.

Example projects on synthetic hydrocarbons

See R&D Funding page for further project details

OPTFUEL - optimised fuels for sustainable transport (FP7)

BIOLIQ - Biomass to Liquid Karlsruhe

BioTfueL - a French/German project aims to integrate all stages of the BTL process chain and bring them to market

BRISK – European research infrastructure for thermal conversion technology, which aims to overcome fragmentation in experimental facilities and foster greater cooperation R&D (FP7)

CEA Bure Saudron - will use foresty and agricultural residues to produce ~23000 tonnes/year of biofuel (diesel, kerosene and naptha)

Rentech - US-based projects focusing on syngas production and synthetic hydrocarbon technology

Major stakeholders

Some major bioethanol stakeholders in the EU are listed below:

Choren Industries GmbH, Germany
Volkswagen AG, Germany
Renault SA, France
Karlsruhe Institute of Technology (KIT), Germany
Lurgi, Germany
IFP, France
NSE Biofuels Oy (Joint venture Neste Oil and Stora Enso), Finland
UPM Kymmene, Finlandeu
Last Updated 6 December, 2011 The Biofuels TP Secretariat is partly funded by the EC under Grant Agreement 241269

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2.3 Deployment of Green Technologies within the Maritime Sector[10]

Title	Deployment of Green Technologies within the Maritime Sector: SO_x Abatement Technology
Mode	rail ☐, road ☐, air ☐, maritime ☒, inland waterways ☐, intermodal ☐
Partner	The European Marine Equipment Council

Shipping is the primary means of transport worldwide. Europe relies on it for goods and travelling from one corner of the continent to the other. Today's globalised world trade would not be able to function without ships, after all approximately 70% of the earth's surface is covered by water.

Considering the staggering percentages of world trade vessels transport (80%), it is remarkable to note that shipping is already the most environmentally friendly mode of transport and that emissions emitted from ships are small (3% of global CO_2 emissions[11]). Operational pollution has been reduced to a negligible amount. MARPOL 73/78 is the most important set of international rules dealing with the environment and the mitigation of ships pollution, has dealt with certain issues. However, there have also been considerable improvements in the efficiency of engines, ship hull designs, propulsion, leading to a decrease of emissions and increase of fuel efficiency.

The environmental footprint of shipping has been significantly improved through inputs from the marine equipment industry, which adopts a holistic approach when looking at the maritime sector. The equipment suppliers are a valued contributor and innovator within the maritime cluster.

The shipbuilding sector encompasses the shipyards and the marine equipment manufacturers including service and knowledge providers. The European marine equipment industry is the global leader in propulsion, cargo handling, communication, automation and environmental systems.

Research and innovation in key maritime technologies should increase the European equipment industry global market share by 30% in 40 years time. The main assumptions for this 30% increase in market share are derived from the following:

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[10] Disclaimer: This case study has been written with the aim of showing the deployment of Green Technologies within the maritime sector with a focus on SOx abatement technology. The project partner has done its best to communicate a very complex topic into the format of this template. Therefore any errors factual or otherwise, misquotation, omissions, misinterpretation, etc. contained herein are not the official position or opinion of the Association or its members.

[11] http://site.rightship.com/resources.ashx/downloads/43/fileName/3E1A79622E5C8AF19C58D5392B60722D/Calculating_and_Comparing_CO2_Emissions_from_Ships_-_Aug_2011.pdf

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1. Enhance worldwide competitiveness through knowledge-driven development and intelligent design and production processes;
2. Improve production and integration processes enabling shipyards to reduce the overall lead-time (ship contract to delivery) by 20%;
3. Minimise safety, security and commercial risk for operators, e.g. by practicing goal based standards in design, production approval and improving efficient operation;
4. Develop advanced system solutions for a new generation of special ships including corresponding landside infrastructure, thereby optimising the inter-modal transport chain;
5. Reduce the through life cost of equipment by 30%;
6. Increase the service market share through innovative after sales, maintenance and training concepts;
7. **Maintain and improving environmental leadership through technical innovation;**
8. Reduce loss of life and incidents, such as hull loses, by enhancing equipment safety and security technologies.

This case study is focused on the seventh point: 'environmental technology leadership.' If today's already existing 'green' technology could be integrated into ships they could become 15-20% greener and cleaner. If there is further innovation of new technologies then a 33% + increase in efficiency and sustainability can be achieved.

Step 1: the starting point of analysis: defining the TIS in focus

In this first step the TIS in focus needs to be defined. The broader picture or knowledge field in question is 'green technologies' within the maritime sector with a particular emphasis placed on a certain product which in this instance is sulphur abatement technology.

'There are several different designs of sulphur abatement technologies or marine exhaust gas cleaning systems (often referred to as scrubbers) that remove sulphur oxides from ship's engine and boiler exhaust gases'[12].

This case is very pertinent to the present discussions with regard to innovation, technical standards and legislative action being taken at EU level and the ongoing revision of the Sulphur Directive. It is a technology already in existence and ready for deployment, however there still seems to be reluctance by the final users and by the maritime cluster at large to support innovative solutions by their deployment both in existing and new vessels.

'Green Technologies,' in this context of maritime transport refer to products that aim at and/or results in a reduction of negative environmental impacts. This technology helps to achieve green shipping which affects the technology innovation system.

It is generally acknowledged that if this technology could be integrated in today's ships then they could become 15-20% greener and cleaner. If there is further demonstration of newly researched and developed technology then a 33%+ eco-friendliness could be achieved ultimately leading to the zero emissions ship in the not too distant future.

[12] http://www.egcsa.com/the-science-3.php

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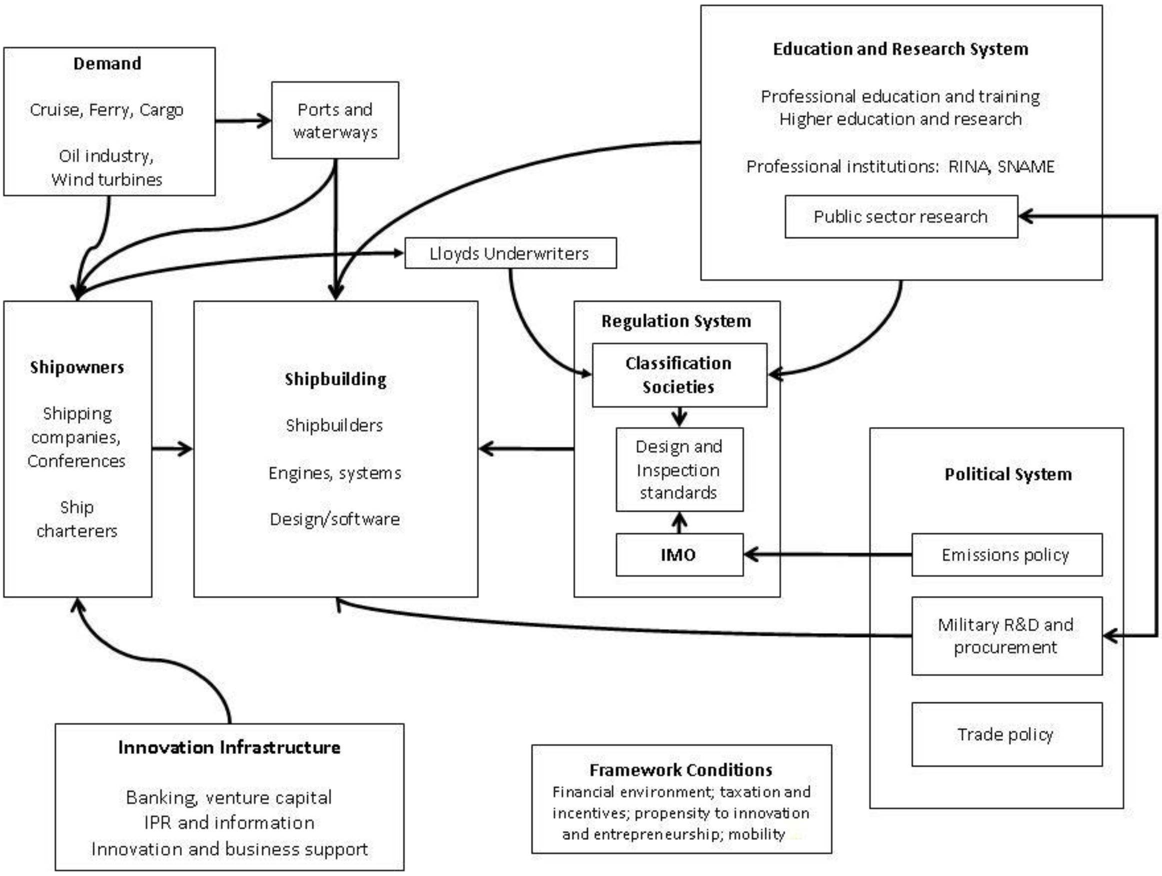
Step 2: identifying the structural components of the TIS

2.1 Actors

Figure 9: Maritime Innovation System



As Figure 9 shows, the maritime industry is diverse and is involved in many different sectors of the market. For the benefit of this case study perhaps the most interesting aspect to look at is the 'value chain' of the shipbuilding industry.

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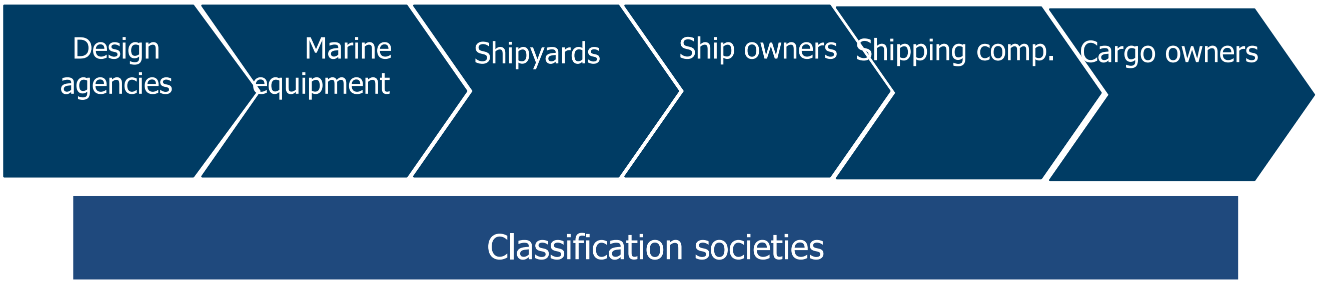
Figure 10: Shipbuilding value chain[13]



A brief description will be given of the main actors of the shipbuilding value chain although it must be remembered that this is an over simplification of the state of the art for the purposes of this case study. For example, size and role cannot be defined in great detail here.

Design Offices[14]:

This is the start of the innovation process because the initial conceptual design is crucial for a ships operational efficiency. Marine equipment manufacturers are increasingly working with the design offices 'to take part in joint development projects. Whether innovations find their way on to the market depends on the interaction' with the final customer which in this case is the ship-owner.

Marine Equipment[15]:

The marine equipment manufacturers are considered to be the major actor in the innovation chain. Their innovations can contribute to 'innovations through particular components that can make a difference for the total performance of the ship'. Marine equipment can make up to 65% of the value of a simple vessel and 80% in a more complex ship such as a cruise liner.

'The majority of innovations are conducted in-house and are financed by internal means'. Developing innovation in-house is a survival mechanism to ensure their longevity in the market. Staying one step ahead of the game ensures that their competitors always have to play catch up on the latest technologies. This is especially the case for SMEs who are not in the position to protect their IPR. This is the case for short term developments.

'On longer term developments the suppliers can set up partnerships with other companies or universities, but mainly to develop specific techniques or technologies'.

Shipyards[16]:

With relation to innovation 'shipyards take a position between the role of integrator, combining innovations from third parties/marine equipment suppliers in an integrated ship

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[13] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

[14] Ibid.

[15] Ibid.

[16] Ibid.

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design and construction, are the driving force behind new ship designs and innovations in response to market demands'.

Ship-owners[17]*:*

The ship-owners are at the end of the day the customers within the shipbuilding value chain and take the major decisions. This results in the fact that they take the ultimate decision to invest in new innovative technologies and products.

Shipping Companies[18]*:*

This actor is the user of the ship. In many cases the ship owner is the same as the shipping company. This generally means that it is still left to the decision of the ship-owner to invest in innovations. If this is not the case then the ship-owner is cautious about his investment costs and the shipping company the cost of the fuel and ship efficiency. When it comes to influencing the adoption of innovation the process can be more complex because the marine equipment manufacturers more often than not have to negotiate with two parties.

Cargo Owners[19]*:*

The transporters of cargo have to take the decision of with whom they should ship their goods. In several cases the 'green' label is important and influencing this decision. Cargo owners therefore can in some cases put pressure on ship-owners to transport cargo on 'green' ships and therefore stimulate innovation.

Classification Societies:

A more in depth look at classification societies will take place in chapter 2.3 under Institutions.

2.2 Networks

Technology innovation systems crucially need to be built upon 'networks'. 'Such networks can be transformed into development blocks, i.e. synergetic clusters of firms and technologies within an industry or a group of industries'[20].

Within a particular group of actors, institutions and technologies linkages will 'be stronger than the linkages with the outside of that group. If these structural factors form a dense configuration, they may be called a network structure or a network'[21].

Within the maritime sector there are many examples of different networks. These are crucial 'as forms of organisation that facilitate the exchange of knowledge and, based on this, an interactive process of learning'[22].

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[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Suurs, Roald A.A, *Motors of Sustainable Innovation*, retrieved from world wide web: http://igitur-archive.library.uu.nl/dissertations/2009-0318-201903/suurs.pdf, p.46

[21] Ibid. p.47

[22] Ibid. p. 47

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The basic network which exists in the maritime sector can be found in the shipbuilding industry. After all when a shipyard has been given an order for a new ship, more often or not it will use its network of 'trusted' companies to provide the necessary technology to be integrated within the ships superstructure.

The most apparent network within the maritime sector at national level is the maritime clusters. If we consider innovation within the maritime clusters then we could look to the Netherlands as an example of an effective 'innovative follower'. The EC Innobarometer considers that Denmark, Germany, Finland, the UK, Sweden and Switzerland are 'innovative leaders'. [23]

The Dutch Maritime Cluster (DMC) is made up of:

- Ship-owners;
- Shipyards;
- Offshore;
- Inland navigation;
- Water construction;
- Ports;
- Marine;
- Fishing;
- Maritime Services;
- Water Sports / Leisure Industry;
- Marine Equipment Manufacturers.

Within Europe it could be considered that this is one of the most complete maritime clusters. Together with the UK, Norway, Germany, France and Italy, the Netherlands gives a large contribution to the maritime position on the world market.

The annual R&D expenditure of the DMC (2010) is around 350mln€. The total amount of R&D personal can be estimated at 4,100. The R&D intensity of the cluster sits at 3.3% which is marginally higher than the average Dutch R&D intensity of around 1.7%[24].

In the period of 2002-2009 the R&D expenditure of the DMC grew by 35% slightly faster than the overall Dutch average. In the same period R&D personnel increased by approximately 26%, this increase is linked to upward trend of R&D expenditure. Looking at the rates of expenditure vs. R&D personnel it can be argued that the marine equipment sector and the offshore industry are the most innovative in the overall cluster (87mln€ vs. 870 / 75mln€ vs. 910). Together the two industries make up half the total R&D expenditure in the overall cluster[25].

These maritime clusters do not only work together for the benefit of harnessing business opportunities and creating an optimum working environment but also appeal to the national governments for financial support for R&D programmes[26].

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[23] Webers, Harry; Pernot, Eli; Van Doornik, Soraya; Peeters, Chris; *De Nederlandse Maritieme Cluster Monitor 2010*, Delft Univeristy Press, 2010, p.187

[24] Ibid.

[25] Ibid.

[26] Ibid.

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At a European level the sector is categorised in industry associations and networks of networks. Politically in Europe there is the Maritime Industries Forum which tries to coordinate the policies of the industry association through a series of different working groups. Equally so when it comes to R&D the maritime sector has organised itself into the Waterborne Technology Platform. This platform attempts to coherently shape the R&D priorities of the sector in order to be able to effectively lobby the European Commission for its share of the R&D funding which is made available under the various Framework Programmes and thereby aids the innovation process[27].

2.3 Institutions

Institutions are the humanly devised constraints that structure human interaction. They are made up of formal constraints (e.g., rules, laws, constitutions), informal constraints (e.g., norms of behaviour, conventions, self-imposed codes of conduct), and their enforcement characteristics. Together they define the incentive structure of societies and specifically economies. Source: North (1994)

Within the maritime sector we have different levels of institutions which define the structure of the industry and it economy.

"Throughout history as the volume of business / shipping increased so did the framework of regulations imposed by insurance companies in the first instance. In the eighteenth century the London insurance company develop a system to check that the ships they insured were soundly built and in good condition. By the early 19th century Lloyds register, which had started life in the 1760s as a register of ships, had assumed the role of setting standards and issuing classification certificates. Several other countries then set up classification, societies, among them Det Norske Veritas (Norway) and Bureau Veritas (France), and by the end of the nineteenth century the industry's technical regulatory system was in place.

Classification Societies have in recent years started to take a more active role in the introduction of innovations. 'Where traditionally, classification societies are called upon to decide if the end product complies with the class rules, they are now moving up the value chain'. They are being involved in the value chain at a very early stage and engage with design offices, marine equipment manufacturers in order to discuss innovations and developments. 'While they may become drivers of innovation…they…should address the balance between their commercial interests and their regulatory task'.[28]

Governments also became involved in regulating shipping. In the UK after a series of scandals involving ships used in emigrant trade, the Merchant Shipping Act 1854 was passed. This set out a legal framework for the registry of ships, tonnage measurement, survey of ships and equipment; carriage of dangerous goods; safety and seaworthiness of ships; protection of seamen; and inspection of provisions. Many national governments have enacted their own maritime law providing the basis for a maritime legal system"[29].

At European level the European Commission has created legislation directly applicable to the shipping sector and to be implemented by the member states of the Community. Legislation

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[27] Ibid.

[28] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

[29] Stopford, Martin; *Maritime Economics, Third Edition*; Routledge, 2009, pp34-35.

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is currently being discussed for CO_2 emissions from ships amongst to name just one example. Particularly relevant to this case study is the Sulphur Directive and its amendments: 1999/32/EC. This directive legislates on the amount of sulphur emissions to come from shipping.

Internationally the maritime sector looks to the International Maritime Organisation to take the lead on maritime legislation. 'The mission of the International Maritime Organization (IMO) as a United Nations specialized agency is to promote safe, secure, environmentally sound, efficient and sustainable shipping through cooperation. This will be accomplished by adopting the highest practicable standards of maritime safety and security, efficiency of navigation and prevention and control of pollution from ships, as well as through consideration of the related legal matters and effective implementation of IMO's instruments with a view to their universal and uniform application'[30].

Step 3: mapping the functional pattern of the TIS

3.1. Knowledge development and diffusion

Knowledge development and technology transfer play an important role within the shipbuilding sector. The primary mechanisms of these processes will be analysed within this chapter of the case study. The level of knowledge development and transfer of technology fluctuates between market sector and actors taking part.

Focussing on the role of the marine equipment companies, it becomes apparent that more often than not they are active in different business sectors and apply their technology to a range of industries, not exclusively for ships. Companies such as Wärtsilä, Siemens and Rolls Royce are active in different sectors and this allows them to transfer knowledge and technology from other economic domains to ships.

In the realm of shipbuilding knowledge development and technology, transfer can take place across different ship types. With regard to this, there is also extensive collaboration between shipyards and equipment manufacturers, i.e. the actors in order to guarantee innovation of new or existing products.

Knowledge development can also occur through the participation of a maritime cluster. "Interviewees from the maritime cluster in the North of the Netherlands reported a relatively strong "integrated" cooperation between companies in the cluster there, also involving R&D institutes like the Faculty of Maritime Technology of the TU Delft which results in more efficient production processes and lower costs"[31].

Given the global nature of the maritime sector, collaboration on knowledge development does not only occur at a local or European level. Many companies are engaged in R&D activities and knowledge diffusion with Asian businesses. An example of this could be 'the intensive cooperation between propulsion suppliers MAN and Wärtsilä and Korean shipyards concerning energy efficiency improvements'[32].

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[30] http://www.imo.org/About/Pages/Default.aspx

[31] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

[32] Ibid.

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When considering green technologies it is important to remember that 'green innovation' is directly and indirectly related market potential that can be created by green drivers. This will be looked at more closely in chapter 3.4. It has also been identified that knowledge development and innovation of R&D activities can be developed for another purpose and consequently have 'green' side effects. An example of this could be specific ship designs which improved stability but also had an impact on fuel consumption and energy efficiency[33].

The European Shipbuilding industry places a lot of emphasis on innovation to ensure that Europe remains competitive in a global market. Much of the R&D as previously mentioned is conducted in house but the clusters of knowledge development and strong value chain ensures that innovation is fostered within shipbuilding but also across other industry sectors.

3.2. Influence on the Direction of Search

Within the scope of green technologies and in particular sulphur abatement technology market drivers as well as regulatory measures / policies play a major role on the development of innovation.

Market demands have an enormous impact on the nature of a company's behaviour and in turn on the products they offer. The biggest demand generated by the market is 'cost'. This has an influence on the ship-owners incentive to invest in green vessels and thereby innovating 'green technologies'. Two main trends have been previously identified which play a significant role. Firstly we have the need to be more fuel efficient and secondly there is the increased environmental awareness which every industry sector faces and is not unique to shipping.

Focussing on fuel efficiency and the need to reduce cost of shipping in a competitive environment can be viewed as an indirect driver of greening the sector. Fuel consumption is intrinsically linked with greenhouse gas (GHG) emissions and therefore a reduction in the use of fuel will mean a reduction in the amount of GHGs emitted from shipping.

The need for fuel savings are being driven by the high price of today's oil, a trend which is not likely to be reversed in the future. This need for savings has an impact on the saving of fuel onboard vessels through adopting fuel efficiency measures, energy efficiency vessels and equipment. Innovation of green technologies is thereby aided by this internal business policy of ship-owners. The market therefore opens up for:

- *Fuel Efficient Systems:*

  Energy efficiency technologies are more likely to be innovated for fuel saving purposes. 'This includes propulsion systems, but also e.g. hull design, scale or 'smart' positioning and navigation systems'. At present in the marine equipment sector, solutions aimed at enhancing the fuel efficiency of vessels are representing the main focus for creating market potential (together with environmental regulation) driven technologies like scrubbers.'
- *Alternative Fuel Types:*

  Alternative fuels are another option open to innovation. Although this could be considered a credible alternative it can be considered that there are more barriers

[33] Ibid.

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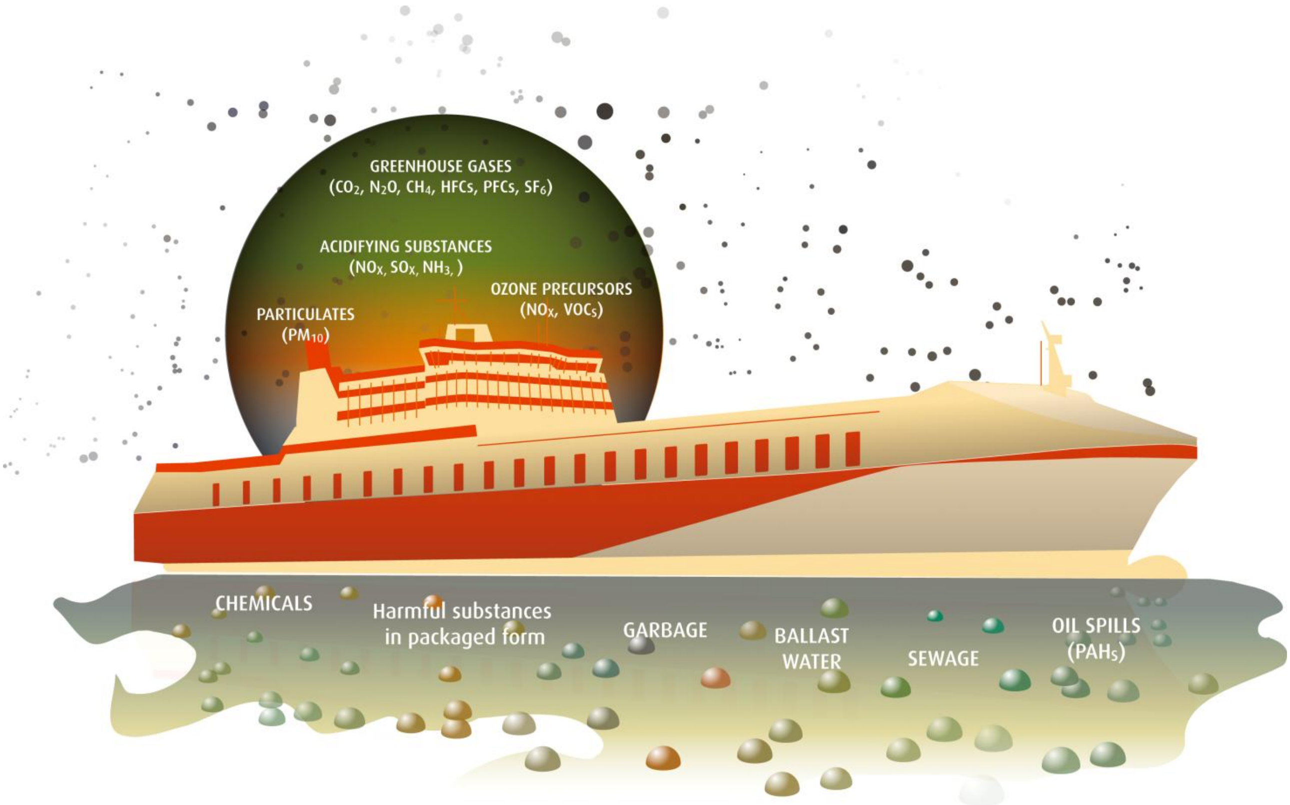
impeding this market. We have the uncertainty of price and the lack of investment in the wider infrastructure to supply alternative fuels. Take LNG as an example. This is widely considered an alternative to fuel oil; however the bunkering infrastructure is not yet in place for credible use[34].

Regulation and policies decision makers adopt have a significant impact on the adoption/innovation of green technologies. These are often to be considered as offering incentives for innovation but in most cases perceived negatively because the measures are more often than not obligatory.

Regulation comes primarily from the institutions within this TIS. As mentioned in chapter 2.3 there are different layers of institutions and as a consequence there are different layers of regulatory policies. In the case of green technologies and the environment the main agenda setter is the International Maritime Organisation[35].

Figure 11: Ship Emissions, EMEC



The IMO is the primary institution which regulates the air and water emissions as depicted in the figure above. The MARPOL Convention (International Convention on the Prevention of

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[34] Ibid

[35] Ibid

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Pollution from Ships) and Ballast Water Convention are in place to deal with ship emissions. IMO MARPOL Annex VI limits sulphur dioxide (SOx) emissions, for example.

SOx reduction can be considered the primary focus in this case, narrowing down the broader 'greening' of shipping. This is also a good example of a case where both institutions at International level and at European (regional level) have adopted policies which directly regulate this particular emission and therefore has an impact on the innovation of sulphur abatement technologies.

MARPOL 73/78 Annex VI concerns itself with regulating air pollution from ships and limits the amount of sulphur which vessels can emit through their exhausts. This regulation stipulates that 'no fuel oil onboard ships shall exceed 4.5% m/m sulphur' in 2012 and then a gradual reduction to 0.5% by January 2020[36]. In Sulphur Oxides Emission Control Areas (SECAs) the limit is set at 1.5% in 2010 and 0.1% in 2015[37].

The European Union has also set limits for the amount of sulphur in fuel oil in addition to the IMO and these can be found in Directive 2005/33/EC. "Parallel requirements in the EU to those in MARPOL Annex VI in respect of the sulphur content of marine fuels…[is]…0.1% maximum sulphur requirement for fuels used by ships at berth in EU ports from 1st January 2010"[38].

The international regulation alongside the parallel EU legislation is the policy framework behind the TIS in the case of sulphur abatement technologies. The IMO offers two ways to prevent sulphur pollution from ships 'use low sulphur fuel oil or scrub the exhaust gases'[39]. It is this latter option which provides the stimulus for the development of innovation through the impact of policy.

3.3. Entrepreneurial experimentation

'A TIS evolves under considerable uncertainty in terms of technologies, applications and markets. This uncertainty is a fundamental feature of technological and industrial development and is not limited to early phases in the evolution of a TIS but is characteristic of later phases as well…The main source of uncertainty reduction is entrepreneurial experimentation, which implies a probing into new technologies and applications'[40].

Using the focus of this case study, sulphur abatement technologies, this chapter will map the following:

- Firms actively involved with the development and experimentation of the technology in question;
- Case studies onboard vessels / experimentation of technologies.

[36] http://www.cmanc.com/web/presentations/internationalmaritimeorganization/captainvagslid.pdf

[37] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

[38] http://www.emsa.europa.eu/implementation-tasks/environment/air-pollution/item/97.html

[39] http://www.cmanc.com/web/presentations/internationalmaritimeorganization/captainvagslid.pdf

[40] A. Bergek et al., Research Policy 37, 2008, 407-429

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As mentioned in the previous chapter in order to meet the requirement of sulphur emissions set by the IMO and EU an option a ship-owner has is to invest in 'scrubbers'. This sulphur abatement technology 'removes SOx from exhaust gases by chemical reaction. The SOx reacts with a substance depending on the system used and is neutralised'[41].

'Scrubbing has been an accepted technology used in land based power plants since the 1930's. The first operational system was used on hard brackish river water at Battersea on the Thames in London'. More recently scrubber technology has been installed 'at Vassilicos in 2006 on a steam turbine boiler plant operated on the coast of Cyprus… Scrubbers have been used at sea since the 1960's' these are known as inert gas systems[42].

Research has shown that the main companies that are involved in the production of 'scrubbers' are European. SMEs as well as large companies are working in this field. A brief attempt at mapping the companies on size and location can be seen in the following table.

Table 4: Main companies in the production of scrubbers

Company Name	Small, Medium or Large	Country
Hamann[43]	Small	Germany
Couple Systems[44]	Small	Germany
Hamworthy[45]	Large	UK
Wärtsilä[46]	Large	Finland
Aalborg[47]	Large	Denmark
Clean Marine[48]	Large	Norway
Marine Exhaust Solutions[49]	SME	Canada
ACTI[50]	Large	Taiwan
DuPont[51]	Large	USA

(This list is non-exhaustive. It is meant to give an example of the size/location of companies involved in the sector)

For the purpose of this chapter and focus on entrepreneurial experimentation the companies Aalborg, Hamworthy and Wärtsilä will be looked at in more detail.

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[41] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

[42] http://www.hamworthy.com/Products-Systems/Hamworthy-Marine/Emissions-Reduction/Exhaust-Gas leaning/TechnologyandhistorySeaWaterScrubbing/

[43] http://www.hamannag.de/files/HEC_SooFi_Press_Release.pdf

[44] http://www.couple-systems.com/

[45] http://www.hamworthy.com/

[46] http://www.wartsila.com/en/Home

[47] www.aalborg-industries.com

[48] http://cleanmarine.no/

[49] http://www.marineexhaustsolutions.com/

[50] http://www.acti.com

[51] http://www2.dupont.com/

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Alfalaval/Aalborg[52]

'Alfal Laval Aalborg has more than 40 years of experience supplying scrubbers as an integrated part of inert gas systems (IGS) onboard ships'. In 2008 as a result of the company's experience with IGSs and together with MAN Diesel an exhaust gas cleaning system was designed and tested.

Based on the previous knowledge and tests carried out, the company was able to design a complete system which they were able to experiment onboard a Ro-Ro vessel (ferry) from the DFDS line called 'Tor Ficaria'. A complete series of tests have been carried out in a wide range of operating conditions in order to secure compliance with the IMOs MARPOL annex VI legislation.

The return on investment for a ship-owner investing in such technology, for a Ro-Ro vessel, has been estimated at 1-2 years. This technology is ready to use on the market and can be retrofitted onboard existing vessels.

Hamworthy Krystallon[53]

Hamworthy has been developing sea water scrubbing systems with the oil company Shell since the mid 1990's. 'Krystallon began their designs in 2002 with a project on MV Pride of Kent. The project was to prove that sea water scrubbing could be adapted for use on an operating marine diesel engine. The first Krystallon system was commissioned in 2005 with a larger system fitted as replacement for the first experimental unit on Pride of Kent in 2006'. The tests showed that after operating for over 30,000 hours 98% of all SOx from a 1MW engine was scrubbed without major operational problems.

Hamworthy's scrubber technology is also ready to be used onboard vessels and in 2012 it was reported that they are 'supplying the world's first full-vessel scrubber system to a Solvang LPG carrier newbuilding'[54].

Wärtsilä[55]

Wärtsilä has also been very active in the field of marine SOx scrubber development in the last decade. In 2005 the Finnish Maritime Cluster initiated a project looking in to scrubbers based on environmental legislation for the reduction of emission of sulphur oxides. Four companies put together a project plan and applied for R&D funding with Wärtsilä as the project leader. Public funding was applied for on the basis that the project had a beneficial ecological effect. By 2007 the consortium was ready to test the scrubber technology on a tanker, the MT 'Suula'. The testing proved successful with the scrubber type capable of working in any sea area and meeting the target set by the IMO legislation.

The technology is ready to be installed onboard vessels. Procuct training for ship designers, shipowners and ship staff is important in the scrubber introduction phase.

What can be deduced from the cases and brief mapping of the companies is that the SOx scrubber development is at a very advanced stage and thoroughly tested for the benefit of

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[52] Alfalaval, *Meet Sulphur Regulations with the Best Economical Solution*, Company Brochure

[53] Hamworthy*, Exhaust Gas Cleaning Systems*, Company Brochure

[54] http://www.simic.net.cn/news_show.php?lan=en&id=95526

[55] Wärtsilä, *Exhaust Gas Scrubber Installed Onboard MT 'Suula',* June 2010, Public Test Report

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entrepreneurial experimentation. These products need to be installed upon vessels in order to meet the 2015 targets of Sulphur reduction.

3.4. Market formation[56]

There is already a well formed market for 'scrubbers' on land already for use on power stations. At sea and with regard to the exhaust gas cleaning systems the market is still at an infant stage although slowly expanding.

As previously outlined in order to meet the requirements from IMO and the EU to reduce sulphur, ship-owners have two options: to use low sulphur fuel or install scrubber technology. Whilst most ships can run on low sulphur fuel, for the benefit of this TIS scrubbers offer more market potential for the marine equipment manufacturers and shipbuilding for innovation.

'Bosch has estimated the market size if scrubbers would be fitted on all ships sailing in the ECA. Depending on the type of scrubber, the annual costs are estimated between €680mln (open scrubber) and €2bln (closed scrubber). These costs are based on a depreciation period of 12.5-15 years and 4% interest. 95% of the costs presented represent investment costs. Expressed as one-off investment costs, the investment costs for the current European SECAs amount between €16 and 46 bln€ for the next 30 years'.

It can be considered that a large part of this market will be developed through the retrofitting of vessels. 'Between 48 and 78% of the installation will be of a retrofit kind in the period up to 2020 depending on the ship type', it has been estimated. 'Retrofitting explains the relatively high market potential for the 2015-2020 period, assuming that all ships in operation will be retrofitted in that period, leaving only the newbuilding market for the period afterwards'.

Figure 12: Market Potential for SOx reduction measures (bn EUR) in SECAs, Ecorys, Green Growth Opportunities in the EU Shipbuilding Sector, Final Report, February 2012

	Current EU SECAs (Baltic / North Sea)	Estimate if Mediterranean were to be a SECA	
2015-2020	8-23	13-39	Mainly Retrofit
2020-2030	1-4	2-5	Mainly for Newbuilding
2025-2030	1-4	2-5	Mainly for Newbuilding
Cumulative 2015-2030	10-31	17-49	

[56] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

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The investments should be seen as an upper limit since some ships may switch to alternative fuel such as LNG or low sulphur. 'The impact of the worldwide fuel sulphur reduction to 0.5% in 2020 may have a significantly bigger impact' on the uptake of this technology as the global fleet will have to drastically reduce SOx emissions.

Since SOx regulation affects all ship this market has the potential to become rather large and mature given that both newbuildings and retrofits of new ships will have to install this innovation in order to meet the targets.

3.5. Legitimation

In order to assess the legitimacy of this TIS in the case of 'scrubbers' a closer look should be given to the acceptance of the technology by the classification societies who test for compliance with rules and secondly the ship-owners who ultimately invest in the technology. These two actors are the primary influences of legitimacy.

Classification Societies[57]

The Classification Societies carry out tests on new innovations and already existing/established products in order to ensure that they comply with the regulations set out in the maritime sector. They then issue a certificate to state whether or not the system or product complies with the rules and is acceptable to be installed onboard vessels. This guarantees the highest level of safety and legitimacy of the product within the market.

Taking the case of the Wärtsilä Scrubber development, certifying bodies were included at an early stage of the process in order to begin the process of certification of the product. A brief overview of the process will be given in order to show the extent of the tests needed for legitimacy.

'The certification process was started in accordance with IMO Resolution MEPC.170 (57). These regulations were slightly improved when the IMO in July 2009 adopted IMO Resolution MEPC.184 (59)'.

'These regulations define limits for parameters which were measured during the tests. The accredited independent body, Pöyry Finland OY, carried out measurements and the tests were performed with both high (3.4%) and low Sulphur (1.5%) heavy fuel oil'.

The tests carried out came to four conclusions:

1. Measured sulphur dioxide removal efficiency was 100% for all operating conditions, throughout the load range, even when using high sulphur fuel;
2. The scrubber fulfils all the effluent quality requirements due to an efficient water treatment unit;
3. Nitrate concentrations in the effluent are under IMO limits;
4. Under MARPOL regulations, it is mandatory to keep certain exhaust gas cleaning system documents onboard. All MARPOL related documents were approved during the certification process.

Fulfilling these requirements and other technical specifications means that a classification society can grant this product a certificate, providing it with legitimacy. The product is then fully marketable.

[57] Wärtsilä, *Exhaust Gas Scrubber Installed Onboard MT 'Suula'*, June 2010, Public Test Report

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Given the fact that the scrubbers of the aforementioned companies Hamworthy, Alfa Laval / Aalborg and Wärtsilä are available to buy on the market means that they comply to the regulatory requirements set out and provided with strong legitimacy showing that the TIS is in alignment with current legislation.

Ship-owners[58]

In order to comply with the regulations set out by the IMO and EU ship-owners have to make a significant investment if their vessels are to have a 0.1% sulphur limit in the ECAs as from 2015. It has become clear that there is a slow uptake of innovations to ensure compliance and therefore would call into question the legitimacy of the technologies available within this TIS. In order to make a brief assessment of the legitimacy a closer look should be given to the position of the ship-owners in this case.

The European Community Shipowners' Association (ECSA) outlines their position to the discussion in their 2010-2011 Annual Report. With the EU revision of the EU Sulphur Directive in 2011 ECSA 'stressed that no new elements going beyond MARPOL Annex VI should be included'. The draft proposal included the requirement of the 0.1% sulphur limit in 2020 for passenger ships in non-ECA areas. The Ship-owners do not 'understand why the provisions on equivalent compliance and protection in the event of non-availability of compliant fuel have not been fully aligned with MARPOL Annex VI'.

The industry has expressed concerns that a modal shift could result from sea to land transport as a direct effect of the amendment to the legislation. 'This result would be counterproductive for the environment and lead to increased external costs'.

The ship-owning community has also carried out an analysis on the 'toolbox' to meet requirements of the % sulphur limit such as the innovations in scrubbers, LNG and availability of low-sulphur fuel and came to the conclusion that they would not be available by 2015. 'Consequently the industry insists on an extension of the 2015 application date one way or another'.

The legitimation of the innovation in question is still uncertain from the point of view of the customer. Legislative finality may give added weight to the legitimacy of the TIS when the amendment to the regulation has passed all the hurdles within the European decision making process. This would thereby encourage the uptake of the tools to meet the requirements.

3.6. Resource mobilization

The true resource mobilization, looking at the greening of technologies and in particular the scrubbing systems is very difficult to quantify. The reason of this being is that many of the companies involved in this TIS are already well established on the markets and these activities are seen as an extension or natural development of the products which they already research and innovate.

Given the focus on the barriers to the innovation of the technologies and systems the following conclusions can be drawn:

[58] http://www.ecsa.be/ar/Rapport%202010-2011.pdf

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- *Volume and Quality of Human Resources:*

  On the whole it could be said that there is a general shortage of engineers needed to carry out the activities which companies are currently undertaking. Therefore it can be assumed that given the ageing population and image problem (shipbuilding as a dying industry) of the sector this is a negative trend which needs to find solutions to be reversed. If production increases dramatically as a result of this TIS becoming more mature and established then it could feel impeded by the lack of a skilled workforce. This having been said, does not apply to all countries in Europe.

- *Attracting Investment to Innovate:*

  Whilst many companies conduct R&D in-house and invest around 4% of their turnover there needs to be a mobilisation of resources to ensure market up-scaling of their products. The perceived lack of investment by the customer will be explored later in this study.

3.7. Development of Positive Externalities

The biggest positive externality resulting from the emerging TIS for green technologies within the maritime sector are the consolidation of the European market position vis-à-vis the rest of the world as explained below.

Generally speaking the European maritime sector benefits from the strong position it has carved out for itself in building high-tech complex vessels and equipment. It has market dominance in several niches, namely, cruise, dredging and offshore. Overall the sector benefits from the green emphasis on industry by society and policy makers. This has 'helped to create a spill-over's towards shipbuilding, and internal as well as cross company knowledge transfer. The geographic clustering of companies in several regions along with the historical ties that have built trust between them, has further enhanced the innovation process by ensuring various players across the value chain participate.

It can be assumed that the European maritime industry is well placed to capture the market for development, innovation and implementation of 'green technologies'. As seen with the narrowed focus on 'scrubbers' the marine equipment manufacturers are in a leading position since they are ahead in developing technologies over overseas competitors. This is a trend also seen in other technologies such as ballast water treatment systems, etc.

This positive externality can be assessed as good to very good for the innovators of the technology, the marine equipment suppliers. However their position in the value chain 'limits the amount of control that can be exerted' to further strengthen the TIS for green maritime technologies and therefore all actors have to be onboard.

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Step 4: assessing the functionality of the TIS and setting process goals[59]

Having studied the dynamics of seven key processes in step three, it can be concluded that the TIS is functioning steadily and already in a developed phase even though there are certain barriers which need to be overcome in order achieve the most optimum form of function. These will be looked at in more detail in step five.

Given the fact that the maritime sector is a truly globalised industry it would be useful to compare the TIS for green technologies and policies supporting green market opportunities in the EU with the rest of the world. A closer look will be given to the markets in China, Korea and Japan. These countries are considered to be the European Shipbuilders strongest competitors.

- *China:*

  China can be considered one of the largest producers of ship in the world. This development has happened over the last 10 or so years through massive investment by the government on improving the quality of the vessels built there.

  There are extensive R&D programmes in place but these are not focussing on the 'greening' of vessels rather mainly on the production process and the reduction of delivery times. What is interesting to note is that China is very quickly able to move into new markets.

  China benefits from 'joint ventures' established with shipyards in Korean and Japan. 'The purpose of these joint ventures is the transfer of knowledge, skills and production know-how. As such green policies adopted by the Korean and Japanese yards have been transferred to the Chinese yards. (spill-over effect)

  The interest in the greening of the sector is, however, gaining ground. In 2011 several conferences and congresses have been hosted in China looking at this topic. 'More and more research into the greening possibilities is carried out by Chinese universities. This may be a precursor for a stronger Chinese R&D focus on the subject in the future'.

- *Korea:*

  R&D in Korea is often conducted within companies which although are private have strong government relations. The majority of projects are closed to the involvement of partners from outside the Korean community. In this respect Korean companies have placed a strong emphasis on the 'greening' of the maritime sector in order to strengthen its competitiveness.

  'The slogan of this campaign is 'beyond green challenge and towards new opportunities'. Apropos this, many companies have also adopted green business models with a focus on sustainable corporate and social responsibility.

  The Korean government with its 'greening' targets created a programme to guarantee funding for cleaner ships. 'The programme is led by the Korean Finance Corporation (KOFC), a government owned company. KOFC operates a ship financing plan that includes a form of interest reduction on loans for cleaner

[59] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

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vessels. Ship-owners who buy a more environmentally friendly vessel, which is often more expensive than a standard vessel, can obtain the loan with lower interest rates'.

- *Japan:*

  In Japan the maritime industry is perceived as being rather closed although the general R&D trends show that the government has a clear greening policy with 'priorities like reducing the CO_2 emissions and research into new fuels.

  Much of the research conducted in Japan has a focus on the use of LNG as an alternative fuel and renewable energies given that the country has very limited natural resources.

Having looked at the cases above it is clear that although activity exists in all three countries Japan and Korea could be considered to be the two with a TIS for 'green technologies' which are more in the maturing stages of development like Europe. Both countries have governmental policies and a strong value chain which assist in the uptake of new innovations. Although the general perception which can be drawn from this brief look is that they need to develop further to reach the same high levels of functionality as that of Europe.

Step 5: Identify inducement and blocking mechanisms

In the previous chapters we have seen what is motivating the development of the TIS for green technologies and the particular case for sulphur abatement systems. This chapter will provide more focus on the barriers the TIS development faces. It will firstly look at the green technologies in a more general way and then more specifically looking at the barriers impeding the market uptake of scrubbers.

Green Technologies[60]:

The availability of 'green technologies' which can be installed onto ships is not considered a barrier for the uptake of innovations. Research has shown that the following themes can be identified as barriers to the development of this TIS:

- *Lack of financing*

  In this current climate of economic 'crisis' there seems to be a real reluctance from banks to provide funding for technology development as the risks involved can be seen as being too high. This mainly affects many newly developed technologies.

- *Costs and lack of standardisation of class rules*

  The classification societies are the body which sets technical standards for the maritime industry and also ensure that companies comply with the rules that have been put in place. 'Sometimes class rules are defined narrowly with the consequence that only specific technologies can be applied to fulfil them. This leads potentially to less diversification at the development and diffusion side. However…the role of the classification societies may also trigger development

[60] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

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of new technologies as these organisations are increasingly involved in and aware of new technology development, which may possibly influence that adaptation'.

The lack of standardised rules and the mutual recognition of class certificates also lead to an additional financial and time burden and therefore may not be an incentive for marine equipment companies to innovate new technologies.

- *Availability of skilled labour*

  In several European Countries the shortage of skilled labour can be perceived as a barrier. A lack of engineers as a result of demographic change and sector image problem makes it difficult for companies hire sufficient qualified staff. The ageing population problem will not make this situation easier in the future.

- *Knowledge bottleneck*

  'Not all innovations developed by the shipbuilding and marine equipment industry appear to be considered effective and reliable by shipping companies and ship owners…this may indicate a knowledge bottleneck …as a result…[they] are reluctant to invest in these technologies and hence to build up credibility in technology'.

- Conservatism in shipping industry

  The shipping industry is seen as rather conservative. Therefore many investors seem to be 'risk adverse' when it comes to the investment in market driven innovations.

SOx – Scrubbers:

Taking a closer look at the innovation of scrubber's barriers can also be seen with their uptake and will be looked at more closely. Although what is apparent with the development of the technology is that there are no impediments and there is a sufficient supply. The following areas deserve a closer look:

- *Reliability of innovations*

  It could be argued that although the scrubbing technology has been established and widely used for land based projects there is not enough application of the product in the maritime sector to guarantee its overall reliability. When looking at meeting the targets in the ECAs the ship-owner has two choices. The first low-sulphur fuels and the impact it has on emissions is already well established. 'If the reliability of a scrubber is questioned, however, shipping companies may run the risk that failure of the scrubber may result in penalties or in the need to use low sulphur fuel'.

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- *Conservatism*

  Seeing that there is a need to install scrubbers today in order to meet the 2015 targets and the fact that there has been a very slow market uptake in general could be put down to the conservatism of the sector.

  In this case the reluctance to install scrubbers could be understood. 'Until the regulation enters into force, the benefits associated with the investment are purely of an external nature'.

- *Regulatory uncertainty*

  Although the rules of MARPOL and the IMO are clear there is still uncertainty about the date of introduction for the SECAs and amendment adoptions of the EU. Until the directive is approved (expected 2012) uncertainty will remain.

- *Uncertainty of low-sulphur fuel price*

  The projected cost 'additional costs for using low-sulphur fuels have a major impact on the business case for a scrubber'. If the fuel is cheaper than the cost for an investment in a scrubber then it does not make business sense to invest in the latter.

Step 6: Specify Key Policy Issues

Having analysed the blocking mechanisms or barriers to the development of the TIS this chapter will look at policy measures which can be put in place to reduce the systematic weaknesses.

The following measures, if considered and implemented, could be considered a stimulus for the development of the TIS for green technologies[61]:

- *Financial stimulation:*

  Financial models which stimulate investment in 'green ships' should be pursued. 'The rationale for such support lies in the fact that further reducing of the environmental footprint is a widely recognised goal and financing of higher investments for more environmentally friendly vessels cannot be expected from market players alone. Organisations such as the European Investment Bank should be looked at in this instance for support'.

- *Market based measures:*

  This is a good instrument to promote innovation by targeting prices to change market conditions and desired uptake of innovation. However, the overall

[61] Ecorys, *Green Growth Opportunities in the EU Shipbuilding Sector*, Final Report, February 2012

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impact this has on competitiveness should be considered. Taxes for example can have a stifling effect on the overall competitiveness of the shipping industry. Although this tax is used in the right way, then 'it can work in accordance with the polluter pays principle, which will have an overall benefit for wider society.

- *Further expansion of regulatory drivers*:

  By being certain that regulatory burden does not stifle competition further expansion of ECA's could be considered (the Mediterranean) in order to strong arm investment for green technologies.

  Regulation has to be certain and no indecisive. This indecision and uncertainty leads to the slow uptake of innovation as already seen in this paper.

- *Strengthening of European RDI strategy:*

  More emphasis should be placed on demonstrators of technologies which could act as the 'convincer' for ship-owners, showing the effectiveness of innovation and the possible risks associated with investment.

  'Specific R&D in specialised production processes for retrofitting. In addition more complex, high value retrofits but with a clear return could be developed in Europe as this builds the comparative strength of Europe's shipbuilding industry.

- *Place more emphasis on a green 'value chain':*

  Support the strengthening of maritime clusters and value chains in their 'greening actions'. An emphasis could be placed on promoting R&D synergies between different actors to meet green goals.

- *Mutual recognition of certificates and standardisation of rules*

  The marine equipment manufacturers could benefit from the mutual recognition of class certificates by classification societies and the standardisation of rules. This would see a reduction in the administrative burden and costs companies face in favour of more investment in R&D and new innovative products.

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2.4 Versatile, efficient and longer wagons for Intermodal Transport

Title	**Versatile, efficient and longer wagons for Intermodal Transport**
Mode	rail ☐, road ☐, air ☐, maritime ☐, inland waterways ☐, intermodal ☒
Partner	UNIZA

The pathway from an innovative idea into the railway market is not an easy and smooth way!
A jointly risk-shared program between the Commission and the industry should help introducing the innovative products into the railway transport system for the benefits of the European citizen and the European economy. (D.L. Cadet, 2012)

It is commonly accepted that in surface transportation, the rail mode is, in theory, more appropriate for transporting large and heavy consignments over long distances whereas road mode is more appropriate for small and light consignments over short distances. Between these extremes there are many transports' demands that may choose one mode or the other one.

In reality however, road transportation wins the mode choice in 80% of the cases Indeed nowadays about 1,5 billion tkm (ton kilometres) are transported in Europe by lorry at distances further than 150 km, conversely only 0,4 billion tkm are transported by train (VEL-Wagon, 2011), this entails important costs for fossil fuels.

There are many possibilities how to increase quality in rail freight transport. One of them is the optimisation of the current wagon fleet to improve availability, flexibility, marketability, commercial speed, cargo security and cost. This optimisation has to respond to the actual trends of transport demand and has to be in consonance with the required and feasible infrastructure upgrades. The future of the rail freight transport is possible to see in its integration as an inseparable mode of transport within the intermodal transport. To reach this goal, development of new types of special "intermodal" wagons, suitable for transport of containers of different types.

The focus in the described case is oriented towards research and development of the freight rail wagon for intermodal transport, which would help to increase its efficiency and therefore also its competitiveness over other modes of transport. Special attention is put on the use of large-sized wagons in the context of intermodal transport. The EC supported FP7 project VEL-WAGON has been chosen for the case study, focusing on the TIS for large-sized wagons for intermodal transport.

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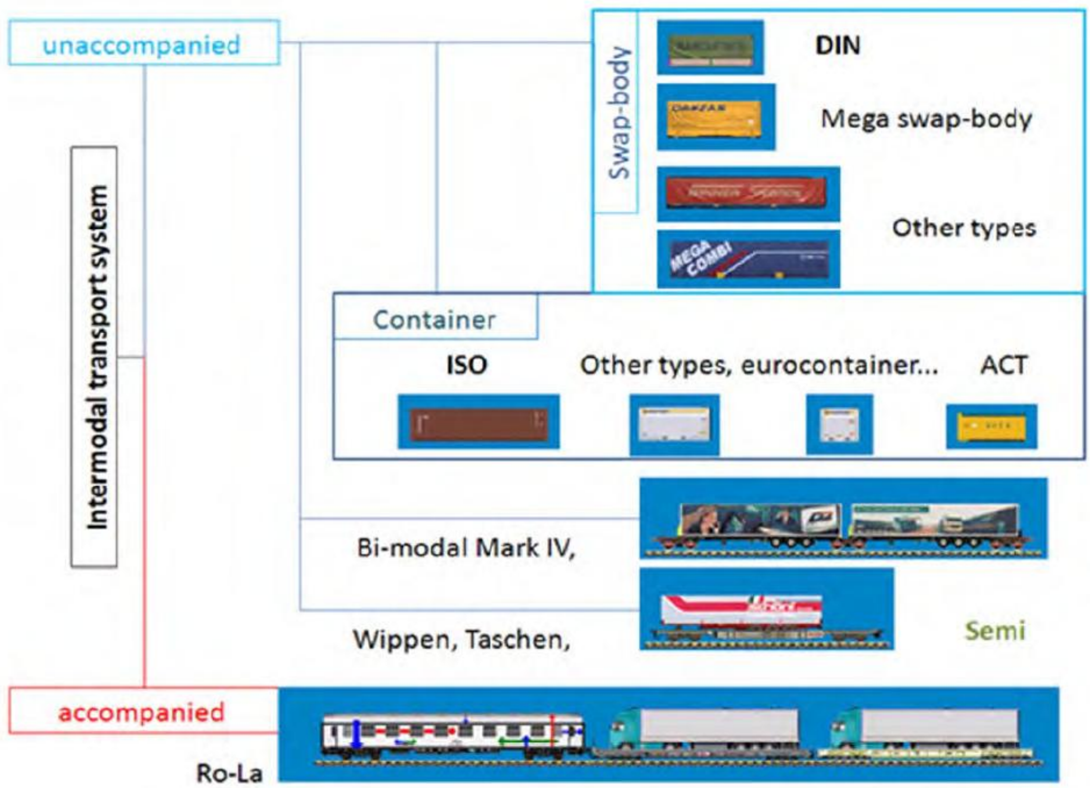
Step 1: the starting point of analysis: defining the TIS in focus

According to the United Nations (Economic Commission for Europe), the European Conference of Ministers of Transport (ECMT) and the European Commission (EC): "*Intermodal transport is the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes.*"
The concept of intermodal freight transport was introduced with great expectations in the 1960s. It should:

- transfer a large portion of road transport to railways,
- reduce traffic congestions on roads,
- improve the environment by more environmental friendly railway and water transport,
- increase the quality and speed of transport,
- improve the safety of transported goods,
- reduce costs and time in material handling during the transportation process.

Figure 13: Types of intermodal transport (rail/road)



Source: VEL-Wagon Consortium

The production system in which wagons are utilised has an important effect on the productivity thereof. Intermodal and company-dedicated wagons tend to run in point-to-point direct configurations with short turn-over times, while other conventional wagons may make use of the single wagon load system where they can be re-marshalled many times,

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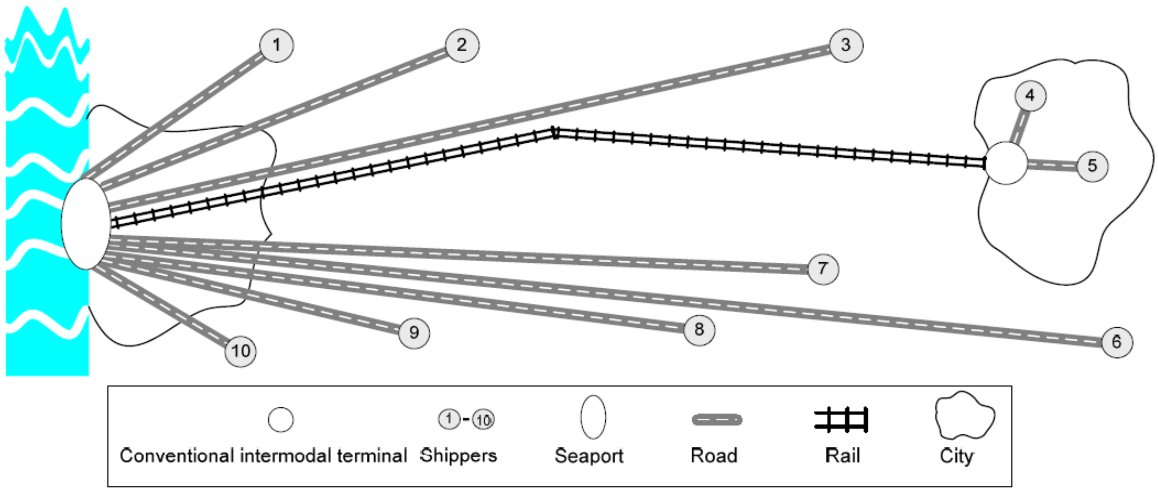
reducing by this their total yearly mileage. A compromised solution has to be found to increase mileage while being flexible. Hence in a nearby future the productivity of wagons has to continue increasing in order to achieve better competition levels against road. This challenge will pave the way for the excellence in freight railways and will enable a more sustainable future of transportation.

The **intermodal traffic** in the EU is divided in two main segments, hinterland and continental transport.

The segment of **hinterland transport** covers the transport of goods packed in containers, supposed to be transported by container ships, e.g. from inland terminals to ports and vice versa. The area from which the containers are delivered to a port for shipping forms that port's hinterland. The containers almost exclusively carry trans-continental cargo, i.e. goods with an overseas origin or destination, and only a very small proportion of them contain European freight transported by coastal shipping services (DIOMIS, 2009).

Figure 14: Hinterland transport



Source: Woxenius, 2010

The segment of continental transport serves the transport of goods between dry land (continental) destinations. It includes short-sea traffic, for example traffic in between the UK and continental Europe, between inland terminals and ferry port facilities. For continental traffic intermodal customers usually use "European" equipment", i.e. domestic freight containers, swap bodies, or liftable semi-trailers (DIOMIS, 2009). **Hinterland container transport** is participated by ISO Containers, mainly 40ft (60%) and 20ft (40%), 45ft containers have a small share and are employed principally in Northern Europe and Short Sea Shipping. The proportion of 40ft containers is growing, especially the Hi-Cube type, in 2020 (if trend continues) almost 70% of the containers will be 40ft Hi-Cubes. Today the average gross weight of a loaded TEU[62] is 12,8 t. In 2020 the TEU weight will not vary very

[62] The **twenty-foot equivalent unit** (often **TEU** or **teu**) is an inexact unit of cargo capacity often used to describe the capacity of container ships and container terminals. It is based on the volume of a 20-foot-long

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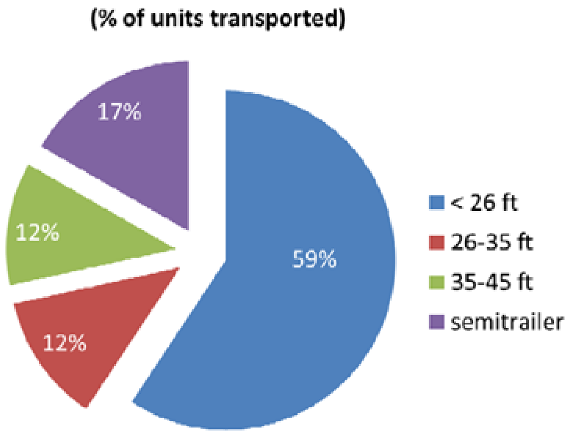
much or even it may decrease. Goods transported in containers can be classified in 4 groups: light goods (~6 t/TEU, 43%), medium light goods 14 t/TEU (~14 t/TEU, 30%), heavy goods (~23 t/TEU, 19%) and very heavy goods (~30 t/TEU, 8%). The optimal wagon length for such combination of units is 80ft. Hence, a popular wagon nowadays is the 6-axled 80ft wagon; however this wagon may be over dimensioned in terms of deadweight and axles for many transport cases.

Figure 15: Continental intermodal transport in EU



Source: VEL-Wagon Consortium

Continental transport is participated mainly from semitrailers, swap bodies and tanks, bulk and silo containers. The semitrailer segment has experienced an important growth during these last years. The average gross weight (VEL-WAGON Newsletter no.2, January 2012) of a loaded semitrailer is 27 t. This weight is apparently decreasing, as semitrailers carry more and more volumetric goods. 45ft unit is quite common and is growing in share. Short tanks, silos and short swap bodies represent the majority of transported units. The light goods in continental transportation tend to travel longer distances than the heavy goods. Hence, it is expected to see a decrease of the average TEU weight for continental intermodal trains. The rolling stock employed for continental transportation is quite varied. The 60ft long wagons predominate but >104ft articulated wagon with two pockets for semitrailers seem to be the trend.

(6.1 m) intermodal container, a standard-sized metal box which can be easily transferred between different modes of transportation, such as ships, trains and trucks. One TEU represents the cargo capacity of a standard intermodal container, 20 feet (6.1 m) long and 8 feet (2.44 m) wide. There is a lack of standardisation in regards to height, ranging between 4 feet 3 inches (1.30 m) and 9 feet 6 inches (2.90 m), with the most common height being 8 feet 6 inches (2.59 m). Also, it is common to designate 45-foot (13.7 m) containers as 2 TEU, rather than 2.25 TEU (source: Wikipedia).

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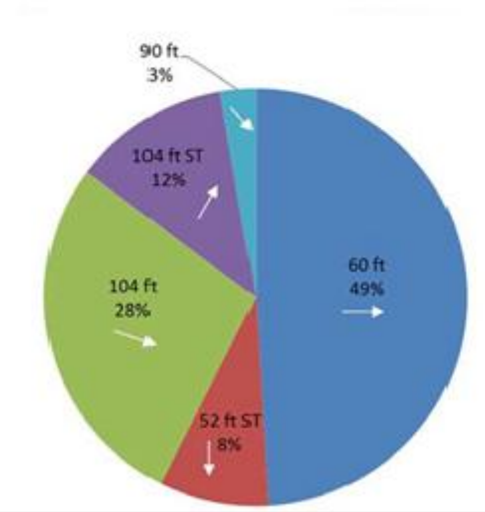
Figure 16: Wagon fleet for Continental Combined Transport



Source: VEL-Wagon Consortium

The TIS under study in closely connected with the FP7 project, with participation of the consortium of EU institutions, developing the versatile, efficient and long wagon for intermodal transport in the European transportation with the acronym VEL-Wagon (www.vel-wagon.eu). The project is targeting the above mentioned concepts by analysing the future necessities on light and versatile wagons that will deploy better performance and quality to compete against the road.

VEL-Wagon pursues strongly the knowledge expansion in the following subjects:

- Future rail-road intermodal transportation market in Europe, especially when it comes to the utilisation of intermodal transport units (ITU) and freight wagons;
- Future wagonload transportation market in Europe, especially when it comes to conventional wagonloads and freight wagons utilization;
- Overview of infrastructure limitations, to extended wagon lengths, axle loads and loading gauges from the technical and economic viewpoint. An effort is put on identification and assessment of necessary infrastructure capacity enlargements, implications of axle load increase, study of suitable corridors for the new type of wagons;
- Wagon enlargement possibilities, especially when it comes to length between bogie pivots, length between pivots and couplers, loading height and loading gauge for ITUs (also semitrailers) and conventional units, tare weight, heavy solicitations on frame as well as dynamic and static properties of such wagons;

Secondarily the TIS is touching upon the following aspects:

- Future necessities on bogies for VEL-Wagon, increased axle load vs. increased number of axles, technical implications and economics thereof;
- Economic implications, life cycle costs (LCC), because of higher demands on the infrastructure and higher price of the wagons due to the increased technical demands (higher axle loads and/or increased number of axles per bogies and increased speed.

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The expected result should:

- increase the loading factor (amount of TEUs per train) in 10%;
- decrease the amount of axles in 15%;
- decrease the gross train weight in 7%;
- improve aerodynamics (fewer gaps);
- decrease noise emissions (fewer axles);
- decrease maintenance (fewer axles).

Regarding its effect on the infrastructure and operations, it should contribute to reduce the energy consumption per transported TEU, not only because it offers better loading factors, but also because it allows employing less deadweight and fewer axles (approx. 17% saving in energy consumption against a reference case), save on maintenance (due to reduced number of axles) and reduces the noise emission (due to reduced number of axles).

Step 2: identifying the structural components of the TIS

2.1 Actors

The studied case concerns rather small part of a general system shown in Figure 17. First of all we shall describe the capabilities of the participating institutions:

The institutions taking part in the analysed technological innovation system are:

- **Technische Universität Berlin (Berlin Institute of Technology),** Fachgebiet Schienenfahrwege und Bahnbetrieb (Chair of Track and Railway Operations) and Fachgebiet Schienenfahrzeuge (Chair of Railway Vehicles), Berlin, Germany,
- **Kungliga Tekniska Högskolan (KTH Royal Institute of Technology),** Train Traffic Group, Stockholm, Sweden,
- **University of Žilina, Žilina, Slovakia,**
- **Tatravagónka a.s. Poprad, Poprad, Slovakia.**

The project is coordinated by the Chair of Track and Railway Operations of Berlin Institute of Technology.

This TIS is interesting and significant in that aspect that apart from comprising the academic institutions, oriented traditionally towards research and education in the area of transport, one of its members is one of the largest freight wagon manufacturers in Europe – Tatravagonka Poprad.

The number of wagon manufacturers in Europe has decreased significantly in recent decades. Recently there are four major wagon manufacturers in Europe:

- IRS Group has its headquarters in Luxemburg, and subsidiaries producing wagons, bogies and forgings in 14 European locations including Romania and Serbia
- Tatravagónka Poprad in Slovakia,
- Greenbrier Europe, with a plant in Poland,
- LEGIOS in the Czech Republic.

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These four companies represent more than 80% of total production capacity in Europe. Several other smaller companies also manufacture freight wagons. However, most of these do not manufacture intermodal wagons, which require too high a minimum capacity to be manufactured at a competitive price, or they focus on special wagons.

While the University of Žilina is the traditional research and development partner of the manufacturer Tatravagónka Poprad, the approval of the FP7 project provided unique opportunity to create **a new international network for development and innovation** on the European scale.

2.1.1 Technische Universität Berlin (Berlin Institute of Technology)

The Technische Universität Berlin (Berlin Institute of Technology - TUB) is in charge of the education of some 30.000 students and 1800 Phd-students. In addition to the core subjects in natural sciences and engineering, the TU Berlin also has faculties and institutes specialising in planning, humanities, social sciences and economics. Therefore not only hardware as vehicles, ships and planes are developed but also traffic planning, sociological and environmental aspects of transportation are covered.

At the Chair of Track and Railway Operations the holistic view of the railway system is regarded as the most important aspect in the fields of research and education. The competencies of the chair are organized in the three areas railway operation, railway track and strategy. The optimization of operation processes, efficiency, energy consumption and environmental impacts are the basic targets for all areas of research. Innovations in rail freight traffic represent one of the main research fields in the area of strategy. In the track laboratories measurements are taken, e.g. for the analysis of the acoustic behaviour of absorption elements.

The Chair of Rolling Stock acts in railway research and teaching concerning the rail vehicle as one element in the complete system of rail traffic and transportation. The work is done either experimentally with a well-equipped laboratory for dynamic vehicle measurements and also numerically with different software tools. The different software enables crash simulations and structural integrity by FEM (finite-element method), simulation of vehicle running behaviour as derailment safety and comfort by multi body simulation software, Life Cycle Costs software, and noise predicting software. The testing laboratory and the workshop are equipped for validation measurements to calibrate and verify the software results for the vehicle and the track, acoustical measurement equipment.

2.1.2 Kungliga Tekniska Högskolan (KTH Royal Institute of Technology), Train Traffic Group, Stockholm, Sweden

The Railway Group at the Royal Institute of Technology Stockholm (KTH) is the leading research institution in rail traffic and technology in Sweden. It pursues interdisciplinary research and offers academic education in both railway technology and railway traffic planning, related to both freight and passenger traffic.

The Railway Group consists of researchers from different divisions at the Royal Institute of Technology, well covering the railway system and its subsystems from rail logistics and management to vehicle and infrastructure technology and train operations. The research

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programmes aim to develop new methodology and contribute with scientific knowledge that can develop the railways as a means of transport and make rail more attractive to customers and more profitable for the railway companies.

The Railway Group is participating in several international projects, e.g. the EU FP-project TOSCA, two ERANET-projects (TESS – Trans-European Temperature-Sensitive Intermodal Shipments; MINT – Model for Intermodal Terminal Networks), and the EU-INTERREG project SCANDRIA, and is cooperating closely with railway undertakings, railway authorities and locomotive and rolling stock suppliers.

Several research projects have already led to improvements in new railway vehicles as well as infrastructure and train operations.

The Railway Group's research fields and competences cover the following main areas:

- railway traffic planning and train operations,
- infrastructure development and capacity analysis,
- intermodal and multimodal terminals,
- wagons and locomotives – conceptual design and technology,
- running dynamics and wheel-rail interaction,
- railway economics and transport cost modelling,
- market analyses,
- railway management and transport policy.

2.1.3 University of Žilina, Žilina, Slovakia

University of Žilina (UNIZA) is a leading higher education and research institution for transport domain in Slovakia with an international renown. Its Centre for Transportation Research –CETRA aims to put to better use the human resources and technological equipment of the University of Žilina developing scientific and research activities in the sphere of transport; creating and supporting multidisciplinary, project-oriented research teams. The Centre is involved in basic and applied research of road, railway, water and air transport, transport electronics and mechanical engineering, applied mathematics, information technologies, management, military transport and forensic engineering.

The main orientation of the research at the University is oriented towards:

- transport equipment, means of transport,
- transport network,
- transport technology,
- modelling and optimisation of transport processes,
- information technology in transport,
- safety of transport,
- quality and efficiency in transport,
- environmental, social and human aspects.

2.1.4 Tatravagónka Poprad a.s., Poprad, Slovakia

Tatravagónka Poprad, (TVP) presently ranks among the most important producers of rail freight vehicles and bogies in Europe. It has more than 85 years of experience in mechanical

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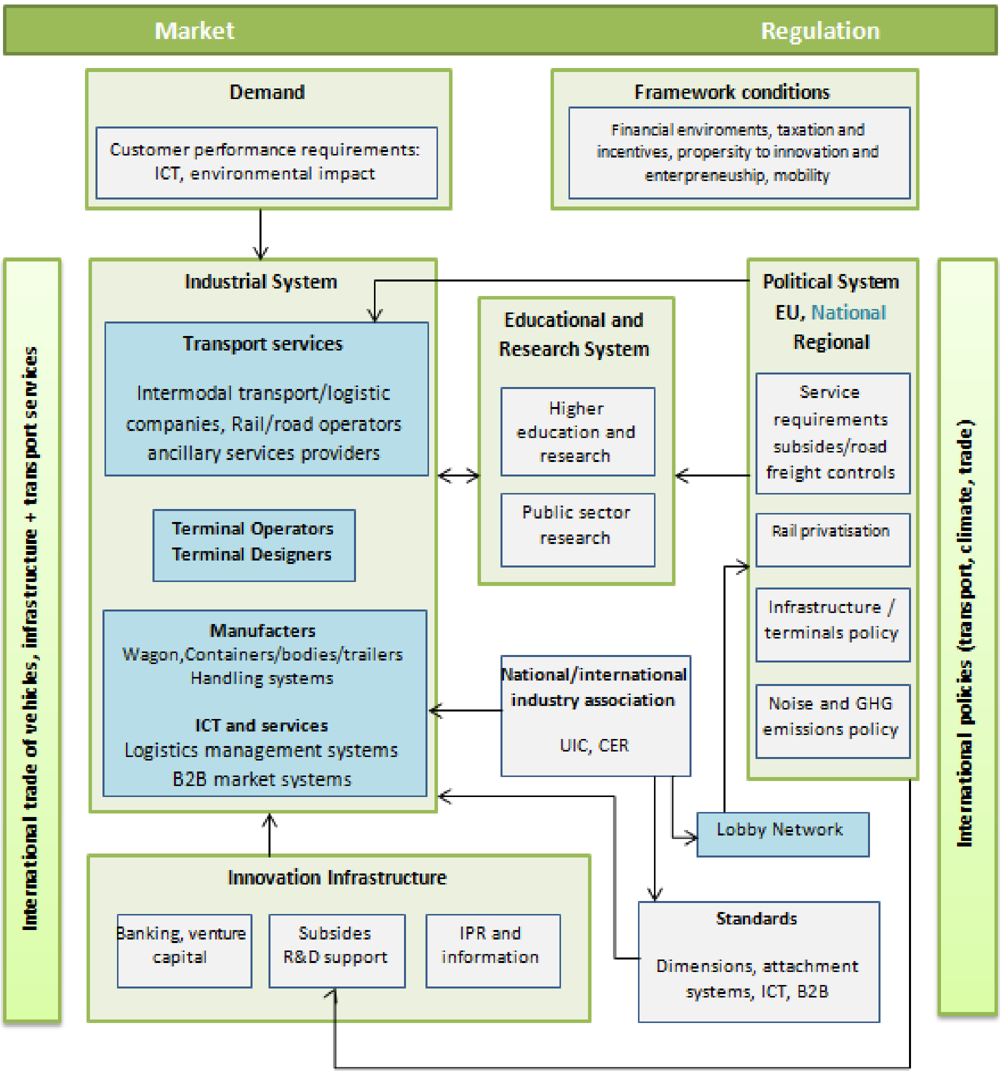
engineering where it has found its stable place thanks to modern, still developing technologies, quality constructions, qualified working power and stable partners.
Due to ability to construct any kind of wagon TVP has become a reliable partner for railways all over Europe, the condition of fulfilling its production plan for future years.
With relying on its long-standing tradition of its development and construction, its mission is to be a reliable partner capable of fulfilling individual as well as the specific requirements of each customer regardless of time.
The line of business of this project partner is:

- development, production and sales of rail freight and passenger transport vehicles and their components, special-purpose versions of such vehicles, rail vehicle subgroups,
- special-purpose metal-working and welding machines and equipment,
- repairs and maintenance of railway vehicles,
- metal-works.

Figure 17: General structure of the intermodal innovation system



Source: Market-Up Consortium

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Considering the roles of these institutions in the structure of the intermodal TIS as shown in Figure 17, we can consider:

a) Tatravagonka Poprad as part of the Transport services – manufacturer of wagons for intermodal transport
b) The participating universities are part of an international Educational and research systems, providing the Industrial system with the results of their common research.

All other parts of the TIS are external to the consortium, i.e. to provide marketable results, usable by the manufacturers as well as the service providers; it is a must for the participants to make research on the demand of the future customers. As the rail has rather strict interoperability, safety and security measures, restrictions given by EU and national political system have to be observed. These are often formulated by UIC and provided in the form of European and/or national regulations and standards.

For the product to be marketable, performance against technological and economic, indicators of recent solutions and fulfilment of the customer demand and expectations must be proved and documented.

2.2 Networks

A number of different external networks are relevant for describing the structural components of technological innovation system.

There are two main networks investigating in intermodal road/rail sector.

The first is International Union of combined Road-Rail Transport Companies UIRR which has 18 member companies and has a working structure that is classical for a commercial company of this type, that is to say a General Meeting of Shareholders, a Board of Directors, member companies, and internal working committees or committees working in co-operation/consultation with external entities.

The second is the International Union of Railways UIC which has 82 active members (including the railways from Europe, Russia, the Middle East, North Africa, South Africa, India, Pakistan, China, Japan, Korea, Kazakhstan, and companies operating worldwide such as Veolia Transport), 80 associate members (including railways from Asia, Africa, America and Australia) and 35 affiliate members (related or ancillary rail transport businesses or services) with main goal to promote rail transport at world level and meet the challenges of mobility and sustainable development.

According to 2001 White Paper where the European Commission mentions a 38% rise in the European domestic freight market (all transport modes included) over the next ten years what predicts a rail freight market share of 15% in the year 2020. According to this rail mode will play a significant part in the modal shift needed for sustainable the mobility, the environment and the competitiveness of the European economy. This led the Combined Transport Group of the UIC, in partnership with the UIRR, to commission a study on the infrastructure capacity reserves of the European rail network. The outcome of the Capacity Study, published in May 2004, highlighted that, in the current context of infrastructure saturation, in order to realise the modal shift towards rail, several measures need to be taken. These measures range from investments in rail and terminal infrastructure, technical-operational improvements, to the fostering of the working procedures of all the stakeholders in combined transport rail-road. The Capacity Study also showed that individual "best practices" to deal with limited resources or to provide a qualitative and more efficient service

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exist, but that they are not sufficiently known to and anticipated by other stakeholders at European level. DIOMIS (2008)

One of the significant initiatives in the rail/road sector of intermodal transport in the EU is the network developed within the project DIOMIS (Developing Infrastructure and Operating Models for Intermodal Shift) lead by UIC. Project DIOMIS was performed in two phases. In late 2007 result of the first phase of DIOMIS I was completed and summarised in the Agenda 2015 for Combined Transport in Europe. The Agenda 2015 recommends a more efficient use of infrastructure, more infrastructure investments and more international coordination in order to synchronise improvement plans. The objective of the recent DIOMIS II report was to provide guidance from the rolling stock point of view for the planned modal shift.

For research of a versatile, efficient and long wagon for intermodal transport a VEL-WAGON project consortium as an international network was established, based on the principles of meaningfulness and contribution to the project.

Intentionally, three university departments with acknowledged experience on railway logistics, railway technology and railway economics are leading the proposal. A very important accompanying industry partner, Tatravagonka Poprad, has studied deeply the project implications, evaluated the risks and then took responsibility for the technical development.

Since a prototype or a real demonstration activity are not in the scope of the project, the necessity of having operators and other related stakeholders as partners was not a priority, which does not mean that their opinion is not essential as final users and thus potential clients of the wagon. With that aim an advisory board with selected persons belonging to main European stakeholders was created and if necessary, could be enlarged. These persons should bring the know-how and arguments for setting the correct project objectives (e.g. wagon requirements, statistical transport data, wagon costing limits etc.). Their implication should help to align the research results with industry expectations and criticism. The number of persons and companies that agreed to be part of the advisory board and the fact that they belong to different – but the most relevant – market actors in regard to their role (railway/intermodal operator, terminal operator, infrastructure provider) shows the great potential of the VEL-Wagon project results for the future market use.

It is supposed, that a larger number of stakeholders will be properly informed about partial project results, included in the network and their opinions integrated during the research progression.

The university departments are indeed aware of the limitations and requirements for the future wagons in Europe and have important and relevant data sources to be called and completed at lower cost and very efficiently. The departments' know-how complements in a synergic manner to offer a balanced and pragmatic research entrepreneurship.

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Subjects dealt with are:

- **TUB:** Intermodal transportation, Life-long cycle (LLC) expertise, railway associated logistics, railway operation and infrastructure planning, long train research (Area: Central and Western Europe)
- **KTH:** Single wagon traffic, train service costing and quality, economics of infrastructure utilisation, heavy load research, terminal integration (Area: Scandinavia, Western Europe)
- **UNIZA:** Terminal operation, technical development of railway vehicles, capacity of infrastructure and trains (Area: Eastern Europe)
- **TVP** as one of the most important producers of rail freight vehicles in Europe brings in its experience in the technical development of railway vehicles, its market know-how and the contacts to a number of potential users and customers of the new VEL-Wagon.

Having the final manufacturer of the new wagon as a project partner, all requirements are provided for a future exploitation of the newly proposed VEL-Wagon.

On the whole, the network is quite well balanced for achieving the project objectives, which will respond to important questions on the general research field of railway logistics and wagon construction.

2.3 Institutions

Institutions are the humanly devised constraints that structure human interaction. They are made up of formal constraints (e.g. rules, laws, constitutions), informal constraints (e.g., norms of behaviour, conventions, self-imposed codes of conduct), and their enforcement characteristics. Together they define the incentive structure of societies and specifically economies.

European and more over regional technical restrictions are the main concern for the development of large-size wagons. The characteristics of these restriction concerns mostly the infrastructure, necessary for loading and unloading of the large-scale wagons, technical parameters of rail tracks and the container terminals. These inflict the limits of the size of the wagons, their mass and load and also the construction materials. Important factor is also the geographic location – it is closely connected to the radii of the track bends, elevations, number of tunnels and their profiles, etc. Another important factor is the traffic load on the corridor supposed for the large-size wagons use, restrictions on the time of the day use and similar. The analysis of feasibility of the rail corridors use for extra-long and heavy trains in the EU has been published in (DIOMIS, 2007).

Some of the technical rules, restrictions, norms and constraints important for innovation policy of intermodal rail wagons are described below:

Pertinent list of rules (selection):

<u>TSI – Wag</u>

Technical Specification of Interoperability relating to the subsystem 'Rolling stock — freight wagons' of the trans-European conventional rail system notified under document number C(2006) 3345, text with EEA relevance 2006/861/EC) (Lex 334):

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I. Modules for the verification procedures: For the verification procedure of the requirements of Freight wagons the contracting entity or its authorised representative established within the Community may chose the following modules:

a) Type Examination procedure (module SB) for the design and development phase, in combination with a module for the production phase either:
- the Production Quality Management System procedure (module SD),
- the Product Verification (module SF);

b) Full quality Management System with Design Examination procedure (module SH2).

II. Innovative solutions of freight wagon:

When a freight wagon includes an innovative solution the manufacturer or the contracting entity shall state the deviation from the relevant section of the TSI – Wag.

The European Railway Agency shall finalise the appropriate functional and interface specifications of this solution and develop the assessment methods.

UIC 530-2 Wagons – Running safety

Conditions specific to wagons with two-axle bogies:

It is recommended that the distance between bogie pins be greater than 6,5 m.

It is recommended that wherever constructional features of the wagon permit, the overhang should be:
- 2,520 m between bogie pins and buffer heads, or 2,545 m between bogie pins and the coupling plane of the automatic coupler, for wagon ends without a crossover walkway or a footboard,
- 2,770 m between bogie pins and buffer heads, or 2,795 m between bogie pins and the coupling plane of the automatic coupler, for wagon ends with a crossover walkway or a footboard.

Wagon safety:
- Conditions for execution of S-curve transition (annex F)
- Relationship of wagon tare, distance over buffers and torsional stiffness at quasi-static conditions Y/Q=1,2, during operation Y/Q=0,8
- Safety of the wagon against derailment as described in TSI WAG as well as in EN 14 363

TSI relating to the subsystem control-command and signalling of the trans-European conventional rail system (COMMISSION DECISION 2006/679/EC), Appendix 1
- Maximal distance between internal wheel-sets of wagon 17,5m

EN 14363: Railway applications: Testing for the acceptance of running characteristics of railway vehicles — Testing of running behaviour and stationary tests

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The maximum permissible cross section of a railway vehicle and its load are defined by the loading gauge, which applies under static conditions. The maximum height and width of European mainline loading gauges are shown in table below, which was extracted from the respective network statements.

As seen in the Table 5, European mainline railway loading gauges range in maximum eight from 3,89 m (UK, loading gauge UK1) to 5,30 m (Finland and the former Soviet Union), and in maximum width from 2,84 m (UK, loading gauge UK1) to 3,60 m (Sweden, loading gauge C).

Table 5: Railway loading gauge maximum dimensions in Europe and the Caucasus

Nation or region	Max. vehicle height above top of rail	Max. vehicle width
Finland	5,30 m (KU)	3,40 m (KU)
ex-Soviet Union	5,30 m	3,25 m
Sweden	4,83 m (C) 4,65 m (A)	3,60 m (C) 3,40 m (A)
High Speed 1, Eurotunnel, Betuwe, Øresund, Lötschberg Base Tunnel etc.	4,65 m (GC)	3,15 m (GC)
Albania, Austria, Bulgaria, Greece, Czechia, Denmark, Germany, Hungary, Luxembourg, Netherlands, Poland, Romania, Slovakia, ex-Yugoslavia	4,65 m (G2)	3,15 m (G2)
Belgium	4,602 (GB-M6)	3,15 m (GB-M6)
Switzerland	4,60 (EBV O2) 4,50 (EBV O1)	3,15 (EBV O1, O2)
Norway	4,595 m (M)	3,40 m (U)
Portugal	4,50 m (Cpb+)	3,44 m (Cpb+)
Spain	4,33 m (Iberian)	3,44 m (Iberian)
France	4,32 m (GA, GB, GB1)	3,15 m (GA, GB, GB1)
Italy	4,28 m (G1)	3,15 m (G1)
Ireland	4,039 m (wagons)	2,90 m (wagons)
Great Britain	3,890 (UK1)	2,844 m (UK1)

Source: VEL-Wagon Consortium

Thus, compared to the size limitations in effect on the highway, the railway loading gauges are wider and in most cases taller as well, with few exceptions. There are also other important parameters of loading gauge for instance its weight. The geographical distribution of railway loading gauges in Europe is shown below. On the European standard track gauge network, the most prevalent loading gauge is the German G2 gauge, which applies in a contiguous belt from Denmark and the Netherlands in the northwest to Turkey in the southeast.

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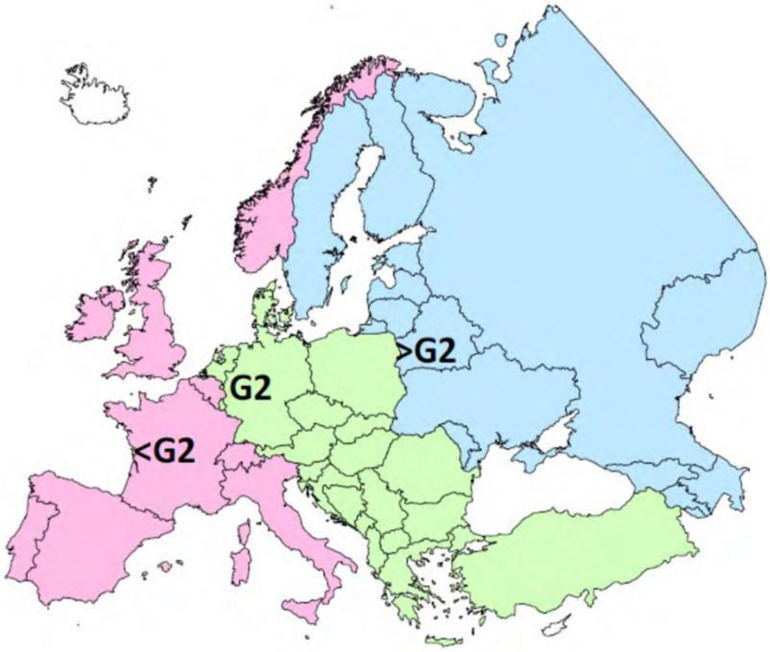
Figure 18: Geographical distribution of railway loading gauges in Europe and the Caucasus



Source: VEL-Wagon Consortium

However, the usefulness of the railway loading gauges is reduced by the typically tapered or rounded shape of their upper portion, whereas the majority of intermodal load units are of rectangular cross section.

Step 3: mapping the functional pattern of the TIS

3.1 Knowledge development and diffusion

Intermodal continental transports utilize a large amount of unit types - much more than hinterland (sea) transportation - and that increases the amount of possible loading cases for the trains. In that sense, there would be an optimal wagon for each case but this wagon could be sub-optimally utilized for other cases. This variety of cases makes it difficult to know which wagon is the optimal for an average situation.

Wagons represent an important investment for companies -c.a. 100.000 € per wagon- and they should be extensively utilized during their whole life cycle -25-30 years- to achieve profitability. For this reason, wagons specialized in one kind of unit are usually employed for other unit types even if they are not 100% efficient at it. Apparently, the articulated wagon for two semitrailers with total length of 106ft (53ft each half) is a popular wagon solution for continental intermodal transports nowadays. Hence this wagon has been used as reference for comparison.

The results of the capacity simulations have shown that an 80ft long wagon could lead to important advantages in efficiency. These advantages would be amplified by averaged cases

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with mixture of units, for example in the case of a shuttle between two important continental terminals with an unknown and varying proportion of units. The only-bulk segment represented by tanks, silos, 30ft dry containers, etc. is the perfect market for 60ft wagons. Hence, the comparison against other wagon types yields always negative results for the compared wagons. The 80ft wagon in spite of that yields less bad results than 106ft wagon when addressing the bulk market. In this way, an 80ft performs at the same level but with fewer axles, shorter trains and less deadweight than a 106ft.

The simulation for 90ft wagons only yields better results for the case of only-45ft units. In the rest of the cases the utilization of a 90ft wagon would lead to poorer loading factors than other solutions.

It could be concluded that the 80ft wagon would bring about an important gain for continental transports since it would enable better utilization of space (loading length) on trains than existing wagon technologies. 80ft wagons would be able to transport same of even more amount of TEUs with fewer axles and less deadweight. Furthermore the aerodynamics would improve (fewer gaps between containers, fewer bogies per meter) and the noise emissions would be reduced due fewer axles per train.

However its application on pure-semitrailer traffics would be on clear disadvantage against existing wagons, in concrete against the 106ft (twin) wagon. For this reason its attribute as pocket wagon could be not that valuable when compared to other existing solutions on the market. However an 80 ft wagon with a pocket would be very useful in shuttles between continental terminals with high traffic with an important mixture of different units.

A strategic procedure would be to design 80ft without pocket and try to make it as cheap as possible. By this it could be very competitive in its market segment.

Summarizing, in continental intermodal transportation a container-only 80 ft. wagon would:

- increase the loading factor (amount of TEUs per train) with 10%;
- decrease the amount of axles with 15%;
- decrease the gross train weight with 7%;
- improve aerodynamics;
- decrease the noise emissions.

3.2 Influence on the direction of search

The freight railways in Europe used to enjoy better times before the deindustrialization process in the late 1900s, affecting Western Europe gradually, and Eastern Europe very abruptly. This process is shifting the European production structure towards an economic system more dependent on information, services and technological development, imposing important quality requirements for transportation that freight railways are presently not able to meet. During such important development times the European railways have lost an important share of their freight market, which in the case of central and eastern European countries has been especially devastating. About 60% of the total tonne-km transported by railways in Eastern Europe disappeared between 1988 and 1993.

Indeed, a major part of the decline of European freight railways can be attributed to the changed production structure; however other reasons such as the poor coordination of international cross-border scheduled routes necessary for longer distances of transportation as well as the inflexibility to connect railway freights to other modes brought an important worsening effect too (Himola, 2007).

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The large decline suffered by freight railways since the 1980s contrasts very much with the increase of other modes, particularly the road freight, which increased its tonne-km output by 180% between the years 1980 and 2000. (EUROSTAT, 2001)

Figure 19: Freight railways' performance in Europe (Mrd. tkm)

Source: UIC, 2009

During the 20th and the early 21st century, road and sea freight underwent a phenomenal expansion, absorbing the major portion of new freight market created and taking market share from the railways. Unfortunately the environmental price paid for this was high, especially regarding the case of road transport. As European governments became aware of the environmental problems, arising from such rapid transportation expansion, they were increasingly looking at freight railways that should offer a better energy utilisation and lower external costs, if used efficiently. Then, ideally, rail transport should be more competitive in an environmentally-concerned market of surface transportation. At the beginning of the 21st century there was clear interest from administrations, lobbies and potential users of rail services in promoting the use of freight railways again. The so-called "Revitalising the railways" as one of the principal measures proposed in the EC 2001 White Paper is a good example. In many cases though, public and national-oriented management of railway transports did, and still do, hinder the proper evolution of rail freight businesses.

While other modes of freight transport enjoyed a propitious regulative context, freight railways were caught amidst monopolistic interests and strong-regulated markets. The liberalization of the European rail freight market taking place from the year 1993 onwards, as in the UK, Sweden or Germany, is still not accomplished by many countries at the time being. This has produced different scenarios for freight railways in which international traffics still have impediments for being efficient. In spite of this, a combination of

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interoperable networks and liberalized markets has paved the way for newcomers to produce benefits in some corridors and areas, especially in the container segment, e.g. the Rhine-Swiss-Italian corridor, and the hinterlands of Antwerp, Rotterdam, Bremen and Hamburg.

Currently, environmental concerns of the society combined with unstable energy prices and increased demand of crude oil and other commodities has positioned railways in the spotlight of many potential users.

3.3 Entrepreneurial experimentation

The use of large-sized wagons has a long tradition in the rail transport but nevertheless the application of large-scale container wagons for intermodal transport is not as widespread, as it would be appropriate. One of the regions, most strongly represented in use of the large-scale wagons in the world is the North America. Unfortunately, the specificity of the rail transport of not only for the individual continents, but also between countries and even regions are so different, that the use (transferability) of proven solutions in different environments is very difficult.

In North America non-articulated long wagons are present, longer than 25 m. There, 93ft long wagons (90ft loading length) can be employed for transporting two semitrailers of 45ft. There are as well 90ft long wagons (85ft - loading length) with a payload of 102 t for the transportation of containers.

As a result of the very high allowed axle load - 32,4 t/axle - on North American tracks, the 85ft cars can carry 25,5 t per TEU. This is about 2 t more per TEU than the standard wagon in Europe, the 60 ft wagon, and about 3 t less per TEU than the European articulated 80 ft wagon.

However, in North America the basis for the intermodal transportation has shifted from the above presented flatcars to the double stack cars, which make use of the tall loading gauge existing there to transport more containers per axle. Double stack cars have superior dimensions for the transportation of containers.

The stand-alone double stack cars can transport multiple combinations of container lengths from 20 ft to 53 ft.

The capacity of such car is 5,3 TEU (considering a 53 ft container equivalent to 2,65 TEUs) and the tare of the wagon is 23 t, hence the technical payload should be 32,5 x 4 – 23= 107 t, which gives about 20 t/TEU.

However typically, double stack cars are used in articulated multiple units, reducing by this the amount of necessary axles and hence reducing the averaged payload per unit.

Considering such configuration, tare of the 5-unit combination would be 53 t; technically maximum gross load 390 t (=32,5 x 12); theoretical maximum payload 337 t; maximum payload per unit 67,4 t; capacity per unit 4,65 TEUs (40 ft plus 53 ft); This yields approximately 14,5 tonnes per TEU (17 t/TEU if considering only 4 TEUs per unit). The manufacturer of the 5-unit double stack car declares an averaged load limit of only 124.700lbs per well which gives only 10,7 t/TEU.

Hence these multi-unit double stack cars would not be appropriate for 20’ containers, especially if heavy. However container techniques in the U.S. favour the utilisation of longer units, which are more appropriate for lower density commodities. The domestic unit of 53 ft

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long and 8,5 ft wide represents an important gain in productivity of North American intermodal logistics.

In Europe the share of 20 ft containers is similar and there is an important utilisation of short swap bodies (>20 ft to 25 ft). However the trend is to employ more and longer units, namely 40 ft and recently 45 ft.

In Australia and CIS countries longer wagons, >25m, are widely utilized, for instance the CQMY and 13-7024 respectively.

The specific requirements of different scenarios of the utilization and technical constraints on the proposed VEL-WAGON output were summarized as follows in the Table 6.

Table 6: Critical points of VEL-Wagon design

Critical points of VEL-Wagon design				
Wagon	**80**		**90**	
Parameter	**Advantage**	**Disadvantage**	**Advantage**	**Disadvantage**
Sag of car body	-	☹	-	☹☹
Self-frequency of car body (frame)	-	☹	-	☹☹☹
Kinematics outline (reduction E_c)	☺	-	-	☹
Profile of railway	☺	-	☺	-
S-curve transition	☺	-	-	☹
Safety – quasi-static conditions Y/Q=1,2	-	☹	-	☹☹
Safety – during operation Y/Q = 0,8	-	☹	-	☹☹

Source: VEL-WAGON Consortium

It is concluded that the challenging situation from a technical point of view commences from 80ft onwards.

An initial analysis of the loading cases, comparing the articulated version of 80' wagon against non-articulated version 80' yields the following schemes.

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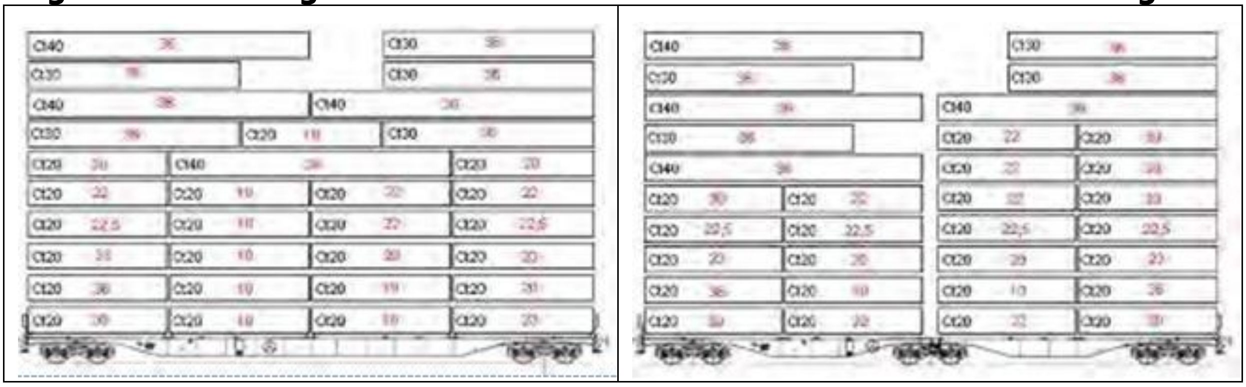
Figure 20: Loading schemes of 80' non-articulated and articulated wagons



a) Non articulated type of wagon b) Articulated type of wagon

Source: VEL-WAGON Consortium

Main advantages and disadvantages are summarized in the Table 7.

Table 7: Non-articulated and articulated wagon's properties summarization

VEL-Wagon 80 ft (non-articulated)	Articulated 80 ft wagon
Advantages:	Advantages:
- lower tare mass	- big mass loading capacity, i.e. high load limit
- fewer bogies	- technical and design parameters
- effective for light transports 20ft, 30ft and 40ft units	- effective for loading by all 20ft and 40ft units
Disadvantages:	Disadvantages:
- low mass loading capacity	- higher tare mass
- inefficiency for heavy 20 ft units, mainly up to 22 t	- higher investment cost
- many design challenges	- inefficiency for loading by light 20ft units and in combination with 30ft and 40ft units
- structural strength,	
- sag of skeleton wagon,	
- natural frequency of vertical bending oscillation	

3.4 Market formation

The volume of transported freight with the use of intermodal traffic is increasing, needing additional capacity and investment in additional cars. Transport of semitrailers by rail is also on its increase, so there is also need for additional pocket wagons, handling standard semitrailer length of 13,6 m to 13,7 m. The use of longer containers of 40ft and 45ft of

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length is also increasing, so there is a growing need for use of additional wagons, capable of their transport. The length of 45ft does not fit with the more common lengths of 20ft and 40ft, but matches 13,7 m closely.

Thus, there is a need for new pocket wagons able to carry 13,7 m semitrailers as well as 40ft and 45ft containers and swap bodies.

After analysing the needs of intermodal traffic (hinterland and continental), it can be concluded that an 80ft container wagon for ISO-containers and swap bodies would offer an important improvement in terms of logistics and energy efficiency.

Longer loading lengths 85ft and 90ft could have an advantage too, but only if the 45ft unit is widely introduced and if it dominates in intermodal traffics, which is not the actual case. A revision of this issue has to take place in approximately 5 years.

On the other hand, an 80ft pocket wagon is an interesting solution for continental transports.

It would target mainstream traffic flows with great diversity on unit types, including semitrailers. However the available solutions on the market for the transportation of only semitrailers would offer a better performance at this time. This issue, together with the 45ft unit issue, have to be examined again in about 5 years.

Hence, an 80ft wagon without pocket, capable only for the transportation of containers and swap bodies, could be more competitive than other wagons in its market range.

3.5 Legitimation

Conventional wagons have the optimal physical and technical characteristics to transport some specific kinds of commodities – usually with a lower value per ton – and fail in being versatile for other transports. There are exceptions as the H and L types of wagons that address general (palletised) cargo which have high value too. The production system in which wagons are utilised has as well an important effect on the productivity thereof.

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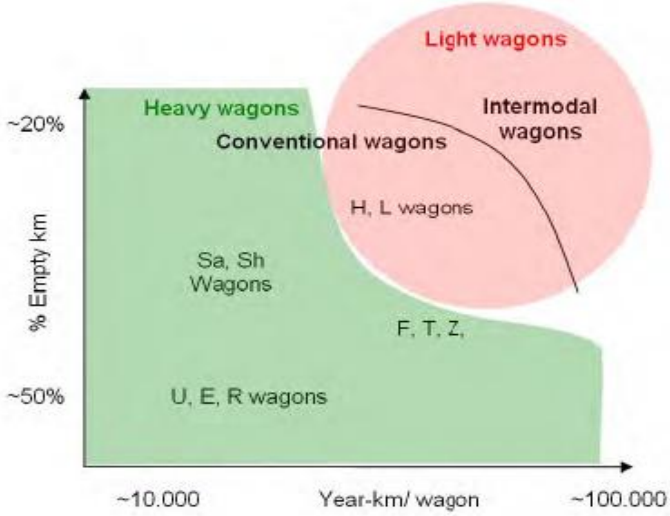
Figure 21: European wagon productivity



Source: EUROSTAT, UIC 2010, DB reports and internal knowledge

Intermodal and company-dedicated wagons tend to run in point-to-point direct configurations with short turn-over times, while other conventional wagons may make use of the single wagon load system where they can be re-marshalled many times, reducing by this their total yearly mileage. A compromised solution has to be found to increase mileage while being flexible. The issue and dependency on the wagon type, mileage and % of loaded runs is shown in Figure 21.

To check for the externalities, which could influence the directions of search within VEL-Wagon project, several tests have been performed, e.g. in the market research phase of the project there were comparisons with different types of wagons performed, based on calculation or simulation. One of the performed comparisons was based on the expected energy demand of trains.

One of the test results shows, that in case of use of the proposed VEL-Wagons, the energy demand of trains can be reduced. This fact is due to the fact, that resistance forces, such as aerodynamic or rolling resistance may be reduced.

The calculation has been performed for a hypothetical train, running between Würzburg and Nürnberg. This 100 km long track section has been chosen for its relative relevance in European intermodal traffic and its average geometric characteristics (medium-hilly route) in the European railway network. With this average example it is possible to draw some qualitative extrapolations to other track geometries, e.g. flat and hilly routes. The energy consumed by trains is calculated using a theoretical approach based on the work of Prof. Wende (Wende, 2003). To calculate and compare forces and energy demands it has been necessary to define a number of parameters for the trains, namely: wagons' type, length and number; traction unit; track properties; operational cycle; type, weight and length of loading units; loading principles for trains as well as other operational parameters. Results are related to different characteristics as loading factor or train length.

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Application of the model in terms of maximum length of a train

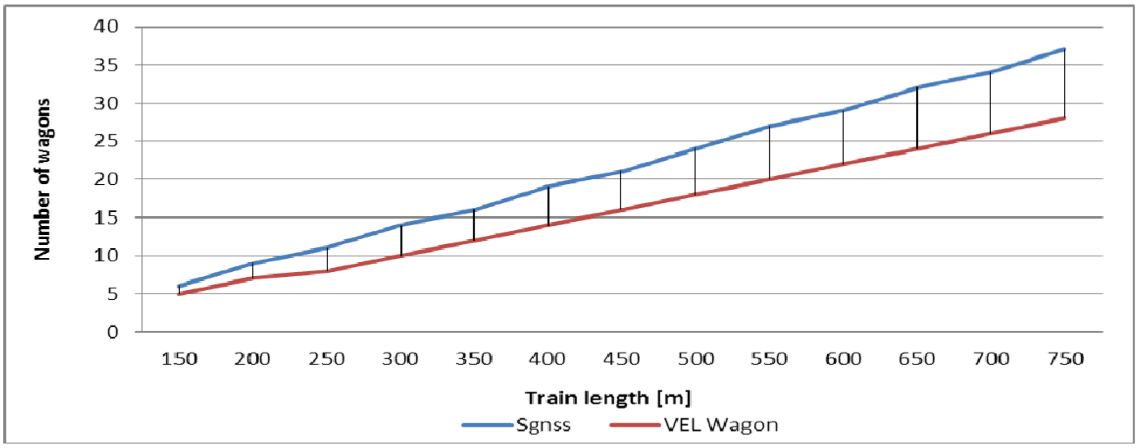
The comparison of block train set up of Sgnss wagons versus block train set up of proposed VEL-Wagons has been performed. In this task the use of the maximum loading capacity has been considered for both Sgnss and VEL-Wagon trains. Table 8 and Figure 22 show the difference in the expected length of the trains.

Table 8: Differences between the number of wagons and number of TEUs in the wagon according to criteria of maximum train length (VEL- Wagon – Sgnss)

	Train length [m]	150	200	250	300	350	400	450	500	550	600	650	700	750
1	Sgnss/train	6	9	11	14	16	19	21	24	27	29	32	34	37
2	VEL wagon/train	5	7	8	10	12	14	16	18	20	22	24	26	28
3	Difference 1 – 2 [wagons]	1	2	3	4	4	5	5	6	7	7	8	8	9
4	TEUs on Sgnss	18	27	33	42	48	57	63	72	81	87	96	102	111
5	TEUs on VEL wagon	20	28	32	40	48	56	64	72	80	88	96	104	112
6	Difference 5 – 4 [TEUs]	2	1	-1	-2	0	-1	1	0	-1	1	0	2	1

Source: VEL-Wagon consortium

Figure 22: Graphical representation of difference in the number of wagons in the wagon set of Sgnss block train and VEL-Wagon block train according to criteria of maximum train length



Source: VEL-Wagon consortium

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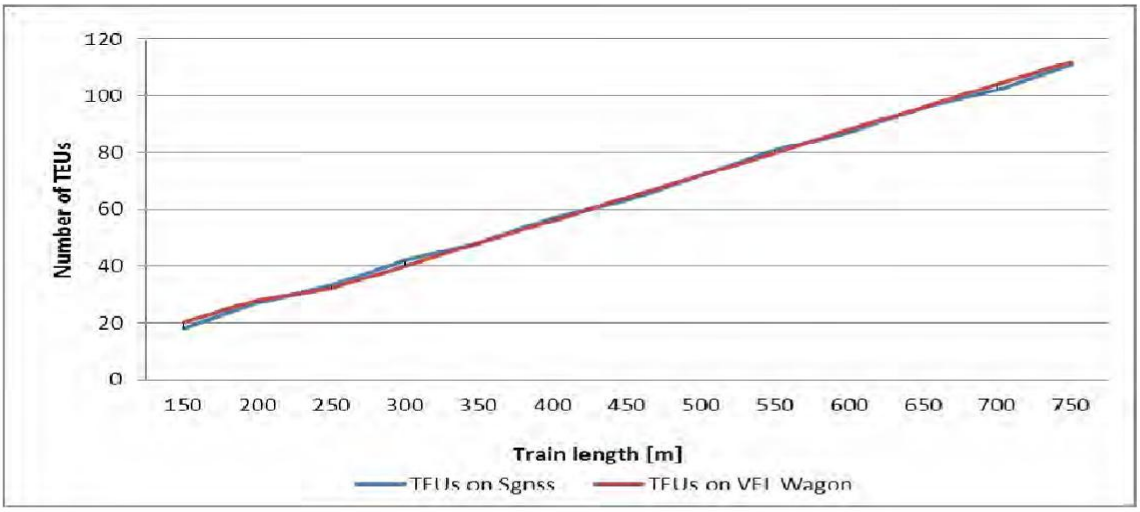
Figure 23: Graphical representation of difference in the number of TEUs in the wagon set of Sgnss block train and VEL wagon block train according to criteria of maximum train length



Source: VEL-Wagon consortium

Conclusion of the comparison is, that in the train including only VEL-Wagons and the length of the set 750 m, the overall number of wagons is significantly lower than the overall number of wagons in wagon set including only Sgnss wagons, while in terms of capacity of the train is almost the same.

The difference is even higher, when comparing a block train set up of Lgs wagons versus block train set up of VEL- Wagons, as seen in the Table 9 and Figure 24.

Table 9: Differences between the number of wagons and number of TEUs in the wagon according to criteria of maximum train length (Vel-Wagon – Sgnss)

	Train length [m]	150	200	250	300	350	400	450	500	550	600	650	700	750
1	Lgs/train	9	13	16	20	23	27	30	34	38	41	45	48	52
2	VEL wagon/train	5	7	8	10	12	14	16	18	20	22	24	26	28
3	Difference 1 – 2 [wagons]	4	6	8	10	11	13	14	16	18	19	21	22	24
4	TEUs on Lgs	18	26	32	40	46	54	60	68	76	82	90	96	104
5	TEUs on VEL wagon	20	28	32	40	48	56	64	72	80	88	96	104	112
6	Difference 5 – 4 [TEUs]	2	2	0	0	2	2	4	4	4	6	6	8	8

Source: VEL-Wagon consortium

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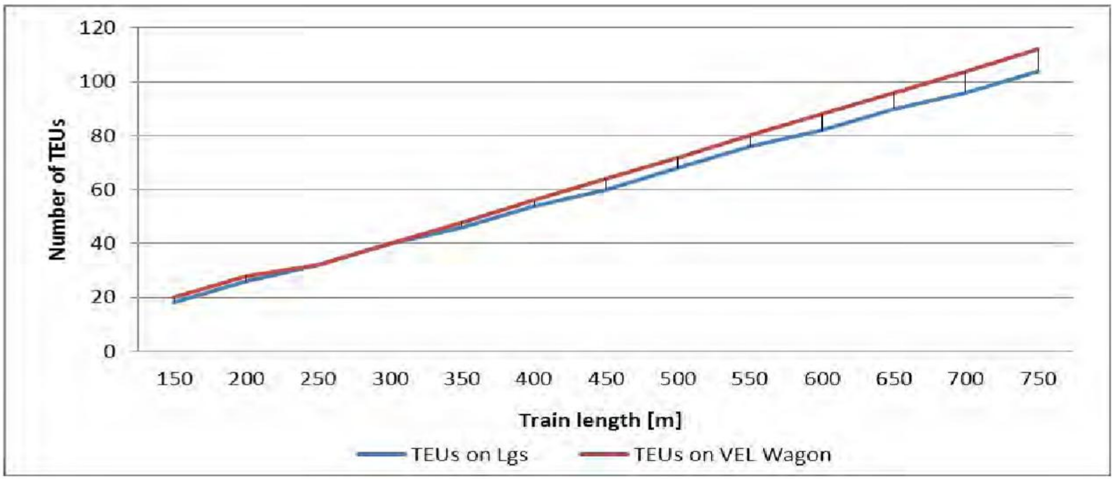
Figure 24: Graphical representation of difference in the number of wagons in the wagon set of Lgs block train and VEL-Wagon block train according to criteria of maximum train length

Source: VEL-Wagon consortium

Figure 25: Graphical representation of difference in the number of TEUs in the wagon set of Lgs block train and VEL wagon block train according to criteria of maximum train length



Source: VEL-Wagon consortium

To reach the defined objectives, several variants of the VEL-Wagon have been considered and compared against each other. Although this was done only in the hypothetical and theoretical domain, it had close connection to the entrepreneurial decision on the "optimal" final variant of the proposed solution.

The elementary attributes of all variants of the concept of the VEL-Wagon were the same:

- Length of semitrailer < 13,7m
- Max. length of container: 45´
- Overall height of semitrailer – 4000 mm to 4500 mm

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- Height of container: 2896mm
- Loading width at least 2,60 m (semi-trailer width = 2,55 m to 2,60 m) 2,90 m desirable (open-top bulk containers “Innofreight Woodtainer XXL”)

- Mass capacity of container – max 38,9 t
- Mass capacity of semitrailer – 39 t
- Axle load – 25 t
- Draw gear – screw couplers and buffers at both ends

10 different competing variants have been proposed by the consortium members. An optimum variant of a new railway car was chosen after application of mathematical methods of choosing optimum variant from number of variants.

3.6 Resources mobilization

In the case of cooperation between universities and industry, the organizational structure of large industrial companies involved in the research should be taken into account. From the point of view of the academic researchers, it may seem that the response to the research issues from the side of the industry is too slow. The mere approval of the documents by the company's management under can sometimes take months. This is mainly caused by the fact, that the company management meetings may be spread over time and the responsible person, entitled to approve the document is not available. The limited and to the productivity committed human resources including the research and development staff can be occupied by other commercial projects and developments, usually for long periods (e.g. two years) in advance. If the research and development project is not bringing some visible income in relatively short period, it is possible, that the resources allocated to the project could be re-assigned during the project life-time to some other, for the industrial firm more economically beneficial, activities.

Involvement of the industrial firms in the research and development project is very valuable, but must reckon with the fact, that in a highly competitive environment, where often the innovation and efficiency can contribute highly to the mere survival of the producer, the industrial firm is reluctant to publish and share the jointly developed results to the public, including their own competition.

As the industrial participants, due to the need to co- finance the research project, provides their own economic and human resources, it is of considerable value to prepare the Consortium agreement of the project, in order to safeguard their investment, while on the other hand not violating the guidelines on the use of the EC contribution.

3.7 Development of positive externalities

The development of VEL-Wagon TIS so far did not generate any economic effect, as its actors are concentrated on the first stages of the development process – from the market research to the prototype development, while the future market uptake, i.e. economic utilisation of the research and innovation is expected in the future. Given the generally rather evolutionary than revolutionary slow pace of acceptation of the changes in the railways, the external impact and effects of the innovation on the economy of intermodal transport can be expected in relatively long term.

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There are however significant positive externalities in development of international network for cooperation in the area, tighter connection between the academia and the industry, new cooperation among institutions from older and new EU member states, which will certainly bear the fruit in the future.

Step 4: assessing the functionality of the TIS and setting process goals

It is rather difficult to assess the described TIS for the manufacturing of the wagons for intermodal transport in the framework of EU27, since the number of manufacturers is very limited. Thanks to WEL-VAGON we can however point at various characteristics of this process. This TIS is focused on the innovative development and its results will be proved only in relatively distant future. The life-cycle of the products to be manufactured is relatively very long, so their effectiveness can be influenced not only by their technical parameters, but also by the ever changing external economic conditions.

Due to the limited time span of the project and the need to deliver the results on time, the Consortium of the described case had to react quickly and set up the internal mechanism for knowledge development and its diffusion. The preparation of rules for the IPR handling, concerning the background, side-ground and the expected new knowledge generated within the consortium – the foreground in the Consortium agreement took some relatively longer time, since the industrial company wanted to be assured, that its rights (and investments) will be safeguarded. According to the survey conducted among the actors, as regards this aspect of collaboration, the consortium is functional and working towards the reaching of the defined goals.

Figure 25: Model of the VEL-Wagon at the Transport Logistic, Munich, May 2011

Source: TU Berlin

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Step 5: identify inducement and blocking mechanisms

External factors can be divided into two groups. Technical, such as regulations and rules, which are closely connected with the specifics of the transport mode, such as intermodal transport, and social, which can be generalized for solution of any innovation activities. Some of technical rules and restriction were mentioned in Step 2.

Inducements:

- Increasing political pressure on modal shift in freight transport
- Application of container transport to railways
- Use of electrically powered trains thus reducing the Greenhouse Gases Emissions

Blocking mechanisms

- Lobby of the freight forwarding firms utilising mostly road transport,
- Flexibility of other modes, especially in case of traffic restrictions
- Lengthy process of railway tracks re-vitalization, building of corridors and new tracks
- Limited number of inland terminals and restrictions on their capacity, capable for serving large wagons.

Step 6: specify the key policy issues

The potential of access of railway transport into various logistic chains is growing constantly. Railway transport has favourable support of European transport policy and it is able to substitute road transport on a number of routes. But this will be possible only when railway transport is oriented on intermodal transport, however in this transport there is less efficiency of reverse-runs. Reason of this situation is mainly the trend of globalization, i.e. the transports on longer distances in bigger, standardized transport units. This has impact especially on the network capacity and wagon load usage, when the wagons with empty ITU are not fully loaded, but they are busy. In this case it is necessary to deal with lower number of lighter wagons with the possibility of better load usage by empty ITU.

In European rail freight transportation the total amount of freight wagons has been gradually decreasing at an approximate rate of 3% per year until reaching approximately 650.000 units in the year 2010, on the other hand the offered tkm has been stagnating or slightly decreasing to reach around 400 milliard tkm in 2010 (UIC stats and EUROSTAT 2011).

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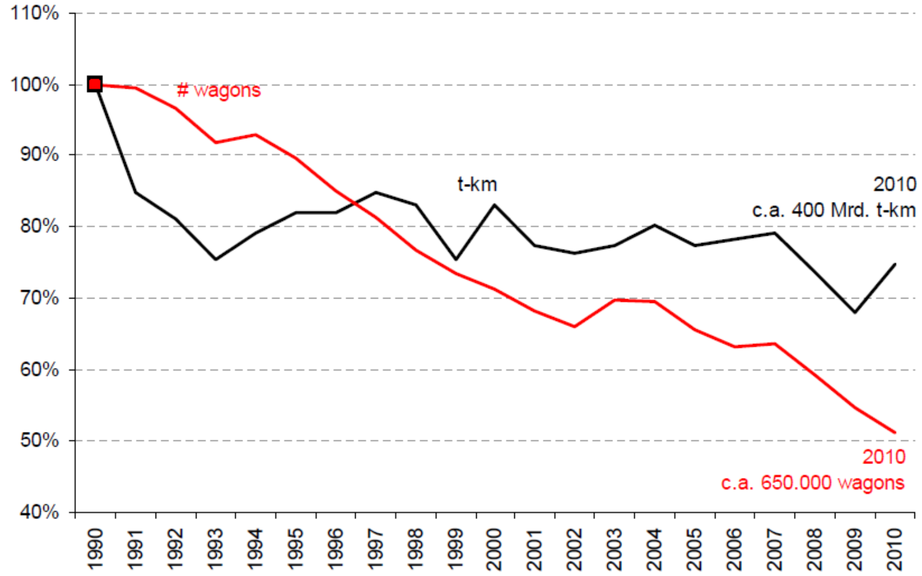
Figure 26: Amount of wagons vs. freight rail performance



Source: EUROSTAT and UIC 2011

This mirrors the actual trend of utilising more efficiently the available wagon fleet, which is achieved by increasing the amount of productive km (loaded km) the wagons make per year. An important part of this overall wagon efficiency is attributable to the exhaustive utilisation of intermodal wagons, which have found a proper place in the globalised market of containerisation. Intermodal wagons usually carry lighter cargoes that have high value, typically, the higher the value of the cargo the lighter it is and the more exigent in respect to quality standards, especially concerning security and safety.

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2.5 Container transferium

Title	Container transferium
Mode	rail ☐, road ☐, air ☐, maritime ☒, inland waterways ☒, intermodal ☐
Partner	UA

The continuous growth of container flows in the Western-European ports has led to increased pressure on the land side, including the hinterland road network of the ports. Research of Aronietis *et al.* (2010) shows that the increased level of congestion on the land side negatively affects the competitive position of ports. In recent years this has led to search for capacity optimization on port hinterland connections. Different mode-, time- and route-shift options and implementation mechanisms are being investigated for the available hinterland transport modes: road, rail and inland waterway transport.

To improve the port hinterland accessibility different initiatives can be taken. One of these initiatives is the development of a container transferium. A container transferium is an inland container terminal located near a port and its functional pattern is aimed at improving efficiency in and around the seaport by means of combining container flows on the port-transferium link. The port value added operations are performed onsite and further hinterland transport is performed from there.

Compared to a traditional inland hub, container transferium is located in the proximity of a seaport and provides a broader range of services. The differences based on different sources are summarized in Table 10.

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Table 10: Comparison of characteristics of an Inland Hub and a Container Transferium

	Inland Hub	Container Transferium
Functions	• Extension of the seaport • Consolidation and deconsolidation centres • Depot for empties • Temporary storage • Cargo bundling point • Broader logistics zone; container repair, VAL activities, forwarders etc. • Truck-Barge	• Extension of the seaport • Consolidation of container flows • Depot for empties • Enable a reliable transport system between the transferium and terminals in the seaport • Customs bonded • Truck-Barge / Barge-Barge
Goals	• Prevent overcrowding of the seaport area / manage traffic • Limit negative externalities of growing volumes • Increase throughput in the port and inland	• Reduce congestion around the port • Reduce environmental problems • Improve efficiency of deep sea terminals • Buffer for peak moments • Optimise barge handling of small parties • Modal shift
Location	• In the vicinity of its service area of loading/unloading, remote from the seaport	• Close to the major facility (seaport)

Source: Schoonen (2008)

A container transferium is different from the inland terminal because of its scope. The purpose of an inland terminal is uniquely to spread the container volumes serving the local customers within the area of 50-150 km (depending on the distance between the inland terminal and the seaport). The scope of the inland terminal is to change the modality of the cargo flow from the port and to serve an area around it.

The purpose of a container transferium (extended yard), being close to the port and having very fast and frequent barge connections with the port (which is not the case/possible with inland terminals) is to serve trucks away from port. Containers are bundled in the container transferium.

The scope of a transferium is based on three main pillars: [63]

- handling of the local cargo volumes;

[63] Kerstens (2012)

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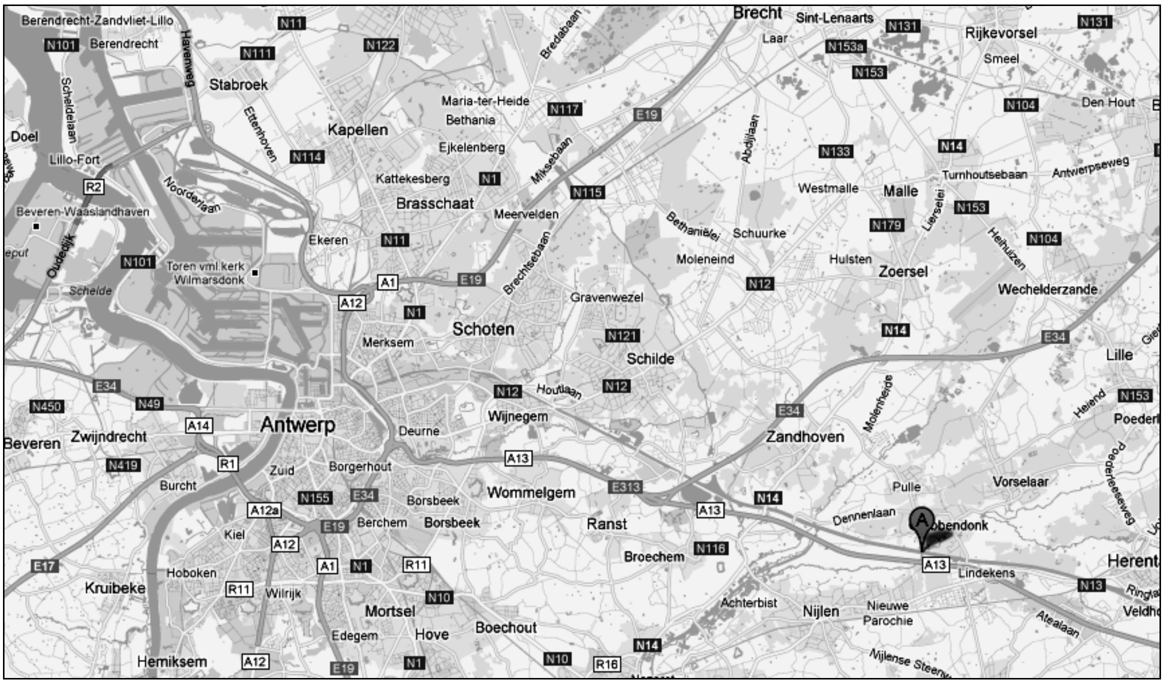
- being a truck bundling hub (for trucks coming from the hinterland) to avoid the last leg to the hinterland
- being a barge bundling hub.

Step 1: the starting point of analysis: defining the TIS in focus

The case study investigated deals with the development of Beverdonk container terminal in Grobbendonk, see Figure 27.

Figure 27: Location of the container transferium



For the development of the container transferium concept the developments in the economy have played a role. On the one hand, the idea to develop a container transferium dates back to pre-crisis time in 2007 and 2008, when the container terminals in the ports were handling historically highest container volumes. There were also high volumes of containers to be handled in the DP World container terminals in Antwerp. This refers to a capacity issue. As such, on the terminals in the ports there was no problem (capacity of terminals is not at maximum, not in pre-crisis time and not in current crisis time), but the problem is located in the hinterland, namely hinterland congestion. On the other hand, due to strikes in the port of Le Havre in 2008, additional container flows had to be handled in the port of Antwerp. To do it, there was a need to increase terminal throughput, but it turned out that it was not possible to do it on the terminal side alone. In practice it turned out that no additional container volumes could be handled by the terminals due to the capacity problems on port hinterland links. Mainly the road congestion throughout the working day was the reason that the containers could not be delivered to and from the terminals.

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In order to protect the core business of DP World (container terminal in port), it was necessary to have more control on the hinterland connections. An extra gate was needed, *a little bit* in the hinterland.[64]

It was decided to investigate the possibility to evade congestion that is present on the Antwerp ringroad by extending the yard of the terminal to a location just outside the congested area. The location of the Beverdonk container terminal in Grobbendonk was chosen because of its strategic position at the junction of the motorway E34 and E313, where most of the trucks serving the port of Antwerp from the East direction have to pass. The location is close to the port with the purpose of organizing an efficient and fast barge service between the transferium and terminals in the port.

Beverdonk Container Transferium NV qualifies under EU definition of small and medium enterprise (SME). It employs less than 10 employees and its initial capital is 64.000 EUR. It does not fit the autonomy requirement, because it is owned by two non-SMEs: DP World (80%) and Antwerp Port Authority (20%).

Currently 2 ha of the terminal are in use, which allow for the maximum capacity of 20.000 TEU/year. In total the development of 10 ha container yard area is planned to reach the maximum capacity of 100.000 TEU/year. The terminal started operations on 2 January 2012.

Step 2: identifying the structural components of the TIS

In this step the structural components of the technological innovation system are described. Those are: actors, networks and institutions. The container transferium case study covers two modes: inland navigation and maritime transport. The technical innovation systems of both these modes are relevant for this innovation case. Therefore, when identifying structural components of the TIS of container transferium, both modes are described.

2.1 Actors

The actors of both, the maritime and inland waterway sector are taking part in the analysed technological innovation system. The information on both technological innovation systems in this subsection comes from Market-up Deliverable D2.1, Aronietis *et al.* (2011).

The structure of the technological innovation system for inland waterways and maritime transport are similar. Consequently, it makes sense to speak of a "Waterborne Community", because the technological platform is the same for both modes of transport.

The Waterborne Community is composed of representatives from Industry (Manufacturers, Users & Service Providers), Society (Regulatory, Research & Education Organisations, and Unions) and Public Authorities (Commission & Members States).

Actors and stakeholders in maritime sector and inland waterways sector

The innovation system for maritime sector and for inland waterways sector is shown in Figure 28 and in Figure 29 respectively. Figures depict the actors in these systems and their interconnections. The structure of both sectoral systems of innovation is based around three main subsystems: industrial, regulation and political. The differences between these sectoral innovation systems exist mainly in regulation and political subsystems.

[64] Kerstens (2012)

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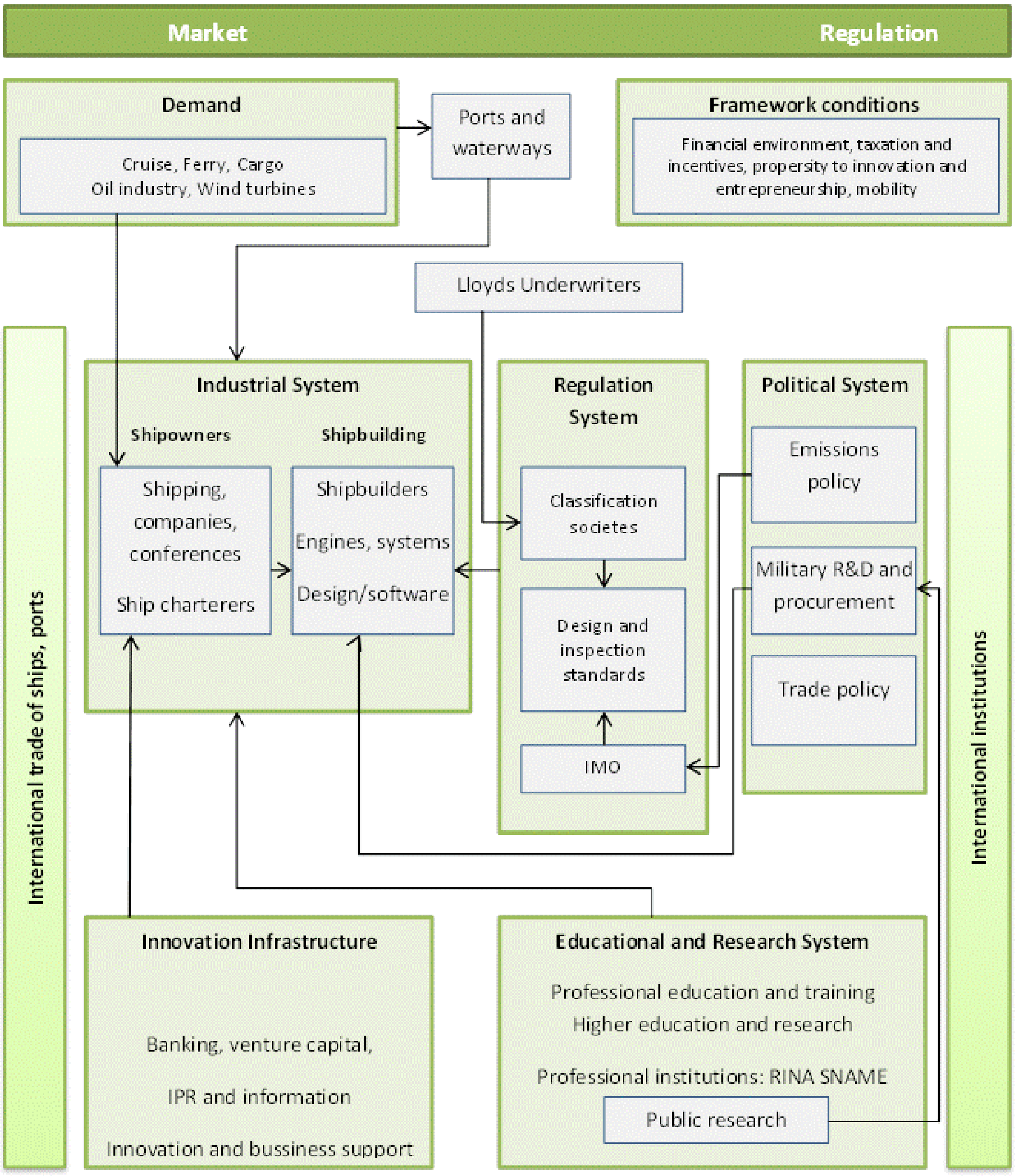
Figure 28: Innovation system in maritime sector



Source: Market-up Deliverable D2.1 (Aronietis *et al.* (2011))

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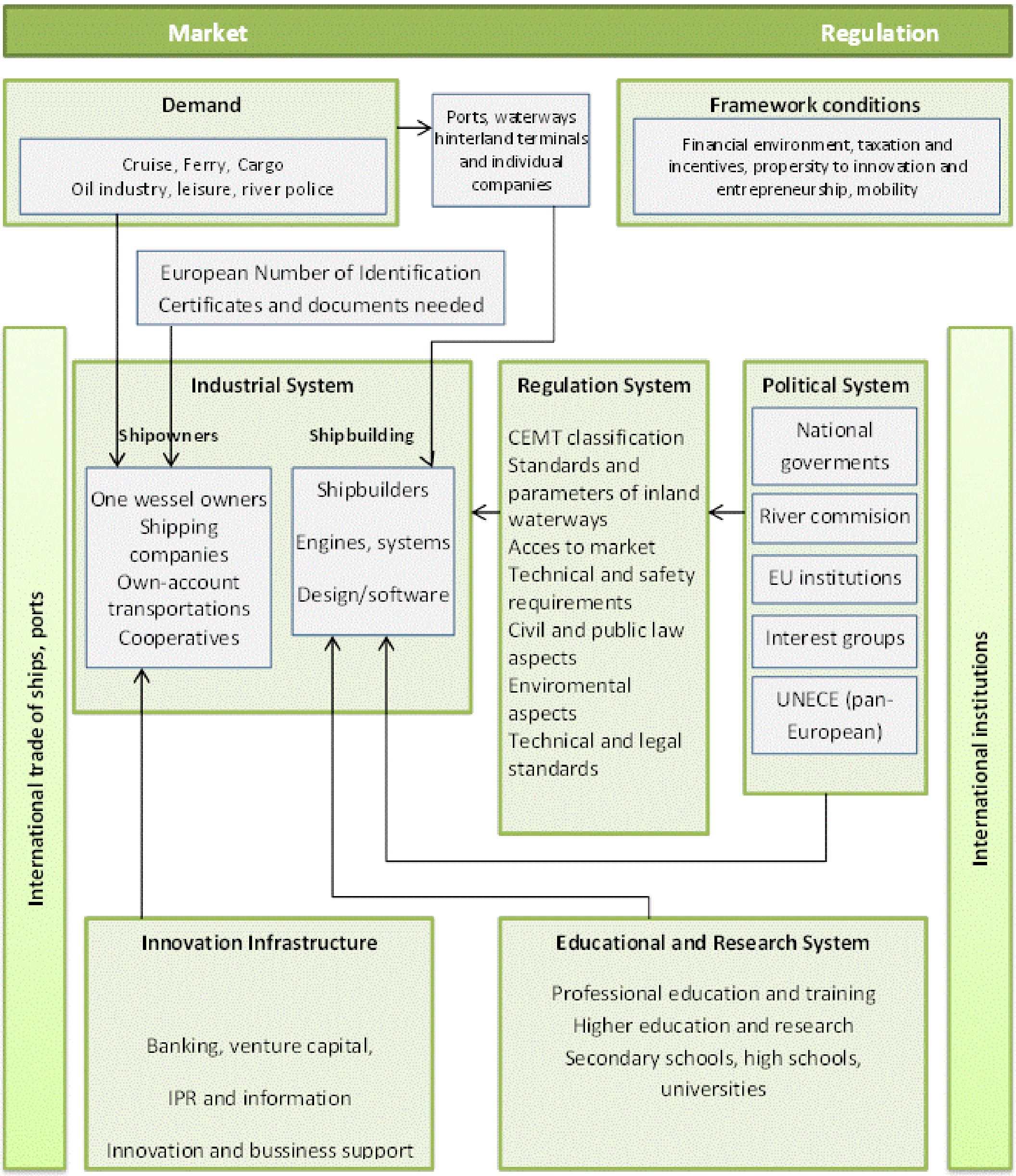
Figure 29: Innovation system in inland navigation sector



Source: Market-up Deliverable D2.1 (Aronietis *et al.* (2011))

R&D in the Waterborne Community

The most important actors and stakeholders of maritime research in the European Union are presented in Table 11 below following the structure presented in Figure 28 with the maritime innovation system.

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Table 11: Actors and stakeholders for maritime research in the European Union

Political System	Education & Research Systems	Innovation Infrastructure	Industrial System
European Commission EMSA IMO National Research Programmes	Research Institutes Maritime Universities Testing Centres	FP7 (Various Programmes) TEN-T MARTEC ERA-NET Life + Marco Polo II TEN-E Leonardo Di Vinci CIP IEE TRKC (now TRIP)	Marine Equipment Waterborne TP Shipyards Ship-owners Inland Shipping Classification Societies Trade Unions Ports & Terminals Dredging Leisure Craft Offshore Renewables

Source: Market-up Deliverable D2.1 (Aronietis *et al.* (2011))

Similarly, the most important actors and stakeholders of inland waterways research in the European Union are presented in Table 12 below following the structure presented in Figure 29 with the inland waterways innovation system.

Table 12: Actors and stakeholders for inland waterways research in the European Union

Political System	Education & Research Systems	Innovation Infrastructure	Industrial System
European Commission River Commissions Interest groups UNECE	EDINNA	FP7 (Various Programmes) TEN-T Life + Marco Polo Eureka	Marine Equipment Waterborne TP Shipyards Ship-owners Inland Shipping Classification Societies Trade Unions Ports Terminals Dredging Leisure Craft

Source: Market-up Deliverable D2.1 (Aronietis *et al.* (2011))

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Actors and stakeholders specific for the Beverdonk container transferium case

For the particular case of container transferium several of the actors mentioned above are involved. The initiator in this case is DP World, a global terminal operator which operates more than 60 terminals in the world[65]. Antwerp Port Authority is involved in the project as the strategic partner with the share of 20% project ownership. With this the Port Authority seeks to offer a neutral platform for port users.

From the political and government side there was support from Flemish minister president. On the practical side, there was support provided from sources, which include European Regional Development Fund (ERDF) and Enterprise Agency (Agentschap Ondernemen) of the Flemish government. The European Commission had to authorise[66] the state aid received.

The real estate company Groep Heylen and the building company Van Wellen are the developers of the warehouse infrastructure at the container transferium.[67]

The land where the container transferium is located is owned by Flemish Region and managed by De Scheepvaart NV. A concession agreement is signed between Container Transferium NV and De Scheepvaart NV for exploitation of these lands for a period of 25 years[68].

From the potential clients side companies like integrator DHL and shipping line Maersk Line are in the working group of the terminal development.

The biggest group of clients of container transferium is expected to be road transport operators, which are mostly SMEs.

There are two categories of shippers that could be clients of the transferium. First, are the local clients. Those potentially include major companies, such as Nike, Energizer, Wilkinson, Lexmark, Casa, Estee Lauder and Bosal, which have already set up their European distribution and postponed-manufacturing activities in this region. Second, are the clients located to the East of transferium, including those from the Rhine-Ruhr area in Germany with mostly time-sensitive cargo.

2.2 Networks

A number of networks have been and are relevant for the development of the container transferium project.

Port of Antwerp is working in close collaboration with the regions in its hinterland, because of common interests with local authorities. A network formed in such collaboration allows reaching the targets of increasing barge and rail transport goals. Also, a space is created for

[65] Data on December 2011. DP World (2012)

[66] European Commission (2011a)

[67] Kerstens (2012)

[68] European Commission (2011b)

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non-maritime port-related activities (value-added services like storage and packaging services).[69]

Economic Network of Albert canal (Economisch Netwerk Albertkanaal) is a network of 25 municipalities which are on the Albert canal. Those municipalities collaborate on with the aim to exploit the opportunities of Albert canal. The list includes Antwerpen, Beringen, Bilzen, Diepenbeek, Geel, Genk, Grobbendonk, Ham, Hasselt, Herentals, Heusden-Zolder, Laakdal, Lanaken, Lummen, Meerhout, Olen, Ranst, Schilde, Schoten, Tessenderlo, Westerlo, Wommelgem, Wijnegem, Zandhoven and Zutendaal.[70]

A network of major companies forming a group of potential costumers is present in the area where the container transferium is located.

For transport modes networks exist, but those are not directly influencing the development of the container transferium project. For the inland waterways, on the European level there are several important groups of actors; the national governments and their representatives, the river commissions, the EU-institutions and interest groups. The latter include EBU (European Barge Union), ESO (European Shipping Organisation), IVR (Internationale Vereniging van het Rijnschepenregister), VBR (Association of Belgian Ship owners) and INE (Inland Navigation Europe). For shipping the networks include International Maritime Organisation (IMO) and specific interest groups. For road transport networks include IRU (International Road Union) and FEBETRA (Fédération royale belge des Transporteurs et des Prestataires de services logistiques).

2.3 Institutions

Institutions such as culture, norms, laws, regulations and routines have had impact on the development of the container transferium case.

From cultural side, in Belgian car-based society, congestion created by heavy goods vehicles on the motorways is considered a bad thing and political actions taken to reduce the part of the congestion created by heavy goods vehicles are welcomed. Therefore there is strong political support for the project: a ceremony[71] was organized on 10 December 2009 where Minister-President of Flanders Kris Peeters officially launched the work to open up the new industrial estate in the municipality of Grobbendonk.

From the legal side, the project has been impacted by the legislation of the EU level. The Treaty on the Functioning of the European Union (TFEU) forbids the subsidies distorting the internal market. Therefore, based on the application of the subsidy granting authority the European Commission had to determine whether the aid in question can be considered to be compatible with the internal market on the basis of the derogations provided for in the TFEU[72]. In the case of container transferium, the Commission decided to raise no objections[73].

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[69] Source: Antwerp Port Authority (2010)

[70] Flemish Government (2012)

[71] Groep Heylen (2009)

[72] European Commission (2011b)

[73] European Commission (2011a)

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Other EU policies with impacts on the intermodal transport projects, and consequently container transferium case, are listed in Table 13.

Table 13: Policy and regulatory framework of the European intermodal transport policy

Year/Reference	Title
1992/COM(92)494	White Paper on the Future of the Common Transport Policy
1992/92/106/EEC	Council Directive on the establishment of common rules for certain types of combined transport of goods between Member States
1992/93/45/EEC	Commission Decision concerning the granting of financial support for pilot schemes to promote combined transport
1997/COM(97)243	Communication on intermodality and intermodal freight transport in the EU
1995/COM(95)691	Green Paper on Fair and efficient pricing
1996/COM(96)421	White Paper A strategy for revitalizing the Community’s railways
1996/1692/96	Community Guidelines for the development of the Trans-European Transport Network
1997/COM(97)242	Communication on Rail Freight Freeways
1997/COM(97)678	Green Paper on Port infrastructure
1998/COM(98)466	White Paper on fair payment of infrastructure use
1998/2196/98	Council Regulation concerning the granting of community financial assistance for actions of an innovative nature to promote combined transport
2001/COM(2003)370	White Paper: European transport policy for 2010: time to decide
2003/COM(2004)56	Commission proposal for a Directive on intermodal loading units
2006/COM(2006)314	Communication on the mid-term review of the European Commission’s 2001 Transport White Paper
2007/COM(2007)607	Communication on the freight transport logistics action plan
2008/COM(2008)433	Communication on the greening transport
2009/COM(2009)82	Communication: Strategic goals and recommendations for the EU’s maritime transport policy until 2018
2009/COM(2009)279	Communication "A sustainable future for transport: Towards an integrated, technology-led and user friendly system"
2011/COM(2011)0144	White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system

Based on Macharis et al. (2009) and European Commission (2012)

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Step 3: mapping the functional pattern of the TIS

3.1. Knowledge development and diffusion

Several developments in the economy have lead to the realization of the need to optimize the port operations, specifically targeting one of the main bottlenecks of the ports – the hinterland connections.

First, there is the scarcity of port land and the high cost of this land. The expansion of the port in the long run can not be indefinite.

Second, in the last decades, European ports have faced increases in goods transport volumes passing through the ports. The road transport volumes on the hinterland connections have increased consequently. In the long run the situation of increasing traffic levels and lack of road space causing congestion requires initiatives to be taken by the stakeholders. The EU policies promoting intermodal transport are boosting port turnover and traffic on the port hinterland links even more.

Third, the use of inland waterway barge shuttle service operating between the port and the transferium allows inland waterway transport operators to work with consolidated cargo increasing efficiency. This reduces the cost per unit of transported containers, but incurs extra transhipment.

For similar reasons, another similar project is under development in Rhine-Scheldt delta in Alblasserdam, near the port of Rotterdam[74]. In its accessibility plan the Port of Rotterdam Authority is developing several initiatives to tackle the accessibility issues. A part of this is the creation of one or more container transferia outside the port area. In this case the container transferium relieves the very busy motorway A15 to the Maasvlakte. Other implementations of the container transferium idea are under investigation elsewhere.

3.2. Influence on the direction of search

The political and economic landscape has been favourable for the development of the container transferium in Beverdonk. This includes the EU policies on intermodality, political support on regional and local level and positive public opinion on the possible impacts of the container transferium project.

The developments that are expected to influence the container transferium and improve its business case are:

- oil prices;
- high fixed costs and the low profit margins in the road haulage industry (search for optimization);
- price pressures from cheaper Eastern-European road haulage operators;
- scarcity of available workforce (drivers);
- haulage rates are expected to increase in the future.

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[74] Havenbedrijf Rotterdam N.V. (2010)

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3.3. Entrepreneurial experimentation

The case of container transferium in Antwerp is the first implementation case of this concept. Another similar project is under development in Rhine-Scheldt delta in Alblasserdam, near the port of Rotterdam[75] to serve Maasvlakte 2 terminal, but no operations have been started yet. Also, in other ports of Europe a similar concept is considered, but there are no implementation cases.

3.4. Market formation

With this project DP World, the innovator, tries to respond to the demand of the market to improve the efficiency of the supply chain. This improved efficiency would allow reducing the costs per unit of shipped goods.

The terminal is marketed as an open access terminal, which means that DP World sets no restrictions on who can use the terminal. This is a way to attract the clients from the potential client base, which includes the companies that are located in the region of the container transferium, but also those that are located further away.

At the container transferium in Beverdonk, two types of activities can be distinguished:

- Handling of volumes created due to warehouses physically around the transferium;
- Handling of volumes of final customers (final origin or destination) in the area to the East of transferium - trucks which would normally pass Beverdonk. The container transferium avoids that these trucks enter the port.

The container transferium intends to provide traditional services that the port terminals provide to the clients: loading, unloading and logistics services. Additionally to those operations of the transferium, also storage of containers and goods is possible.

The development of the container transferium is based on a strong business case, which allows the trucking operators to save time and therefore improve productivity.

For a trucking company Beverdonk container transferium acts like an extension of a terminal at the port. The trucker can bring/pick up a container that has to be delivered to/from port in the transferium. The container transit between the transferium and terminal in the port is organized via barge shuttle service.

Trucking companies (mostly SMEs), the clients of the container transferium, are the ones directly benefitting from this innovation. An average time saving for a trucker is 2-3 hours per box delivered to a terminal. At an average costs of operation of 45 €/hour for a road haulier, there is grounds for savings even when the cost of extra handling and barge transfer is taken into account. In most cases, the truckers agree on a fixed price, meaning that the faster the task is performed, the more savings.

Two alternative situations:

- Port area – destination (including bottleneck E313)
- Port area – Beverdonk – destination

From a transport economic point of view, one might think that adding an extra transhipment would make the total transport cost more expensive. It turns out that this is not the case, because congestion time is avoided. In other words, more tasks can be performed. For

[75] Havenbedrijf Rotterdam N.V. (2010)

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example, in the first situation it might be possible to perform 3 tasks, whereas in the second situation 15 tasks might be performed. This is characterized by savings for the trucking companies. The system will be beneficial as well for big and small companies. In this system, the truckers also pay a fee to the container terminal.

The connection between the container terminal and the port is performed by barge. These barges serve all points in the port, including DP World's competitors. As such, the competitors will not use the container terminal directly, but their customers will (drop box in Beverdonk and via barge to DP World's competitor).

The non-time sensitive cargo from the Rhine area is usually transported to the port of Antwerp using barge connections, which are well developed. The focus of the transferium is mainly on the cargo from this area which is time-sensitive. For this sort of cargo the biggest concern for truckers is the closing time (24 hours before departure of the vessel) of the ship. Therefore it is arranged that ship closing time in the container transferium is the same as it is at the terminal in the port of Antwerp.

For example, a case of a client located in the proximity of the transferium can be described. It is a shipper who deals with export cargo and works on a tight schedule shipping 1 container to the port every hour. After becoming client of the container transferium the efficiency of the operations of the shipper has increased substantially. The number of containers that can be transported to port using one truck has increased from 4 containers per day to 12. At a comparable cost of transportation per container, the savings due to efficiency increases are substantial.

It is planned that in the near future the territory of the container transferium will be considered as customs territory, which will enable the containers to be transferred between the transferium and the port without performing customs operations. Also, in the near future, as the volume grows, the barge shuttle services will be dedicated for terminals in the port of Antwerp.

The additional services provided in the container transferium include all services that would normally be offered in a terminal at the port, like container repair, fumigation, stuffing, stripping, long and short term storage.

The government has played a significant role in increasing the competitiveness of the terminal. The subsidies received (see 3.6) cover part of the terminal building expenses and allow the terminal to offer its clients more advantageous prices (in the starting phase).

Additionally, the planned implementation in Belgium of kilometre charging for heavy goods vehicles according to Eurovignette directive, will allow the container transferium to exploit its advantageous geographical location.

3.5. Legitimation

Apart from the economic benefits to the innovator, a number of benefits for the society exist in relation with implementation of the project. Those have been promoted by the innovator to gain legitimacy for the project. Some most important arguments[76] used for legitimation are mentioned below.

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[76] This section mentions arguments which are not necessarily scientifically proven, but that have been used for legitimation purposes of the container transferium project.

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One of the main goals of this project is the increase of efficiency of road transport operations[77]. Inland waterway transport is used for goods transport operations between the terminal in the port and transferium, therefore the traffic on the road network, specifically on the Antwerp ring-road and the initial stretch of the TEN-T motorway E313 is reduced. Also, the modal split of the port of Antwerp will be "improved".

For the operations of the inland waterways transport, optimization of operations will follow. The inland waterway barge shuttle service operating to the transferium will reduce the number of the inland barges going into the port, because of bundling of containers. As a result the capacity of the port of Antwerp on the inland navigation side will increase. The transferium project allows optimizing the use of existing port territory.

The container transferium is an extended gateway of the port to the hinterland. It means that the logistics operations are extended to the region where the container transferium is located, thus moving the logistics operations closer to the destination of the goods.

The support from the Port Authority's side is linked with its hinterland policy aimed at among other things increasing the share of barge and rail transport in the modal split and giving the port greater power in logistics chain.[78]

In the area where the container transferium is located, a number of companies have developed premises for their logistics operations. For legitimating of the project this is positive, because it shows the public that the cargo of these companies might be partially taken off the roads in the area.

3.6. Resource mobilization

A range of resources have been mobilized to develop the container transferium project. The Beverdonk Container Terminal NV finances itself by bank loans, with subsidies from Flemish Region and the European Fund for Regional Development (ERDF) for 41.56% of the total project cost.

European Regional Development Fund (ERDF) provided subsidies for the total amount of 1.3 million euro. The total cost of the project was 3.2 million euro. Also, subsidy from the Flemish government of 703 thousand euro was available.[79]

The land where the container transferium is located is owned by Flemish Region and managed by De Scheepvaart NV. A concession agreement is signed between Container Transferium NV and De Scheepvaart NV for exploitation of these lands for a period of 25 years[80].

3.7. Development of positive externalities

The operations of container transferium are currently in the initiation phase, with the operations started on 2 January 2012. Therefore, no positive externalities could be observed during research. However, some positive externalities predicted include positive effects on

[77] Van de Wygaert (2011)

[78] Antwerp Port Authority (2010)

[79] Van de Wygaert (2011) and Flemish Government (2010)

[80] European Commission (2011b)

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the modal split of the port, arising from rerouting of the road transport operations, and possible decongestion of parts of the road network. Also, due to the first-of-a-kind nature of the container transferium project, knowledge spill-overs and information generation effects might arise.

Step 4: assessing the functionality of the TIS and setting process goals

The development of the TIS in focus, until this point in time, can be considered successful. The innovation case of container transferium currently[81] is in the first months of operation. Several developments in the economy have been favourable to the development of the container transferium case. Those conditions in conjunction with the realization that the port hinterland connection capacity is not sufficient in the long run have induced the search for available alternatives. Also, future forecast developments like influence of oil prices, situation in road haulage market, prices pressures from competition and clients, and scarcity of workforce are reinforcing the economic viability of this alternative in the long run.

The case in focus is the first implementation of the concept in Rhine-Scheldt delta, so no historic data is available on the entrepreneurial experimentation in the TIS. A particular strength of the case is that development of the container transferium is based on a strong business case, which is reinforced by the forecast developments in the economy. The benefits for the clients of the transferium are "here and now".

Also, apart from the economic benefits to the innovator, a number of benefits for the society are expected. This ensures the viability of the political support for the project. Active use of available financial support from different levels of government (regional and EU) should provide a good start for long-term success of the project. In comparison with other projects, where the modality of the goods is changed, in this case the cost of the project to the society (subsides) is there only in the initiation phase of the project. Also, no additional cost is put on the shipper or transport operator (like with pricing schemes). It is self-sustaining in the long run with no additional subsidies.

No immediate weaknesses are present, but certain risks might arise in the future. Those might be related to the weakening of the position of the international road transport and strengthening of other long-distance transport modes, in line with the current EU policies. Also, with intensification of the use of inland waterway transport, the congestion might impact the barge shuttle service. There is risk that the possibilities to expand the market might be limited in the long run, although markets (road-local; road-Rheine; barge-barge) for the concept exit.

The functional pattern seems to operate optimally with no immediate weaknesses that might hinder market uptake of the container transferium project. This is mainly because of the very strong business case, political support at different levels of government, and no substantial hindering mechanism present.

[81] At the time of doing the research on the case study, first quarter of 2012.

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Step 5: identify inducement and blocking mechanisms

Several inducement and blocking mechanisms with greater or lesser influence on the case study were identified during research[82]:

Inducement / positive mechanisms and issues:

- Flemish government is in the process of looking for such initiatives to support;
- the social need: insufficient capacity of highways;
- no opposition on the local level;
- helps to win votes for regional politicians.

Blocking / hindering mechanisms and issues:

- fierce negative comments from competing terminals in the port;
- competition from other terminals (e.g., Euroports Containers Meerhout);
- the customer base, mainly road hauliers, were initially not aware of the advantages. Truckers had to be convinced.

Step 6: specify key policy issues

With the TIS in focus in mind of the concept of the container transferium, certain political issues are important and should be on the table in the future for strengthening the TIS.

One of the success factors in practical operation of the transferium is that a truck should have the possibility to make a turnaround at the transferium. It means that when it brings a loaded or empty container to the terminal, another empty or loaded container should be there for the next road haulage operation. For the container transferium it is important that the repositioning of empty containers is supported by the government. Currently schemes of subsidies are enacted within the container transport chain. Those currently subsidise the movement of loaded containers to attract the cargo flows. However, for shipping lines, which are the ones making the port choice decisions, a substantial part of the costs are related to repositioning of the empty containers. Smart subsidising of the empty container flows might be on the political agenda in the future with the purpose of attracting cargo flows to the ports in Flanders.

Another factor that is important is the availability of good infrastructure. For the case of transferium, where the economics of the project are based on time savings that the transferium provides, the quality of the road infrastructure is important. It should ensure easy access to the transferium for road hauliers.

[82] Kerstens (2012)

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2.6 Cargo sprinter

Title	**Cargo Sprinter**
Mode	rail ☒, road ☐, air ☐, maritime ☐, inland waterways ☐, intermodal ☐
Partner	BME

Step 1: the starting point of analysis: defining the TIS in focus

Considering the current position of rail freight transport, there are several questions we have to face. The decrease in the market share of rail poses a complicated problem to be solved. The present case study focuses on enhancing the role of rail in freight transport to, from and through urban areas.

Rail has been displaced as road transport services have grown and evolved into a flexible, slick, secure and cost-efficient system by offering sophisticated door-to-door services. As the Just-in-Time management philosophy has gained ground in commerce, the road transport sector has developed not just the function of delivery but of storage as well, which rail has scarcely succeeded to fulfil again.

The main drawbacks to the use of rail in urban freight are the limited physical flexibility, the competition with passenger transport for line capacity and the high cost of rail infrastructure and related transfers. Moreover, rail must meet the continuously rising expectations of shippers and receivers in order to recapture some of the freight market back from road trucks.

For these reasons, the Cargo Sprinter train technology deployed in Germany may have the capability to match road regarding technical, operational, commercial and service development that the road sector has successfully implemented. It is a self-propelled transport unit designed and manufactured by Windhoff, also thought of as a container truck that runs on rails. The Cargo Sprinter brings the optimum combination of environmentally sound rail transport and flexible freight transport by finding the solution for door-to-door transport in rail. This concept provides an alternative to the cardinal problem of rail transport: that the last 50 kilometres of the route as approaching urban areas and terminal transfers require high cost and long travel times. It can also make economically feasible to carry small amounts of freight to the individual sidings of warehouses without the complications of traditional locomotive-hauled trains. The further developed latest version of Railrunner Cargo Sprinter may give logistics a new dimension as a fast, flexible and cost-efficient way of door-to-door transport. Moreover it can run on railway tracks independent of overhead electrical conductors, hence it can be used anywhere in the world.

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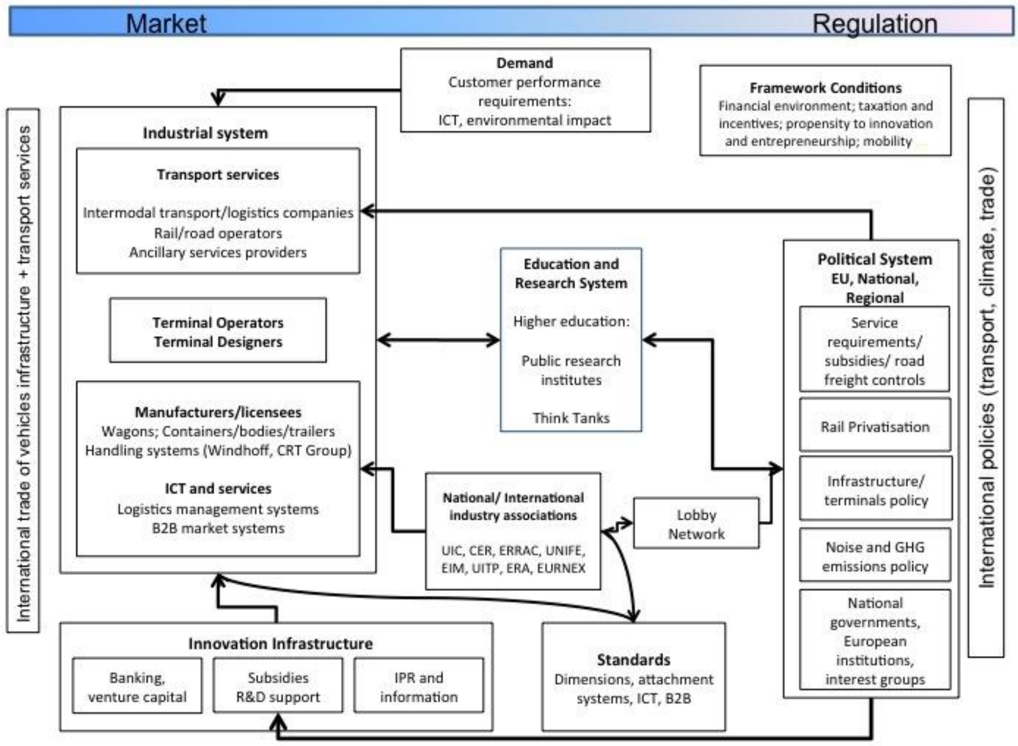
Step 2: identifying the structural components of the TIS

In this step the structural components of the technological innovation system are described. Those are: actors, networks and institutions.

2.1 Actors

Figure 30: Rail freight innovation system



The idea of flexible rail freight has been around for a long time. Different solutions have emerged to solve the problem, such as roadrailers or the Iron Highway (more on those later). The Cargo Sprinter technology is a relatively recent addition to these solutions. The following paragraphs will give an overview of the actors involved in the innovation system seen on Figure 30.

From the market side, one of the most important actors is the developer and manufacturer itself, Windhoff Bahn und Anlagetechnik GmbH. As railway manufacturers go, Windhoff is not a large company. They designed the Cargo Sprinter concept, and have manufactured the vehicles as well, also being involved in making modifications to the original design. They have also licensed the technology to other firms, such as Colin Rees Transport Group (CRT), an intermodal transport company based in Australia.

National and international industry associations also play an important role in this innovation system. These range from entities enforcing safety and interoperability such as the European Railway Agency (ERA), through actors promoting rail research such as European Rail Research Advisory Council (ERRAC) to associations representing design, manufacturing,

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maintenance and refurbishment companies in the railway sector such as the Association of the European Rail Industry (UNIFE).

On the regulation side, framework conditions and political institutions (the EU, national governments, etc.) play a crucial role in defining the areas of research and policy intervention. Recent policy documents suggest that rail, specifically rail freight, is an area of interest and necessary intervention on a European and national level for Member States, especially with regard to the desirable increases in the role of rail in passenger and freight transport (modal shift).

2.2 Networks

A number of different networks can be relevant for describing this structural component of technological innovation system.

International Union of Railways (UIC): UIC is the worldwide organization of the railway sector with 197 members worldwide (integrated railway companies, infrastructure managers, railway or combined transport operators, rolling stock and traction leasing companies, service providers, etc.). The main objectives of UIC include promoting rail on a global scale, proposing new ways to increase technical and environmental performance, promote interoperability, etc.

The Association of the European Rail Industry (UNIFE): UNIFE aims to promote rail market growth in the service of sustainable mobility, support European policies favouring rail, and to provide its members with market, technical and political intelligence in the field.

Community of European Railway and Infrastructure Companies (CER): CER is the common platform for railway projects, infrastructure and vehicle leasing companies from the EU, Accession Countries, Norway and Switzerland.

European Rail Infrastructure Managers (EIM): EIM works to improve the development of the rail transport mode. It also acts as an advocacy organization towards the European and provides expertise to the appropriate European bodies including the European Rail Agency (ERA).

European Railway Agency (ERA): The Agency was set up to help create an integrated European railway area by reinforcing safety and interoperability, while it also acts as the system authority for the European Rail Traffic Management System (ERTMS), which has been set up to create unique signalling standards throughout Europe.

European Rail Research Network of Excellence (EURNEX): This network is made up of 47 scientific institutes in the area of transport and mobility all over Europe. EURNEX is a research cluster in the European Research Area in the rail sector. It is driven by operators and industries and it is supported by the EC, providing multidisciplinary R&D.

2.3 Institutions

As one of the most pressing problems of interstate rail traffic has traditionally been the lack of standardization and conditions across countries in the EU (and the world), EC regulations are of exceptional importance regarding this TIS. Interoperability is a European Commission initiative. Its goal is promoting a single European market in the rail sector. Some of the most important regulations of note are (the list is not exhaustive):

1. 96/48/EC on High Speed Rail;

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2. 2001/16/EC on interoperability;
3. 2004/49/EC on safety;
4. 2004/50/EC amending the Directives on interoperability and safety.

These Directives were aimed at removing the technical barriers to the supply of equipment and the running of trains between Member States. The Cargo Sprinter has been designed to run at high speeds (up to 120km/h), although it should be mentioned that gauge-related interoperability problems are still present, requiring modifications.

Step 3: mapping the functional pattern of the TIS

In this step of the analysis the functional pattern of the technological innovation system is described. The functional parameters shown in Figure 1, 3a are described:

3.1. Knowledge development and diffusion

There are multiple challenges facing the rail sector that have an impact on knowledge development trends on the European scale: competition with emerging rail suppliers (China), new and ever more stringent requirements in safety and security, an increasing emphasis on sustainability and life-cycle approaches, and the transformation of the sector with the proliferation of high-speed development projects worldwide. Rail freight transport is an important element to creating a low carbon economy.

Rail transport – and transport in general – has taken a hit in this respect as a result of the crisis. According to the European Patent Office Report, transport patent applications have decreased to 5 869 in 2010, down from 6 823 in, 2008, a 14% decrease (EPO, 2011). With this statistic, transport has the second lowest number among the different fields, just barely above Telecommunication. It is also worth mentioning that these numbers are not an indication of the general situation regarding patent applications, as despite the economic woes, as the EPO reports that the number of patent submissions is rising, and in fact it was the highest ever in 2010 since the Office was established 34 years ago.

Regarding financing sources, the Cargo Sprinter technology has no specific funding source of note. Rail and rail freight in general have funding sources available, however, they do not apply to the Cargo Sprinter specifically. Intermodal solutions such as this are generally funded by companies from the market (as was the case with the Iron Highway and the Ramp Car).

With regards to funding sources, Marco Polo is worth mentioning. It aims to drive passenger and freight traffic from road to rail and waterborne modes through supplying grants for producers, manufacturers and haulers would otherwise be hard-pressed or reluctant to invest in making this change. The program budget for 2007-2013 is €450 million.

3.2. Influence on the direction of search

With the environmental and sustainability agenda becoming ever more important in the further development of the transport system of the European Union, shifting goods and passengers from road transport to less polluting forms has become the core of the transport policy, along with the goal to foster the integration of different modes of transport (intermodality). Making the switch from road to rail can only be done through incentives, (targeted investments, pricing schemes reflecting the real costs of road use) encouraging passenger and freight traffic realignment to other modes. The primary goal in this respect is

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to shift passengers and freight from road to rail, and attempting to replace short-haul air transport.

To achieve these goals, an improvement is necessary. Rail must improve speeds and service levels if it is to attract freight traffic from roads.

3.3. Entrepreneurial experimentation

The Cargo Sprinter technology made its debut in Australia between Junee and Albury in 2002. The trial included running empty and loaded with empty containers as well as a publicity trip to provide an opportunity for locals to inspect the Cargo Sprinter. The actual power units were built by the manufacturer, Windhoff, in Germany, and the vehicles have later been modified to meet AROU (Australian Rail Operations Unit) standards for vehicles in Australia and to correspond to local conditions. Changes included air conditioning and toilets in the cab, longer fuel range and centralized couplings. Two $1 million prototypes arrived in February 2002 for accreditation and proving trials in each state. Commencement of scheduled service was initially planned for a daily round trip between Melbourne and Albury with up to 12 x 40ft containers.

Another version of the technology has been in use in the UK. A total of 25 two-car units were ordered by Railtrack from Windhoff to act as a replacement for departmental vehicles (many of which were obsolete and have originally been converted from passenger stock).

Because of the different goals and needs, design changes were necessary. The vehicles supplied to Railtrack had a "master" vehicle and a "powered slave" vehicle, meaning both units were fitted with engines (the first batch ordered had an unpowered slave unit). Having two powered units yields improved acceleration and top speed. However, this improvement also necessitated a redesign of the suspension – there were initial problems with the vehicles being "out of gauge" when running empty.

A more recent example of entrepreneurial experimentation is from Switzerland: Windhoff has supplied the SBB (Swiss Federal Railways - Schweizerische Bundesbahnen) with 22 multi-purpose vehicles in 2009. In this case, the vehicles have been procured to serve as multi-purpose infrastructure maintenance vehicles and cranes as opposed to cargo transfer. The vehicles procured were of 3 different sub-types: the Hubi vehicles (combining a small staff accommodation and toilet module plus a working platform), the Combi (multi-purpose infrastructure maintenance vehicle), and the Krani units (featuring two cranes).

The modified vehicles were 20 m long, powered by a diesel engine capable of 40 km/h maximum speed during operation, with full remote control. They also feature a vertical lift-working platform and a crane, which are also powered from the hydrostatic drive, as well as power takeoff outlets for hand-held tools. With a tare weight of around 58 tons, the vehicle can carry up to 14 tons of material without exceeding the maximum 22.5-ton axle load.

The flexibility of the Cargo Sprinter concept is demonstrated by another Swiss example. The SBB's Gotthard base tunnel (completion in 2015) and the Lötschberg base tunnel of BLS (Bern-Lötschberg-Simplon railway) required sophisticated rescue equipment. To meet these needs, a 3-car train set was ordered by SBB and a 4-car train set was ordered by BLS from Windhoff in 2003. The LRZ-NT SBB & BLS (Lösch- und Rettungszug Neue Technologie - New Technology Fire-Fighting and Rescue Train) has been procured to be used primarily for rescue and support operations inside railway tunnels. The modified version featured three different fire-fighting systems. Water and foam could be sprayed both via the monitors or

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water cannons and via the fittings below the cabin. The pump output was 6000 l/min., and the water cannon has an effective reach of up to 70 m at an output of 2 400 liters per minute. A modern CAFS system (Compressed Air Foam System) was also installed. Employing a special foaming agent plus a water/air mixture, the resultant wet foam is highly effective as a fire extinguisher. The train sets included (windhoff.de):

1. One powered equipment vehicle with fire-fighting and support equipment (i.e. equipment compartment, generator set, breathing gas compressor, workshop, storage room, connection points for breathing masks, a Signum Integra train control system, radios) and a power source meeting EURO III standards.
2. One non-powered tank wagon with a 50 m^3 tank. This vehicle features a water tank, tanks for foam fluid, a power generator with pumps, CAFS (Compressed Air Foam System), connecting points for breathing masks, and a breathing gas system for the cabin,
3. One powered rescue vehicle**,** with a train crew cabin, a rescue compartment for up to 60 people, an access stair module, breathing gas system for the cabin and rescue compartment, connecting points for breathing masks, Signum Integra signalling system, and radios.

As it is clear from the examples above, this technology has been used (and sometimes reinvented) for different purposes in different countries, sometimes being transformed in its purpose altogether (i.e. the Swiss example). Entrepreneurial experimentation has been vibrant, but this has not lead to widespread adaptation in the intended purpose. Probably the best example for successful adaptation is Australia.

3.4. Market formation

In the case of rail freight, the issue with market formation is the fact that the majority of freight transport currently goes on road, meaning that while there is a market for this activity, a competing solution is currently dominating. According to Eurostat, 77.5% of inland freight transport was transported by road, 16.5% by rail and 5.9% by inland waterways in 2009. The tendency is also unfavourable: the share of rail was down in 2009 from 19.7% in 2000. This realignment of inland freight transport from rail to road also carries with it the environmental consequences of increased GHG emissions and goes against the European objective of creating a low carbon economy.

The main drivers behind these processes are flexibility and interoperability, rail's disadvantages against road transport. These can be summarized as follows:

1. Routes and timing cannot be tailored to individual needs;
2. No door-to-door service;
3. High costs of terminal operations (loading and unloading) in time and resources;
4. High investment-intensity can lead to inefficient monopolies with increased costs;
5. Economies of scale require long distances and large cargo volumes;
6. Limited coverage of rural areas;
7. Gauge, signalling systems, safety requirements, etc. are not uniform as in road.

These disadvantages of rail make it very difficult to reverse current trends. The Cargo Sprinter Technology addresses some of these issues (e.g. lower terminal operation costs, shipping less cargo faster and in a more flexible way), it also shares some of them (the locomotive itself is quite expensive). The flexibility and adaptability of the technology is

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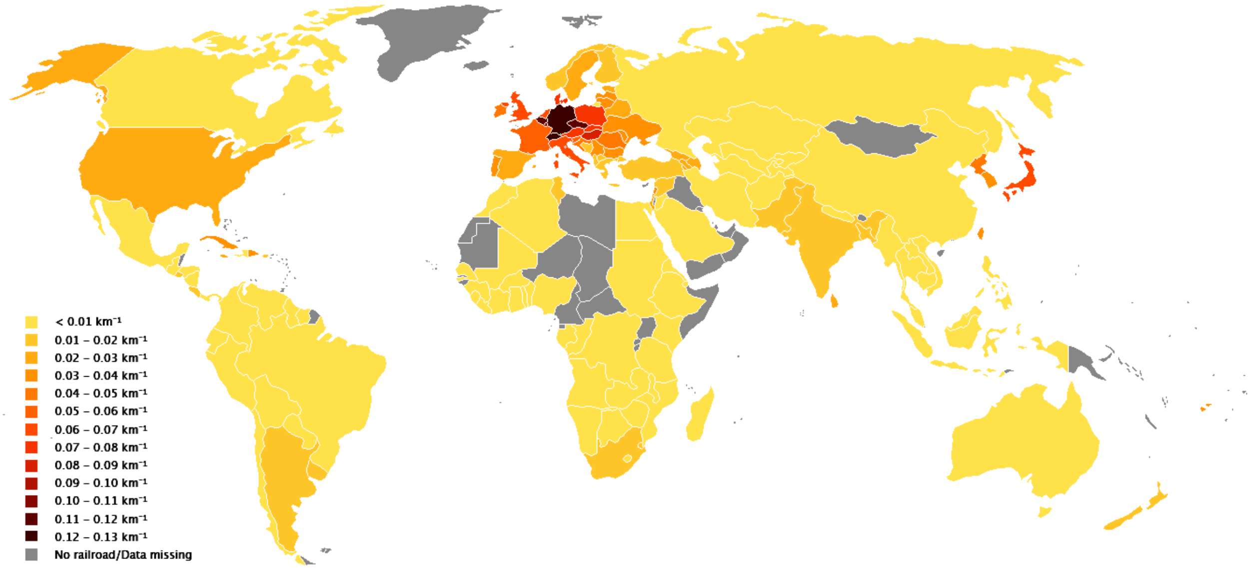
demonstrated by the variety of uses in different countries from utility vehicle to fire fighting (see section on "Entrepreneurial experimentation").

3.5. Legitimation

The European region has traditionally been strong in the railway sector and the European Union continues to be superior in this field. This leading role becomes evident when looking at the concentration of the railway network as a function of country area (see Figure 31).

Figure 31: Rail network divided by country area (darker is better)



This picture is somewhat modified by social factors and population trends, both of which have a profound impact on railway statistics. The end result still underlines the importance of rail and therefore the social acceptance of efficient solutions such as the Cargo Sprinter technology (the EU is third after India and China in passenger-km, and fifth in freight ton-km). The dense existing rail network also allows for efficient improvements in the medium term, especially considering that there are very limited options for dramatically increasing maritime transport speeds or reducing air transport costs. Coupled with the increasing concerns regarding CO_2 emissions, regulatory changes favouring rail freight transport can be expected in the EU.

The Cargo Sprinter technology can be adapted to different conditions and modified to meet various needs. It is designed to work with existing infrastructure and is therefore compliant with relevant existing institutions and has social acceptance. In fact, the latter is growing as a result of the general sentiment and strategic vision in Europe that transport emissions (passenger as well as freight) need to be reduced and that rail is to have a considerable role in this endeavour. The 2011 White Paper on Transport, in particular, states that "rail, especially for freight, is sometimes seen as an unattractive mode. But examples in some Member States prove that it can offer quality service. The challenge is to ensure structural change to enable rail to compete effectively and take a significantly greater proportion of medium- and long-distance freight (…). Considerable investment will be needed to expand or

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to upgrade the capacity of the rail network. New rolling stock with silent brakes and automatic couplings should gradually be introduced."

As demonstrated by the above, the legitimation of rail freight already exists, and this is shared to a degree by this specific technology.

3.6. Resource mobilization

The Cargo Sprinter technology is quite peculiar in this respect in that it requires only a limited amount and range of resources (giving it the competitive edge against existing technologies). The technology is already mostly developed, although slight modifications and improvements (such as the implementation of a wireless distributed power system) will certainly be made going forward. The most important resource to be mobilized in this case is financial capital, as the locomotives themselves are quite expensive to purchase. Being that this TIS focuses on rail and one of its distinct advantages is requiring less infrastructure than conventional solutions, it is safe to say that necessary infrastructure elements are already in place.

3.7. Development of positive externalities

By its nature, the Cargo Sprinter TIS does not generate considerable external economies, as it requires raw materials limited in amount and type. Another factor decreasing its impact in this area is the low rate of adaptation. This is mostly due to economic considerations: mode change for cargo transfers usually only makes sense for long haul, the market for the swift delivery of cargo over short distances is relatively limited. These factors together severely limit the ability of this TIS to generate external economies worth considering.

Step 4: assessing the functionality of the TIS and setting process goals

The train technology deployed in Germany has been used in proof of concept trials aiming to demonstrate the commercial viability of short-haul rail freight transport in the UK under a European project called Innovative Rail Intermodal Services (IRIS) in FP4. Trials were also sponsored by the Strategic Rail Authority (SRA). The trial runs in IRIS have shown that there are a number of technical issues with this particular train technology. One of the conclusions of the project was that costs for new market entrants should be lowered by as much as possible, in part by using existing technologies instead of investing in new, expensive solutions.

One of the other problems with introducing this technology has to do with the responsiveness of infrastructure managers and operators, since short-haul, fast freight transfer with smaller trains is more volatile as it changes with the needs of shippers (time, location, origin, destination, frequency, etc.), and requires a greater capacity to adapt to changing conditions. To fully exploit the potential of the Cargo Sprinter would require a completely different infrastructure management regime, but it would make rail more competitive with road.

Even though the technology itself has been developed by Windhoff in 1996, the last 14 years have not seen the proliferation of the technology where and how it was expected. Adoption in Europe remains below initial expectations, even as the White Paper on Transport and other European initiatives in this field could (and could have) significantly contributed to a

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more widespread application. Instead, countries outside the European Union have invested in the technology (e.g. Switzerland, Australia, see the chapter on "Entrepreneurial experimentation), and have sometimes adapted it to their needs, going as far as changing the overall purpose of the locomotives (from transporting freight over shorter distances in flexible manner to fire fighting).

The "maiden voyage" of the technology was in 1996. From 1997, 10 units were operated on the Hannover - Frankfurt airport trip as a test bed. Mass production and use did not come to pass, however, and the prototypes were sold in 2004 (to be used with much more success in Australia – see section on Entrepreneurial Experimentation). There were multiple reasons for the failure of this technology to become more mainstream: among other things, there were technical difficulties, a lack of political support and contrasting transport policy (long-distance freight with large trains became the norm). As for use outside Germany as a freight carrier, two power cars were transferred to Switzerland in late 2008 after several adjustments to be used as cargo shuttle. Since April 2009, one train daily transports gravel for the construction of the Zurich diameter line, while another set has been operating since June 2009 for Rail Logistics on the Felsberg-Frauenfeld-Härkingen-Dailliens line.

For a comparison with other similar TIS, the Iron Highway, a "trailer on flat car" (TOFC) concept seems suitable. It was prototyped in the US during the 1990's, and although the Iron Highway has seen limited success and been phased out, more current designs building on the same idea have been developed and are still in use today (such as the Wabtec ramp car of Canada, which first an between Montreal and Toronto in 2002). This concept combines adapted railroad technology with intermodal operation (see Figure 32).

Figure 32: The TOFC concept

The setup is made up of self-propelled bidirectional elements containing a flat deck with a split-ramp loader in the middle and control cabs at both ends. These elements are then combined to form a freight train capable of transporting standard highway trailers secured by built-in fifth wheels. The advantages of this setup are the following:

1. Minimal terminal requirements (no lifting equipment, only needs road and rail access);

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2. Minimal truck-haul and drayage costs;
3. Simple, flexible setup with low costs.

This setup can be towed by conventional locomotives and gives rail the advantage of door-to-door service. The TOFC concept has been successful in getting attention in the intermodal market and continues to be used to this day.

Another similar TIS that lends itself to comparison is the roadrailer concept. In its initial stages in the 1950s, the technology consisted of trailers that were constructed with retractable integrated rail wheel sets. These wheels were in the upper position when the trailer ran on road, and were lowered when it was pulled behind a train. One of the advantages of this concept was that these vehicles could be attached to just about any kind of train (passenger or freight) without complex preparations, as their use did not require flatcars, however, it was also the primary cause of their failure: this setup meant that considerable excess weight was added to the cars (because of the built-in rail wheels).

To address this problem, the more modern versions do not have integrated rail wheels, instead using regular trucks (bogies – a set of rail wheels on a chassis) that connect them together (see Figure 33).

Figure 33: Roadrailers with the bogie between them

Various rail companies have started experimenting with the technology in the 1980s, as it had distinct advantages: it was lightweight, had reduced rolling resistance and was less capital-intensive to set up, since using no flatcars meant that the need for expensive crane systems to move cargo between modes was eliminated (cargo is transferred using the truck's air suspension systems in a matter of minutes). Another significant advantage of modern models is slack-free coupling, which virtually eliminates one of the most significant sources of product damage. These units are still in use in the United States and Australia

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(one example is Triple Crown Services Company in the US), and have proven successful in providing intermodal freight shipping services.

The main difference between roadrailers and the Cargo Sprinter is that the latter requires more investment (the rail car itself is expensive) and has less flexibility, as it requires crane systems to transfer cargo containers (even if it still needs less infrastructure at sidings than conventional solutions).

Step 5: identify inducement and blocking mechanisms

There are numerous factors that inhibit the larger scale deployment and marketability of the Cargo Sprinter Technology:

1. Track access charges;
2. Road has the ultimate flexibility;
3. External costs;
4. Track capacity;
5. Price;
6. Current trends;
7. Domination of incumbents.

First and foremost, track access charges affect large, long-haul freight trains less, giving them a competitive advantage and making short-haul freight much less viable (effectively discriminating against smaller trains). This is especially so in the case of the Cargo Sprinter, as it is unable to carry sufficient tonnage to make its use economical. It is also true that rail alone is not capable of offering one of the greatest advantages of road: door-to-door service. Although there is a great deal of congestion on Europe's roads, suburban railway lines are also crowded, which presents a problem. Since the Cargo Sprinter itself is an expensive investment, it would require high value cargo that needs faster trains to ship it (e.g. perishables), warranting a premium shipping rate. Not only is such cargo limited, but as soon as the speed decreases due to overloaded suburban lines, the Cargo Sprinter will no longer have any advantage over a standard locomotive. Also, the current trend in rail shipping is for trains to get bigger and trips longer, to achieve economies of scale. In this sense, the Cargo Sprinter is sailing against the wind. Finally, rail transport is a sector where the domination of established market players is particularly hard to break. This is in part due to public liability costs, deterring newcomer operators from the market. The other reason is the capital intensity of the sector, which also cements the inefficient monopolies.

The situation is not that bleak, however, as the technology also has several factors going for it:

1. Speed;
2. Cabs at each end;
3. Excels in handling moderate volumes and servicing smaller rail terminals;
4. High power to weight ratio;
5. Quiet operation;
6. Regional freight operation, or as a feeder service for higher volume lines;
7. Units can be combined;
8. Ability to utilize the track outside the existing train path schedule (off-peak);
9. Less fuel consumption and emissions per ton-km.

First of all, speed is a very important advantage. Because of the setup itself (cabs at each end of the train), the time needed to turn around is eliminated. The locomotive itself is

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capable of higher speeds than an average freight train, has a high power to weight ratio, while also needing less infrastructure at sidings and shorter loading/unloading times, while long trains require huge crossing loops and large terminals; often in land-starved environmentally-sensitive urban communities. The quiet operation of the Cargo Sprinter, on the other hand, means the train has good residential amenity and can access the smaller terminals in urban areas. It is also a good solution for servicing smaller rail terminals with smaller cargo volumes, which are uneconomic for 'big trains' chasing economies of scale, making it suitable for shorter, more flexible shipping with faster turnarounds to and from the port; or servicing freight (such as perishables) out of smaller terminals, or even act as a feeder service for lines with high freight volumes. The units are also very flexible, making it possible to combine two of them to be used as shunting units at stations, or up to 7 units may be combined to service multiple stations in one journey with a common leg (the train would be separated at a waypoint and head off in different directions and then be recombined on the return journey). Finally, the Cargo Sprinter is able to deliver goods with much less fuel cost and greenhouse gas emissions.

It is clear the technology has some drawbacks that prevented it from gaining more traction on the market. These barriers are partly short-term or pertain to initial investment, and could be successfully targeted by policy. The next section will detail possible policy tools and methods that would make the Cargo Sprinter more economically viable.

Step 6: specify key policy issues

The transport policy of the European Union is clearly committed to making rail more relevant in both the passenger and the freight transport market by increasing service levels and attempting to address the competitiveness advantage of road transport. These goals have been set in many of the Commission's policy documents (one of the most recent being the White Paper on Transport in 2011), but there is still a long way to go to reach them. The Cargo Sprinter technology would benefit from these endeavours, but a few policy solutions that would make it more marketable stand out. These are the following:

1. Enforcing PPP;
2. Transhipment costs;
3. Interoperability;
4. Access and rights;
5. Competition;
6. Cooperation;
7. Common strategy in track access charges.

One of the reasons for the better competitiveness of road transport is the fact that road users generate more external costs, while paying for them to lesser degree. It is up to transport policy solutions to close this gap by applying the Polluter Pays Principle on transport externalities. This can be done through policy solutions such as taxes or congestion charging. Since the air pollution associated with moving a ton-km of cargo is far less by rail, these solutions would also be in line with climate policy targets. It should be noted that the benefits of subsidizing rail freight may be offset by an increased number of passenger cars, an inefficient reallocation where the subsidies would encourage the use of roads by car drivers at great cost.

Another important element is transhipment costs (the costs associated with loading and unloading freight at terminals), which are proportional to the carrying capacity of a given

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vessel. These terminal costs play an important role in determining the relative competitiveness of different modes (Rodrigue et. al., 2009). Since ships have the largest carrying capacity, loading and unloading is time-intensive and costly. The same is true for rail to a lesser degree, with road having the most competitive transhipment costs. Therefore, maritime and rail transport is not as viable for short-haul as road. Addressing this problem of high transhipment costs would make short-haul rail, and therefore Cargo Sprinter, more competitive and feasible.

Standardization is one of the most important elements of any strategy aiming to create a safe, competitive and efficient rail transport system. While there certainly are efforts in this area, they are mostly focused on High Speed Rail. There are some developments, as the EU has concentrated efforts to create interoperable passenger and freight railway network through the standardization of signalling, power systems and track gauges. While funds have been allocated to interoperability projects in Latvia, Lithuania and Estonia, as well as the Iberian Peninsula to enhance connections between Portugal, Spain and the rest of Europe, loading gauge (the physical dimensions of railway vehicles) still remains a problem. Smooth interoperability is essential to the general objective of changing modal split in the favour of rail.

Rail infrastructure is just as limited as road, and therefore it is crucial that rail freight trains get access to critical infrastructure in competition with passenger transport (which dominates over freight in the typical European setting), and that these conditions are not determined by the monopolies of existing operators, inhibiting the entry of newcomers to the market. This can be achieved by the separation of operators from the infrastructure, and creating a strong, independent regulatory body. Since short-haul rail is more unpredictable, this will still not solve the problem completely as there is a possibility that track capacity will be utilized in long-term contracts.

There have been efforts in the rail sector to break the inefficient monopolies in the rail sector with some degree of success. Rail is losing the intermodal battle with road, and this situation has been brought about in part by the lack of intramodal competition. Rail companies have become dependent on subsidies, while governments (often being the owner) have adopted policies that conserved this unfavourable situation through these subsidies, eliminating competition between providers, leading to stagnating or worsening service levels and competitiveness. The pressure of competition through multiple market players would contribute to improved service levels and make it easier for new entrants to gain market share. The efforts in this area need to continue to improve rail's market position.

There is a great potential in fostering cooperation between rail operators across Europe that has only been partially exploited. Better cooperation would allow Europe's railway companies to develop coordinated strategies and common policies (e.g. regarding the procurement of rolling stock). It would also allow for synergies in the intermodal battle for customers (marketing), and contribute to addressing the key issue of interoperability.

Track access charges are a crucial element determining the competitiveness of the rail sector. However, they are heavily dependent on the government funding infrastructure managers receive, and therefore vary widely within the EU. It is thus essential that track access charges are fair and at a level not too high for operators. Member States have different (and sometimes conflicting) strategies on rail freight (e.g. subsidizing short haul vs. long haul), increasing its costs and decreasing its competitiveness. A common European strategy regarding track access charges would solve some of the problems faced by rail

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freight regarding competitiveness going forward. One of the solutions that have come up recently would benefit the Cargo Sprinter greatly: noise-differentiated track access charges. This idea has surfaced because there were no incentives for rail operators to equip their vehicles with silent braking systems. It must be noted, however, that such a strong intervention might actually increase the modal shift away from rail even further.

In summary, increasing competition, cooperation and fostering interoperability would improve the position of rail freight in general, while addressing track access charges and transhipment costs would create a more competitive position for the Cargo Sprinter technology.

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2.7 Biofuels in aviation

Title	**Biofuels in Aviation**
Mode	rail ☐, road ☐, air ☒, maritime ☐, inland waterways ☐, intermodal ☐
Partner	ISI

Step 1: the starting point of analysis: defining the TIS in focus

This TIS analysis focuses on the knowledge field of biofuels. In this context, biofuels are defined as fuels made from several feedstocks via hydrogenolysis of plant or waste oil (Hydroprocessed Esters and Fatty Acids 'HEFA' respectively Hydrotreated Renewable Jet 'HRJ') or biomass liquefaction (Biomass-To-Liquid 'BTL'). The range of applications concentrates on the aviation branch while the main focus lies on commercial aviation, i.e. subsonic planes propelled by jet engines. The spatial focus of this analysis lies on the European Union (EU) as the results are provided to policy makers within the European Commission. However, geographical delineation is not easy as the aviation industry is a global operating industry where actors are strongly interlinked. Thus, actors from outside the EU will be also considered if necessary.

The aviation industry is highly interested in so-called drop-in biofuels which are defined as fully interchangeable with fossil fuels. Fuels certified as being "drop-in" have the advantage that there is no additional infrastructure needed in order to supply these fuels to planes. Furthermore, there are no modifications on planes or engines needed. Thus, particular attention will be given to producers, raw material providers and research organisations concentrating on these kinds of fuels. Plane and engine manufacturers will only play a minor role in this analysis as they do not have to change their current products or production processes for the use of drop-in biofuels. However, they will be needed in order to accompany certification of their products for the use of biofuels.

Step 2: identifying the structural components of the TIS

In this step, the structural components of the technological innovation system are described. Those are actors, networks and institutions.

2.1 Actors

There is a vast amount of actors within the aviation biofuels innovation system. Most of them are internationally oriented as the fuel business is mainly an international business without regional restrictions. Furthermore, most actors are not only acting in the aviation business. For example, biofuel producers do not only produce fuels for aircraft, but also for the automotive or the maritime sector. This is due to technical reasons, because kerosene is

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a by-product of the refining process of diesel or petrol.[83] Other companies are involved in many businesses, because they simply seek to diversify their risks (e.g. venture capitalists).

Actors within the TIS of aviation biofuels can be divided in several subcategories:

- **Aviation Biofuel Customers**: Companies operating aircraft for passenger or freight transportation.
- **Aircraft Manufacturers**: Companies manufacturing aircraft.
- **Engine Manufacturers**: Companies manufacturing aircraft engines.
- **Feedstock Providers**: Companies providing raw materials to produce biofuels (e.g. sugarcane, miscanthus, switchgrass, algae or corn / corn stover).
- **Biofuel Producers**: Companies operating or planning to operate facilities to produce biofuels.
- **Biofuel Distributors**: Companies distributing biofuels to customers.
- **Private R&D**: Companies conducting research and development in order to develop knowledge about biofuels. Private R&D companies are mainly funded by companies (e.g. biofuel producers) interested in acquiring knowledge about biofuels.
- **Public R&D**: Institutes and organisations conducting research and development in order to develop knowledge about biofuels. Public R&D is mainly funded by governmental bodies (e.g. European Commission or national ministries).
- **Technology Providers**: Companies offering knowledge and resources (e.g. patents) to build production facilities and to set up production processes.
- **Technology Consultants**: Companies giving advice to their customers, e.g. how to found a company, implement technologies, set up processes or perform marketing. Their service is mainly used by entrepreneurs who need advice for their activities.
- **Venture Capitalists**: Finance companies providing seed capital to entrepreneurs in exchange to shares of their company.
- **Oil and gas companies**: Large companies producing oil and gas mainly from fossil sources. Many of them are also active in the biofuel business.

Actors in the aviation biofuel sector and the country of their headquarters are shown in the appendices.[84] As this innovation system is still permanently changing (actors entering or leaving the system), it is hard to map all actors influencing the system. Thus, providing a complete table is probably not possible.

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[83] Petrol: between 4 and 11 carbon atoms per molecule; Diesel: between 9 and 22 carbon atoms per molecule; Kerosene: between 8 and 13 carbon atoms per molecule

[84] Sources: Carbon War Room 2012; European Biofuels Technology Platform 2012a; European Biofuels Technology Platform 2012d; Aviation initiative for renewable energy in Germany e.V. 2012a; SkyNRG 2012

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Definition and role of small and medium-sized enterprises

The European Commission (2005) defines small and medium-sized enterprises (SME) as enterprises with less than 250 employees and an annual turnover of less than 50 million Euro or an annual balance sheet of less than 43 million Euro. These numbers include also holding voting rights of other enterprises of more than 25 per cent. An enterprise may exceed either the second or the third criteria without losing its status as an SME.[85]

The aviation industry is a quite capital-intensive industry. Common airlines, freight forwarders and aircraft and engine manufacturers are always large companies with far more than 250 employees. Also established oil and gas companies, venture capitalists and technology providers are unlikely to meet the EU requirements for SMEs due to large turnovers and balance sheets. Private and public R&D and technology consultants could match the definition. However, those companies are generally broadly diversified and their feature of being an SME does not play an important role to the aviation biofuels TIS.

Feedstock providers, Biofuel producers and biofuel distributors are of special interest to this analysis. As long as they are not connected to large energy companies, they are often founded as autonomous spin-offs from research institutes and universities (e.g. *Bioliq* and *Karlsruhe Institut für Technologie*, *SNG Demo Plant Güssing* and *TU Wien*, *Greasoline Pilot Plant* and *Fraunhofer UMSICHT*).[86] As producers for aviation biofuels have still not reached the commercial stage,[87] their turnovers and balance sheets are likely not to exceed the limits of SMEs. This will probably change as soon as the biofuel producers are ready to enter the growth phase. Also mergers takeovers between the actors are likely to play an important role. (Prospective) feedstock providers are generally smaller companies and thus most of them are SMEs or even smaller.[88]

2.2 Networks

Networks in the aviation biofuels system are still in their formation phase. Most of the networks in this system are international, which means that also non-European actors are part of these networks. But also these actors have to be included into the analysis in order to provide a comprehensive view of the system. Most important networks are:

- **Aviation Initiative for Renewable Energy in Germany (aireg):**

The members of this platform are working together to promote the implementation of biofuels within the aviation industry, especially in Germany.[89] This network is a lobby network and thus a problem-solving network.

85 Cf. European Commission 2005, pp. 14f

86 Cf. European Biofuels Technology Platform 2012d

87 Cf. European Commission 2011c, p. 26

88 Cf. European Commission 2011c, pp. 82f

89 Cf. Aviation initiative for renewable energy in Germany e.V. 2012b

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- **SkyNRG:**

This company was founded by the Dutch companies *KLM/Air France*, *Northsea Group* and *Spring Associates* to form a new distributor especially for aviation biofuels.[90] This network is a buyer/supplier network.

- **Renewablejetfuels.org:**

This website was launched by *Elsevier* and the NGO *The Carbon War Room* to enhance transparency of the aviation biofuel system. Furthermore, this website shall bring actors together to facilitate gaining knowledge about important technologies influencing the system and to improve decisions taken by the actors.[91] This network can be seen as lobby network, but also as knowledge sharing network. Thus, it is a problem-solving network.

- **Commercial Aviation Alternative Fuels Initiative (CAAFI):**

CAAFI was founded by all important aviation initiatives of North America including the Aerospace Industries Association (AIA), the Airports Council International - North America (ACI-NA), the Air Transport Association of America (ATA) and the Federal Aviation Administration (FAA) to help all interested actors to join forces for bringing environmentally friendly jet fuels to the market.[92] This network is a knowledge sharing and thus a problem-solving network.

- **European Biofuels Technology Platform (EBTP):**

This technology platform was set up by the European Commission to help developing biofuels and to support market uptake of all biofuel products. However, this platform is not explicitly dedicated to aviation biofuels. Thus, not all members of this network will be important to this analysis.[93] As the name says, this network is a technology platform and thus a problem-solving network.

- **Research projects (SWAFEA / ALFA-BIRD)**

Research projects are important institutions for actors to develop and exchange knowledge and built relationships. Within the EU, there have been two large research projects funded by the European Commission. These are the projects 'Sustainable Way for Alternative Fuel and Energy in Aviation' (SWAFEA) and 'Alternative Fuels and Biofuels for Aircraft Development' (ALFA-BIRD). Overall, these projects have been funded with 14 million Euro and 45 international partners have taken part in these projects.[94] This network is a problem solving network.

2.3 Institutions

Fossil fuels did dominate the fuel market for more than 100 years and they still do today. This implies that a substitute product will struggle becoming more attractive than an

[90] Cf. SkyNRG 2012

[91] Cf. Carbon War Room 2012

[92] Cf. Commercial Aviation Alternative Fuels Initiative 2012

[93] Cf. European Biofuels Technology Platform 2012c

[94] Cf. European Biofuels Technology Platform 2012a

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established fossil product. Alternatives to conventional jetfuels are very rare as products which are able to be used in cars or ships are not useable in the aviation industry. This is due to the fact that jetfuels need a high energy density to propel an aircraft turbine. Nevertheless, technologies to produce environmentally friendly aviation fuels are already available (BTL, HRJ).[95]

Although research is quite advanced today, there are still no large-scale production plants for aviation biofuels worldwide. High investment costs for setting up production facilities and a still underdeveloped market make a market entry unattractive.[96] However, there are many pilot and demonstration facilities which imply larger projects in the future.[97] Furthermore, policy decisions like the integration of aviation into the European Emission Trading Scheme (ETS) in 2012,[98] tax reductions and financial incentives for biofuel producers and users (like feed-in tariffs in the electricity production sector, e.g. the German Renewable Energy Act)[99] and goals set by policy (e.g. a commitment to cut greenhouse gas emissions until 2020 by at least 20% within the European Union[100]) do also play an important role. In future, these actions are supposed to make aviation biofuels more attractive to entrepreneurs, investors and customers. Nevertheless, this system will stay highly dependent on public founding and investments by venture capitalists.[101]

Also certification of aviation biofuels has strong influence on their market uptake. In 2011, the American Society for Testing and Materials (ASTM) included HEFA jetfuels (i.e. HRJ) in their *"Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbon"* (ASTM D7566). All fuels produced by the Fischer-Tropsch process (i.e. XTL) have already been approved due to the production and use of coal-derived jetfuels based on this process by *Sasol* (South Africa). These synthetic paraffinic kerosene types are allowed to be used in up to 50 per cent blends with refined aviation turbine fuel.[102]

As stated before, fossil fuel producers are dominating the fuel market today. These established oil and gas companies will have low interest in changing the existing system. Although there are some activities in biofuels networks (refer to chapter 2.2), they will probably not make huge efforts in moving to new businesses. The example of *Shell* and *Choren Industries*, one of the world's leading companies using the BTL technology, illustrates this. In 2009, *Shell* did suddenly and without a clear reason withdraw from the investment after four years collaboration and a good progress in research.[103]

Nevertheless, society rewards positive actions concerning biofuels. Airlines and freight forwarders have thus strong interest in biofuels as the use of them improves their

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95 Cf. Massachusetts Institute of Technology 2010, p. 120

96 Cf. European Commission 2011c, p. 13

97 Cf. European Biofuels Technology Platform 2012d

98 Cf. European Commission 2011c, p. 7

99 Cf. Federal Ministry for the Environment, N. C. a. N. S. 2012

100 Cf. European Commission 2007

101 Cf. European Commission 2011c, p. 77

102 Cf. International Air Transport Association 2011b, pp. 11f

103 Cf. Reuters 2009

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reputation. Many airlines did make at least a demonstration flight on biofuel until today.[104] Some airlines even start using small amounts of biofuel on their regular passenger flights (e.g. Lufthansa).[105] In future, it is possible that eco-friendly travellers will not only reward but rather demand ecological engagement of the airline they intend to travel with.

Overall, market uptake of aviation biofuels will be quite challenging due to technological restrictions on jetfuels and thus high investments needed for large-scale production of them. Furthermore, resistance of established companies relying on fossil fuels will slow down market uptake. However, policy and society are strong supporters of regenerative energies. Their financial, legislative and moral support will facilitate market uptake of aviation biofuel producers.

2.4 Mapping the structural framework

The structural framework in Figure 34 shows the interdependencies among all actors, networks and institutions. Other than the value chain, this framework also maps non-market feedbacks (emerging e.g. due to the innovation infrastructure) and includes the political system. Especially European legislation plays an important role to the internationally oriented aviation biofuels innovation system, because policies like the adoption of quotas or the Emission Trading Scheme only have noticeable impact when they are introduced by several governments together and not by only one country.

The political system can influence the industrial system indirectly in several ways. The political system predominantly shapes the innovation infrastructure, framework conditions and the public education and research system. These components in turn have strong influence on customer demand and the industrial system. On the other hand, the industrial system tries to influence politics by forming lobby networks.

The aviation industry is not a part of the industrial system of aviation biofuels, but influences it as well by joining networks or partnerships, e.g. for testing compatibility of fuels and engines. International trade of fuels is mainly influenced by customer demand and regulations set by policy. The education and research system and the industrial system influence each other by providing workforce and knowledge on the one hand and by providing research funds and setting research aims on the other hand.

[104] Cf. Blakey et al. 2011, p. 2875

[105] Cf. Lufthansa 2012

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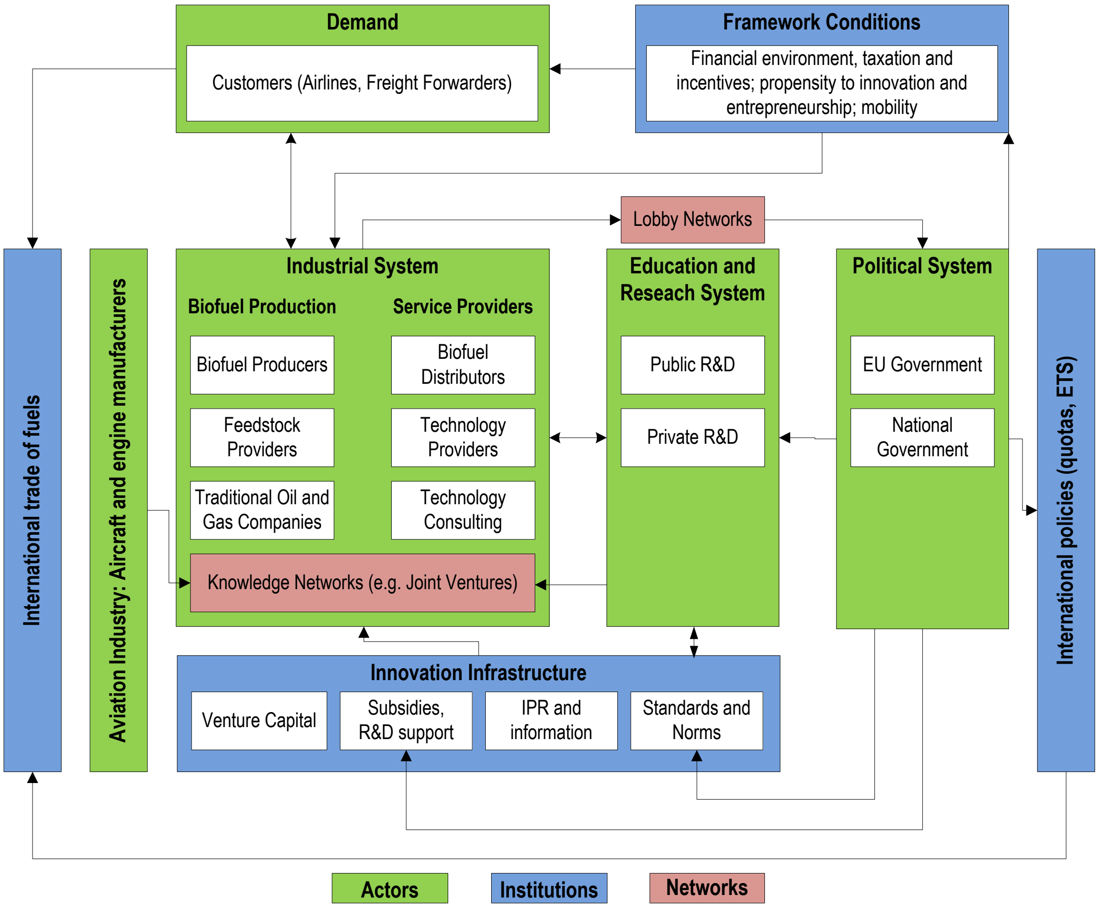
Figure 34: Structural framework of the technological innovation system of aviation biofuels



Source: Own presentation based on Kuhlmann and Arnold (2001, p. 2)

Step 3: mapping the functional pattern of the TIS

In this step of the analysis, the functional pattern of the technological innovation system will be described.

3.1. Knowledge development and diffusion

During the past decade, the topic of biofuels as an alternative to fossil fuels did take up momentum very fast. An online research in the *Web of Knowledge*[106] database for scientific publications (refer to Figure 35) shows that there were less than one hundred publications per year concerning this topic until 2002. In 2011, the database counts more than 3,100 published papers. Regarding papers dealing with biofuels and their use for the aviation industry, first activities can be observed since 2008. Thus, also research about aviation biofuels is taking up momentum although development is probably far behind the

106 Cf. Thomson Reuters 2012

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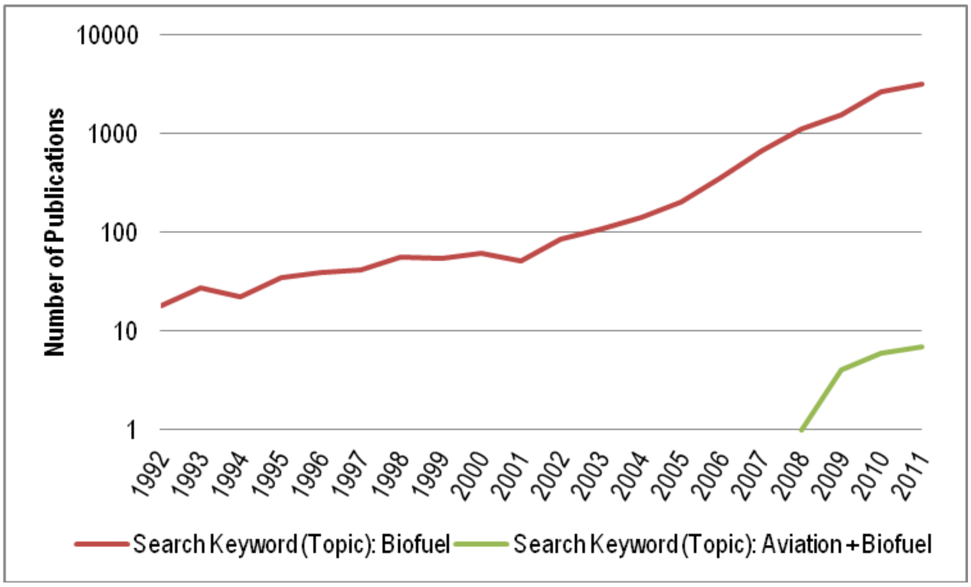
automotive industry, where biodiesel and blends of ethanol and petrol (E-5 and E-10) are already common.[107]

Figure 35: Development of scientific publications tagged with "Biofuel" and "Aviation + Biofuel" (Topic) – further search option: Lemmatisation – On.



Source: Own Presentation based on Thomson Reuters (2012)

The *Google Scholar*[108] database provides similar results (refer to Figure 36). Here, the number of search results is about some magnitudes higher, because this database scans the whole article for keywords. On the contrary, the *Web of Science* database searches for certain topic tags assigned to the paper. This makes *Google Scholar* more inaccurate as also articles only mentioning the keywords but dealing with different topics are included in the results. Nevertheless, the results of *Google Scholar* confirm the results of *Web of Knowledge*.

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[107] Cf. European Biofuels Technology Platform 2012b;

[108] Cf. Google 2012

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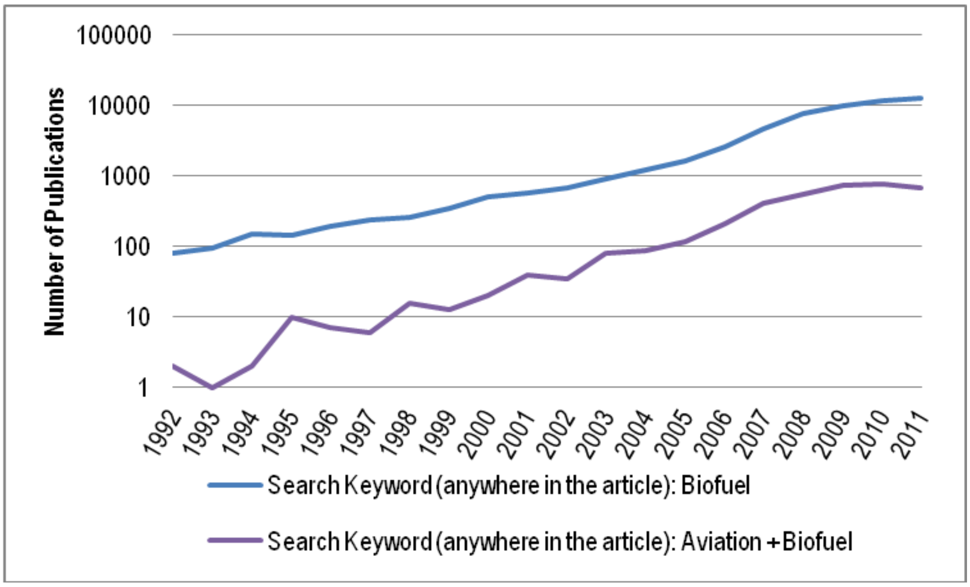
Figure 36: Development of scientific publications with the keywords "Biofuel" and "Aviation + Biofuel" occurring in the text – further search options: articles excluding patents, articles with at least summaries



Source: Own presentation based on Google (2012)

An additional indicator for knowledge development in this innovation system is the number of research projects and their funding. These are pilot and demonstration plants for biofuels[109] as well as demonstration flights on biofuel. In Europe, there are 28 demonstration and pilot plants for biofuels, of which approximately three quarters have been built between 2006 and 2011. Public and private R&D funding for 23 of these demonstration and pilot plants reaches approximately 1.7 billion Euro.[110] Overall, the European Union allocates approximately 24.1 billion Euro to research themes like 'transport', 'environment' and 'energy' which could be suitable for research on biofuels. The budgets are made available by the *7th framework programme*[111] and the future *Horizon 2020*[112] programme. Worldwide subsidies for first and second generation biofuels reached 22 billion US-Dollar (16.5 billion Euro) in 2010.[113] For further information on other possible funding programmes by the EU to support aviation biofuels refer to appendix 2.

Global patent applications regarding second generation biofuels experienced strong growth within the last decade. In Figure 37, the development of applications of worldwide patents concerning second generation biofuels is shown. Beginning in 2001, the number of patents

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[109] Because the oil refining process always results in several different products (e.g. petrol, diesel kerosene), it is not possible to distinguish between certain industries here.

[110] Cf. European Biofuels Technology Platform 2012d; actual funding is higher, because five projects did not publish financial data

[111] Cf. European Commission 2012a

[112] Cf. European Commission 2011a

[113] Cf. International Energy Agency (IEA) 2011b, p. 535

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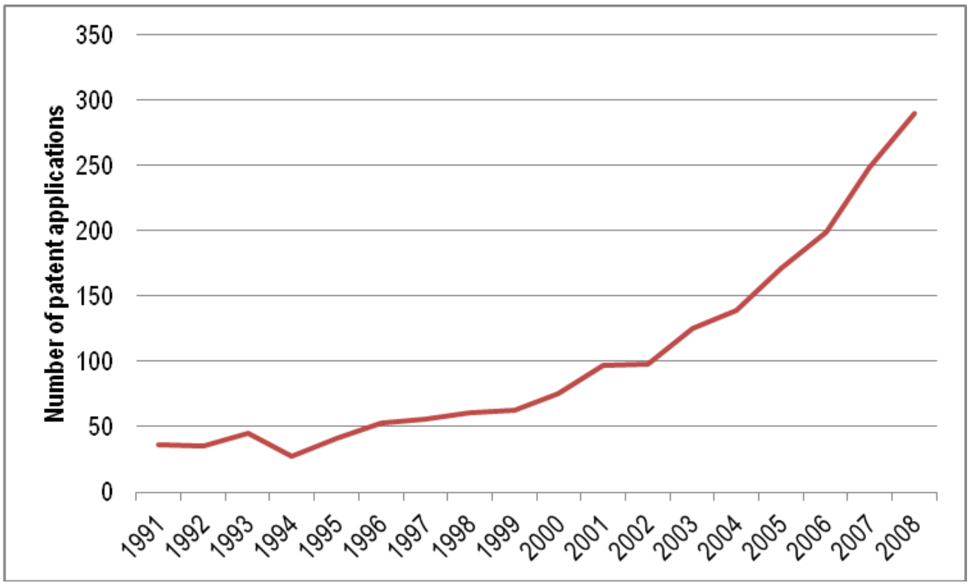
filed continuously increases. This indicates that also research and development departments within companies increasingly engage in knowledge development of biofuels.

Figure 37: Development of international patent applications from 1991 to 2008 regarding second generation biofuels



Source: Own presentation based on a PATSTAT search done in Walz et al. (2011, p. 81)

Furthermore, there have been several demonstration flights by several airlines and air forces since 2008.[114] In the second half of 2011, first regular passenger flights were made using biofuel blends.[115] This means that practical knowledge about jet biofuels develops very fast.

The growing number of research papers published (refer to Figure 35 and Figure 36) also indicates that knowledge diffusion tends to grow, because more and more information about aviation biofuels is made publicly available. Additionally, there is a growing number of conferences concerning biofuels[116] and new networks are forming (refer to chapter 2.2). This also supports knowledge diffusion.

3.2. Influence on the direction of search

The articulation of interest by leading customers mainly influences the direction of search. The International Air Transport Association (IATA) is the official representation of all commercial airlines. Therefore, sustainability goals formulated by the IATA reflect the interest of all potential customers for aviation biofuels:

- *"An average improvement in fuel efficiency of 1.5% per year from 2009 to 2020;*

[114] Cf. Air Transport Action Group (ATAG) 2012a

[115] Cf. Air Transport Action Group (ATAG) 2012b

[116] Cf. European Biofuels Technology Platform 2012e

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- *A cap on aviation CO2 emissions from 2020 (carbon-neutral growth);*
- *A reduction in CO2 emissions of 50% by 2050, relative to 2005 levels."*[117]

The Advisory Council for Aeronautics Research and Innovation in Europe (ACARE) was formed in 2001 by EU member states, the European Commission and European companies acting in the aviation industry. This advisory council significantly influences governmental research policy within the European Union by deciding on research projects and evaluating research results. As there are no binding guidelines regarding the deployment of aviation biofuels until today, the sustainability goals formulated by ACARE can be seen as the expectations of the European Commission:

- *„In 2050 technologies and procedures available allow a 75% reduction in CO2 emissions per passenger kilometre to support the ATAG [Air Transport Action Group; author's note] target and a 90% reduction in NOx emissions. The perceived noise emission of flying aircraft is reduced by 65%. These are relative to the capabilities of typical new aircraft in 2000.*
- *Aircraft movements are emission-free when taxiing.*
- *Air vehicles are designed and manufactured to be recyclable.*
- *Europe is established as a centre of excellence on sustainable alternative fuels, including those for aviation, based on a strong European energy policy.*
- *Europe is at the forefront of atmospheric research and takes the lead in the formulation of a prioritised environmental action plan and establishment of global environmental standards.*"[118]

Biofuels will play an important role in order to reach the goals of the IATA and the European Commission. As the goals are reachable on many technology paths, there are many ways open for research. Regarding biofuels, there are several suitable feedstocks and processes available to produce environmentally friendly fuels.[119] The goals indicate that customers and policy only demand to reduce emissions regardless which specific technology is used. This leaves researchers a broad scope to examine each possible technology path.

New entrants mainly influence the direction of search. Therefore, incentives should enhance the attractiveness for new entrants to enter the system. One important incentive is the belief in growth potential formulated by potential customers. The IATA thinks that reaching a three to six per cent market share for biofuels in 2020 is possible to the aviation industry.[120] Additionally, the European Commission provides incentives to entrepreneurs by legislative decisions (e.g. ETS).[121]

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[117] European Commission 2011c, p. 24

[118] European Commission 2011b, p. 15

[119] Cf. Massachusetts Institute of Technology 2010, pp. 113f

[120] Cf. International Air Transport Association 2011a

[121] Cf. European Commission 2012b

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3.3. Entrepreneurial experimentation

As stated in chapter 3.1, there are 28 demonstration and pilot plants in Europe allowing to gather practical knowledge about different production technologies and feedstocks for biofuels. Additionally, the high amount of published research papers implies that theoretical research and experimentation is moving on improving the productivity of suitable biomass and oil feedstocks as well as known production technologies. Thus, experimentation is much diversified.

It is far from easy to map the number of new entrants, because most biofuel companies are not only focussed on aviation biofuels. Thus, it is hard to distinguish between new entrants who are interested into aviation and those who are not. One way to tackle this problem is only to map companies already integrated into networks explicitly addressing aviation biofuels. Looking at the founding date of those companies a statement can be made whether most companies are comparably new (e.g. younger than ten years) or comparably old (e.g. older than ten years). According to *renewablejetfuels.org,* most companies dealing with biofuels, especially (potential) biofuel producers, feedstock and technology providers and biofuel distributors, were founded within the past decade.[122] Also the companies owning European demonstration and pilot plants were mainly founded within the same period.[123] This young age of the actors in this system means that there was excessive activity of entrepreneurs during the past ten years. However, there are also some companies who did already exit the market due to financial trouble. For example, Choren Industries (Germany) and Sekab (Sweden) announced to end operations in 2011.[124] Thus, long-term survival of the entrants is questionable.

Also the number of different technologies employed is comparably high. According to the *SWAFEA-project* founded by the European Commission, there are six processing pathways to produce biofuels. These pathways are illustrated in Figure 38. This means that there is a large spectrum of technologies studied regarding the production of biofuels. However, as XTL and HEFA/HRJ fuels are already approved for their use in aircraft engines (refer to chapter 2.3), these fuel types are considered as the most promising production pathways.[125] In the past, research did mainly focus on ethanol, because knowledge about alcohol fermentation is quite advanced and ethanol has proven to be deployable in ground transportation.[126] However, ethanol is questionable regarding sustainability and its performance. Furthermore, it tends to mix with water from the environment, which makes it corrosive and thus non-drop-in to aircraft engines.[127] Nevertheless, 14 of the 28 research and demonstration plants produce ethanol while only five focus on BTL and HEFA/HRJ fuels.[128]

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122 Cf. Carbon War Room 2012

123 Cf. European Biofuels Technology Platform 2012d

124 Cf. Choren Industries 2011; SEKAB 2011

125 Cf. European Commission 2011c, p. 31

126 Cf. European Biofuels Technology Platform 2012b

127 Cf. Savage 2011, pp. 9f; Lee et al. 2010, pp. 4719f

128 Cf. European Biofuels Technology Platform 2012d

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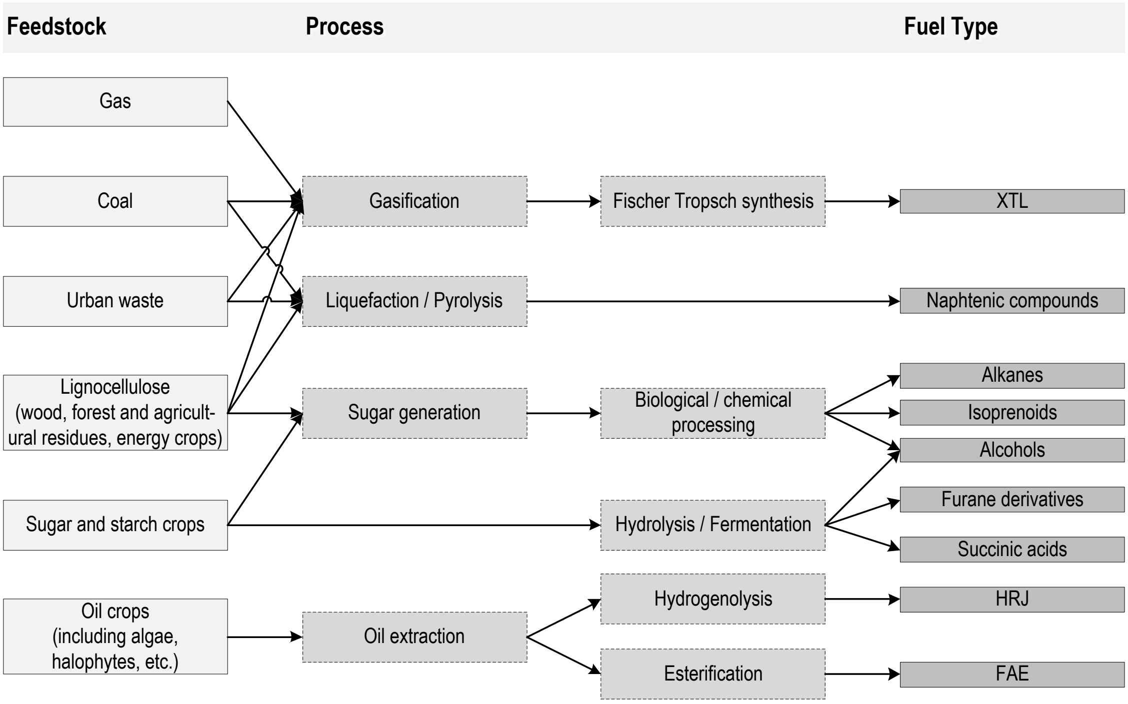
Figure 38: Feedstocks, processing pathways and fuel types for candidate alternative fuels



Source: Own presentation based on European Commission (2011c, p. 31)

3.4. Market formation

There are only few companies worldwide already selling biofuels to airlines. All of them only sell biofuels for demonstration projects as the production capacity is too small for commercialisation at the moment. Hence, there is no noteworthy market share for aviation biofuels existing today. IATA considers a market share for second generation aviation biofuels of three to six percent possible in 2020.[129] Thus, the aviation biofuel market is still a "nursing market". However, many European companies recently announced to form buyer-supplier alliances. All alliances with at least one European partner are outlined in Figure 39. The vast amount of alliances which include all large European airlines imply that future customers believe in a soon market uptake of aviation biofuels. They all want to ensure their future biofuel supply.

[129] Cf. International Air Transport Association 2011a

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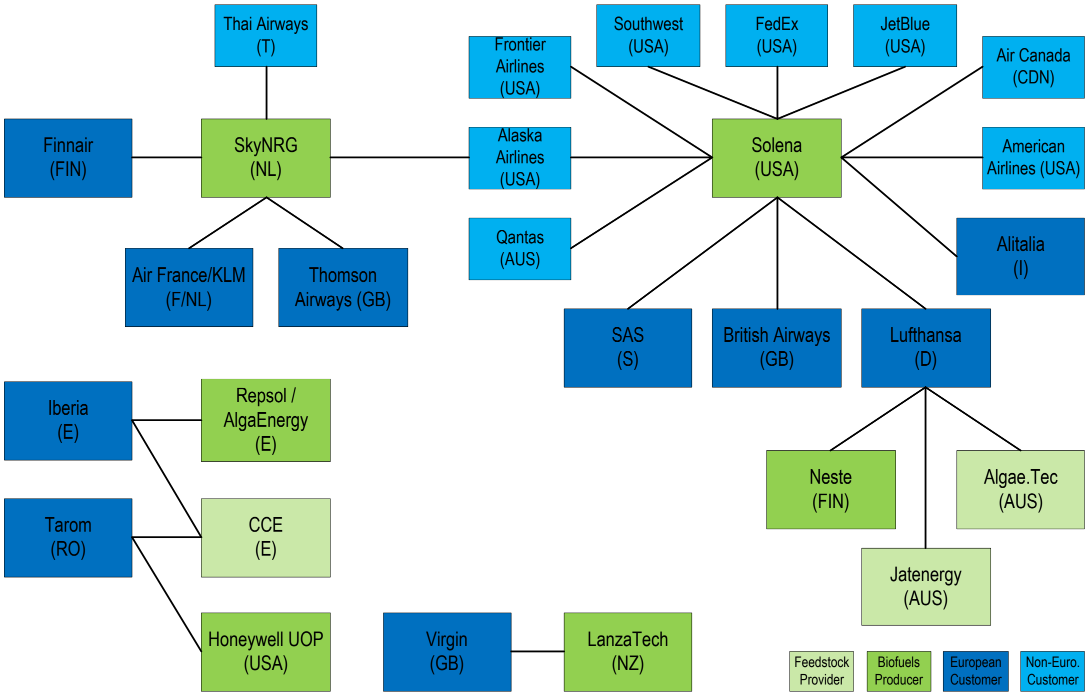
Figure 39: Buyer-supplier alliances with at least one European partner



Source: Own presentation based on news releases on Air Transport Action Group (ATAG) (2012c) and GreenAir Communications (2012)

Although there are strong indicators for a market uptake, market formation will mainly be dependent on aviation biofuels to become cost-competitive against fossil fuels. This will probably take a while. Researchers predict aviation biofuels to become cost-competitive between the next ten to twenty years.[130] However, institutional stimuli to make biofuels more attractive (e.g. ETS) and to develop knowledge (by research funding) are needed to reach this aim.

As the production capacity for biofuels will stay low in the short-term, but demand is said to increase, another problem for aviation is to compete against other transportation modes. Aviation is a relatively small market compared to ground transportation. Thus, it is likely that biofuel production by most companies will mainly focus on ground transportation. Hence, this will be an additional barrier for market uptake of aviation biofuels.[131]

European policy tries to facilitate market formation of aviation biofuels by including aviation into the European Emission Trading Scheme (refer to chapter 2.3) and making these fuels thus more cost-competitive. Furthermore, renewable energies and biofuels play an important

130 Cf. Lee and Mo 2011, p. 3791; International Air Transport Association 2010, p. 33; European Commission 2011c, p. 81

131 Cf. International Air Transport Association 2010, p. 13; Massachusetts Institute of Technology 2010, p. 119; European Commission 2011c, p. 14

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role in the *7th Framework Programme* (overall budget: approx. 50 billion Euro)[132] and *Horizon 2020* (overall budget: approx. 79 billion Euro),[133] both research funding programmes created by the European Union. The 7th framework programme allocates 8.4 billion Euro to the themes 'transport', 'environment' and 'energy' which could possibly apply for research regarding biofuel. The Horizon 2020 programme plans to allocate around 15.7 billion Euro to the themes 'energy', 'transport' and 'climate action' which could also possibly apply for research regarding biofuels.

3.5. Legitimation

The main requirement for prospective aviation biofuels is being safe and being reliable.[134] According to this, biofuels will only receive social, economic and legislative acceptance when they prove to be as safe as conventional jetfuels. Therefore, the precondition for the statements made in this chapter is the safety approval of biofuels for their use in aircrafts.

Social acceptance is mainly dependent on the conscience of the society. However, end customers are also price-sensitive and will probably only be willing to pay higher prices (i.e. higher ticket fares) up to a certain level. Cost-competitiveness will thus be an important topic for creating social legitimation. Furthermore, using biofuel feedstocks also suitable for food production is broadly acknowledged as not being sustainable. Also cultivation of biofuel plants on former farm- or woodland has been vigorously criticised in the past.[135] Thus, social legitimation will only be granted for non-food-feedstocks not being cultivated on former farm- or woodland.

Economic acceptance is mainly dependent on the cost-competiveness of aviation biofuels. Airlines will only use biofuels if those are able to compete against fossil fuels. Otherwise they will mainly rely on the cheaper alternative. Another factor is the security of supply. Being another source for jetfuels apart from fossil fuels can influence the economic legitimation of aviation biofuels positively.

Politics also influence legitimation. Policy decisions to support the deployment of aviation biofuels play an important role for biofuels in competing fossil fuels. The Emission Trading Scheme for example will help biofuels to reach economic legitimacy. Also funding of research projects and financial support for increasing production capacities will help biofuels to reach economic legitimacy. Nevertheless, policy makers could force economic acceptance to arise by introducing mandatory quotas for second generation aviation biofuels, which they have not done yet.[136]

3.6. Resource mobilization

Mapping resource mobilisation activities of the aviation biofuels innovation system is complicated, because the system is still in the formation phase and thus resources are still quite limited. Regarding pilot and demonstration projects for biofuels within Europe, known

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[132] Cf. European Commission 2012a

[133] Cf. European Commission 2011a

[134] Cf. Blakey et al. 2011, p. 2866; Lee et al. 2010, p. 4678

[135] Cf. International Air Transport Association 2010, p. 47

[136] Cf. European Commission 2011c, p. 83

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private and public funding amounts 1.7 billion Euro. As most projects are not older than ten years (refer to chapter 3.1), rising investments into biofuel technologies are indicated. Along with these findings, the rising number of new research projects and companies founded within the past ten years (refer to chapter 3.3) imply that there is also a rising number of employees within the system. Because venture capitalists do normally not tell where they invest their capital, a reliable statement concerning the funds provided by these companies cannot be made.

3.7. Development of positive externalities

Positive externalities arising from the system in the form of pooled labour markets or specialised intermediate goods and service providers have not yet arisen, because the system is in the formation phase with limited resources. In a later phase those will possibly arise.

Knowledge externalities regarding aviation biofuels formed through the emergence of knowledge networks like the SWAFEA and the ALFA-BIRD projects. In these projects, science institutes, members of the biofuel and the aviation industry and potential customers did work together on solutions for several problems regarding biofuels. They further estimated capital and timeframes needed for the deployment of aviation biofuels.[137] Buyer-supplier alliances (refer to Figure 39) are likely to develop knowledge externalities as well, because also knowledge sharing is an important objective of the members of these alliances.

Step 4: assessing the functionality of the TIS and setting process goals

The two options to assess the system are judging it by analysing the phase of development or by comparing it to similar systems. The only region with significant activities regarding aviation biofuels is the North American region. However, also this system is in the formation phase and there are many linkages between both the European and the American system. Thus, a comparison between both systems seem little practical while an analysis of the phase of development based on the findings of the previous step seems more straight-forward.

The first step assessing the system by analysing the phase of development is judging if the system is in the formation or in the growth phase. Depending on the phase different measures are used to assess the system. The indicators and the assessment of their fulfilment are summarised in Figure 40.

[137] Cf. European Biofuels Technology Platform 2012a

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Figure 40: Fulfilment of indicators being in the formative phase by the aviation biofuels system

Indicators for the system being in the formative phase	Fulfilment
time dimension (formative phase lasts at least ten years)	✓
uncertainties regarding technologies, markets and applications	✗
unarticulated demand	✗
poor relation of price and performance	✓
diffusion and economic activities do not reach estimated performance	✓
poor self-reinforcing functions, weak positive externalities	✓

Source: Own presentation

The innovation system of biofuels is at least 20 years old (refer to mapped publications, chapter 3.1), but considering aviation biofuels, this innovation system is not older than ten years. First publications concerning this topic came up in 2008. Regarding the technologies and the markets, there are still some uncertainties although the technology is theoretically working (refer to chapter 3.1) and customers already articulated demand (refer to chapter 3.2). Because there are still only demonstration and pilot projects, the price of aviation biofuels is very high compared to fossil fuels (refer to chapter 3.4). This implies that also market diffusion of aviation biofuels is quite low. As stated in chapter 3.7, no positive externalities have yet arisen through the emergence of aviation biofuels. Overall, as most indicators are found to be true, the findings imply that the TIS of aviation biofuels is in the formation phase.

The next step is to asses each function being strong or being weak. This assessment is summarised in Figure 41 and Figure 42. There, the indicators derived from the framework suggested by Bergek et al. (2008) are characterised regarding the focal system and assessed for strong ('+'), medium ('±') or weak ('-') performance.

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Figure 41: Function Assessment for the Technological Innovation System of Aviation Biofuels (1)

Function	Indicators for assessing the TIS	Characteristics	Assessment
Knowledge Development and Diffusion	Number of R&D projects	28 pilot and demonstration plants in Europe, most of them built since 2005.	+
	Number of patent applications	2003/2004: 264 international applications 2005/2006: 371 international applications 2007/2008: 539 international applications	+
	Investments into R & D	1.7 billion Euro private and public funding for 23 demonstration and pilot plants. 22 billion US-Dollar (~16.5 billion Euro) worldwide subsidies for biofuels in 2010. 24.1 billion Euro is possible to be allocated to biofuel research via the European framework programmes.	±
	Bibliometrics (volume of publications)	3,200 publications on biofuels in 2011, compared to less than 100 in 2002.	+
	Number of workshops /conferences Network size and intensity (research cooperations)	Many conferences and vast amount of cooperations in networks (biofuels in general, aviation biofuels in special).	+
Influence on the Direction of search	Beliefs in growth potential.	IATA thinks a 3 to 6 % market share for aviation biofuels in 2020 is possible.	+
	factor/product prices, e.g. taxes and prices in the energy sector.	European Commission tries to make aviation biofuels more attractive by introducing the Emission Trading Scheme to aviation.	±
	Extent of regulatory pressures, e.g. regulations on minimum level of adoption ("green" electricity certificates, etc.) and tax regimes. Articulation of interest by leading customers.	IATA and EU have high expectations regarding CO2 emissions which are only reachable by extensive use of biofuels.	+
Entrepreneurial Experimentation	Number of new entrants, including diversifying established firms.	Most companies founded within the past decade. However, financing problems forced some entrants to stop their operations again.	±
	Number of diversification activities of incumbent actors.	Not applicable, too early	~
	Number of experiments with the new technology.	28 pilot and demonstration plants in Europe, most of them built since 2005. However, many of them focus on non-drop-in ethanol.	±
	Number of different types of applications.	Not applicable, only use is propelling planes.	~
	Breadth of technologies used.	6 technology paths available.	+

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Figure 42: Function Assessment for the Technological Innovation System of Aviation Biofuels (2)

Function	Indicators for assessing the TIS	Characteristics	Assessment
Market Formation	Institutional stimuli for market formation	European Commission tries to make aviation biofuels more attractive by introducing the Emission Trading Scheme to aviation. *7th Framework Programme* and *Horizon 2020* (overall budget: approx. 129 billion Euro) are created by the European Commission to fund research concerning renewable energies including biofuels. Thereof approx. 24.1 billion Euro could be allocated to research on biofuels.	±
	Specific tax regimes and new (e.g. environmental) standards promoting the new technology	European Commission tries to make aviation biofuels more attractive by introducing the Emission Trading Scheme to aviation.	±
	Articulated customer demand.	IATA has high expectations regarding CO2 emissions which are only reachable by extensive use of biofuels. Furthermore, buyer-supplier alliances are forming. However, lacking cost-competitiveness and competition between transport modes for biofuels are likely to hamper market formation.	±
Legitimation	Support of advocacy groups and social / economic / legislative acceptance.	Social acceptance is high (precondition: safety approval; furthermore dependant on additional ticket fares and the kind of feedstock used)	+
		Economic acceptance is medium (precondition: safety approval; further important topics: cost-competitiveness, the need for alternatives to fossil fuels). Economic acceptance could be higher if politics would set mandatory feed-in quotas.	±
		Legislative acceptance is high (demanding goals for aviation biofuels; specific actions: research funding, Emission Trading Scheme; precondition: safety approval)	+
Resource Mobilisation	Rising volume of capital.	Approx. 1.7 billion Euro invested into pilot and demonstration plants. Most of these funds were invested within the past ten years.	±
	Increasing volume of seed and venture capital.	No assessment possible. Data is held confidential by venture capitalists.	~
	Increasing volume and quality of human resources (e.g. number of university degrees).	Rising number of new research projects and companies entering the system imply a rising number of employees within this system.	+
	Changes in complementary assets.	As the innovation system is in its formation phase and resource mobilisation regarding complementary assets is thus still low, these assets cannot be described yet.	–

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Development of Positive Externalities	Emergence of pooled labour markets	None, too early in the formation phase.	–
	Emergence of specialised intermediate goods and service providers	None, too early in the formation phase.	–
	Knowledge spill-overs	Knowledge networks (SWAFEA, Alfa-Bird projects) Buyer-supplier alliances	±

The achievements of knowledge development and diffusion within the past decade are good. However, it should be remarked that most of the data available does consider biofuels in general rather than aviation biofuels. Considering that first publications about aviation biofuels and first demonstration projects took place in 2008, it is likely that only a little share of the research done until today did particularly deal with aviation biofuels. Nonetheless, as biofuels for ground and air transportation are strongly interlinked, aviation biofuels experienced benefits through knowledge spill-overs from the connected system. In a process view, the next step is to deepen the broad knowledge about biofuels in order to gather more knowledge about their behaviour in aircraft. Therefore, also the influence on the direction of search should be guided into this direction.

The number of entrepreneurial activities is on a high level as there are many technology paths available and many research projects in execution. However, new entrants can struggle financing their ventures. Especially setting up production facilities is very costly and some companies are not able to reach a commercial stage where the investments pay off. The process goal regarding entrepreneurial experimentation is to maintain the high level of entrepreneurial activities in order to deepen knowledge about biofuels but also to reach large-scale production as soon as possible.

As the aviation biofuels system is in the formation phase, there is no considerable market share yet. The market formation function should thus be assessed considering institutional stimuli and articulated customer demand which are both appropriate to the formation phase. Process goals for this function are market stimulation by providing financial and regulatory incentives.

The social acceptance of aviation biofuels is high although there are some constraints regarding the sustainability of biofuels concerning food security, land use and health issues.[138] As there are no flights fuelled by biofuels on a regular basis, there are no impacts on the ticket price yet. Regarding economics, many airlines did already announce their interest in biofuels (refer to chapter 3.4). However, there is no fuel available, because there is still no large-scale production implemented yet.[139] When entering the growth phase, it is likely that cost-competitiveness will play a more important role. Regarding politics, there is a consensus that biofuels are the most promising solution to reduce carbon emissions (refer to chapter 3.2). Thus, legislative acceptance is high. Process goals regarding legitimation are the reduction of uncertainties regarding the sustainability of biofuels and the creation of cost-competitiveness.

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[138] Cf. Eisentraut 2010, pp. 76ff

[139] Cf. Reuters 2012

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The cumulative investments for facilities and infrastructure needed to produce biofuels range from approximately 160 billion Euro (using exclusively the HRJ solution) up to 700 billion Euro (using exclusively the BTL solution). The aviation share of these costs ranges between 30 and 180 billion Euro.[140] Lower complexity of HRJ plants is mainly responsible for the wide range of estimated costs. However, HRJ plants are dependent on certain feedstocks (oil crops) while BTL plants can use every feedstock available.[141] Known investments for European pilot and demonstration plants reach approximately 1.7 billion Euro. This means that the system is still far away from entering the growth phase, although there are positive developments regarding increasing work force and a rising number of research projects. In order to ease market formation, the process goal regarding this function is to increase the resources available, most importantly financial resources and complementary assets.

Until today, positive externalities have only arisen through knowledge spill-overs. Other externalities will possibly arise in future. Thus the function is comparably weak which is expected during the formation phase. Process goals regarding this function are the development of more networks and the promotion of knowledge exchange.

Step 5: Identify inducement and blocking mechanisms

In the previous step, the functions 'entrepreneurial experimentation', 'knowledge development and diffusion', influence on the direction of search' and 'legitimation' have been assessed being strong. On the other hand, the performance of 'market formation', 'resource mobilisation' and 'development of positive externalities' is not ideal. Therefore, considering the findings of Suurs (2009), the system is currently driven by the entrepreneurial motor (refer to Figure 43).[142]

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140 Cf. European Commission 2011c, p. 70

141 Cf. European Commission 2011c, p. 74

142 Cf. Suurs 2009, pp. 210–226

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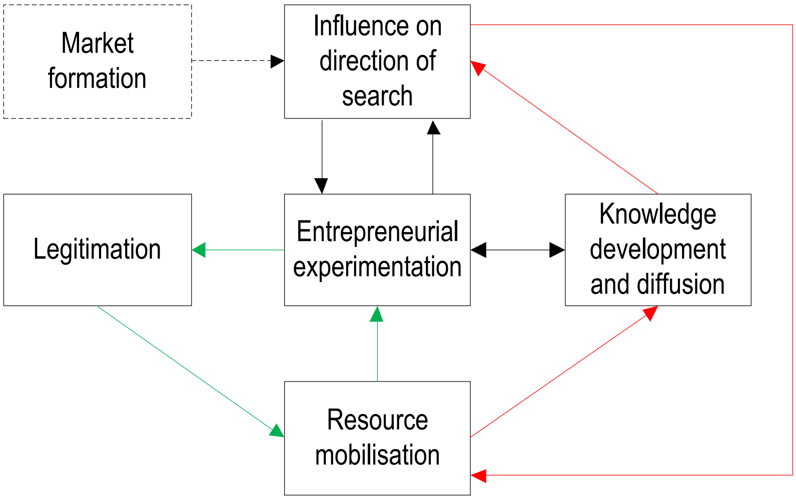
Figure 43: The entrepreneurial motor (red arrows: main STP motor; green arrows: main entrepreneurial motor)



Source: Own presentation based on Suurs (2009, p. 215)

The STP motor is already fully developed. Regarding the aviation biofuels innovation system the critical function of the 'entrepreneurial motor' is 'resource mobilisation'. Through several funding programmes, R&D is able to acquire enough money for developing marketable products. However, resources are still too low for implementing large-scale production of biofuels. Investors are deterred to make further investments due to the lacking cost-competitiveness of aviation biofuels compared to fossil kerosene (Fossil kerosene: 550 Euro / tonne; HRJ/BTL: 1400-1500 Euro / tonne).[143] This leads also to problems with the feedstock production which requires more incentives in order to make the production of second generation biofuel feedstocks attractive to farmers.

The blocking mechanisms regarding 'resource mobilisation' are strongly connected to the blocking mechanisms regarding 'entrepreneurial experimentation'. New entrants are encouraged by research funding programmes to start research on projects, but when it comes to build up larger production capacities, high amounts of financial resources are needed. Due to the lacking cost-competitiveness, these can often not be acquired which forces the entrepreneurs to stop their operations (refer to chapter 3.3). This influences 'entrepreneurial experimentation' negatively. However, there are also inducement mechanisms regarding this function, most importantly the diversified availability of possible technology paths and research funding granted through the EU framework programmes (refer to chapter 3.6).

'Knowledge development and diffusion' and the 'direction of search' are closely connected to 'entrepreneurial experimentation'. The technology pathway most entrepreneurs decide to take has high impact on research regarding biofuels. Focusing on ethanol (and its primary feedstocks sugarcane and sugar beet) as a biofuel hampers knowledge development on

143 Cf. European Commission 2011c, pp. 69–73

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more promising biofuel production pathways like BTL and HEFA/HRJ fuels. Due to this, also research on feedstocks like jatropha, camelina and algae is hampered (refer to chapter 3.3). The most important inducement mechanisms for the function 'influence on direction of search' are the carbon reduction goals set by IATA and the EU (refer to chapter 3.2). Regarding 'knowledge development and diffusion', research funding and subsidies have a positive influence (refer to chapter 3.1).

'Legitimation' is mainly driven by positive factors like high acceptance and high demand for biofuels in the aviation industry as well as in the society and in politics. First fuels have been certified for their use in aircraft by ASTM (refer to chapter 2.3) which is also an important inducement mechanism concerning 'legitimation'. Nevertheless, acceptance would be even higher if politics would introduce mandatory quotas for second generation aviation biofuels at a certain time (refer to chapter 3.5).

'Market formation' is not a pressing issue for a system in the formative phase. However, although there is not a recognisable market at the moment, some inducement mechanisms have already formed. In the first place, these are buyer-supplier networks and institutional stimuli like the introduction of the ETS to the aviation industry. One pressing blocking mechanisms is the competition between transport modes for suitable biofuels (refer to chapter 3.4). Further blocking mechanisms arise currently mainly through the blocking mechanisms connected to 'resource mobilisation'.

Regarding the 'development of positive externalities', there are inducement mechanisms arising from knowledge networks and buyer-supplier alliances (refer to chapter 3.7). However, it is still too early to describe this function to its full extend as the system is still too young. Positive externalities and connected inducement and blocking mechanisms are likely to arise in a later phase and can therefore be described when the system has entered the growth phase. Key inducement and blocking mechanisms are illustrated in Figure 44.

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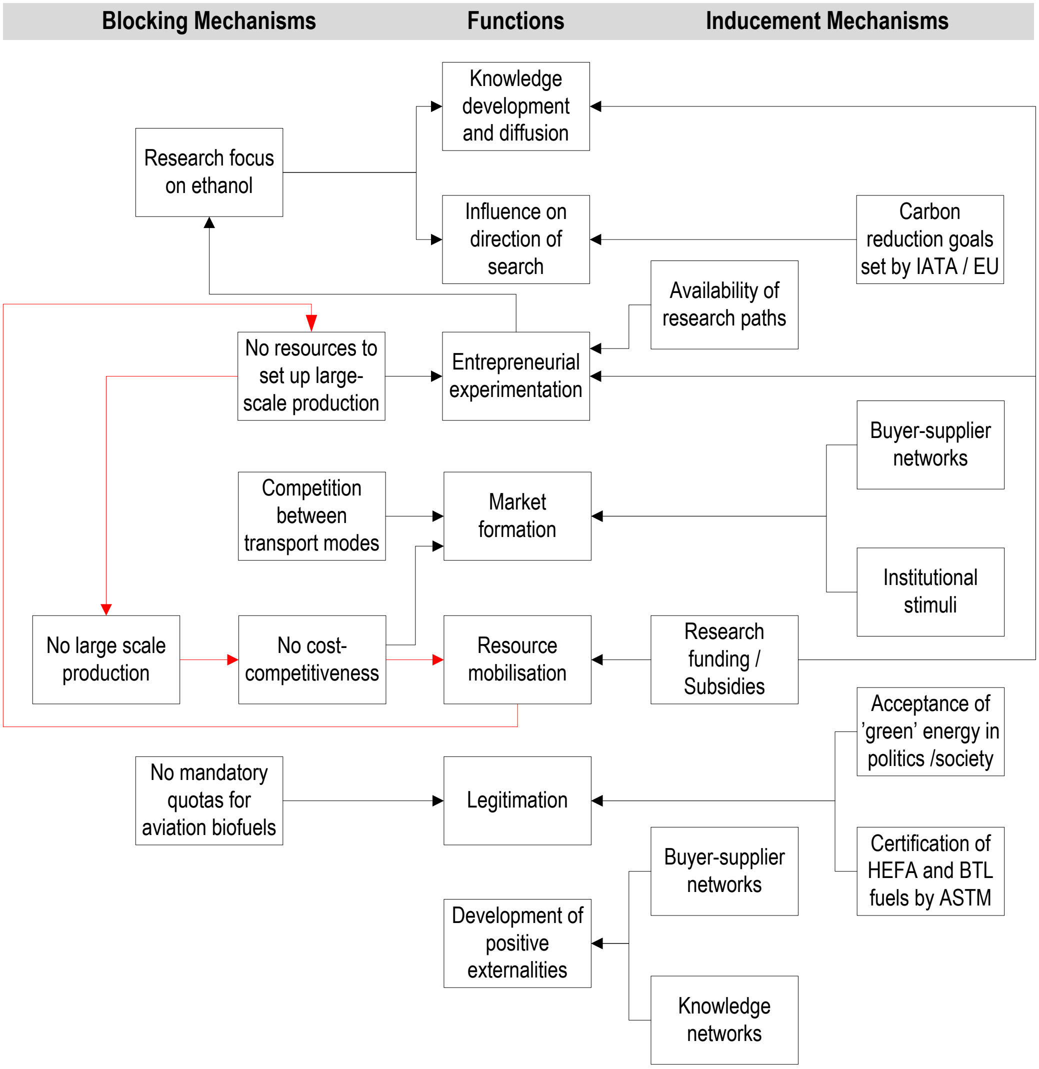
Figure 44: Inducement and blocking mechanisms regarding the aviation biofuels innovation system



Source: Own presentation

The red arrows illustrate a 'vicious circle' which is likely to hamper the development of the aviation biofuels TIS. Combining Figure 43 and Figure 44, it can be seen how central and how critical the function 'resource mobilisation' is to the system. Therefore, actions taken by policy makers should particularly aim on improving this function by influencing the connected mechanisms.

Step 6: Specify key policy issues

6.1. Setting financial incentives

Important future issues to politics will be setting up large scale production plants, promoting research on second generation biofuels and feedstocks and finding arable land for feedstock

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production. Political activities should furthermore aim on creating cost-competitiveness between jet biofuels and conventional fossil kerosene.

Financial support should be given to companies who successfully finished their demonstration projects and are seeking to gain knowledge about large-scale production in order to be able to construct larger production facilities. Here, policy should aim in the first place on companies and projects dealing with BTL or HRJ/HEFA fuels. Regarding feedstocks, policy should promote research regarding plants not competing for land where food crops or forests are grown. Therefore, jatropha and camelina will be the most promising feedstocks.[144] In the long-term, development of algae feedstocks should be supported as these are most likely able to satisfy the huge demand for biomass and will not be dependent on any farmland.[145] A further issue regarding feedstocks is the identification of suitable areas within Europe which can fulfil the huge demand for biomass and to build up the infrastructure needed in rural areas which should be supported by policy. Governments also have to offer credits at low interest rates via state-owned banks (e.g. the German *Kreditanstalt für Wiederaufbau*) in order to ease acquiring capital especially for SMEs. Concerning these topics, policy has to point out the unique features of HRJ/HEFA and BTL fuels and promote private funding of projects and companies dealing with these fuels.

Currently, European policy tries to support cost-competitiveness of aviation biofuels by introducing the ETS. An additional tool to reach cost-competitiveness is the taxation of fossil kerosene. Currently, fossil jetfuels are tax-free within Europe which indirectly subsidises their use. For creating cost-competitiveness, setting taxes on fossil jetfuels are an important topic. Furthermore, policy has to subsidise the production and the use bio jetfuels instead of fossil jetfuels.

As stated before, special attention has to be given to biofuel and feedstock producers. Biofuel producers are often young companies independent from oil companies. If they already produce biofuel, they are often at a pilot or demonstration stage. Therefore, they are SMEs with the perspective to become larger when achieving large-scale production. However, they need huge amounts of money for scaling up the production which has to be partly provided by SME funds of the EU. Also feedstock producers are mainly SMEs, but they will probably not expand very quickly, because farmers do normally not have enough land to employ 250 workers. Therefore, agricultural and SME subsidies should be given to biomass growers, especially also those experimenting with algae.

6.2. Setting non-financial incentives

Apart from financial activities to influence the aviation biofuels TIS, policy is also able to shape the system by non-financial activities.

Regarding the competition between the transport modes, policy should promote using biofuels in the first place in the air transport mode, because there are no alternatives other than liquid fuels (i.e. hydrocarbons) to propel planes. As there are some alternatives to provide energy to ground transportation (e.g. vehicles powered by ethanol, batteries or fuel cells), European funding regarding ground transportation should aim on these alternatives in

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[144] Cf. International Air Transport Association 2010, pp. 18f

[145] Cf. European Commission 2011c, p. 11; Wijffels and Barbosa 2010, p. 798; International Air Transport Association 2010, p. 21; Massachusetts Institute of Technology 2010, p. 114

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order to allocate as much biofuel production capacity as possible to aviation biofuels and facilitate market formation for them. As stated before, political activities should focus on BTL and HRJ/HEFA pathways.

To improve legitimation, the task for policy makers is to ensure sustainability and safety of aviation biofuels. Therefore, it is possible to develop certification or standardisation rules which aviation biofuels used in Europe are required to fulfil (beside the already existing American standard). As the main task of policy is not investing into companies, future legislation should create clear conditions (e.g. define feed-in quotas for biofuels) in order to ease decisions for potential investors and thus create economical legitimation. To mobilise additional resources, policy should encourage venture capitalists to provide capital to companies intending to scale up their production (e.g. by initialising networks between venture capitalists and prospective biofuel producers).

Development of positive externalities within the aviation biofuels system happens mainly due to linkages built between the actors of the system. Research projects are important institutions for promoting exchange of knowledge and getting the actors closer together. As the European Commission and European governments are important financiers of research projects, the main task for European policy is here to initiate new research projects regarding particularly aviation biofuels in order to allow actors to exchange knowledge and to develop relationships beyond the scope of these research projects.

In Figure 45, monetary and non-monetary policy issues are summarised. The issues are divided into the economic activities 'feedstock production', 'biofuel production' and 'biofuel use'. Regarding monetary activities, special attention should be given to SMEs (e.g. spin-offs from universities and research institutes) as these represent the largest fraction within biofuel producers and feedstock growers.

Figure 45: Policy issues to support the aviation biofuel TIS

		Economic activity influenced by policy		
		Feedstock production	**Biofuel production**	**Biofuel use**
Policy Issues	**Non-monetary activities**	• Identify areas within Europe meeting the requirements of 2nd generation feedstocks and large enough for large scale production.	• Develop standardisation / certification processes • Encourage venture capitalists and investors to invest into biofuel companies • Set up research projects to promote knowledge exchange	• Define a feed-In quota for jet biofuels • Promote use of biofuels primarily in air transportation
	Monetary activities	• Research funding on 2nd generation feedstocks (jatropha, camelina, algae) • Subsidies for feedstock production • Improve infrastructure in rural areas suitable for feedstock production	• Research funding on 2nd generation bio jetfuels (BTL, HEFA / HRJ) • Funds / credits to scale up production capacities • Subsidies for aviation biofuel production	• Subsidies for the use of bio jetfuels • Start taxation of fossil jetfuels

Source: Own presentation

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Appendix 1: Aviation Biofuel Actors

Name	Country
Aircraft Manufacturers	
Airbus	Europe
Boeing	USA
Bombardier	Canada
Dassault	France
Embraer	Brasil
Biofuel Customers	
Air Berlin	Germany
Air France KLM	France/Netherlands
Alitalia	Italy
British Airways	Great Britain
Condor	Germany
Deutsche Post	Germany
easyjet	Great Britain
Finnair	Finland
IATA	USA
Iberia	Spain
LOT Polish Airlines	Poland
Lufthansa	Germany
Ryanair	Ireland
SAS	Sweden
TAROM	Romania
Thomson Airways	Great Britain
TUIfly	Germany
Virgin	Great Britain
Biofuel Distributors	
BioJet	USA
NorthSeaGroup	Netherlands
Paradigm Bioaviation LLC	USA
SkyNRG	Netherlands
Biofuel Producers	
Abengoa	Spain
Advanced Bioenergy Technology	USA
Agilyx	USA
AltAir Fuels	USA

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Altona Energy	Great Britain
Amyris	USA
Bio2G	Sweden
Biogasol	Denmark
Bioliq	Germany
Biomat SA	Uruguay
BioSNG	Netherlands
British Sugar	Great Britain
Byogy Renewaables	USA
Chemrec	Sweden
Chemtex	Italy
Choren Industries	Germany
Cutec Institut	Germany
Dynamic Fuels	USA
Dynamotive Energy Systems	Canada
Efrim Energy	USA
Elevance	USA
Envergent Technologies	USA
Evercat	USA
Greasoline	Germany
Gryaab	Sweden
Güssing Fernwärme	Austria
IMECAL	Spain
Imperium Renewable Inc.	USA
Inbicon	Denmark
Inventure	USA
Jatro AG	Germany
Joule Unlimited	USA
KiOR Inc	USA
Lanzatech	New Zealand
Licella	Australia
Neste Oil	Finland
Primus Green Energy	USA
Procethol2G	France
Sapphire	USA
Sekab E-Technology	Sweden
Solazyme	USA
Solena	USA
ST1	Finland
Süd Chemie	Germany
Sundrop Fuels	USA

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Syngest	USA
Syntroleum Corporation	USA
UPM	Sweden
Verbio AG	Germany
Weyland	Norway
Zeachem	USA
Engine Manufacturers	
Avio	Italy
GE Aviation	USA
MTU Aero Engines	Germany
Rolls Royce	Great Britain
Snecma	France
Feedstock Providers	
Jatenergy	Australia
Kent Bioenergy	USA
Phycal	USA
Oil and Gas Companies	
BP	Great Britain
Petrobras	Brasil
Sasol Technology	South Africa
Shell	Netherlands
Tesoro	USA
Private R&D	
Bauhaus Luftfahrt	Germany
Bauhaus Luftfahrt	Germany
Bio-Green Planet	USA
Biopolis S.L.	Spain
CERFACS	France
Cobalt Technologies	USA
Concawe	Belgium
General Atomics	USA
Ginkgo Bioworks	USA
Ineris	France
Mercurius Biofuels	USA
Phytosolutions	Germany
Sanofi	France
SG Biofuels	USA

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Sustainable Oils	USA
Technologica Group	Belgium
VSI	India
Public R&D	
Applied Research Associates	USA
CNRS	France
DBFZ	Germany
DLR	Germany
European Virtual Institute for Integrated Risk Management	Germany
Forschungszentrum Jülich	Germany
Fraunhofer IBP	Germany
Fraunhofer UMSICHT	Germany
Graz University of Technology	Austria
ifp energies nouvelles	France
Ineris	France
Inra	France
Karlsruhe Institut für Technologie	Germany
Leuphana Universität Lüneburg	Germany
Linnaeus University	Sweden
LISBP	France
Onera	France
Plant Research International	Netherlands
REII	USA
Technical University of Denmark	Denmark
TU Hamburg-Harburg	Germany
TU Wien	Austria
University of Sheffield	Great Britain
University of Toronto	Canada
Technology Consulting	
Altran	France
Booz & Company	USA
dena	Germany
Erdyn	France
In4Tech	Italy
JatroSolutions	Germany
spring associates	Netherlands
Technology Providers	
Agribased Biofuels	USA

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Alfa laval AB	Sweden
Algae Link NV	Netherlands
AlphaJet	USA
Avjet Biotech Inc	USA
Biotechnical Processes International (BPI)	Ireland
Centurion Biofuels	Canada
DuPont	USA
GEA Filtration	USA
Genomatica	USA
Gevo	USA
Global Thermostat	USA
Honeywell UOP	USA
Inbicon	Denmark
Lanxess	Germany
Lesaffre International	France
MBD Energy	Australia
Megazyme International	Ireland
Novozymes	Denmark
Petroalgae	USA
Praj Industries	India
Proviron	Belgium
Qteros	USA
Renmatrix	USA
Rentech	USA
Sartorius Stedim Biotech	France
Solix BioSystems	USA
Terrabon	USA
VG Energy	USA
Virent	USA
Venture Capitalists	
Blackstone Group	USA
Firelake Capital Management LLC	USA
GreatPoint Ventures	USA
Khosla Ventures	USA
Mohr Davidow Ventures	USA
Omninet Capital LLC	USA

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Appendix 2: EU R&D funding regarding biofuels

EU policy has several financing instruments which are suitable for funding research, pilot and demonstration projects regarding biofuels in general and aviation biofuels in particular. Those instruments are:

- *"The **Seventh Framework Programme (FP7)** is the main instrument for funding research in Europe.*
- ***NER300** refers to an instrument to allocate 300M allowances under the New Entrants' Reserve of the Emissions Trading Directive 2009/29/EC to CCS demonstration projects and to innovative renewables.*
- ***Horizon 2020** will start on 1st January 2014 and will bring together the framework programme and other EC innovation/research funding programmes into a new integrated funding system. [...]*
- ***Intelligent Energy Europe** funds various projects relating to sustainable feedstocks and sustainable transport [...].*
- ***INTERREG IVC** [is] financed by the European Regional Development Fund [and] helps regions of Europe [to] share knowledge and transfer experience to improve regional policy, and supports projects relating to sustainable feedstocks for bioenergy and biofuels (e.g. algae, forest, etc).*
- *[The] **European Industrial Bioenergy Initiative** [is] one of the industrial initiatives to accelerate key energy technologies for a low-carbon future under the SET Plan, with risk and investment "shared" by the EU, Member States and industry. [...]"*

  European Biofuels Technology Platform (2012f)

The largest amount of funds is granted to the aviation biofuels system and to the biofuels system by the Seventh Framework Programme.

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3. General conclusions

This chapter presents the general conclusions based on the TIS analysis of the case studies. It focuses on the market uptake results of the innovation cases investigated. It summarizes the conclusions done by the partners on the functionality of the technological innovation systems. Also, main inducement and blocking mechanisms are summarized for the seven innovation cases analysed. The key policy issues are also summarized to establish a link to existing challenges for market uptake of the innovations and to provide recommendations to address these.

Table 14: The selected case studies

Area of research	Topic of Case study	Mode	Abbreviation
Electromobility	Electromobility	Road	EM
Alternative motor fuels	Biofuels for surface transport	Rail, road, maritime, inland waterways	BF
Maritime Transport	Deployment of Green Technologies within the Maritime Sector: SO_x Abatement Technology	Maritime	SO
Intermodality	Intermodal versatile efficient and longer wagons	Rail	LW
Maritime and Inland waterways	Container transferium	Inland navigation, maritime	CT
Rail	Cargo sprinter	Rail	CS
Aeronautics	Biofuels in aviation	Air	BA

3.1 Functionality of the TIS

The TIS analysis of each case study provides lessons on the functionality of the TIS and the factors that are important for successful market take-up of the innovation in focus. Some issues noted are case-specific, and, therefore, are not important in the context of this analysis. Those are left out here. But the issues which have impact on the successful functioning of TIS in several of the investigated cases, allow to identify how well the system is functioning and to determine how the functional pattern should develop to reach higher functionality or "targeted" functional pattern.

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For several of the investigated cases (EM, BF, CS, BA) there are **problems in the area of market formation**. The reasons in each of the cases might be different. For a better functionality of the TIS, to reach success on market take-up of such innovations a change in the "market regime" might be required. This would mean a change in the rules of the game in the market where already substitute technologies exist.

Legitimation of an innovation is important for its successful path to the market. For several of the innovation cases investigated (EM, BF, BA, CT) **the need to prove the benefits of the innovation has been important in the legitimation context**. The functionality of TIS appeared to be sub-optimal for the cases where there were problems with demonstration of benefits of the innovation. In contrary, where the positive benefits have been clearly demonstrated or proven (like in CT case), this had positive impacts on functionality of TIS and facilitated market take-up of the innovation.

Some of the cases (BF, BA, CT) showed **signs of the negative impacts from alternative technologies, possibly those already on the market**. The impacts could range from already taking up market niche to the contradictory policies, which would support the innovation on one hand but also support the competition as well.

Resource mobilization plays a very important role in all of the case studies. The case studies analyzed show that efficient actions in resource mobilization ensure the successful market up-take of the innovations in the different transport sectors.

External factors to TIS, like developments in the economy, **can have favourable or unfavourable impacts on the TIS**. The outcomes seem to be dependent on the functional pattern of the TIS. For example, an innovation aimed at optimization of a process and efficiency increases is likely to benefit from the increases in competitive pressures in the economy.

The case studies cover a variety of cases with different economic grounds. We see that the **cases with a strong business case have a much better functionality of the TIS, which lead to better results or potential for successful and fast market take-up of the innovation**.

The cases investigated have demonstrated that the impacts of the policies and specific political actions are great for the innovations in transport sector. Specific (project oriented) or general political support is demonstrated to be crucial for optimal functionality of the TIS. It is interesting that this conclusion is supported by data obtained in every single case study investigated.

A pilot demonstration can show the industry the benefits and weaknesses of the business case. The impacts on the functionality of TIS can be positive, but also adverse.

In cases investigated, where similar or technologically linked TIS exist (like BA, or SO), there were **knowledge spillovers** observed. These **have played a positive role in improving the functional pattern of the TIS**.

3.2 Main inducement and blocking mechanisms

Each of the case studies investigated has allowed the researchers of the consortium to identify the inducement and blocking mechanisms relevant for the innovation. The most important ones, those which are characteristic for several of the case studies are described here.

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Inducement mechanisms

The most important inducement mechanism, identified in all the innovation cases investigated, is the **government support**. This support could be monetary, involve development of specific regulations, or be in the form of regulations and practical solutions for problems in the market take-up process of the innovations. Here the factor of the political acceptability or viability can play a role: **innovations that "help to win votes" have higher chances of getting political support**.

The real or perceived need or usefulness of the innovation to the society is another inducement mechanism which facilitates the market take-up of an innovation. This was observed in the cases of EM, BF and BA.

Presence of no opposition to the innovation can be a facilitating mechanism for the market take-up of an innovation, like it was observed in the case of CT. In other cases, where the opposition from the competing industry, conservatism in the market or the structure of the mature market created the opposition (like with BD, BA, SO) for the innovation, this was a barrier for bringing of the product to the market.

Often the presence of infrastructure for use of the product is an important inducement mechanism for the market take-up of an innovation, like it was seen in the cases of EM and CS. Sometimes the infrastructure impacts the technical specifications of the innovative product, like in the case of LW.

It was noted that a **change needs stimulus external to the developers of the innovation to bring it to the market**, like it was in the cases of BF, BA and SO. The stimulus could come from the political level making the use of a technology obligatory, or reaching of some intended results obligatory by the potential market of the innovation.

Blocking mechanisms

The blocking mechanism for an innovation case **could arise from alternative technologies** (those already on the market or also those emerging), like it was noted in the case of CT and BF. This would usually be done by taking up the niche in the market. Sometimes, the existing market structure itself (with the players in it) is organized in such a way that it does not allow the entry of new companies or technologies with different scale of operations, like it is in the case of CS.

For some products that have to be brought to the market **the knowledge of the potential customer can be a problem**. Often the potential clients are not aware of the benefits of the innovative product, like it was observed in the case of CT and BF. This barrier to innovation can be overcome with informing the potential client about the economic benefits of the innovation.

For some of the cases investigated (like EM, SO) a barrier was **the state of development of the technology at the current moment of the time**. The customer just does not consider the technology "good enough" or is expecting further dramatic improvements in the technology in very near future, thereby being better off by postponing the choice.

A very important blocking mechanism for some of the innovations (EM, BA, CS, SO) are the **cost-related issues**. These are related to the high price of the innovative product which means too long payback period in comparison with the current alternative.

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3.3 Key policy issues

In case the successful market take-up of an innovation is desired, the policy should aim at remedying poor functionality in relevant TISs by strengthening or adding inducement mechanisms and weakening or removing the blocking mechanisms. Here the key policy issues related to TIS that should be dealt with in order to reduce systematic weaknesses of the TIS are summarised in the context of the investigated case studies.

The most important policy issue, which comes out of analysis of all the case studies, is the one of **ensuring the economic viability of the innovation**. This includes creating or supporting a market situation in which the innovation is economically viable. Different measures could be applied here. Depending on the innovation, those measures could range from "cheap" or state guaranteed loans, to measures that make the "unfavoured" competing technological option too expensive for the customer.

Another important issue, which was observed for the innovation cases investigated, is the **impact of the innovation on the level of externalities that the public has to bear** as a result of the innovation. The importance of this issue is more from the public perspective, because a company does not always care how "green" the innovation that it produces is.

The **international policy goals**, in this case the policy goals of the European Union are very important in the context of market take-up of the innovations. For several innovative cases (EM, BF, BA, LW) those goals were important, because they were linked with the possibility to phase out the current technology, which means increasing the market potential of the new technology.

An important aspect for increasing the functional performance of a TIS is **the development of a standardised infrastructure**. It is very important for most of the innovation cases investigated (like EM, BF, CT, BA and CS). This is closely linked with the **fostering of competition in the market the innovation is about to enter**.

Cases like BF and BA showed that **politically targeting the manufacturing industry to make their products suitable for use with the innovation** (in this case: biofuel) can be an important political issue for successful market take-up of some innovations.

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Annex A – Templates

These templates were used by partners for analysis of the innovation cases and for reporting the findings.

TIS Analysis Template

Title	
Mode	rail ☐, road ☐, air ☐, maritime ☐, inland waterways ☐, intermodal ☐
Partner	

<Give a Review of the innovation and R&D in the specific topic of each case study
- current status
- backwards review>

Step 1: the starting point of analysis: defining the TIS in focus

To perform the first step of the analysis the TIS that will be analysed has to be defined. In order to do that give a short description of the case study.

<add description of the case to be analysed here, approx. 250 words>

Step 2: identifying the structural components of the TIS

In this step the structural components of the technological innovation system are described. Those are: actors, networks and institutions.

2.1 Actors

The actors taking part in the analysed technological innovation system should be described here.

<insert figure showing the actors of innovation system> Example:

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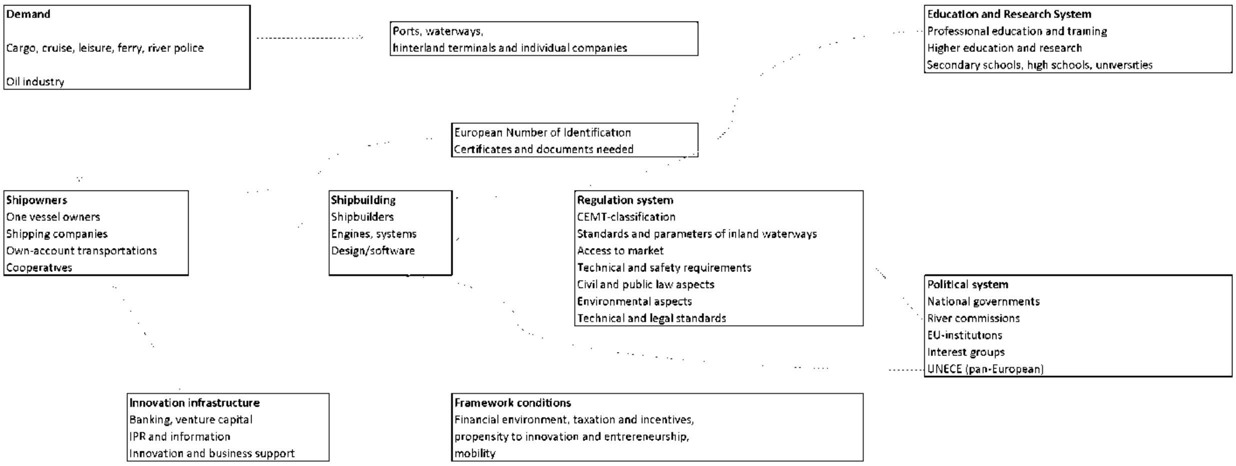
Figure 1: Inland navigation innovation system



<description of the … innovation system, up to 1 page>

2.2 Networks

A number of different networks can be relevant for describing this structural component of technological innovation system.

<Give a description of networks, up to 1 page. Those can be: knowledge sharing networks, lobby networks, standardisation networks, technology platforms, supplier groups having a common customer, etc. Figures and references can be included.>

2.3 Institutions

Institutional component of technological innovation system is described here.

<Give a description of institutions such as culture, norms, laws, regulations and routines that have had impact on the innovative case in focus. Approx. 1 page.

Definition: Institutions are the humanly devised constraints that structure human interaction. They are made up of formal constraints (e.g., rules, laws, constitutions), informal constraints (e.g., norms of behavior, conventions, self-imposed codes of conduct), and their enforcement characteristics. Together they define the incentive structure of societies and specifically economies. Source: North (1994) >

Step 3: mapping the functional pattern of the TIS

In this step of the analysis the functional pattern of the technological innovation system is described. The functional parameters shown in Figure 1, 3a are described:

3.1. Knowledge development and diffusion

<Describe knowledge development, trends, include data on financing sources, patent application trends (if available), etc. Max. 1 page.>

3.2. Influence on the direction of search

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<Describe the impacts that the policy has had on the development of the innovation. Approx. 1-2 pages.>

3.3. Entrepreneurial experimentation

<Here an analyst has to map the number and variety of industrial experimentation within the case analysed: number of entrants in the field, types of applications, character of complimentary technologies employed, breadth of technologies, etc. Approx 2-3 pages.>

3.4. Market formation

<For an emerging TIS the market may not yet exist. Or markets for products of similar functionality already exist. Describe here the status of existing market, market formation and government policy that had influence on it. Max. 1 page.>

3.5. Legitimation

<Legitimacy is a matter of social acceptance and compliance of the new product with the relevant institutions. Describe legitimacy of the case in focus. Max 1 page.>

3.6. Resource mobilization

<As a TIS evolves, a range of different resources needs to be mobilized. Give short description of the extent of the resources required for the development of the TIS in focus. Those can include, but are not limited to competence/human capital, financial capital, complementary assets (like infrastructure), etc. Max. 1 page.>

3.7. Development of positive externalities

<The nature of innovation and diffusion process suggest the generation of positive external economies. Those can be emergence of labour markets, emergence of specialized intermediate goods and services providers, and emergence of information flows and knowledge spill-overs. Describe the positive externalities that have arisen as a result of the case in focus. Approx ½ page.>

Step 4: assessing the functionality of the TIS and setting process goals

<In Step 3 the dynamics of seven key processes have been described. In this step the question *how well the system is functioning* should be answered. To do that, in a short text (1) describe the phase of development of the TIS in focus, (2) compare the focal TIS with other similar TISs across regions or nations. In relation to the TIS specify policy goals in terms of how the functional pattern should develop to reach higher functionality or "targeted" functional pattern. 1-2 pages.>

Step 5: identify inducement and blocking mechanisms

<What the TIS achieves is only in part a result of internal dynamics of the system. Exogenous factors play an important role. Identify and describe these inducement and blocking mechanisms. 1-2 pages.>

Step 6: specify key policy issues

<The inducement and blocking mechanisms are described in step 5. The policy should aim at remedying poor functionality in relevant TISs by strengthening/adding inducement mechanisms and weakening/removing blocking mechanisms. Describe the key policy issues related to TIS in focus that should be dealt with in order to reduce systematic weaknesses of the TIS. 1-2 pages.>

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Template for Non-technical Communications Package

Non-technical communications package for each case study is prepared to facilitate the communication with stakeholders and policy makers.

Title	
Mode	rail ☐, road ☐, air ☐, maritime ☐, inland wateray ☐, intermodal ☐
Partner	

Introduction

<Give an introductory description of the case, approx. 150-250 words>

Description

<Describe the case in detail. The description should be non-technical. Include:
- detailed description of the case;
- benefits that the innovation case provides, also in the context of promoting low-carbon ecnomy;
- link with SMEs;
- visual material: photo, graphs etc.

Approx 1 page.>

Sources

<List sources which include additional relevant information on the case. Include internet references. Ideally 3-5 sources.>

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Annex B – Non-technical communications package

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