Towards zero emissions in rail transport

Hydrogen rail infrastructure

Timetable for deploying fuel cell railcars in Germany

Commissioned by the

Bundesministerium für Verkehr und digitale Infrastruktur

Coordinated by the

NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

EY
Building a better working world

Contacts

Commissioning of the study
Federal Ministry of Transport and Digital Infrastructure (BMVI)
Unit G21 Electric Mobility
Invalidenstrasse 44
10115 Berlin

Phone +49 (0) 30 18 300 0
Fax +49 (0) 30 18 300 1920
Email Ref-g21@bmvi.bund.de

Coordination of the study
NOW National Organisation Hydrogen and
Fuel Cell Technology
Thorsten Herbert
Fasanenstrasse 5
10623 Berlin

Phone +49 (0) 30 311 61 16-18
Fax +49 (0) 30 311 61 16-99
Email thorsten.herbert@now-gmbh.de

Project management and monitoring of the study
Ernst & Young GmbH
Wirtschaftsprüfungsgesellschaft
Dr. Rainer Scholz
Rothenbaumchaussee 76-78
20148 Hamburg

Phone +49 (0) 40 361 32 - 17056
Fax +49 (0) 40 181 3943 - 17056
Email rainer.scholz@de.ey.com

Imprint

Funded by
The Federal Ministry of Transport and Digital Infrastructure (BMVI)
Invalidenstrasse 41
10115 Berlin

Coordinated/ published by
NOW National Organisation Hydrogen
and Fuel Cell Technology
Fasanenstrasse 5
10623 Berlin

AUTHORS
Ernst & Young GmbH (EY)
Dr. Rainer Scholz, Nadija Gläser, Daniel Plauch, Timo Schmidt

COLLABORATION
NOW >> Philipp Braunsdorf
EY >> Tobias Merten, Dr. Ralf Seidenspinner, Christian Hedrich, Peter Wettengel
Ludwig Bölkow Systemtechnik >> Dr. Ulrich Bünger, Jan Zerhusen, Martin Zerta
Becker Büttner Held >> Dr. Henning Thomas, Dr. Martin Altrock, Dr. Christian Jung, Dr. Roman Ringwald
SIGNON Group >> Gerd Moderzinski
TÜV SÜD Rail >> Dr. Jürgen Heyn
IFOK GmbH >> Christian Klasen

Design >> ZWEIPRO Kommunikationsdesign, Düsseldorf

Printing >> das druckhaus, Korschenbroich

Year of publication >> 2016

Contents

Foreword

STATE SECRETARY RAINER BOMBA IN THE FEDERAL MINISTRY OF TRANSPORT AND DIGITAL INFRASTRUCTURE

Technological leadership in the sectors of the future secures economic growth, prosperity and jobs. The pioneering role in providing environmentally friendly transport services, taken on by rail transport, must continue to be bolstered using innovative technologies. Therefore it is a crucial issue for our ministry to support future-oriented concepts like the increased use of fuel cell-based trains.

The transport sector is playing a decisive role in the energy changeover and in climate protection. Battery electricity from renewable energies or wind-hydrogen in the fuel tank will not only reduce CO2 emissions, but will also decrease dependency on fuel imports. Being the pioneer in electric mobility means having the edge in terms of knowledge and technology for competing internationally. But it also means being the role model for environmentally friendly, resource-protecting transport.

NIP – NATIONAL INNOVATION PROGRAMME FOR HYDROGEN AND FUEL CELL TECHNOLOGY

The Federal Ministry of Transport and Digital Infrastructure (BMVI) has been supporting industry for several years with comprehensive programmes for the market preparation of electromobile services in the area of hydrogen and fuel cell technology. As the ministry for mobility and modernity, by 2016 the BMVI had contributed a total of 500 million euro of public funds towards research projects carried out by industry and the scientific world. Within its specifically created National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP), product and process innovations are tested under everyday conditions.

MOBILITY AND FUEL STRATEGY

The energy consumption of the transport sector plays a key role in the energy policy of the federal government. The mobility and fuel strategy (Mobilitäts- und Kraftstoffstrategie – MKS), in which we involve all relevant stakeholders, represents a contribution by transport policy to saving energy by analysing common energy and fuel options. In the process, the MKS becomes a learning strategy for the long-term implementation of the energy changeover in transport.

STRENGTHENING PARTNERSHIP AND ACCEPTANCE

Future mobility requires an alliance based on partnership across politics, industry and science on both national and international levels. Through the NIP, a close and well-functioning network has already been established. Together with our neighbour countries we must develop compatible pan-European infrastructures for hydrogen and battery electricity. In our journey towards our electromobile future, we must however above all inspire people. Because mobility technologies based on batteries or fuel cells will only be a market success when they are accepted and adopted by users.

ZERO EMISSIONS IN RAIL TRAFFIC

The German rail network is up to 50% non-electrified, therefore the use of diesel-operated trains with their resulting pollutants is common. Fuel cell-based trains offer a promising approach to minimising emissions in rail transport. Intelligent linking of non-electrified rail routes with existing hydrogen sources provides the opportunity to completely dispense with fossil fuels altogether and thus avoid producing emissions over the long term not only in everyday operation, but also in terms of the logistics required. With this feasibility study and the definition of important prerequisites, we are delighted to take one step closer to this scenario.

Best Regards,
Rainer Bomba

Can the introduction of fuel cell railcars work in Germany?

Around 50% of German rail networks are not electrified. Overhead wire construction is cost intensive, on little-used sections not profitable, and in scenic areas often not wanted. Nevertheless, operators and the public have a great interest in ridding such rail network sections of emissions, traditionally serviced by diesel vehicles. Using electric trains with hydrogen-operated fuel cells presents an interesting and promising alternative here, which further underscores Germany's technological leadership, bringing with it the necessary flexibility in a changing local transport sector, particularly in rural areas.

Commissioned by the Federal Ministry of Transport and Digital Infrastructure (BMVI) and the National Organisation Hydrogen and Fuel Cell Technology (NOW), the consortium behind this study researched from October 2015 to May 2016 the framework conditions for deploying fuel cell railcars in Germany. The manufacturer Alstom is currently developing a new train generation with fuel cell drive in the framework of the National Innovation Programme for Hydrogen and Fuel Cell Technology ("NIP" – coordinated by the NOW). Two prototypes from this project will already be deployed in 2017 in Bremervörde in Lower Saxony.

The data on which this study is based was compiled in stakeholder group interviews, expert interviews, own expert estimates and surveys. The analysis of costs data in particular and profitability is based on expert estimates, which in respective individual cases will need to be validated with suppliers' concrete price quotes.

As a first step the study examines the operational requirements arising from serviceable rail operation. An important finding is that there will be no operational restrictions regarding vehicle scheduling for regional routes in Germany, as the range of the trains or rotations per day is sufficient. Aside from zero emissions, the conversion of braking energy to kinetic energy is another advantage: the combined fuel cell-battery drive can exploit its potential particularly well on routes with many stops and changing altitude profiles.

Parallel to the operational requirements, both the requirements of hydrogen provision as well as the availability of hydrogen (hydrogen sources) were described in the study. These include the identification of hydrogen sources near eligible non-electrified routes in Germany as well as supply logistics. Initially supply transport of hydrogen via road in tankers or through a pipeline (in existing pipe systems) will be recommended. Over the medium and long term, rail transport with tank cars is considered suitable. The focus is also on tank containers both for road and rail transport.

A further priority of the study deals with legal framework conditions, particularly with regard to licensing law as well as energy and public procurement law. To date it has not been clarified whether a clear legal framework exists. Having analysed the legal framework conditions however, this study asserts that under the current legal framework, the licensing of hydrogen facilities for hydrogen generation, transport and refuelling is already possible in accordance with the relevant licensing processes. In an award procedure a combined tender for all services from procurement to refuelling of the trains is feasible at least in the introductory phase of the technology.

Furthermore the study discusses which financing and operator structures can be achieved with respect to the goal of identifying operator concepts suitable for implementation. An important finding is that the additional service module "hydrogen provision" brings risks with it, which hitherto could not be optimally represented in the usual operator structures. One possible way of reasonably spreading the risk is the financing of the vehicle pool and making it available through the regional authorities to the rail transport companies. In this way politics and administration can directly influence the implementation of their sustainability strategies.

As a cooperation partner in the development of prototypes, the Lower Saxony regional authority LNVG will deploy the vehicles on a route that has already been identified and plans the subsequent deployment of a fleet. Public participation in the form of a transparent and discursive introduction process with an exemplifying campaign has been developed regarding this case study in the region of Bremervörde. It is important here that there is public understanding of the technology, which results in support for the concept.

In the economic feasibility study the distinction will be made between initial investments and running operational costs. Because of higher investment costs in the hydrogen trains, for procurement there is an economic disadvantage of 25% compared with diesel trains. However if one observes the running costs of infrastructure, in the base scenario there is an economic advantage of 4.8% for the hydrogen drive. Allowing for a better comparability, the inclusion of the effects of cost reduction and subventions for diesel fuel increases this advantage to 23%. Therefore aside from regional zero emissions, hydrogen infrastructure can also represent an interesting and competitive alternative to diesel infrastructure from the economic perspective.

Finally the results of the study show that deploying fuel cell trains is economically feasible in principle. However the right framework conditions in the introduction phase must be created. These will be explained in this publication and the necessary steps for implementation demonstrated.

Do we need an extended legal framework?

For the construction and operation of hydrogen refuelling stations for operating rail vehicles the existing legal framework is adequate. The criteria for the approval of such facilities and the relevant procedures for establishing authorisation already exist (see table on the right). No new legal institutions or inspection instruments must be introduced.

The authorisation procedures in question concern mainly measures to be carried out within existing railway infrastructures. Facilities for storing and filling facilities are a necessary part of the railway infrastructure, as locomotives in driving mode can only be refuelled in a rail network. Only the generation of hydrogen is possible outside the railway infrastructure.

BImSchG authorisation

For hydrogen generation by means of electrolyser outside the railway infrastructure, an authorisation of the required facilities must be periodically obtained according to § 4 Federal Pollution Control Act (Bundes-Immissionsschutzgesetz – BImSchG). The authorisation prerequisites for facilities requiring authorisation under the BImSchG, arise from § 6 BImSchG.

Scope: Crucial to obtaining authorisation is the fulfilment of operator obligations under § 5 BImSchG as well as further requirements specified there. In addition other provisions under public law and occupational health and safety from the construction and operation of the facility may not be precluded. Authorisation under BImSchG grants authorisation for all aspects. This means that almost all other regulatory decisions that could be relevant for the facility will be included. Therefore under a BImSchG procedure all other public law requirements for hydrogen generation facilities are to be checked.

Duration: In contrast to the planning approval procedure, there is a statutory maximum duration for a BImSchG procedure. A full license application is generally decided upon within seven months, or even three months for simplified procedures.

PLANNING APPROVAL PROCEDURE

The construction and commissioning of a refuelling system or a hydrogen generation facility (on-site electrolysis) in the railway infrastructure requires in each case a planning approval process according to § 18 of the General Railway Act (Allgemeinen Eisenbahngesetzes – AEG).

Application: "Refuelling facilities" also belong to railway facilities according to § 2(3c) No. 1 AEG. Project-specific planning documents must always be attached to an application for planning permission. The required documents for a hydrogen refuelling facility arise from planning permission regulation (No. 12), the environmental guidelines and the "Application documents of the Federal Railway Agency (EBA)" guidelines. The planning permission process itself complies with §§ 72 to 78 of the General Administrative Law Act (Verwaltungsverfahrensgesetz – VwVfG).

Scope: In the planning permission process the public and private interests affected by the projects as well as environmental compatibility will be evaluated and weighed against each other. Furthermore it will be clarified whether the project is:

> Implementable from a technical perspective
> Complies with current codes and safety standards
> Affects public interests
> Affects the private rights or interests of third parties and to what extent these are to be taken into consideration in the approval decision.

Authorities: The authorities responsible for the planning permission is the Federal Railway Agency (EBA). The EBA checks documents for completeness, plausibility and technical feasibility. Subsequently the documents will be forwarded from the EBA to the hearing authorities of the federal state where the project is to be carried out. The hearing procedure takes place independently and autonomously by the respective state authority. A hearing procedure always means public participation. The planning permission documents are to be publicly displayed in the municipalities concerned to ascertain possible objections. Following the hearing procedure the hearing authorities submit their concluding statements with a summary of all objections raised to the EBA. The latter then decides on the admissibility of the project.

The objective admission criteria for refuelling stations with a storage capacity of less than 3 tonnes of hydrogen is found in the Operational Safety Ordinance (Betriebssicherheitsverordnung – BetrSichV). For storage capacities of 3 tonnes and above, they are found in the Federal Pollution Control Act (Bundes-Immissionsschutzgesetz – BImSchG). In the latter case an environmental impact assessment is to be carried out where significant adverse environmental effects are anticipated.

Duration: An estimation of the duration of the planning permission procedure is hardly possible. Indeed, in technically innovative projects, multiple laws, concerns and interests must be weighed against each other. An environmental impact assessment is frequently required within the planning permission procedure. The number of objections is not calculable, and neither the AEG nor the VwVfG contains statutory time limits. Thus we recommend to involve and inform the EBA from the very early stage of the plans.

Process	Variations	Approval requirement
Hydrogen generation (electrolysis)	On site: Electrolyser in railway infrastructure	Planning permission procedure § 18 AEG
	Electrolyser in industrial park outside the railway infrastructure	Generally BImSchG approval according to § 4 BImSchG, also No. 4.1.12 of the Annex 1 to 4. BImSchV
Hydrogen transport	Pipeline exclusively on private or public property	Possibly planning permission/ approval according to § 20(1) and No. 19.4 to 19.6 Annex 1 UVPG (Environmental Impact Assessment Act)
	Pipeline within railway infrastructure	Planning permission procedure § 18 AEG
Hydrogen refuelling stations	Refuelling stations in railway infrastructure	Planning permission procedure § 18 AEG

Summary
The approval of hydrogen facilities for the generation, transport and refuelling is already possible under existing legal frameworks. The scope of each process can however be time-consuming. It is also recommended to involve and inform the EBA early on in the process.

What operator models facilitate the use of hydrogen technology?

CONVENTIONAL PROCUREMENT IN GERMANY

The standard form of awarding transport services contracts in railway local public transport allows for the provision of vehicles through a rail transport company. The company is commissioned for the transport service on the route specified. For this vehicles must be made available and a high level of investment in the procurement made. Furthermore maintenance and repair of the trains lie within the rail transport company's area of responsibility. Depending on the state concerned, these constructs can differ from one another.

NEW SERVICE COMPONENT: HYDROGEN INFRASTRUCTURE

The commissioning authority faces the challenge of ensuring the provision, maintenance and repair of the trains, providing the transport service as well as the hydrogen infrastructure.

For the provision of the H2 infrastructure there are two options: integrated or separate procurement. Currently there is no experience regarding the effectiveness and feasibility of either procurement option. Unlike existing diesel infrastructure, both a new refuelling station and the entire associated procurement logistics as well as the whole economic added-value system would have to be created for hydrogen use.

SUITABLE MODELS FOR INTRODUCING H2 INFRASTRUCTURE

Within this study different models were analysed, which support the introduction of a hydrogen infrastructure with an adequate distribution of risk between the commissioning authority and the transport company. The models developed are to be primarily understood as a basic concept and illustrate a spectrum of conceivable procurement possibilities. The final structuring and advantages depend on the concrete specific framework conditions (in particular development and state of spread of H2 technology for rail infrastructure).

OPTION 1 – PROVISION WITH SEPARATE CONTRACTING OF HYDROGEN PROVISION

The following models build upon a procurement approach which envisages a separate provision of hydrogen supply.

CONVENTIONAL PROCUREMENT OF VEHICLES

The provision, maintenance and repair of vehicles as well as the transport service is undertaken by the rail transport company.

ADVANTAGES

- Transport service provided from under one roof
- Commissioning body profits from market knowledge of the respective rail transport company
- Generation of service and value chain synergies through the rail transport company

DISADVANTAGES

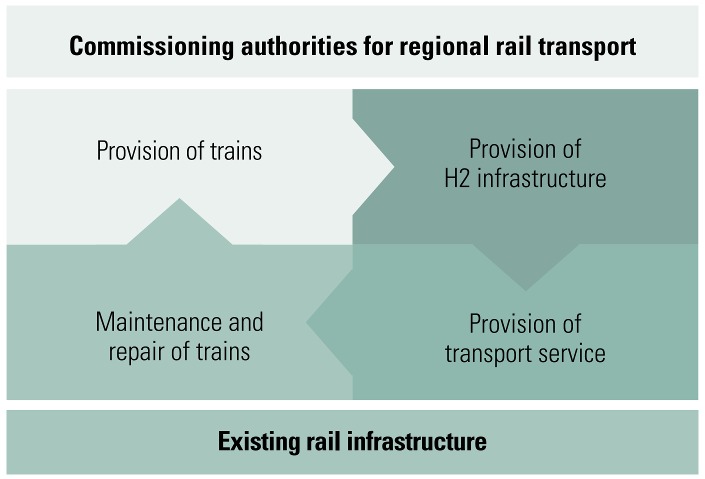
- High market entry hurdles (especially for small and medium rail transport companies because of higher investment costs)

In order to facilitate rail transport companies despite higher start-up investment and to increase competition, different supporting instruments on the part of the commissioning authority would be developed to relieve the rail transport company:

- Reauthorisation guarantee
- Redeployment guarantee (vehicles)
- Assumption of interest rate change risk
- Capital service guarantee
- Residual value guarantee

COMMISSIONING AUTHORITY VEHICLE POOL

In this basic model the commissioning authority itself procures the vehicles and keeps them in a vehicle pool, independent of the awarding of the transport service. They will be provided to the respective rail transport company over the period of the transport contract. The commissioning authority assumes the function of a lessor in the figurative sense.



Important service components in the spectrum between commissioning authorities and transport companies

PROCUREMENT LAW

Regarding aspects of procurement law the following must be considered in operational models:

- The introduction of a new technology is accompanied by risks for the operator, which through an integrated tendering process including hydrogen provision could be mitigated by a supplier. In the short to medium term this integration is conceivable.
- Over the long term, the principle of small manageable batches will be important, which envisages a distribution of deliveries (provision of vehicles and provision of hydrogen) in several batches in the spirit of competition and cost transparency.
- The direct awarding of an integrated solution is not possible based on these principles.

ADVANTAGES

- Interest advantage (in the procurement by means of public financing)
- Scale effect (cheaper procurement conditions when ordering in greater quantities)
- Elimination of residual value risk of the vehicles on the part of the rail transport company

DISADVANTAGES

- Possible experience potential on the part of the rail transport company not used (e.g. in vehicle procurement)
- The commissioning authority carries diverse risks in vehicle procurement (incl. technological risks) and must assume additional competences and staff

In addition there are further alternative implementation models, e.g. the vehicle service model, in which the procurement and provision of the trains takes place via a project corporation.

OPTION 2 – PROVISION WITH INTEGRATED AWARDING OF THE HYDROGEN SUPPLY

The innovative (procurement) component of the supply of H2 (incl. provision of the relevant infrastructure) could be arranged as in the following models:

LNVG H2 MODEL

The planned procurement model of the Landesnahverkehrgesellschaft Niedersachsen (State local public transport company of Lower Saxony) (LNVG H2 model), links the commissioning authority vehicle pool model with H2 supply responsibility. The provision of the transport service will be tendered separately. Extensive competences and responsibilities will be conferred to vehicle manufacturers, along with the corresponding opportunities and risks. In addition the vehicle manufacturer is responsible for the refuelling of the trains with hydrogen in this model. It can also assume the role of integrator and confer the work to a subcontractor.

ADVANTAGES

- All advantages of the commissioning authority vehicle pool
- Provision of vehicles and (hydrogen) infrastructure under one roof (no interface issue for commission authority)
- Assumption of risk (esp. technical risk) by private partners

DISADVANTAGES

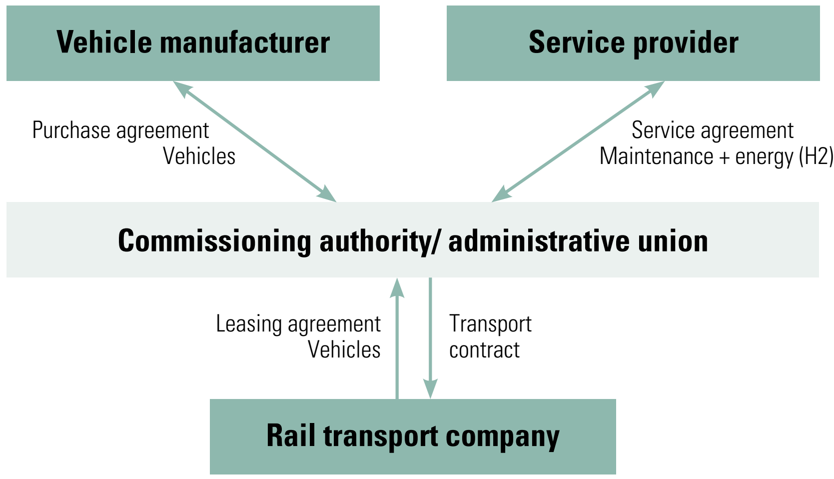
- All the disadvantages of the commissioning authority vehicle pool
- Reduction of the competitive field

H2 SERVICE MODEL

The vehicle service model with the inclusion of H2 delivery builds on the LNVG H2 model: the basic structure corresponds to the vehicle service model, whereby the project corporation expands to H2 supply (joint venture) and to full service provider including refuelling of the trains.

Summary

There is a range of models and combination possibilities, which are accompanied by the corresponding advantages and disadvantages.
The advantages of an integrated procurement model are that all services are carried out centrally under one roof. In addition private partners assume risks and responsibility, but can undertake technical coordination and exploit synergies. Interfaces will also be reduced through central implementation and controlling expenditure of the commissioning authority kept low. However bundling services can influence the competitive field and possibly confine it.
Generally speaking, in the project-tailored structuring of the procurement plan and its accompanying operator model design, the project or state/commission authority boundary conditions must always be analysed and taken into account. In addition it is advisable to carry out careful market analysis and surveys and to increase the information base.



The LNVG H2 model

How will key players and citizens be involved and what measures are envisaged to increase market acceptance?

If infrastructure and technological projects are to achieve acceptance by society, a well-conceived and professionally-executed public consultation is required. The sooner key players and citizens can be involved, the lesser the risk of conflict.

The first of a three-part structured approach can support a positive fundamental attitude in society towards fuel cell technology in rail transport through information and opportunities for dialogue.

PART 1 – BASIS FOR GOOD PUBLIC CONSULTATION

The need for participation of citizens in the developments in their immediate environment has increased sharply over the past few years. In conceiving and implementing infrastructural plans however, gaps can frequently be observed between the public consultation on offer and the real need for discussion between the relevant actors and local residents. In this way conflicts often occur when not all concerned feel informed either adequately or in a timely manner. In these situations commissioning authorities are often surprised by sudden criticism, despite adhering to all requirements of formal mandatory consultation beforehand.

This "participation paradox" is illustrated in the diagram below. The delta which grows as the project advances between (a) the potential influence by citizens and (b) their engagement and interests, makes the potential for conflict clear.

Planned infrastructure projects should therefore be examined as early as possible for their conflict potential and the conception as well as implementation of the public consultation should be supplemented with informal dialogue and participation elements (information, consultations, co-design), along with the mandatory formal consultation.

PART 2 – STRATEGIC PUBLIC PARTICIPATION

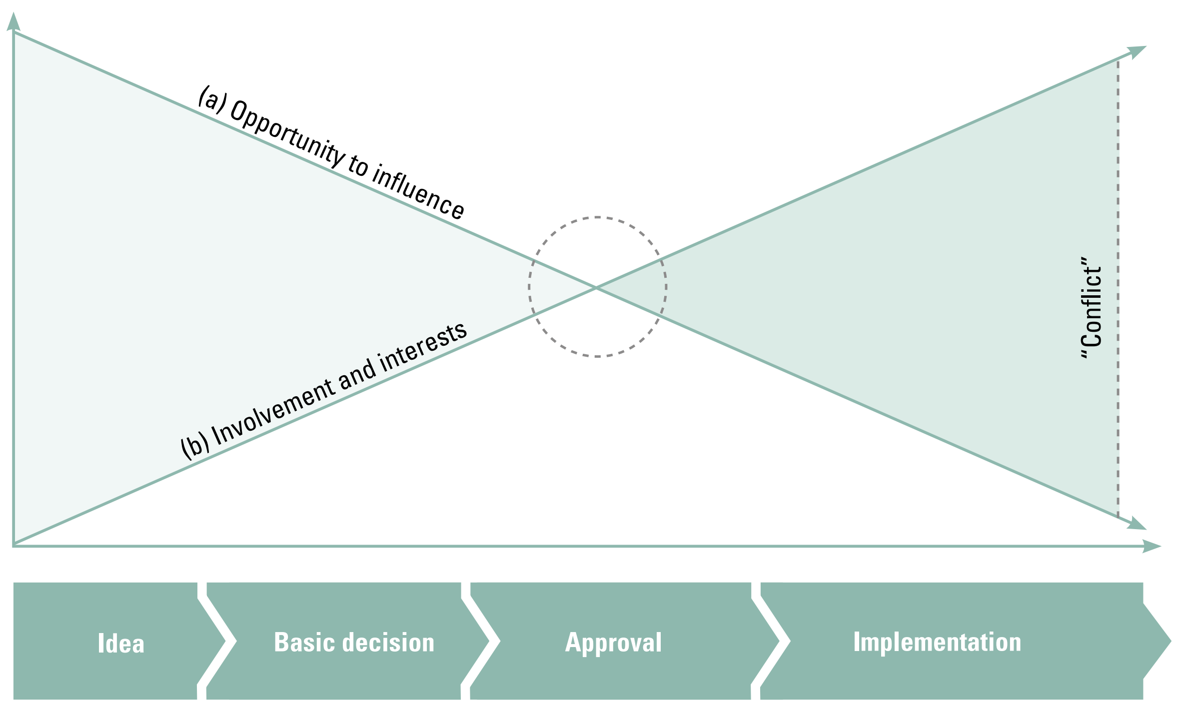
The overarching aim is for the introduction of hydrogen technology in rail transport to be positively viewed by the regional and broader public. Germans view the technology generally positively, yet the safe application of the technology as well as the sustainability of the hydrogen used is deemed a crucial basic prerequisite for long-lasting acceptance. These and other aspects identified through issues, sensitivity and stakeholder analyses must be communicated in a transparent and comprehensive way tailored to each specific target group and in addition the corresponding dialogue formats offered in a timely manner.

The strategic approach of the public consultation consists of three steps:

1. Acquire the key specialists as advocates for the use of hydrogen and fuel cell technology in rail transport,
2. Turn citizens (esp. passengers and residents) into experts (laymen) along the way,
3. Transfer the experience gained in the pilot project to other regions, taking stakeholders and citizens into account.

For this approach a combination of information and consultation elements present themselves. Those interested thereby obtain comprehensive and comprehensible information and supplementary dialogue opportunities for further questions, details and discussions.

For a professional interlinking of all interested parties as well as implementation using clear communication plan, the individual steps should be coordinated by a project office for communication and public relations work, to accompany the introduction of the technology.



Participation paradox of public consultation

PART 3 – INTRODUCTION CAMPAIGN USING THE EXAMPLE OF THE LOWER SAXONY CASE STUDY

Because of its pilot nature, the first introduction of the technology in Lower Saxony also directly affects the introduction of the technology in other regions. Accordingly it must be prepared carefully. Based on the first two parts, the following key points of good communication and public consultation for the pilot route in Lower Saxony can be identified.

By the end of 2016: The fuel cell train is still on the test bench in France. This time should be used to bundle together all existing information from the participating actors, to coordinate and prepare for communication, for example in a suitable narrative. After this the project communication priorities of the named stakeholders must be distributed and all relevant political representatives on regional, state and national level must be informed about the scheme.

1st half-year 2017: The fuel cell train is on the test course. Specialists and NGOs are to be provided with concrete information about the project. Invitations to symposiums, test drives as well as workshop and train tours serve this purpose; in each case following approval from the Federal Railway Authority. In addition background discussions for the media should be organised.

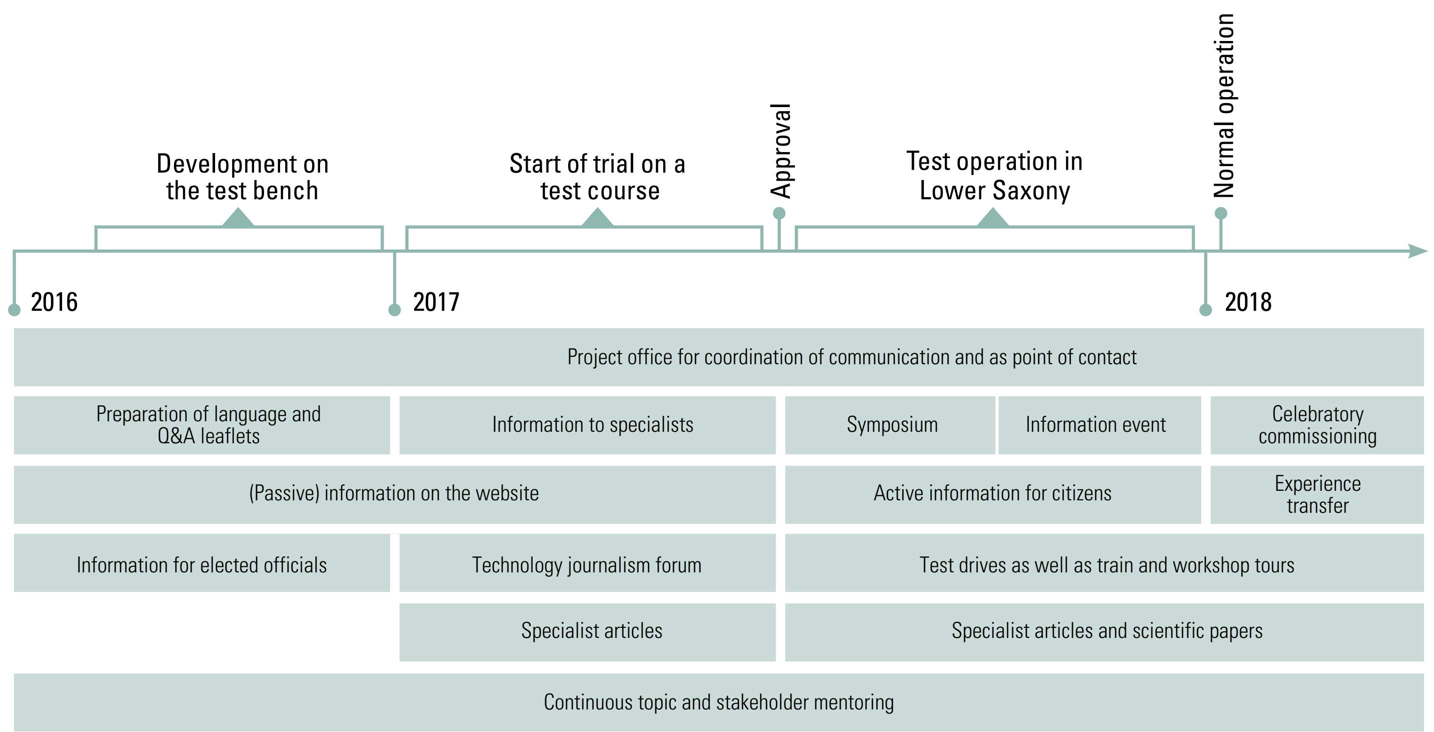
2nd half-year 2017: The fuel cell train is approved and will be tested in trial operation in Lower Saxony. Now communication and public consultation should be intensified in the region. Parallel to a journalistic background discussion, information brochures should be distributed across the whole region, which explain the advantages of the technology and answer the most important issues about safety and sustainability, name clear contacts for queries and include invitations to test drives and tours.

In addition the innovative technology should be made easy to understand in science magazines (TV, print, internet) and also for the national public.

From 2018: The fuel cell train will be deployed in regular operation in passenger transport. The official commissioning will take place at a celebratory event. Afterwards the information is to continue to be provided and the participating actors will share their experiences via specialist articles as well as participation in specialist events, which will increase the visibility of the project.

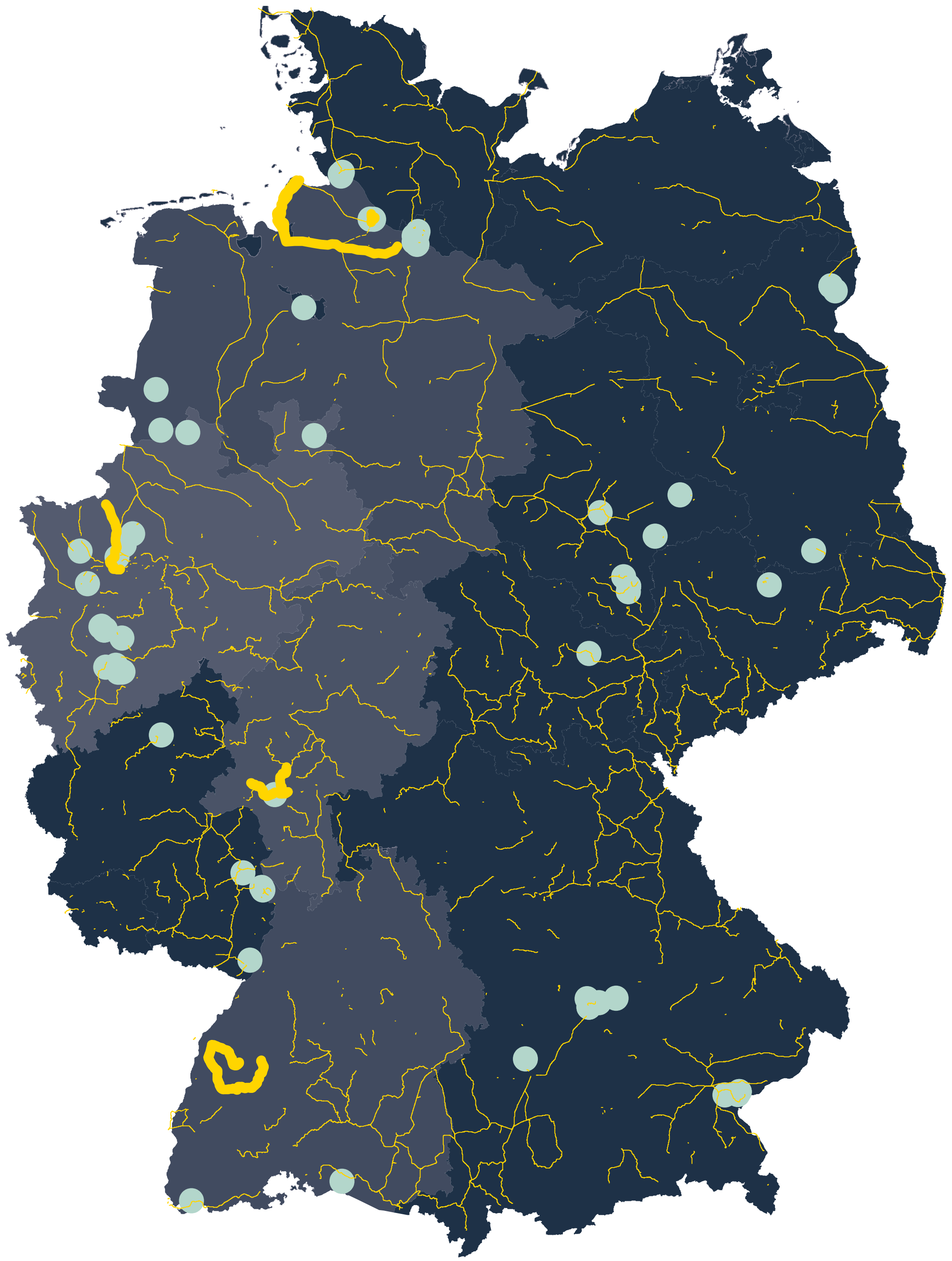
Recommendations for further action: For communication and public consultation as well as the accompanying acceptance research there is a multitude of possible measures which can be coordinated from a central point and must be linked together. It is recommended that a project office be set up until the new trains are deployed in regular operation. Based on a communication plan, the project office analyses on an ongoing basis the awareness of all actors, bundles together existing information, requests, and need for discussion, coordinates the implementation of different information and consultation measures and regularly adjusts planning due to new developments and knowledge.

The project office as well as the entire public consultation is seen to be particularly trustworthy when overseen by a public institution wishing to advance the energy changeover in transport with this measure and has no commercial interests. In the present case the government and the state of Lower Saxony are eligible here. The project-related PR work through the respective grant recipients remains outside of this structure.



Overview of the recommended launch campaign

How can a fully operational and safe supply of hydrogen be achieved?



This map shows the existing hydrogen sources in Germany and the non-electrified routes in the German rail network. From this it is clear where the cost-effective deployment options are for fuel cell trains in the short term. It also shows that there is not always an existing hydrogen source along the potential routes. Supply logistics will play a major role overall. In this context suitable supply paths were identified and evaluated.

H2 sources/use
Not electrified
H2 pilot routes

HYDROGEN SOURCES

HYDROGEN AS A BY-PRODUCT OF INDUSTRIAL PROCESSES

Some industrial processes (e.g. chlor-alkali electrolysis) produce the by-product hydrogen in addition to the main product desired. This can be sold as a fuel for the transport sector inexpensively. In most cases the H2 must be purified.

H2 GENERATION IN A NATURAL GAS STEAM REFORMER

Hydrogen is mostly manufactured today by steam reforming of hydrocarbons. Production mainly takes place directly where the hydrogen is needed and is made available to the desired process through local pipelines. A part of the hydrogen generated can be made available to other consumers following the appropriate conditioning (compression, liquefaction).

H2 GENERATION BY ELECTROLYSIS

The generation of hydrogen via electrolysis is one of the most promising possibilities for generating large quantities of hydrogen from renewable electricity and thus aside from reducing pollutants and noise, also for reducing greenhouse gas emissions. At present there are two different technologies available for use in industrial quantities: alkaline electrolysis and PEM electrolysis.

HYDROGEN SUPPLY PATHS AND THEIR EVALUATION

The identification and analysis of five possible supply paths has shown that firstly, with regard to economic viability, the supply of the by-product of hydrogen is to be prioritised above all. Today on-site electrolysis goes hand in hand with high investment costs, particularly when increased operational costs occur through taxation under the EEG. An exemption from this taxation is only possible when an immediate use of the generated electricity for the rail service is proven. According to current assessments this is not the case. The liquefaction of hydrogen from the steam reformer is only possible in three facilities in Europe, which can develop great dependencies. In a vehicle fleet of 10-12 railcars, we expect a daily requirement of 2t of hydrogen.

HYDROGEN IN GASEOUS FORM AS A BY-PRODUCT VIA TRUCK OR RAIL TRAILER

Small and medium hydrogen consumers, for whom on-site hydrogen generation is unprofitable because of high investment costs, can be supplied with hydrogen as a by-product by truck or train* from central manufacturing facilities. This is done in gas form in pressure containers.
Recommendation: Hydrogen as a by-product and hydrogen from existing steam reforming facilities can be made available comparatively cheaply. Depending on the distance to the consumer, this can be delivered at a reasonable cost.

Transport road: The hydrogen transport technology which is predominantly used today for road transport requires however several 40t trucks per day, which can lead to substantial acceptance problems among local residents. Emerging transport technologies with 500 bar carbon fibre tanks can considerably reduce the truck delivery frequency.

Rail transport: Because of their higher permissible weight, rail freight cars can transport a substantially greater amount of hydrogen per car. At the same time several cars can be connected to a single train, which can further reduce the number of trips. The appropriate hydrogen pressure containers for rail transport have already been used in Europe in the past – a new generation of these containers has yet to be developed and produced in greater numbers. Here container systems can be used, which would need to be checked according to the operational conditions of the rail service.

*Currently there is only limited experience of rail delivery in Europe

HYDROGEN AS A GASEOUS BY-PRODUCT VIA PIPELINE

Compared to other distribution options, pipelines have a particular advantage when large quantities must be transported over the long-term between the H2 generator and consumer. Pipeline systems or extensions of existing systems are feasible in principle. For small H2 flow rates a pipeline is economically rather less attractive.
Recommendation: For the pipeline solution, local framework conditions must be precisely analysed. In this way an already existing nearby pipeline, the hydrogen quantity, length of the planned pipeline as well as potential additional customers can have an effect on economic effectiveness.

SAFETY-RELATED TECHNICAL PRECONDITIONS FOR REFUELLING

Hydrogen in general: H2 is a colourless, odourless, highly flammable, reactive, non-toxic gas.
Hydrogen rises very quickly upwards because of its low density. Because the refuelling tanks of fuel cell railcars are placed on the roof, it evaporates rapidly upwards in possible leakages.

Hydrogen refuelling stations: In principle a specific risk assessment according to industrial safety regulations must be carried out for each refuelling station, in order to be able to take into account the location-specific framework conditions. Existing safety norms can be applied for hydrogen infrastructure in rail transport, even though there is no system of rules for this purpose. Serviceable regulations are for example the Operation Safety Ordinance, TRBS 3151 on the avoidance of fire, explosion and pressure hazards at refuelling stations and gas filling systems for filling ground vehicles as well as the VdTÜV specification sheet DRGA 514 on the requirements for hydrogen refuelling stations, pressurised gases, etc.

Design of the refuelling station: In establishing the necessary measures following the risk assessment to combat pressure, fire and explosion hazards, the interactions between the different system sections (e.g. between the refuelling station and a gas filling system) are to be taken into consideration. Fulfilling additional requirements such as a shutdown control switch and protection of the storage containers are also to be noted.

Zone allocation of potentially explosive atmospheres: In the risk assessment of a refuelling facility it is assumed that there are multiple areas where the existence of a dangerous, potentially explosive atmosphere must be reckoned with. These areas are to be designated as hazardous atmospheres.

Requirements of lightning and surge protection: The dangers incurred by a lightning strike and the associated release of fuels or their fumes as well as operating materials are to be determined and minimised. Requirement for assembly: The components of the hydrogen refuelling station can be housed in areas or cabinet housing or as open-air facilities. In the process the system components must always be reliably secured against the entry of unauthorised persons.

Electrotechnical requirements: At the time of construction the requirements in force must be adhered to under the Explosion Protection Directive as well as TRBS.

Hazards caused by rail power systems: In the area of rail facilities, hazards include the overhead lines and their associated high voltage (15kV) and flows (40 kA short circuit current). In particular the low level of required ignition power for a hydrogen-air gas mixture is quickly exceeded in the railway power supply systems and must be effectively prevented. Although the fuel cell railcars usually will not (have to) operate under overhead lines, nevertheless preventative measures should be taken. These measures concern mainly safe distances, earthing and potential equalisation measures as well was safety-specific functions related to traction power supply (incl. overhead lines).

Maintenance and repair: The specifications of the Operational Safety Ordinance are binding for the carrying out of all maintenance work. Staff is to be trained on the specific risk assessment. Because hydrogen rises upwards, possible accumulations must be eliminated. For this reason the buildings are equipped with a ceiling exhaust system.

THE REFUELLING PROCESS

The design of the fuel cells of the planned vehicle is based on a hydrogen purity of 5.0 (ISO 14687-2). This must be particularly taken into account for the design of the refuelling station, if for example hydrogen as a by-product is used that does not reflect this purity and must be purified.

The refuelling of the vehicle happens in a closed filling system with a nominal filling pressure of 35 MPa. Depending on the design of the refilling installation, refuelling speeds can vary. With the WEH TK 16 H2 HF nozzle refuelling speeds can reach up to 7.2 kg/min. This system is currently already demonstrating itself effectively in local public transport.

The refuelling device at the vehicle is based on the same norms as when using diesel vehicles. The parallel refuelling of both tank systems will be secured through 2 filling nozzles per independent system and enables a fast refuelling cycle which is comparable to conventional diesel refuelling.

The average attainable refuelling speed is majorly dependent on the design of refuelling facilities. When procuring a refuelling facility, the required average refuelling speed as well as the necessary refuelling frequency (e.g. 2 trains per hour) should be clearly specified at an early stage. In specifying the refuelling facilities, a refuelling cycle of approx. 20 min/ train is required, analogous to a conventional diesel facility.

Summary

> The by-product of hydrogen and hydrogen from steam reformation are today under existing regulation available more cheaply than hydrogen from on-site electrolysis.
The framework conditions on site can have a decisive influence on the economic efficiency of individual supply options.
> For acceptance reasons, hydrogen transport by rail is preferable to road transport.
> As a colourless, reactive and non-toxic gas, hydrogen evaporates completely upwards.
> Existing safety norms are applicable to hydrogen infrastructure.
> When planning the refuelling station, the required purity of hydrogen for the fuel cells must be carefully observed.
> When designing the refuelling station, a similar refuelling cycle to that of diesel railcars to be planned (20 min. per train)

Can fuel cell trains for regional transport be deployed now?

OVERVIEW

Speed: In order to be deployed in the German rail network, regional trains as feeder services must achieve speeds of approx. 120 to 160 km/h in order not to jeopardise the long-distance timetable. The fuel cell trains in this study fulfil this requirement with a maximum speed of 140 km/h and as such are fundamentally deployable.

Range: For the routes earmarked to date, the range of 650 km represents no limitation whatsoever for scheduling or timetabling.

Refuelling: With a nominal pressure of 35 MPa and a refuelling speed of up to 7.2 kg/min, the fuel cell train refuelling facilities already today correspond with applicable norms. The nominal pressure of 35 MPa has already proven itself in the area of fuel cell buses in public transport. Within the scope of the timetabling process, the calculated average refuelling time – and thereby the unavailability of the train – is to be taken as 45 minutes for the complete refuelling process (see page 18, the refuelling process).

Safety: For safety reasons, it is recommended that an automatic immobiliser system along with a pressure-proof refuelling mechanism be used throughout the entire refuelling process at the nozzle on the rail track to prevent any of the 99.999 vol-% hydrogen escaping. An initial calculation made by this study puts the cost of such facilities at a total of approx. 2 EUR/kg H2.

EFFICIENCY BENEFITS OF FUEL CELL DRIVES

Compared to diesel rail cars, fuel cell trains with a battery hybrid component demonstrate the following benefits: fast acceleration and the possibility of recuperating energy from the braking process. Overall, efficiency benefits exist over pure diesel drives, as illustrated in the simulation results* attained, among others, from the "Bremervörde" and "Königstein" reference routes examined in this study:

Especially in the case of the results in the "Königstein" reference route, it is clear that fuel cell trains boast efficiency benefits compared to diesel drives on routes with many stations as well as large differences in elevation along the route.

It can be assumed that the continually growing demand in the vehicle technology will lead to further developments in this drive type, which will subsequently have a direct impact on increasing its efficiency. As such, hydrogen consumption can be expected to fall by a further 10-15%, resulting in the documented efficiency benefits increasing correspondingly. Timetabling and refuelling plans can thereby also be optimised.

SITE PLANNING IN REGARD TO OPERATIONS

In terms of site planning of the refuelling facilities in the rail infrastructure, the following aspects must be taken into consideration.

At virtually all railway companies, the refuelling of the vehicles is a part of the vehicle provisioning process and is generally conducted on the premises of the depot or yard. The production of hydrogen, transport of hydrogen to the refuelling facility and hydrogen refuelling facility itself all count among the components of a comprehensive hydrogen and refuelling infrastructure. When conducting site planning, it must be taken into consideration that the fuel nozzles are located directly at the tracks within the standard norm threshold range.

Additionally, in accordance with the risk analysis, the following is to be taken into account for the site planning of trackside refuelling facilities:

> Minimum 5 m clearance between nozzle and storage vessel
> Maximum permissible length of the refuelling hose line of 5 m
> A hose retraction system ensures reliable hose accommodation
> In addition to the train stop (immobiliser) system, a breakaway coupling should also be provided

Reference route	Comparative data				
	Route length per round	Number of stations	Consumption figures		Fuel cell energy requirements compared with diesel drive
			Diesel	Hydrogen	
	km	–	l/km (kWh/km)	kg/km (kWh/km)	
Buxtehude – Bremerhaven – **Bremervörde** – Cuxhaven – Buxtehude	240	44	1.08 (10.8)	0.23 (7.7)	-29%
Frankfurt – **Königstein** – Frankfurt	50.2	18	1.82 (18.2)	0.34 (11.3)	-38%

Simulation results on consumption data of fuel cell trains on the reference routes.

* Own calculation based on manufacturer simulations

In the example, the fuel cell rail car consumes approx. 150 kg hydrogen per day in normal operations. For a fleet of 10 to 12 vehicles, this translates to a daily hydrogen requirement of 1.5 to 2 tonnes. Currently, this would require deliveries from 4 trucks (490 kg H2 per transport unit) or 3 rail tank wagons (660 kg H2 per transport unit). Hydrogen can be made available for the refuelling facility in several ways:

> If an on-site electrolysis method is selected, a site near the route with an area of around 1,000 m2 needs to be located for this purpose – which will generally be difficult to find.
> Deliveries via truck or rail tank wagons do not require the same approvals and operational effort as the on-site method above, but the delivery logistics – especially in the case of residential areas – must nevertheless be taken into account. In terms of approvals, however, this method is capable of being realised with significantly less administrative effort.

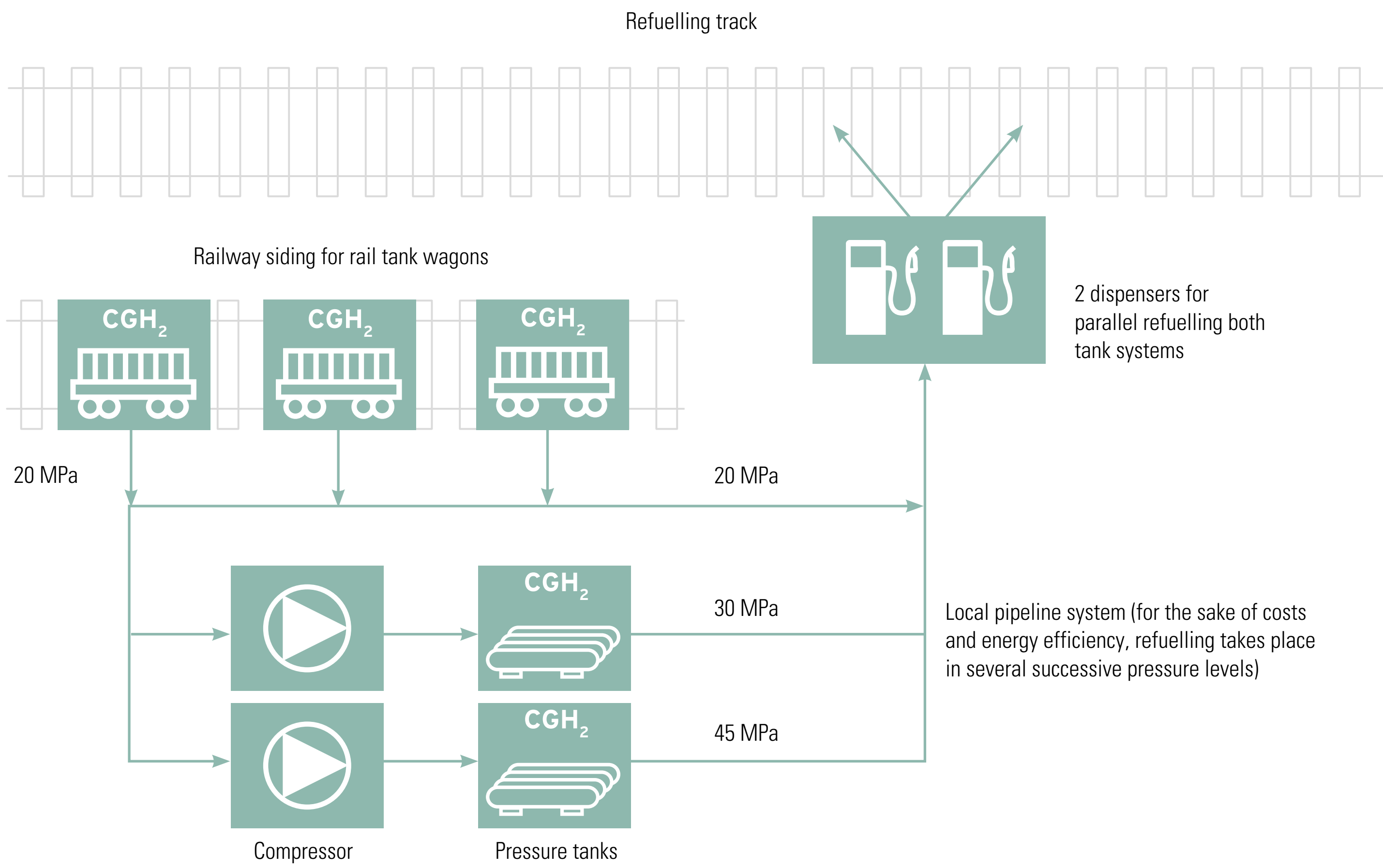
The following illustration shows the scope of the components required for refuelling facilities in rail infrastructure. Rail and infrastructure companies must make corresponding plans in a timely manner along the rail network to ensure a sufficient hydrogen supply and smooth operations.

Summary

While the operational planning of a comprehensive hydrogen infrastructure with all necessary components represents a challenge, already today, the standard-compliant deployment of fuel cell trains in German rail transportation is possible.

A clear efficiency benefit in terms of consumption is visible compared to diesel rail cars – particularly on routes with many stations as well as in situations with large differences in elevation along the route.

For the integration of fuel cell trains in the general rail services, rail companies must therefore carefully plan scheduling, taking into account the requisite technological and time factors.



Set-up of track-side hydrogen infrastructure

What needs to be considered when launching innovative technologies for public services?

VARIOUS FACTORS NEED TO BE TAKEN INTO ACCOUNT WHEN INTRODUCING AND MANAGING INNOVATIVE TECHNOLOGIES – ESPECIALLY IN THE CASE OF LARGE PUBLIC PROJECTS AND INNOVATIONS.

In contrast to private commercial projects, regulatory measures and directives often control innovations in the public sector, which in turn greatly influences and stimulates the introduction process of the innovative technology.

For example, as part of an aim to achieve an elimination of emissions in rail transportation, corresponding directives can have an accelerating impact on the introduction and sustainable establishment of associated technology. An example for a successfully managed introduction of an innovative technology is the take-up of electric vehicles in vehicle fleets in Germany: only through a public sector directive to reduce fleet emissions did an increase in electric vehicles is commercial vehicle fleets transpire. As such, public regulations at a local level and the communication thereof represent a possibility to positively influence the introduction process in local rail public transport. Continuous, open communication with cooperation partners is crucial for an efficient and effective introduction, as the partners should also be involved in the introduction as suppliers and future users. For the public contracting authority, this results in the necessity to plan supporting prerequisites such as the scope of resource deployment and provision of information at an early stage.

Fundamentally, an appropriate introduction process should be reflected in the initiation of targeted public-private partnerships, as this enables the flexible use of resources and expertise. To promote the establishment of effective public-private partnerships it is recommendable that the public authorities assume the risks of the initial introduction of the innovative technology and therefore help motivate private players to invest. This may, for example, be in the form of subsidies (e.g. grants or tax incentives) or sponsorships.

To further positively influence the introduction of innovative technology it is important to ensure stability and acceptance for the sake of all involved as well as the general public. Here too, it is important to maintain open communication with all involved parties from an early stage in order to help make a positive impact on the introduction process.

An important issue during the introduction of innovative technologies by public institutions is the imbalanced basis of assessment compared to established technologies: for the assessment of economic efficiency of the new technology it is necessary to establish timeframes based on assumptions and depreciation periods that can be used as a basis for making comparable assessments with established technologies. Using the example of hydrogen infrastructure, this means in comparison to diesel infrastructure, that the latter benefits from positive operational and accounting advantages as economies of scale are in current effect and the usage timeframe of existing infrastructure exceeds the depreciation period. As such, the resulting distortion of economic efficiency comparisons can thereby hinder the introduction of a fundamentally sound new technology. But if one considers the future savings potentials along with increases in efficiency that may go hand-in-hand with the provision of the innovative technology, a corresponding correction of such a distortion should be addressed as part of the introduction and innovation management. The inclusion of an adjustment factor in the assessment of economic efficiency as a way to balance established and new technologies is therefore a useful means to control the introduction in an appropriate manner.

Summary
The following factors are to be taken into account with the introduction of new technology in a public context:

> The targeted implementation of open communication of regulatory directives and decisions at an early stage.
> Assumption of the risks associated with the introduction, by the public authorities.
> Target-oriented and open cooperation with implementation partners as well as the establishment of public-private partnerships.
> The consideration of adjustment factors in economic efficiency comparisons of existing and new technologies.

Can hydrogen infrastructure be profitable and competitive?

METHODOLOGY

In the first step, the costs for the provision of infrastructure per rail vehicle are determined (in millions of euro net per annum without investment costs) for hydrogen and diesel infrastructure in the basic scenario with the today most probable assessments and corresponding costs. For this purpose, the economic efficiency assessment for the hydrogen infrastructure (vehicles with fuel cell drive) and the diesel infrastructure (vehicles with diesel drive) will be conducted on the basis of the following cost items:

> Investment costs (separate assessment)
> Operating costs
> Fuel costs
> Fees for the use of the rail infrastructure

The costs are based on expert estimates, enquiries and manufacturer information (October 2015 – May 2016), which are to be validated for the respective cases at a later point in time. For the items mentioned, relevant input parameters (costs, consumption data, vehicle mileage, etc.) are to be determined and assumptions made there for. In order to further enhance the comparability of the overall results, the following parameters based on the determined infrastructure provision costs will also be incorporated in a second step:

> Adjustment factor for the technology's stage of maturity (hydrogen infrastructure) (see also page 24)
> Subsidies for diesel fuel

The individual items and parameters for the economic efficiency assessment will next be explained in further detail for the basic scenario. (Worst and best cases will not be considered in this publication.)

COST ITEMS AND PARAMETERS

Investment costs

According to our research of the market, the investment costs for one conventional train with diesel drive in Germany are approx. EUR 4.0 to 4.5 million net, on average. In contrast, the investment costs for a series train with fuel cell drive are, according to expert estimates, approx. 25% above those of a diesel rail car and therefore approx. EUR 5.0 to 5.6 million net. For the basic scenario of diesel trains, investment costs in the middle band of around 4.3 million euro net will be assumed. This correspondingly results in the higher investment costs for a train with fuel cell drive of approx. EUR 5.3 million net.

Operating costs

The consumption of fuel per train is derived from the figures provided by the manufacturers for the reference routes. According to the collected data, the average consumption of hydrogen is 0.23 kg H2/km and a ratio of hydrogen to diesel consumption of 1 to 5.2*. This allows the average consumption of diesel fuel to be calculated at 1.2 litres diesel/km. An annual mileage of 200,000 km is being assumed for the trains.

The **repair and maintenance** costs for a conventional (two part) diesel train is given at approx. EUR 0.08 net per km without ancillary costs, according to experts. For a train with fuel cell drive, experts anticipate a reduced cost in the range of 5-20% compared to diesel trains. Cost saving effects can therefore be assumed, as the maintenance effort and expense for diesel motors is assessed significantly higher than for fuel cell and electric motors (whereas the drivetrain and motor-drive shaft-final output remains the same). In contrast, maintenance costs for the diesel refuelling facility are estimated to be lower than that of its hydrogen counterpart (as the latter incorporates a higher proportion of pressure tanks and pipes). Overall, however, this leads to economic efficiency advantages in favour of trains with fuel cell drives. For the basic scenario, a level of 10% is assumed. Further (unspecified) operating costs such as for the cleaning of fuel cell and diesel rail cars were not considered in this study.

Fuel costs

In terms of the fuel and general refuelling costs at the filling nozzle, the following cost data applies for hydrogen (without VAT or other duties):

> Based on prior conclusions, costs of EUR 5.05 net /kgH2 including margin are assumed for the basic scenario (by-product hydrogen, rail transport).

Fees

The track prices are set independent of the train drive type on the reference route at approx. EUR 2.25 net per km. The prices for each stop at a station are also independent of the drive type and comprise approx. EUR 2.47 net per stop.

Adjustment factor

In a hydrogen market (bus/rail/car) with the potential for the sale of large numbers, cost reductions of around 10-20% can be expected due to technical advancement and series production effects. For the basic scenario of the hydrogen infrastructure, a cost reduction of 15% is assumed, which is expressed by an adjustment factor of 0.85.

Subsidies (diesel fuel)

Diesel is currently taxed approx. EUR 0.18 per litre less than Super fuel (ROZ 95). This differential amount is taken up as a subsidy and added to the diesel price for the purpose of the economic efficiency assessment, therefore benefiting hydrogen fuel in the assessment.

Adjusted infrastructure provision costs

After taking the adjustment factor for the maturity of the technology as well as the diesel subsidies into account, hydrogen infrastructure can boast an economic efficiency advantage of approx. 23%. The difference amounts to approx. EUR 0.23 million net per annum. The following table contrasts the individual cost components and thereby compares the identified infrastructure costs of fuel cell drives with that of diesel drives (EUR figures net).

> Also: 200.000 --> 200,000 > 0,72 --> 0.72 usw...	Unit	Hydrogen infrastructure	Diesel infrastructure
		Fuel cell drive	Diesel drive
One-off investment costs			
Assumed investment costs per train	Million EUR	Approx. 5.3	Approx. 4.3
Annual mileage	km/year	200,000	200,000
Ongoing operating costs			
Operating costs			
Maintenance without ancillary costs	EUR/km	0.72	0.80
Fuel costs			
Fuel consumption	kg H2/km, litres Diesel/km, resp.	0,23	1.20
Refuelling at nozzle	EUR/kg H2, EUR/l Diesel, resp.	5.05	1.10
Fees			
Track prices	EUR/km	2.25	2.25
Price per stop at station	EUR/Station	2.47	2.47
Infrastructure provision costs (running costs)	Million EUR/year	0.92	0.96
Adjustment factor for technology maturity	Factor	0.85	–
Subsidies	EUR/l Diesel	–	0.18
Adjusted infrastructure provision costs (running costs)	Million EUR/year	0.78	Approx. 1.0

Comparison of cost items diesel drive and fuel cell drive per train and year.

Summary for the basic scenario

The costs for the provision of infrastructure show an economic efficiency advantage of 4.8% or approx. EUR 47,000 net per train per year in favour of hydrogen infrastructure (one-off investment costs for the trains not included). If one additionally assumes further cost reduction effects of 15% for hydrogen infrastructure within a timeframe of 4-6 years and one considers the current diesel fuel subsidies, the economic efficiency advantage of hydrogen infrastructure increases to 23%. The positive difference for hydrogen infrastructure is therefore EUR 0.66 million net per year. As such, in the basic scenario, in terms of economic factors, hydrogen infrastructure represents an interesting and competitive alternative to diesel infrastructure.

* Own calculation based on manufacturer simulations

Approaches for shaping the legal and regulatory framework conditions

ANCILLARY POWER COSTS DURING HYDROGEN PRODUCTION

The examinations of energy industry law throughout this study have shown that for the necessary procurement of electricity for the production of hydrogen via electrolysis, all electricity ancillary costs (network charges, EEG levy and electricity tax) can be fundamentally applicable. While there may be some potential for exemptions or reductions in some individual cases depending on the particular situation, from the perspective of hydrogen use in rail transportation it seems quite "random" whether these exemptions or reductions will apply. However, a reduction in the EEG levy applies for the use of electricity in electric trains. Legislators should therefore expressly clarify whether this reduction possibility also applies in the case of hydrogen train companies for which electricity is used to produce hydrogen.

Approach: Obtaining legal clarification regarding levies and taxes in the case of hydrogen usage by rail companies. The reduction in the EEG levy for rail companies should be expressly covered for hydrogen production with subsequent use in rail transportation – the same applies for existing exemptions of network charges and electricity tax.

COMPREHENSIVE APPROVAL PROCEDURES

As already illustrated on page 8, for the establishment and operation of the respective infrastructure, a planning approval procedure is generally necessary, which leads to high administrative and procedural requirements for all parties involved. While this has the advantage that no further approvals need to be subsequently obtained, the high amount of time and effort this takes will nevertheless present a major challenge for operators.

Approach: Operators should obtain assistance to go through the approvals process. Helpful would be clarifications within laws, directives or administrative regulations. In addition, it would also appear that the development and provision of guidelines from public authorities (or, if applicable also private firms) would also prove to be helpful and recommendable.

TASK DISTRIBUTION FOR HYDROGEN PRODUCTION, TRANSPORT AND REFUELLING

As operator of the hydrogen production facilities – particularly electrolysers – as well as pipelines, storage facilities and refuelling stations, various different companies are involved. Especially when railway companies or railway infrastructure companies want to take over the abovementioned tasks, significant financial effects arise. Railway infrastructure companies must fundamentally provide all third parties access to use the infrastructure for the same conditions as each other. The fees charged are, however, subject to regulatory control.

Approach: The examination of the legal provisions of railway law showed that a complete overview of tasks is necessary, which in today's regulatory framework is allocated to various players. If railway companies wish to assume the tasks in their entirety or in part, it must be possible for them to cover their costs, for example, through fare charges.

PROCUREMENT LAW

Following legal examination, it is fundamentally possible to prescribe the use of hydrogen trains – or more generally, the use of emission free rail mobility – in procurement procedures.

To this end, however, the legal requirements as well as the actual development and availability of such technologies must be taken into account.

Approach: It is to be established how tendering parties may access the necessary infrastructure for the use of hydrogen in rail vehicles. A possible approach could involve an integrated tendering process whereby the operation of the rail vehicles is called to tender together with the tender for the development of respective infrastructure. It must, however, still be precisely considered what tasks must be included, especially in the case when exploitable hydrogen sources already exist in the surrounding area (e.g. for the transport of the hydrogen).

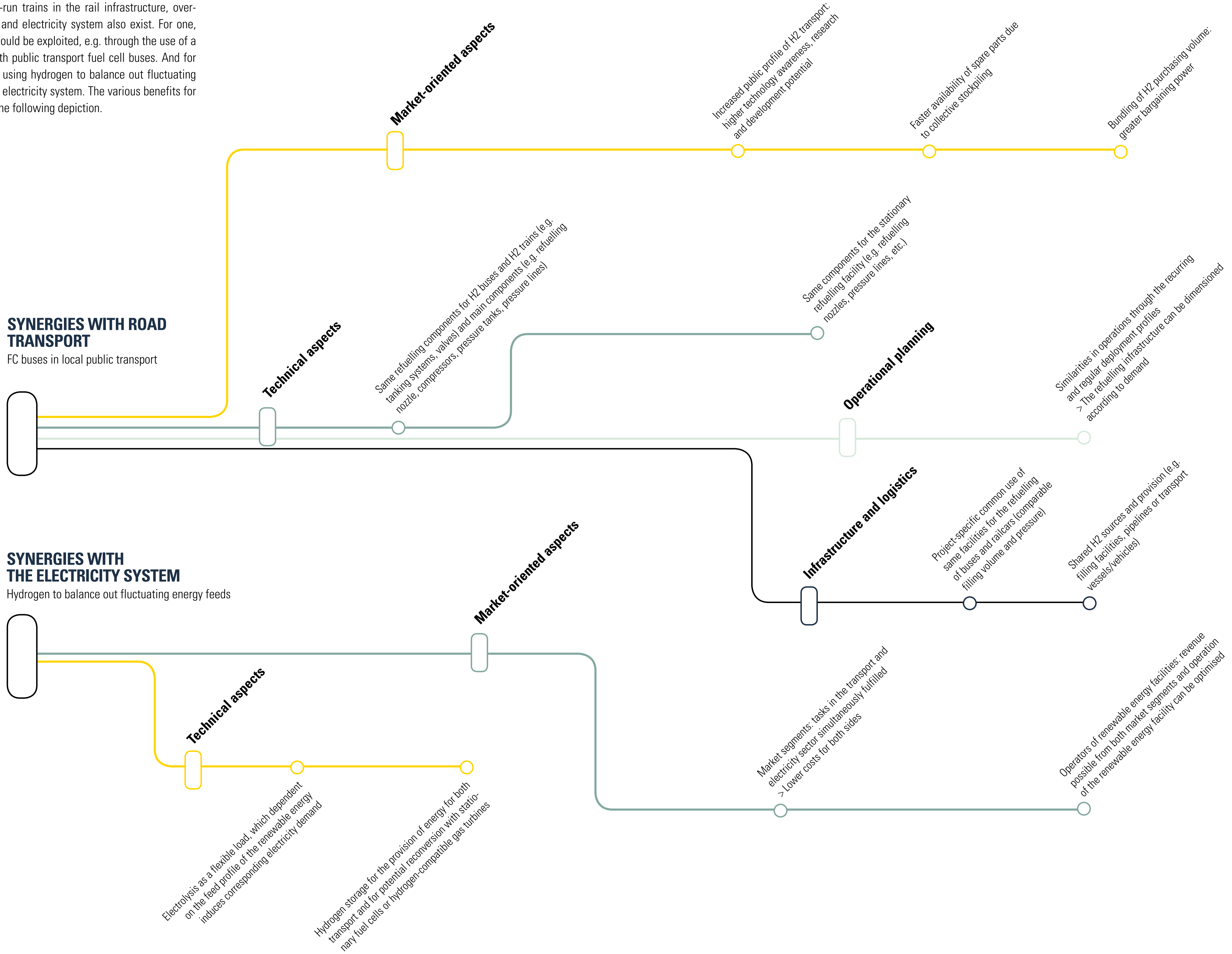
START-UP FINANCING FOR THE INTRODUCTION OF A HYDROGEN INFRASTRUCTURE

With a view to the significantly higher investment costs for the trains in combination with the provision of infrastructure costs (see economic efficiency assessment on pages 26/27), compared to diesel infrastructure, hydrogen infrastructure will not yet be competitive during its period of introduction. Considering the policy objective of emission-free public rail transport and aspects not yet added to the equation including the environmental effects and impact on public health due to the emissions from diesel vehicles, the introductory phase must be shaped in a way to make it more economical for public, semi-public and private players.

Cost reductions for vehicles will also transpire as the number of units sold increases and technology advances. Savings of 10-20% are anticipated in the medium term. Start-up financing in the form of funding could be a short to medium term approach to provide support until the technology and processes become established.

Synergies with road transport and the electricity system

Besides an integration of hydrogen-run trains in the rail infrastructure, overarching potentials for the transport and electricity system also exist. For one, synergies with the transport sector could be exploited, e.g. through the use of a common refuelling infrastructure with public transport fuel cell buses. And for the other, there is the possibility of using hydrogen to balance out fluctuating feeds of (renewable) energy into the electricity system. The various benefits for their possibilities are illustrated on the following depiction.



Partners

Ernst & Young GmbH
Wirtschaftsprüfungsgesellschaft
Project management, realisation models and economic efficiency analyses

Ludwig-Bölkow-Systemtechnik GmbH
Hydrogen infrastructure and provision, synergy potentials

Becker Büttner Held
Legal framework

TÜV SÜD Rail GmbH
Risk assessment and generic system specification

IFOK GmbH
Public involvement

SIGNON Deutschland GmbH
Operational planning