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Declaration by the scientific representative of the project coordinator

I, as Scientific Representative of the Coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement, declare that:

- The attached Periodic Report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):

☐ has fully achieved its objectives and technical goals for the period;

☒ has achieved most of its objectives and technical goals for the period with relatively minor deviations.

☐ has failed to achieve critical objectives and/or is not at all on schedule.

- The public website, if applicable:

☒ is up to date

☐ is not up to date

- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organizations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of Scientific Representative of the Coordinator:

Kerstin K. Müller
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Date:.28/02/2017

For most of the projects, the signature of this declaration could be done directly via the IT reporting tool through an adapted IT mechanism.

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Part A – Final Publishable Summary Report

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1 CHIC Project in brief

The Clean Hydrogen in European Cities (CHIC) Project was the crucial next step for the full commercialisation of hydrogen powered fuel cell buses. The project commenced in 2010 with an initial 25, subsequently 23 partners from Cities, Regions, Industry and Research Organisations (See Annex 18.1 unterhalb). CHIC was a public-private partnership and received substantial funding from the Fuel Cell & Hydrogen Joint Undertaking (FCH JU). The project was completed in December 2016.

CHIC operated 54 hydrogen fuel cell (H_2FC) buses and 4 hydrogen powered internal combustion engine buses in 9 cities in Europe and Canada. The buses were delivered by 5 different bus manufacturers and had fuel cells from two different suppliers.

The CHIC project has met, and in many instances significantly exceeded, expectations. It has provided further necessary evidence for the functionality of hydrogen fuel cell buses and the refuelling infrastructure, and the practicality of their commercialisation in the near term.

The CHIC project has tested hybrid architecture in the buses (hydrogen and electricity storage on board) for the first time in full revenue service resulting in very significant fuel efficiency gains. It has shown conclusively that the issues of fuel cell lifetime, hydrogen purity and safety are not of significant concern for the technology.

In total, the hydrogen buses have operated for more than 519,000 hours and travelled some 9,600,000 kms during the lifetime of the project. The average hydrogen consumption has been just over 12 kg/100 kms with a range from 8 kg/100 kms to more than 16 kg/100 kms. All the 12 m H_2FC buses achieved a fuel economy of less than 10 kg/100 kms

The fuel cell buses in the five Phase 1 cities alone, which had the newest buses, operated for nearly 279,000 hours and travelled 4,000,000 kms, and had a hydrogen consumption of less than 10 kg/100 kms.

Considerable progress in infrastructure has also been demonstrated. Refuelling has been more reliable than ever before with higher availability, and shorter fill times. The refuelling stations have operated with an average availability of more than 94% over the entire project lifetime, and at greater than 98% for half the sites in the latter half of the project. There have been no hydrogen production purity issues.

Meeting the demanding daily operational requirements of public transport operations in a number of diverse cities across Europe and in Canada is perhaps the most significant achievement. This, combined with the step change, generational improvement in performance, including fuel consumption, and availability augurs well for the technology into the future.

The table below gives an overview of the CHIC project and summarises the key results and achievements.

Table 1.1 CHIC at a glance: context and results

Project Context	
Duration of the Project	From 2010 - 2016
Numbers of Project Partners[1]	23 partners (initially 25) from 8 countries; 9 bus operators; 5 bus OEMs
Project Investment: Total	€81.8 million
Project Investment provided by Fuel Cell Hydrogen Joint Undertaking (FCH JU)	€25.88 million
H_2FC Buses demonstrated	• 54 Fuel Cell buses (28 Phase 0; 26 Phase 1) • 4 Internal Combustion Engine Buses
Hydrogen Refuelling Stations Demonstrated	• 4 Co-Funded by FCH JU (Phase 1) Cities • 5 Co-Funded through other programmes (1 Phase 1 & 4 Phase 0) Cities
Results Hydrogen Infrastructure	
Capacity Upgradeability On-site Production Efficiency Availability	• Refuel 200kg a day (5 vehicles/hr min.), except for Phase 0 city Cologne • All capable of upgrading to refuel a minimum of 400 kg a day. • All sites >54% • All sites >94% (4 sites) – Three sites >98%
Results Hydrogen Bus Operations	
Fuel Cell lifetime per stack	• 6820h average all H_2FC buses • 6690h average Phase 1 cities • 56 Stacks passed the 6000h goal • 29 Stacks passed the 6000h goal (Phase 1 cities only)
Availability Overall [%]	69%
Fuel consumption	12.1kg/100km all H_2FC buses including also articulated and Whistler buses 9.9kg/100km (Phase 1 cities)
Project total running distance	9.6 million km
Project total hours of operation	519,000 hours
Quality & Safety; Environmental Impact; Community Attitudes to H_2 in Transport.	
Accidents	Nil
Diesel Replaced	> 1.5 million litres across the Phase 1 sites > 4.3 million litres across all sites
Global Warming Potential	85% savings for fully green H_2 fuel in fuel cell buses.
Individuals Interviewed re views on buses & hydrogen powered transport	Project Environment: 185 Critics and Sceptics: 63
Dissemination & Exploitation	
Local Sites General	50 – 80 special events in each of 6 cities Website (30,000 unique visitors/yr)
Greenfields (Phase 2) Cities Identified & Involved	5 City Clusters established (France, Germany, Netherlands, Northern Europe; UK)

[1] As of December 2016

There are, nonetheless, important performance and cost indicators where both the bus and refuelling infrastructure need to improve.

Availability, that is having fuel and buses able to be put into service when needed, is the fundamental performance requirement for bus operators. The current availability for both the buses and the refuelling stations, particularly the variability over time, needs to be improved to give confidence to future operators. While this will include technological improvements, suppliers and maintainers will also need to improve their capabilities, particularly spare part supplies and response times. Another essential requirement is that the technology be affordable. The operational costs of producing and dispensing hydrogen at the site have been greater than targeted range of between 5 – 10 €/kg. At the current level of input costs, particularly the costs of electricity, the path to meeting this target is unclear.

CHIC studies have also shown areas where Government policies can recognise the full costs to the community of using fossil fuels, and ensure that they are allocated appropriately. In an era when air quality is a very significant issue, clean hydrogen fuel cell powered public transport can contribute greatly to reducing community health costs. These benefits could be passed onto the bus operators through reduced taxation and other Government charges.

The data obtained in CHIC have provided the platform and the confidence upon which large scale bus deployments can be built. A combination of these economies of scale and 'smart' Government policy should take care of the remaining barriers to commercialisation.

2 Project Context and Objectives

2.1 Policy Context

The CHIC project was developed against the background of several predecessor projects demonstrating the feasibility of using hydrogen fuel cell technology in public transport buses. These projects included CUTE (Clean Urban Transport for Europe) [2001-2006] with concurrent related projects in ECTOS in Iceland (Ecological City Transport System and STEP in Western Australia (Sustainable Transport Energy in Perth), and HyFLEET:CUTE [2006 – 2009].

There was also a significant high level policy background. Over the past several decades the European Union (EU) and Member States had published a number of major policy objectives which could be partially addressed by the successful implementation of hydrogen fuel cell public transport bus fleets. The EU has committed to a number of significant actions to reduce the extent and impact of, for example, climate change, and to improve air quality. Reducing transport emissions through the replacement of fossil fuel powered buses with H_2FC buses would greatly reduce local emissions, and overall emissions, especially if hydrogen is produced through low carbon pathways. Such a strategy would also reduce the health impacts from fossil fuels which have become increasingly evident.

Concurrently, the EU has crafted energy policies aimed at increasing energy security for the Union, and energy self-sufficiency. The range of options available for hydrogen generation can contribute to this objective. At the same time the development of the whole hydrogen powered transport system and the associated technology and systems will require new skills and enterprises that can contribute to the EU policies on economic development and employment.

The drive train technology in buses participating in CHIC that originated from previous projects utilised only fuel cells with no supporting power options. While this demonstrated the efficacy of fuel cell systems, the potential benefits of hybridisation have been clearly demonstrated in the next phase. Hybridisation with battery systems was introduced into subsequent generations demonstrated in CHIC and showed significant improvements in range, reliability and fuel economy.

The predecessor projects also only operated fuel cell buses from one supplier, EvoBus GmbH. It was recognised that it would be important to encourage more OEMs of both buses and refuelling stations to enter the field if the technology was going to develop to commercialisation. More suppliers would increase competition which was likely to reduce costs, increase innovation and increase options for different solutions. It would also increase the number of buses in operation, an important and missing element, to test the vehicle and refuelling technology, as well as increasing and testing hydrogen refuelling station technology, potentially solving the ‘chicken and egg’ conundrum.

2.2 CHIC Project Objectives

In this context, the overriding objective of the CHIC project was preparation for the commercialisation of H_2FC hybrid bus technology and associated infrastructure solutions.

The objectives of the CHIC project were to:

- Implement a fleet of 26 hydrogen powered, hybrid drive 'pre-commercial' H_2FC public transport buses in medium size fleets in 5 regions across Europe aiming at significantly enhanced fuel economy; and high levels of availability, and reduced maintenance and external technical input requirements;
- Establish and enhance hydrogen production and refuelling infrastructure and facilitate the production of locally and regionally available sustainable transport energy for urban public transport;
- Establish a Task Force on Quality and Safety to ensure good and rapid information flow between the sites to ensure safe operation of infrastructure;
- Evaluate buses from a number of different bus manufacturers and with different H_2FC suppliers, including other fuel cell buses operating in addition to the 26 funded through CHIC;
- Contribute to the approval and certification strategies for Europe on H_2FC buses and hydrogen refuelling infrastructure through sharing the learning from the bus and infrastructure certification processes;
- Develop a project assessment framework to allow a holistic project evaluation by conducting a life cycle based sustainability assessment;
- Facilitate EU objectives and policies by researching and demonstrating the environmental, human health, energy efficiency, social and economic benefits of hydrogen powered H_2FC public transport, and pro-actively communicating these advantages to citizens, communities, decision-makers and decision-formers;
- Identify advantages and improvement potentials of hydrogen powered H_2FC buses versus other recent development in alternative drive train technologies, as well as the complementarities and synergies e.g. electric vehicles and conventional ones e.g. diesel and compressed natural gas (CNG);
- Facilitate Green Urban Transport through the introduction of H_2FC powered public transport buses in multiple cities and communities across Europe by formally linking 'old' and 'new' hydrogen communities and transferring skills and knowledge between them.

These objectives linked strongly with the FCH JU objectives as can be seen in the Figure below.

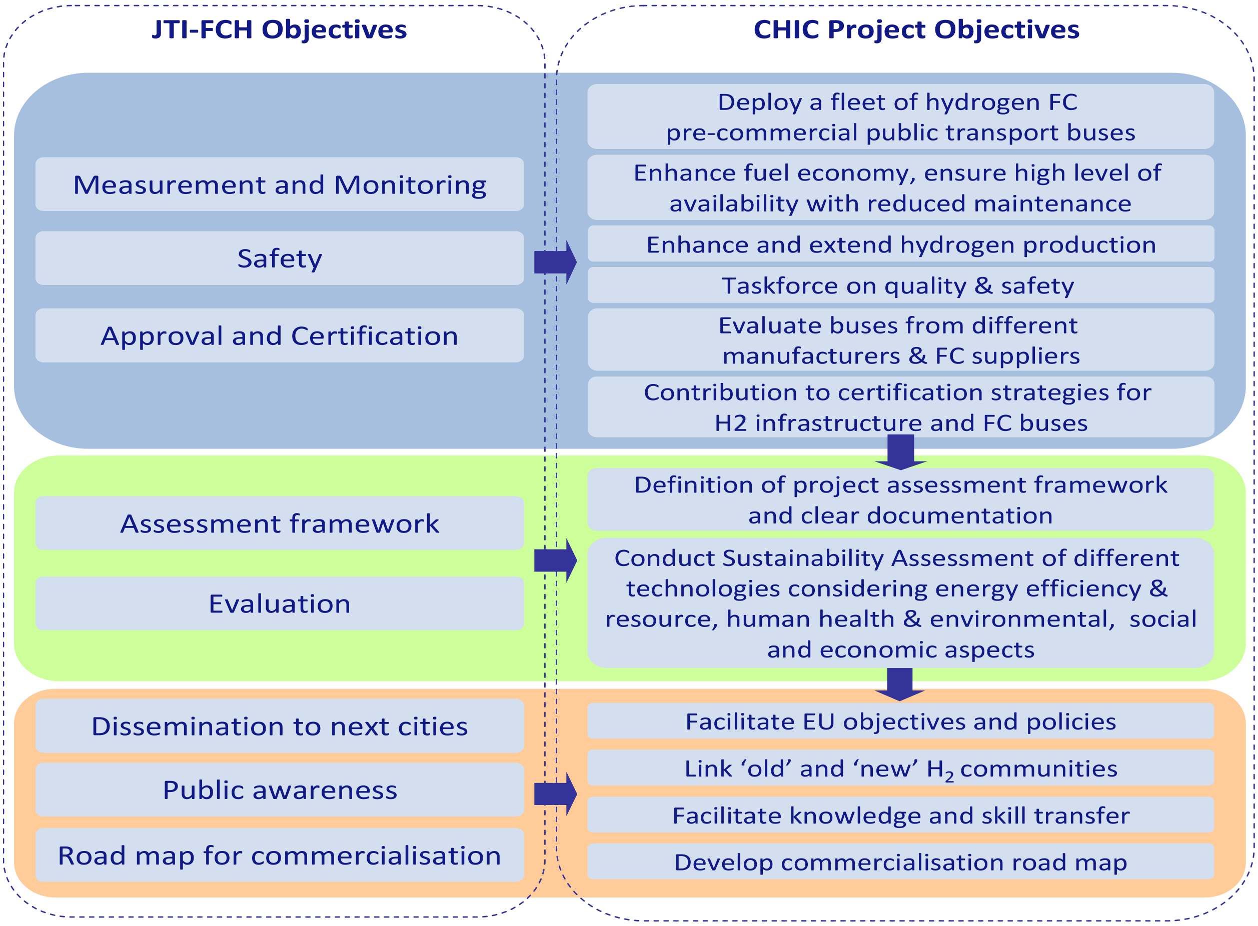


Figure 2.1 JTI-FCH and CHIC Objectives

2.3 CHIC Implementation Concepts

The CHIC project was implemented around concepts of

- Progressing the bus and refuelling technology significantly beyond what had been demonstrated previously;
- Operating the technology in ways that were as close as possible to full, normal public transport bus operation regimes;
- Assessing and evaluating the environmental and social aspects of the technology and the operational systems leading to a better understanding of their long term sustainability;
- Linking to regions that express interest in future involvement in operating fuel cell technology, and transferring as much learning as possible to those regions with the aim of building a market; and
- Identifying possible attitudinal and policy road blocks, and recommending strategies for overcoming them.

The strategy to implement these concepts involved the following key elements.

2.3.1 Diversity of bus acquisition, technology and operation

Buses from five different bus manufacturers using fuel cells from two different suppliers were acquired and operated in the project.

Previous projects had almost universally taken place with buses from only one supplier using a single technology solution. Expanding the technological solutions and engaging with different manufacturers to enter an increasing market is an essential and important step to market development. A market where there are larger numbers of different vehicle options being available from multiple suppliers and being purchased by multiple end users.

The city partners in CHIC were located in a range of different environmental and operating conditions. The Whistler buses operated on hilly, interurban routes in cold, often snowing, conditions. The Oslo, Aargau and Bolzano buses operated in broadly similar temperature conditions but very different operational traffic conditions. The London buses operated in dense, slow, urban traffic in the centre of the city, and with very long daily duty cycles. The climatic conditions for the operation of the Milan buses ranged from hot and humid in the summer, to cold and foggy in winter.

The daily operating regimes in the cities also varied greatly. While buses in Bolzano commonly covered 200 to 250 kms daily in their duty cycle, London, Cologne and Hamburg were in the 150 to 200 kms daily duty cycle. However, Milan buses covered a range of daily distances from less than 50 kms per day up to 200 kms, and Oslo also covered a wide range of distances, commonly up to 400 kms per day and occasionally as great as 500 kms.

Daily hours of duty also varied similarly with the London buses commonly operating between 15 and 20 hours of service in a day.

This broad operational environmental range was important in order to test the degree to which the hydrogen powered transport systems might be suitable for different locations and operational requirements.

Different cities used different purchasing options. These ranged from open tender through to one on one negotiations with their current bus suppliers. These processes and their outcomes are discussed below.

Some buses in partner cities were already operating at the start of CHIC. Whistler in Canada had acquired a fleet of non-hybridised fuel cell buses to supplement their public transport arrangements for the 2010 Winter Olympic Games. Berlin had a fleet of hydrogen powered internal combustion engine buses that had been operating for some time. Data from both these fleets were supplied into the CHIC evaluations.

2.3.2 Operational evaluations

The range of manufacturers, technologies, and operating regimes presented a rich environment for data collection and evaluation of both the technologies, and the macro systems, as well as the socio-economic impacts. CHIC partners included a number of stakeholders with internationally recognised expertise in evaluating the progress and outcomes of the activities.

The fundamental evaluation task was to assess the bus and refuelling technology. A number of key performance indicators and targets were developed around issues such as availability, technology efficiency, contribution to improving environmental outcomes, and public transport impacts.

Broader environmental and social aspects were also examined. While having an effective and efficient technological system was essential, unless it could contribute to these higher level objectives the utility was likely to be limited. This led to actions aimed at understanding the perceived limitations of hydrogen powered fuel cell public transport bus systems. CHIC took the approach of engaging intensively with those who were closest to the technology and with influential individuals and organisations completely outside the hydrogen 'industry' who might not support such a new system. Intensive interactions and consultations led to developing a good understanding of the issues that needed to be addressed.

2.3.3 Broadening the understanding of and support for the technology

Extending the understanding and reach of fuel cell systems into new regions and potential markets is important to prime future commercial markets. To this end, the CHIC project was structured to capture as much learning from its own work, as well as the work of other projects, and extend that to interested stakeholders.

Phase 0 cities were those which had previous experience with the technology and were mostly not implementing new infrastructure. These were Whistler in Canada, Hamburg, Berlin and Cologne in Germany. The key operational cities for new buses were called Phase 1 cities. These were Aargau (Switzerland), Bolzano and Milan (Italy), London (UK), and Oslo (Norway).

CHIC activities therefore included conducting a number of general and specific issue workshops. If new cities and regions were going to become engaged in implementing fuel cell bus systems, it was important that they obtained as much guidance as possible from those who had gained experience before. Understanding what was involved in planning, financing, infrastructure, obtaining permits and essential skills could greatly ease the path.

CHIC partners followed up with a range of publications and guidebooks to supplement this work.

The end result of these considerations was the development of the largest hydrogen powered fuel cell bus project in the world at the time, supported by an extensive inter-locking framework of evaluation and supporting studies. CHIC has addressed its own internal objectives, met its own policy objectives and shown how fuel cell public transport bus systems can be major contributors to a number of important EU policy objectives.

The breadth and depth of expertise involved in the project, combined with the experiences in CHIC and other work have also enabled the development of a number of recommendations for future projects. This will facilitate and accelerate the broad scale introduction of hydrogen powered fuel cell public transport bus systems.

3 Main Science and Technology Results and Foreground

3.1 The CHIC Project: Introduction

The CHIC project has provided important verification of the functionality of hydrogen fuel cell public transport bus systems, and the practicality of their commercialisation in the near term. Meeting the demanding daily operational requirements of public transport operations in a number of diverse cities across Europe and in Canada is a very significant achievement.

The project has successful demonstrated and rigorously tested bus hybrid architecture for the first time in full revenue service resulting in very significant fuel efficiency gains. The results have shown conclusively that the issues of fuel cell lifetime, hydrogen purity and safety are not issues of significant concern for the technology.

CHIC has also successful demonstrated and tested hydrogen production and refuelling systems for fuel cell bus operations. Compared with predecessor projects, CHIC hydrogen filling stations (HRS) had a higher availability and were able to reduce refuelling times.

The data obtained in CHIC have provided the platform and the confidence upon which large scale bus deployments are currently being developed. The CHIC partners have provided advice and support for other hydrogen transport projects that do not as yet have the depth of experience available within CHIC.

The CHIC project has met and, in many instances, significantly exceeded expectations.

The refuelling infrastructure has met five of the six project goals. On the bus side, four out of five project goals have also been met. While the overall project bus availability target was not met in all cities, for the last three years of the project, bus fleets in three cities regularly met and exceeded the target.

CHIC partners have produced numerous reports (Deliverables) some of which are publicly available and some of which are confidential to the FCH JU. Publicly available documents can be accessed at http://chic-project.eu/

3.2 The CHIC Project: Structure

The CHIC project ran from April 2010 to December 2016. It involved up to 25 partners from 8 countries. This included 9 bus operators and 5 bus suppliers. The total investment in the project was €81.8 million, of which €25.88 million was provided by the FCH JU.

A total of 9 hydrogen refuelling stations were operated, with data from 7 stations included in the analysis. Berlin and Whistler were not required to provide HRS data. Some stations were supplied by hydrogen brought to the site from external sources of production, while others generated the hydrogen on-site. All stations were capable of refuelling up to 200 kg /day and being upgraded to a higher capacity.

A total of 54 H_2FC buses and 4 hydrogen internal combustion engine buses were operated.

The project was structured around a number of cities grouped into three different ‘Phases’.

- The major focus of the project was on the Phase 1 cities which were implementing the most recent vehicle and refuelling technology. These cities were Aargau (Switzerland), Bolzano and Milan (Italy), London (UK), and Oslo (Norway). These cities operated 26 H_2FC buses and represented the expansion of hydrogen powered transport in both numbers of regions and size of fleets.

- Phase 0 cities either already had established or were soon to implement hydrogen H_2FC bus projects which were funded from non-JU sources. Most were regions which had considerable learning and expertise in hydrogen powered transport which could be shared with all other partners in CHIC. These were Berlin, Cologne and Hamburg (Germany), and Whistler (Canada) and were the 'leaders and teachers'.

Figure 3.1 H_2FC bus deployments within the CHIC project

- The third group, the Phase 2 regions, were seen as the potential future expansion of hydrogen powered fuel cell bus transport - the 'next generation leaders and teachers'. These were cities that showed substantial political desire to become involved in hydrogen bus deployment.

3.3 The CHIC Project: Hydrogen Infrastructure

As with any public transport system, the fuel supply system for fuel cell powered buses is critical. Operators need to have fuel available at the appropriate quality and quantity when and where they need it. Producing the required hydrogen and being able to refuel it into the buses has to meet this fundamental requirement.

The main objective of the refuelling activities of CHIC was to successfully and safely operate existing refuelling stations and to develop and implement new stations with improved performance.

3.3.1 Planning, acquisition and approvals

Planning for the refuelling infrastructure was undertaken locally by each site, sometimes in collaboration with a potential supplier. While there was considerable expertise and experience available, each site had to take account of its local and national planning laws and regulations, codes and standards and arrive at a satisfactory solution for the local situation.

Technical specification for tendering was a key issue. Finding the middle ground between detailed engineering specification, and more open performance requirements which enabled the supplier to provide solution options continues to be a challenge, as in many construction and infrastructure projects. No definitive solution was found in CHIC. However the discussions between partners have resulted in guidance documents for cities seeking to purchase refuellers. The FCH JU project *NewBusFuel*, which was initiated by the CHIC partners emanating from this background, will provide more comprehensive guidance on this topic.

The HRS acquisition process did cause some delays in project commencement. In some cases new national legal requirements were introduced during lengthy planning processes. In this case, the purchasing processes had to be re-commenced. Other issues resulted from original inadequacy in financial planning and/or commitment of resources.

Gaining the necessary regulatory approvals continued to cause some issues and delays in some cities. Common standards and processes are still not in place across Europe and local variations meant that local solutions were needed. One of the key lessons was that the more closely the regulators were involved in the planning, and the more collaborative learning there was between the project planners and the regulators, the more smoothly the approval path.

3.3.2 Hydrogen production

Producing hydrogen is not new. Hydrogen is used in a range of industrial processes and is produced in large quantities. It is also transported from production to utilisation locations by truck in bulk and in gas bottles, as well as by pipeline. Most final product hydrogen is a gas but there is also some liquid hydrogen produced in a few plants. The liquefaction of the gas requires greater inputs of energy.

Hydrogen for fuel cells has to be of a much higher purity than that for industrial purposes. This means that industrial hydrogen requires purification before it can be used in fuel cell vehicles.

A vehicle refuelling station has a number of elements which are shown in the generalised diagram unterhalb. As can be seen there are two main ways to supply hydrogen to the refuelling station.

- On-site production of hydrogen involves installing a hydrogen generation unit such as an electrolyser. Only on-site electrolysis was deployed in CHIC, but there are commercially available generation units using natural gas or biogas.
- External hydrogen supply involves hydrogen being transported to the refueller, commonly in compressed form on trailers. It can also be in liquid form. Hydrogen could also be brought to the site by pipeline if one happens to be available. However, these are limited. If the delivery pressure is sufficiently high, such as 500 bar, an on-site compressor may not be required as refuelling car occur using the pressure difference between the trailer and the bus. If delivery pressure is in the order of 200 bar then a compressor will be required.

Compression may or may not be required for storage and dispensing. On-site production will almost always require compression for storage. External delivery may not require compression, depending on the pressure and state of the delivered H_2.

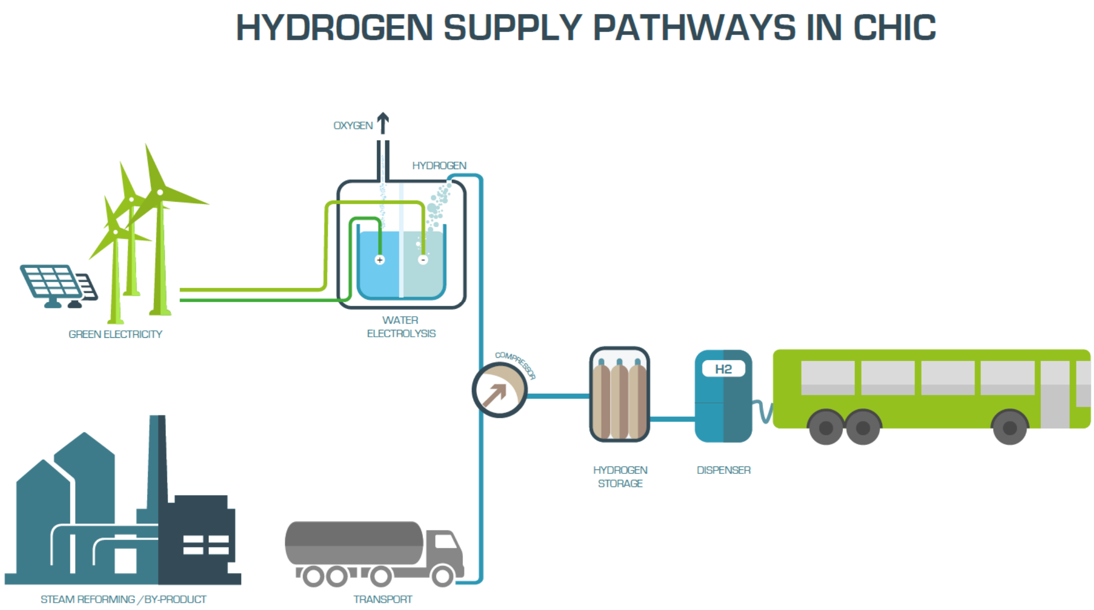


Figure 3.2 Generalised schematic of the hydrogen infrastructure facilities in CHIC

The key characteristics of the CHIC refuelling stations are shown in the table below. It should be noted that the standard pressure for hydrogen storage on buses is 350 bar[2], while for cars it is commonly 700 bar.

Table 3.1 Key characteristics of hydrogen refuelling stations in CHIC

Site	On-site electrolysis: daily capacity [kg H_2]	Regular external H_2 delivery	Daily refuelling capacity [kg H_2]	Number of H_2FC buses	Supplementary information
Phase 1 Sites					
Aargau	130	Yes	300	5	
Bolzano	390	No	350	5	Additional dispenser for cars (700 bar)
London	No	Yes	320	8	Transportation by liquid H_2 tanker to site and high-pressure gaseous H_2 delivery to Station Unit up to autumn 2014; gaseous high-pressure transportation and delivery since 2014.
Milan	215	No	200	3	
Oslo	260	No	250	5	
Phase 0 Sites					
Berlin[3]	No	Yes	200	4 (Fleet size 14 in HyFLEET : CUTE)	Additional dispenser for cars (350 and 700 bar)
Cologne	No	Yes	120	2 (+ 2 extra since May 2014)	
Hamburg	260	Yes	700	4	Additional dispenser for cars (350 and 700 bar)
Whistler[4]	No	Yes	1,000	20	Liquid delivery and storage

Most refuelling stations were located either at, or very close to bus depots or final stops of bus lines. Some stations were open to the public and could be used to refuel H_2FC cars.

As outlined in the policy discussion above, the flexibility of hydrogen based systems can be seen in the range of different options implemented. Every region can produce its own fuel based on its specific circumstances, such as existing infrastructure, raw material inputs and energy sources. The end result can be significant local and regional environmental and economic benefits.

3.3.3 Station performance

The operation of the refuelling systems has been very successful. The FCH JU has published a number of target performance indicators in its Multi Annual Implementation Plan.

[2] Hydrogen pressure is measured in bar. This is a metric unit of pressure, but not part of the International System of Units (SI). One (1) bar is exactly equal to 100000 Pascal.
[3] In Berlin, the Heerstrasse Strasse Station closed in 2013 and an alternative station at Sachsendamm was utilised until the end of 2014. This change led to the decision to cease operations of the H2ICE Buses in December 2014
[4] Whistler: Project concluded in March 2014

The CHIC refuellers have met or exceeded most of these targets, with OPEX (operational expenditure) being the significant exception. The key results are shown below.

Table 3.2 Key performance indicators for hydrogen refuelling stations in CHIC

Key performance indicators		Phase 0 Sites		Phase 1 Sites				
	Project targets for Phase 1 sites	**Cologne**	**Hamburg**	**Aargau**	**Bolzano**	**London**	**Milan**	**Oslo**
Refuelling capacity	200 kg/day	120 kg/day	700 kg/day	300 kg/ day	350 kg/ day	320 kg/ day	200 kg/ day	250 kg/ day
Availability of station based on operation time Overall project period [%]	>98%	>96%	>95% (>98% since July 2013)	>94% (>99% since January 2015)	>99%	>98%	>98%	>95%
OPEX	< 5 / 10 €/kg	All available OPEX figures from the Phase 1 Sites exceed the target, ranging from 12 to 28 €/kg. This is partly due to low capacity factors of the units for on-site generation, and therefore likely to improve with expected higher availabilities of the buses. High power prices and maintenance needs are also contributing factors.						
H_2 purity	SAE J2719	Not all contaminants can currently be measured with the accuracy stipulated in SAE J2719. As a result, it was decided to forego this KPI in consultation with the FCH JU during the project as the development of an analytical technique was not in scope.						
Replacement of Diesel Fuel	>500,000 litres total for whole project	113,100 litres	181,335 litres	497,26 8 litres	239,672 litres	506,476 litres	112,330litres	279,861 litres
Speed of dispensing	No target set	2.1 kg/min	Not measured	2.6 kg/min	2.8 kg/min	Not measured	Not measured	2.8 kg/min

3.3.3.1 Availability

Over the entire life of the project the average availability of the CHIC stations was 97%. Three of the sites surpassed the 98% availability target on a continuous basis. Some stations achieved 99% availability. Aargau had an availability of 94% with compressor problems being the main cause for this low value.

Most stations experienced 'teething' problems in the initial start-up phase. In part this was commonly due to necessary commissioning processes and learning by the operators. In some cases there were issues around slow supplier response times and spare part supplies. Scheduled maintenance requirements account for about one quarter of downtime.

The other major reason for station downtime (53%) was due to issues with hydrogen compressors. This would have been significantly higher if there had been no compressor redundancy.

A compressor failure in the Oslo refueller led to four of the five Oslo buses being contaminated with oil and being out of service for an extended period.

3.3.3.2 Hydrogen production efficiency

Electrolyser efficiency mostly fell within the expected range. All electrolysers demonstrated that they were capable of efficiencies greater than 50%, and some greater than 54%. The rate of utilisation was a major influencing factor with most units being capable of producing more hydrogen than was being utilised by the current fleet. when the utilisation was high. In part this was the result of the much improved fuel efficiency of the current buses.

3.3.3.3 Hydrogen production operating expense (OPEX)

The targets with respect to the specific OPEX along the entire on-site supply chain of hydrogen production and dispensing were not met by any of the sites. The reasons for this include high prices for power and low capacity factors of the facilities.

Investigation of the impact of various cost factors on the overall level of OPEX showed that, in order to meet the initial 10 €/kg OPEX target, the capacity factor of the station would have to be significantly higher than 50%. Also, power prices, including grid charges, energy taxes, sustainable energy surcharge etc., would have to be in the range of 0.10 € per kWh (or even lower at lower capacity factors). Power prices at the time of this study ranged from 0.12 to 0.17 €/kWh.

The study suggested that it may be feasible for future larger and more efficient facilities[5] to achieve the even more challenging 5 €/kg OPEX target. The key prerequisite would be an average price of power below about 0.08 €/kWh. This would likely require exemption from at least some of the above mentioned cost elements such as taxes and charges, including renewable energy surcharges. This issue is discussed further in section 3.5.3.

3.3.3.4 Hydrogen purity

Contamination of hydrogen has rarely occurred in CHIC and not at all from the hydrogen production processes themselves. Water in the form of high humidity, and nitrogen were found in hydrogen once each, and oil in hydrogen twice. The oil contamination caused major downtime of the buses. These incidents were the results of component failure in combination with the absence or the inadequacy of a dedicated device for the detection of the contaminant.

The current standard for hydrogen fuel quality (ISO/DIS 14687-2 "*Hydrogen fuel - Product specification*" that stipulates the same tolerances as SAE J2719 "*Hydrogen Fuel Quality for Fuel Cell Vehicles*" (http://standards.sae.org/j2719_201109/) is considered un-necessarily conservative and increases the fuel price. There are very few laboratories globally that can measure all the listed substances at the stipulated accuracy.

Online monitoring close to the nozzle is also currently not practical and this sampling procedure is no longer favoured by technology providers. The effort in terms of technology and costs would be immense, and suitable solutions that would work outside a laboratory environment are not in sight. Regular offline checks of samples taken from or close to the nozzle appear to be more appropriate.

A more practical fuel standard is needed.

[5] Designed for servicing a fuel cell bus fleet of around 120 vehicles

3.3.4 Remaining challenges and priorities for action for HRS

There remain some technological and system challenges to be met to further improve the performance of the refuelling stations, particularly with respect to station availability and reliability.

- Compressors are the single biggest cause of station failure. A number of different root causes were involved, including oil leaks from membrane failures, compressor head cracks and connection leaks. Most failures were remedied quickly, but some involved considerable delay in either the response of the responsible group, the supply of spare parts, or the impact downstream on the buses.
- Hydrogen metering continues to be problematic with none of the available equipment meeting statutory standards. For hydrogen to be a mainstream transport energy input there needs to be reliable and accurate methods for metering. This is both a statutory requirement of Governments, as well as a commercial issue for both supplier and purchaser.
- Green hydrogen is essential in order to maximise the environmental and sustainability benefits. While it is not seen to be a high priority among bus operators in the short term, a clear path to green hydrogen with timed milestones will be a pre-requisite for support from environmental groups and from other key decision makers in Government.
- A more practical fuel standard would help reduce HRS componentry and therefore costs.
- Permitting can still be laborious and time-consuming. The common experience is that individual local authorities follow their own procedures within an overarching framework. Regulations on designs for large hydrogen fuelling stations, construction and safety need to be harmonised at an EU and international level.
- Reduction in the OPEX of HRS is necessary. One avenue to achieve this is through government policy changes in relation to taxes and charges which are particularly significant for on-site electrolysis.

The best options in terms of hydrogen infrastructure are still evolving. Bus operators want an integrated solution for hydrogen supply that mirrors the capability of the diesel supply route and has a capacity to expand with a growing fleet.

3.4 The CHIC Project: Fuel Cell Bus Operations

The key focus of these activities in CHIC was to rigorously test the operations of fuel cell buses in regular service. It was important to fully evaluate the durability of the H_2FC drive train and the propulsion components. The environments of the five Phase 1 cities meant that this could be done in different climatic, topographic and city specific conditions.

The monitoring and evaluation was carried out so that the results could be measured against the FCH JU targets for fuel cell bus performance.

3.4.1 Bus procurement

A total of fifty-four (54) Fuel Cell buses operated during the life of the project. Of these, twenty six were co-funded by the FCH JU and were part of Phase 1 city operations and therefore the focus of the evaluations. Each of these cities operated 5 H_2FC buses except for Milan which operated three. An additional four (4) ICE hydrogen buses operated in Berlin till the end of 2014.

The fuel cell buses were sourced from five (5) different OEM suppliers, with two different suppliers of fuel cells. Their technical specifications are shown below.

Table 3.3 Technical Specification of Fuel Cell Buses

		Bus Supplier					
Key Technical Data of the Vehicle	**Unit**	**APTS**	**EvoBus Mercedes-Benz**	**New Flyer**	**Van Hool**		**Wrightbus**
Operated in CHIC city	-	Cologne	Hamburg, Aargau, Bolzano, Milan	Whistler	Cologne	Oslo	London
Overall length	m	18.49	11.95	12.5	13.16		11.9
Net Weight	kg	20,590	13,200	15,422	15,700	16,070	10,350-11,350
Max. Passenger Number	No.	95 + 1 wheelchair	76	60	100 + 1 wheelchair	74 + 1 wheelch air	49
Number of Axles	No.	3	2	2	3		2
Drive Power	kW	240	2 x 120 max	2 x 85	2 x 85		2 x 67
Fuel cell manufacturer	-	Ballard	AFCC	Ballard	Ballard		Ballard
Power Fuel Cell System	kW	150	120	150	150	150	75
Energy Storage Type (Type of Battery, Supercap)	-	NiMH+ Supercap	Li-Ion battery	Li-Ion battery	Li-Ion battery		Supercaps No Battery
Max. Battery Power	kW	Max. 200	250	N/A	90 (max. 120)	100	105
Energy Storage Capacity	kWh	Supercaps : 2 Battery: 26	26.9	47	24	17.4	20
Hydrogen Cylinders (@350 bar)	No.	8	7	8	8	7	4
Hydrogen Storage Capacity	kg	40	35	56	40	35	31

Bolzano, London and Oslo used a public tender procurement process for their buses. Aargau and Milan negotiated directly with their current largest bus supplier. The project started in April 2010 and the last procurement contract was signed in October 2012. Changes to national tendering laws and finalising funding arrangements contributed to delays in buses being procured and commencing operations in Bolzano and Milan. Milan operations were further delayed as a result of permitting issues for the refueller. All CHIC buses were on the road from November 2013.

The operation of the Berlin and Whistler buses ended in 2014 as was planned. All other sites continued operation through to the conclusion of the project.

Issues arising and lessons learnt from the bus procurement were similar to those from the refuelling station procurement. Some financial and budgeting arrangements were insufficiently robust to cater for delays in the procurement, or cost increases due to factors such as exchange rate variations. Some of these issues, particularly the clear designation for specific technical and process responsibilities within the project, impacted operations later in the project. Some delays were for reasons quite outside the control of the project parties.

3.4.2 Bus Operations

The drive train architecture on the CHIC Phase 1, H_2FC buses had some important differences from those operated in previous projects. The various technology improvements helped to achieve a significantly improved fuel efficiency and fuel cell system life compared with previous fuel cell bus generations.

Key improvements were:

- Fuel cell system
  - Smaller and cheaper systems
  - Higher power density
  - Extended life
- Electric energy storage (Battery system/Supercapacitor system/Energy recuperation system)
  - A hybridized powertrain with the energy storage system buffering peak loads, boosting acceleration, and allowing energy recovery from braking
- H_2 storage system
  - Fewer tanks while maintaining range as a result of better fuel efficiency

These improvements were reflected in the performance of the buses in diverse locations and under diverse conditions. They demonstrated:

- greatly reduced fuel consumption over previous generations,
- operation for longer daily duty cycles similar to those of diesel powered buses, and
- greatly extended FC stack lifetimes.

A summary of the results of the H_2FC buses in shown in the table unterhalb. They are compared with various targets, including those published by the FCH JU. All goals were exceeded, most by a considerable margin, with the exception of overall availability. Overall availability was 69% compared with the goal of >85%. However, the Berlin ICE fleet, and Bolzano fuel cell buses did exceed this goal. Cologne 13 metre buses and the buses in Aargau, Bolzano, Hamburg, London and Milan surpassed this goal in individual months. Numerous individual buses also exceeded the goal.

Table 3.4 Key Performance Indicator Results for H_2FC Buses in the CHIC Project (total & per site)

Project Goals concerning H_2FC buses (as per DOW)		Overall Project status (Phase 0 & Phase 1)	Phase 0 Cities					Phase 1 Cities					
			Berlin	Cologne	Cologne	Hamburg	Whistler	Overall Phase 1	Aargau	Bolzano	London	Milan	Oslo
			12m	18m	13m	12m	12,5m		12m	12m	12m	12m	13,2m
			ICE-Bus	FC-Bus	FC-Bus	FC-Bus	FC-Bus		FC-Bus	FC-Bus	FC-Bus	FC-Bus	FC-Bus
FC lifetime per bus [h]	> 6.000	**6,820**[6]		2,052	5,331	4,759	9,178	**6,690**	5,063	6,186	12,214	4,721	4,180
No of Stacks beyond Goal		**56**		-	-	5	22	**29**	9	9	9	2	-
Availability [%]	> 85	**69%**	92%	39%	83%	59%	67%	**70%**	81%	89%	67%	66%	47%
Fuel consumption [kg/100 km]	< 13	**12.1**	22.8	16.5	13.7	8.7	14.9	**9.9**	7.9	8.7	9.8	10.4	13.2
Project total running distance [Mio. km]	> 2.75	**9.6**	0.9	0.1	0.1	0.5	4.0	**4.0**	1.3	0.6	1.4	0.2	0.6
Project total hours of operation [thousands h]	> 160	**519**		6.1	10.1	32.0	201.9	**269.4**	60.2	33.5	133.6	17.4	24.7

[6] FC lifetime is the average across the entire fleet. Figures for each city are the average for that city

3.4.2.1 Fuel Cell Lifetime

The CHIC goal was to achieve a lifetime in excess of 6,000 hours. This goal has been achieved with the average FC lifetime being 6,820 hours.

Many individual FC stacks have operated for significantly longer times.

- London has had one set of FC stack that has operated in excess of 23,000 hours, and 8 stacks with more than 10,000 hours,
- Whistler had six sets that operated in excess of 10,000 hours,
- Aargau had one set that operated in excess of 10,000 hours and 3 stacks that operated for more than 8,000 hours, and
- Hamburg had one set of stacks that operated in excess of 7,000 hours.

While the fuel cell stacks have performed well, deeper interpretation of the data is difficult because of the individual approaches by different OEMs to monitoring the performance of their stacks, research and development, and strategies for maintaining their performance. Because of these factors, it is likely that the data being reported effectively under-report the true lifetimes.

For example, London and Ballard entered into a contract to extend the operational lifetime of the London buses to 2020. As a consequence, some fuel cell modules which had relatively low operating hours, and were nowhere near their end of life, were replaced. At the same time it was decided to continue to operate one module as long as possible to test the longest lifetime achievable. That module currently has in excess of 23,000 hours of operation.

Conversely, other OEMs may decide to maintain their fuel cell stacks continually throughout operations in order to optimise lifetime. Despite these confounding factors, the fact remains that the fuel cell stacks have not only met but exceeded all expectations.

It is important to note, however, that here has been considerable variability in the individual stack performance from less than 3,000 hours to more than 23,000 hours. This variability may be a result of manufacturing processes, or possibly the result of different operating regimes. It may also be an artefact of the small sample size being evaluated. Nevertheless, it is a point that needs further evaluation and clarification so that operators can be assured of consistency in lifetimes and maintenance arrangements.

3.4.2.2 Bus availability

Only the Berlin ICE buses and the Bolzano H_2FC buses achieved the CHIC goal of 85% availability over the life of the project, with 92% and 89% availability respectively. The average availability of all CHIC buses was 69%.

However, the goal was approached and passed on numerous occasions by at least three bus fleets. Bolzano and Milan fleets, and the Cologne 13 metre buses have all repeatedly recorded monthly availability in excess of 85% for the last three years. The fleets in Bolzano, Hamburg, London and Milan also surpassed this goal in certain months. The Aargau buses also surpassed the target but the data were calculated on a distance basis rather than the time basis used by other cities.

A number of faults impacted on the bus availability. Some of these outages resulted from failures in fuel cell and hydrogen related components, as well as the conventional bus components. In some cases, there was a lack of spare parts for the fuel cell system which resulted in unusually long re-supply times. In part this can be seen as an expected event in projects with relatively small numbers of vehicles operating relatively novel equipment. In some cases, there was only one supplier of particular components. There was also a very short operational history of the technology so the OEMs had little basis on which to arrange stocks of spare parts.

Conventional bus related component failures were the biggest single cause of no operation. The majority of the H_2FC system related failures were not caused by the FC stacks but by auxiliary and related components. The most common failures included:

- failures of the DC/DC converters,
- software failures
- cooling pump failures, and
- unwarranted and/or incorrect warning lights requiring driver actions.

Bolzano also experienced failures with the anode module and the humidifier, as well as the wheel hub motors.

Following the mid-term review in mid-2014, a number of meetings were held between the OEMs and the operators to overcome the issues of improved after-sales services and spare parts, and action plans were developed to improve bus availability. Actions included:

- increasing stocks of spare parts,
- reducing re-supply times to operators,
- upgrades of software, electronic systems and warning lights and instructions, and
- increased and shorter communication lines.

Some issues, such as with the DC-DC converter, required upgrading of components to a newer version. Other issues signalled the need for shorter inspection periods and/or replacement. The end result was a significant improvement in performance and availability.

Oslo experienced two instances of oil contamination in the buses in 2013 and 2015, both of which originated from the refuelling station. They resulted in significant downtime for the Oslo buses, and incurred considerable cost and effort for cleaning. Some of the downtime resulted from lack of replacement parts and long lead times to acquire them, as well as discussions among various suppliers about responsibilities for actions and costs.

The 2015 event resulted in oil contamination in the entire system from the refuelling nozzle, hydrogen pipe work, to the tanks. Four buses had to be sent back to the Van Hool factory. Three of these buses were out of service for nearly one year. One bus was back in service after just over 6 months.

London had a number of issues with the maintenance arrangements for the hydrogen fuel cell buses that continued to impact on bus performance and availability throughout the project. The original maintenance structure was set up so that the vehicle integrator would perform the driveline maintenance (fuel cell, hybrid and hydrogen), and the chassis maintenance would be carried out by the bus operator.

Following the bankruptcy of the original integrator of the London buses, the maintenance contract was taken over by another company. This arrangement was not successful and the maintenance work was taken over by the bus operator with support from Ballard. However, the absence of the initial prime contractor meant that some issues took a considerable time to resolve. The unavailability of original design documentation for electrical or software systems, combined with knowledge and skill gaps also meant that updates could not be made to the buses to improve on the performance.

Despite these initial difficulties, the buses have mostly operated with high availability and reliability. The various parties have gained considerable additional skills and knowledge which was incorporated into their mainstream bus maintenance staff. This does suggest that the level of training and expertise that is essential to successfully operate a fuel cell bus fleet may not be as large or specialised as previously thought.

As for the FC stack operating hours, there is considerable variability in bus availability both within and between cities. The precise reasons for this are not fully understood. While some variables such as specific failures, operating locations and regimes, may be part of the reason, this level of variability needs to be greatly reduced in future.

3.4.2.3 Fuel Consumption

The CHIC goal was to achieve a fuel consumption of less than 13 kg of H_2 per 100 km travelled. This goal was for the 12 m buses alone, but has been achieved across the whole fleet with the average fuel consumption across the fleet of 12.1kg / 100km. The average fuel consumption of all Phase 1 city buses was 9.9kg / 100 km.

The reduction in fuel consumption in the CHIC project is significant with the 12 m buses in the previous HyFLEET:CUTE project averaging more than 18 kg/100km.

There was some variability in consumption both within and between sites. To some extent this could be explained by the different operating regimes in different cities, such as temperature, geography, distances, speed and also the small sample size being evaluated, as mentioned previously. However, it is unclear if these are the only variables that are impacting results, or if there are factors in the technology that need to be considered.

3.4.2.4 Distance travelled

The CHIC goal was to achieve a total running distance in excess of 2.75 million kms. This goal has been achieved with the total running distance for all buses in the project of 9.6 million kms. The total distance covered by the Phase 1 city buses alone was 4.0 million kms.

This is another major achievement of the CHIC bus technology. In most cities the H_2FC buses were operated in regimes similar to that of conventional diesel buses. The results demonstrate that they were able to meet these operational challenges. The significant overachievement demonstrates that despite not achieving the availability project target, the buses were able to operate reliably for long periods and cover significant distances.

3.4.2.5 Fuel Cell Bus operation

The CHIC goal was to achieve a total hours of fuel cell bus operation in excess of 160,000 hours. This goal has been over achieved with the total hours of operation of 519,000 hours. The operating hours of the Phase 1 city buses alone was 269,400 hours

This is another major achievement of the CHIC buses. The Phase 1 cities alone have surpassed the goal, and the London and Aargau bus fleets together have operated for more than 200,000 hours, and consistently operated long daily duty cycles.

3.4.3 Remaining challenges and priorities for action for H_2FC buses

The CHIC project development, implementation and results have highlighted some challenges which need to be addressed.

3.4.3.1 Fuel Cell system and software simplification for operators and improving reliability

Systems warning drivers and maintenance staff of actual or approaching system failures were not reliably accurate or appropriate, and resulted in unnecessary time out of service. Inappropriate warning lights instructing drivers to stop the bus and shut down systems were relatively common early in the project and required OEM software modifications.

Advisory and warning messages and instructions for action need to be accurate and reliable.

3.4.3.2 Performance variability

Above all else, operators want and need consistent performance from their buses. This reduces uncertainty, unreliability in operations, and therefore costs. This is also essential for H_2FC buses to be seen as a realistic and practical technology for the near future.

While different operating regimes might explain some of the variability in availability, fuel consumption and perhaps fuel cell stack lifetime, the technology itself is most likely to be the major cause. Variability in performance leads to operators being uncertain about technology capability which in turn leads to a “wait and see” approach.

3.4.3.3 Availability

This is the fundamental performance requirement of bus operators and passengers. They all want and need buses to be available for day to day service, and as reliable as diesel buses.

While the various influences and understandable limitations of the current system have been discussed above, it is clear that OEMs have some work to do to ensure that availability improves and stays at a consistent level with little variability. It would seem that the fundamentals of fuel cell vehicle power are reasonably well developed. The achievement of consistent performance might come from increased production numbers, or more suppliers providing options for different solutions. But this issue must surely be the focus in the future. Unless and until the required consistency in availability / reliability is safeguarded for the operators, H_2FC buses may well struggle to break into the bus market in big numbers.

Broader supporting systems, such as spare part and maintenance logistics and pre-introduction testing and performance bench-marking, also present a challenge to OEMs. The technology is still developing and the costs involved in developing the technology and mature support systems that will meet expectations, and indeed requirements, of operators are significant.

Solutions for these issues need to be found in the next generation of H_2FC bus projects.

3.5 The CHIC Project: Evaluation studies

The operations within CHIC were monitored and evaluated closely. These activities covered the hydrogen production and refuelling technology and systems, the buses and the surrounding context - societal, environmental and economic.

3.5.1 Performance Assessment Framework Background

Assessment frameworks developed for previous projects formed the basis for the framework implemented in CHIC. The assessment framework permitted data analysis 'on demand' throughout the project.

An enormous amount of data was successfully collected and processed for the H_2FC buses. The total number of data points collected and processed for H_2FC buses across the board was around 2,100,000. In total 61 monthly reports were compiled from December 2011 up to and including December 2016.

In total, 67 indicators were collected per bus per day. The following indicators were reported monthly:

- Project summary Data (current month/project to date)
  - Total mileage [km]
  - Total hours FC system [h]
  - Total H_2 refuelled [kg]
- Data per site (current month/totals since start of operation)
  - Total distance [km]
  - Total hours on FC System [h]
  - Average consumption [kg H_2/100 km]
  - H_2 refuelled [kg]
  - Number of fillings [-]
  - Bus availability [%]

3.5.2 Environmental Assessment

The objective of this study was to evaluate the impact of the H_2FC buses on the environment over their lifetime, and to show whether they provided an environmental benefit in comparison with other drivetrains. The focus was on global warming which was assessed as the likely major environmental impact of a hydrogen bus system. However, Acidification Potential (AP)[7], Eutrophication Potential (EP)[8] and POCP (Photochemical Ozone Creation Potential)[9]] were also assessed.

A Life Cycle Assessment (LCA) covering the entire life cycle of the buses, including manufacturing, operation, maintenance and end-of-life was performed. Tests were done at three sites to measure the emissions from the H_2FC bus versus emissions from a

[7] Acid gases that are released into the air and the falling "acid rain" which is absorbed by plants, soil and surface waters leading to leaf damage and superacidity of the soil, which has further serious implications for plant life.

[8] Nutrification of land and water (eutrophicaton) is an additional input of plant nutrients into water which can bring about excessive growth of certain (water) plants. This does not only represent a change in the stock of a species, but also in the balance between species with very significant run on effects in the bio-sphere.

[9] POCP (Photochemical Ozone Creation potential) is a measure for estimating airborne substances' potential for forming atmospheric oxidants which can lead to smog pollution.

conventional diesel bus. Different scenarios of H_2 supply routes were assessed, such as H_2 delivered to the HRS and H_2 from local electrolysis with different power sources. The H_2FC buses were then benchmarked against conventional drivetrains and new propulsion systems, viz. diesel, diesel-hybrid, biodiesel, CNG and battery only. Additionally, the effects on the soil and land that is used for the production of biofuels as well as hydrogen were investigated.

The major factor that affects the life cycle environmental impact of the buses is the H_2 production route. When the H_2 is produced through the use of renewable energy, the environmental performance of H_2FC buses is considerably better than diesel buses. The LCA results for the effects on the soil and land show, that for most of the land use indicators, the production of hydrogen has less impact on the land quality when compared to biofuels.

The next biggest impacts come from the manufacturing and maintenance phases, including the origin of the resources and the power generation for these activities. In part this is because there are no local emissions from the operation of H_2FC buses.

This study also concluded that 6,980t CO_2e (as of September 2016) was saved through the operation of H_2FC buses and avoiding the use of diesel buses within CHIC.

3.5.3 Economic assessment

The major costs associated with moving to H_2FC buses apart from the bus purchase costs, are the investment costs for necessary infrastructure such as H_2FC bus workshops and refuelling stations, the maintenance cost of H_2FC buses when compared with diesel buses, and the OPEX of H_2 production.

Data were collected from the project partners to evaluate these costs. As expected, there was considerable variability depending on a range of factors including:

- the source of hydrogen and whether it was to be produced on-site or delivered.
- the existing facilities and whether they were capable of being retrofitted to take account of H_2 in the workshop and necessary structures to maintain the H_2FC buses.

The range of investment costs for H_2FC bus workshops were:

- Retrofitting an existing workshop under ideal conditions (including using some existing components): 30,000 – 60,000 € per bay
- Incremental cost if a new workshop is built or an existing one is completely retrofitted: 75,000 – 230,000 €
- Changes to workshop structure such as extra windows or fire protective doors: 5,000 – 15,000 €
- Rooftop working platform: 5,000 – 150,000 €
- Power outlet for overnight power supply at parking space: 1,000 – 1,500€

The range of investment costs for hydrogen refuelling stations were:

- H_2 delivery, without on-site production: 5,300 to 7,100 € per kg refuelling capacity
- H_2 delivery plus on site production (40 % of rated refuelling capacity): ~8,000 €/(kg/d)
- On site production without H_2 delivery: 13,000 to 19,000 €/(kg/d)

The range of H_2FC bus maintenance costs within CHIC were between 0.40 & 1.73 €/km. The major influence on these differences was the approach taken to maintenance. The cities that trained their own staff had lower costs, while cities with full service contracts had higher costs.

In summary, the costs for implementing a fleet of fuel cell buses depend on a number of variables. Understanding the options and carefully assessing the attendant costs and benefits during the planning stage is very important.

The Operational expenditure (OPEX) evaluation focussed on fuel costs and the comparison between costs of green H_2 and diesel. Projections were based on costs of 1 €/l diesel in 2015 rising to 1.35 €/l in 2025 (price for bus operators excluding VAT). Based on the consumption of the average CHIC diesel reference bus, this results in a range of 47.20 €/100km (2105) rising to 63.72 €/100km in 2025.

Table 3.5 Diesel fuel cost per 100km

Year	Diesel cost [€/l]	Consumption [l/100km]	Fuel Cost [€/100km]
2015	1.00	47.2	47.20
2025	1.35	47.2	63.72

Using the 47.20 €/100km for the reference diesel bus and the average H_2FC bus consumption of 12.0 kg H_2/100km, a H_2 fuel cost of 3.93 €/kg H_2 would be necessary in order for H_2 to be cost competitive with diesel during the operation phase.

Power prices at the CHIC sites are between 12 – 17 ct/kWh. Using a mid-range price of 15 ct/kWh results in power cost of 9.26 €/kg $H_{2,}$ which is substantially more than the ‘competitive’ total price of 3.93 €/kg H_2 calculated above.

Table 3.6 Power cost for 1 kg H_2

Power price [€/kWh]	Electrolyser efficiency	power needed for 1 kg H_2 [kWh/kg]	power cost for 1 kg H_2 [€/kg]
0.15	54%	61.7	9.26
0.08	69%	48.3	3.86

If the consumption of H_2 is assumed to reduce by 2025 to 10 kg H_2/100km for the H_2FC bus while the diesel bus has the same consumption as 2015, and this is combined with the assumed 2025 diesel cost, the H_2 cost would need to be 6.37 €/kg to be competitive.

The operational expenditure (OPEX) was also evaluated, in part to assess the requirements to reach 5 €/kg OPEX. A future filling station with 2,500 kg daily capacity for a depot of about 120 buses was assumed and combined with reduced cost for equipment and a higher electrolyser efficiency of 69%. With these parameters a power price of 8 ct/kWh including all taxes would be necessary to reach 5 €/kg H_2 OPEX. It was considered that a power price of this order might be feasible with appropriate policies in place, such as tax exemptions and/or taxing according to the size and distribution of the health impacts of fossil fuel use.

In summary, current price and cost settings are unlikely to establish a framework within which the cost targets set by the FCH JU can be met. Other policy actions will be required.

3.5.4 Social Acceptance Assessment

The objectives of the societal implications of implementing a hydrogen fuel cell bus system focussed on

- investigating the process of social acceptance of a hydrogen based transport system in the community that worked with, funded and used the buses;
- investigating the opinions of the 'sceptics and critics' who express doubts or concerns about hydrogen powered transport and to provide a platform for dialogue on these issues;
- conducting a Life Cycle Working Environment study.

These studies, achieved through face to face interview and written survey research, were designed to add to the store of knowledge available about how the new technology buses interacted with the community in which they operated. Unique to the CHIC studies were a focus on the formation of the attitudes of those who operated and funded the buses; the views of those who were influential decision makers on 'clean' transport futures outside the hydrogen 'industry' and a life cycle approach to the effect of the new buses on learning times, skill levels and gender equity in employment.

The information from these studies was used as part of the analysis of the social component of the sustainability assessment.

3.5.5 Sustainability Assessment – bringing the three pillars together

The sustainability of operating H_2FC buses in public transport was evaluated based on the demonstration activities of the CHIC project, the buses, bus workshops and hydrogen (H_2) production and refuelling stations.

The definition of sustainability adopted by the UN World Commission on Environment and Development (the 'Brundtland Commission') was used. This defines sustainable development as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[10] This was adapted to: *"If we use H_2FC buses today, can future generations also use them and on a broad-scale, without damaging the environment or their quality of life?"*

3.5.5.1 Environmental factors

Calculating the tank-to-wheel fuel efficiency the average CHIC 12 m H_2FC bus is 26% more fuel efficient than the corresponding 12 m diesel bus

The climate change impact (Global Warming Potential - GWP) in addition to three other impact categories, was evaluated using a full life cycle perspective including manufacturing of the buses, bus operation plus production of fuel and maintenance up to the end of life, including the recycling benefit. Two scenarios were considered:

[10] Sourced from: http://www.un-documents.net/our-common-future.pdf, 1987

- Actual H_2 fuel mix in the CHIC project: 72% green H_2 and 28% H_2 from conventional energy sources (mix of steam methane reformer and by-product H_2)
- 100% green H_2 (electrolysis with renewable energy)

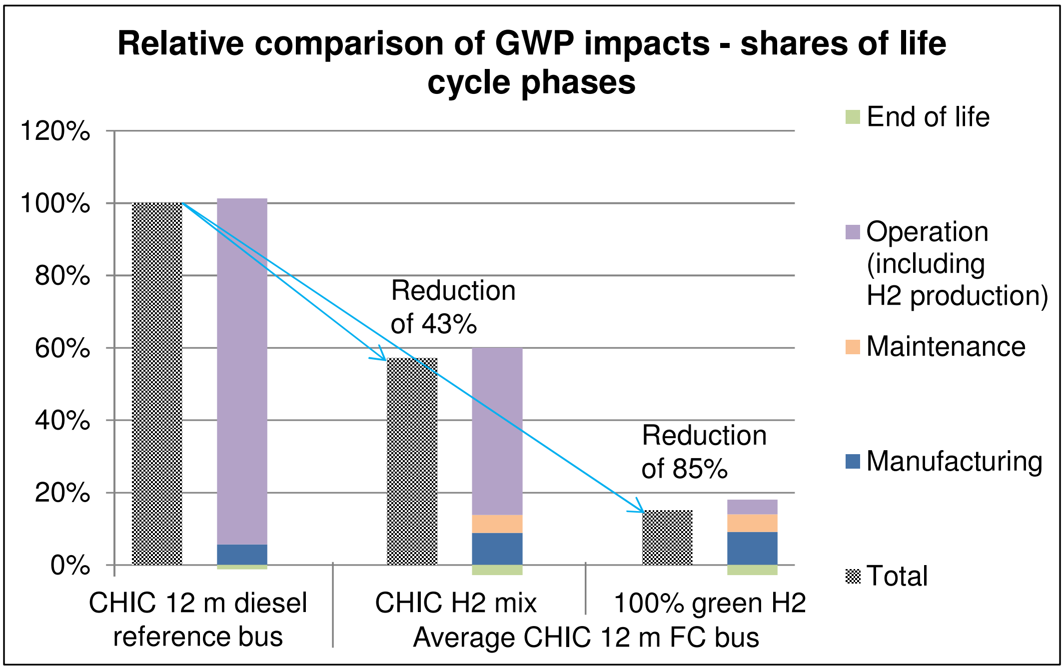


Figure 3.3 Relative Global Warming Potential comparison of 12 m buses

Figure 3.3 shows a reduction of the GWP impact by 43% compared with the diesel bus using the actual CHIC H_2 mix. A possible 85% reduction could have been realized if green H_2 only had been used.

3.5.5.2 Economic factors

The economic aspect of the sustainability of H_2FC buses was assessed over the bus life cycle, including the required infrastructure.

As noted above, the costs for the refuelling and maintenance infrastructure are in large part determined by decisions around the source of hydrogen, the costs of retrofitting or constructing new facilities, and the refuelling capacity and speed. The costs vary widely.

While the economic argument in favour of H_2FC buses compared with conventional diesel buses is not apparent at the moment, cost reductions have been predicted in terms of both purchase price, as well as the Total Cost of Ownership (TCO). For future 12 m H_2FC bus generations, the difference in TCO in 2030 has been projected to be 10% to 23% above that of an equivalent diesel bus[11]. However, these projections did not take into account the findings of various studies showing that the major community health benefits from switching to fuel cell buses and the resultant major reduction in emissions.

[11] Roland Berger GmbH (2015) Fuel Cell Electric Buses – Potential for Sustainable Public Transport in Europe, München, Germany

The direct combustion emissions of a Euro V diesel bus were measured at the exhaust for London specific conditions. These measurements were combined with the costs related to health impacts on London specific conditions, along with general figures for the European Union, to derive indirect health costs of the local combustion emissions of the exhaust of a diesel bus.

When the indirect costs are included, the TCO of the H_2FC bus approaches parity with those of the diesel bus in 2030 in the production-at-scale scenario. Figure 3.4 unterhalb shows the TCO of the production-at-scale scenario with added indirect costs from impact of emissions on health. The bar line given is the range of the indirect cost only.

It is very important to note the current apparent inequity of the distribution of costs and benefits. While the indirect costs that are caused by emissions impacting on health are paid by society as a whole, the costs for avoiding such emissions (i.e. the benefits to society) have to be carried by the bus operators at the moment. Options to deal with this imbalance in costs and benefits by, for example, penalty taxes have to be evaluated in the future.

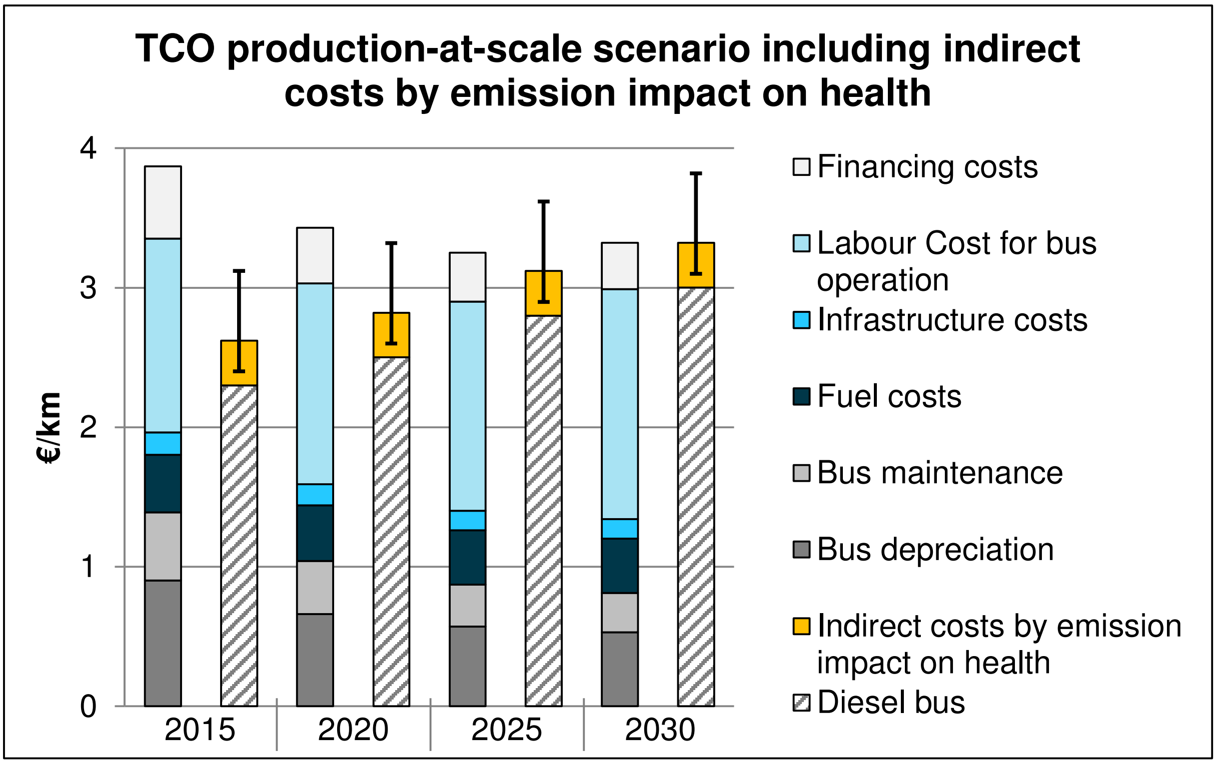


Figure 3.4 TCO of the production-at-scale scenario, but including indirect costs by emission impact on health[12]

3.5.5.3 Social factors: People and hydrogen technology

At the local and regional community level closely associated with the bus demonstrations within CHIC, the buses were seen as an “option” which was either “already a (serious) alternative to other bus technologies and fuels” or “only an alternative, still having to compete with alternative technologies and fuels”. There was clear potential, indeed a need,

[12] Adapted from Roland Berger GmbH, 2015 ibid.

to more systematically and rigorously build on existing levels of good will towards the technology.

One key ‘gap’ that was identified in the research with ‘sceptics’ was the lack of overt support or advocacy from environmental groups and interests. In part this related to the over promising concerning performance and timeframes, and perceptions of under delivering. However, the current lack of ‘green’ hydrogen in fuel cell bus supply chains was also a major factor. While this situation was acceptable in the short term, the need to quickly move to hydrogen supplies produced from fully renewably supply chains was strongly expressed.

Full evaluation of the Life Cycle Working Environment, a technique to include work environment into life cycle assessment, proved problematic. While it is clear that both drivers and maintenance staff require additional knowledge and skills, quantifiable data were not available. Understanding the impact of fuel cell powered transport on the working environment in detail will be important for future training and staff recruitment strategies.

Widespread acceptance of hydrogen powered transport by the general community does not seem to be problematic. The prime issue for most of the public is the quality of public transport services. Provision of reliable bus service that enable people to make their connections and arrive at their work places and appointments on time is the fundamental concern. That these services are delivered in an environmentally sustainable way is an expected and looked for bonus, and is the challenge for advocates of hydrogen powered transport.

Overall, the sustainability analysis shows that the operation of the CHIC fuel cell buses has been more sustainable than using equivalent diesel bus system when evaluated across the full life cycle of the buses. Most importantly there was no “show-stopper” identified that would prevent future generations from using H_2FC buses in public transport, which can be expected to perform even better than the vehicles operated in the CHIC project.

The use of green H_2 will be a prerequisite to maximise the sustainability advantage and ensure a positive public perception.

3.5.6 Technology Readiness of the HRS

The different understandings of the capabilities of the refuelling stations and the H_2FC buses held by some bus operators and the OEMs gave rise to some frustration and conflict between some CHIC partners at the start of the project. These differences were examined using the Technology Readiness Level (TRL) concept.

On average the CHIC stations were judged by the bus operators to be at TRL 7, i.e. “Demonstration in an operational environment”, with some stations above and below this. This reflects the fact that, although there was a good overall level of performance with the quantitative project targets being met or mostly met, some of the operators were not satisfied with their hydrogen stations. A mismatch remained between performance expectations and what the HRS could actually achieve in day-to-day service.

CHIC facilitated several discussions of technology expectations between operators and infrastructure providers, and a set of qualitative performance criteria for adequately characterising hydrogen refuelling stations for fuel cell bus fleets were developed. However no universal set of quantitative expectations was agreed. Local circumstances (i.e. the way a bus depot is organized) can have an important impact on expectations and needs, such as the expected speed of refuelling.

Some of the factors currently preventing a higher TRL from being achieved are:

- Immature supply chain, causing unnecessary downtime due to slow supply of spare parts. Since the number of HRS built and operated is currently small, components suppliers are reluctant to keep “exotic” spare parts for these installations in stock, and their manufacturers will not produce them ahead of being required.
- Dispensing equipment and procedures are not always sufficiently robust to allow unmanned refuelling, and trained people are currently required to undertake the task.
- High availability is currently only achieved through high redundancy.
- Storage of hydrogen requires more volume than storage of diesel.
- Delivery of hydrogen fuel to the station from a remote source requires a higher logistical effort than delivery of diesel.

A well-documented and understandable set of performance criteria for future generations of fuel cell buses is key to ensuring that operators understand exactly what operational capability they are getting and they can plan that into their project and their general fleet operations. The qualitative criteria developed in CHIC provide that basis. Using Technology Readiness Levels (TRLs) will not in itself meet this need. There are various different TRL systems which are not consistent with each other, and within each system there are relatively high levels of subjectivity which can also lead to misunderstandings.

4 Potential Impact, Major Dissemination Activities and Exploitation of Results

The potential impact of hydrogen powered fuel cell buses is immense. They can:

- contribute markedly to improved local and wider regional air quality;
- reduce noise pollution from bus operations;
- reduce public health costs;
- reduce the use of fossil fuels and therefore the impact on global warming ;
- enable customised local transport energy solutions to be developed and implemented;
- contribute to increase economic activity and employment; and
- improve the quality of life of citizens.

All of these are also important European Union policy objectives.

Quality public transport services are an important aspect of a liveable city. They contribute significantly to a sustainable economy and the quality of life of the citizens. And in most cities bus services form the backbone of the public transport system.

Diesel fuel has been the mainstay energy source for public transport buses powered through Internal Combustion Engines (ICEs). At various times and in some cities, some ICE buses have been powered by Natural Gas (consisting mainly of methane), mostly as Compressed Natural Gas (CNG). Electric powered trolley buses have also been utilised.

While these buses have been able to provide the desired operational services, in recent decades there has been increasing concern about the use of fossil fuels as the basic energy input. These concerns have had two major bases.

Debate about the longevity of the world's oil supply has been ongoing since the 1950's. A peak of oil production in the 1970's followed by declining production and increasing prices was predicted. Given the contrasting time frames for oil formation versus extraction, recent developments in oil and gas extraction, as well as national supply strategies, and the relatively low price of oil would suggest that oil availability is not the dominant pressing concern it was a quarter of a century ago.

Environmental impacts, including impacts on human health, dominate current debates about the continued extraction and use of fossil fuel extraction. There is international consensus on the links between fossil fuel burning and climate change, and that continuing to burn fossil fuels at the rate that we are is not sustainable.

Hydrogen Fuel Cells are a technology which have the potential to be 'game changers' in this situation. They produce electric energy with the only emission being heat and water vapour making them essentially emission free during operation. This provides the additional benefit of improving air quality in cities where the emissions from diesel buses in particular add significantly to local air pollution. The basic fuel, hydrogen, can be obtained in a wide variety of ways using locally available energy sources. This has the potential to free local communities from availability and price constraints that might be imposed by external suppliers.

Additionally, management of the intellectual property surrounding the hydrogen production, refuelling, fuel cell development and construction, and system operation has the potential to provide significant economic benefits.

The end result is the possibility of establishing a public transport bus system that is based around a fuel that is locally obtained and controlled, while operating emission free at the local level. Hydrogen fuel cell bus operating systems provide the possibility of a truly sustainable public transport bus system.

The CHIC Project is a clear outcome of the policies of the European Union, and the natural progression of the development of the fuel cell technology and the supporting systems.

4.1 Dissemination activities

The CHIC project built on the dissemination activities in earlier projects and to actively utilise what was learnt in them. The activities were focussed on building awareness and interest in the obvious potential of hydrogen fuel cell buses among a more targeted audience, in line with the progress of the technology from research phase to commercialisation stage.

Midway through the project it was decided to review the dissemination strategy and initiate new activities as well as developing new publications and related materials. The figure below summarises the revised strategy, and the focus allocated to the different target groups.

Table 4.1 Target groups for dissemination under revised strategy.

	Target Audience	Tools developed under the first dissemination strategy	Tools developed/revised in the revised dissemination strategy
a	Dissemination between the project partners	Intranet	Partial restructure of the intranet site Development of an internal monthly newsletter Use of the twitter account to convey partner information or information from linked entities (e.g. @H2 South Tyrol)
b	General Dissemination LOW PRIORITY	Website Facebook account: CHIC page Twitter	Make available a comprehensive website, public dissemination presentations, videos etc. which can provide the interested public with information about the project, the technology, its core benefits and the way forward.
c	Dissemination to local stakeholders PRIORITY	Well informed and engaged local stakeholders are paramount for the success of any existing project and its continuation	Led by local operators: Disseminate targeted information about the project and its technology (status, future, benefits, opportunities); become ambassadors of the technology, support the creation of local networks of interested parties, report about project progress, manage the acceptance level Consortium support on ad-hoc basis
d	Dissemination	The bus and	Disseminate targeted information about the

	to industry players PRIORITY	hydrogen sectors benefit from being informed about the technology status, the progress made on the project and the key lessons learned	project and its technology (status, future, benefits, opportunities) Industry players need to be made aware of the technical and commercial readiness of the sector, along with the challenges faced
e	Dissemination to EU policy stakeholders	EU policy stakeholders influence the decision-making process for the whole bus sector	Disseminate targeted information about the project and its technology (status, future, benefits, vision) to help justify support (and funding) for the next phase of hydrogen bus commercialisation; lobbying for regulatory changes to facilitate the roll-out of FCB (e.g. common safety standards)
f	'Phase 2' candidate cities (Proactive transport agencies and bus operators) MAIN PRIORITY	Transit agencies, bus operators etc. who are planning to test low-emission bus solutions in their own fleets or considering this option. These could be the next generation of H_2FC bus adopters	Disseminate targeted information about the project and its technology (status, future, benefits, opportunities) Discuss technical and commercial readiness of the sector, in order to inform their decision making process on clean bus along with the challenges faced Discuss financing option and grant opportunities Facilitate the networking with the existing technology providers and industry players (also within CHIC) in order to plan / scope the next generation of projects Share findings of the acceptance process

A number of tools were developed to support this strategy. They are summarised below.

Table 4.2 Dissemination tools developed during the project

Target Audience	Tools developed under the 1st dissemination strategy	Tools developed/revised in the revised dissemination strategy
All	Visual identity: • Logos (2 styles/2 colours) • Word and PPP templates • Roll-up • A4 CHIC folders • Bus pass/ticket holder • Leaflet • Summary of the project, "Boiler plate" • Newsletter	• Agreement on visual identity to use one logo only, and one colour • New templates developed • New leaflet developed with focus on results • Summary of the project developed with focus on results • It was decided to send an internal newsletter instead of the external newsletter and to publicise updates on the project via other channels than the newsletter • Emerging conclusions document developed: updated every 6 months (or

		more frequently when presentations given)
Internal (between the project partners)	• Intranet • Mission statement	• Partial restructure of the intranet • Development of an internal monthly newsletter • Use of twitter to convey partner/regions information (e.g. @H2 South Tyrol)

General Dissemination	• CHIC website
	• CHIC Facebook page
	• CHIC Twitter account
		• Reshuffle of the website both format and content:
		  o less technical information,
		  o focus on the fuel cell bus sector (versus "all information on hydrogen"),
		  o more reader friendly
		  o publication of public results of the project
		  o creation of a video gallery, picture gallery, a Q&A section, one page describing each local project
		• Development of a general presentation

Local stakeholders	Local dissemination materials: leaflets, roll-up, postcards etc	• Led by local operators – no material developed at WPL level • Development of a Q&A to answer potential critics • Summary of CHIC Emerging Conclusions in English, German and French • Verification of publication of general CHIC information on city partner's and public transport authorities' websites
Industry players	None	• CHIC emerging conclusions (short + detailed version) • Use of LinkedIn / Twitter • Publications
EU policy stakeholders	CHIC newsletter distributed	• Publications in EU magazines • Briefing developed for Hydrogen Europe • Press releases • Use of LinkedIn / Twitter
'Phase 2' cities	Guidelines for delivering a fuel cell bus project (D.4.8a and b)	• CHIC emerging conclusions (short version + detailed version) • Guidelines for delivering a fuel cell bus project (D.4.8c) • Use of information from D3.7 • Use of LinkedIn/Twitter

4.1.1 Whole of Project Activity

The CHIC project has been present via a presentation and/or stand in over 40 national and international conferences/events. Attention was given to the publication of CHIC results and a press release was published.

A central element of the revised dissemination strategy was an *Emerging Conclusions* document, developed in 2013, to convey the results of the project. The document, in whole or part as required, was used by all project partners in the general presentation of the project (to be “cut” and used as necessary). The document was routinely updated at each biannual meeting.

CHIC dissemination used a variety of outreach tools. These included the CHIC website, Facebook and Twitter. The website was substantially upgraded in the second half of the project and an increase in the number of ‘hits’ as well as downloads of information was observed. Similar increases in Facebook and Twitter activity was observed. The twitter account increased its followers by 314% in the two-year period from December 2014 to December 2016.

In line with the dissemination strategy, CHIC dissemination team also engaged with relevant industry parties. Updates on the CHIC project were regularly shared with the hydrogen community at national and international events such as the Hannover Fair (2014, 2015), the World Hydrogen Economy Forum (2013, 2016), the European Hydrogen Economy Forum (2014), F-Cell (2012, 2013, 2014) and a range of German Hydrogen Fora.

On the public transport side, bilateral discussions with bus OEMs took place as part of the H_2FC bus dissemination coalition and the cluster activities. CHIC was also featured in specialised public transport

There was also a focus on connecting with Brussels based associations of local and regional authorities active in mobility; urban mobility civil servants within the European Commission and public transport stakeholders. CHIC participated in Busworld (2011, 2013, 2015) and contributed to the Busworld Academy knowledge platform for the bus & coach sector. CHIC also engaged with the International Road Union (IRU) and the UITP. The activities were done in collaboration with sister projects.

4.1.1.1 Final Brochure

A CHIC final public brochure “*Clean Hydrogen in European Cities 2010 – 2016: Fuel Cell Electric Buses: a proven zero emission solution - key facts, result and recommendations.*” was published in November 2016. The brochure was developed with contributions from a range of CHIC partners. The main target groups of the CHIC final brochure were identified as transport operators and local authorities who were not already familiar with fuel cell bus technologies, e.g. potential Phase 2 cities. The 52 page brochure was unveiled at the Zero Emission Bus (ZEB) Conference on 30th November 2016. A press release was issued which received good press coverage on social media/online.

Each of the 250 participants in the ZEB conference received a brochure as part of the Conference bag. A total number of 4,900 brochures were printed, and distributed to stakeholders in addition to the project partners, including to the dissemination partners of the other fuel cell bus projects.

4.1.1.2 Zero Emission Bus Conference & the International Fuel Cell Bus Workshop

A key dissemination event in the CHIC project was the combined Zero Emission Bus (ZEB) Conference and International Fuel Cell Bus Workshop (IFCBW). The concept was to highlight CHIC as the flagship hydrogen vehicle demonstration project of the FCH JU, and to give wide reach to the key findings. This enabled the organisers to demonstrate that CHIC was not “just another project” but rather the first real deployment project paving the way for large scale commercialisation of fuel cell buses.

The International ZEB Conference took place on 30th November 2016 in City Hall, London, followed by the 10th edition of the IFCBW on 1st December 2016. Over 250 high level stakeholders from 22 countries, including China, US, Europe, and South Korea attended the event, allowing for a truly global discussion and exchange of knowledge. Representatives from local authorities, transit operators, industry, and national and financial regulatory and funding agencies held discussions around ZEB technologies’ readiness levels and commercialisation paths. The conference very publically showcased H_2FC bus technology displaying its readiness to be deployed across the world.

The organisers teamed up with the IFCBW event to create a genuinely international event, linking up existing technologies in the sector for the first time in a joint event. It made sense to present the European fuel cell bus development efforts of CHIC as part of this coherent whole, showcasing global advances in H_2FC bus technologies. The Mayor of London, Sadiq Khan, was the keynote speaker. He used the ZEB event was used as a springboard to launch London’s zero emission initiatives in earnest.

CHIC also partnered in an IFCBW in Hamburg in 2013.

4.1.2 Local Site Activity

At each site, the local project was launched with a dedicated ceremony. Hundreds of local events took place (use of buses as a shuttle at special events, visits of school and post-school students and children, high level policy makers etc.). Six cities reported between 50 - 80 special events, regular press coverage and publications, and press releases published when milestones were reached.

Along with the launch events that took place in each Phase 1 city, the city partners managed to leverage interest in the hydrogen and fuel cell bus technology through the organisation of a large number of awareness raising and educational activities. A wide range of dissemination materials were developed in the local languages e.g. dedicated leaflets, promotional videos. All activities were led by the cities

Cologne, Hamburg and London are large cities that have been demonstrating the technology for some time and can be considered “global ambassadors” of fuel cell buses, receiving visits from around the world.

Whistler and Berlin continued to run their buses acquired as part of predecessor projects but had substantially completed their dissemination work during that project. They continued to provide data and share experience with the other CHIC partners up until their programmes ceased in 2014.

4.1.3 Building a 'Phase 2' Coalition

Dozens of cities and bus operators have been made aware of the CHIC results and the option to deploy fuel cell buses. In the first place this was achieved through the coalition built by the FCH JU, in their study on the commercialisation of fuel cell buses, and a workshop organised by CHIC as part of the study. The follow up activity for the "joint procurement of fuel cell buses" was the continuation of this work.

CHIC experiences were shared with cities and operators via regional workshops and bilateral discussion. Activities included looking at the local business case, liaising with local authorities, operators, national civil servants, funding agencies, bus manufacturers and infrastructure providers. In UK this activity led to the identification of a cluster of cities ready to apply for further EU funding. This work has, in turn, led to a follow-on Pan-European project commencing in late 2016 – "Joint Initiative for Hydrogen Vehicles across Europe' (JIVE) for 144 fuel cell buses to be operated throughout Europe.

4.1.4 Building a H_2FC Bus Dissemination Coalition

CHIC enabled the fuel cell bus sector to speak with one voice by setting up a dissemination working group for the fuel cell bus sector. This included representatives from other fuel cell bus projects, Hydrogen Europe and the FCH JU. Better coordination in this area has led to increased efficiency and visibility for the sector.

4.2 Beneficiaries

The major beneficiaries from the widespread implementation of H_2FC public transport bus systems into the community will be the community itself. The future benefits will come in the form of a sustainable transport system operating with zero local emissions, powered by an energy source that can be locally obtained and utilised with greatly reduced, and potentially minimal, impact on local and global climates, as well as on human and environmental health.

The potential of H_2FC public transport bus systems to significantly reduced emission impacts and environmental benefits, including on human health, are indisputable.

Concurrently, communities will benefit economically. Developing, commercialising and marketing hydrogen production and refuelling technology, alongside H_2FC vehicle technology have the potential to be major sources of future economic activity. The intellectual property associated with these systems can be utilised for both stationary and mobile energy production with resultant economic growth, revitalised industries and enterprises, and a range of sustainable employment opportunities throughout the community.

These widespread benefits have been recognised in a succession of European Commission planning documents most recently in "*A European Strategy for Low-Emission Mobility"* (July 2016), and through a number of pre-cursor bus projects such as CUTE and HyFLEET:CUTE, the European Union has established global leadership in the technology. The benefits are now beginning to be realised by innovative companies across Europe.

The CHIC project has been a major and important step along with path to bringing these benefits to fruition and speeding up their realisation.

4.3 The Way Forward: Recommended Priorities for Action

The CHIC partners and their activities highlighted some key areas where there could be a focus of work by the FCH JU, governments at all levels, and industry. These have prompted the development of some recommendations for future actions, some of which have already been observed in upcoming FCH JU plans and calls for proposals. Also developments such as the formation of the Hydrogen Council was foreshadowed.

4.3.1 Optimising Benefits and Opportunities for European Communities

There is little doubt that this technology will be a commercial prospect in the foreseeable future. It is a technology being pursued by very significant private and public entities in the USA, Canada, Japan, Korea and China. All see the prospects the technology provides for meeting environmental imperatives, achieving energy security and securing commercial gain. Europe has been at the forefront of this innovative and paradigm shifting transport energy change, and the H_2FC buses have been the vehicle through which it has and is being achieved. It is important to maintain the initiative and leadership to optimise environmental and economic gains.

All industry partners involved in CHIC have developed better technology and experience with H_2FC buses and the Hydrogen Refuelling Infrastructure as a result of the CHIC project. They see opportunities for and are committed to commercialisation, selling this clean technology to public transport providers worldwide. But there are important support frameworks that need to be developed and implemented to ensure that European industry can maintain this leadership, and the community can obtain the benefits.

<u>Act to harmonise regulation</u>
Establishing a harmonised and consistent European wide system for regulating the establishment and operation of hydrogen infrastructure would facilitate development and could be progressed as a containable and achievable outcome in the short term. The current diversity of regulation both within and between member states, and the diversity in their application by local and regional authorities, is often difficult to navigate, as well as frequently lengthening project time lines and increasing costs. The challenge is to arrive at a system that is harmonised across Europe, and potentially globally, while still allowing for essential flexibility to account for local conditions.

<u>More to do on the policy front</u>
While H_2FC bus technology and the supporting infrastructure continue to improve and are now almost capable of providing services at a similar level to conventional buses, there is still no certainty about future Government policies and their possible impacts on the buses. Governments at all levels continue to embrace policies to address climate change which would benefit from the widespread introduction of H_2 fuel cell powered transport, but there is no long term clarity on what policies will be introduced to facilitate such an initiative.

Industry has already invested heavily, albeit with financial and programme support and encouragement from Governments, to develop the vehicle and refuelling technology to its current level. The next steps to full commercialisation will require a step change increase in investment. While there is no long term certainty about future Government policies regarding support for low emission technologies, including taxation and excise arrangements, there is likely to be some industry reluctance to make major, long term investments.

Financial support in the form of incentives and tax concessions, which take full account of the community wide benefits of implementing fleets of clean public transport buses, would benefit the market introduction. This is particularly important at this early stage of broad scale introduction of the technology. Operators and their passengers want and need a high degree of certainly in the availability and operation of the buses and their surrounding infrastructure. However, this requires mature support structures and systems which come at a cost. With large fleets this can be amortised over all the capital investment. With small fleets it is difficult and, probably unrealistic, for individual operators or equipment suppliers to meet this cost. Some financial support would significantly facilitate the path forward. If these were to be considered they should include a definite time horizon for their continuation so that industry can plan ahead with certainty. The taxation arrangements which Germany established to support the use of CNG in transport may provide a model for industry assurance. The statutory certainty about government taxes and charges generated industry confidence to move forward with investments.

The industry support arrangements surrounding FCH JU transport projects are less than optimal. The small sample size for buses and HRS means there were no substantial data to guide spare part stocks. The high cost of specialised components, possibly to be superseded in future models, means that OEMs were hesitant to order large back-up stocks on the chance that they might be needed. This context in CHIC led to delays in repairs and replacement which was not the expectation of operators who had presumed that the maintenance capabilities would be similar to conventional bus systems.

This ‘chicken and egg’ circle needs to be broken, and will likely need inputs from a number of actors. While it is reasonable to expect suppliers to provide quality support for their products, it is unreasonable to expect them to be immediately at the highest level while there is no certainty about the future Government policies which may or may not support their products.

Recommendation
The FCH JU should initiate the development of Draft Policy Proposals for discussion with Governments. The suite of Draft Proposals should form an overarching structure which facilitates the implementation of near zero emission transport, including the fuel supply chain. The Proposals should include taxation and excise proposals.

4.3.2 ‘Green’ Hydrogen

While the technology of the HRS continues to improve, the proportion of hydrogen that is produced through renewable energy inputs and therefore with minimal emissions, remains relatively low.

Perhaps the main argument for hydrogen and fuel cell technology is the capability for it to be very low in emissions. While this is currently the case at the bus tail pipe, few sites have similarly low emission H_2 production supply chains. Producing H_2 from fossil fuel sources or with major inputs from fossil fuels significantly increases emissions and environmental impact compared with renewably produced hydrogen, and greatly reduces the supporting argument for implementing H_2FC buses.

The limited amount of 'green' hydrogen in the H_2FC bus supply chain may, perhaps in large part, play a role in the absence of environmental lobby groups supporting or vocally advocating fuel cell public transport. Low emission transport is a major plank of their advocacy, but they are unsure of when or how H_2FC transport will support their objectives. Strong and concrete statements from H_2 stakeholders about time frames and milestones for increasing the proportion of 'green' hydrogen would be helpful. These could include commitments to change once certain technical performance levels are achieved.

Very high proportions of 'green' hydrogen in the supply chains of future H_2FC bus projects should be a priority, and perhaps an absolute requirement for funding support.

Recommendation
The FCH JU should consider requiring all H_2FC vehicle projects to have a fixed minimal proportion of the H_2 supply produced from renewable non-fossil fuel energy sources in the coming years. This requirement should be flagged in their Multi-Annual Plan with increasing minimum percentages of 'green' hydrogen stated.

4.3.3 A Focus on Infrastructure

Vehicles need refuelling infrastructure and refuelling infrastructure need vehicles.

Vehicle OEMs have been proactive in developing various consortia and synergistic arrangements to support and progress the vehicle technology. Similar consortia for infrastructure have been slow to develop. There is some suggestion that this lack of infrastructure consortia with a focus on energising the development of their technology throughout their membership, attracting funds and promoting their overall interests, may be slowing the development and installation of refuelling technology and supply chains.

Traditionally vehicle OEMs have not had to concern themselves with refuelling infrastructure as major global fossil fuel companies have been only too eager to establish and promote their refuelling systems. There are very few analogous companies with the financial backing and system wide interests and reach in the H_2 refuelling world.

There are many options for arrangements where Government support and facilitation could be pivotal in supporting the infrastructure providers. Breaking the 'chicken and egg' cycle here would be a significant boost to progressing H_2FC initiatives.

There is also a need to establish a consistent regulatory framework around H_2 refuelling infrastructure. The same infrastructure installed in different cities may require different kinds of permits from different arms of Government, and meet different standards. The costs in work required to provide the information, as well as the time delays with capital equipment lying idle and possibly incurring maintenance costs, can be significant.

As with fuel cell buses, there is a need for consistent, harmonised regulatory standards for hydrogen refuelling infrastructure and systems across Europe, while still enabling essential local variation.

At the technical level, there is still room for performance improvements. The footprint of stations needs to be reduced, and the energy efficiency of production improved. The metering of hydrogen supplied continues to be problematic which will be a major concern to Governments considering various excise arrangements.

Practical methods of sampling and testing H2 purity to levels that can be achieved by more than an extremely limited number of laboratories are also technical challenges that need to be addressed and resolved

Recommendation
The FCH JU should facilitate the establishment of a H_2 Refuelling Infrastructure Alliance that would promote the development and implementation of H_2 refuelling technology and infrastructure. Membership would include technology suppliers and the Alliance would form a counterpoint to and be supportive of the vehicle OEM groups which are collaborating to accelerate the development and commercialisation of H_2FC vehicles. The German Clean Energy Partnership (CEP) and H2 Mobility project may provide useful models.

Recommendation
The FCH JU should increase its efforts to establish a single set of harmonised regulatory processes, standards and permits required for the establishment of H_2 refuelling stations.

Recommendation
Future FCH JU H_2 refuelling infrastructure funding should focus on improving the development of infrastructure solutions that have a larger capacity, reduced footprint, increased efficiency of production and greater reliability.

4.3.4 Bus Performance

The fundamental performance of the buses was sound. However, as with the infrastructure, there is room for improvement.

The availability of the CHIC buses was predicted to be less than that achieved in the previous HyFLEET:CUTE project due to more of the maintenance and technical support being provided directly by the operators. Nevertheless, the reduction in availability and the variability in aspects of bus performance were greater than anticipated, and certainly greater than is required for efficient and effective public transport operations that can meet the expectations of operators and passengers.

While the small fleets, and therefore small sample sizes may certainly provide one reason for the variability, there are very likely to be reasons that extend beyond this. Upcoming projects with larger bus fleets will provide increased sample size and therefore potentially less variability, but there is no certainty that this will produce the required improvement.

The reasons for buses being out of service were many and varied. Some of them, such as oil contamination of the hydrogen fuel and suppliers becoming insolvent, were not at all related to the vehicle technology or could be anticipated by improved planning. But there remain technological failures, such as with valves and batteries that can and must be overcome. Having buses available and fully operational as and when they are needed is the fundamental basis of a quality public transport service. Unless and until the levels of availability reach those of diesel buses, H_2FC buses will struggle to gain acceptance from bus operators, passengers, or public officials responsible for funding.

Recommendation
Future FCH JU funding for H_2FC buses should focus on requiring improved reliability and, importantly, reduced variability in performance.

4.3.5 Costs and Benefits

Current bus and refuelling technology is expensive. The current stage of development and size of projects and vehicle fleets is a significant reason for this as outlined above.

Various studies have produced detailed reports and projections showing how costs will come down in the future as the technology continues to mature, and production numbers increase. Never the less, there remains some scepticism from some stakeholders external to the hydrogen and fuel cell industry, about studies funded by H_2 and FC industry stakeholders.

While total costs of ownership need to be a major focus for bus and refuelling OEMs, the benefits of this ‘clean’ technology should also be more systematically costed to clearly put the broader economic argument on the table. The benefits to the community (better health, new jobs etc) and industry (new commercial products) can have a Euro figure put to them, and it needs to be done.

However these studies need to be, and more importantly be seen to be, totally independent of hydrogen interests. Arrangements incorporating independent steering committees, data management, or editorial committees with high profile independent Chairs would be sure to increase acceptance, as well as penetration of the findings. The US arrangements where independent bodies such as the National Renewable Energy Laboratories (NREL), or Government agencies such as the Federal Transit Administration (FTA) lead these studies, provides a useful model.

Recommendation
The FCH JU should initiate cost and financial modelling studies that are managed and overseen by parties that are independent from hydrogen and fuel cell interests.

Recommendation
Establish a credible, costed ‘benefit’ argument for hydrogen powered public transport to put the price of the new technology system into a more accurate perspective.

4.3.6 Future Projects

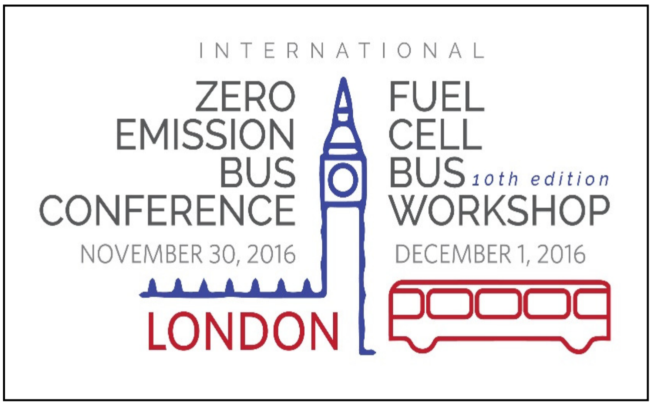
Commercial operations of fuel cell buses in public transport will not be with fleets of 5 buses. Nor is it likely to be with fleets of 20 buses. It is more likely to be with fleets of up to 100 buses operating from a single depot. Refuelling may require H_2 supplies in the order of 4 tonnes daily. Projects of this size will put the total system to a full scale, credible pseudo-commercial test. Passing this test will provide the fundamental basis for widespread acceptance by bus operators and their funders.

Studies such as NewBusFuel are providing important theoretical and conceptual data for large refuelling stations incorporating different production and refuelling strategies. JIVE will provide important testing of larger bus fleets. However it will only be the demonstration at operational bus depot scale that will provide the necessary kick start up to the next level of commercialisation.

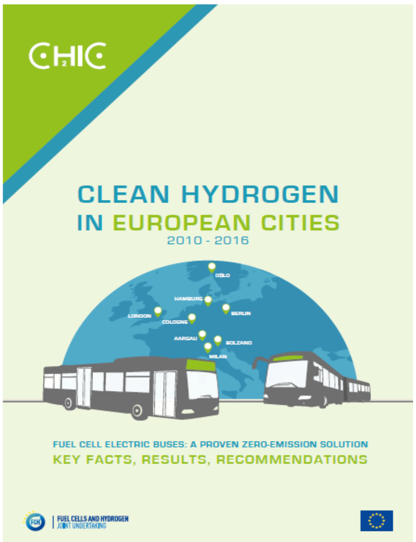
The complete Final CHIC Report contains many more detailed actions at the end of each Chapter for particular aspects of its activities. These must be the starting points for new projects. Ensuring that experience is built on requires direct, focussed and disciplined action.

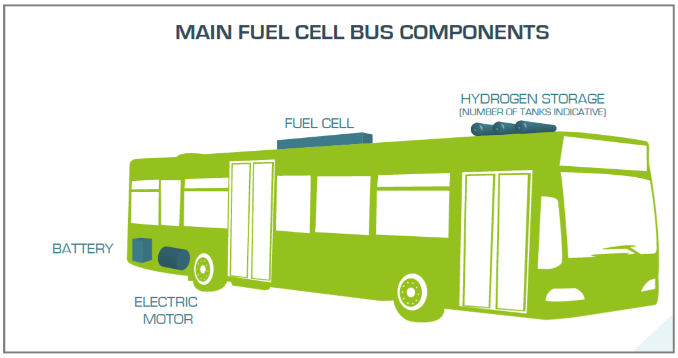
Recommendation
The FCH JU should consider establishing a whole depot H_2FC bus project with a fleet of approximately 100 buses.

4.4 Project Photo Gallery



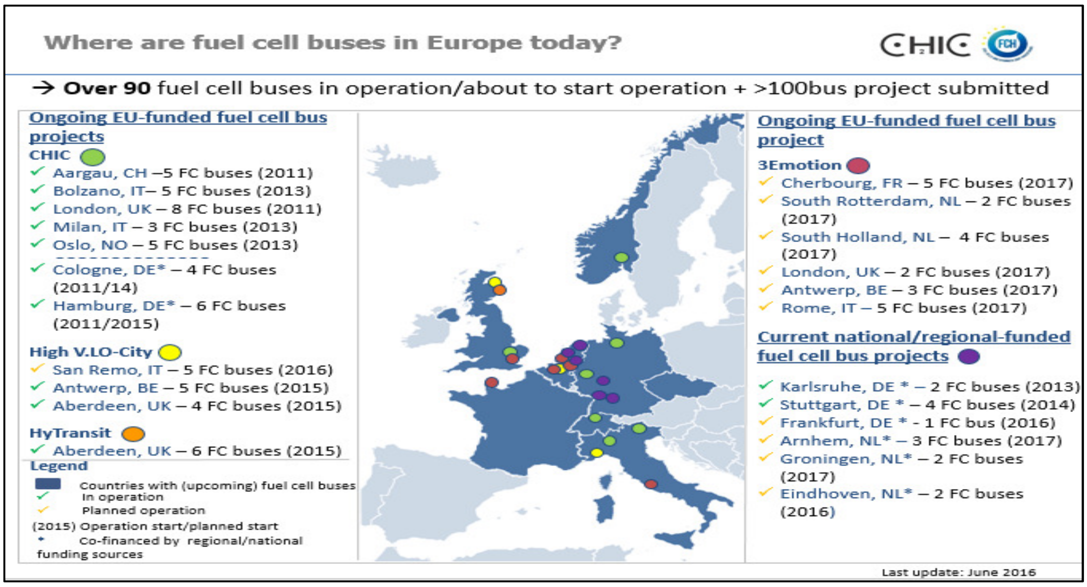
Above: The logo for the ZEB/IFCBW event (Final CHIC Conference) and City of London, Mayor Sadiq Kahn opens the Conference





Above and Left: CHIC Project Final Brochure

Below: H2FC Bus Deployment at end of CHIC Project



5 Public Project Website and Contact Details

The CHIC website can be found at http://chic-project.eu/

People interested in learning more about the project can contact the project at http://chic-project.eu/?action=contactus

6 Annexes

6.1 The CHIC Project Partner List

Participant organisation name	Abbreviation
EvoBus GmbH	EvoBus
Air Products Plc	AirProducts
Azienda Transporti Milanesi S.p.A.	ATM S.p.A.
Berliner Verkehrsbetriebe A.ö.R.	BVG
Element Energy Limited	Element Energy
Euro Keys SPRL[13]	EuroKeys
Air Liquide Hydrogen Energy	AL
HyCologne - Wasserstoff Region Rheinland e.V.	HyCologne
European Association for Hydrogen and Fuel Cells and Electro-mobility in European Regions[14]	HyER
Infraserv GmbH & Co. Höchst KG	ISH
BC Transit	BCT
Linde AG	Linde
London Bus Services Ltd	LBSL
thinkstep AG	TS
PLANET - Planungsgruppe Energie und Technik GbR	PLANET
PostAuto Schweiz AG	PostAuto
SHELL Downstream Service International BV	SHELL
Spilett new technologies GmbH	Spilett
Suedtiroler Transportstrukturen AG	STA AG
TOTAL Deutschland GmbH	Total
Universität Stuttgart	USTUTT
Vattenfall Europe Innovation GmbH	VEI
Ruter AS	Ruter
Wrightbus Limited	Wrightbus Ltd
hySOLUTIONS GmbH	HG

[13] Eurokeys SPRL ceased operations in 2014.
[14] HyER left the project in 2014 and its responsibilities were taken over by Element Energy

6.2 Glossary of Terms and Abbreviations

AFCC	Automotive Fuel Cell Cooperation (joint venture of Daimler AG and Ford Motor Company)
AP	Air Products
AP	
CO_2e	Carbon Dioxide equivalent - standard unit for measuring carbon footprints by expressing the impact of each different greenhouse gas in terms of the amount of CO2 that would create the same amount of warming
D.(x.x)	Deliverable (x.x) – A required output of the project
DC	Direct current
DoW	Description of Work
CEP	Clean Energy Partnership
EU	European Union
FC	Fuel cell
FCH JU	Fuel Cell and Hydrogen Joint Undertaking
GWP	Global warming potential
H_2	Hydrogen
H_2FC	Hydrogen Fuel Cell
HRS	Hydrogen refuelling station
ICE	Internal combustion engine
Kg/Km	Kilograms/Kilometres
LCA	Life cycle assessment - a technique to assess environmental impacts associated with all the stages of a product's life
LCWE	Life cycle working environment
MEP	Member of the European Parliament
OEM	Original equipment manufacturer.
OPEX	Operating expenditure
RE	Renewable energy
SoFi	Web based Software solution for all types of Corporate Sustainability Reporting issues
TCO	Total cost of ownership
TF (e.g DTF)	Taskforce (e.g. Dissemination Taskforce)
TRL	Technology readiness level
WP/L	Work package/Leader

7 Use and Dissemination of Foreground

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[15] (if available)	Is/Will open access[16] provided to this publication?
1	BC Transit Fuel Cell Bus Project: Evaluation Results Report	Eudy, L. & Post, M.		Technical Report NREL/TP-5400-60603	National Renewable Energy Laboratory	Denver, U.S.A.	February 2014	All	http://www.nrel.gov/docs/fy14osti/60603.pdf	Yes
2	BC Transit Fuel Cell Bus Project: Evaluation Results Second Report	Eudy, L. & Post M.		Technical Report NREL/TP-5400-62317	National Renewable Energy Laboratory	Denver, U.S.A.	September 2014		http://www.nrel.gov/docs/fy14osti/62317.pdf	Yes
3	Brennstoffzellenbusse und	Klaus Stolzenburg	Nutzung regenerati	2016 (published	Fachhochschule	Stralsund	2016	pp. 129 – 134	ISBN 978-3-9817740-1-6	Yes

[15] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[16] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

	Wasserstofftankstellen im täglichen Einsatz: Erfahrungen aus dem Projekt CHIC		ver Energiequellen und Wasserstofftechnik	annually)	Stralsund				http://www.fh-stralsund.de/forschung/institute/ires/veranstaltungen/	

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

Type	Type of activities[17]	Main leader	Title	Date/Period	Place	Type of audience[18]	Size of audience	Countries addressed
1								
2								

SEE ATTACHED EXCEL SPREADSHEET FROM CHIC PROJECT.

[17] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[18] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[19]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
	THIS SECTION IS NOT APPLICABLE TO THE CHIC PROJECT.				

TEMPLATE B2

Type of Exploitable Foreground[20]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[21]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	THIS SECTION IS NOT APPLICABLE TO THE CHIC PROJECT.							

[19] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[21] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

8 Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*

Grant Agreement Number:	256848
Title of Project:	Clean Hydrogen in European Cities (CHIC) Project
Name and Title of Coordinator:	Kerstin K Müller

B Ethics

1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***Yes*** ***Yes***
2. Please indicate whether your project involved any of the following issues (tick box) :	***None Applic-able***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	

• Research having direct military use	0 Yes 0 No
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator [22]	2 (April 2010- Nov. 2011, 2 Oct. 2014 – Dec. 2016)	1 (Nov 2011 – Sept. 2014)
Work package leaders[23]	2	3
Experienced researchers (i.e. PhD holders)[24]	5	7
PhD Students[25]	7	6
Other[26]	8	23

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**4**
Of which, indicate the number of men:	2

[22] This refers only to whole of project level. There were 2 Financial Coordinators during the project: both were women

[23] This refers only to whole of project level

[24] These are aggregated figures for all partners

[25] These are aggregated figures for all partners

[26] These are aggregated figures for all partners

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?
○ Yes
☒ No

6. Which of the following actions did you carry out and how effective were they? N/A

	Not at all effective → Very effective
❑ Design and implement an equal opportunity policy	○ ○ ○ ○ ○
❑ Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○
❑ Organise conferences and workshops on gender	○ ○ ○ ○ ○
❑ Actions to improve work-life balance	○ ○ ○ ○ ○
○ Other:	

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?
○ Yes- please specify
☒ No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?
☒ Yes- please specify **7 PARTNERS REPLIED YES** — See list of dissemination activities for the Project
☒ No - **13 PARTNERS ANSWERED NO**

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?
☒ Yes- please specify **6 PARTNERS ANSWERED YES** — Mixture of websites, explanatory PPT presentations, DVDs
☒ No -**13 PARTNERS ANSWERED NO**

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?
○ Main discipline[27]: **2 (2.2;2.3) & 5 (5.4)**
○ Associated discipline[27]: **1 (1.4; 1.3)** ○ Associated discipline[27]: **5 (5.3)**

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*
☒ Yes 12Y
☒ No 7N

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?
☒ No **- 4**
☒ Yes- in determining what research should be performed **- 2**
☒ Yes - in implementing the research - 6
☒ Yes, in communicating /disseminating / using the results of the project **- 7**

[27] Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	☒ ☒	**Yes - 5** **No - 7**

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ☒ No **- 1**
- ☒ Yes- in framing the research agenda **- 2**
- ☒ Yes - in implementing the research agenda **- 5**
- ☒ Yes, in communicating /disseminating / using the results of the project **- 11**

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ☒ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ☒ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields? (*views of partners*)

Agriculture Audiovisual and Media Budget Competition **Consumers - 3** **Culture - 1** Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		**Energy - 8** Enlargement Enterprise **Environment-11** **External Relations-1** External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security **Public Health - 4** **Regional Policy - 8** **Research and Innovation - 9** Space Taxation **Transport - 11**	

13c If Yes, at which level?

- ☒ Local / regional levels – **14 partners**
- ☒ National level – **9 partners**
- ☒ European level – **7 partners**
- ☒ International level – **8 partners**

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**3**
To how many of these is open access[28] provided?	**3**
How many of these are published in open access journals?	
How many of these are published in open repositories?	**1**
To how many of these is open access not provided?	
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[29]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**N/A**

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**N/A**
	Registered design	**N/A**
	Other	**N/A**

17. How many spin-off companies were created / are planned as a direct result of the project?	**N/A**
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project: (*views of partners*)

☒ Increase in employment, **- 1**	☒ In small & medium-sized enterprises **- 3**
☒ Safeguard employment, **- 5**	☒ In large companies **- 3**
☒ Decrease in employment, **-1**	☒ None of the above / not relevant to the project **- 5**
☒ Difficult to estimate / not possible to quantify**- 8**	

[28] Open Access is defined as free of charge access for anyone via Internet.
[29] For instance: classification for security project.

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:* **12**[30]
Difficult to estimate / not possible to quantify	☒ **6 partners could not estimate**.

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

☒ Yes – **7Y** ☒ No - **10N**

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

☒ Yes – **5Y** ☒ No- **11N**

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☒	Press Release – **14 partners**	☒	Coverage in specialist press – **6 partners**
☒	Media briefing – **5 partners**	☒	Coverage in general (non-specialist) press – **4 partners**
☒	TV coverage / report – **4 partners**	☒	Coverage in national press – **5 partners**
☒	Radio coverage / report – **3 partners**	☒	Coverage in international press – **4 partners**
☒	Brochures /posters / flyers – **10 partners**	☒	Website for the general public / internet – **9 partners**
☒	DVD /Film /Multimedia – **4 partners**	☒	Event targeting general public (festival, conference, exhibition, science café) – **9 partners**

23 In which languages are the information products for the general public produced?

☒	Language of the coordinator – **5 partners**	☒	English – **14 partners**
☒	Other language(s) – **7 partners**		

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

[30] 8 of these were in one partner. It would seem most partners undertook this work within existing resources.

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]

9 Final Report on the Distribution of the European Union Financial Contribution

Report on the distribution of the European Union financial contribution between beneficiaries

Participant Organisation Name	Request for FCH JU Contribution (EURO)
EvoBus GmbH	494.936,00
Air Products Plc	319.547,00
Azienda Transporti Milanesi S.p.A. (ATM)	3.538.032,00
Berliner Verkehrsbetriebe A.ö.R. (BVG)	0,00
Element Energy Limited	328.016,00
EuroKeys	12.118,00
Air Liquide Hydrogen Energy (AL)	0,00
HyCologne - Wasserstoff Region Rheinland e.V.	0,00
HyER	106.024,00
Infraserv GmbH & Co. Höchst KG (ISH)	42.000,00
BC Transit (BCT)	0,00
Linde AG	0,00
London Bus Services Ltd (LBSL)	5.673.690,00
thinkstep AG (former PE International)	239.831,00
PLANET - Planungsgruppe Energie und Technik GbR	210.571,00
PostAuto Schweiz AG	4.578.848,00
SHELL Downstream Service International BV	0,00
Spilett new technologies GmbH	85.282,00
Südtiroler Transportstrukturen AG (STA)	4.439.152,00
TOTAL Deutschland GmbH	0,00
Universität Stuttgart (USTUTT)	262.587,00
Vattenfall Europe Innovation GmbH (VEI)	0,00
Ruter AS	5.500.000,00
Wrightbus Limited	0,00
hySOLUTIONS GmbH (HG)	47.700,00
Total	**25.878.334,00**