



HyLIFT-EUROPE

Large scale demonstration of fuel cell powered material handling vehicles

Final Report

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Disclaimer

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Contents

1	Final publishable summary report	4
1.1	Executive summary	4
1.2	Summary description of project context and objectives.....	5
1.3	Main S&T results / foregrounds	8
1.4	Potential impact, main dissemination activities and exploitation of results	22
1.5	Address of project website and relevant contact details.....	34
2	Use and dissemination of foreground.....	35
3	Report on societal implications.....	49

1 Final publishable summary report

1.1 Executive summary

Over recent years, the commercial case for hydrogen powered fuel cell materials handling vehicles has become increasingly attractive, with the costs of the technology becoming increasingly competitive in relation to the incumbent drive trains. These developments have led to several large-scale deployments of such vehicles in the USA.

For a variety of reasons, the commercial case for hydrogen powered fuel cell materials handling vehicles in European operations has not kept pace and, as a result, there have as yet not been any similar large-scale deployments of materials handling vehicles in Europe.

However, the cost reductions and technology improvements required to boost commercialisation in Europe are very close. The first step to achieve commercialization of products in Europe was initiated in the context of the HyLIFT-DEMO project, supported by the FCH JU, which deployed 11 fuel cell materials handling vehicles in commercial operations in a 3.5-year demonstration project finished in 2014.

The HyLIFT-EUROPE project represents the next logical step from HyLIFT-DEMO and addresses the topic “SP1-JTI-FCH.2011.4.1: Demonstration of fuel cell-powered Material Handling Equipment vehicles including infrastructure” in the 4th call of the European Fuel Cells & Hydrogen Joint Undertaking Implementation Plan (AIP 2011). HyLIFT-EUROPE provides the next step towards market deployment by increasing the demonstrated volume to about 200 vehicles.

Lessons learned from HyLIFT-DEMO have shown that in order to demonstrate such a high number of vehicles, several vehicle types are needed to satisfy a wide range of customer needs.

HyLIFT-EUROPE deploys two new and dedicated state-of-the-art hydrogen refuelling solutions for materials handling vehicles at two sites in France. This hydrogen refuelling technology has now reached a status that has the potential to be commercially rolled out across Europe.

The fuel cell technology demonstrated was procured by the vehicle OEM according to the FCH JU rules (“principles of economy, efficiency and effectiveness”) from the just developing market. The systems are fully integrated in the above-mentioned materials handling vehicles by the participating vehicle OEM.

The hydrogen refuelling stations (HRSSs) deployed use the latest refuelling technology. The project partners cover the entire value chain and all the disciplines and technologies required for providing fully working hydrogen powered fuel cell materials handling vehicle solutions. The value chain consists of both large and SME companies, who collaborated in this project with the aim of establishing a strong European presence in the hydrogen powered fuel cell materials handling vehicle market.

In keeping the call objectives, the principal objective of the HyLIFT-EUROPE project was to deploy large numbers of fuel cell materials handling vehicles and associated refuelling infrastructure, with the aim of bringing the European materials handling vehicle market closer to commercialisation.

1.2 Summary description of project context and objectives

Background

Over recent years, the commercial case for hydrogen powered fuel cell materials handling vehicles has become increasingly attractive, with the costs of the technology becoming increasingly competitive in relation to the incumbent drive trains. These developments have led to the first large scale deployments of small forklifts in 24-hour operations in the U.S.

For a variety of reasons, the commercial case for hydrogen powered fuel cell forklifts in European operations has historically not been as strong, and as a result there are as yet no similar large-scale deployments of materials handling vehicles in Europe.

However, the cost reductions and technology improvements required to achieve commercialisation in Europe are now to be reached. The first step towards achieving a commercial product to be offered in Europe was the HyLIFT-DEMO project supported by FCH JU, which deployed 11 fuel cell powered materials handling vehicles in commercial operations in a 3.5-year demonstration project.

The HyLIFT-EUROPE project represented the next logical step from HyLIFT-DEMO and addresses the topic “SP1-JTI-FCH.2011.4.1: Demonstration of fuel cell-powered Material Handling Equipment vehicles including infrastructure” in the 4th call of the European Fuel Cells & Hydrogen Joint Undertaking Implementation Plan (AIP 2011). HyLIFT-EUROPE provided the next step towards market deployment by increasing volume to more than 200 vehicles.

Lessons learned from HyLIFT-DEMO have shown that in order to demonstrate such a high number of vehicles, several vehicle types are needed in order to satisfy a wide range of customer needs. Initially, in HyLIFT-EUROPE a total of two materials handling vehicle manufacturers were participating, who offered different vehicle segments, including forklifts and warehouse trucks (STILL) and airport tow tractors (MULAG). As MULAG was not successful in signing vehicle-user contracts for fuel cell tow tractors by JUN 2016 due to the fact that they were not provided with a capable fuel cell system, according to the agreed demonstration plan all efforts to start demonstration activities were terminated.

The high volume of vehicles to be deployed in HyLIFT-EUROPE should provide significant cost reductions (by allowing companies to make significant investments in e.g. tooling, supply chain set-up and serial production) in order to pave the way for a subsequent supported market deployment similar to the on-going activities in the U.S.

To allow for the demonstration of the materials handling vehicles involved in the project, HyLIFT-EUROPE initially planned to deploy 5-20 new and dedicated state-of-the-art materials handling refuelling solutions in a variety of locations with commercial potential across Europe, once again providing cost reductions through volume

deployment and at the same time significantly expanding the European hydrogen refuelling station coverage. In the course of the project it turned out that at this stage of market deployment it would make more sense to target only the sites where major demonstrations could take place so as to demonstrate the full potential of the hydrogen and fuel cell solution. In this context, Prelocentre, a logistic specialist for fresh products and Carrefour, one of the largest supermarket chains in the world, were selected by the project partners and decided to convert their warehouses to the hydrogen solution. These deployments have contributed to make hydrogen available have helped paving the way for subsequent commercial deployments of hydrogen powered fuel cell materials handling vehicles in Europe. The project has aimed at demonstrating the competitiveness of the deployment of hydrogen vehicles, in particular with regards to the vehicles from STILL. To speed-up the deployments in Europe the vehicle-user Prelocentre exceptionally joined the consortium at the beginning of 2015. The first deployment of hydrogen powered fuel cell forklifts in Europe in a green-field site is being demonstrated at Prelocentre's premises.

Project concept

The initial aim of HyLIFT-EUROPE was to deploy more than 200 fuel cell materials handling vehicles and associated fuel cell materials handling vehicle refuelling infrastructure to 5-20 sites across Europe, whilst meeting all the requirements of topic 4.1 of the FCH JU 2011 call for proposals. At the time of the revision of the project (3rd Contract Amendment) it became clear that due to the lack of further customers there will be only two sites (Prelocentre & Carrefour).

The fuel cell technology demonstrated had been sourced by the vehicle OEMs according to the FCH JU rules (“principles of economy, efficiency and effectiveness”) from the just developing market.

The two hydrogen refuelling stations (HRSs) had been deployed by Air Liquide using latest refuelling technology.

Several of the HyLIFT-DEMO partners participated in HyLIFT-EUROPE, as well as a number of new participants strengthening the value chain coverage by joining the consortium.

Project objectives

In keeping with the call objectives, the principal objective of the HyLIFT-EUROPE project was to deploy large numbers of fuel cell materials handling vehicles and associated hydrogen refuelling infrastructure, with the aim of bringing the European materials handling vehicle market closer to commercialisation through volume cost reductions.

The detailed objectives of the project, which also align with the call objectives, were:

- **Demonstration of more than 200 units of fuel cell powered materials handling vehicles at vehicle-user sites across Europe.** This will prove the feasibility and reliability in genuine daily heavy commercial use in the rugged industrial environment. The significant volume will help to lower the costs of materials handling vehicles in Europe and associated materials handling

vehicle refuelling infrastructure through volume production and to achieve genuine parity with the costs of the incumbent drive trains in most locations. This will be one of the first major commercially viable deployments of fuel cell powered materials handling vehicles in Europe and will facilitate the early introduction of hydrogen as a fuel for other industrial materials handling vehicles.

- **Demonstration of state-of-the-art supporting hydrogen refuelling infrastructure at 5-20 vehicle-user demonstration sites throughout Europe.** This will prove the safety and practical case for the use of hydrogen as a transportation fuel in the safety- and reliability-critical industrial and airport airside environments. Additionally, the deployment of new hydrogen refuelling stations providing affordable hydrogen to selected European locations which have the potential to achieve genuine parity with the costs of the incumbent drive trains will enable OEMs to further deploy hydrogen fuel cell materials handling vehicles at these locations and help to extend the European hydrogen fuel network.

In the course of the project it turned out that no airport customers could be identified and, as a result, no hydrogen infrastructure will be installed at an airport airside environment. The industrial demonstration will focus on two large industrial sites.

- **Validate Total Cost of Ownership (TCO) & path towards commercial targets.** Data acquisition will be conducted on the demonstration vehicles, allowing the validation of performance targets on durability, efficiency and costs for the hydrogen and fuel cell technology. The project will also validate TCOs at different vehicle-user sites, for all kinds of materials handling vehicles demonstrated. This will provide recommendations for next steps towards reaching targets enabling a supported market deployment of fuel cell materials handling vehicles.
- **Plan and ensure initiation of supported market deployment beyond 2018 of hydrogen powered fuel cell materials handling vehicles.** As part of this project, vehicle manufacturers will plan for their future deployment of hydrogen fuel cell vehicles and suggestions for European / national / regional deployment support mechanisms will be developed. The project and demonstration volume in itself will provide a first step towards this commercialisation by selling the vehicles at commercially competitive prices directly through OEM manufacturers and thereby introducing a new route to market for fuel cell materials handling vehicles. The project will allow European vehicle manufacturers to develop the know-how required to build hydrogen powered fuel cell materials handling vehicles.
- **Best practice guide for HRS installation.** Best practice guides will document in detail the lessons learned from obtaining safety approval as well as construction and operation permits for the hydrogen refuelling infrastructure in industrial environments, to be shared with potential future vehicle-users thereby streamlining the procedures for future deployments.

- **European dissemination and supporting of the European industry.** HyLIFT-EUROPE represents the largest European trial of hydrogen fuel cell materials handling vehicles so far. These facts and project results as well as experiences will be disseminated throughout Europe targeting early adopters of hydrogen vehicles, focused on European large industrial users of materials handling vehicles, as well as on key policy and industry stakeholders, and the general public. Demonstration of the vehicles at large industrial companies will ensure maximum exposure of the project and will be supplemented by other targeted dissemination events, as well as a project website. The trials of the vehicles in various locations will also be used as a marketing opportunity of hydrogen fuel cell materials handling vehicles. The demonstration and dissemination efforts will support the European industry in expanding their present lead within the materials handling sector to also include fuel cell drive trains. HyLIFT-EUROPE will allow European SMEs and industry to gain the expertise required for taking a lead role in the deployment of further fuel cell materials handling vehicles, either within Europe, or through the worldwide export of products and services.

1.3 Main S&T results / foregrounds

Summary of project achievements

In general, the achievements were:

- Integration of the vehicle-user Prelocentre into the consortium which now deploys 75 fuel cell materials handling vehicles in France in a logistics environment with a hydrogen refuelling station supplied by Air Liquide. It is the first deployment of hydrogen powered fuel cell forklifts at a green field site in Europe. Onsite operations started in SEP 2015
- Presentation of MULAG's hydrogen powered fuel cell airport tow tractor at the inter airport Europe fairs 2013 and 2015, one of the world's leading trade fairs for airport equipment as well as at an in-house exhibition of a fuel cell system manufacturer
- Vehicle trials of MULAG's airport tow tractor at Cologne/Bonn Airport and Hamburg Airport. Further tests were performed at the sites of various fuel cell system manufacturers
- Elaboration on the identification of vehicle-users and demonstration sites across Europe including workshops with potential customers focusing on fuel cell drive trains
- In 2015 STILL succeeded in the technical implementation as well as in passing the qualification tests for fuel cell powered counterbalance and reach-trucks
- Demonstration of STILL hydrogen fuel cell powered forklifts and an Air Liquide HRS at a retailer's premises (France) in OCT 2014
- Presentation of the STILL forklift truck RX60-25 FC at the EC TEN-T Days in Riga in JUN 2015

- Completion of the HRS site selection process and initial safety case approval for installation of an airside HRS at Heathrow Airport, leading to a first draft of the “Installation of airside hydrogen refuelling stations in airports: lessons learnt and best practice guide”
- In 2016 STILL and Air Liquide managed to secure a contract with a second French retailer, Carrefour. The contract for the deployment of fuel cell materials handling vehicles was followed by a second one signed in 2017
- Delivery of 57 fuel cell systems and trucks to Carrefour by STILL in 2016
- Delivery of additional 80 fuel cell systems and trucks to Carrefour by STILL in 2017
- In total 137 fuel cell vehicles are deployed at a brand-new Carrefour distribution center in France
- Presentation of the HyLIFT-EUROPE project at several events
- Project achievements in reporting period 6
- The sixth and final reporting period in HyLIFT-EUROPE was dedicated to hydrogen powered fuel cell materials handling vehicle demonstration per definition. It was a requirement of FCH JU that all fuel cell vehicles eligible for financial support have to be in demonstration for at least one full year. Therefore, the goal and also the achievement for this period was a smooth operation of all fuel cell vehicles and of the two hydrogen refuelling stations at both sites (Prelocentre & Carrefour). These deployments were accompanied by a monitoring process resulting in (confidential) deliverables documenting the return of experience as well as TCO and performance evaluations for both sites.

In detail the following results could be achieved in the course of the project:

WP 2 – Demonstration planning and vehicle user selection

WP Leader: Air Liquide

Task 2.1 Identification & TCO evaluation of potential vehicle-users

Potential vehicle-users should be identified in areas having access to low-cost hydrogen and based on promising case-specific TCO calculations made in a dialogue with the vehicle-users to determine the case for the use of materials handling vehicles at their sites. In preparation of these meetings, seminars should be held at each vehicle manufacturer, where sales teams were trained in the identification of vehicle-users with the most appropriate characteristics for an attractive TCO case for fuel cell vehicles.

STILL

At the beginning of the project, STILL was in touch with several potential vehicle-users and performed rudimental TCO calculations in collaboration with the potential

customers. They were successful in identifying a significant list of interested potential customers from the automotive industry, the chemical industry, the beverage retail business, the logistics sector and from various other sectors.

Experiences from the various discussions with potential customers are the following:

- Replacement of big fleets in one first step is unrealistic; a step-by-step approach has to be sought
- A realistic number of forklift trucks in a first fleet are 2 - 6 trucks
- Fuel cell system costs are no longer the general showstopper. The costs of a fuel cell system (taking the FCH JU financial support into account) are already in reach of the costs of a set of 3 batteries
- Customers (additionally) are requesting other types of forklifts and warehouse trucks powered by hydrogen fuel cells
- STILL required the clear commitment and support for the hydrogen and refuelling station supply from the HyLIFT-EUROPE partners in charge in order to enable the provision of clear statements and cost estimates to potential customers
- The identification of customers offering a real business case is still a challenge

During customer events of STILL the fuel cell trucks were shown to potential customers and interested people.



Source: STILL GmbH

In JUN 2015 the counterbalance fuel cell forklift truck (RX 60-25) was presented at the TEN-T-Day in Riga.



Source: STILL GmbH

In order to improve the economical attractiveness of fuel cell operations in materials handling trucks, two main topics could be identified:

- Costs for hydrogen
- Costs for maintenance

Both have a very big impact on customer's TCO calculations. In the current pricing situation for fuel cells, the operational costs are the determining success factor of a fuel cell project application.

Furthermore, in order to sign customer contracts for fuel cell materials handling vehicles in the future, the following soft factors have to be solved:

- Enabling multi sourcing of fuel cells
- Easier procedures for getting permissions for fuel cell and hydrogen refuelling operations
- Acceptance of suppliers to provide infrastructure, fuel cells and services to customers, who are operating fleets of less than 10 trucks

MULAG

As MULAG's hydrogen powered fuel cell vehicle is dedicated to the use at airports they were in close contact with many European airports interested in this technology. For example, MULAG contributed to the German task force fuel cell technology at airports (Arbeitsgemeinschaft deutscher Verkehrsflughäfen) whenever possible. MULAG was very active and used all opportunities to keep the various airports' interest up, although no vehicles for further trials and demos were available at that time. Furthermore, MULAG was in close and permanent exchange with NOW in order to get and keep in touch with the required contact points. Nevertheless, MULAG severely suffered from the fact that they had no working fuel cell system available from the supplier foreseen.

Air Liquide

Air Liquide performed customer prospection as part of HyLIFT-EUROPE, with major actors of the industry including Carrefour.

In particular, fruitful discussions took place with Carrefour in 2015 and paved the way for a deployment at a French Carrefour site. Main focus of the discussions at that time was to identify the most appropriate site, depending on customer needs, TCO calculations and distance from a hydrogen source. Several possibilities for the supply chain had also been assessed.

Generally speaking, due to ongoing changes in the supermarket logistics industry the hydrogen solution becomes more and more interesting: due to the peaks of activities observed during several periods of the year (holiday season, Christmas season, etc.), the industrial operating scheme tends to be organised in 3 shifts rather than in 2 shifts. The flexibility offered by the hydrogen solution, as well as its environmental benefits clearly contribute to the interest of Carrefour for this solution. One of the results of the activities performed as part of the HyLIFT-EUROPE project is that the hydrogen fuel cell forklift solution is now part of the Carrefour Corporate Social Responsibility Guidelines.

LBST

Also, LBST has contributed to this task as many potential vehicle-users approached the project coordinator triggered by the various dissemination activities during the project. LBST then explains the concept and the goals of the project and its opportunities for potential customers in detail. Furthermore, LBST has participated in meetings, answered phone calls and exchanged e-mails with potential vehicle-users. LBST was also the general contact point for the activities in the field of fuel cell materials handling vehicles for the German NOW.

Task 2.2 Arranging test trials with vehicle-users and securing agreements

Test trials should be arranged with potential vehicle-users identified who have a compelling TCO case and where the management has taken a principle decision to engage in such a trial. Based on the success of these trials, agreements should be secured with the vehicle-users on participation in the demonstration activities. This included both agreements on procurement or leasing of vehicles as well as agreements on hydrogen fuel provision.

STILL

Because of the change of the supplier of the fuel cell system at the end of the first reporting period vehicles equipped with fuel cell systems from the new supplier were only available in MAY 2014 and the vehicles were shown at the CeMAT fair 2014 in Hannover for the first time. Test trials with a potential vehicle-user were performed in OCT 2014 at a site of Carrefour in France together with Air Liquide.

Unfortunately, in 2014 no agreements with vehicle-users for participation in demonstration activities could be secured. In the light of this situation and taking into account the length and the complexity of purchasing procedures within the materials handling vehicle user field the necessary support from the relevant project partners

had to be intensified. Therefore, the activities in this regard had to proceed and efforts had to be enlarged. Both were reflected in a HyLIFT-EUROPE Contract Amendment and a demonstration plan defined the consequences in case of non-compliance with the targets set.

In 2015 the fuel cell vehicle could be made available for testing and trials at three sites of a large automotive OEM.

After many fuel cell vehicle presentations and also truck demonstrations at the customer site in 2016 negotiations had been successful with Carrefour in France. As a team, STILL France, Air Liquide, and the fuel cell system supplier closed a deal with Carrefour in Verdun. A total of 57 trucks was ordered in a first wave in 2016. A second wave followed in 2017 with additional 80 trucks summing up to a large fleet of 137 trucks. Four different types of trucks were approved for fuel cell use.

MULAG

Even if hydrogen refuelling was a real challenge in both cases, MULAG was able to perform test trials at both the Hamburg Airport and the Cologne/Bonn Airport. Unfortunately, the trials unveiled the underperformance of the fuel cell system for this specific application and therefore no further test trials could be performed.

Unfortunately, also in 2015 MULAG was still lacking a working fuel cell system from the designated supplier that could have been used for demonstration activities. Therefore, no test trials with vehicle-users could be performed and no vehicle-user agreements could be signed. In consequence, the airport tow tractor activities were terminated.

WP 3 – Technical planning

WP Leader: Air Liquide

Task 3.1 Technical interfaces & configuration of fuel cell & vehicles

Forklifts & warehouse trucks

Both, the technical interfaces and the configuration of the fuel cell system and vehicle were clarified and agreed on in the first project year and the first vehicle comprising a fuel cell system from the new supplier was demonstrated at the CeMAT logistics fair in Hannover / Germany in May 2014.

In order to enable the easiest way of installing and maintaining fuel cells inside warehouse trucks, STILL had to get in close cooperation with the design department of the fuel cell system supplier. This process led to an add-on-piece inside the trucks for fixing and protecting the fuel cell on the one hand, and creating the ballast weight for ensuring stability and driving behaviour on the other hand.

Further optimization of fuel cell system integration (e.g. cable routing in vehicle) and support to local technical service person took place until the end of the project.

Airport tow tractors

In the case of airport tow tractors, the trials at the Hamburg and the Cologne/Bonn airports and the related real-world experiences enabled both MULAG and the fuel cell

system supplier to develop and agree on an advanced performance specification. The discussions on the technical interfaces and especially on the fuel cell system configuration and in consequence on the vehicle configuration were finalized in late 2014. In order to assure the continuous proceeding of the systems improvement MULAG and the fuel cell system supplier held regular conference calls (weekly). Furthermore, the optimisation of hardware and software of the H2Drive system was ongoing to improve stability and reliability of the H2Drive system operations until the airport tow tractor activities were terminated in JUN 2016.

Task 3.2 Technical planning of hydrogen supply & infrastructure

In 2016 the technical planning of the hydrogen supply and the hydrogen infrastructure of the solution to be installed at Carrefour was developed. This solution included a redundant design to ensure a high level of availability.

The first solution presented to Carrefour was in 2 phases:

- 1st phase: temporary fuelling station (1 dispenser & 1 temporary compressor with 30 kg/d capacity)
- 2nd phase: permanent refuelling station (2 dispensers & 2 compressors of 100+ kg/d capacity)

Finally, it was decided not to use the temporary station due to high cost and limited use (2 months maximum before the permanent installation).

Task 3.3 Safety & emergency procedures & guideline for HRS airport airside installation

Context: This task was associated with a project deliverable called "Guideline to installation of HRSs at airside in airports". The original intention was to produce a guideline report on safety approval processes to install airside HRSs following the installation of an airside HRS at a real airport. Unfortunately, the activities to install an airside hydrogen refuelling station were postponed due to the lack of availability of fuel cell baggage tugs to operate at this airport. Lessons learnt from the work carried out to deploy hydrogen fuelled vehicles and refuelling infrastructure airside at an airport were captured in a best practice guide (completed in JAN 2014).

WP 4 – Fuel cell material handling vehicle demonstration

WP Leader: LBST

Task 4.1 Manufacturing of demonstration vehicles

Forklifts & warehouse trucks

In 2013 STILL purchased one fuel cell system from the new supplier and integrated it into the vehicle. The internal performance tests and the qualification procedures were performed in late 2013 and early 2014. The vehicle was presented at the CeMAT logistics fair in Hannover in May 2014.

In the course of 2014, a second "trial" truck was manufactured. Both trucks were used for several "trial" demonstrations at various automotive OEMs and further occasions.

After signing the contracts with Carrefour, the production of these vehicles begun.

In quarter 3 and 4 in 2016 STILL managed the cooperation for this project between various STILL departments and sites as well as with an external supplier for specific assembly kits.

The delivery of the first batch comprising a fleet of 57 trucks could be finished in MAR/APR 2017.

A second batch comprising 80 trucks was manufactured and shipped to Carrefour during 2017 and all 137 trucks were in use at the customer site by the end of 2017.

Airport tow tractors

In the case of the airport tow tractors MULAG had put significant efforts in arranging the test trials at Hamburg and Cologne/Bonn airports and in collecting the test results in 2013 and 2014. After these trials had disclosed that the existing fuel cell system performance was not appropriate to fulfil the specific requirements of an airport tow tractor, unexpected and unplanned efforts became necessary. The first step was to adapt the fuel cell system performance specification according to the trial results. In consequence this required the tow tractor to be equipped with larger batteries and an additional hydrogen tank in order to reach the required performance. In order to test the new performance, the vehicle was modified in a quick-fix solution that is appropriate for performing the tests but not appropriate for trials at customer sites. The reasons were not only of optical nature but had technical backgrounds as well (e.g. too high a centre of gravity). In order to proceed with the trials at potential customer sites it would have become necessary to build a new vehicle.

As in 2015 MULAG still lacked a working fuel cell system from the designated supplier that could be used for demonstration activities it became clear that MULAG would leave the project in the year 2016. Therefore, all development and manufacturing activities were terminated.

Task 4.2 Demonstration of fuel cell vehicles

Prelocentre case

From the very beginning of their operations in an industrial environment Prelocentre had decided to use hydrogen forklifts only. The initial fleet composition was in coherence with the operational needs as follows:

- 25 forklifts Class 3 (24 V)
- 3 forklifts Class 1 (80 V)

As the warehouses and their operations had been extended during the course of the project, the fleet had grown over time. In JAN 2016, 38 forklifts had been in operation already and at the end of the project in DEC 2018 the fleet comprised 75 vehicles.

Here a summary of the feedback received from Prelocentre after 3.5 years of operations:

- Solution very easy to use for the workers
- No major disturbance of the operations due to the use of hydrogen powered fuel cell forklifts
- Reliability of the technology with 100% availability of the fuel cell thanks to the technician working on site for fuel cell maintenance
- The use of such an innovative technology is still motivating for all the workers

→ Based on this positive return of experience Prelocentre has confirmed that they will keep using the fuel cell forklift solution and will order additional products as their activities are significantly increasing.

Carrefour case

Operation of demonstration vehicles

In Carrefour Vendin with 137 trucks equipped with fuel cells, it is more a “Pilot Project Fleet” than a “Demonstration fleet”. Carrefour is very happy with the technology and specially with the availability of the trucks. The main advantage is that, when they need to work in 3 shifts instead of 2, they do no longer need to hire additional trucks on a short-term rental basis.

Training of vehicle-users

In cooperation with the fuel cell system supplier and Air Liquide, STILL had trained around 40 managers and trainers from Carrefour. The training modules focused mostly on security processes for the right use of the trucks, the fuel cells and the hydrogen refuelling procedure. The drivers of Carrefour were trained by their own trainers. All necessary procedures are repeated and explained at each “Security Briefing” with all the drivers. Each new driver has to attend the specific fuel cell training before he is allowed to drive a truck.

Continuous servicing and maintenance

The use of fuel cells instead of lead-acid batteries does not require additive maintenance on the truck’s side. The maintenance of the fuel cells requires a dedicated highly qualified maintenance team. But on the other hand, there is no need to fill with water or replace the lead-acid batteries and you save some space and at least one person dedicated to the battery management for each shift.

Regular updates / optimisation of fuel cell hybrid systems and vehicles

Compared to fuel cells, a lead-acid battery's efficiency is decreasing at the end of every shift and also by about 4% per year. Till today, there is no technical solution to change this situation. With the fuel cells, by improving the components or the programming of the fuel cell, you can improve the efficiency during the whole life of the fuel cell. Additionally, also the noise-level of the fans should be improved.

Data collection

In Vendin, like in all other Carrefour supply chain sites, STILL hands out customer key performance indicators on a monthly basis for their trucks e.g. working hours, services or truck damages. Within the fuel cell project, the fuel cell system supplier and Air Liquide also provide Carrefour with their specific performance indicators on a monthly basis.

Repairs and part replacement

With regards to the trucks, as all the adaptations for the fuel cell integration were studied and designed by the factories, there had not been any problems at all with the availability of spare parts. For the fuel cell systems, the partners decided to have two 24 V and one 48 V spare fuel cells in Vendin. As the technicians of the fuel cell system supplier have been in permanent contact with their factory for technical support, there is no major problem regarding availability of spare parts.

Performance level achieved

As the energy given by the fuel cells is always at the top level compared to lead-acid batteries, the performance level achieved with all the trucks is as expected and higher than that of lead-acid batteries. The other main asset of course is, of environmental nature. It is a highly recyclable solution, which does not contain toxic acids or pollutants.

Vehicle user feedback

For the drivers, the first argument in favour of the fuel cells is the arduousness associated with changing conventional lead-acid batteries which have to be removed. Although switching is usually done using mechanized or semi-automated systems, operation is also much cleaner. Therefore, the working conditions of the operators have improved, while avoiding the risk of accidents that may occur during handling of conventional batteries.

Recommendations

The main difference between lead-acid batteries and fuel cells is the noise level because the battery makes no noise at all. From the drivers point of view, this is the only point that may need to be improved by the fuel cell manufacturer.

Further standards are required for the fuel cell systems to enable an easier truck integration. Next to that a push on hydrogen infrastructure and costs is highly required, in order to be able to offer hydrogen as an intralogistics energy solution, next to existing technologies such as battery and internal combustion engine trucks.

WP 5 – Hydrogen refuelling infrastructure demonstration

WP leader: Air Liquide

Task 5.1 HRSs & hydrogen supply for temporary sites

During the course of the project Air Liquide had been able to supply temporary hydrogen refuelling stations to allow for potential customers to carry out 2-4 week trials of fuel cell materials handling vehicles. Air Liquide had to supply hydrogen to the

trial sites where possible. Trials should not start before a strong commitment from the vehicle-users could be identified. Related to the forklifts and warehouse trucks one trial was performed in 2014 at a Carrefour site in France. For this trial Air Liquide had provided the required hydrogen refuelling infrastructure. The hydrogen powered fuel cell tow tractors from MULAG had used other solutions for the hydrogen supply during the trials performed at the Hamburg and Cologne/Bonn airports in the 1st reporting period. In case of Hamburg Airport, the already existing hydrogen refuelling station was used. In case of Cologne/Bonn Airport the airport company Flughafen Köln-Bonn GmbH had financially supported the trials by renting a mobile hydrogen refuelling solution from Linde Gas.

The two basic options for temporary hydrogen refuelling at promising customer sites for trials and demos which Air Liquide could offer were a truck-based solution as well as a movable trans-fill system.

Task 5.2 Manufacturing of HRSs

Prelocentre site

In 2015 Air Liquide Advanced Business selected Air Liquide Advanced Technologies as the supplier for the hydrogen refuelling station at the Prelocentre site. Manufacturing and installation of the HRS was finalized by AUG 2015 and the start of the commissioning could take place in time.

Carrefour site

The first solution considered for Carrefour in 2016 was planned to be implemented in two phases. Air Liquide Advanced Technologies started to manufacture this HRS with a high level of redundancy to fit Carrefour requirements (2 dispensers and 2 compressors).

The onsite civil works started with levelling and trenching activities already in 2016.

Two dispensers were installed at the Carrefour site in MAY 2017.

Finally, in 2017 in agreement with Carrefour it was decided to add a third dispenser to reduce refuelling time in the entire warehouse.

The third dispenser and two additional medium pressure buffers were installed by Air Liquide Advanced Technologies in APR 2018.

Task 5.3 Commissioning of HRSs

Prelocentre site

Air Liquide worked actively in 2015 to ensure that the hydrogen refuelling station could be operational at the Prelocentre site on time (28 AUG 2015) so as to respect Prelocentre's requirements. Indeed, as it is a green field site, the HRS had to be ready to start right at the beginning of the operations.

The main details for the implementation of the HRS are disclosed in a public deliverable called "Manufacturing and commissioning of first HRSs at vehicle-user site".

Carrefour site

The Carrefour Vendin site has been in operation since JUL 2017 and was commissioned in JUN 2017. The onsite work took approximately 8 months. The implementation steps are shown in the figure below.

All in all, the project was on time and there were no major disturbances in the project progress. This is especially true for the permitting process, which took a long time for previous site developments. Since the new reference code has been published (thanks to the HAWL project), the permitting process could be reduced to two months which corresponds to a normal lead time.

Task 5.4 Operation of HRSs

Prelocentre site

Since 01 SEP 2015, all the workers from Prelocentre have been working exclusively on hydrogen powered fuel cell forklifts.

The highlights of the HyLIFT-EUROPE monitoring activities at Prelocentre can be summarized as follows:

- about 21 tons of hydrogen have been refuelled to fuel cell materials handling vehicles at Prelocentre since 2016
- more than 70,000 vehicle fillings took place since 2016

The HRS availability of the last 12 months in the project is good and reached 98.1%.

Carrefour site

Since 2018, workers of Carrefour Vendin have been working on 137 hydrogen powered fuel cell forklifts.

The highlights of the HyLIFT-EUROPE monitoring activities at Carrefour Vendin can be summarized as follows:

- More than 18 tons of hydrogen dispensed over 12 months
- More than 37,000 fillings over 12 months

The HRS availability in the last 12 months in the project is good and reached 98.8%.

WP 6 – Demonstration monitoring & TCO validation

WP Leader: LBST

Task 6.1 Data collection & monitoring

This task covered the following activities:

- Collection of HRS operation data from Air Liquide
- Collection of vehicle operation data from STILL and Prelocentre

HyLIFT-EUROPE partners have contributed to the FCH JU project data reporting in TRUST by providing input data for both vehicles (two classes) and hydrogen refuelling stations.

The data have been used for the calculations of the performance of operating fuel cell forklifts and warehouse trucks at the Prelocentre and the Carrefour sites.

Task 6.2 Calculation of true performance of operating fuel cell forklifts and warehouse trucks at the Prelocentre site

A draft TCO model was prepared for the tow tractor and draft data collection templates for project partners were prepared and circulated for comment, but in the absence of any real vehicle data or deployment plans, it was not possible to obtain any useful feedback or data from partners in the early phase of the project.

An initial Total Cost of Ownership (TCO) calculation for the Prelocentre case based on figure assumptions was performed in order to support the decision-making procedure early in the project. This TCO has become part of a deliverable called "Identification and priority for users with obvious TCO benefit". A TCO calculation based on real-world data became part of a deliverable called "Return of experience, TCO and performance evaluation for the Prelocentre site" provided at the end of the project.

Task 6.3 Calculation of actual performance of operating fuel cell forklifts and warehouse trucks at the Carrefour site

A TCO calculation based on real-world data was performed as part of a deliverable called "Return of experience, TCO and performance evaluation for the Carrefour site" and was submitted in DEC 2018.

Task 6.4 Laboratory tests to support fuel cell operation

This task was cancelled.

Task 6.5 Vehicle User Group

It was planned to establish a Vehicle User Group (VUG), where operators of fuel cell vehicles could share experiences of operating a fleet of fuel cell vehicles. Potential operators of fuel cell vehicles should be invited to join the VUG to learn about experiences prior to investing in fuel cell vehicles. The group was expected to grow with more members from the project and from outside the project. As until FEB 2017 only two vehicle-users could be secured, the idea of the VUG had been cancelled and a HyLIFT-News service informing an interested community in the latest news on fuel cells in materials handling has been established instead.

Since the beginning of the HyLIFT-News service up to MAY 2018 the number of recipients had grown to 175. It comprised representatives from all stakeholders along the value chain of hydrogen powered materials handling vehicles

On 25 MAY 2018 the new European General Data Protection Regulation (commonly referred to as GDPR) entered into force and therefore it became necessary to initiate an active opt-in procedure in order to proceed with the HyLIFT-News service.

On 22 MAY 2018 all recipients of the previous mailing list were asked for opting in, a reminder was sent on 24 MAY 2018 and finally a total of 62 stakeholders remained on the mailing list.

From the feedback received it could be drawn that this HyLIFT-News service was highly appreciated and exploited by the addressees.

WP 7 - Planning commercialisation, network & dissemination

WP leader: FAST / EHA

Task 7.1 General dissemination

As there is a specific section on dissemination activities in this report please refer to chapter 1.4 “Potential impact, main dissemination activities and exploitation of results” in order to learn more about the project’s activities in this fields.

Task 7.2 Material handling business sector dissemination and networking

See Task 7.1

Task 7.3 European dissemination and networking

See Task 7.1

Task 7.4 Planning product maturation & mass production

During 2018 FAST, with the collaboration of the partners, developed a deliverable called "Industry plans and decisions on commercialisation activities". The preliminary outline for the deliverable that was compiled in the format of an article had been prepared at the end of 2017 to be presented to the partners during the General Assembly meeting of HyLIFT-EUROPE in JAN 2018, where it was unanimously approved. The deliverable compiles the results of a dedicated survey among the HyLIFT-EUROPE industry partners. Unfortunately, the deliverable is confidential.

A dedicated survey was sent to the industry partners to investigate barriers and drivers of the market and key factors that mainly influence the choice of customers for or against the hydrogen solution. Furthermore, the interviews aimed at understanding the goals and the next steps of the industry in this business segment in order to show how the market may evolve in the next years.

Task 7.5 Recommendations for market deployment & commercialisation

As part of a deliverable called "Recommendations for market deployment and commercialisation" FAST/EHA at the end of 2014 started a first round of interviews on the view of partners and first customers based on a set of questions agreed with the consortium. This feedback was further elaborated into a consolidated version including preliminary conclusions that was shared with the consortium over the course

of 2015. Due to changes in the DoW and delays in final contracts the final deliverable was published in DEC 2015.

1.4 Potential impact, main dissemination activities and exploitation of results

Potential impact

The following section seeks to describe the impact the HyLIFT-EUROPE project has with regard to reaching the targets / objectives of the Annual Implementation Plan (AIP) that has called for this project.

AIP objective:

Focus on cost competitive TCO compared to conventional vehicles with inclusion of FCH JU support.

Corresponding project objectives / targets:

As the TCO takes into account all expenses of owning and operating a materials handling vehicle and therefore is the main selection criteria for vehicle-users, thus HyLIFT-EUROPE will focus on those vehicle-users promising the best TCO benefit for fuel cell vehicles.

Achievements:

One of the main achievements in the course of the project was to attract two vehicle-users who participated in the project and deployed significant fleets of hydrogen powered materials handling vehicles. Both vehicle-users are stemming from the food retail sector where a competitive TCO compared to conventional vehicles can be expected in the medium term also without financial support. Unfortunately, no vehicle-user from the automotive industry could be attracted although also there a competitive TCO can be expected in the medium term.

AIP objective:

Projects to be based on FC technology platforms with high credibility for fleet level MHE vehicle demonstration and applications which will achieve or exceed cost, efficiency and durability benchmarks.

Corresponding project objectives / targets:

The approach to replace the standard battery box by the fuel cell system is the ideal approach to establish a standard FC technology platform which can be used in numerous (industrial) applications, thereby enabling high production volumes and achieving required cost targets.

Achievements:

Unfortunately, there is not yet a Europe-based fuel cell technology platform with high credibility for fleet level materials handling vehicle demonstration available. Therefore, the participating OEM partner relied on a fuel cell system purchased from a U.S.-based supplier. In doing so cost, efficiency and durability benchmarks could be reached.

AIP objective:

Show clear cost targets for different applications, document competitive TCO and show performance improvements and/or cost reductions achieved by development work and demonstration unit volumes.

Corresponding project objectives / targets:

The sales price target for the fuel cell system is <2,300 €/kW. As this system has the same space requirements as the standardized battery boxes it can be used in a wide range of applications and thus again enable large unit volumes. The envisaged performance improvement will take the fuel cell system efficiency from 45% to 50%.

Achievements:

The deployments of hydrogen powered fuel cell materials handling vehicles in HyLIFT-EUROPE took place only at two sites with comparable character and with vehicles from two different OEMs. Therefore, cost targets for different applications could not be shown. Nevertheless, the two demo sites are of very high value due to the fact that they offer a showcase of large-scale deployment of hydrogen powered fuel cell materials handling vehicles in Europe for the first time.

AIP objective:

Evaluate achieved benefits (e.g. in terms of savings, increased output, emission reduction, operating hours, etc.).

Corresponding project objectives / targets:

In the course of the project the achieved benefits will be documented and evaluated. Focus will be on the TCO calculation clearly showing if the fuel cell technology can provide benefits compared to conventional technology. Increased output respectively prolonged operating hours will be documented via the Monitoring & Assessment Framework.

Achievements:

The best proof of significant benefits with regard to savings, increased output and operating hours is the fact that the vehicle-user Prelocentre, starting with only 28 vehicles has increased its fleet to 75 hydrogen powered materials handling vehicles without only thinking of changing to battery powered vehicles. The achievements with regard to emission reductions are directly linked on the one hand to the electricity mix contracted and on the other hand on the hydrogen purchased. It is mainly a question of the energy purchased and less depending on the technology deployed.

AIP objective:

Total cost of fuel cell system (at early volume production): <3,000 €/kW.

Corresponding project objectives / targets:

The fuel cell systems to be demonstrated are to reach a price of 2,300 €/kW.

Achievements:

The cost targets could be achieved, but no further details will be published.

AIP objective:

System life time (with service / stack refurbishment): >7,500 hours.

Corresponding project objectives / targets:

The fuel cell systems to be demonstrated are to reach a life-time of >10,000 hours (with service & stack replacements).

Achievements:

In the course of the project none of the fuel cell systems could clock more than 10,000 hours of operation. Nevertheless, it is expected that, taking services and stack replacements into account, fuel cell system life-times of beyond 10,000 hours can be achieved.

AIP objective:

Fuel cell system efficiency (tank to wheel): >45%.

Corresponding project objectives / targets:

The fuel cell systems to be demonstrated are to reach a system efficiency of >48%.

Achievements:

Even if it has not been measured in the course of the project, it is assumed that a system efficiency of >48% could be reached.

AIP objective:

Refuelling time: 3 min.

Corresponding project objectives / targets:

The fuel cell systems allow for fast refuelling (2-3 minutes) without any issues related to the increase of temperature inside the tank due to the pressure increase. Also, the cascade filling from the refuelling station will allow for rapid and fast refuelling and will not depend on e.g. compressor capacity and ambient temperature.

Achievements:

The objective of a refuelling time of 3 min could be achieved in almost all cases.

AIP objective:

Hydrogen price dispensed at pump (end-user price): <10 €/kg.

Corresponding project objectives / targets:

The hydrogen refuelling infrastructure to be demonstrated is to enable a price of 8-12 €/kg (average target <10 €/kg).

Achievements:

The price targets for the hydrogen price dispensed at pump could be achieved, but no further details will be published.

AIP objective:

Availability of vehicles and refuelling to match conventional and competing technologies.

Corresponding project objectives / targets:

In total the demonstration of more than 200 vehicles and 2 HRSs is planned (initially 5-20 HRSs). These figures together with the FCH JU funding should allow for reaching the same TCO level as of conventional and competing technologies.

Achievements:

The availability of both the hydrogen powered fuel cell materials handling vehicles and the hydrogen infrastructure could achieve good values. For the vehicles this could be achieved by spare fuel cell systems and a technician available at the site. The hydrogen refuelling stations achieved an availability of 98.1% in the case of Prelocentre and an availability of 98.8% in the case of Carrefour.

AIP objective:

Show solid approach for permitting and provide recommendations with regard to RCS in this area.

Corresponding project objectives / targets:

Air Liquide has already coordinated the HAWL project and drafted a best practice guideline for HRS installations.

Achievements:

Since the new reference code for the permission of hydrogen fuelling stations in warehouses has been validated by the French CSPRT in OCT 2015 (thanks to the HAWL project), the permitting process for such installations in France could be reduced to two months which corresponds to a normal lead time. Similar efforts should follow in other European countries.

AIP objective:

Base projects on business plans and committed partners to continue pathway to volume deployment and commercial rollout.

Corresponding project objectives / targets:

As this project is clearly seen as the logical next step after HyLIFT-DEMO and before the start of the supported market deployment the partner selection focused clearly on fully committed partners to commonly enter into commercialisation. Furthermore, the project has dedicated specific tasks to the development of industry plans & decisions on commercialisation activities.

Achievements:

Even if the big breakthrough for fuel cells in materials handling vehicles could not be achieved in the course of the HyLIFT-EUROPE project, it was able to establish two large showcases in Europe, where hydrogen powered fuel cell materials handling vehicles are operated in fleets larger than 70 vehicles. All partners involved in this

success are still committed to this technology and are watching out for further opportunities.

AIP objective:

Demonstrate 50 or more FC MHE vehicles at one or across several end-user sites and applications proving commercial customer value proposition

Corresponding project objectives / targets:

In total the demonstration of more than 200 materials handling vehicles is planned within HyLIFT-EUROPE at two demonstration sites (initially up to 20 demonstration sites were planned).

Achievements:

HyLIFT-EUROPE was successful in deploying 212 units of hydrogen powered fuel cell materials handling vehicles at two vehicle-user sites in Europe. Both fleets, the one at Carrefour and the other one at Prelocentre, outperform the 50 unit objective by far.

AIP objective:

Include necessary and relevant supporting hydrogen supply infrastructure

Corresponding project objectives / targets:

The project partner Air Liquide, who already has plenty of experience in hydrogen refuelling technology even in the field of materials handling takes care of the inclusion of necessary and relevant supporting hydrogen supply infrastructure.

Achievements:

Air Liquide has supplied and is now operating a hydrogen station that refuels the forklifts at Prelocentre, a logistics company in Saint-Cyr-en-Val, near Orléans. This site is the first European all-hydrogen logistics platform, and is equipped with 4756 forklifts powered by fuel cells.

At Carrefour, Air Liquide has installed a station containing three charging points located at different strategic areas within the platform. This allows each of the 137 forklifts to be charged in only three minutes, with a charge lasting an average of eight hours.

AIP objective:

Carry out life cycle assessment study according to ILCD Handbook requirements

Corresponding project objectives / targets:

Initially, it was planned to carry out an LCA analysis as part of the documentation and service planning. Furthermore, a deposit was expected to be used on the fuel cell system to ensure recycling of the fuel cell stack and system components.

Achievements:

Unfortunately, after STILL switching to a project external fuel cell supplier and MULAG leaving the project, no LCA could be carried out.

AIP objective:

Lean consortium to focus on demonstration activities and to involve system developers, materials handling equipment providers, technology providers, fuel suppliers, end users and supporters for permitting and RCS development

Corresponding project objectives / targets:

In order to allow as much demonstration as possible the HyLIFT-EUROPE consortium comprises only one partner for nearly all stages of the overall value chain.

Achievements:

In the course of the project, a number of changes in the composition of the project consortium had to be dealt with. Finally, the project ended up with one vehicle OEM, an industrial gases company taking care of the hydrogen infrastructure, one vehicle-user, one partner taking care of the dissemination activities and the project coordinator. For future projects the consortium recommends to involve the vehicle-users from the very beginning in order to avoid delays.

AIP objective:

Focus on the maximum number of MHE vehicles for demonstration e.g. by pooling of several end-users

Corresponding project objectives / targets:

In order to achieve a high production volume of fuel cell systems which is necessary to realise positive effects of serial production the consortium will do its very best to maximize the number of vehicles to be demonstrated.

Achievements:

Even if the project managed to reach a significant number of hydrogen powered materials handling vehicles deployed, it could not contribute to the establishment respectively to the support of a Europe-based fuel cell system manufacturer and the corresponding supply chain as the fuel cell systems were purchased from an U.S.-based supplier.

AIP objective:

Coordinate with materials handling demonstration projects funded under previous 2009 and 2010 calls.

Corresponding project objectives / targets:

The coordination with other materials handling demonstration projects was and is safeguarded as the key partners of HyLIFT-EUROPE are also participating in these projects (HyLIFT-DEMO, HAWL).

Achievements:

As long as the other projects HAWL and HyLIFT-DEMO were up and running the coordination and cooperation with them was quite smooth due to the fact that the project HAWL was coordinated by the project partner Air Liquide and the project HyLIFT-DEMO was coordinated by the project coordinator LBST.

Dissemination activities

General dissemination

- The website www.hylift.eu has been operated by LBST and has been regularly updated with news, project information and press releases.
- A video of the operations and the hydrogen refuelling at the Prelocentre premises has been prepared by Air Liquide and is available at <https://www.youtube.com/watch?v=uUPVJBO9rh0>
- A video of the operations and the hydrogen refuelling at the Carrefour premises has been prepared by STILL in collaboration with all the partners of the project and is available at <https://www.still.de/en-DE/company/news-press/news/detail/pioneering-use-of-hydrogen-in-intralogistics.html>
- The final brochure for dissemination purposes of the HyLIFT-EUROPE project was provided in 2018 in two versions:
 - one at the beginning of the year with only one demonstration site (Prelocentre) and
 - an updated one later in the year when the second location (Carrefour) was to be published.
- Specific communication material has been designed and developed for the organization of the final workshop: save the date, invitation, brochure and roll-ups.
- Final dissemination workshop

The final dissemination workshop aimed at showing the operations of the largest fleet of fuel cell materials handling vehicles in Europe and the related infrastructure for hydrogen refuelling.

Carrefour, one of the largest supermarket chains in the world, was selected by the project partners and decided to convert one of its warehouses to the hydrogen solution. A first very successful dissemination workshop took place at the Prelocentre site on 7 JUN 2016 and the final workshop of the project took place at the Carrefour Vendin-le-Vieil site on 22 NOV 2018, targeting the key stakeholders for the future commercialisation of hydrogen fuel cell materials handling vehicles.

The workshop offered the chance to see the operation of multiple FC trucks, to experience the operation in a warehouse powered by hydrogen and to foster the collaboration between vehicle-users and technology providers.

The event ran very smoothly and the feedback from the public was very positive.

All the attendees were satisfied and had the chance to visit the warehouse, learn more about hydrogen and fuel cells, meet colleagues and have had interesting discussions.

About 50 people participated in the workshop including representatives from relevant companies, journalists as well as European institutions such as the FCH JU.

Materials handling business sector dissemination and networking

- Participation in fairs and conferences within the materials handling vehicle sector
 - MULAG has presented its hydrogen powered fuel cell airport tow tractor at the inter airport 2013 in Munich, one of the world's leading trade fairs for airport equipment
 - STILL demonstrated their latest hydrogen fuel cell forklift at the CeMAT fair which took place in Hannover / Germany in May 2014
 - MULAG demonstrated their latest hydrogen fuel cell airport tow tractor at the inter airport Europe fair which took place in Munich / Germany in OCT 2015
- Articles in relevant business magazines within materials handling and press releases with case studies
 - FM – Das Logistikmagazin, issue 07-08/2013
 - Logistik und Fördertechnik, issue 12/2013
 - HyLIFT-EUROPE press release (commonly with HyLIFT-DEMO) 11 JUN 2013
 - Article in Industry Europe, Volume 26/5 – 2016 supported by LBST
 - HyLIFT-EUROPE participated in an interview programme to assess the European Added Value of FP7 and H2020 activities in the area of fuel cell and hydrogen. This activity was supported by LBST
 - FCH JU press release diffused through FAST/EHA network
- NOW, the German National Organisation Hydrogen and Fuel Cell Technology organized a user-oriented workshop entitled "Use of hydrogen and fuel cells in intralogistics - status quo and perspectives" in Stuttgart, Germany, on 27 SEP 2017. Hubert Landinger, LBST, gave a presentation entitled "International perspectives for fuel cell powered vehicles in logistics" representing the HyLIFT-EUROPE project.
- Programme Review Days 2017, Brussels, Belgium, 23/24 NOV 2017, presentation entitled "HyLIFT-EUROPE – Large scale demonstration of fuel cell powered material handling vehicles" given by Hubert Landinger, LBST.
- For the second time VDI Wissensforum organized a symposium dedicated to battery and charging technology entitled "Energy supply for mobile applications in production and logistics". The event took place in Düsseldorf, Germany, on 06/07 DEC 2017. Hubert Landinger, LBST, gave a presentation

entitled "International perspectives for fuel cell powered vehicles in logistics – update 2017" representing the HyLIFT-EUROPE project.

- CIN Symposium Economic and Environmental Benefits with Hydrogen and Fuel Cells in Materials Handling and Intralogistics, Frankfurt, 06 NOV 2018, Participants from the consortium: LBST, STILL, Prelocentre. The programme is available here:
<https://www.now-gmbh.de/content/1-aktuelles/2-veranstaltungen/20181106-intralogistik2018/programme-cin-symposium.pdf>
- CeMAT, Hannover, 23-27 APR 2018; in the framework of the Hannover Fair / CeMAT STILL presented its forklifts. STILL exhibits in a pavilion as one of the three leading industrial truck manufacturers present at HANNOVER MESSE. Also, a fuel cell truck was on display.

European dissemination and networking

This task comprised the participation at international and European hydrogen & fuel cell conferences with papers & presentations as well as the dissemination through various European fuel cell networks and organisations, e.g.

- European Fuel Cells & Hydrogen Joint Undertaking (FCH JU) Transportation Pillar
- European Hydrogen Association (EHA) and national members
- European Association for Hydrogen & Fuel Cells and Electro-mobility in European Regions (HyER)
- Danish Hydrogen & Fuel Cell Partnership and similar
- UKHFCA, London Hydrogen Partnership and Heathrow Clean Vehicles Partnership

International and European hydrogen & fuel cell conferences with papers & presentations:

- Hubert Landinger, LBST, participated in the VDI Wissensforum with a presentation entitled "International perspectives for fuel cell powered vehicles in logistics – update 2017", where HyLIFT-EUROPE was presented.
- Cristina Maggi, FAST, presented a poster of the project HyLIFT-EUROPE at the European Fuel Cell 2017 - Piero Lunghi Conference & Exhibition, held in Naples from 12-15 DEC 2017. For this occasion, an abstract has been elaborated and has been made public in the proceedings of the conference. The proceedings are available online:
http://www.enea.it/it/sequici/pubblicazioni/pdf-volumi/2018/v2017-proceedings_efc2017.pdf



- Abstract and presentations were prepared for
 - European Battery, Hybrid and Fuel Cell Electric Vehicle Convention on Infrastructure, Geneva, 14 MAR 2018, in the framework of the International Motor Show (FAST/EHA)
Programme: <http://www.eevc.eu/docs/eevc-infra-03032018.pdf>
- Other Events for European networking and dissemination
 - Hannover Fair, 23 APR 2018: FAST/EHA, as usual, participated in the event to spread the HyLIFT-EUROPE messages on a personal level to the many stakeholders who attend this event every year
 - Hydrogen Summit, Sofia, 28 MAY 2018: A great opportunity to have networking activities and dissemination for HyLIFT-EUROPE and secure the presence of the project also in this event that gathered the hydrogen stakeholders and also speakers from the European Parliament, the European Commission, FCH JU and further policy makers
- Programme Review Days 2018, Brussels, Belgium, 14/15 NOV 2018, presentation entitled "HyLIFT-EUROPE – Large scale demonstration of fuel cell powered material handling vehicles" given by Hubert Landinger, LBST
- “Stati generali Idrogeno e Celle a Combustibile 2018”, Milano, Italy, 28 NOV 2018. Dissemination with stakeholders at personal level

Dissemination throughout European hydrogen and fuel cell networks:

EHA:

<http://www.h2euro.org/category/latest-news/eha-project-info/material-handling-applications/>

<https://www.h2euro.org/latest-news/carrefour-lifts-material-handling-to-higher-levels/>

H2IT:

<http://www.h2it.org/it/2017/italiano-dimostrazione-della-possibilita-di-implementare-su-larga-scala-carrelli-elevatori-alimentati-a-celle-a-combustibile>

CIN:

<http://www.cleanintra-logistics.net/portfolio-item/still-liefert-an-carrefour-ingsgesamt-137-lagertechnikfahrzeuge/?lang=en>

HyLIFT-EUROPE consortium:

http://www.hylift-europe.eu/public/Publications/PressRelease-HyLIFT-EUROPE-Carrefour_Final.pdf

Hydrogen Today:

<https://hydrogentoday.info/news/4762>

Air Liquide:

<https://energies.airliquide.com/air-liquide-opens-new-hydrogen-station-carrefour-supply-europes-largest-forklift-trucks-fleet>

Plug Power:

<https://www.ir.plugpower.com/Press-Releases/Press-Release-Details/2018/Carrefour-Supply-Chain-Showcases-GenDrive-Powered-Lift-Truck-Fleet-at-Grand-Opening-in-France/default.aspx>

STILL:

<https://www.still.com.br/22375+M53873476ece.0.0.html>

Exploitation of results

In HyLIFT-EUROPE it was the ambition of the participating companies to ensure market introduction of fuel cell materials handling vehicles and hydrogen infrastructure by 2018. One work package (WP7) in the project was dedicated to the commercialisation planning and preparation.

The first step was to build upon the results of the predecessor project HyLIFT-DEMO and to secure initiation of product maturation of the next generation of materials handling vehicles and hydrogen infrastructure, reaching full commercial targets in 2018, thus enabling market introduction. Specifically, a commercialisation plan should be developed as part of the project and corporate decisions within the involved companies should be secured so that the plan could be initiated and market introduction could commence in 2018.

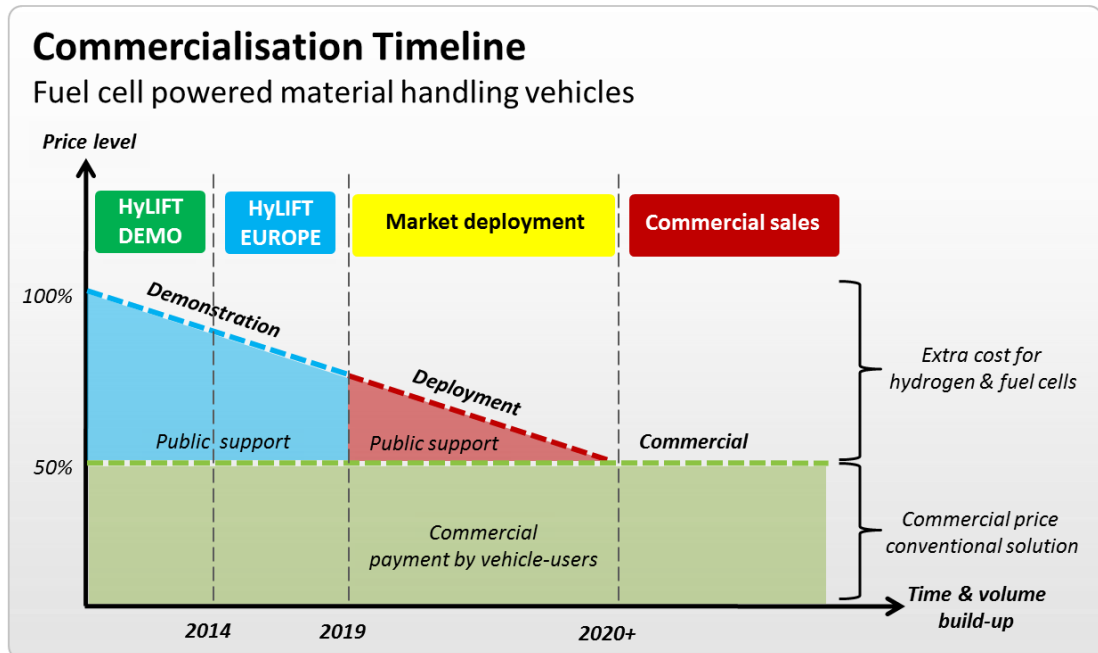
The early sales should be targeted to end-users with attributes that gives strongest value proposition and lowest Total Cost of Ownership (TCO) for fuel cell materials handling vehicles, as this should ease sales and lower customer's switching barriers. The following end-user attributes were foreseen:

- Materials handling vehicle fleet sizes of 30-50 vehicles (forklifts and warehouse trucks), intensely used at least 3,000 hours per year (a fleet size of more than 10 vehicles was initially foreseen for airport tow tractors)
- Customers with high LPG / diesel / electricity prices
- Customers with corporate social responsibility policies and need for emission reductions

The commercialisation efforts were directly linked with the business plans and efforts of the HyLIFT-EUROPE project partners.

Unfortunately, it turned out that full commercial market deployment could not be achieved within this project. The technology applied in this project is not yet fully commercial. Therefore, deployment support mechanisms are still required beyond HyLIFT-EUROPE and therefore have to be reflected by FCH JU in the context of Horizon Europe.

Therefore, in the course of the HyLIFT-EUROPE project the timeline for market deployment and commercialisation has been adapted as follows:



Updated commercialisation timeline for hydrogen powered materials handling vehicles

1.5 Address of project website and relevant contact details

The HyLIFT-EUROPE project information and public results can be found at <http://www.hylift-europe.eu>

The HyLIFT-EUROPE logo:



Beneficiaries of HyLIFT-EUROPE:

Beneficiary Nr.	Beneficiary name	Beneficiary short name	Country	Date enter project	Date exit project	Contact
1 coord.	Ludwig-Bölkow-Systemtechnik GmbH	LBST	DE	1	72	www.lbst.de
2	STILL GmbH	STILL	DE	1	72	www.still.de
3	MULAG Fahrzeugwerk Heinz Wössner GmbH u. Co. KG	MULAG	DE	1	48	www.mulag.de
4	Air Products GmbH	AP	DE	1	18	www.airproducts.de
5	Copenhagen Hydrogen Network A/S	CHN	DK	1	18	https://energies.airliquide.com
6	Element Energy Ltd.	EE	UK	1	48	http://www.element-energy.co.uk/
7	Federazione delle Associazioni Scientifiche e Tecniche / European Hydrogen Association	FAST/EHA	IT	1	72	http://www.fast.mi.it/ / https://www.h2euro.org/
8	EC, DG Joint Research Centre, Directorate C – Energy, Transport and Climate	JRC	BE	1	48	https://ec.europa.eu/jrc/en
9	Heathrow Airport Ltd.	HAL	UK	1	48	https://www.heathrow.com/
10	H2 Logic A/S	H2L	DK	1	19	https://nelhydrogen.com/
11	Air Liquide Advanced Business	AL	FR	19	72	https://advancedtech.airliquide.com/
12	Dantherm Power A/S	DTP	DK	20	48	www.ballard.com
13	Prelocentre	PRE	FR	26	72	http://www.mairie-chaponnay.fr/annuaire/prelodus/

2 Use and dissemination of foreground

Section A

Part A1 List of scientific publications

No scientific publications relating to the foreground of the project were produced in the course of the project. Therefore, no table A1 is included in this report.

Part A2 List of dissemination activities

See next page.

A2: List of dissemination activities								
NO.	Type of activities¹	Main leader	Title	Date/Period	Place	Type of audience²	Size of audience	Countries addressed
1	Web sites/Applications	Ludwig-Boelkow-Systemtechnik GmbH	www.hylift-europe.eu	01.01.2013	Internet	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		World
2	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"Fuel Cells and Hydrogen for maritime and harbour applications: current status and future	14.06.2013	Venice / Italy	Scientific community (higher education, Research) -		Europe

¹ 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.

² 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).

			perspectives in the EU" @ FCH JU workshop			Industry - Policy makers		
3	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"Large scale demonstration of hydrogen powered materials handling vehicles" @ Workshop Landesinitiative Energie-speicher und -systeme Niedersachsen / Wasserstoffregion Hannover	19.09.2013	Hannover / Germany	Scientific community (higher education, Research) - Industry - Policy makers		Germany, Austria, Switzerland
4	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"Large scale demonstration of hydrogen powered materials handling vehicles" @ f-cell	01.10.2013	Stuttgart / Germany	Scientific community (higher education, Research) - Industry - Policy makers		Europe
5	Articles published in the popular press	Ludwig-Boelkow-Systemtechnik GmbH	"Leuchtturmprojekte sollen Weg ebnen"	01.09.2013	BWK Bd. 65 (2013) Nr. 9	Scientific community (higher education, Research) - Industry		Germany, Austria, Switzerland

6	Posters	Ludwig-Boelkow-Systemtechnik GmbH	"HyLIFT-EUROPE" / Poster for FCH JU General Stakeholder Assembly	11.11.2013	Brussels / Belgium	Scientific community (higher education, Research) - Industry - Policy makers		Europe
7	Interviews	Ludwig-Boelkow-Systemtechnik GmbH	"Future of hydrogen"	01.07.2013	http://www.venetoinnovazione.it/?q=eng/Landing	Scientific community (higher education, Research) - Industry - Policy makers		World
8	Exhibitions	MULAG FAHRZEUGWERK HEINZ WÖSSNER GMBH U. CO. KG	inter airport 2013	08.10.2013	Munich / Germany	Industry		World
9	Articles published in the popular press	Ludwig-Boelkow-Systemtechnik GmbH	"Brennstoffzellensta-pler im Dauereinsatz"	07.08.2013	FM / Das Logistikma-gazin, issue 07-08/2013	Scientific community (higher education, Research) - Industry		Germany, Austria, Switzerland
10	Articles published in the popular press	Ludwig-Boelkow-Systemtechnik GmbH	"Brennstoffzelle bei Wind und Wetter"	01.12.2013	Logistik und Fördertechnik, issue 12/2013	Scientific community (higher education,		Germany, Austria, Switzerland

						Research) - Industry		
11	Press releases	Ludwig-Boelkow- Systemtechnik GmbH	"Hydrogen to revolutionise drive trains of materials handling vehicles in Europe"	11.06.2013	press release	Scientific community (higher education, Research) - Industry - Policy makers - Medias		Europe
12	Oral presentation to a scientific event	Ludwig-Boelkow- Systemtechnik GmbH	"Large scale demonstration of hydrogen powered materials handling vehicles" @ Landesinitiative Energiespeicher und -systeme Niedersachsen	04.04.2014	Osnabrück / Germany	Scientific community (higher education, Research) - Industry - Policy makers		Germany, Austria, Switzerland
13	Web sites/Applications	Ludwig-Boelkow- Systemtechnik GmbH	"HyLIFT: projects on hydrogen powered fuel cell materials handling vehicles in Europe" at WHEC 2014	15.06.2014	Gwangju / Korea (abstract was not accepted for oral presentatio n)	Scientific community (higher education, Research) - Industry - Policy makers		World

14	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"HyLIFT-EUROPE" @ FCH JU Review Days	10.11.2014	Brussels / Belgium	Scientific community (higher education, Research) - Industry - Policy makers		Europe
15	Posters	Ludwig-Boelkow-Systemtechnik GmbH	"HyLIFT-EUROPE" / Poster for FCH JU General Stakeholder Assembly	10.11.2014	Brussels / Belgium	Scientific community (higher education, Research) - Industry - Policy makers		Europe
16	Articles published in the popular press	Ludwig-Boelkow-Systemtechnik GmbH	"Flurförderzeuge / Gas geben mit Wasserstoff"	01.06.2014	Logistik Heute, Volume 36, Nr. 6, JUN 2014, pages 48-49	Scientific community (higher education, Research) - Industry		Germany, Austria, Switzerland
17	Articles published in the popular press	Ludwig-Boelkow-Systemtechnik GmbH	"Schritt für Schritt / STILL: Brennstoffzellen in Flurförderzeugen - nächste Phase"	14.04.2014	Hebezeuge Fördermitte I, Nr. 5, JUN 2014, pages 320-321	Scientific community (higher education, Research) - Industry		Germany, Austria, Switzerland
18	Exhibitions	STILL GMBH	CeMAT 2014	19.05.2014	Hannover / Germany	Scientific community		World

						(higher education, Research) - Industry		
19	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"International Perspectives for Fuel Cells for Materials Handling Vehicles (MHVs)" @ 10th International Colloquium Fuels - Conventional and Future Energy for Automobiles	22.01.2015	Stuttgart-Ostfildern / Germany	Scientific community (higher education, Research) - Industry		Europe
20	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"The HyLIFT-EUROPE project and fuel cell powered airport tow tractors" @ Workshop on aeronautical applications of fuel cells and hydrogen technologies	16.09.2015	Lampoldshausen / Germany	Scientific community (higher education, Research) - Industry		Europe
21	Oral presentation to a wider public	Ludwig-Boelkow-Systemtechnik GmbH	"Internationale Perspektiven für brennstoffzellenbetriebene Fahrzeuge in der	29.10.2015	Berlin / Germany	Scientific community (higher education,		Germany, Austria, Switzerland

			Logistik" @ NOW workshop "Intralogistik mit Wasserstoff und brennstoffzellen-betriebenen Flurförderzeugen"			Research) - Industry		
22	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"Das HyLIFT-EUROPE Projekt und internationale Perspektiven für brennstoffzellen-betriebene Fahrzeuge in der Logistik" @ ttz workshop "Wasserstoff als regenerativer Energiespeicher für die maritime Wirtschaft"	12.11.2015	Bremen / Germany	Scientific community (higher education, Research) - Industry		Germany
23	Posters	Ludwig-Boelkow-Systemtechnik GmbH	"HyLIFT-EUROPE" / Poster for FCH JU General Stakeholder Assembly	17.11.2015	Brussels / Belgium	Scientific community (higher education, Research) - Industry - Policy makers		Europe
24	Exhibitions	MULAG FAHRZEUGWERK	inter airport 2015	06.10.2015	Munich / Germany	Scientific community		World

		HEINZ WÖSSNER GMBH U. CO. KG				(higher education, Research) - Industry		
25	Oral presentation to a scientific event	Ludwig-Boelkow- Systemtechnik GmbH	"Internationale Perspektiven für brennstoffzellen- betriebene Fahrzeuge in der Logistik" @ 15. Brennstoffzellenforu m - Innovationen für eine nachhaltige Logistik organised by the Hessian ministry for economy, energy, transport and rural development	13.09.2016	Frankfurt / Germany	Scientific community (higher education, Research) - Industry - Policy makers		Germany, Austria, Switzerland
26	Oral presentation to a scientific event	Ludwig-Boelkow- Systemtechnik GmbH	"Internationale Perspektiven für brennstoffzellen- betriebene Fahrzeuge in der Logistik" @ VDI Fachkonferenz Batterie- und Ladetechnik	29.11.2016	Cologne / Germany	Scientific community (higher education, Research) - Industry		Germany, Austria, Switzerland
27	Posters	Ludwig-Boelkow- Systemtechnik GmbH	"HyLIFT-EUROPE" / Poster for FCH JU	21.11.2016	Brussels / Belgium	Scientific community		Europe

			General Stakeholder Assembly			(higher education, Research) - Industry - Policy makers		
28	Organisation of Workshops	FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE	HyLIFT-EUROPE mid-term dissemination workshop	07.06.2016	St Cyr-en-Val near Orleans / France	Scientific community (higher education, Research) - Industry - Policy makers - Medias		Europe
29	Articles published in the popular press	Ludwig-Boelkow-Systemtechnik GmbH	"HyLIFT-EUROPE: Powering the Future"	01.05.2016	Industry Europe, Volume 26/5 – 2016	Scientific community (higher education, Research) - Industry - Policy makers		Europe
30	Posters	FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE	"HyLIFT-EUROPE / Large scale demonstration of fuel cell powered materials handling vehicles" @ European Fuel Cell Piero Lunghi Conference and Exhibition 2017	12.12.2017	Naples / Italy	Scientific community (higher education, Research) - Industry - Policy makers		Europe

31	Posters	FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE	"Crossing borders and boundaries" @ Hannover Fair 2017	24.04.2017	Hannover / Germany	Scientific community (higher education, Research) - Industry		World
32	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"International perspectives for fuel cell powered vehicles in logistics" @ NOW workshop entitled "Use of hydrogen and fuel cells in intralogistics - status quo and perspectives"	27.09.2017	Stuttgart / Germany	Scientific community (higher education, Research) - Industry		Europe
33	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"HyLIFT-EUROPE – Large scale demonstration of fuel cell powered material handling vehicles" @ FCH JU Programme Review Days	23.11.2017	Brussels / Belgium	Scientific community (higher education, Research) - Industry		Europe
34	Oral presentation to a scientific event	Ludwig-Boelkow-Systemtechnik GmbH	"International perspectives for fuel cell powered vehicles in logistics - update 2017" @ VDI Wissensforum	06.12.2017	Düsseldorf / Germany	Scientific community (higher education, Research) - Industry		Germany, Austria, Switzerland

			"Energy supply for mobile applications in production and logistics"					
35	Videos	STILL GMBH	"Pioneering use of hydrogen in intralogistics"	03.12.2018	https://www.still.de/en-DE/company/news-press/news/detail/pioneering-use-of-hydrogen-in-intralogisti	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		World
36	Videos	AIR LIQUIDE ADVANCED BUSINESS	100% hydrogen-powered logistics: a first for Europe!	09.08.2016	https://www.youtube.com/watch?v=uUPVJBO9rh0	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		World
37	Flyers	FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE	"HyLIFT - Clean Efficient Power For Materials Handling"	29.06.2018	http://www.hylift-europe.eu/public/Publications/HY	Scientific community (higher education, Research) - Industry - Civil		World

					LIFT_Flyer-V7.pdf	society - Policy makers - Medias		
38	Posters	FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE	"HyLIFT-EUROPE / Large scale demonstration of fuel cell powered materials handling vehicles"	29.06.2018	http://www.hylift-europe.eu/public/Publications/HyLIFT_EUROPE_Posters_Final.pdf	Scientific community (higher education, Research) - Industry - Civil society - Policy makers - Medias		World
39	Organisation of Workshops	FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE	"HyLIFT-EUROPE - Final dissemination workshop"	22.11.2018	Carrefour / Vendin-le-Vieil / France	Scientific community (higher education, Research) - Industry - Policy makers		Europe
40	Exhibitions	STILL GMBH	CeMAT 2018	23.04.2018	Hannover / Germany	Scientific community (higher education, Research) - Industry		World
41	Oral presentation to a scientific event	FAST - FEDERAZIONE DELLE ASSOCIAZIONI	"HyLIFT-EUROPE: Fuel Cell Materials Handling Vehicle Market	14.03.2018	Geneva / Switzerland	Scientific community (higher education,		Europe

		SCIENTIFICHE E TECNICHE	Developments in Europe" @ European Battery, Hybrid and Fuel Cell Electric Vehicle Convention on Infrastructure			Research) - Industry - Policy makers		
42	Oral presentation to a scientific event	Ludwig-Boelkow- Systemtechnik GmbH	"HyLIFT-EUROPE" @ FCH JU Review Days	14.11.2018	Brussels / Belgium	Scientific community (higher education, Research) - Industry - Policy makers		Europe



Section B

Part B1 List of applications for patents, trademarks, registered designs, etc.

No patents, trademarks, registered designs, etc. were applied in the course of the HyLIFT-EUROPE project.

Part B2 List of exploitable foregrounds

No exploitable foregrounds were produced in the course of the HyLIFT-EUROPE project.

3 Report on societal implications

The report on societal implications has been submitted online via the Participant Portal.