ANNUAL ACTIVITY REPORT 2019

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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ANNUAL ACTIVITY REPORT 2019

In accordance with Article 17 of the Statutes of the FCH 2 JU annexed to Council Regulation (EU) No. 559/2014 and with Article 20 of the Financial Rules of the FCH 2 JU.

The annual activity report will be made publicly available following its approval by the Governing Board.

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FACTSHEET

NAME	Fuel Cells and Hydrogen 2 Joint Undertaking
OBJECTIVES	a) To contribute to the implementation of Regulation (EU) No. 1291/2013, and in particular the Secure, Clean and Efficient Energy Challenge and the Smart, Green and Integrated Transport Challenge under part III of I of Decision 2013/743/EU (b) To contribute to the objectives of the Joint Technology Initiative on Fuel Cells and Hydrogen, through the development of a strong, sustainable and globally competitive FCH sector in the Union
FOUNDING LEGAL ACT	Council Regulation (EU) No. 559/2014 of 6 May 2014 – OJ L169/108-129 of 7.6.2014
EXECUTIVE DIRECTOR	Bart Biebuyck
GOVERNING BOARD	Chair: Valérie Bouillon-Delporte Vice-Chair: Patrick Child Governing Board composition: http://www.fch.europa.eu/page/governing-board
OTHER BODIES	States Representative Group, Scientific Committee, Stakeholder Forum
STAFF	24 temporary agents and 3 contract agents
2019 BUDGET	EUR 91.7 million of which EUR 86.1 million allocated to operational activities and EUR 5.6 million to administrative expenses
BUDGET IMPLEMENTATION	86 % in terms of commitment appropriations 98 % in terms of payment appropriations
GRANTS	109 signed for a total value of EUR 541.0 million
STRATEGIC RESEARCH AGENDA	Multi-Annual Work Plan 2014-2021 Addendum to the MAWP endorsed by the Governing Board on 15 June 2018
CALL IMPLEMENTATION	Number of calls launched in 2019: 1 Number of proposals submitted: 44 Number of eligible proposals: 43 Number of proposals funded: 17 Global project portfolio (since setting up): 155 projects under FP7 (of which 150 closed and 5 open) and 109 signed projects under H2020 (of which 11 closed and 98 open) Number and value of tenders (if any): 3 studies were contracted in 2019 for a total value of EUR 1.5 million
PARTICIPATION, INCLUDING SMES	Total number of participations in funded projects: 1,146 of which: % of SMEs: 25 % of SME funding: 31.5

FOREWORD

Racing towards a Clean Hydrogen economy was the theme of our 2019 Stakeholder Forum visualised by the two hydrogen racing cars parked in the heart of Europe. The race towards Europe's goal of a climate-neutral economy by 2050 using the European Green Deal as a vehicle has begun. Frans Timmermans, the Executive Vice-President of the European Commission sees 'a pivotal role for hydrogen' to reach the finish.

During 2019, we continued our focus on the outreach and dissemination of project results to show citizens and policymakers the potential of fuel cell and hydrogen technology and the major achievements that have been realised in this public-private partnership. Central and Eastern European countries remained our focal point and we actively attended several events there.

The regions and cities initiative we started in 2016, numbering 92 regions, was taken to the next level with the setting up of the European Hydrogen Valleys Partnership under the Smart Specialisation platform and the launch of the Project Development Assistance programme for the regions. In addition, the North Netherlands region was successful in our call for proposals to achieve the first hydrogen valley in Europe by 2025. The valley will highlight the sectoral integration and stimulate strong citizen involvement.

With 263 projects, a combined public-private investment of nearly EUR 2.0 billion has been realised since 2008. These investments have produced significant progress in the maturity of the technology, which was demonstrated in our Programme Review Days. This progress and the results from our studies have led to new initiatives from the European Commission, such as the IPCEI and a potential new partnership on Clean Hydrogen. Furthermore, internationally, the latest G20 Declaration and reports by the IEA, IRENA and the Hydrogen Energy Ministerial mention the importance of hydrogen as a vector to decarbonise our societies.

The Hydrogen Roadmap for Europe, released in 2019, calculated that by 2050 fuel cells and hydrogen could create 5.4 million jobs in Europe, abate 560 million tonnes of CO_2 annually and generate a yearly turnover of EUR 820 billion. However, these jobs and growth will not come automatically. Other regions in the world are now starting to invest massively in this technology; up to eight times more than Europe. Thanks in a big part to the FCH 2 JU , the EU has achieved a global leadership position in this sector and the Joint Undertaking will be key to keeping that.

Therefore, it is important to continue to invest heavily in research and innovation and to set up a strong coordination and cooperation structure in Europe. Thanks to its wealth of experience, the FCH 2 JU can take on this role and become the hydrogen knowledge and coordination hub for Europe. To maintain leadership and create jobs and growth in Europe, partnering between policymakers, the private sector and citizens – on every level, local and international – is the answer, which is exactly Europe's great strength.

In 2019, the FCH 2 JU had the best budget execution ever in its history, reached excellent leverage effects and a low error rate. This demonstrates that it continues to provide an excellent example of a mature, sound and well-controlled environment. This success has been achieved thanks to the hard work and dedication of many people, passionate about tackling climate change by using hydrogen and fuel cells technology, such as colleagues in the European Commission, the Governing Board, the States Representative Group, the Scientific Committee and the many stakeholders who give their valuable inputs on our plans and activities.

Finally, I would like to thank my entire team in the Programme Office who give the best of themselves every day to serve the interests of European citizens. The huge response to the public consultation on a Clean Hydrogen Partnership is a clear recognition in that sense.

Enjoy the read!

Bart BIEBUYCK
Executive Director FCH 2 JU

EXECUTIVE SUMMARY

2019 was another very dynamic year for the FCH 2 JU, marked by the greater impact made by its projects, progress on initiatives, important events and further development of its outreach activities. Furthermore, achievements in terms of leverage and budget execution reached historical highs, the error rate from H2020 *ex-post* audits remained low, and the strong internal control environment was confirmed.

Highlights during the year include:

- Continued progress was achieved in all areas, from the demonstration of vehicles to the operation of electrolisers for green hydrogen production, to name but a few, and not forgetting manufacturing processes and research for the next generation of applications, as described under section 1.2.1 of this report and in more detail in the 2019 Programme Review Report[1].

  Updated maps of FCH projects, a dedicated page on State-of-the-Art (SoA) and MAWP targets[2] are available on the FCH website as well as the European Supply Chain map[3].

  New success stories[4] were published covering subjects ranging from creating low-carbon and sustainable solutions, enabling market entry for new products, developing 'next-generation' products based on previous research, to opening new markets for European expertise in FCH technology.

- CertifHy 2[5] project was completed in March 2019 and has built on the momentum of the first phase. It has served as a catalyst for implementing an EU-wide GO scheme for green and low-carbon hydrogen and is a milestone towards a possible hydrogen certification mechanism in the context of the Renewable Energy Directive (RED II).

- The European Hydrogen Safety Panel (EHSP) updated and made public a safety guidance document[6] for FCH projects and programmes in Europe. Together with the Joint Research Centre (JRC), it also completed the review and assessment of the events contained in the European Hydrogen Safety Reference Database (HIAD.2.0) extracting the lessons learnt[7] and recommendations for future research in this field.

- Building on the work carried out in 2018 under the **Regions Initiative** and the conclusions of the report 'Fuel Cells and Hydrogen for Green Energy in European Cities and Regions'[8], a number of major developments took place, in particular:
  (1) The launch in May of the **European Hydrogen Valleys Partnership (EH-S3P)** under the Smart Specialisation Platform[9], which aims to enhance the role of green hydrogen in the European energy transition process.
  (2) The signature in October of a contract for managing a pilot **Project Development Assistance (PDA) facility** to help develop detailed project planning in regions and cities with a lower maturity level, paying special attention to Central and Eastern Europe. The aim is to work on project concepts and move them from their current stage to implementation.
  (3) The inclusion in the AWP2019 (topic FCH-03-1-2019) of an **H2 Valley topic** aiming to showcase a large demonstration (flagship) project with hydrogen as the energy carrier for various types of use (transport, power, heat and industry). This led to the award of a grant for HEAVENN[10], the successful 'H2 Valley' signed in December 2019, with an FCH contribution of EUR 20 million and total cost of EUR 82 million.

1 The report will be published in spring 2020 on the FCH 2 JU website: https://fch.europa.eu/page/programme-review-days-2018

2 https://www.fch.europa.eu/soa-and-targets

3 https://www.fch.europa.eu/page/FCH-value-chain

4 https://www.fch.europa.eu/sites/default/files/FCH%202019.4582-WEB-2.pdf

5 https://www.fch.europa.eu/page/certifhy-designing-first-eu-wide-green-hydrogen-guarantee-origin-new-hydrogen-market

6 https://www.fch.europa.eu/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects_Release1p31_20190705.pdf

7 https://www.fch.europa.eu/sites/default/files/Assessment%20and%20lessons%20learnt%20from%20HIAD%202.0.pdf

8 https://www.fch.europa.eu/sites/default/files/181123_FCHJU_Regions_Cities_Final_Report_FINAL.pdf

9 http://s3platform.jrc.ec.europa.eu/home

10 https://cordis.europa.eu/project/id/875090/it

- The FCH organised and attended a wide range of events throughout 2019, from project-oriented events to participation in major exhibitions and outreach events. Many of them provided a full range of communication coverage, including web streaming, promotion on social media, event branding and media engagement. Slido was used at most events organised throughout 2019, with polls and question-and-answer (Q&A) sessions leading to better engagement with the audience. Once again, the Joint Undertaking's flagship events – the Stakeholder Forum and the FCH 2 JU Awards – were at the centre of both policy and communication efforts.

  Stakeholder Forum 2019

  Under the title 'Racing towards a clean hydrogen economy', the Stakeholder Forum brought together the European Fuel Cell and Hydrogen community and facilitated an open discussion on the impact, achievements and strategic direction of the FCH 2 JU programme, as well as the latest developments in the sector.

  The conference enjoyed the participation of high-level representatives from the European Commission, national governments, European industry leaders and international organisations. They included Frans Timmermans, Executive Vice-President of the European Commission, Ditte Juul Jørgensen, European Commission Director-General for Energy, Mauro Petriccione, Director-General for Climate Action at the European Commission and Patrick Child, Deputy Director-General for Research and Innovation in the European Commission.

  FCH 2 JU Awards 2019

  The Awards were presented at a ceremony at the Royal Museums of Fine Arts in Brussels on **20 November 2019**, attended by around 300 representatives from industry, research and EU institutions. The 2019 Awards Ceremony was the second organised by the FCH 2 JU . The winners were chosen by public vote, which mobilised the European fuel cells and hydrogen community around the 24 nominees, 12 for each category (success stories and innovation).

- **Significant leverage**: In 2019, the leverage effect from only members reached 1.51 (compared to the required 0.57). In other words, for every euro of EU contribution for all signed H2020 FCH 2 JU grant agreements, as at 31 December 2019, members of Hydrogen Europe Industry and Hydrogen Europe Research committed to spend EUR 1.51 either on FCH 2 JU projects or on additional activities.

- **Budget execution** remained **excellent** with 86 % in terms of commitment appropriations and 98 % in terms of payment appropriations.

- In 2019, FCH 2 JU achieved **sufficient results from H2020 *ex-post* audits to form a solid base for an *ex-post* pillar of declaration on assurance** stemming from an indicative **representative error rate of –0.94 % (residual error rate of –0.70 %) on the FCH 2 JU contribution in H2020.**

- In 2019, FCH 2 JU was not the subject of an individual dedicated IAS audit. With all recommendations coming from prior audits closed before 2019, the IAS communicated that FCH 2 JU would only be the subject of two rather than three specific internal audits identified in the new Strategic Internal Audit Plan for 2019-2021. This further demonstrates that **FCH 2 JU continues to provide an excellent example of a mature, sound and well-controlled environment.**

- The smooth administrative functioning of the FCH 2 JU was further enhanced by the introduction of the e-Tendering and e-Submission modules, which significantly simplify the procurement activities.

- The FCH 2 JU Governing Board, the European Commission, Hydrogen Europe and Hydrogen Europe Research pursued strategic analysis and preparation for the future roadmap in the context of the next Framework Programme Horizon Europe and in the international context regarding climate and energy.

In this positive international and European context, it is expected that a future partnership – Clean Hydrogen Europe – will be instrumental in implementation of the clean energy transition, taking into account:

- the release of the International Energy Agency (IEA) report[11] in June at the G20 in Osaka, Japan which confirmed the key role hydrogen should play in the energy transition;

11 https://www.iea.org/reports/the-future-of-hydrogen

- the publication of the Global Action Agenda of the Tokyo statement[12] at the Hydrogen Energy Ministerial in September reaffirming that hydrogen can be a key contributor to clean, safe and affordable energy for the future;

- the identification by DG GROW of 'hydrogen technologies and systems' as a key strategic value chain for EU industrial policy[13] leading to its recognition as part of the Strategic Forum for Important Projects of Common European Interest (IPCEI)[14],

- the announcement of the European Green Deal[15] as a priority of the new European Commission and the declaration of Frans Timmermans, Executive Vice-President of the European Commission who sees 'a pivotal role for hydrogen' in Europe's goal of a climate neutral economy by 2050; and

- the strong achievements of the FCH 2 JU summarised here above and further developed in this report.

12 https://h2em2019.go.jp/summary/summary_en.pdf

13 https://ec.europa.eu/growth/content/hydrogen-climate-action_en

14 https://ec.europa.eu/docsroom/documents/37824

15 https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

INTRODUCTION

Council Regulation No. 559/2014 set up the current Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU) under the Horizon 2020 Framework Programme as a unique institutionalised public-private partnership (IPPP) supporting research, technological development and demonstration (RTD) activities in FCH technologies in Europe, aiming to accelerate their commercialisation by 2020. This demonstrates the EU's continued confidence and support for FC and hydrogen (FCH) as key technologies (fuel cells as an energy-efficient converter and hydrogen as a clean-energy carrier) for decarbonising Europe's energy system and creating a secure sustainable energy supply capable of generating new jobs.

Conscious of its dependence on imports of energy resources, mainly from unstable countries, the European Union (EU) has set targets to reduce the related risks. This is stated in the European Commission's (EC) 2014 Energy Security Strategy[16] which focuses on the need for improved energy efficiency as well as on the need to increase the EU's own energy production, to diversify supply sources and routes, to consolidate its internal energy system, and to protect its critical infrastructure.

At the international level, during the Paris climate conference (COP21) in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement sets out a global action plan to set the world on track to avoid dangerous climate change by limiting global warming to 2 °C, *'... and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius'*.

Underpinning this, the 2015 Communication from the European Commission[17] on 'A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy' includes – among all lines of action – energy security, solidarity and trust, energy efficiency, decarbonising the economy, and research, innovation and competitiveness.

In November 2016, the EC adopted the 'Clean Energy for All Europeans' package[18], which included revised legislative proposals covering energy efficiency, energy performance in buildings, renewable energy, the design of the electricity market, security of electricity supply, and governance rules for the Energy Union. In addition, the European Commission Staff Working Document (SWD) on Energy storage published as part of the 'Second Report on the State of the Energy Union', on 1 February 2017[19], outlines the role of energy storage in relation to electricity, presents the advantages of different technologies and innovative solutions in different contexts, and discusses further possible policy approaches. It has been acknowledged that energy storage, including hydrogen-storage-based solutions, has not yet developed its full potential in the energy markets. Developing affordable and integrated energy-storage solutions is highlighted as a priority to facilitate and enable the transition to a low-carbon energy system based largely on renewables.

On 8 November 2017, the European Commission also proposed to update the EU Gas Directive[20] to ensure that all major gas pipelines entering EU territory comply with EU rules, are operated with the same levels of transparency, are accessible to other operators, and are operated in an efficient way. The proposal aims to improve the functioning of the EU internal gas market, increase competition between suppliers, and boost Europe's energy security. The role of hydrogen is also mentioned as one of the solutions to decarbonise the EU gas network and increase security of supply.

On that same date, the European Commission adopted and published the so-called 'Clean Mobility Package' which sets out to reinforce the EU's global leadership in clean vehicles by proposing new targets for EU fleet-wide average CO_2 emissions from new passenger cars and vans to help accelerate the transition to low- and zero-emission vehicles. As part of the package, an action plan and investment solutions were proposed for the trans-European deployment of alternative fuels infrastructure, which includes hydrogen as one of the clean fuels for transport. The aim is to raise the level of ambition of national plans, to increase investment, and to improve consumer acceptance. In addition, a proposal was made to amend the Clean Vehicles Directive to promote clean mobility solutions in public procurement tenders, thereby providing a solid boost for demand and the further deployment of clean mobility solutions, including fuel cell vehicles.

Furthermore, in 2018, for the first time there was a global agreement within the International Maritime Organization (IMO) on targets to reduce greenhouse gas (GHG) emissions from maritime transport by a minimum of 50 % by 2050 and phase them out completely before the end of the century. This represents a substantial challenge and the possibility of using fuel cells, together with hydrogen or other zero-carbon fuels, as a very promising energy source for large-scale shipping is increasingly being considered.

16 European Energy Security Strategy, (SWD(2014) 330 final).

17 COM(2015)80, Energy Union Package.

18 Clean Energy for All Europeans package: https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition

19 https://ec.europa.eu/energy/sites/ener/files/documents/swd2017_61_document_travail_service_part1_v6.pdf

20 https://ec.europa.eu/info/news/commission-proposes-update-gas-directive-2017-nov-08_en

On 18 September 2018, the use of hydrogen as a future-oriented energy form was among the items on the agenda of the informal meeting of EU energy ministers[21]. *'The Austrian Presidency of the Council of the European Union proposed a hydrogen initiative that many Member States approved of and signed,'* said Elisabeth Köstinger, chair of the EU energy minister meetings. *'Under this initiative, the signatory states commit to continuing research and investment in the production and use of hydrogen as a future-oriented technology,'* she added. EU Commissioner Miguel Arias Cañete also welcomed the initiative of the Austrian Presidency of the Council of the European Union: *'Green hydrogen offers significant potential for the decarbonisation of the European economy. The Commission warmly welcomes the hydrogen initiative as it will further harness the innovative drive across the EU.'*

In November 2018, the European Commission published the 2050 long-term strategy[22] calling for a climate-neutral Europe by 2050 (COM (2018) 773). The strategy shows how Europe can lead the way to climate neutrality by investing in realistic technological solutions, empowering citizens, and aligning action in key areas such as industrial policy, finance or research – while ensuring social fairness for a just transition. *'The eight scenarios build upon no-regret policies such as strong usage of renewable energy and energy efficiency. Five of them look at different technologies and actions which foster the move towards a net-zero greenhouse gas economy. They vary the intensity of application of electrification, hydrogen and e-fuels (i.e. power-to-X) as well as end-user energy efficiency and the role of a circular economy, as actions to reduce emissions.'* In all these pathways, electricity consumption increases although there are notable differences. *'Pathways that focus more on electrification in end-use sectors also see the need for high deployment of storage (six times today's levels) to deal with variability in the electricity system, but pathways which deploy more hydrogen require more electricity to produce the hydrogen in the first place.'* It also concludes that: *'Pathways more reliant on carbon-free energy carriers require less transformation and investment in the end-use sector, but also the highest investment needs in the energy supply sectors'*. Consequently, *'further significant steps in research and development are needed in the production of decarbonised fuels as well as vehicle technologies such as batteries, fuel cells and hydrogen gas engines'*. Furthermore, *'EU research should focus on transformational carbon-neutral solutions in areas such as electrification (renewables, smart networks and batteries), hydrogen and fuel cells, and energy storage.'*

In line with its ultimate long-term strategy and following the political agreement reached by the Parliament and the Council in June 2018, the revised Renewables Energy Directive (RED II)[23] establishes a binding EU target of at least 32 % for 2030, with a view to increasing this figure in 2023. In this context, it calls on Member States to establish a methodology for guarantees of origin of renewable gases (including hydrogen) and subsequently a certification system.

In December 2018, Member States also submitted their draft integrated National Climate and Energy Plans (NECPs)[24] for the period 2021-2030. Several have already made ambitious plans based on (renewable) hydrogen to decarbonise their entire economy. The final plans had to be submitted by the end of 2019.

In June 2019, the Common rules for the internal market for electricity Directive[25] entered into force. It establishes common rules for the generation, transmission, distribution, energy storage (including hydrogen) and supply of electricity, together with provisions for consumer protection, with a view to creating truly integrated competitive, consumer-centred, flexible, fair and transparent electricity markets in the EU. Within the same package, Regulation (EU) 2019/943 on the internal market for electricity[26] entered into force which sets *'fundamental principles for well-functioning, integrated electricity markets, which allow all resource providers and electricity customers non-discriminatory market access, empower consumers, ensure competitiveness on the global market as well as demand response, energy storage and energy efficiency, and facilitate aggregation of distributed demand and supply, and enable market and sectoral integration and market-based remuneration of electricity generated from renewable sources'*.

As regards all the policy developments in 2019, as described above, the FCH 2 JU has addressed them through many actions, research and demonstration activities both in line with the above-mentioned EU-wide objectives as well as with all of its objectives as listed in Council Regulation 559/2014 of 6 May 2014. The Annual Activity Report (AAR) highlights the main activities and the achievements of the FCH 2 JU in 2019 in line with the Annual Work Plan (AWP) 2019 adopted by the Governing Board (GB) on 17 December 2018.

21 https://www.eu2018.at/latest-news/news/09-18-Informal-meeting-of-energy-ministers.html

22 https://ec.europa.eu/clima/policies/strategies/2050

23 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC

24 https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans

25 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0944&from=EN

26 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0943&from=EN

01
IMPLEMENTATION OF THE ANNUAL WORK PLAN 2019

1.1 KEY OBJECTIVES 2019 AND ASSOCIATED RISKS

The overall objective of FCH 2 JU is to implement an optimal research and innovation programme at the EU level to develop a portfolio of clean and efficient solutions that exploit the properties of hydrogen as an energy carrier and fuel cells (FC) as energy converters to the point of market readiness. This will provide feedback and related support to EU policies on sustainable energy and transport, climate change, the environment and industrial competitiveness, as embodied in the Europe 2020 strategy, and job creation. It will also help to achieve the EU's overarching goal of smart, sustainable and inclusive growth. The overall direction of the programme is guided by the multi-annual plans: Multi-Annual Implementation Plan (MAIP) for 2008-2014 under FP7 and MAWP for 2014-2020 under Horizon 2020. These plans specify targets for the state of FCH technologies in Europe (covering cost, durability and performance) and specific key performance indicators (KPIs). The programme's progress and therefore scientific/technological achievements are always assessed according to the progress towards achieving these targets and KPIs. As the technology has progressed substantially in recent years and new applications have begun to emerge, these KPIs (fixed in 2014) were revised and included in an addendum to the MAWP, endorsed by the FCH 2 JU GB on 15 June 2018. The main objectives and achievements are presented in Section 1.2.

Leverage effect in H2020

A key objective and measure of the JUs' success is their capacity to leverage private funding.

On the one hand, calculation of the *leverage effect* takes into account the operational component (private financial and in-kind contributions to projects for each euro committed by the European Commission) and, on the other hand, any additional leverage (private contributions to additional activities not directly linked to the project portfolio but contributing to the JUs' overall objectives).

The Council Regulation establishing the FCH 2 JU[27] explicitly mentions **the minimum target leverage effect over the whole 2014–2020 period at 0.57**[28].

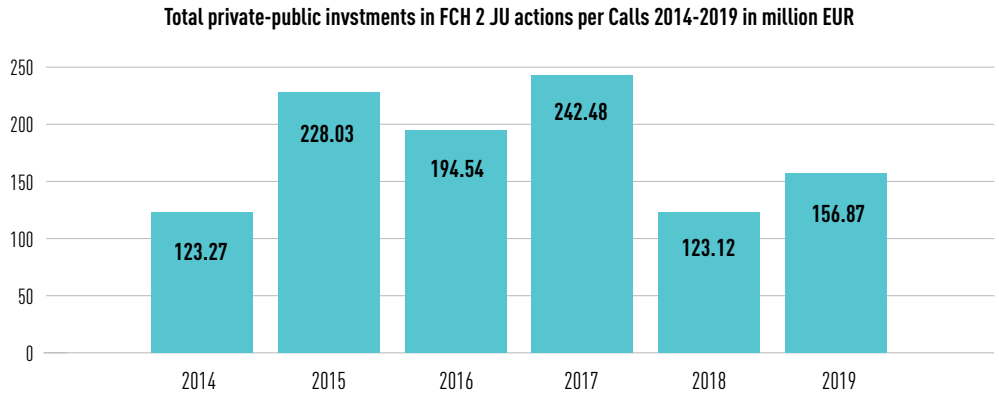
In 2019, the FCH 2 JU aimed to demonstrate to the Council and European Parliament that the overall commitment of the industry and research has significantly surpassed the minimum requirement of EUR 380 million for H2020.

By the end of 2019, under the H2020 programme, the FCH 2 JU had supported **109 projects for a combined public–private investment of more than EUR 1 billion**.

27 Council Regulation (EU) No. 559/2014 of 6 May 2014 establishing the Fuel Cells and Hydrogen 2 Joint Undertaking.

28 Total minimum contribution from members other than the EU (EUR 380 million) over the total EU contribution (EUR 665 million).

CHART 1.1.1: TOTAL COMMITTED PRIVATE AND PUBLIC INVESTMENT IN FCH 2 JU ACTIONS OVER 2014-2019 IN EUR MILLION



In addition, in 2019, industry and research members **surpassed the threshold of EUR 665 million of additional activities certified** (covering the years 2014-2018).

This demonstrates the sector's huge willingness to invest.

For a detailed calculation of the leverage-effect formula, the following contributions made by members other than the EU and their constituent or affiliated entities have been considered:

- Contributions to the **administrative costs** of the FCH 2 JU;
- Co-financing required to carry out research and innovation actions supported by the FCH 2 JU (i.e. contributions to indirect actions through **co-funding FCH 2 JU projects**, the so-called '**IKOP**');
- Contributions towards additional activities by members other than the EU or their constituent or affiliated entities, as specified in an additional activities plan. These **additional activities** (so-called '**IKAA**') should represent contributions to the broader Fuel Cells and Hydrogen Joint Technology Initiative and the sector as a whole.

The amounts of each contribution, as at 31 December 2019, are detailed in the tables below.

Administrative costs

TABLE 1.1.1: FINANCIAL CONTRIBUTIONS OF THE MEMBERS TO FCH 2 JU ADMINISTRATIVE COSTS IN 2014-2019

CONTRIBUTIONS TO RUNNING COSTS RECEIVED BY 31 DECEMBER 2019 / YEAR	INDUSTRY GROUPING	RESEARCH GROUPING	TOTAL
	CASH IN EUR	CASH IN EUR	CASH IN EUR
2014	259,244	42,203	**301,447**
2015	412,288	67,116	**479,404**
2016	401,937	65,432	**467,369**
2017	48,812	7,946	**56,758**
2018	2,014,054	327,869	**2,341,923**
2019	2,308,907	375,869	**2,684,776**
Total 2014-2019	**5,445,242**	**886,435**	**6,331,677**

The lower amounts of cash contributions until 2017 can be explained by the fact that the administrative costs were also funded by Seventh Framework Programme (FP7) contributions.

In-kind contributions in operational activities (IKOP)

The table below provides an overview of private-sector co-financing in all FCH 2 JU projects signed up to 31 December 2019. The total amounts committed per FCH 2 JU member, per all private partners and per the EU are broken down according to individual Calls.

When comparing total private contributions in projects to the total EU contribution, we can observe a close parity of 1:1 (EUR 537 million of EU committed contribution vs. EUR 532 million of private contributions).

TABLE 1.1.2: IN-KIND CONTRIBUTIONS AND EU CONTRIBUTIONS FOR GRANTS UNDER CALLS 2014-2019

CALL YEAR	NUMBER OF PROJECTS	TOTAL EU CONTRIBUTION (A) IN EUR	COMMITTED IN-KIND CONTRIBUTIONS (IKOP) FROM MEMBERS (B) IN EUR	COMMITTED IN-KIND CONTRIBUTIONS FROM NON-MEMBERS (C) IN EUR	TOTAL COMMITTED PRIVATE CONTRIBUTIONS (D = B + C) IN EUR	TOTAL COMMITTED EU + PRIVATE CONTRIBUTIONS (E = A + D) IN EUR
Call 2014	15	80,456,120	26,670,180	16,139,012	42,809,193	123,265,313
Call 2015	15	107,234,987	61,724,104	59,074,494	120,798,599	228,033,586
Call 2016	19	93,974,248	6,786,153	93,782,331	100,568,484	194,542,732
Call 2017	24	114,318,293	16,093,338	112,064,517	128,157,855	242,476,147
Call 2018	19	71,610,138	10,190,872	41,316,583	51,507,455	123,117,592
Call 2019	17	69,129,862	14,793,889	72,947,702	87,741,592	156,871,453
TOTAL	**109**	**536,723,647**	**136,258,538**	**395,324,639**	**531,583,177**	**1,068,306,824**

Considering that funding rates in projects follow H2020 rules (i.e. up to 100 % of direct costs in research and innovation actions (RIAs) and coordination and support actions (CSAs) and up to 70 % in innovation actions (IAs)), these private contributions are significantly higher than was initially foreseen. This is due to the fact that most of the largest demonstration projects have effective funding rates lower than 70 % (of direct costs), as they are very close to the market.

In-kind contributions in additional activities (IKAA)

The underlying purpose of *additional activities* is to demonstrate private investments in the sector and ensure a balanced contribution is made by both the private and public entities in the context of the partnership.

In 2019, members of Hydrogen Europe and Hydrogen Europe Research and their affiliate entities jointly delivered a cumulative amount of EUR 667 million certified IKAA (for the period 2014-2018), which is significantly more than the minimum requirement for IKAA of EUR 285 million, as defined in the Council Regulation.

In addition, for 2019, the members estimated the certification of an additional EUR 238 million of extra activities, demonstrating a strong and continuous commitment to the goals of the partnership.

IKAA IN EUR MILLION	2014/2015	2016	2017	2018	2019	TOTAL
Certified IKAA as at 31 December 2019	217.56	164.65	107.34	177.45	-	**667.00**
IKAA Preliminary Report 2019*					238.26	**238.26**
TOTAL IKAA	**217.56**	**164.65**	**107.34**	**177.45**	**238.26**	**905.26**

** Estimated figures for the year 2019, reported to the FCH 2 JU Governing Board based on information available as at 31 January 2020, subject to certification later in 2020*

More details on in-kind contributions for additional activities can be found in section 1.7.

Values of leverage effect for the Calls concluded by December 2019

The following values have been taken into account in order to combine an operational component and additional activities part of private investments over public investment in the FCH 2 JU:

TABLE 1.1.4: VALUES OF LEVERAGE EFFECT AS AT 31 DECEMBER 2019 COMPARED TO THE OVERALL HORIZON 2020 TARGETS

CONTRIBUTIONS FOR LEVERAGE EFFECT CALCULATION IN MIL. EUR		TARGET CONTRIBUTIONS AS PER FCH 2 JU COUNCIL REGULATION	FORMULA A	FORMULA B1[29]	FORMULA C
EU		665	537	537	537
Members	Administrative expenses (paid as at 31 December 2019)		6	6	6
	IKOP (actual & committed as at 31 December 2019)		136	136	136
	IKAA certified (2014 – 2018)		667	667	667
	IKAA estimated (2019)				238
	Total members	380	**809**	809	1047
Non-Members	Contributions to actions (Call 2014 – 2019)			395	395
	Sub-total Members + Non-members	n/a	n/a	**1204**	**1443**
Leverage effect		***0,57***	***1,51***	***2,24***	***2,69***

(A) Leverage effect – members only as at 31 December 2019 = (**6.33** + **136.11** + **667.00** / **536.72**) = 809 / 537 = **1.51**

In other words, for every EUR 1 of EU contribution for all FCH 2 JU signed H2020 grant agreements up to 31 December 2019, members of Hydrogen Europe Industry and Hydrogen Europe Research committed to spend EUR 1.51 either on FCH 2 JU projects or in certified additional activities.

(B) Leverage effect – all private partners as at 31 December 2019 = (**6.33** + **531.58** + **667.00** / **536.72**) = 1 205 / 537 = **2.24**

This formula is fully aligned with the method used in the SWD accompanying the Interim Evaluation of the PPPs[30].

Compared to the previous formula (A), in addition to the contributions from members other than the EU, it also includes contributions to FCH 2 JU projects from non-members of Hydrogen Europe or Hydrogen Europe Research members.

In other words, for 1 EUR of EU contribution for all FCH 2 JU signed H2020 grant agreements until 31 December 2019, the private partners committed to spend EUR 2.24 either on FCH 2 JU projects or in certified additional activities.

(C) Leverage effect – all private partners as at 31 December 2019 (including estimated additional activities of members for 2019) = (**6.33** + **531.58** + **905.26** / **536.72**) = 1 443 / 537 = **2.69**

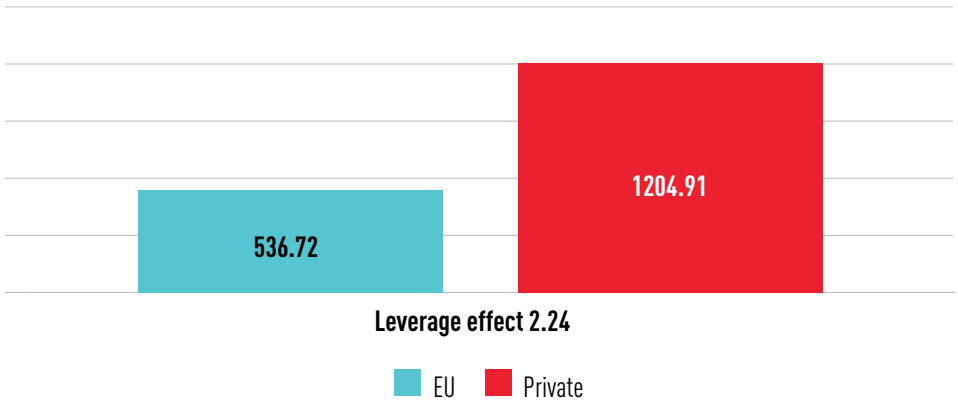
This third calculation also encompasses *additional activities* of members for 2019. In other words, for EUR 1 of EU contribution for all FCH 2 JU signed H2020 grant agreements until 31 December 2019, the private partners committed to spend EUR 2.69 either on FCH 2 JU projects or in *additional activities*.

While the definite amount of leveraged funding will only be known at the end of the JU's operations, current values for the leverage effect point to private-sector **committed funding** that **already exceeds the set targets by as much as four times the minimum**.

29 http://ec.europa.eu/research/evaluations/pdf/20171009_a187_swd.pdf, page 44, Table 12.

30 http://ec.europa.eu/research/evaluations/pdf/20171009_a187_swd.pdf, page 44, Table 12.

CHART 1.1.2: TOTAL COMMITTED PRIVATE AND PUBLIC INVESTMENT IN FCH 2 JU OVER THE PERIOD OF 2014-2019 (COMMITTED PRIVATE FUNDING IN ALL SIGNED FCH 2 JU ACTIONS AND CERTIFIED ADDITIONAL ACTIVITIES 2014-2018) UP TO 31 DECEMBER 2019



Risk assessment – 2019

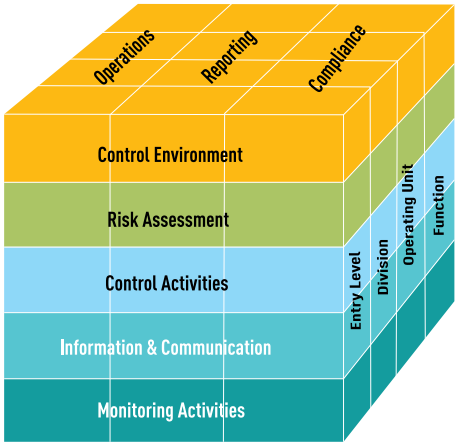
Risk management is a crucial part of the strategic decision-making process. Robust risk management frameworks help to ensure that taxpayers ' money is used effectively and efficiently, that potential risks to achieving objectives are identified in a timely fashion and that appropriate mitigating action is taken.

On 16 August 2018, the FCH 2 JU Governing Board adopted a new Internal Control Framework (ICF) – referring to document ARES (2018)4420458 **stemming from the most updated internationally acknowledged COSO model of internal control** (see the illustration below), in line with the EC's ICF.

In 2019, the main elements of the transition to the new ICF which were required to be observed were:

- 17 principles are more evenly spread over 5 components (as opposed to older internal control standards where most standards were linked to the 'control activities' component);
- the five components must operate together in an integrated manner – therefore, **a risk assessment exercise should be conducted in conjunction with other components**;
- four interlinked principles of the ICF must be present and functioning under the 'risk assessment' component *which specifies suitable objectives, identifies and analyses risk, assesses fraud risk and identifies and analyses significant change.*

COMMITTEE OF SPONSORING ORGANIZATIONS OF THE TREADWAY COMMISSION (COSO) MODEL OF INTERNAL CONTROL – INTEGRATED FRAMEWORK



Source: https://www.coso.org/Documents/990025P-Executive-Summary-final-may20.pdf

To enable the requirements of the four main principles for the 'risk assessment' component to be fulfilled, the following guiding questions were incorporated into the **annual risk management exercise, conducted in October 2019**, whereby the FCH 2 JU team assessed risks and responses to those risks in terms of the action plans presented in the AWP 2019:

- Are the risks and action plans identified in the previous year's exercise and presented in the AWP 2019 still relevant?
- Are the Programme Office (PO) objectives clearly set and up to date? Are there any significant risks to the achievement of AWP/MAWP objectives that emerged during the course of this year?
- Are there any fraud-related risks which are not covered by controls in place?
- Are there any significant changes in the external/internal environment that can have a significant impact on our organisation?

The aim of this annual exercise was **to identify risks that could harm achievements of the FCH objectives**, including (among others) operational, financial and compliance risks.

During the exercise, the following aspects of all the risks presented in AWP 2019 were assessed:

1. Relevance of the risk -> is the risk still present? Has it materialised?
2. Rating the risk -> did the rating (in terms of impact/likelihood) increase or decrease?
3. Relevance and fulfilment of the action plan -> should we continue/expand/reduce action plans?

Based on internal discussions involving all personnel in the organisation, the risks were either removed (when considered no longer relevant) or modified, while the action plans were reviewed for adequacy and completeness.

The table below provides a summary of the outcome of the exercise on risks and fulfilment of the action plans, as at 31 December 2019:

TABLE 1.1.5: FULFILMENT OF THE ACTION PLANS

RISK IDENTIFIED – AWP 2019	ACTION PLAN – AWP 2019	STATUS AS AT 31 DECEMBER 2019
Due to Brexit, programme participation by UK entities (currently representing a significant part of FCH 2 JU funding) at the application stage and during project execution could be adversely affected, including fluctuations in project budgets and commitments from UK-based companies.	Follow developments closely; maintain active dialogue with the EC.	During 2019, the participation of UK-based entities declined, although not dramatically. There is more clarity in the process (the Brexit withdrawal agreement). There is only one more Call left in H2020 so the risk level has been lowered to medium.
Business continuity risk in the case of key staff turnover due to the JU's lean structure.	In case of the absence of key staff, FCH 2 JU ensures appropriate back-up solutions in the short term. In the medium term, FCH 2 JU is prepared to hire short-term temporary contract people (e.g. interims) to ensure full business continuity. Other potential measures should be explored.	Reducing the risk to low. Having taken measures in 2019, the FCH did not experience any increased turnover during the year. Back-up plans and on-the-job training, including job-enrichment opportunities were explored. Priority training and efficiency training were provided.
Timely execution and closure of the *ex-post* audits for H2020 (including less control over the H2020 *ex-post* audit process due to the transfer of the responsibility to the Common Implementation Centre (formerly Common Support Centre) at the EC, which could weaken the assurance of the Executive Director.	For H2020 audits, an active dialogue via regular participation on joint meetings has been established with the CIC's Common Audit Support unit. JUs' horizontal issues are addressed by cooperation with other JUs. Timely monitoring and actions are ensured via regular dialogue between the Executive Director and Internal Control and Audit manager. Monitoring function of the H2020 audits should be further enhanced via SYGMA/COMPASS workflows.	Reducing risk to low. FCH addressed the issue and suggested appropriate measures for monitoring the process in a letter to the director of the Common Implementation Centre (CIC). On receipt of the letter, CIC replied by streamlining the process and prioritising the JUs' audits, acknowledging a priority closure by the need for a separate discharge. In case of prolonged audits, those are closely monitored by FCH and discussed with responsible EC personnel, with no delays. SYGMA/COMPASS workflows for audit process were introduced and put to use in 2019 which further improved the monitoring of the audit status. Full functionality of the SYGMA/COMPASS based on agreed working arrangements is expected in 2020.

Representative error rate may increase due to the simplified *ex-ante* controls under H2020 agreed horizontally for the research family. Significant representative error rates in H2020 due to decreased *ex-ante* controls. Consequently, risk of receiving a qualified opinion and not getting the discharge from the European Parliament due to fact that the Court of Auditors' threshold for representative error rate stays at 2 %.	Introduction of the targeted *ex-ante* controls for the projects/ beneficiaries with an identified higher inherent risk. Application of the feedback from *ex-post* audits and lessons learnt on *ex-ante* controls. Reinforcement of communication campaign with introduction of financial webinars.	Since FCH is still at the beginning of the H2020 *ex-post* audit campaign, and taking into account pressures from the EC and European Court of Auditors (ECA) to reduce audit samples, the effect of a few negative errors may have a lasting effect on the overall representative error rate. Controls at *ex-ante* level remain very limited and simplifications introduced by H2020 did not significantly reduce the overall RTD-level error rate.
A leak of confidential data from projects to the public and a breach of confidentiality clauses signed by the Authorising Officer with FCH 2 JU beneficiaries due to the lack of assurance coming from the CIC in the implementation of the Dissemination Strategy (due in particular to the incorrect design of the IT tools which are intended to handle confidential data in H2020).	Closely follow recent developments in IT tools by participating in the dedicated Dissemination and Exploitation Network (D&E-Net) working groups. Continuous dialogue with the CIC in order to reach an agreement on the treatment of confidential data and related liabilities.	The risk no longer exists since FCH, together with other JUs, has taken appropriate measures to safeguard data confidentiality. Sensitive data remain confidential at FCH level. The issue of access to confidential data remains to be resolved under the new Horizon Europe Framework Programme. Further to his action, a letter was sent to the director of the CIC (Ref. Ares(2019)4123649 – 28/06/2019) concerning access to JU project results and confidential information.
Disruption of operations due to the incorrect functioning of the IT tools, their continuous development and failure of the IT equipment.	Back-up systems are in place to mitigate loss of data. Regular follow-up is performed on the IT issues raised via tickets. Participation in training for new software and tools introduced via CIC/locally. Ensure back-up and proper documentation for the tools developed internally.	Level of the risk was reduced to low. Proper training and continuous improvements in using the IT tools, including new tools, is envisaged. There were no instances of disruption of operations due to IT-related failures. Business continuity plans are in place and fully tested. Mock test of the plans will be carried out on an annual basis. Some internally developed tools are scheduled to be replaced by EC tools in 2020 to ensure appropriate back-up, maintenance support and problem resolution. Since there was an instance where the knowledge-management tool did not function for a period of one month, the service provider contract management has been revised and strengthened to avoid repetition in 2020. Appropriate back-up systems were put in place.

The outcome of the 2019 risk assessment workshop on new or continuing risks for 2020 are included in the AWP 2020.

In 2019, in addition to a regular risk assessment exercise, **FCH 2 JU participated in a 'peer review' exercise** which brought together **all decentralised agencies to discuss the critical risks** identified by each of them individually. Agencies working in the same area or facing similar types of risks were encouraged to share their risk assessments to enable an **exchange of best practices on methodology**, helping to promote coherence in the identification and assessment of risks and in developing responses to them.

FCH 2 JU participated in this peer review exercise with its risk identified in 2018 in one of the six clusters, the **Move and Energy Cluster.**

As a result of this exercise (in which 32 agencies participated), and thanks to the feedback gathered, **FCH 2 JU refined its risk assessment process** and, in its action plan for AWP 2020, took inspiration from the best practices developed by the other services.

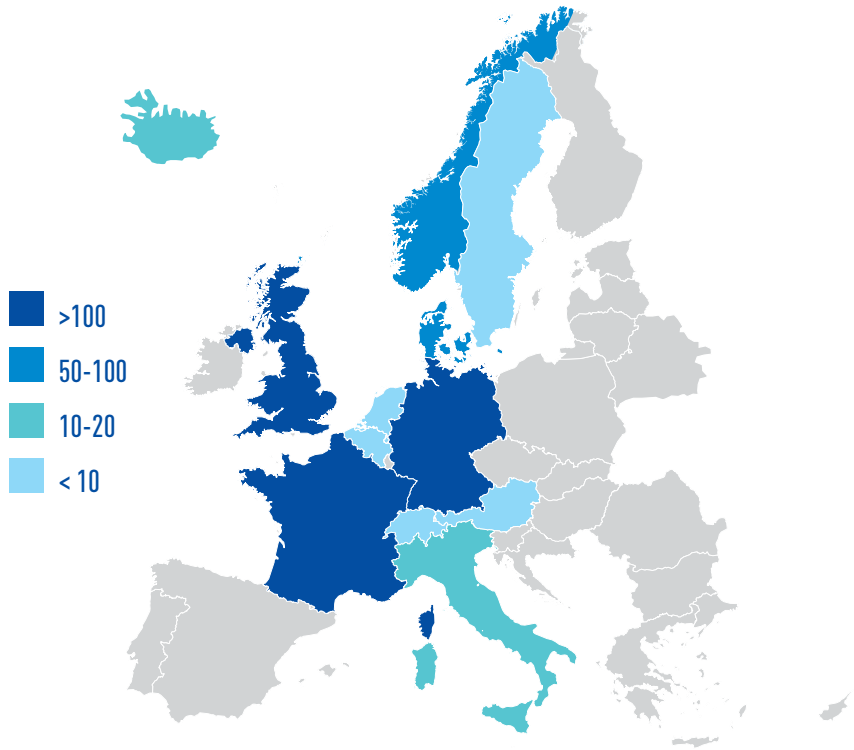
1.2 RESEARCH AND INNOVATION ACTIVITIES

1.2.1 SCIENTIFIC AND TECHNOLOGICAL ACHIEVEMENTS

FCH 2 JU demonstration projects currently deploy over 2 000 **light-duty vehicles**, more than 840[31] of which were already in operation in 2019 (while the rest are planned for the coming years within the projects that are still running). Over the last year, the recently finished SWARM[32] project has successfully deployed 13 small, low-weight hybrid electric-hydrogen vehicles in three EU regions. H2ME and H2ME2 are successfully continuing their activities, having deployed 124 cars in 2019, while the ZEFER[33] project has been working to demonstrate viable business cases for captive fleets of FCEVs (fuel cell electric vehicles) such as taxi, private hire and police services. The project managed to deploy 71 light-duty vehicles used as taxi fleet in Paris and Brussels as well as police cars in London.

Based on data collected in 2019 in TRUST (Technology Reporting Using Structured Templates) on the performance of 378 cars (running in 2018), these vehicles drove at least 5.2 million kilometres (km) for a reported consumption of 57 tonnes of hydrogen. In comparison to 2017 figures of 1.83 million km driven and the consumption of 23 tonnes, this significant increase is the result of taxi fleet operations and the more intensive use of cars. In total, FCH 2 JU-funded cars[34] have now driven a total of almost 10 million km and accumulated over 80 tonnes of H2 since 2016. The average fuel consumption of 1.17 kilogramme (kg) per 100 km[35] is close to the MAWP 2020 target (1.15 kg per 100 km) and therefore it could be claimed that this target has been achieved. The average vehicle availability reached 99.7 % in 2018 which means the expected MAWP 2020 targets for availability (98 %) and fuel cell system durability (5 000 hours) have also been accomplished[36]. The cars are ready for commercialisation with a driving range of up to 594 km and over 150 000 km travelled by one single car in FCH 2 JU projects.

FIGURE 1: DISTRIBUTION OF FCEV DEPLOYED BY FCH 2 JU DEMONSTRATION PROJECTS



31 Excluding 40 decommissioned (after project end).

32 www.swarm-project.eu/

33 https://zefer.eu/

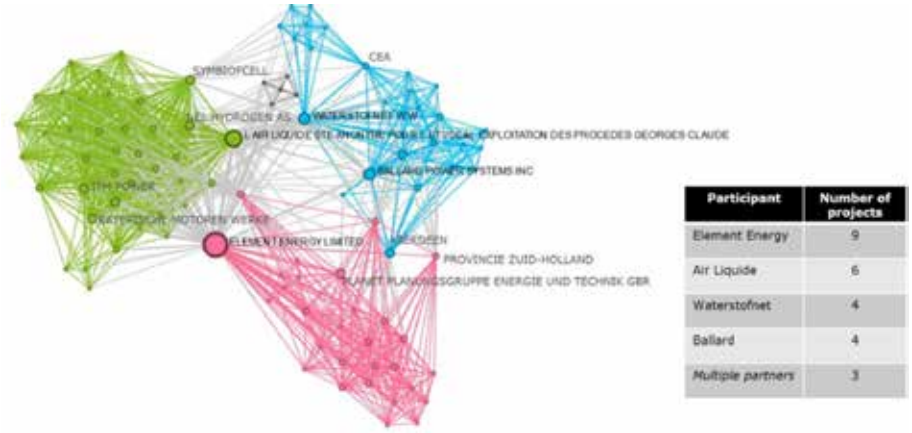
34 Including hybrid vehicles (symbio).

35 Average fuel consumption was calculated by combining the reported driving ranges with the declared fuel consumptions; projects only reporting one of the two parameters were excluded from the average fuel consumption calculations.

36 For all projects reporting these specific data.

As regards the beneficiaries involved, Figure 2[37] shows the connections between partners under this cluster of projects (as extracted from the TIM[38] tool). It can be seen that there are groups of consortia with certain players providing links between the groups. The green grouping largely includes the fleet related to H2ME, H2ME[39] and 3EMOTION[40], whilst the blue grouping contains the partners within the bus and material handling vehicles (MHV) projects (e.g. HIGH V.LO CITY[41], HyTransit[42], HyLIFT[43]). The pink grouping is mainly the partners within the JIVE and JIVE2[44] consortia. The key players providing the links between these groups are Element Energy, which generally acts as project coordinator, FC system suppliers such as Ballard, and hydrogen refuelling station (HRS) providers (such as Air Liquide). Figure 2 also presents the three main clusters in which vehicles and infrastructure are being demonstrated: Belgium-Netherlands, United Kingdom, and France-Germany-Italy.

FIGURE 2: TIM PLOT SHOWING THE PARTICIPANTS IN 11 PROJECTS[45]; THE INSET TABLE SHOWS THE TOP FIVE PARTICIPANTS



Participant	Number of projects
Element Energy	9
Air Liquide	6
Waterstofnet	4
Ballard	4
Multiple partners	3

To meet the **hydrogen refuelling** requirements for further EU uptake, the necessary infrastructure network is also currently being deployed in FCH 2 JU projects. The geographical coverage of hydrogen refuelling infrastructure is expanding into new cities and regions, supporting the increasing number of FCEV being deployed (see Figure 1). The deployment of refuelling stations in new regions (e.g. Iceland, Bordeaux, Nancy) is enabling the enlargement of coverage by FCH 2 JU demonstration projects. In densely populated areas (London or Paris), the concentration of several HRS supports the emergence of and allows for the flexible service of taxi fleet or private car-hire systems. This has positively influenced hydrogen sales, load and availability of the fuelling stations involved.

The total number of HRS is 101 (including planned, deployed and two decommissioned units), 64 of which (46 for cars, 10 for buses, 8 for MHVs) have already been deployed (48 were reported in 2018[46]). Currently, there is about 1 HRS per 15 vehicles and it is expected that with the 66 HRSs planned, in addition to the car fleets which are on the way, the ratio will be 1 HRS per 25 vehicles.

To date, the FCH 2 JU-funded HRS network **for cars** covers 10 countries and, in 2018, delivered 40.3 tonnes[47] of hydrogen in 18 600 refuelling operations. The average HRS availability was 90.4 % (although average availability from 2016 is >96 %), possibly due to higher HRS usage

37 The size of the node (circle) represents the number of projects a partner is involved in, whilst the thickness of the lines linking the nodes represents the number of projects two partners have in common. TIM indicates clusters of partners by colour using its own algorithm. For clarity, only the partners involved in the largest numbers of projects are shown.

38 https://www.fch.europa.eu/page/tools-innovation-monitoring-tim

39 https://www.3emotion.eu/

40 https://www.3emotion.eu/

41 http://highvlocity.eu/

42 https://www.fuelcellbuses.eu/projects/hytransit

43 http://www.hylift-europe.eu/

44 https://www.fuelcellbuses.eu/projects/jive

45 Ongoing during 2018, reported in 2019 data collection exercise.

46 In TRUST data collection exercise, reflecting buses under ongoing FCH 2 JU projects during 2018.

47 This number does not entirely match the consumption of hydrogen reported above for cars as some FCH 2 JU-funded HRS are also open to the public and not simply restricted to FCH 2 JU projects.

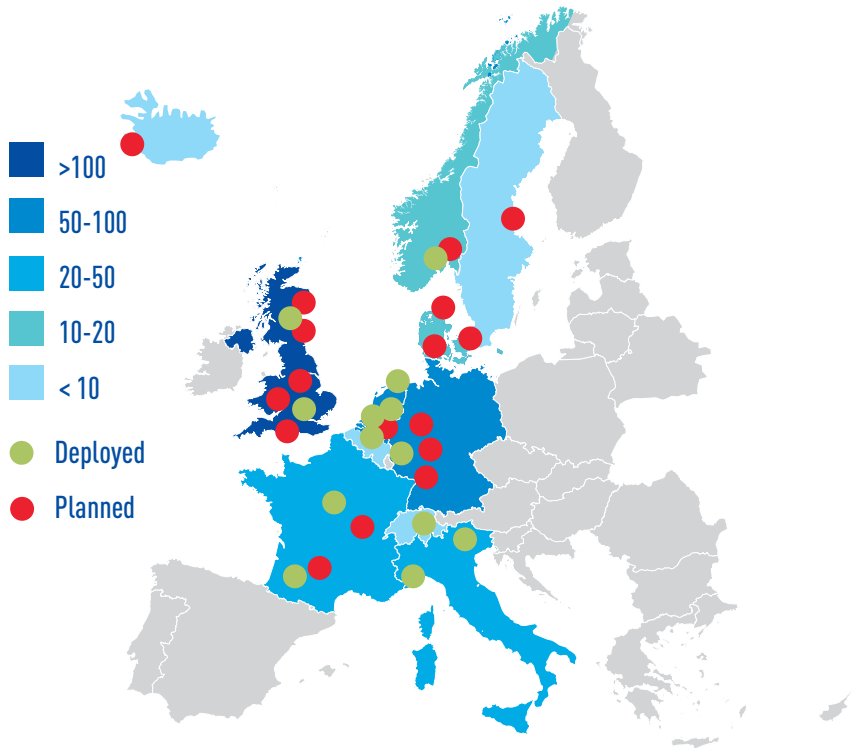
resulting in more frequent breakdowns. Most of these installations already meet the MAWP 2020 targets for station capital expenditure (CAPEX) of 2.1 €/kg/day. Car demonstration projects report that 94 % of dispensed hydrogen (based on mass) was produced using electricity certified as 'green'.

Further activities concerning the hydrogen-refuelling infrastructure include the EU HRS availability system[48], an initiative also funded by the FCH 2 JU, which offers a portal providing information regarding the live status of each HRS in Europe. Currently, 139 hydrogen-refuelling stations are connected and send live data.

In supporting all these activities, FCH 2 JU also executed a study on 'Proposition of a Testing Protocol for Certification of Existing and Future HRS – Development of a Metering Protocol for Hydrogen Refuelling Stations[49] which aims to define, in agreement with EU national metrological institutes, a structured approach for enabling the certification of metering systems for HRS in Europe. The test protocol was tested at seven HRSs (not all associated to FCH 2 JU projects) in Europe. These tests were finalised in the spring of 2019 and the final report is under publication.

Bus demonstrations concerned 54 vehicles[50] operating in 10 cities while more than 300 are planned for deployment in the next few years (see Figure 3). EU FCH bus deployment can be considered SoA, having grown considerably from earlier projects to the most recent. In that respect, the targeted bus prices, hydrogen price and maintenance costs are well in line with FCH 2 JU MAWP targets, considering the project time horizon of 2023.

FIGURE 3: DISTRIBUTION OF BUSES DEPLOYED BY THE FCH 2 JU DEMONSTRATION PROJECTS



Considering the bus demonstrations reported in TRUST between 2016 and 2018, a total distance of over 7 million km has been accumulated, with close to 1 million km added in 2018. In the last three years, over 421 tonnes of hydrogen have been consumed. In 2018, the minimum fuel consumption was reported at 8 kg hydrogen per 100 km, meeting the 2020 MAWP target (the values range from 8 to 10.2 kg/100 km) and recording an important improvement compared to 2017 when the most efficient value reported reached 9 kgH_2/100 km.

Furthermore, the 2020 MAWP targets for FC system cost and vehicle cost (based on procurement prices) have also been met while those for FC system durability (20 000 h) as well as those for yearly operating costs (16 000 €/kW) are still to be achieved with the new fleets to be deployed. Availability results of 80.4 % reveal the impact of ageing degradation, including the fact that the buses are adversely affected by the long period required to receive replacement parts from international suppliers.

48 https://h2-map.eu/

49 https://www.fch.europa.eu/publications/proposition-testing-protocol-certification-existing-and-future-hrs

50 Excluding five deployed buses that have been discontinued after project end.

Current bus demonstrations have provided further positive evidence on the performance and functionality of hydrogen fuel cell buses and associated refuelling infrastructure, steadily reducing barriers for their commercialisation in the short term. Operational experience has been acquired with different bus drive trains and with different methods of hydrogen production. The availability and cost of FCH buses seem to have profited from the experience gained from former projects and are improving with time. A good exchange of information and experience among FC buses demonstration projects has been noticed, too.

FCH 2 JU has also funded the related installation of 11 HRSs in 10 European cities, reaching an average availability of 97 % since the start of operations. Despite fluctuations in the reported average availabilities over time, according to Figure 4, the best values were close to 100 % which demonstrate a strong position for bus refuelling stations and a steady increase in the availability of light-duty vehicles (LDV) refuelling stations – also taking into consideration the increasing use of those HRSs over time. The amount of H2 dispensed between 2016 and 2018 exceeded 400 tonnes (Figure) while, in 2018, only 110 tonnes were consumed in 5 600 refuelling operations. More than 87 % of this dispensed hydrogen was produced using electricity certified as 'green' in the projects.

FIGURE 4: HRS AVAILABILITY VALUES REPORTED IN TRUST (2016-2018)

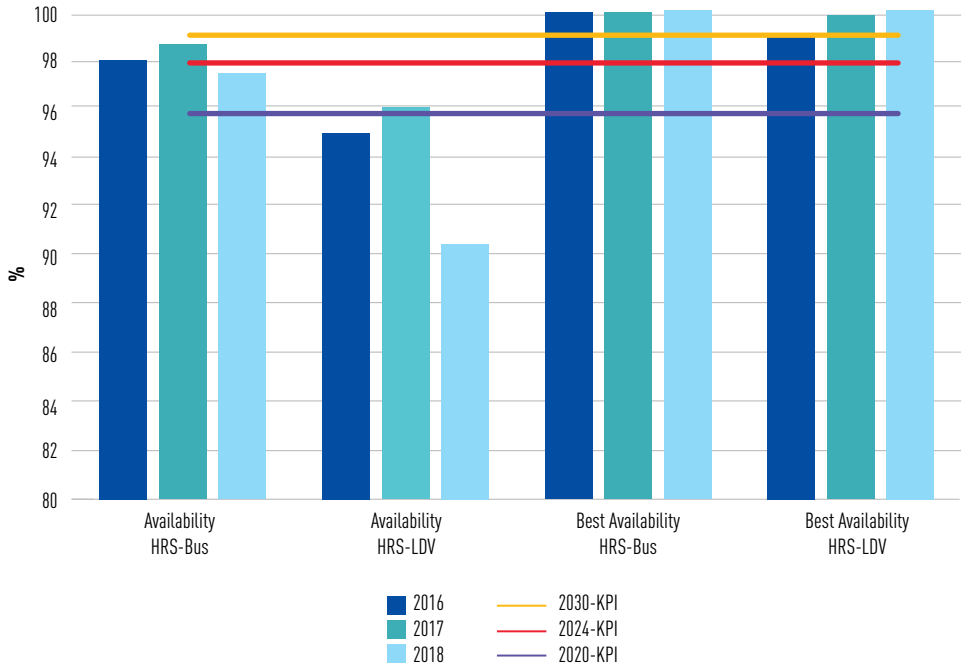
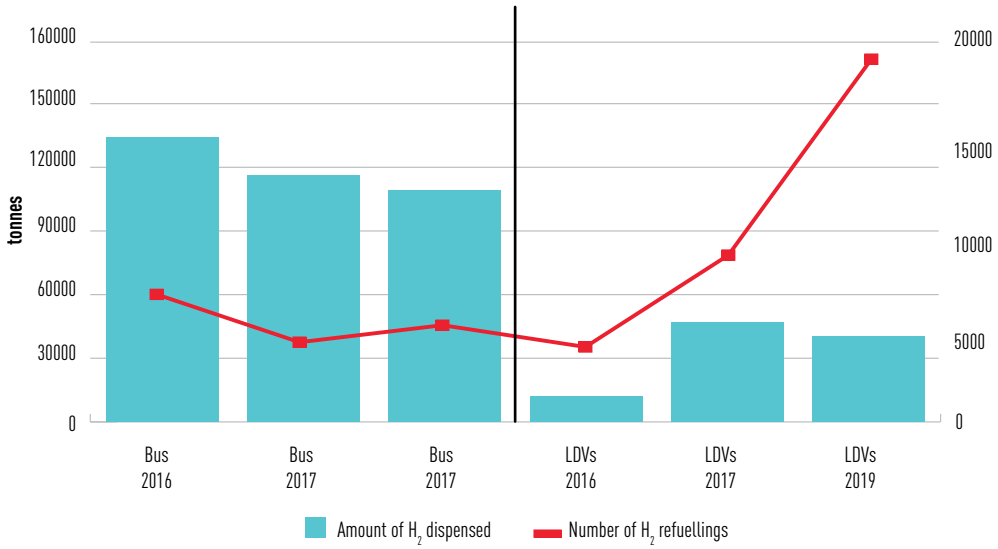
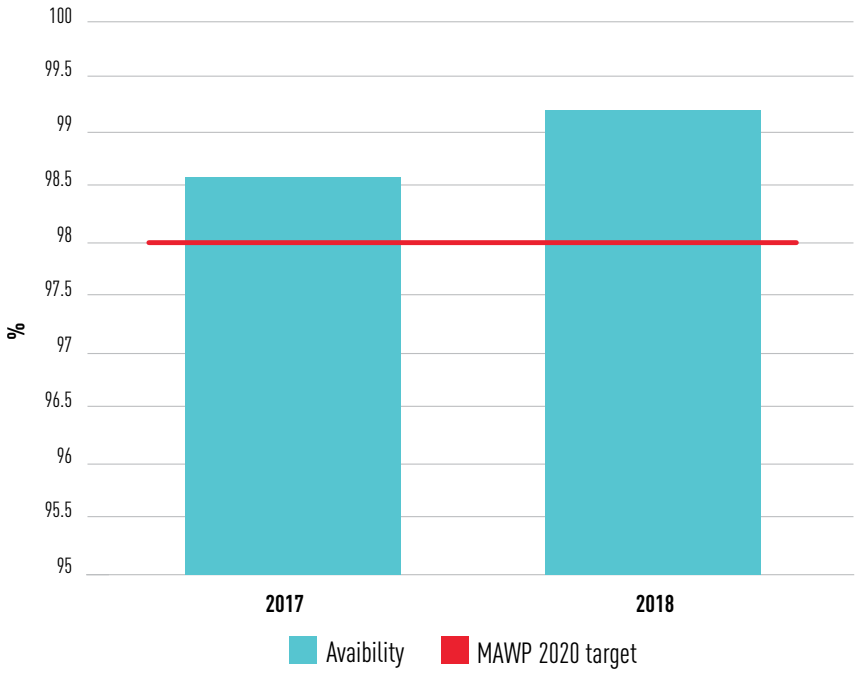


FIGURE 5: AMOUNT OF H_2 DISPENSED AND NUMBER OF H_2 REFUELLINGS REPORTED IN TRUST FOR BUS AND CARS HRS (2016-2018)



Although demonstrations of MHVs finished in 2018, they were still captured in the 2019 data collection exercise. HyLIFT-EUROPE[51] managed to demonstrate and operate a fleet of 212 MHVs across two sites. These vehicles are technically mature enough for commercialisation, and some EU MHV manufacturers are already offering FCH MHVs for the European market. Based on the project findings, a number of different FC systems have been certified for use in the EU, and satisfactory system performance by FC-based MHVs with hydrogen refuelling has been confirmed for indoor applications. Thanks to the FCH 2 JU-funded demonstration of hydrogen MHVs, a national French regulation for hydrogen in warehouse applications has been established as well as a best practice document for obtaining approval when installing airside HRS in airports. MHV demo activities accumulated more than 2 million hours of operation (2016-2018) with about 335 000 hours in 2018 alone. In 2018, 68 100 refuelling operations were performed which, when compared to 2017, show more intensive use with fewer refuellings but a higher volume of H_2 dispensed. 2020 MAWP targets for the mean time between failures (750 h) and availability (99.2 %) have all been achieved, or even surpassed (FIGURE 6).

FIGURE 6: AVAILABILITY VALUES REPORTED IN TRUST VS. MAWP 2020 TARGETS



In 2018, heavy-duty truck applications began within the FCH 2 JU with the REVIVE project which demonstrates heavy-duty rubbish trucks. During 2019, the trucks were still under construction and the first vehicles will soon be deployed. REVIVE[52] is potentially very relevant for the FCH 2 JU programme as it will set the basis and SoA for future HDV demonstration projects. Its activities also include life-cycle assessment (LCA) accounting for the reduction of CO_2 emissions, air pollution and noise. REVIVE is expected to improve the readiness of FC technologies to fit heavy-duty vehicles and thus will help to develop an EU fuel cell supply.

Similarly, the FCH 2 JU is now moving into field demonstrations for more heavy-duty applications (demonstrating and exploiting the results from the research activities – see below) and has just started to support more activities in maritime, port-related applications and aviation (see more details below).

As regards **research-oriented activities for transport applications**, aligned with the FCH 2 JU objective of ´minimal use of critical raw materials,[53] the PEGASUS[54] project has already achieved the synthesis of platinum group metals (PGM)-free catalysts with four different routes (pathways) and benchmarked different non-noble metals as active catalytic centres. It integrated the synthesised PGM-free catalyst in membrane electrode assemblies (MEAs) printed by the deposition of a thin (50 µm) active layer and designed a scanning electrochemical microscopy set-up to benchmark materials against *ex-situ* fine electrochemical measurement. Project CRESCENDO[55] also developed two diagnostic methods for determining

51 http://www.hylift-europe.eu/

52 https://h2revive.eu/

53 https://www.fch.europa.eu/page/multi-annual-work-plan

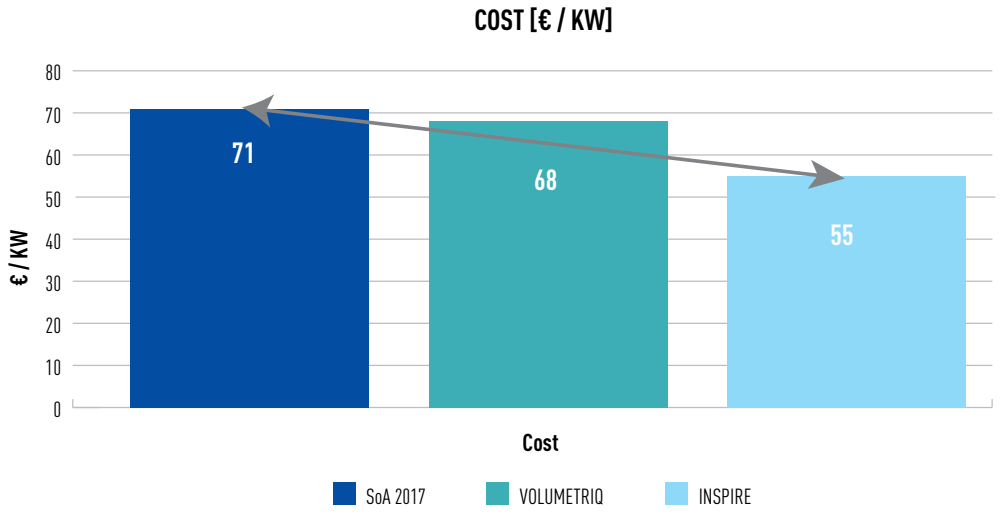
54 https://www.pegasus-pemfc.eu/

55 https://www.crescendo-fuelcell.eu/

active site density and turnover frequency of non-PGM catalysts. To date, CRESCENDO has reached most of its ambitious targets, including the ultimate catalyst activity, MEA performance and durability. For both projects, the understanding generated and the clear development pathways developed in the first half of project duration should place them in a good position to reach their final targets within their lifetime.

Considerable progress in the production of SoA **stacks for automotive applications** was also achieved by dedicated projects focusing on delivering mature stack components and production lines able to meet automotive performance specifications in large volume production along with innovative quality and control (QC) techniques. Building on experience gained in earlier projects, INSPIRE[56] and VOLUMETRIQ[57] managed to produce FC stacks (rated capacities of 120 kW in VOLUMETRIQ, 150 kW in INSPIRE and 98kW in INN-BALANCE[58]) while showing progressive cost reduction (Figure 7). Volumetric energy densities and areal energy densities showing progress towards MAWP targets with values of 7.1 kW/l and 1.6 W/cm_2, respectively (Figure 8). In addition, the achieved mass activity of 0.6 A/mg_{Pt} (INSPIRE) already meets the project's target. However, the cathode catalyst loading remains at 0.3 mg_{Pt}/cm_2 as against the MAWP target of <0.125 mg_{Pt}/cm_2 (Figure 4) and therefore needs further work. Finally, VOLUMETRIQ demonstrated a new manufacturing technique optimised for high quantities to guarantee high-quality manufacturing throughput and implemented new QC tools.

FIGURE 7: FUEL CELL STACK COSTS SOA 2017 VS. VOLUMETRIQ, INSPIRE PROJECTS

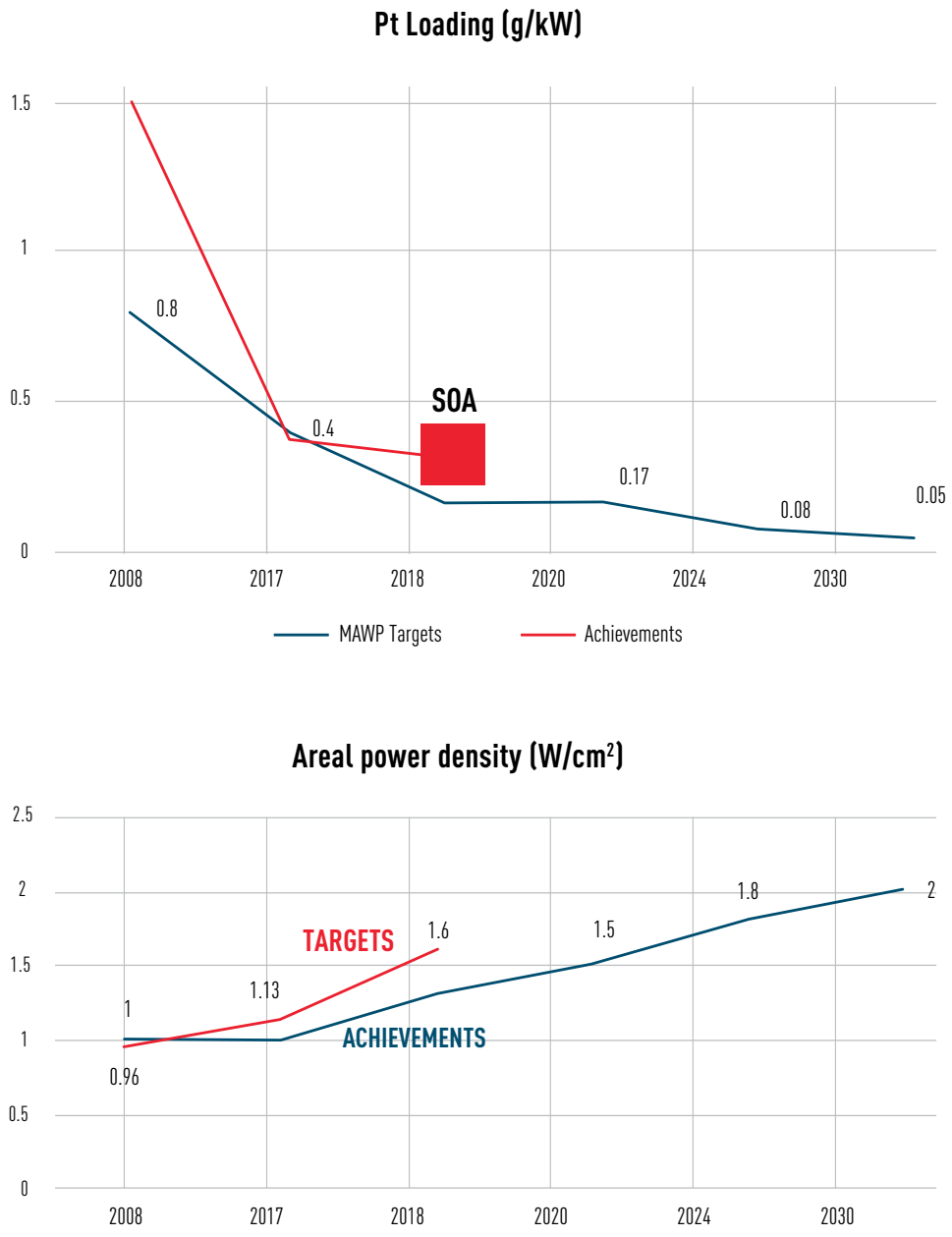


56 https://www.inspire-fuelcell.eu/

57 https://www.volumetriq.eu/

58 https://www.innbalance-fch-project.eu/

FIGURE 8: TARGETS AND ACHIEVEMENTS FOR PLATINUM LOADINGS AND AREAL POWER DENSITY; THESE TWO KPIS CAN BE COMBINED TO OBTAIN AREAL PLATINUM LOADINGS



The successful outcome of these projects, including DIGIMAN[59], Fit-4-AMandA[60], INLINE[61] and INN-BALANCE stems from the involvement of automotive original equipment manufacturers (OEMs) taking part as project partners or via industrial advisory boards. Another reason for their success is due to a well-established 'stepwise approach' going through research and development (R&D) cycles, each feeding into the next (including continuation projects) when complete. The quality assurance and quality control activities performed in the aforementioned projects have the potential to act as enablers for market growth and to establish an effective manufacturing chain.

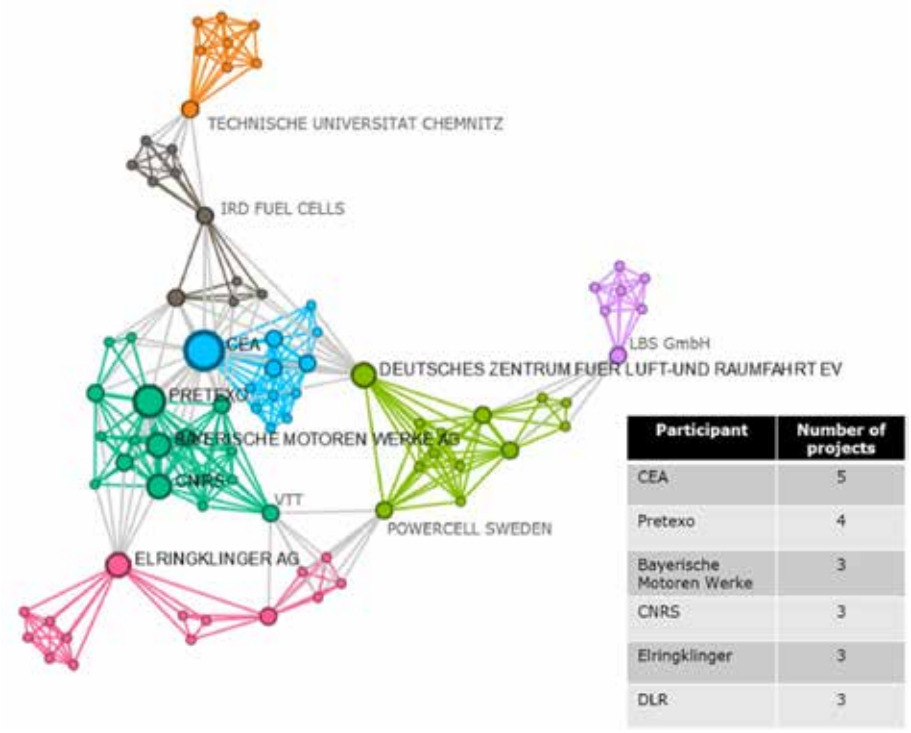
59 https://digiman.eu/

60 https://fit-4-amanda.eu/

61 https://www.inline-project.eu/

Figure 9 shows the connections between the partners participating in these relevant FCH 2 JU projects. It shows how consortia are often quite independent from each other, with individual partners often providing links between projects. There are some notable exceptions, namely the two projects dedicated to aeronautic applications (HYCARUS[62] and FLHYSAFE[63]) which are largely present in the blue cluster. The green cluster includes partners in the manufacturing projects INSPIRE[64], VOLUMETRIQ[65] and DIGIMAN[66]. In terms of geographical prominence, Germany and France are most active in low technology readiness level (TRL) transport research activities.

FIGURE 9: TIM PLOT SHOWING THE PARTICIPANTS IN 15 PROJECTS; THE INSET TABLE SHOWS THE TOP SIX PARTICIPANTS[67]



Participant	Number of projects
CEA	5
Pretexo	4
Bayerische Motoren Werke	3
CNRS	3
Elringklinger	3
DLR	3

As regards research activities on **refuelling (compression) and on-board hydrogen storage**, the COSMHYC[68] and H2REF[69] projects both address the advances in the technology of compressing hydrogen at refuelling stations by focusing on building and testing novel prototype compressors. COSMHYC is developing a hybrid system by combining a metal hydride compressor and a mechanical diaphragm compressor. H2REF is developing a novel hydraulic-based compression and buffering system. They both have high potential for improving the techno-economics of hydrogen compression at refuelling stations where the compressor is a critical component as it is still the main source of a station's downtime. The compressor developed by COSMHYC may also have potential in decentralised hydrogen storage. Interaction with projects which demonstrate hydrogen refuelling stations is common practice nowadays with COSMHYC benefiting from the experience gained in the H2ME car demonstration project, for example. COSMHYC has already improved the prototype design and also aims to design the technical specifications for an energy consumption below 6 kWh/kg of hydrogen.

62 http://hycarus.eu/

63 https://www.flhysafe.eu/

64 https://www.inspire-fuelcell.eu/

65 https://www.volumetriq.eu/

66 https://digiman.eu/

67 In this plot, the size of the node (circle) represents the number of projects a partner is involved in, whilst the thickness of the lines linking the nodes represents the number of projects two partners have in common. TIM indicates clusters of partners by colour using its own algorithm. For clarity, only the partners involved in the largest numbers of projects are shown.

68 https://cosmhyc.eu/

69 https://cordis.europa.eu/project/id/671463

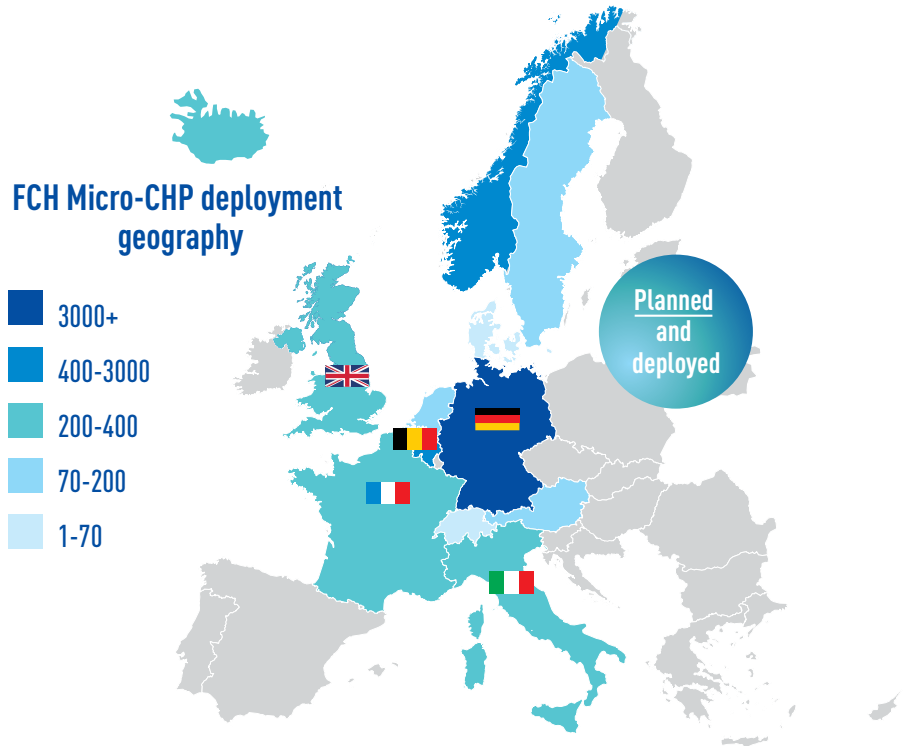
As regards on-board storage, the TAHYA[70] project provides a safe, complete and high-performance hydrogen-storage system, cost competitive in the mass production of a credible EU brand. The project has delivered a first prototype to Volkswagen for implementation in a car prior to launching the optimisation process. The efforts made towards meeting the set targets seem promising, particularly as regards cost reduction.

Continuing with activities related to **auxiliary power units (APUs) and FC system integration**, nowadays this is a topic of growing interest in the **maritime sector** because of the expected changes in the regulation of emissions in the near term. Ship operators see hydrogen as a means to meet ever-stringent emission limits. Project MARANDA[71] develops specific components for FC systems used in maritime environments (high humidity and salinity) giving safety aspects due consideration. The project is also identifying Regulatory Codes and Standards (RCS) gaps which act as a bottleneck for the implementation of hydrogen technologies in this sector.

The HYCARUS project has already developed an **aviation APU** as a final prototype while the process permitting this prototype to fly in a pressurised aircraft cabin has still to be completed. The FLHYSAFE project, which draws on experience gained in HYCARUS, will develop and test a modular FC system (FCS) to replace the current Ram Air Turbine (RAT) technology used for emergency power in a commercial aircraft. To date, this project has already completed the emergency power unit system specification, including a detailed functional analysis.

Fuel cells have also shown great potential for the provision of **heat and power in domestic and small commercial buildings** due to their high total and electrical efficiencies and their ability to run on conventional heating fuels. Cost reduction in the PACE[72] project comes mainly from the shift to automatic production lines and the introduction of the next generation of systems. It is Europe's largest deployment of FC μ-CHP (combined heat and power) to date and has already allowed manufacturers to start reducing costs and build markets. By the end of October 2019, the number of sold systems exceeded 1 700 while the number of physical commissioning reached 892 units. In general, CAPEX is on average in line with SoA references for 2017 (13 000 €/kW), and some OEMs have already reached 2020 targets (10 000 €/kW) (see FIGURE 11). Reported average availability lies between 93 % and 100 %, most often being higher than 97 % (already achieving the MAWP 2020 target). The reported average lifetime (12.3 years), the average durability of key components (stacks) (55.5 kh), and the efficiency (both electrical 47.4 % and thermal 40 %) are also in line with the expected SoA references for 2017 and MAWP 2020 targets.

FIGURE 10: DEPLOYED AND PLANNED FC MICRO-CHP INSTALLATIONS ACROSS THE EU

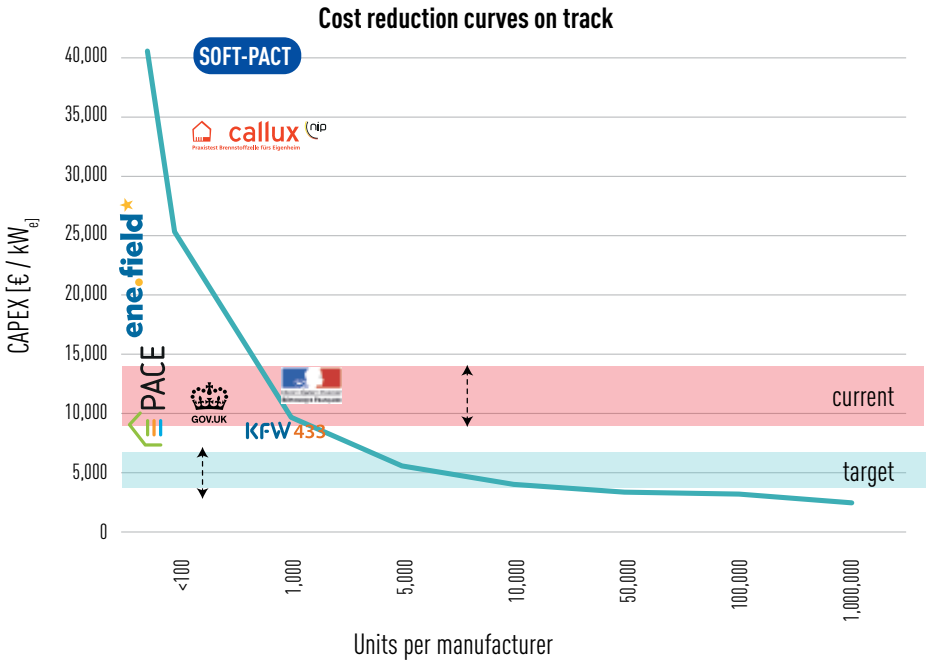


70 https://tahya.eu/

71 https://www.vtt.fi/sites/maranda

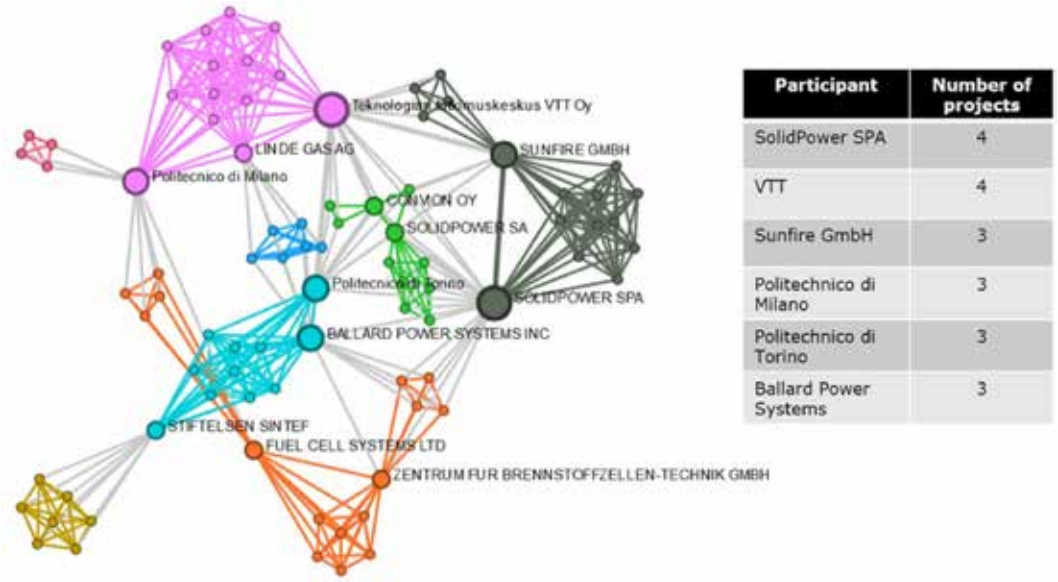
72 http://www.pace-energy.eu/

FIGURE 11: TECHNOLOGY READINESS AND MARKET UPTAKE FOR MICRO-CHP SYSTEMS IN THE EU



In general, as regards FC for **power production (stationary FC CHP)**, Figure 12 shows how consortia are strongly linked to each other. Only two projects have just one partner in common with other projects and there are no stand-alone projects with no interactions. All other consortia have multiple links between one another. The key partners are the FC stacks/system providers SOLIDpower, Sunfire, Ballard and Convion; universities: Politecnico di Milano and Politecnico di Torino; and research institutes VTT (Teknologian tutkimuskeskus), ZBT (Zentrum Fur Brennstoffzellen-Technik GmbH) and SINTEF. In terms of Member State participation, Italy participates in the most projects in this panel, followed by Germany and the UK. Mid-eastern Europe is represented by Croatia, Poland and Hungary.

FIGURE 12: TIM PLOT SHOWING THE PARTICIPANTS OF 13 PROJECTS; THE TABLE INSERT SHOWS THE TOP 6 PARTNERS[73]



Participant	Number of projects
SolidPower SPA	4
VTT	4
Sunfire GmbH	3
Politechnico di Milano	3
Politechnico di Torino	3
Ballard Power Systems	3

73 In this plot, the size of the node (circle) represents the number of projects a partner is involved in, whilst the thickness of the lines linking the nodes represents the number of projects two partners have in common. TIM indicates clusters of partners by colour using its own algorithm. For clarity, only the partners involved in the largest numbers of projects are shown.

FCH 2 JU has also continued demonstrations of **mid-size FC applications**. The DEMOSOFC[74] project plans to install a 175 kW_e system which is expected to supply ~30 % of the site's electricity consumption and almost 100 % of the thermal energy. During 2018, a cumulative number of 7 470 h of operation were completed, confirming high electrical efficiency (53 % electrical and 31 % thermal), which meant the efficiency SoA figures for 2017 were also met. Within the same sector, the ComSos[75] project aims to demonstrate the advantages of a mid-sized SOFC-based CHP system in an industrial or utility services environment.

Based on knowledge from the transport sector, the AutoRE[76] project targets the **Proof of Concept CHP system** in industrial environment based on a 50 kW_e automotive proton exchange membrane (PEM) FC stack. The goal is to reduce system costs by using an FC that is already fabricated in commercial volumes associated with the automotive sector. The CH2P project focuses on flexible solid oxide fuel cell (SOFC)-based co-generation of heat, power and hydrogen for distributed H_2 production in HRSs. High conversion efficiency (up to 75 %), stack durabilities up to 40 000h and low-cost hydrogen (<4.5 €/kg) are expected.

The demonstration of **large-scale FC systems** aims to overcome deployment difficulties and identify business models suitable for large installations, while most of the MAWP 2020 objectives are still to be achieved. in December 2019 the CLEARgenDemo[77] project successfully installed a 1-megawatt (MW) FC system in Martinique[78]. Knowledge from this project will be taken up for a power-to-power national project in French Guyane.

The project DEMCOPEM-2MW[79] has demonstrated a CHP PEM FC power plant (2 MW_e and 1.5 MW_{th}[80]) integrated into a chloralkali production plant. The by-product hydrogen is used to generate electricity, heat and water for the chloralkali production process, lowering electricity consumption by 20 %. The demonstration site was selected in China because of profitable market conditions (and the related technology business model), such as its high electricity price, problems with stability of electricity supply and the high potential of chlor-alkali production. Since September 2016, the PEM in operation has been working for 11 240 h, with net electric efficiency of 55 % LHV. The plant produced more than 13 GWh of electricity and provided over 7 GWh of thermal energy at approximately 65 °C. Plant average availability reached 95 %. The project claims excellent flexibility in terms of part-load, standby operation and on-off control for plant operation. The costs (CAPEX and OPEX – operating expenses) related to a possible roll-out phase are estimated at 3 000 €/kW, which is in line with the MAWP targets for 2020.

Demonstrations projects focusing on **off-grid applications** offer FC solutions both in remote places as well as in temporarily powered event areas. The REMOTE[81] project aims to prove the technical and economic feasibility of FC technologies combined with renewables and hydrogen-storage solutions in the four island grids or remote areas. The systems will replace fossil fuels and will enable costs for new transmission lines to be avoided (two locations), and local communities to be served – both residential and small industry needs. The project has already reported a stack durability of 20 000 h and rated electrical efficiency at 40 %. Similarly, the EVERYWH$_2$ERE[82] project aims to demonstrate FC technology replacing diesel-fuelled internal combustion engine (ICE) temporary gensets, 4x25 kW + 4x100 kW during music festivals, temporary events, and at construction sites, and to evaluate the logistical and techno-economic feasibility of this solution. The project has already reported a CAPEX of 5 500 €/kWe (fully integrated genset), stack durability of 10 000 h, and a rated electrical efficiency of 55 %, which need to be confirmed now by real operation figures.

In preparing for field demonstrations, the **proof of concept** project STAGE-SOFC[83] has developed a 5 kW_e SOFC system prototype for small-scale CHP and off-grid applications. The first prototype has achieved electrical efficiency of >45 % and thermal efficiency of 40 % without much water handling. The FC supplier has also reported a lifetime of 10 years, stack durability of 20 000 h, and 99 % availability (based on 100 h laboratory operation time).

As regards FC energy research-oriented activities, both the HEALTH-CODE[84] and INSIGHT projects are currently working on '**Next generation, degradation, performance and diagnostics**' activities. They have already achieved the expected targets in fault-detection accuracy and claim to have enabled an increase in FC lifetime with a small financial impact (less than three percentage points on the system cost). One significant

74 http://www.demosofc.eu/

75 https://www.comsos.eu/

76 https://www.autore-eu.com/

77 https://www.cleargen.eu/

78 https://sara-cleargen.sciencesconf.org/

79 https://demcopem-2mw.eu/

80 Although foreseen conceptually, there is no plan to integrate the heat into the industrial system.

81 https://www.remote-euproject.eu/about/

82 http://www.everywh2ere.eu/

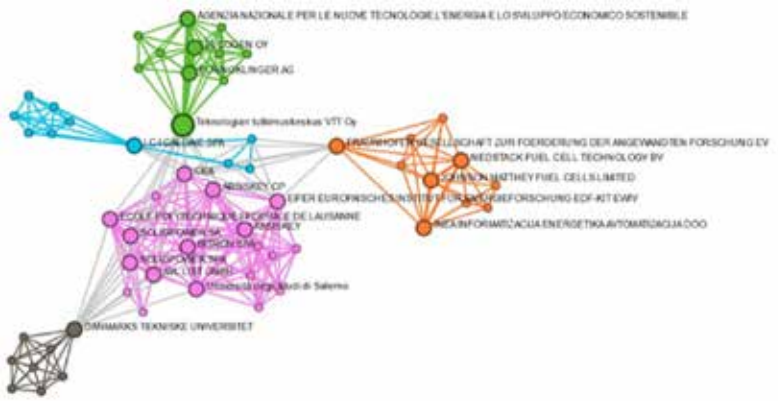
83 https://cordis.europa.eu/project/id/621213

84 https://pemfc.health-code.eu/

experimental result achieved by INSIGHT concerns the build-up of a library of data associated with typical faults and associated mitigation measurements. Although the detection of faults at the cell level has been satisfactorily proven with a good level of accuracy, the detection at stack level remains challenging.

FIGURE 13 shows the connections between partners present in the projects and how consortia in this area are quite independent from one another, the only exceptions being HEALTH-CODE[85] and INSIGHT[86]. Italy and Germany are the strongest contributors in this panel, and in the demo activities, too.

FIGURE 13: TIM PLOT SHOWING THE PARTICIPANTS IN 10 PROJECTS; THE INSET TABLE SHOWS THE TOP 5 PARTICIPANTS[87]



Participant	Number of projects
VTT	3
DTU	2
Nedstack	2
Johnson Matthey	2
Multiple other participants	2

Building on the results of previous demonstration projects ('feedback-loop'), GRASSHOPPER[88] is developing the concept for a new MW-size PEM FC power plant. A 100kW stack was developed with improved components, and the balance of plant (BoP) will be tested soon. The design phase is complete and focuses on reducing the cost while increasing the durability of a MW-size FC. In addition, the OxiGEN[89] project aims to develop an all-ceramic SOFC platform based on the Saint-Gobain SOFC design, with a focus on improving the efficiency and durability of the stack. In total, FC stacks from projects in this area have accumulated more than 60 000 hours of operation since 2016.

In manufacturing processes, every consortium has used varying approaches to improve and enable the manufacturability of essential SOFC and PEM stack components. The projects' overall goal is to make possible the efficient manufacturing upscaling of FC technologies.

As regards manufacturing processes, the Cell3Ditor[90] project has developed all process materials (inks and slurries), a 3D printer and the manufacturing process (and has developed the necessary process for patenting all of these innovative solutions). The HEATSTACK[91] project has also achieved good results in terms of design, including the reduction of chromium evaporation in the cathode air preheater. The SOSLeM[92] project is developing new and optimised processes for the production of FC interconnectors by lean manufacturing processes, improved sealing adhesion, and automation of the welding process for SOFC stack production. In addition, the qSOFC[93] project has developed new automated vision-machine-inspection methods and novel stack manufacturing/conditioning procedures, thereby increasing the speed of the Elcogen manufacturing line. Compliance with REACH Regulations for the manufacturing process has also been investigated and achieved. The rated electrical efficiency for SOFC has reached an impressive maximum of 74 $\%_{el}$ at stack level.

85 https://pemfc.health-code.eu/

86 http://insight-project.eu/

87 In this plot, the size of the node (circle) represents the number of projects a partner is involved in, whilst the thickness of the lines linking the nodes represents the number of projects two partners have in common. For clarity, only the partners involved in the largest numbers of projects are shown. TIM indicates clusters of partners by colour using its own algorithm. For clarity, only the partners involved in the largest numbers of projects are shown.

88 http://www.grasshopperproject.eu/nedstack/

89 http://oxigen-fch-project.eu/

90 http://www.cell3ditor.eu/

91 http://www.heatstack.eu/

92 https://www.soslem.eu/

93 http://www.qsofc.eu/

Finally, the INNO-SOFC[94] project has developed a 60-kW SOFC system based on an all-EU value chain. The project interfaced with other FCH 2 JU projects and thus adopted the stack developments advanced by the NELLHI[95] project and exchanged technical information with other consortia (qSOFC, and DEMOSOFC, in particular). The achieved results have been very positive: a high rated lifetime at stack level, and 60 % system electrical efficiency (with a significant 74 % total stack efficiency) while system cost estimates for large volumes are around 4 000 €/kW.

Many FCH 2 JU activities have addressed the use of hydrogen as a solution for energy storage, relating the integration of renewables and electricity grid balancing, in particular through electrolysis technology. Projects focusing on **low-temperature electrolysis** show a scaling up at multi-MW level for both alkaline and PEM electrolysis for industrial applications. During 2019, a new development can be noted in particular, namely the efforts to develop the next generation of PEM electrolysers (with improved performance and reduced costs).

As regards **alkaline electrolysis**, the main focus of the DEMO4GRID[96] and ELYNTEGRATION[97] projects is to demonstrate the technology in environments where dynamic operation is needed, such as for the provision of grid services. They are progressing well towards the main KPIs for 2020, such as reducing electricity consumption to 50 kWh/kg H_2 and capital costs to 600 €/kW for alkaline electrolysers. For example, ELYNTEGRATION has achieved an operational range of 10-150 % and the system has also been optimised for highly dynamic operation with a hot start time of 2 seconds, while the system efficiency is already 52 kWh/kg and the lifetime is 30 years. The advanced components and materials developed in the project were tested with accelerated stress testing (AST) procedures, and input on testing procedures was provided for the QUALYGRIDS[98] project. The stack design developed in this project was then implemented at a larger scale in DEMO4GRID which will install a 3.2-MW pressurised alkaline electrolyser.

The FCH 2 JU funding awarded to **PEM electrolysis** projects since the beginning of the programme has enabled remarkable advances in the SoA. The high-pressure 1.25-MW PEM electrolyser deployed as part of the HYBALANCE[99] project designed specifically for dynamic production of hydrogen was built in Hobro in northern Denmark, while an atmospheric pressure 6-MW PEM electrolyser has been developed by Siemens and installed and operated at the Voestalpine Linz steel plant in Austria through the H2FUTURE project. Here, the hydrogen produced will support the fossil-fuel-based steelmaking technology as part of the stepwise decarbonisation approach to steel production proposed by the steel manufacturer. Consequently, the direct reduction of iron ore by hydrogen has the potential to significantly lower the environmental impact of steelmaking. The REFHYNE[100] project plans to deploy a high-pressure 10-MW electrolyser of ITM power at a Shell refinery, as well as providing primary and secondary grid services. Last year, the project finalised the detailed engineering of the electrolyser system thereby fulfilling the refinery requirements.

On the research side, the HPEM2GAS[101] project and its follow-up projects NEPTUNE[102] and PRETZEL[103] are working on reducing the cost of hydrogen for large-scale provision. The HPEM2GAS project has succeeded in lowering energy consumption at high current densities, as well as reducing degradation at low PGM loading. A 180-kW prototype system has been developed and is being validated in a field test. The hydrogen produced will be injected into the local gas grid. The newly developed components have been integrated into the 180-kW prototype electrolysis system for field testing to demonstrate the provision of grid services. The outcome of this project will be taken up by the 2018 Call NEPTUNE project which is aiming to achieve a current density of 4 A/cm^2 at low PGM loading. NEPTUNE is addressing the challenge of reducing membrane thickness, which makes a large contribution to overall resistance while preventing gas cross-over, especially at part load. Promising results have been obtained at the MEA level with 0.2 mgRC[104]/cm^2 in the anode catalyst layer (in total, 0.63 mgPGM/cm^2) at 140 °C operational temperature, also demonstrating high performance. In parallel, the PRETZEL project, funded under the same 2018 Call topic, aims to reduce CAPEX by operating at a high current density of 4 A/cm^2 and 100 bar, at a maximum temperature of 90 °C. Among the many highly ambitious targets are an overload capacity of 150 %, a hot start time of 1 second, and 10 seconds for a cold start.

94 http://www.innosofc.eu/

95 http://www.nellhi.eu/

96 https://www.demo4grid.eu/

97 http://elyntegration.eu/

98 https://www.qualygrids.eu/

99 http://hybalance.eu/

100 https://refhyne.eu/

101 https://hpem2gas.eu/

102 https://neptune-pem.eu/en/

103 http://pretzel-electrolyzer.eu/

104 https://www.neptune-pem.eu/images/D5.1_ASSESSMENT_OF_MEMBRANE_ELECTRODE_ASSEMBLIES_FOR_HIGH_TEMPERATURE_AND_HIGH-PRESSURE_OPERATION.pdf

Often **remote regions or islands** have a high potential for renewables but lack connections to the electrical grid and have high curtailment rates. Three FCH 2 JU projects are currently seeking to provide solutions for such systems. The main goal of ELY4OFF[105] is the development and demonstration of an autonomous off-grid, high-pressure electrolysis system (PEMEL, 50 kW) linked to renewable energy sources. The power electrolyser has a nominal efficiency of 82 % and a maximum overload capacity of 150 %. An assessment of potential target markets has been made through a business case analysis and a study of national requirements has been performed in order to overcome RCS barriers. The HAEOLUS[106] project will deploy a 2.5-MW high-pressure electrolyser with a rated system efficiency of 76 % and a current density of 2 A/cm^2. In this remote location in Norway, the project plans to combine wind power and hydrogen production by using several modes of operation (re-electrification, mini-grid, fuel production). Based on local energy costs, the plant could be able to produce hydrogen for a cost of 4-5 €/kg. The BIG HIT[107] project is demonstrating several hydrogen energy solutions in the Orkney Islands, Scotland, which have a poor grid connection to the mainland and are therefore facing curtailment of their renewables of around 30 %. Hydrogen will be used on the Orkneys for power, heat and transport applications, and serves to both store and transport energy. BIG HIT has deployed a 1-MW high-pressure electrolyser, hydrogen trailers, hydrogen boilers, fuel cells and 5 FC vans. The electrolyser has been built and commissioned and will provide hydrogen for the HRS and other uses. Part of the hydrogen is transported via a ferry to another island. The project had to come up with a specific solution for the tube trailers in order to optimise transport capacity while respecting the requirements of Scotland's road and maritime regulations. A detailed societal and environmental analysis of the electrolyser was also performed.

To accompany these activities, the INSIDE[108] project has developed **diagnostic tools** for monitoring locally resolved current densities in water electrolysers and to contribute to the development of AST protocols. Segmented bipolar plates for locally resolved current density measurements for all type of low-temperature electrolysers were developed. The outcomes of the QualyGridS[109] project are crucial for establishing a business case for electrolysers to provide grid services. The project has developed testing protocols for low-temperature electrolysers which consider a variety of different grid services as well as multiple hydrogen end-users. The grid service tests have been experimentally validated on different types and sizes of electrolysers. A techno-economic analysis of business cases has been carried out and the most profitable grid service identified. In some cases, it may be able to reduce the levelised cost of hydrogen up to a maximum of 22 % with high overload capacity.

With reference to **high-temperature electrolysis production**, projects are also progressing towards achieving MAWP targets. At stack level, electricity consumption values down to 33 kWh/kg have already been reached which could mean that the MAWP target at system level could also be achieved with further optimisation of the BoP components. Both the MAWP 2020 target for production loss rate <1.9 %/1 000h and that for availability have been met by most of the projects. Moreover, promising cost projections for large-scale production (100 MW/annum) of 1 500 €/kW have also been reported.

In addition, the GrInHy[110] and REFLEX[111] projects are focusing on **reversible operation**. GrInHy has built and operated a 180 kW Solid Oxide Electrolysis (SOEL) plant, with a 20 % reversible capacity at a steel mill. The prototype has been running for over a year in electrolysis, FC or hot-standby mode, reaching electrical efficiencies of 78 % LHV in electrolysis and 52 % LHV in FC mode. It has also tested an electrolyte-(3YSZ) supported solid oxide cell with a lanthanum strontium cobaltite ferrite (LSCF) oxygen and a nickel/gadolinia-doped ceria (Ni/GDC) steam/hydrogen electrode, which was operated for one year in steam electrolysis mode. A low degradation rate of 0.4 %/1 000h was observed, which is an encouraging result regarding the suitability of solid oxide electrolyser cell (SOEC) for dynamic operation. The REFLEX project is developing reversible solid oxide cell (rSOC) technology to be implemented as an integrated energy-storage solution (Smart Energy Hub) at community/district level. The MAWP target for reversible capacity of 25 % has also been met. Achievements by this ongoing project include a current density of -1.25A/cm^2 at 700 °C in SOEC mode, and fuel utilisation of 85 %.

Finally, the durability of operating an electrolyser in **co-electrolysis** mode is under investigation by the ECO[112] project which has already achieved a degradation rate below 1 %/1 000h. Electrode optimisation has led to a reduction in the operating temperature of 50-100 °C. The project has also analysed potential business cases and performed techno-economic analysis for several cases studies. In some cases, the levelised cost of the product (synthetic methane) could be as low as €60/MWh$_{LHV}$.

105 http://ely4off.eu/

106 http://www.haeolus.eu/

107 https://www.bighit.eu/

108 http://inside-project.eu/

109 https://www.qualygrids.eu/

110 https://www.green-industrial-hydrogen.com/

111 https://www.reflex-energy.eu/

112 https://www.eco-soec-project.eu/

As regards other different routes for hydrogen production from renewable sources of energy, decentralised hydrogen production from biogas through **reforming** is the target of two ongoing projects, BIONICO[113] and BioROBUR^{PLUS}[114]. The technology developed by the BioROBUR^{PLUS} project is oxidative steam reforming (OSR) which enables flexible operation that is well suited for integration in a biogas plant. The reactor concept's high level of thermal integration allows for an efficiency of >80 % High Heating Value (HHV). Suitable catalyst material and structured supports have been selected, tested and optimised for the operating conditions of the reformer (>700 °C). Building upon the achievements of numerous predecessor projects, BIONICO is further developing and testing a catalytic membrane reactor (CMR). Here the separation of hydrogen is integrated which provides for cost savings on downstream purification. The project has developed and produced 120 palladium (Pd)-based ceramic-supported tubular membranes able to work at high temperature (550 °C) for the BIONICO pilot reactor. The project has achieved the targets of 72 % efficiency and a system energy use as low as 3.65 kWh/kg H_2 through simulations.

In terms of **high-temperature water-splitting** and **photo-electrochemical** activities, the HYDROSOL-PLANT[115] project has demonstrated the production of hydrogen through thermo-chemical cycles and completed the construction and integration of the 750 kWth solar reactors and peripherals on the solar platform. This is the largest solar redox reactor globally to date, putting the EU in a leading position for the implementation of this technology. The project partners' high level of commitment resulted in progress which can be exploited by the follow-up project HYDROSOL-beyond[116]. The PECSYS[117] project is targeting the development of an integrated photovoltaic (PV)-electrochemical cell device with an integrated photo electrochemical concept up to prototype scale. Several concepts have been investigated, such as optimising detached PV and electrolysers so that no additional electronic converters are needed, or integrated systems, where the electrolyser is integrated into the PV housing. Nearing the KPI of 10 % solar to H_2 efficiency, 8.5 % has been demonstrated at an H2 generation rate of 2.75 g/h/m^2.

In supporting all sectors and FCH applications, significant achievements are also recorded in the field of **cross-cutting activities**. The HYDRAITE[118] and ID-FAST[119] projects have performed **pre-normative (PNR) research** to fill specific gaps in fundamental knowledge and standardisation for fuel quality assurance and FC testing methodology, respectively. A major achievement by HYDRAITE concerns the development in Europe of certified laboratories capable of measuring hydrogen impurities against the entire set of species according to the specifications laid down in the international standards. A further important output by HYDRAITE will be supporting international standardisation activities in the field. Project ID-FAST is developing AST for proton exchange membrane fuel cell (PEMFC) for automotive applications, and a methodology enabling the prediction of durability. A major part of the work is dedicated to understanding real-life degradation behaviour and identifying the impact of individual stressors.

In terms of **safety**, the HySEA[120] project has studied the behaviour of hydrogen releases in semi-confined spaces. It has produced an impressive collection of experimental evidence to improve understanding and prediction capabilities. In addition, the PRESLHY[121] project is tackling the safety of liquid hydrogen, with the very ambitious goal of closing knowledge gaps related to its behaviour in accident conditions. PRESLHY is the first EU project for more than 10 years that is dedicated completely to the study of liquid hydrogen. Safety-related findings from these projects will be used to formulate safety requirements in standards and regulations presently under development. One of HYSEA's final outputs is a model for vented hydrogen deflagrations.

As regards **education and training**, the NET-Tools[122] project is focusing on the development of new e-education methods based on ICT tools, to enhance the knowledge, productivity and competitiveness of those interested in FCH technology deployment. The tangible output from NET-Tools was an e-learning platform based on open source software, which is still under development. In addition, project TeacHy[123] is developing learning tools and materials addressing a broad range of customers, primarily university students (undergraduates and postgraduates) but including vocational training. The overarching goal is to offer students across the EU access to high-quality, harmonised, and certified training material.

113 http://www.bionicoproject.eu/

114 http://www.bioroburplus.org/

115 http://hydrosol-plant.certh.gr/

116 http://www.hydrosol-beyond.certh.gr/root.en.aspx

117 https://www.helmholtz-berlin.de/projects/pecsys/

118 https://hydraite.eu/

119 https://cordis.europa.eu/project/id/779565

120 http://www.hysea.eu/

121 https://preslhy.eu/

122 https://www.h2fc-net.eu/

123 http://www.teachy.eu/about-teachy.php

In addressing the sustainability aspects of FCH technologies, the HyTechCycling[124] project has explored **recycling and dismantling** technologies, and strategies applied to the whole FCH technology chain. The project made comprehensive use of the LCA methodology and approaches defined in the FC-HyGuide[125] project and performed a full 'cradle-to-grave' LCA. Another of HyTechCycling's major achievements is the identification and classification of critical materials in FCs (both PEMFC and SOFC technologies) and water electrolysers (alkaline and PEM) and their material flows in existing recycling and dismantling technologies. The project represents the first structured approach to the critical raw material challenge, which addresses an important EU initiative[126] and the 'critical raw' objective[127] of the FCH 2 JU Regulation.

1.2.2 KNOWLEDGE MANAGEMENT

Knowledge management activities have continued with TRUST being used as the central data-collection tool enabling comprehensive data collection and analysis. According to the annual planning and in line with their contractual obligations, in late April 2019, ongoing projects (81 in total) were requested to provide data concerning their research and innovation results generated in 2018. Consequently, this allowed for an assessment of the projects' progress against the targets defined in the MAWP 2014-2020[128] (and its Addendum[129]). At the start of the data collection exercise, improvements were made to the existing templates. In addition, a new template on 'heavy-duty trucks' was created and 23 different questionnaires were used. Project teams answered comprehensive questionnaires (so-called 'templates') according to the type of technologies involved in each project and the related activities carried out. To date, data from four calendar years have been collected (2015-2018) which – when data completeness had been achieved – have already enabled a comparison of the data, the technology's progress and key MAWP targets over time. The templates can be consulted online at: https://www.fch.europa.eu/projects/knowledge-management.

Previous success in terms of data collection continued in 2019: all projects answered the questionnaires and provided input on most of the queries. TRUST data-collection activities continued to be streamlined with the annual programme review exercise which provided for an effective analysis of the projects' results. Projects were encouraged to open up the data (make public the relevant KPIs reached) as much as possible, while all confidential data were appropriately cleaned and anonymised. The results and reported progress were included as content during the portfolio analysis part of the Programme Review 2019 (the report is currently being finalised and the preliminary results are presented above) as well as in the Programme Review Days (PRD) event, including the project officers' portfolio overviews and project posters[130].

Updating the internal database, which contains the overall plans and deployments in the EU, also continued in 2019. This database was fed with information from projects and from general/specific press coverage concerning the plans for and deployment of FCH technologies, such as electrolysers, vehicles, HRS and stationary units, including detailed information on country, size, technology, etc. Information from other parts of the world may also be included for benchmarking. In particular, for cars, this is complemented with reference to FC-car deployment figures (passenger car data only) obtained directly from the European Automobile Manufacturers' Association (ACEA) which is recorded on a quarterly basis. Where possible, vehicle sales figures are captured every six months from the vehicle manufacturers themselves. As the data per manufacturer are treated as confidential, only aggregated values (EU/country) are being disclosed.

By continually using TRUST in recent years, needs for further improvement have been identified. FCH 2 JU submitted a request for further upgrades and maintenance support through the IT Grant Management Framework Contract. The contract is expected to be signed and implemented during 2020.

As part of the Joint Research Centre (JRC) Rolling Plans 2018 and 2019, the FCH-adapted TIM[97] database initially developed in 2018 was further adapted and expanded to include scientific publications, patents, participation in projects and others which have been mapped according to authors' organisations. The three FCH datasets created during 2018 included alkaline, solid oxide and PEM technologies. These were further refined and split into electrolysis and FC applications, resulting in six final datasets. In addition, a 'non-electrolysis hydrogen production' dataset was developed alongside the existing FCH 2 JU dataset, including only information from FCH 2 JU beneficiaries and resulting in a total of eight FCH 2 JU TIM datasets. This should enable developments in FCH technologies and the related impact of FCH 2 JU funding to be properly tracked in future. A dedicated webpage has been developed on the FCH 2 JU website to host these related TIM spaces and make them available to the

124 http://hytechcycling.eu/

125 http://www.fc-hyguide.eu/

126 COM(2008) 699 The raw materials initiative – meeting our critical needs for growth and jobs in Europe: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0699:FIN:en:PDF

127 EU Regulation 559/2014 establishing the Fuel Cells and Hydrogen 2 Joint Undertaking. Article 2, (e) 'reduce the use of the EU defined "Critical raw materials", for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements'.

128 https://www.fch.europa.eu/sites/default/files/FCH%202%20JU%20MAWP-%20final%20%28ID%204221004%29.pdf

129 https://www.fch.europa.eu/sites/default/files/MAWP%20final%20version_endorsed%20GB%2015062018%20%28ID%203712421%29.pdf

130 https://www.fch.europa.eu/page/posters-and-presentations

community. Preparatory work has started together with JRC in order to allow sources related to FCH publications, as produced by the TIM tool, to be used by the forthcoming FCH Observatory. Finally, results from FCH 2 JU-adapted TIM datasets have already been included in a number of publications and presentations produced by the PO and JRC (work currently ongoing).

In 2019, emphasis was placed on revising the appearance of projects on the FCH 2 JU website. To avoid duplication of the information presented on the CORDIS website, the details were limited on the project acronym, title, logo, abstract plus the CORDIS and project website links. In addition, a dedicated webpage[131] was created including the SoA and MAWP targets, as included in the MAWP Addendum. All the maps displayed on the FCH 2 JU website were updated to display the most up-to-date information aligned with the EUROPA website guidelines. In particular, the main map on the homepage[132] geo-locating FCH 2 JU project coordinators was updated, including the overview of signing regions[133] and the European supply chain map[134].

1.2.3 RCS SC GROUP ACTIVITIES

The industry-led Regulations, Codes and Standards Strategy Coordination (RCS SC) group, comprising 18 representatives from Hydrogen Europe and Hydrogen Europe Research, is supported by the European Commission's JRC and the FCH 2 JU PO. The RCS SC group coordinates the strategy on RCS, with a focus on identifying strategic themes for RCS development and their proposed follow-up. The aim of this work is to provide the FCH 2 JU programme with an evidence-based analysis of urgent priorities for PNR and standardisation needs supporting the design of future annual work plans.

In 2019, two main lines of activity of the RCS SC Group were performed:

1. The group provided its annual support to the AWP 2020 process. In January, a RCS/PNR guidance document was issued, providing insights on the strategic themes and specific challenges considered as priorities by the RCS SC group. During the drafting process, feedback was provided on the alignment of the topics proposed for the AWP 2020 with the PNR/RCS priorities. The strategic priorities had been identified based on a gap analysis, project recommendations and further input provided by the RSC SC group experts regarding international activities.

2. In June 2019, a workshop on Regulations, Codes and Standards entitled 'Sharing Field Experiences' was held at the FCH 2 JU premises. Co-organised by the RCS SC group, the JRC and the PO, the objective of the workshop was to share the wealth of experience that has been gained during implementation of the demonstration projects. This has enabled the identification of future strategic themes for RCS development by providing an overview of any RCS gaps identified during the running of projects (e.g. permitting process, certification issues, lack of standards, etc.). This is of critical importance for setting priorities in future research, standardisation and certification efforts. The workshop included presentations by representatives of selected demonstration projects and members of the EHSP. The outcome of the initiative will be a short, public report summarising the discussion and presenting recommendations for future RCS-related activities by the FCH 2 JU . Recommendations were made to facilitate deriving the appropriate lessons learned from field experiences. For example, it was suggested that RCS information from projects could be collected and summarised in a report to be shared with the SC group and/or the community. It has been established that more guidance is needed for stakeholders regarding which standards are to be used for the various applications, a topic which will be explored further by the FCH 2 JU and the RCS SC group.

During 2019, the RCS SC group also discussed how knowledge acquired from the projects could best feed into the development of standards used during the project.

1.2.4 EUROPEAN HYDROGEN SAFETY PANEL (EHSP)

The FCH 2 JU launched the EHSP initiative in 2017. Its mission is to assist the FCH 2 JU at both programme and project level by providing assurance that hydrogen safety is adequately managed, and to promote and disseminate an H2 safety culture both within and outside of the FCH 2 JU programme.

131 https://www.fch.europa.eu/soa-and-targets

132 https://www.fch.europa.eu/

133 https://www.fch.europa.eu/overview-regions

134 https://www.fch.europa.eu/page/FCH-value-chain

The EHSP is composed of a multidisciplinary pool of experts – 16 in 2019 – grouped in ad-hoc working groups (task forces) according to the tasks to be performed and to their expertise. Collectively, the members of the EHSP have the necessary scientific competencies and expertise covering the technical domain needed to make science-based recommendations to the FCH 2 JU.

Below is a summary of the activities performed by the EHSP during 2019, per task force.

Support at project level

ESHP activities under this category aim at coordinating a package of measures to avoid any accident by integrating safety knowledge, expertise and planning into FCH 2 JU-funded projects by ensuring that all projects address and incorporate the SoA in hydrogen safety appropriately.

In 2019, the EHSP updated the **safety planning guidance document** for FCH projects drafted in 2018 and made it public[135]. The document provides information on safety planning, monitoring and reporting for the FCH projects (and programmes) concerned in Europe and sets out an integrated approach to project-safety planning, monitoring and reporting needs to best address technical and organisational aspects related to hydrogen safety. In addition, in the form of more practical guidance, the EHSP also developed a practical and simple-to-use template for developing a safety plan. The template was used to assist an ongoing project in setting up a safety plan in order to get preliminary in-the-field experience about its use before releasing the final version. The final template is expected to be finished at the beginning of 2020 and will be publicly available on the FCH 2 JU webpage alongside the guidance document.

As part of the activities within this task force, the EHSP also developed a checklist for both existing and upcoming FCH 2 JU projects, based on criteria related to safety aspects. The checklist is expected to be finalised in early 2020 and will be used to support the assessment of all FCH 2 JU projects from a safety-related perspective, becoming an additional tool to identify projects likely to be followed up, contacted or supported by the EHSP. To this end, the EHSP is committed to providing expertise in case the project consortium does not have its own safety expertise or is seeking an independent view. Finally, the EHSP updated the 101 presentation which was developed in 2018 and encompasses aspects such as the SoA, safety principles and planning, data collection, etc., to name but a few.

Support at programme level

EHSP work under this category includes a set of activities intrinsically linked with the activities of the previous task force but with a broader and cross-cutting dimension, focusing on the FCH 2 JU programme itself and how safety-related aspects can be enhanced within the overall programme and activities.

In 2019, the main activity within this task force concerned the development of a strategic document to set out a **Multi-Annual Work Plan 2020–2024 for the EHSP. The document describes EHSP** activities within the hydrogen safety community as a framework until 2024. It includes background information about the EHSP initiative and its mission, vision, objectives and operation. It also includes details of past and current activities, current and future relationships between the EHSP and other organisations involved in hydrogen safety worldwide, profiles of a work plan for the future, etc. The document was extensively discussed throughout the year and is expected to be published in early 2020, providing a clear framework for EHSP activities in the years to come.

In addition, following the activities initiated last year, the EHSP supported the FCH 2 JU in identifying safety issues and researching them which may require further support within the programme in order to better understand and assess the current and near-future needs relating to hydrogen safety. A final version of the document is under revision and is likely to be released in mid-2020.

In 2019, the EHSP provided support at the programme level upon request by the PO. This included participating in a workshop organised by a funded project and providing a presentation on safety-related aspects in HRS, or in the workshop on regulations, codes and standards organised by the FCH 2 JU RCS SCG in June 2019 (mentioned above).

Finally, as the result of some preliminary contacts made during 2019, the EHSP held a bilateral meeting with the Hydrogen Safety Panel (HSP) traditionally supported by the US Department of Energy's Fuel Cell Technologies Office, in the context of the International Conference on Hydrogen Safety (ICHS 2019) organised by the International Association of Hydrogen safety (IA HySafe) in Adelaide, Australia[136]. The goals of the meeting were to present the panels' activities to one another and to identify and discuss potential areas of cooperation in the future. Future contacts and discussions will be arranged in 2020 to agree concrete areas of cooperation.

135 https://www.fch.europa.eu/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects_Release1p31_20190705.pdf

136 https://hysafe.info/ichs2019/

Data collection and assessment

As learning from others is an essential element of a high-level safety culture, activities in this category are centred around the collection and analysis of hydrogen-safety-related data to derive lessons learned and provide further general recommendations to all stakeholders.

Over 2019, EHSP activities in this category concluded the assessment which had been initiated during the previous year on safety data and events contained in the revamped European Hydrogen Safety Reference Database (HIAD 2.0) operated by the JRC and supported by the FCH 2 JU. In close collaboration with the JRC, EHSP members completed the review and assessment of 270 events and the lessons learned from this assessment were released in a **public report**[137]. The report, which is publicly available on the FCH 2 JU website, gives a clear view of the current situation concerning the European Hydrogen Safety Reference Database while providing the foundations for future research in this field.

Furthermore, in 2019, the EHSP started to import historic cases from the 735 incidents hosted in the database by the UK's University of Warwick and other cases from the French ARIA database (Analyse, Recherche et Information sur les Accidents). These activities will continue in 2020.

Finally – and related to the activities of the previous task force – a set of activities over the year also focused on reviewing the contribution and progress in research in the field of hydrogen safety made by FCH 2 JU projects, which helped to provide a clear baseline for drafting the Multi-Annual Work Plan 2020-2024 for the EHSP. Work will continue in 2020.

Public outreach

Framed within the context of the intended broad exchange of information, in 2019, the EHSP developed a comprehensive **communication strategy 2020–2024**. The document outlines specific considerations for the EHSP communication strategy and the inherent challenges associated with the safe implementation of hydrogen as an energy carrier in society. It suggests clear and measurable communication goals and objectives, provides an analysis of the target audience for communication, prioritised by groups, etc. It also gives a summary of relevant communication channels and a list of key messages for the most relevant target audiences. At the end of 2019, the final draft of the document was being edited and a brief summary of the internal communication strategy will be released for the general public in early 2020.

In terms of reaching out to the general public, it is worth mentioning that EHSP members participated in the 'Hydrogen Safety Public Forum' organised in September 2019 by the South Australia Government's Department for Energy and Mining.

Finally, activities also encompassed updates of the EHSP initiative on the FCH 2 JU website.

1.2.5 COLLABORATION WITH THE JRC

The European Commission's JRC undertakes high-quality research in the FCH field, which is of considerable relevance to implementation of FCH 2 JU activities.

For the duration of Horizon 2020, a Framework Contract between FCH 2 JU and JRC was drawn up in 2016. The scope of this contract covers the activities the JRC provides at the level of the FCH 2 JU programme. These activities are outlined in annual rolling plans which also describe the specific deliverables to be provided against payment (heading B of Article 2 in the Framework Contract).

The annual Rolling Plan 2019 constituted part of the AWP 2019, with an indicative budget of EUR 865 000 foreseen from the FCH 2 JU operational budget. The JRC activities covered by the Framework Contract were planned and agreed between the JRC and the PO, with the involvement of one representative each from Hydrogen Europe and Hydrogen Europe Research.

In line with the JRC's mission, these support activities have primarily contributed to the formulation and implementation of the FCH 2 JU strategy and activities in the areas of RCS, safety, harmonisation of testing protocols and technology monitoring and assessment.

137 https://www.fch.europa.eu/sites/default/files/Assessment%20and%20lessons%20learnt%20from%20HIAD%202.0%20-%20Final%20publishable%20version%20%28version%201.3%29.pdf

JRC support to the formulation and implementation of RCS strategy

The industry-led RCS SC group (see RCS section above) is assisted by both the JRC and the FCH 2 JU PO. In 2019, the JRC co-organised an RCS workshop together with the PO to share field experiences from FCH 2 JU demonstration projects. The JRC also supported RCS SC group activities regarding their input of strategic RCS/PNR priorities for the drafting process of the AWP 2020. JRC regularly informs the RCS SC group on selected international initiatives, such as the RCS working group of the International Partnership for Hydrogen into the Economy (IPHE), and the UNECE GTR13 Phase 2 on the safety of FCEVs.

JRC's direct contribution to implementing RCS strategy

As regards the harmonisation activities for developing the harmonised test hardware for single-cell PEMFC testing, the JRC has finalised the design of the second prototype and successfully concluded the experimental validation tests on this hardware. The results will be published shortly in a technical report. The design and manufacturing recommendations have already been shared with several stakeholders. For example, the ID-FAST project will make use of the hardware in its testing campaign. JRC also provides technical assistance for the assembly and operation of test cells, on request. The technical documentation can be shared with all interested stakeholders.

JRC continued to coordinate the harmonisation of electrolyser testing. For low-temperature electrolysers, the terminology and test procedures for single cell and stack testing have been published. The final draft document on test protocols will be sent to the working group in the first quarter of 2020 for final feedback before a public stakeholder consultation, which will be available on the FCH 2 JU website. The working group on harmonisation activities for high-temperature electrolyser was set up. In 2019, it was agreed to prepare an EU-harmonised terminology document based on the documentation for low-temperature electrolysis.

JRC's contribution to programme monitoring and assessment

The JRC has supported knowledge management through technology monitoring and assessment of the FCH 2 JU project portfolio. A methodology was developed to enable the evolution of selected KPIs to be tracked for the duration of the FCH 2 JU programme. An in-depth analysis was performed of the programme's progress against the MAWP KPIs for specific technologies, an activity which will continue in 2020. In collaboration with the FCH 2 JU Knowledge Management team, the JRC has populated and revised the TIM system (see section on knowledge management above) with customised FCH technology fields. The Hydrogen Production Methods technology field has been delivered. The European Media Monitor has been validated and further improved. In addition, the JRC has performed the annual programme review (see below) and issued a report on its findings. This report was used to prepare the public version of the annual programme review report.

Based on the outcomes of the JRC inventory of LCA for FCs and H2 technologies work performed by FCH 2 JU projects in 2019, a workshop was held with LCA experts. Its goal was to identify critical requirements, to discuss a common approach to the LCA of FCs and H2 technologies, and to propose the creation of a life cycle inventory database as a useful tool for projects performing LCAs. The outcomes from the workshop will be summarised in a public report.

JRC's contribution to safety and safety awareness

In recent years, the JRC has upgraded the Hydrogen Incidents and Accidents Database (HIAD) which is used for collecting safety-related events regarding hydrogen technology applications. The development of a new, simplified version of the database, Hydrogen Events and Lessons LEarNed (HELLEN), was undertaken in order to collect incidents from FCH 2 JU projects. This work was concluded in 2017 and the database is now a tool for a repository of safety information generated by the FCH 2 JU programme, including communication, lessons learned and the safety improvement dimension. The JRC is collecting and analysing all reported incidents and informs the PO via an annual report.

At the same time, the JRC is maintaining a public database (namely HIAD 2.0) which only contains publicly available reports on safety-related events. In 2019, the Centre also had an active supporting role towards the EHSP (see above), in particular in supporting tasks at the programme level and data collection and assessment. As part of the last task, almost 300 events were added to HIAD 2.0 in 2019. These events were collected and analysed from the Warwick University database. The JRC's specific role in this analysis involved providing access to the database, supporting EHSP experts, and validating the events. In the other task, the JRC is helping by contributing to the workshop on research priorities for hydrogen safety with an update on European R&I progresses and a methodology for consensus achievement.

The FCH 2 JU also continued to support the JRC by participating in the activities of the IEA Hydrogen Implementing Agreement in Task 38 on Power to Hydrogen and Hydrogen to X and Task 39 on Marine applications. In both tasks, common, agreed input has been delivered.

1.2.6 SUPPORT TO FCH 2 JU POLICIES AND FUNDING/FINANCIAL ENGINEERING

Policy support and feedback

The FCH 2 JU is contributing to the activities of a number of EC services. Although contributions vary in content and format, they all share the common goal of providing fact-based information on the SoA of FCH technologies and their contribution to EU initiatives and policies. This is particularly true in the energy, transport and industry sectors as well as regarding competitiveness and growth and for the environment policy files.

During 2019, in practical terms, this meant taking part in a number of technical groups organised by the EC and other international bodies, playing an active role during the meetings, providing written technical input and ensuring that FCH technologies are properly represented in the relevant sectors.

As in previous years, supporting Directorates-General (DGs) ENER, R&I, MOVE and CLIMA, the FCH 2 JU continued to actively follow and contribute to the European Strategic Energy Technology Plan (SET-Plan) activities, Action 6 'Energy Efficiency for Industry' and Action 8 on 'Renewable Fuels'. In 2019, the Implementation Working Group for Action 6 focused on facilitating the development of ideas into projects and on cross-border co-operation. A consultancy firm (Ecorys) has been contracted to support DG ENER in those tasks. Action 8 work focused on identifying the right funding instruments to implement its targets, on better external communication, and on identifying flagship projects that would support technology improvements in the field of bioenergy and renewable fuels. The FCH 2 JU was included in the Core Group of the Action while, following its suggestion, Hydrogen Europe also became a member of the Working Group for Action 8.

In addition, as in 2018, the FCH 2 JU continued its exchanges with DG ENV, in particular with those responsible for air-quality policies. In 2019, these activities focused on the potential of hydrogen gensets as an alternative to dirty diesel generation.

During 2019, the FCH 2 JU continued its participation in the ART Fuels Forum established under the project 'Support for alternative and renewable liquid and gaseous fuels forum[138] (policy and market issues)'. It also provided input for the drafting of the alternative fuels roadmap update by the Strategic Transport Research and Innovation Agenda.

FCH 2 JU support for EC policymakers goes beyond energy, transport and environmental policies. During 2019, the FCH 2 JU continued to work closely with DG GROW. The FCH 2 JU studies 'Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies'[139] and 'Hydrogen Roadmap Europe'[140] were key to informing the early stages of the work led by DG GROW on the selection of 'hydrogen technologies and systems' as an EC Key Strategic Value Chain for the EU industrial policy[141]. This evidence-based policy-input approach has led to recognition of the contribution the FCH sector can make to economic growth, jobs and competitiveness in the EU. As a result, the November 2019 Report by the Strategic Forum on Important Projects of Common European Interest[142] (IPCEI) includes recommendations to boost Europe's competitiveness and global leadership in six strategic and future-oriented industrial sectors, including hydrogen technologies and systems. The FCH 2 JU is supporting DG GROW in the preparation of IPCEIs on hydrogen[143].

The FCH 2 JU has finalised a study on the development of a 'guarantees of origin' scheme for hydrogen with a strong focus on ensuring its alignment with the foreseen regulatory frameworks at EU level (e.g. RED II) as well as with other European standardisation efforts. This study will also provide the basis for the revision of the relevant standard EN 16325 on 'guarantees of origin', specifically on the hydrogen chapter. A continuation of this study is expected in 2020 in an effort to propose a possible hydrogen certification mechanism that can be used for compliance with the renewables targets within RED II in view of the release of the relevant delegated acts and to facilitate the establishment of harmonised guarantee of origin schemes across Member States.

138 http://artfuelsforum.eu/

139 https://www.fch.europa.eu/page/FCH-value-chain

140 https://www.fch.europa.eu/publications/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

141 https://ec.europa.eu/growth/content/hydrogen-climate-action_en

142 https://ec.europa.eu/docsroom/documents/37824

143 https://www.hydrogen4climateaction.eu/

In 2019, the FCH 2 JU published a tender and signed a contract for a study on 'Opportunities arising from the inclusion of Hydrogen Energy Technologies in the National Energy & Climate Plans (NECPs)'. This study aims to identify such opportunities and inform the teams of national experts working on the finalisation of the NECPs. Final versions of the NECPs were to be submitted by Member States by the end of 2019. The FCH 2 JU study with the final fiches is expected to be ready in early 2020, which should enable Member States to integrate their findings for the first revision of the NECPs, in 2 years' time. Undertaking this study has also helped to establish closer links with DG ENER services dealing with the NECPs.

In 2019, the FCH 2 JU made progress with preparation of the 'Observatory' dedicated to FCH technologies. Scheduled to go live in 2020, it aims to become the reference point for all parties interested in knowing more about these technologies. It will include information on technology deployment, policies, training and education as well as financing. This portal will become a precious tool for all policymakers and other stakeholders interested in the use of FCH technologies as a decarbonisation solution primarily in the energy and transport sectors.

The FCH 2 JU also published the tender 'Study on European Business Cases for FCH Trucks and Technology Development Roadmap' in 2019. The aim of the study is to define business case and market potential analysis for the use of FCH technologies as part of the energy solutions for the heavy-duty road transport sector. The tender will be awarded in early 2020.

In the maritime sector, the absence of RCS for hydrogen as a maritime fuel has been the core subject of regular exchanges and meetings between the FCH 2 JU, DG ???, DG MOVE, the European Maritime Safety Agency and the JRC. Given the international context of maritime regulation, FCH 2 JU organised jointly with the US Department of Energy a technical workshop called 'H2@Ports' which gathered representatives from all over the world on issues linked to FCH in the maritime sector.

The FCH 2 JU has continued exchanges to include executive agencies charged with managing other parts of Horizon 2020 in areas relevant to FCH technologies. For example, in the transport sector, the FCH 2 JU continues to work with the Innovation and Networks Executive Agency (INEA) on activities related to FCEVs, FC buses and HRS. In the energy sector, 2019 also saw a close collaboration with INEA to identify synergies and opportunities for cooperation. In addition, FCH 2 JU continues to work with the Executive Agency for Small and Medium-sized Enterprises. In particular, it is supporting those working with public authorities[144] to foster the implementation of sustainable energy and transport solutions. This collaboration aims to help the FHC JU to widen the number of regional authorities it can reach.

The FCH 2 JU has also continued to be proactive in taking up opportunities for collaboration with other JUs, EU agencies, initiatives and actions with the potential for synergy with its research agenda. Examples of such collaborations are the common study with S2R to identify where FC technologies best fit in the rail sector, the linked project JIVE-MEHRLIN on the deployment of FC buses with the Connecting Europe Facility, the link between the Life'N Grab Hy (Interreg), HECTOR (Interreg), and REVIVE (FCH 2 JU) projects which signed a letter of cooperation on 6 December 2019 on the deployment of FC rubbish trucks, the link between the FLAGSHIPS with HySeas III (H2020) projects on hydrogen passenger ferries, the NOW German project Elektra on a fluvial barge pusher, and the complementary programmes and recently launched common study with Clean Sky 2 for the use of fuel cells in the aeronautic sector.

In addition, during 2019, the FCH 2 JU continued exchanges in transport and energy with the European Defence Agency[145] (EDA) to maintain the ongoing debate on the role of hydrogen in the decarbonisation and self-sufficiency of military buildings, camps and vehicle fleets. The FCH 2 JU is currently exploring how this collaboration with EDA could continue during the next phase[146] of the Consultation Forum for Sustainable Energy in the Defence and Security Sectors, which brings together European ministries of defence.

To foster the adoption of FCH solutions on Islands, in 2019, the FCH 2 JU started an exchange with those responsible for the EC's 'Clean energy for EU islands' initiative[147]. As part of this, the FCH 2 JU presented the portfolio of readily available FCH solutions for islands to the initiative's secretariat[148]. Furthermore, the FCH 2 JU AWP 2020 includes a topic aiming to support a flagship project to showcase the role of hydrogen in decarbonising EU islands.

144 https://ec.europa.eu/easme/en/section/horizon-2020-energy-efficiency/public-authorities

145 https://eda.europa.eu/

146 https://eda.europa.eu/european-defence-energy-network/phase-iii

147 https://ec.europa.eu/energy/en/topics/renewable-energy/initiatives-and-events/clean-energy-eu-islands

148 https://euislands.eu/

Working with regions

Building on the work done in 2018 and following the completion and conclusions of the study 'Fuel Cells and Hydrogen for Green Energy in European Cities and Regions'[149], in 2019, the FCH 2 JU implemented a number of measures to address the gaps identified, including:

- A Smart Specialisation Platform: Leveraging on the existing network and capacity building generated under the FCH Regions initiative, the FCH 2 JU has facilitated and supported a group of four co-leading regions from the Netherlands, France (2) and Spain, to set up a new thematic interregional partnership on FCH within the Industrial Modernisation Smart Specialisation Strategies (S3) platform. The so-called European Hydrogen Valleys Partnership[150] (EHV-S3P) aims to enhance the role of green hydrogen in the European energy transition process. It will support regions in their efforts to raise the technological and commercial readiness of FCH applications, facilitate matchmaking and co-investment between European regions also leveraging EU funds' blending opportunities, and strengthen the value chain for FCH technologies via interregional cooperation. The partnership will become an active stakeholder on EU policymaking on hydrogen, moving towards decarbonisation of the EU's economy with a bottom-up approach (from local regions to the EU). The EHV-S3P (comprising 32 regions) was approved by DG GROW during the first half of 2019 and has already delivered two workshops gathering a large community of EU regions.

- Project Development Assistance (PDA): In 2019, the FCH 2 JU launched and awarded the management of a pilot PDA facility to help develop detailed project planning in regions and cities with a lower maturity level, with special attention to Central and Eastern Europe. The aim is to work on project concepts and move them from their current stages to implementation.

- H2 Valley under the AWP2019: By including an H2 Valley topic in the AWP2019 (topic FCH-03-1-2019), the FCH Regions Initiative managed to attract extensive support from local and regional governments across Europe. Over 90 separate regional and municipal public authorities from 22 countries representing about one quarter of Europe's population, surface area and GDP, have committed to this Initiative's goals. The surveys undertaken have assessed project implementation intentions in excess of EUR 1.8 billion over the next 5 years. Of the 36 responses, 24 participating regions and cities have expressed an ambition to become an 'H2 Valley' in the future, with 10 regions pursuing concrete plans for implementation in the years ahead. Regions with ambitions to become H2 Valleys are mainly in countries that already have substantial experience in FCH deployments, in particular the UK, Belgium, the Netherlands, Germany and France. With the aim of showcasing a large demonstration (flagship) project with hydrogen as the energy carrier for various types of uses (transport, power, heat and industry), the FCH 2 JU included a topic in the 2019 Call for proposals to develop hydrogen valleys (topic FCH-03-1-2019). The topic, worth EUR 20 million, was considered fit for the most mature project intentions with typical investment volumes ranging from EUR 50 million to as much as EUR 400 million. A contract was signed in 2019 for HEAVENN[151], the successful H2 Valley.

It is worth mentioning that the Regions and Cities Initiative bottom-up approach facilitated and driven by the FCH 2 JU in recent years has encouraged local and regional governments to include FCH within their regional priorities when managing certain European Structural and Investment Funds. Building on this, it was positive to see that, during 2019, other Member States' specialised funding agencies took up this challenge, having seen the advantages of the different supporting mechanisms tested by the FCH 2 JU concerning regions and cities at different stages of project development and since then have followed similar strategies. This is the case for NOW's HyLand[152] – Hydrogen Regions in Germany – in which funding for regions and municipalities ranges from support for awareness campaigns or the initial organisation of actors' involvement (HyStarter), creating integrated concepts and in-depth analyses (HyExpert), and effective deployment (HyPerformer).

Funding and financial engineering

With the aim of accelerating the market introduction and deployment of the technologies stemming from the projects supported by FCH 2 JU, funding/financial engineering activities are becoming one of its core activities. The JU is now providing advice and support to both prospective and past beneficiaries of FCH 2 JU projects in order to combine funding from various programmes and optimise structured finance operations.

The Undertaking has been working with and establishing a close relationship with several European Investment Bank (EIB) departments, namely the InnovFin EDP/InnovFin advisory hub; Equity, new products and special transactions; Growth capital and innovation finance; and transport operations.

149 More information at https://www.fch.europa.eu/page/about-initiative

150 https://s3platform.jrc.ec.europa.eu/hydrogen-valleys

151 HEAVENN stands for Hydrogen Energy Applications for Valley Environments in Northern Netherlands. More information at https://www.fch.europa.eu/page/energy #HEAVENN

152 More information at https://www.fch.europa.eu/news/hydrogen-regions-get-further-support-germany

The FCH 2 JU continued to work with the EIB and the industry to facilitate access to financial instruments, such as the InnovFin energy demonstration projects or others being used for de-risking projects which have access to the European Fund for Strategic Investments.

It is essential that the finance community becomes and remains fully aware of the SoA in terms of FCH technology solutions (via the results of FCH 2 JU projects), their market readiness, the benefits they bring, and the impacts they may achieve through the provision of private-sector funding and financing support (across the spectrum of new entrants, start-ups, small and medium-sized enterprises (SMEs) and established firms in the FCH marketplace). In view of enabling the FCH 2 JU beneficiaries to access venture capital, the FCH 2 JU partnered with the event organiser Tech Tour to include in November 2019 for the first time in the Tech Tour Energy Transition (9th edition; TTET2019) hydrogen technologies as the sixth sector of this Cleantech VC event[153]. To ensure the industry pitches would be as professional as ever, and leveraging on the positive experience tested at the last Programme Review Days 2018, the FCH 2 JU once again partnered with DG R&I to offer on-demand services to interested companies – the Support Services for Exploitation of Research Results. Invitations were sent to more than 30 beneficiaries from which 6 companies were selected to pitch at the TTET2019 – Powidian, Nedstack, Convion, Elcogen, HyGear and E-Trucks Europe. However, due to conflicting events and possibly a lack of 'appetite' on the part of the CEOs of these companies, only the E-trucks' CEO received personalised training for the pitch one day ahead of the event. The training proved very effective, leading to a better presentation and performance at the pitching event. Although the event included more than 30 companies pitching to more than 55 VC companies, corporate VCs, promotional banks (e.g. EIB) and commercial banks (e.g. ABN AMRO), it was a great place to test the attractiveness of FCH 2 JU-supported companies to the VCs. The several sessions around hydrogen technologies were very busy and triggered the liveliest debates.

The format of the event met FCH 2 JU expectations, serving its ecosystem with targeted exposure to investors ready to support its scaling-up plans. The full impact of the event will have to be tracked but expectations are that the pitches made and the awareness raised among the investors and financiers' community may lead to actual deals in the years to come. Replicability could be considered in the near future since the FCH 2 JU ecosystem benefits from this type of targeted exposure to investors ready to support their scaling-up plans. The main achievements can be summarised as: (1) raising awareness and appetite for hydrogen investments leveraging on the good momentum; (2) great networking and productive companies-Investors matchmaking; (3) clear understanding that there is a need to get business certainty and mitigate risks (off take) to be able to invest in the sector; and (4) investors' willingness to deploy vertically integrated projects to address and mitigate the risks of an 'infant' yet fast-growing hydrogen value chain.

1.2.7 INTERNATIONAL COOPERATION

Given the importance of international cooperation in science and technology, explicitly recognised in the EU's Innovation Union flagship initiative[154] and the Horizon 2020 programme, and described in the Communication 'Enhancing and focusing EU international cooperation in research and innovation: a strategic approach'[155], the FCH 2 JU has continued to be active at the international level, in order to align with, facilitate and accelerate the worldwide market introduction of FCH technologies.

As the deployment of FCH technology is carried out globally and key partners of the FCH 2 JU are involved in these developments, the JU has continued to develop links with the major deployment programmes globally. This has taken place mainly through the IPHE but also through bilateral periodic discussions with the US Department of Energy, Japan METI/NEDO (Ministry of Energy and Transport) and in particular the *Mission Innovation – Innovation Challenge 8: Renewable and Clean Hydrogen*[156] *(MI-IC8)* to harmonise standards and regulations and to accelerate market preparation.

In this respect, the FCH 2 JU collaborated closely with EC representatives on the Mission Innovation – IC8 and, in March 2019, co-organised the workshop[157] on hydrogen valleys in Antwerp, Belgium. This led to the launch of a tender to set up a platform for exchanges between worldwide initiatives on hydrogen valleys and to the signature of the related contract in November 2019 (see also section 1.4).

153 The programme revolved around the following six sectors: Energy Generation – Solar generation, Wind and Fusion; Energy Storage – Solid State Batteries, Flow Batteries and Flywheels; Energy Efficiency – Transmission & Distribution, Energy Savings and Efficient Buildings; Hydrogen & Alternative Fuels – Generation, Storage, Transportation and Usage; Data and Analytics – Predictive Analytics and Smart Grid; Industry & Offshore – Maritime, Offshore and Advanced Manufacturing. More information at https://techtour.com/events/2019/11/event-tech-tour-energy-transition-2019.html?pageId=3066049

154 https://ec.europa.eu/info/research-and-innovation/strategy/goals-research-and-innovation-policy/innovation-union_en

155 https://ec.europa.eu/research/iscp/pdf/policy/com_2012_497_communication_from_commission_to_inst_en.pdf

156 http://mission-innovation.net/our-work/innovation-challenges/renewable-and-clean-hydrogen/

157 https://www.fch.europa.eu/page/mission-innovation-antwerp-2019

In support of the JRC, the FCH 2 JU continued to contribute to the activities of the IEA Hydrogen Technology Collaboration Programme executive committee to optimise and share the effort. In particular, it focused on the IEA tasks related to power-to-x (task 38), maritime applications (task 39), and data and modelling[158] (task 41).

As in previous years, the FCH 2 JU exchanged best practice with the US DoE among reviewers during both the US DoE Annual Merit Review and FCH 2 JU proposal evaluations. Furthermore, in September 2019, it co-organised with the US Department of Energy Fuel Cell Technologies Office and the US Maritime Administration, the H2@Ports workshop[159] in San Francisco, CA. The aim was to explore opportunities for cooperation and collaboration on hydrogen technology for maritime and port applications (see also section 2.1.2).

Call 2019 topics were open to collaboration with the IPHE[160] and MI-IC8 countries. In this context, it is worth highlighting the PRHYDE[161] project on heavy-duty refuelling protocols for large tank systems, which foresees cooperation with the United States and Japan as well as with China and Korea, with the aim of using the project results to develop an international standard.

The FCH 2 JU also cooperated with DG ENER by providing input for and participating in the G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth in Japan in June 2019. This was marked by the announcement of the Joint Statement on the future cooperation on hydrogen and fuel cells between Japan, the United States and the EU, as well as by the G20 IEA hydrogen report[162] launch event.

1.3 CALLS FOR PROPOSALS AND GRANT INFORMATION

1.3.1 PROPOSALS

2018 Call

In the AAR 2018, two grants agreements (GAs) were indicated as ongoing. Indeed, the signature process took longer than usual due to the complexity of these two major demonstration projects:

- 826236 – H2Haul[163]: the GA was signed on 23 July 2019.
- 826056 – WIND2HYRAIL: the GA process was not conclusive since a national public procurement upon which the proposal was based was not awarded to WIND2HYRAIL's consortium. As a consequence, GA preparation started with the next proposal on reserve list on the same topic: 826089 – Djewels. The GA for proposal 826089 – Djewels was signed on 3 December 2019.

2019 Call

The 2019 Call for proposals (H2020-JTI-FCH-2019-1) was published on 15 January 2019 and, in accordance with the AWP 2019, included 17 topics: 5 in the transport pillar, 8 in the energy pillar, 1 in overarching activities, and 3 in cross-cutting activities, with an indicative budget of EUR 80.8 million. The Call closed on 23 April 2019.

On 29 January 2019, a public information day was organised in Brussels. The 2019 call received 44 proposals: the results of the evaluation of these proposals are presented below in paragraph 1.3.2.

All consortia were informed of the evaluation results at the same time, 104 days (time to inform – TTI) after the closure of the call, well in advance of the TTI target fixed by the Commission (153 days). Immediately after the information had been sent, preparation of the GAs began. All 17 GAs were signed in 2019 within an average of 230 days and before the time to grant (TTG) target fixed by the Commission, i.e. 243 days after the closure of the Call.

158 The FCH 2 JU hosted a Task 41 Definition Meeting – Data and Modelling – on 29 August 2019 in Brussels, Belgium. Topics of discussion included how to model hydrogen in the value chain and improve current methods, experiences from other tasks and data consolidation of parameters describing hydrogen technologies.

159 https://www.energy.gov/eere/fuelcells/h2ports-workshop

160 https://www.iphe.net/

161 https://www.fch.europa.eu/page/cross-cutting#PRHYDE

162 https://www.iea.org/reports/the-future-of-hydrogen

163 https://www.h2haul.eu/

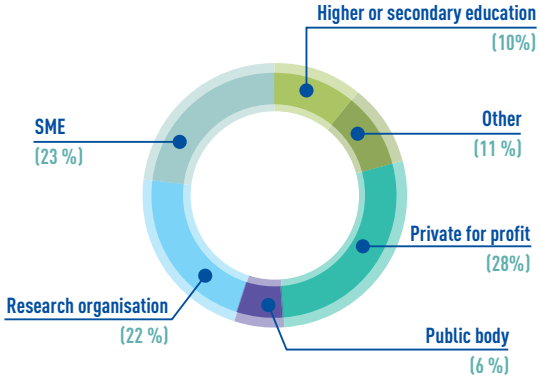
TABLE 1.3.1.1 CALL 2019- TIME TO SIGN AND GRANT

CALL	PROPOSAL NUMBER	ACRONYM	TTI	TTS	TTG
H2020-JTI-FCH-2019-1	875024	ANIONE	104	126	230
H2020-JTI-FCH-2019-1	875155	CAMELOT	104	129	233
H2020-JTI-FCH-2019-1	875088	CHANNEL	104	129	233
H2020-JTI-FCH-2019-1	875081	EMPOWER	104	122	226
H2020-JTI-FCH-2019-1	875025	FURTHER-FC	104	122	226
H2020-JTI-FCH-2019-1	875090	HEAVENN	104	130	234
H2020-JTI-FCH-2019-1	875091	HIGGS	104	128	232
H2020-JTI-FCH-2019-1	875089	HyResponder	104	126	**230**
H2020-JTI-FCH-2019-1	875123	MultiPLHY	104	128	**232**
H2020-JTI-FCH-2019-1	875118	NEWELY	104	128	**232**
H2020-JTI-FCH-2019-1	874577	NewSOC	104	120	**224**
H2020-JTI-FCH-2019-1	874997	PRHYDE	104	134	**238**
H2020-JTI-FCH-2019-1	875047	RUBY	104	124	**228**
H2020-JTI-FCH-2019-1	875148	SWITCH	104	122	**226**
H2020-JTI-FCH-2019-1	875156	ShipFC	104	125	**229**
H2020-JTI-FCH-2019-1	874983	THyGA	104	125	**229**
H2020-JTI-FCH-2019-1	875087	VIRTUAL-FCS	104	129	**233**

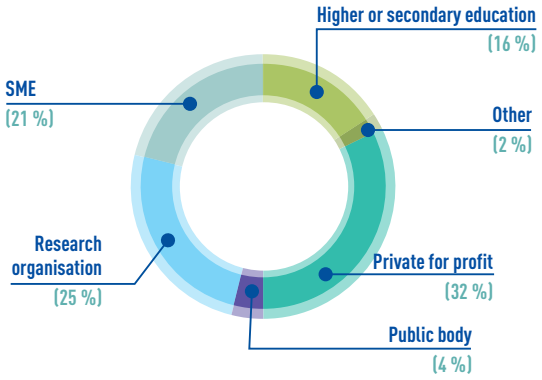
The 17 projects listed above include 195 participations for the total FCH 2 JU contribution of EUR 69.1 million.

The figures below indicate the distribution of the number of participants and the FCH 2 JU contribution by participant category.

Graph 1.3.1: Breakdown of contribution by participant category (in EUR)



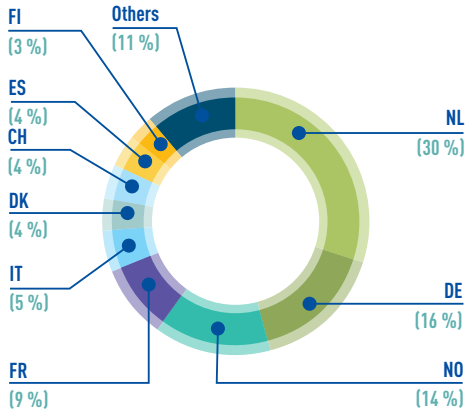
Graph 1.3.2: Breakdown of participant category (by legal type)



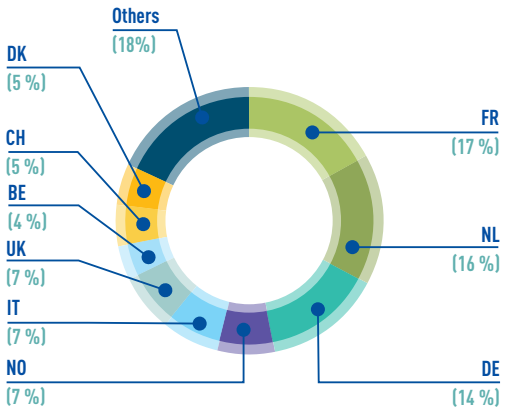
Beneficiaries from 23 EU Member States or Associated Countries are participating in the 17 projects and have / will received funding. In addition, entities from four third countries are participating in seven projects.

The figures below indicate the distribution of the participants and the FCH 2 JU contribution by country.

Graph 1.3.3: FCH contribution by country (in EUR)



Graph 1.3.4: Number of participants by country



1.3.2 EVALUATION: PROCEDURES AND GLOBAL EVALUATION OUTCOME, REDRESS, STATISTICS (NO OF EVALUATORS, GENDER, AREA, ETC.)

Under the AWP 2019, approved by the GB on 17 December 2018, the FCH2 JU published the H2020-JTI-FCH-2019-1 Call for proposals on 15 January 2019 (Official Journal C018). In accordance with the FCH2 JU rules (vade mecum) on proposal submission and evaluation, adopted on 30 June 2014 by the GB, an evaluation report, including all annexes (main list, reserve list, ineligible list, evaluation summary reports, statistical information on proposals received, and experts' report, panel report and observer report) was submitted to the Board for approval. Of the 44 proposals received, one (2.3 %) failed to meet one of the eligibility criteria because its content did not correspond, wholly or in part, to any topic description in Call H2020-JTI-FCH-2019-1.

Distribution of the remaining 43 proposals, according to pillar and Call topic, is provided below:

TABLE 1.3.2.1: NUMBER OF PROPOSALS EVALUATED

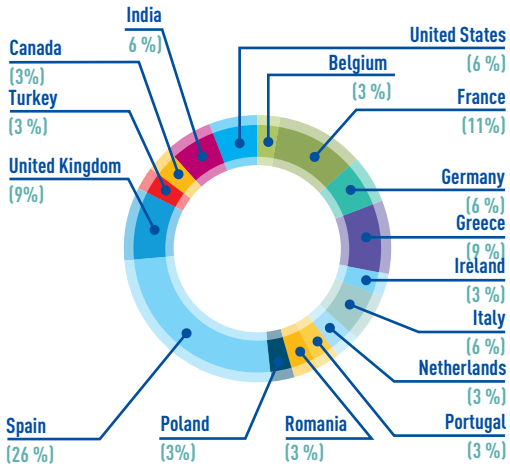
AREA	TOPIC	TOTAL
Transport	FCH-01-1-2019	1
	FCH-01-2-2019	4
	FCH-01-3-2019	3
	FCH-01-4-2019	2
Energy	FCH-02-1-2019	2
	FCH-02-2-2019	1
	FCH-02-3-2019	3
	FCH-02-4-2019	8
	FCH-02-5-2019	2
	FCH-02-6-2019	1
	FCH-02-7-2019	4
	FCH-02-8-2019	2
Overarching	FCH-03-1-2019	6
Cross-cutting	FCH-04-1-2019	1
	FCH-04-2-2019	1
	FCH-04-3-2019	2
	Grand total	**43**

The 43 proposals included 420 participations. The proposals were evaluated by 32 independent experts with 3 chairs to assist with managing the entire evaluation process, including the task of quality control and 1 observer for the evaluation procedure.

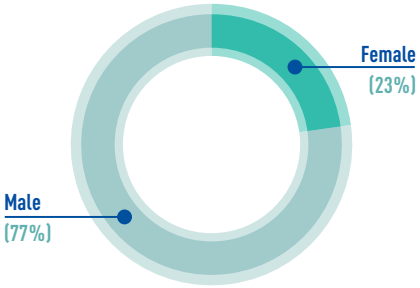
26 proposals (60 %) passed all the Call thresholds.

The figures below provide statistics on the 35 experts (excluding the observer expert):

Graph 1.3.5: Breakdown of experts by country



Graph 1.3.6: Breakdown of experts by gender



The final ranking list for the Call provided by the FCH2 JU PO did not deviate from the experts' recommendations.

Distribution of the retained proposals and budget per panel is provided in the table below:

TABLE 1.3.2.2: BREAKDOWN OF PROPOSALS PER PILLAR AND ACTIVITY

	PANEL	NUMBER OF ELIGIBLE PROPOSALS RECEIVED	NUMBER OF PROPOSALS RETAINED (MAIN LISTS)	NUMBER OF PROPOSALS IN RESERVE LIST	CUMULATIVE RECOMMENDED EU CONTRIBUTION	AVAILABLE BUDGET IN PANEL
Transport	FCH-01-1-2019	1	0	0	0.00 €	10,000,000.00 €
	FCH-01-2-2019	4	1	1	9,975,477.50 €	10,000,000.00 €
	FCH-01-3-2019+FCH-01-4-2019	5	3	0	6,393,157.10 €	5,800,000.00 €
	FCH-01-5-2019	0	0	0	N/A	1,500,000.00 €
Energy	FCH-02-1+FCH-02-2+FCH-02-3-2019	6	2	1	9,986,246.39 €	15,000,000.00 €
	FCH-02-4-2019	8	3	2	6,204,747.50 €	2,000,000.00 €
	FCH-02-5+FCH-02-6+FCH-02-7+FCH-02-8-2019	9	4	4	11,606,990.00 €	11,500,000.00 €
Over-arching	FCH-03-1-2019	6	1	0	20,000,000.00 €	20,000,000.00 €
Cross-cutting	FCH-04-1-2019	1	1	0	1,000,000.00 €	1,000,000.00 €
	FCH-04-2+FCH-04-3	3	2	1	3,963,243.25 €	4,000,000.00 €
	Total	**43**	**17**	**9**	**69,129,861.74 €**	**80,800,000.00 €**

Having informed the applicants on the outcome of the evaluation, no requests were received for review (redress) which proves yet again the excellent quality of the evaluation process.

1.4 CALL FOR TENDERS

The FCH 2 JU has funded four studies through Calls for tender.

On the basis of AWP 2019, the FCH 2 JU launched four operational procurements (open procedures) on the following topics:

1. Support to Mission Innovation – Innovation Challenge 8 (Hydrogen). Platform for Exchanges between Worldwide Initiatives on Hydrogen Valleys

Government interest in hydrogen technologies is driven by hydrogen's versatility, cross-sectorial uses, and its potential for enabling deep decarbonisation. Although many demonstration projects have successfully shown the maturity and benefits of individual hydrogen technologies, typically either in isolation or in limited size, the viability of hydrogen as a 'systemic solution' has yet to be showcased at scale. Considering the resource constraints of Mission Innovation Members, and the limitations imposed by the timeline of Mission Innovation – Innovation Challenge 8 (MI – IC 8), it was deemed crucial to identify actions that will generate maximum impact in the short term. In this context, the EC, through its public-private partnership FCH 2 JU, launched a public procurement procedure to set up a global information-sharing platform within MI-IC8 to facilitate the emergence and implementation of large-scale hydrogen projects and to leverage the knowledge where intellectual property rights issues are less sensitive.

The contract for the implementation of such services was signed on 25 November 2019 for a period of 18 months and a budget of EUR 490 000. It included provisions for a set of deliverables per task, and a final publishable report to be delivered at the end of the contract.

2. Project Development Assistance for Regions

The objective of this contract is two-fold:

1) To bring a set of at least 10 projects from regions and cities to a high level of preparedness by providing the said regions and cities with the necessary technical, financial and legal services (selection of region and cities will be done via a public call for expression of interest); and

2) To facilitate the creation of an inter-regional and cross-city network in which the selected regions and cities from these 10 or more projects could exchange information with others that may fail to benefit from such services at this moment in time but wish to gather more knowledge, expertise or information. This objective should be accomplished by helping foster collaborations from interested public authorities in view of indirectly assisting otherwise less-mature projects and thereby enhancing their chances of becoming a reality in the future.

The service contract was signed on 8 October 2019 for a period of 20 months and a budget of EUR 742 080. Several reports and deliverables (e.g. establishing a platform to effectively exchange lessons learnt among those locations with experience in implementing FCH projects and those looking to do so in the future) are expected, including an inception and an interim report, and one comprehensive final report at the end of the contract.

3. Study on European Business Cases for FCH Trucks and Technology Development Roadmap

The subject of this study is to: (i) deliver initial studies with the aim of providing a business case and market potential analysis for the use of FCH technologies as part of the energy solutions for the heavy-duty road transport sector (with different range and load profiles); and (ii) to provide case studies by FCH application (different composition, freight load and range) expressing potential opportunities and carry out a concept design for each case study compared with alternative solutions.

This Call for tenders was published in the *Official Journal of the European Union* on 13 November 2019 and closed on 20 December 2019. The evaluation procedure and implementation of the evaluation results will take place during 2020.

4. Study on Opportunities arising from the Inclusion of Hydrogen Energy Technologies in the National Energy and Climate Plans

The study aims to identify opportunities in terms of jobs, growth, environmental sustainability and energy security through the inclusion of hydrogen energy technologies in EU Member States' National Energy and Climate Plans while, at the same time, estimating the financial impact. Hydrogen provides both a mechanism for sector integration and sector coupling as well as the option to store energy on a large scale

over long periods or to transport it from regions of supply to centres of demand. Therefore, hydrogen is systemic and a must-have to ensure the transition of the energy system.

The service contract was signed on 19 July 2019 for a period of 9 months and a budget of EUR 270 000.

One remaining Call for tenders indicated under Section H. Public Procurements of the AWP 2019, namely:

- Certification of green H_2

has not been published yet and will be transferred to the public procurements to be carried out in 2020. Although the drafting of tender specifications for these studies was initiated during 2019, because of modifications to policy, on the one hand, and new developments in the sector, on the other hand, the scope of the Call for tenders is being re-evaluated and is currently under discussion with the EC's corresponding services.

1.5 DISSEMINATION AND INFORMATION OF PROJECT RESULTS

Closely aligned with the knowledge management actions, the monitoring of FCH 2 JU project dissemination and exploitation activities continued during 2019. The FCH 2 JU has been part of the **Horizon 2020 Dissemination and Exploitation Network (D&E-Net)** established by the EC's DG R&I under the H2020 Strategy for the common dissemination and exploitation of research and innovation data and results for the remaining period of 2018-2020. In 2018, the D&E-Net principal working group launched six subgroups, which continued during 2019: (1) D&E practices across the R&I family and capacity building; (2) Data sharing and visualisation; (3) Activating multipliers and synergies; (4) Horizon Results Platform & Go-to-Market guidance for POs; (5) Strengthening policy feedback; and (6) Exploitation and impact in Framework Programmes (FPs).

The FCH 2 JU has appointed representatives for each working group and has been following their activities closely while contributing to the periodical meetings. Key outcomes of these working groups supported by the FCH 2 JU comprise: a) the updated D&E section of the Horizon 2020 vade mecum; b) the project officer timeline; c) a 'to-do-list' related to D&E activities in Horizon-funded projects; d) a live mapping of D&E best practices; e) the 'go to market' guidance for project officers; and f) the Horizon Results Platform[164] where projects are provided with a dedicated platform on which to present their project results to targeted audiences (e.g. business partners, angel investors, VC, policymakers, business development assistance and others). Eventually, this platform will help the projects' beneficiaries to establish fruitful partnerships. Initially, the FCH 2 JU participated in the pilot launch of this tool with 10 projects, while currently all FCH 2 JU projects have been contacted via email to benefit from this new initiative. Moreover, at the request of the CIC, the IAS has performed a consulting exercise in the existing process of research and innovation policy feedback in which the FCH 2 JU was consulted. The process and implementation actions will be concluded in early 2020.

Under the energy pillar, 14 eligible FCH 2 JU projects requested **Support Services for Exploitation of Research Results** (SSERR) services[165] whereby projects receive consultancy-type advice on exploitation aspects. Furthermore, the FCH 2 JU partnered with the Tech Tour Energy Transition (TTET2019) to offer our ecosystem targeted exposure to investors at a Cleantech Venture Capital (VC) event (see above). In view of ensuring the industry pitches would be as professional as possible and leveraging on the positive experience tested at the last Programme Review Days 2018, the FCH 2 JU once again collaborated with the DG R&I to offer on-demand services to interested companies through SSERR. Invitations were sent to more than 30 beneficiaries of which six companies were selected for pitching at the TTET2019 – PowiDian, Nedstack, Convion, Elcogen, HyGear and E-Trucks Europe. The E-trucks' CEO received personalised training for the pitching one day ahead of the event, which proved very effective.

Despite the fact that the EC Dissemination and Exploitation Booster was only launched during the last quarter 2019, two projects have already expressed interest in benefitting from those services. The PO informed the projects' consortia via a number of different communications means, such as events (Info Day, Coordinators' Day, PRD, dedicated emails, etc.) about the importance of these services and tools for enhancing project dissemination and exploitation plans. Dissemination and exploitation of project results awareness started before signature of the GA, during its preparation and will be closely monitored throughout its duration.

In 2018, the FCH 2 JU began its participation in the **Innovation Radar** pilot and by the end of 2019 the exercise had already been conducted for 37 projects. This initiative aims to identify high-potential innovations and the key innovators in H2020 projects. So far, the Innovation Radar pilot exercise has been conducted in project mid-term reviews when a dedicated expert is mandated to identify potential innovations and has to fill out a questionnaire in order to provide the information in a structured manner. The purpose of this exercise was not only to identify promising actors with the potential to grow, but also to stimulate and propel them to 'make it happen' faster and more efficiently. With the help of the questionnaire, the

164 https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform

165 http://sserr.meta-group.com/SitePages/default.aspx

Innovation Radar expert provided concrete recommendations on the innovation aspects of the projects and for individual innovator organisations within the consortium. As the exercise was linked to the mid-term review, where applicable, these recommendations were also integrated into the formal review report. So far, based on the results of 37 projects, a total of **84 innovations** have been recorded. These are displayed in and have been categorised according to the Innovation Radar methodology, between 'exploration', 'commitment', 'creation' and 'optimisation'. These categories are meant to span the path between the most basic TRLs of 'exploration' to the most advanced and closest to potential product 'optimisation'. A very positive result has also been the identification of at least 22 innovations that score above 50 points in the innovation potential indicator, making them ideal first candidates for follow-up actions for exploitation and proposals for financing. In addition, Innovation Radar provided the evidence required by the EC's DG R&I for selecting an FCH 2 JU beneficiary from the qSOFC project as a finalist to receive the **Innovation Radar Prize 2019** [166]. Two of the innovations identified through Innovation Radar were also nominated for the award **Women-led Innovations 2019**[167],[168].

FIGURE 14: RANKING OF THE DIFFERENT INNOVATIONS BASE ON THEIR INNOVATOR CAPACITY SCORE AND INNOVATION POTENTIAL INDEX

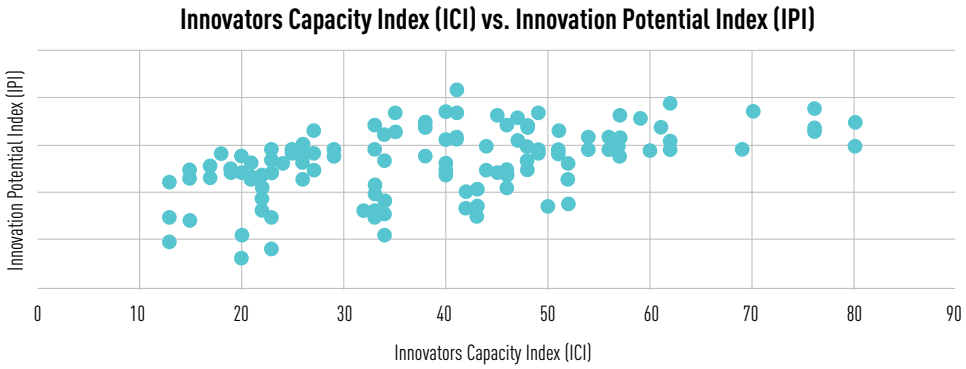
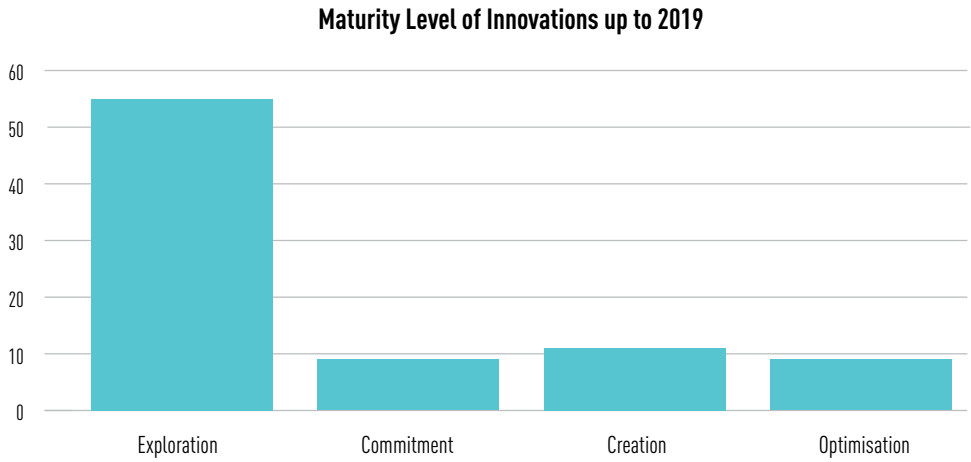


FIGURE 15: CLUSTERING OF INNOVATIONS BASED ON THE MATURITY LEVEL



Through the information provided by this pilot, the FCH 2 JU has collected valuable feedback which is communicated during liaisons with DG R&I and DG CONNECT. This has been done in an effort to find out how the initiative can be further improved as well as to explore how the information collected can be further utilised by other EC services that support the commercial exploitation of research results (e.g. Dissemination and Exploitation boosters, Horizon Results platform, etc.). Furthermore, the innovations/innovators identified will be supported for further exploitation of their results (e.g. pitching to possible investors, etc.). Finally, the FCH 2 JU will monitor any FCH 2 JU project activity within these initiatives to provide dedicated assistance in either the exploitation or dissemination of results.

166 https://ec.europa.eu/futurium/en/innovation-radar-prize-2019/industrial-and-enabling-tech-2019

167 https://ec.europa.eu/futurium/en/women-led-innovations-2019/politecnico-di-torino

168 https://ec.europa.eu/futurium/en/women-led-innovations-2019/instituto-superior-tecnico-para-investigacao-e-desenvolvimento-ist-id

1.5.1 PROJECT INFORMATION ON THE FCH 2 JU WEBSITE

The FCH 2 JU website includes a dedicated page for each funded project (263 projects to date, covering Calls 2008-2019) including the title of the project, abstract and relevant links. Public project deliverables and publishable summaries can be found in the relevant CORDIS links indicated on each project webpage (for more information see section 1.2.2). The information is searchable in dedicated query pages. Also, a dedicated map positioning FCH 2 JU beneficiaries was created and hosted on the main FCH 2 JU homepage. Where relevant, additional communications (new projects signed) and dissemination activities (e.g. project achievements at mid-term or end date) are 'pushed' in the form of news on the FCH 2 JU website or via Twitter, with links to the project pages. Furthermore, a dedicated webpage was created last year including the SoA and future FCH 2 JU targets, as included in the MAWP Addendum.

1.5.2 PROGRAMME REVIEW DAYS

The 2018 PRD report[169], which was finalised and published on the FCH 2 JU website in October 2019, presents the outcome of the review performed by the JRC in 2018. The ninth edition of the PRD was held on 19-20 November 2019 at the EC's Charlemagne building. The aim was to assess the programme's progress and achievements in relation to the targets set in the MAWP Addendum and the relevant AWPs, as well as in relation to the international SoA developments.

A total of 81 project posters were produced covering the entire portfolio of FP7 and H2020 projects which were ongoing during 2018. The posters were presented during the PRD with a tailor-made interactive interface and dedicated smart screens displaying the digital project posters.

Oral presentations were delivered by 27 projects and 4 tenders/studies and initiatives, in 7 sessions/panels:

Day 1 – 19 November 2019

1) Session Hydrogen for Sectoral Integration – Research;

2) Session Hydrogen for Sectoral Integration – Trials and Deployment;

3) Session Fuel Cell Applications for Energy – Next Generation of Products;

4) Session Fuel Cell Applications for Energy – Trials and Deployment;

Day 2 – 20 November 2019

5) Session Fuel Cell Applications for Transport – Next Generation of Products;

6) Session Fuel Cell Applications for Transport – Trials and Deployment; and

7) Session Support for Market Uptake.

Each session opened with a presentation, including analysis[170] of the projects' portfolios. The Scientific Committee as co-moderators and the audience were able to clarify various issues (by performing the review) during Q&A sessions.

This year an **event mobile application** was developed dedicated to the PRD and Stakeholder Forum events and was used by over 280 participants. The event app included useful information for the users, such as the agendas, project posters and presentations, and exhibits list by means of a user-friendly interphase.

A total of **463 registered participants attended the PRD**. In addition, based on IP addresses, more than 207 web-streaming viewers followed the two-day PRD 2019 event. Post-event activities, including a survey among participants, indicated that balanced participation was achieved by industry, research organisations and other EU and national/regional institutions (Figure 16). National representations also demonstrated satisfactory coverage across European countries (Figure 17). It must be noted that increased participations were recorded from non-EU Member

169 https://www.fch.europa.eu/programme-review-page/programme-review-report-2018

170 Part of the analysis was supported by data collected in TRUST.

States such as China, Japan, South Korea, Chile and South Africa.

Participants were very satisfied with the agenda, the content of the presentations and invited speakers as well as the interaction opportunities during the event (Figures 18 and 19).

FIGURE 16: PARTICIPATION BY ORGANISATION IN PROGRAMME REVIEW DAYS

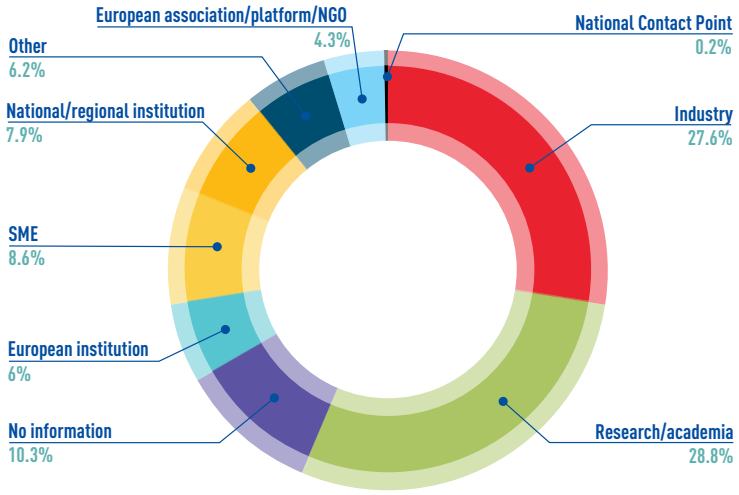


FIGURE 17: PARTICIPATION BY COUNTRY IN PROGRAMME REVIEW DAYS

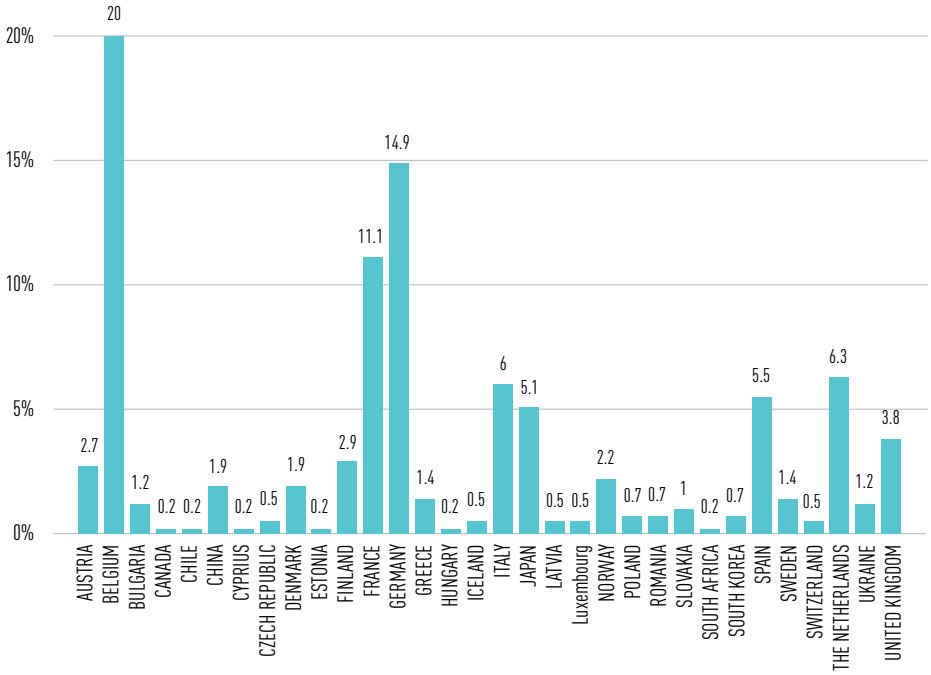


FIGURE 18: LEVEL OF SATISFACTION: AGENDA, QUALITY OF PROGRAMME

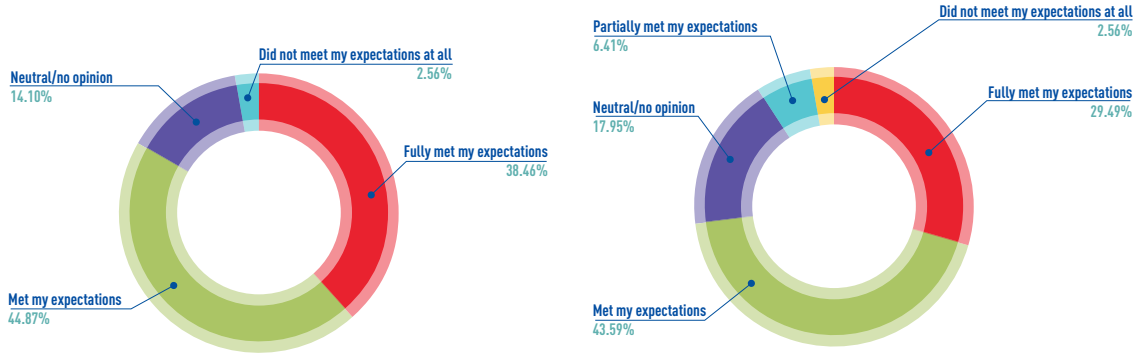
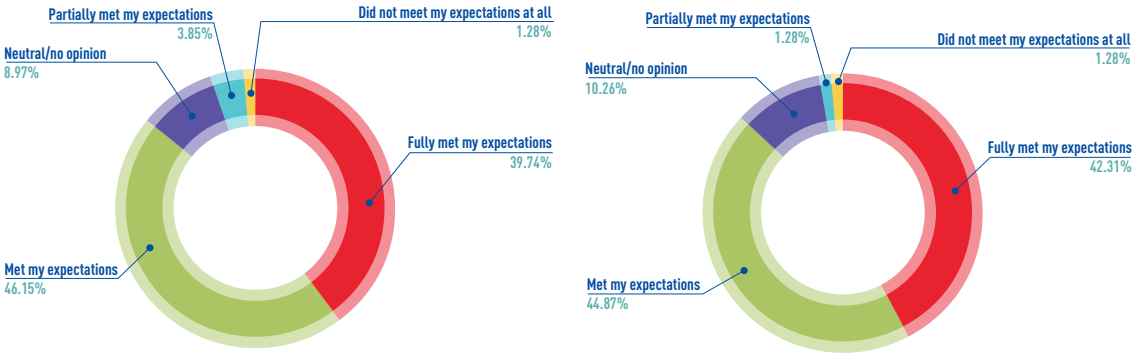


FIGURE 19: LEVEL OF SATISFACTION: SPEAKERS INVITED, INTERACTION OPPORTUNITIES



1.6 OPERATIONAL BUDGET EXECUTION

The total budget available in 2019 (including internal assigned revenues) reached EUR 91 730 585 in terms of commitment appropriations and EUR 113 855 981 in terms of payment appropriations. Commitment utilisation rate reached 85.6 % (93.5 % in 2018) whereas payment execution rate reached 99.7 % (83.4 % in 2018), the latter being the best execution rate in FCH 2 JU history (the previous one was 89.6 % in 2017).

In more detail:

FP7 budget

In 2019, 9 periodic reports were assessed (3 interim and 6 final), with the total amount of payments reaching EUR 5.8 million. The budget execution (in terms of payment appropriations) reached 95.1 % (79.6 % in 2017), which is also the best performance in FCH history.

H2020 budget

There were 44 interim and 8 final payments in 2019. In addition, H2020 operational payment appropriations were used for 19 pre-financing payments (2 from Call 2018 and 17 from Call 2019), as well as for studies, the JRC's work and the work of experts in the context of the EHSP.

Budget execution in terms of payment appropriations reached 100 % (83.4 % in 2018). As for FP7 payments, this constitutes the best execution rate in FCH history.

In terms of commitment appropriations, the execution rate reached 86.3 % (95.8 % in 2018). Compared to 2018, the lower rate was due to the outcome of the Call whereby two topics were not covered (FCH-01-1-2019: Demonstrating the blueprint for a zero-emission logistics ecosystem, and FCH-01-1-2019: Underground storage HRS), the impact of which was EUR 11.5 million.

For further details on the budget, see Section 2.3.

1.7 IN-KIND CONTRIBUTIONS

In-kind contributions in H2020

The FCH 2 JU legal framework for in-kind contributions[171] is defined in Council Regulation 559/2014 of 6 May 2014 establishing the FCH 2 JU, in which Article 4 provides that:

'The Members of the FCH 2 Joint Undertaking other than the Union shall make or arrange for their constituent entities or their affiliated entities to make a total contribution of at least EUR 380 million over the period defined in Article 1.'

When assessing the level of contributions according to the above-mentioned Article, the FCH 2 JU distinguishes between different types of contributions:

- Cash contributions
- In-kind contributions in operational activities (IKOP)
- In-kind contributions in additional activities (IKAA)

Thus, the **overall minimum threshold of EUR 380 million for the H2020 programme** refers to the sum of all three types of contributions.

In 2019, FCH 2 JU members other than the EU were able to demonstrate an **overall figure of EUR 678.71 million** of actual and certified contributions from private members, largely exceeding the minimum targets.

The table and graph below provide an overview of members' contributions under FCH 2 JU:

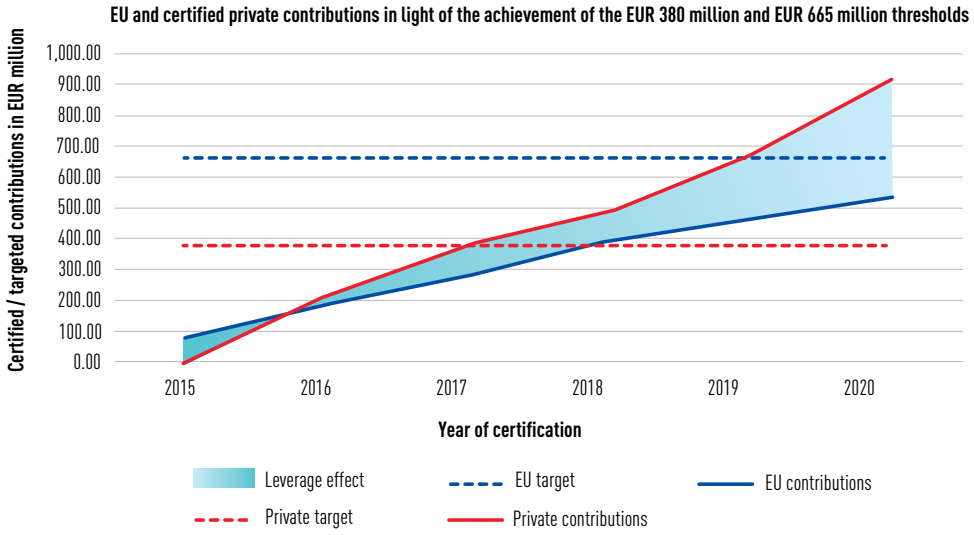
TABLE 1.7.1: FINANCIAL AND CERTIFIED IN-KIND CONTRIBUTIONS FROM PRIVATE MEMBERS AS AT 31 DECEMBER 2019

FINANCIAL AND CERTIFIED IN-KIND CONTRIBUTIONS	IN EUR MILLION
Financial contributions to FCH 2 JU administrative costs	
Industry	5.45
Research	0.89
TOTAL financial contributions	**6.33**
Indirect actions – in-kind contributions 'IKOP'	
Total certified IKOP as at 31 December 2019*	**5.38**
Additional activities – certified 'IKAA'	
Certified *additional activities* as at 31 December 2018	486.30
Newly certified *additional activities* in 2019	180.70
Total certified IKAA as at 31 December 2019	**667.00**
Total: as at 31 December 2019	**678.71**

** According to the IKOP methodology, the majority of the in- kind contributions are only certified at the end of the project (upon reception of the CFS certificate).*

171 This legal framework was complemented by a methodology for both IKOP and IKAA agreed by the FCH 2 JU GB on 18 November 2015 and 9 December 2016, respectively.

FIGURE 20: EU AND CERTIFIED PRIVATE CONTRIBUTIONS AS AT 31 DECEMBER 2019 WITH OUTLOOK FOR 2020



In-kind contributions in operational activities (IKOP)

IKOP are costs incurred in implementing indirect actions minus the contribution of the FCH 2 JU and any other EU contribution to those costs (Statutes, Article 13.3.b).

To be considered as IKOP, these costs must be incurred by members of Hydrogen Europe or Hydrogen Europe Research or their affiliates participating in FCH 2 JU indirect actions.

The regulation provides that IKOP should be valued according to members' usual accounting practices and applicable national and international accounting standards (Regulation, Article 4.4).

The Council Regulation allows the members to base their declaration of IKOP on the basis of their 'total costs' (according to their usual accounting practices) which may be slightly higher than their 'eligible costs' (according to H2020 rules). On a proposal from the Industry and Research Groupings, the GB decided to limit IKOP to eligible costs for cost-efficiency and simplification reasons.

As a result, the IKOP in H2020 projects for FCH 2 JU are limited to the amount of eligible costs as per H2020 rules, minus the EU contribution.

Calculation of the level of in-kind contributions is based on the methodology endorsed by the GB on 18 November 2015. *Ex-ante* controls for the IKOP under H2020 follow the harmonised practice in line with the common strategy of the rest of the RTD family, with the aim of simplifying and easing the controls performed when the payment is approved.

Ex-post certification of IKOP is provided by the *ex-ante* certificate of financial statements (CFS) which, compared to the FP7 programme, are only applicable for the final project period where the amount of FCH contribution to direct costs is higher than EUR 325 000.

Validation of the amount of IKOP is provided at Executive Director level, upon receipt of the CFS certificate and/or based on the result of the *ex-post* audits.

The amount of IKOP reflected in the FCH 2 JU accounts is based on all signed running projects as at 31 December 2019, considering mainly the estimated costs (mostly pro rata), as well as costs claims which were received but had not been validated at the cut-off date.

As at 31 December 2019, the estimated in-kind contributions for the 109 projects signed for the H2020 programme (2014-2019 Calls) were as follows (in EUR):

TABLE 1.7.2: OVERVIEW OF IN-KIND CONTRIBUTIONS IN OPERATIONAL ACTIVITIES (IKOP)

H2020 IN 2019	ACCUMULATED VALIDATED IKOP AT 01/01/2019	VALIDATED IKOP FOR 2019	IKOP RECEIVED BUT NOT VALIDATED AT 31/12/2019	IKOP ESTIMATE (PRO RATA) AT 31/12/2019	IKOP ESTIMATE TO BE VALIDATED	FORECAST OF AGGREGATED LEVEL OF IKOP
Industry grouping	1 825 132	3 404 867	26 372 704	23 069 543	81 343 198	136 015 443
Research grouping	0	146 119	0	1 653	95 323	243 094
TOTAL	**1 825 132**	**3 550 986**	**26 372 704**	**23 071 195**	**81 438 520**	**136 258 538**

Most of the IKOPs were not certified, as this will happen later during the H2020 programme at the final payment of the projects when the CFS are due.

In-kind contributions in additional activities (IKAA)

According to the FCH 2 JU regulation, *additional activities* (AA) are defined as activities carried out by members of Hydrogen Europe and Hydrogen Europe Research and their affiliates contributing to the FCH 2 JU programme's objectives but undertaken outside of its work plan, which are not funded by the EU or the JU.

The regulation provides that determination of the costs taken into account for the valuation of the in-kind contributions shall be in accordance with the usual cost accounting practices of the entities concerned, the applicable accounting standards of the country where the entity is established, and the applicable international accounting standards and international financial reporting standards (Article 4.4).

The FCH 2 JU regulation establishes a minimum level of IKAA at EUR 285 million over the period defined in Article 1 of the regulation.

The planning, reporting and certification process of the additional activities in 2019 followed a formal FCH 2 JU IKAA methodology, describing a robust control process to ensure the planned, reported and certified IKAA figures are reasonable (the methodology was agreed by the FCH 2 JU GB on 9 December 2016).

In 2019, the following important activities took place (in chronological order):

1. (Preliminary) Reporting of the values of the IKAA contributions for 2018 by Hydrogen Europe and Hydrogen Europe Research Members as at 31 January 2019

As per the Council Regulation, members of the FCH 2 JU other than the EU shall report each year by 31 January to the FCH 2 JU GB on the value of the contributions in additional activities made in each of the previous financial years.

In accordance with the regulation, the 2018 IKAA preliminary report was submitted on 31 January 2019 to the FCH 2 JU GB for information. An estimated IKAA of EUR 186.63 million was reported as achieved compared to the initial 2018 IKAA plan of EUR 250.16 million adopted by the FCH 2 JU GB on 15 December 2017.

The trend of reporting lower amounts in the preliminary reporting is normal since the initial plan is created based on long-term estimates of possible activities which are adjusted at the time of reporting.

2. Adoption of the IKAA 2019 Plan

On 9 April 2019, the IKAA 2019 Plan for the sum of EUR 198.49 million was adopted by the FCH 2 JU GB. The IKAA 2019 Plan was submitted by members in December 2018 with a prospective outlook of the activities in 2019.

3. The public version of the IKAA 2019 Plan

A total of 56 Hydrogen Europe and Hydrogen Europe Research members prepared their investment plans in additional activities for the period 1 January to 31 December 2019, including 157 different additional activities for a total amount of EUR 200.84 million.

In the 2019 reporting period, the certification threshold of EUR 325.000 liberated 25 % of reporting members (14 out of 56) from the obligation of certification, representing 1.1 % of the approved IKAA 2019 Plan amount.

The public version of the IKAA 2019 Plan was prepared by Hydrogen Europe and Hydrogen Europe Research and was published on the FCH 2 JU website: https://fch.europa.eu/page/in-kind-additional-activities.

4. IKAA certifications for the period 2017 and 2018[172]

The final 2018 IKAA Report submitted to the FCH 2 JU GB in June 2019 included a certified amount of EUR 90.92 million (for the activities from the IKAA 2018 Plan).

In addition, some members provided a certificate for the period 2017 for a total of EUR 3.24 million, leading to an increase in the total certified IKAA amount to EUR 580.47 million for the period 2014-2018 (EUR 486.31 million certified for 2014-2017).

The difference between the 2018 IKAA planned and realised figures was mainly due to certifications which were pending at the time of the initial submission in April 2019.

5. Additional IKAA certifications for the 2018 period

In October 2019, the members delivered additional certificates for additional activities, inherently derived from the 2018 IKAA Plan which encapsulated planned activities declared by the members at the beginning of the period and which were pending certification in June 2019.

To ensure strict continuity and compliance with the adopted Plan, no new activities (for the 2018 reporting period) compared to the adopted 2018 IKAA Plan, were included in that report.

With newly certified activities for 2018, for an amount of EUR 86.53 million, the total certified IKAA amount for 2014-2018 reached EUR 667.00.

6. Establishing the IKAA 2020 Plan

Hydrogen Europe Industry and Hydrogen Europe Research members jointly submitted their Additional Activities Plan covering the period 1 January 2020 to 31 December 2020 to be adopted by the FCH 2 JU GB in November 2019. The Plan included Additional Activities for a total amount of EUR 313.56 million.

In the IKAA 2020 Plan, the members have provided the highest amount of estimated annual IKAA since the beginning of the H2020 programme, demonstrating a strong and growing commitment to the partnership's goals, far beyond the minimum requirements established in the Council Regulation.

The IKAA 2020 Plan was adopted by the FCH 2 JU GB on 13 December 2019.

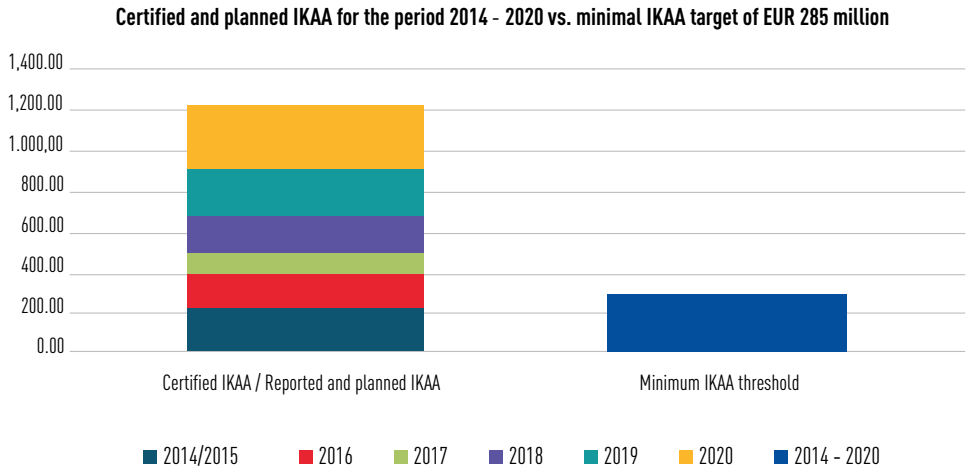
7. General overview of additional activities as at 31 December 2019

This section provides an overview of the cumulative amount of additional activities:

- Certified IKAA for the period 2014-2018 (based on the certificates received and validated at 31 December 2019, totalling EUR 667.00 million);
- Planned IKAA for the period 2019-2020 (based on 2019 IKAA Preliminary Report and the 2020 IKAA Plan, totalling EUR 551.82 million).

172 In 2019, the IKAA planning, reporting and certification process followed the formal FCH 2 JU IKAA methodology, describing a robust control process to ensure the planned, reported and certified IKAA figures are reasonable (the methodology was agreed by the FCH 2 JU GB on 9 December 2016).

FIGURE 21: CERTIFIED, REPORTED AND PLANNED IKAA FOR 2014-2020



The FCH 2 JU believes that the scope of investments captured in the IKAA plans 2019-2020, together with data already certified for 2014-2018, is a clear testimony of the FCH sector members' strong commitment, the continued progress of these technologies towards the market, and the strong leverage of FCH 2 JU investment. The Joint Undertaking believes that these investments in additional activities embody a robust contribution towards achieving joint objectives set in the FCH 2 JU regulation.

FP7

The FCH JU founding regulation (Council Regulation 521/2008 as amended by Regulation 1183/2011) states that the FCH JU operational costs shall be covered through the financial contribution of the European Union and through in-kind contributions from the legal entities participating in the activities.

Calculation of the level of in-kind contributions follows a methodology approved by the FCH JU GB on 10 February 2012. Verification of these costs includes: i) *ex-ante* controls before validation of the cost claims submitted by the beneficiaries (either based on desk-review assessment by the PO and/or certificates on financial statements provided by independent auditors); and ii) *ex-post* audits after validation of the cost claims, carried out by independent auditors appointed by FCH JU , in line with the FCH JU *ex-post* audit strategy.

In addition, in accordance with the methodology, the aggregated level of in-kind contributions is assessed every year by an independent external auditor.

In 2019, KPMG carried out the assessment and confirmed the amount of the aggregated level of in-kind contributions certified by the FCH JU ED (cut-off date 31 December 2018).

The full publishable report can be found at: http://www.fch.europa.eu/page/annual-activity-reports

The 2019 audit assessment (cut-of date 31 December 2019) was carried out by KPMG in February 2020.

As at 31 December 2019, details of the aggregated level of in-kind contributions are as follows (in EUR):

TABLE 1.7.3: AGGREGATED LEVEL OF IN-KIND CONTRIBUTIONS

FP7 YEAR 2019	ACCUMULATED VALIDATED IN-KIND CONTRIBUTIONS AT 01/01/2019	VALIDATED IN-KIND CONTRIBUTIONS IN YEAR 2019	IN-KIND CONTRIBUTIONS RECEIVED BUT NOT VALIDATED AT 31/12/2019	IN-KIND CONTRIBUTION ESTIMATE (PRO-RATA) AT 31/12/2019	IN-KIND CONTRIBUTION ESTIMATE TO BE VALIDATED AS FROM 01/01/2020	FORECAST OF AGGREGATED LEVEL OF IN-KIND CONTRIBUTIONS
Industry grouping	278,756,080	7,710,142	896,991	7,357,919	14,503,206	309,224,339
Research grouping	141,257,290	1,898,376	2,033,224	1,587,665	7,661,426	154,437,981
TOTAL	**420,013,370**	**9,608,518**	**2,930,216**	**8,945,584**	**22,164,632**	**463,662,320**

02
SUPPORT TO OPERATIONS

2.1 COMMUNICATION ACTIVITIES

2.1.1 COMMUNICATION OBJECTIVES 2019

Throughout 2019, the communication activities continued to promote FCH 2 JU activities and objectives, building on the programme's success stories to demonstrate the benefit of the instrument and the impact of its results. The FCH 2 JU participated in numerous events to increase the visibility of its actions and projects, enhanced its media efforts and launched awareness campaigns around its flagship Stakeholder Forum.

The **key communication themes** across the year included:

- FCH 2 JU is a successful partnership between the EU, research and industry which has achieved breakthroughs for European research and innovation
- There is a growing momentum for FCH technology. Market readiness of the technology and the need to support the development of the market conditions
- Project results and success stories: concrete benefits for the European citizens, socio-economic benefits, benefits and involvement of SMEs, etc.

Target audiences

The target audiences reached out to by the FCH 2 JU communication strategy in 2019 were:

- Policymakers: EU institutions (European Commission, European Parliament, Committee of the Regions, Council of the EU), individual Member States (relevant representatives of governments and permanent representations), municipalities and regional authorities
- FCH stakeholders (governance: European Commission Hydrogen Europe, Hydrogen Research, National Contact Points, technical experts, associations, etc.)
- FCH current beneficiaries
- FCH potential beneficiaries
- Financial actors
- Decision supporters/multipliers (civil society, associations, NGOs)
- General public

The FCH 2 JU continued to reach out to key actors from the **European institutions** to keep them informed about the Joint Undertaking's activities and results. This translated into the organisation of several joint events in cooperation with various EC DGs: participation in the **Open Doors Day** and the **R&I days** (under the umbrella of DG R&I), participation in **EUSEW** and **SET-PLAN** (in cooperation with DG ENER), co-organisation of a **Mission Innovation Workshop** with DG R&I, and others. The Undertaking also made use of EU-specific media outlets such as Politico and Euractiv to target the policymakers in Brussels.

Programme participation in the Horizon 2020 Info days for Energy and Transport provided an opportunity to address directly interested beneficiaries and to reach out to a larger pool of **beneficiaries**. The programme communications also targeted **potential (new) participants** in the FCH 2 JU 's Calls for proposals, through up-to-date, relevant information provided via online channels (website, news updates, social media) and during events, such as the annual Info Day organised around the launch of the Call for proposals and the coordinators' day, leading to the signature of the GAs.

It continued to target **new audiences** in various European countries, including EU-13 countries such as Romania, Slovakia, Czechia and Croatia, in order to enhance knowledge of the FCH 2 JU as a funding initiative and of the technology itself, and to attract interest from public authorities and potential applicants.

The participation of a **wider public** was stimulated throughout various channels: organisation of presentations and technology demonstrations at various events, a public information campaign carried out in Brussels, and by intensifying activity on social media channels.

Cooperation with other JUs (Shift2Rail and Clean Sky in particular) enabled the FCH 2 JU to reach out to **audiences from different industries** such as rail and aviation.

2.1.2 PUBLIC OUTREACH ACTIVITIES – EVENTS

The FCH organised and attended a wide range of events throughout 2019, from project-oriented events to participation in major exhibitions and outreach events. Many of them provided a full range of communication coverage, including web streaming, promotion on social media, event branding, and media engagement. Slido was used in most events organised throughout 2019, with polls and Q&A sessions leading to better engagement from the audience. The Joint Undertaking's flagship events – the Stakeholder Forum and the FCH 2 JU Awards – were once again at the centre of both policy and communication efforts.

Stakeholder Forum

The FCH 2 JU Stakeholder Forum took place on 21 November 2019 in the EC's Charlemagne building.

Under the title 'Racing towards a clean hydrogen economy', the Stakeholder Forum brought together the European FCH community and facilitated an open discussion on the impact, achievements and strategic direction of the FCH 2 JU programme, as well as on the latest developments in the sector. The event included panel discussions around the following themes:

- FCH 2 JU : making an impact by accelerating innovation and securing competitiveness
- Market activation and synergies
- Growth and jobs: making the most of hydrogen's potential
- Hydrogen at the international scale

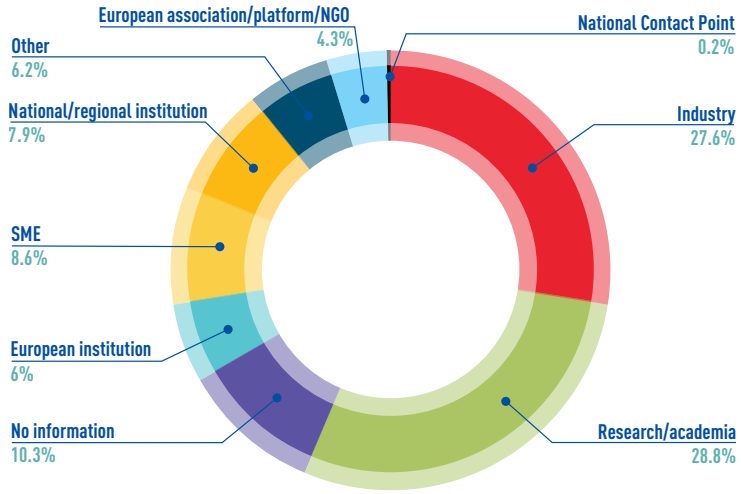
The conference benefitted from the participation of high-level representatives from the EC, national governments, European industry leaders and international organisations. Among these were Frans Timmermans, Executive Vice-President of the European Commission, European Commission Director-General for Energy, Ditte Juul Jørgensen, and Mauro Petriccione, Director-General for Climate Action at the EC.

Discussions **among more than 600[173] Forum participants in Brussels' Charlemagne building** focused on how to tackle the remaining hurdles to deployment, the importance of promoting an innovation culture in activating new markets, and the impact of synergies and international scale-up efforts on growth and jobs. Delegates explored the latest developments in the sector, showing how Europe is capitalising on new FCH developments and forging ahead towards a zero-emission economy.

Taking into account the recommendations of the GB and the results of the survey following SF 2018, the FCH 2 JU broadened the target audience for its Stakeholder Forum 2019 by inviting students from universities in Delft (NL) and Aberdeen (UK) to present their hydrogen-related projects.

173 Including online participants.

PARTICIPATION BY TYPE OF ORGANISATION IN THE STAKEHOLDER FORUM



Furthermore, during the Stakeholder Forum, participants and those passing by the EC's Charlemagne building had the opportunity to see some of the most innovative racing vehicles powered by hydrogen. They were presented by the ACO (Automobile Club de l'Ouest) – H24Racing team and Forze Hydrogen Electric Racing from the University of Delft – the first hydrogen electric racing team in the world. Moreover, the FCH 2 JU , together with the ACO and Hydrogen Europe, signed a letter of intent to promote hydrogen technology, demonstrate its potential and actively contribute to the energy transition.

During the event, the FCH encouraged interactive participation through live Q&A sessions via Slido. As a novelty, an event app facilitated the distribution of information about the event sessions and other practicalities.

Project-oriented events

FCH 2 JU Awards 2019

The Awards were presented at a ceremony in the Royal Museums of Fine Arts in Brussels on **20 November 2019**, attended by about 300 industry, research and EU representatives. The 2019 Awards Ceremony is the second held by the FCH 2 JU . The winners were chosen by public vote, which mobilised the European FCH community around the 24 nominees – 12 for each category (success stories and innovation).

The successful projects reduce FC technology production costs, speed up manufacturing, develop new materials to increase FC performance and demonstrate how people can rely on hydrogen energy. Overall, they pave the way for a world-class European FC industry that sustains clean energy.

SOSLeM took home the top prize in the **Best Project Innovation** category for their novel testing device which enables FC manufacturers to scale-up production volumes. The award was presented by Deputy Director General for Research and Innovation, Patrick Child.

The Best Success Story, Driving forward fuel-cell technology, is looking at a series of projects (VOLUMETRIQ, INSPIRE, CRESCENDO, GAIA and PEGASUS) which are making FCs more affordable and competitive. It was presented by the chair of the FCH 2 JU GB Valérie Bouillon-Delporte.

Hydrogen achievements in Scotland (Orkney Islands) were in the spotlight as the BIG HIT project was selected and presented by the PO with a **special award for Best Outreach**. Through active communication, the project helped to create a wider proactive atmosphere in favour of hydrogen research and development in Europe.

FCH 2 JU Info Day

The Info Day, organised on **29 January 2019**, was an opportunity for potential participants to receive further insights into the description of the topics and rules for participation in the 2019 Call for proposals, and to benefit from networking opportunities. The event was organised in the White Atrium premises in Brussels, and included a brokerage session, as per the previous year. The event was broadcast live and around 100 participants joined on-site. National info days were organised in France and Spain to present the topics to a local audience.

Coordinators Day 2019

Following the evaluation of the proposals received in the 2019 Call, the FCH 2 JU PO invited the coordinators of the successful projects for a day of presentations on **20 September 2019** covering all the necessary details on the preparation and signature of a GA.

Horizon info Days

FCH 2 JU participated in the **Horizon 2020 Info Days** for **Energy (25–27 June)** and **Transport (7 October 2019)** where it presented the opportunities for funding in FCH technologies. These events enabled the Undertaking to reach out to a wider pool of interested beneficiaries.

Industry events

Participation in industry events, such as the **Hannover Messe** and **EVS32**, provided opportunities for interaction with different types of stakeholders – industry, general public and the media.

Hannover Messe is one of the world's largest industrial fairs and also provides the venue for Europe's largest hydrogen, fuel cells and battery exhibition. FCH 2 JU 's team was present at the 2019 edition of the Hannover Fair on 1-5 April 2019, in a joint stand with NOW and GP JOULE, part of the Group Exhibit Hydrogen + Fuel Cells Europe. They provided information on the latest projects, Calls for proposals, and future developments throughout the event and also participated in the following public forum talks:

- Press conference in the presence of Mirela Atanasiu
- Hydrogen for Sectoral Integration, presented by Mirela Atanasiu
- A European Stack for Transport Applications, presented by Bart Biebuyck

The FCH 2 JU -funded project PACE also participated in the technical forum with a presentation on 'Fuel Cell micro-Cogeneration Picking-up PACE Towards Europe's Future Hydrogen Economy'. Other projects were presented at different stands.

Hydrogen projects in the Nordic countries – joint event with Hydrogen Sweden and the Energy Observer

This event aimed to give an insight into the plans for developing the FCH sector in the Nordic countries and the projects funded by the FCH 2 JU, while taking the opportunity to discuss recent technological advances in the field aboard the Energy Observer in Stockholm.

The event was organised by the FCH 2 JU in partnership with Hydrogen Sweden and the Energy Observer, the first hydrogen vessel in the world, which was visiting Stockholm from 24 May to 2 June 2019. This lead to the signature by Sweden of the Hydrogen Initiative launched in September 2018 by the Austrian Presidency of the EU, at an informal meeting of EU energy ministers in Linz, Austria.

The 32nd Electric Vehicle Symposium (EVS32) was held in Lyon from 18 to 23 May 2019. The FCH 2 JU team hosted a booth within the exhibition's new 'hydrogen cluster' area, providing information on the Undertaking's projects and about hydrogen in general.

In parallel, in cooperation with Hydrogen Europe, it organised three half-day hydrogen lecture sessions during which a total of 25 projects, partners and other stakeholders gave presentations on the following topics:

- Deployment of Fuel Cell Buses – Infrastructure and Hydrogen Regions
- Fuel Cell Electric Vehicles and Hydrogen Refuelling Stations
- Fuel Cells in Heavy Duty Transport and FCH Research

In addition, FCH 2 JU Executive Director Bart Biebuyck participated in the AEC2019 panel on 'The key role of transnational projects to boost hydrogen mobility'.

Events under the umbrella of the European Commission

During 2019, the FCH 2 JU attended the Open Day of the European Institutions and the R&I Days organised by the European Commission, which allowed it to reached out to a wider public as part of the exhibitions organised for the R&I family. Through its clean mobility projects, the Undertaking presented and demonstrated several hydrogen vehicles and offered participants test drives and/or transport in hydrogen cars and buses.






EUSEW 2019

As part of the EU Sustainable Energy Week (EUSEW), on 20 June 2019, the FCH 2 JU hosted a session on 'hydrogen valleys'. Participants discussed the elements needed to develop and implement an integrated approach to ramping up the use of hydrogen in different European regions (hydrogen valleys). It looked at policy, finance/investments, business models, local (regional) contexts and technology, among other issues, to show how the development of hydrogen valleys can foster economic growth in European regions while responding to local energy needs and reducing pollution.

International events (under Mission Innovation and other international initiatives):

> Mission Innovation Workshop on Hydrogen Valleys

The two-day Antwerp workshop focused on the concept of hydrogen valleys as a pathway for demonstrating the significance of hydrogen in the energy transition. The workshop gathered more than 80 attendees interested in nascent hydrogen valley projects from Mission Innovation Hydrogen Challenge member countries. The participants included representatives of government and international organisations, industry and research. The workshop benefitted from the presence in the Port of Antwerp of the Energy Observer hydrogen vessel.

> H2@PORTS Workshop

The H2@Ports workshop, held on 10-12 September 2019 in San Francisco, CA, explored opportunities for cooperation and collaboration on hydrogen technology for maritime and port applications. The workshop was hosted by the US Department of Energy Fuel Cell Technologies Office and the US Maritime Administration, and organised in collaboration with the Fuel Cells and Hydrogen Joint Undertaking. The workshop was aligned with IPHE's (International Partnership for Hydrogen and Fuels Cells in the Economy) goals and contributed to the objectives of Mission Innovation's Renewable and Clean Hydrogen Challenge.

> The 8th International Conference on Hydrogen Safety (ICHS 2019)

The lessons learnt from the Hydrogen Safety Reference Database and the EHSP Safety Planning Guidelines were presented at the International Conference on Hydrogen Safety (ICHS 2019) in Adelaide, Australia, on 24-26 September 2019, under the auspices of the International Association for Hydrogen Safety (HySafe).

Events targeting the EU-13 countries

In addition to project activities, the FCH 2 JU PO has increased its efforts to raise public awareness at Member State and regional level, in particular where low or non-existent interest in R&D FCH activities has been observed. In 2019, the FCH 2 JU participated in the following events in Eastern and Central European countries:

> SET Plan & ENVE Conference 2019

'Making the energy transition happen locally', Bucharest, 12-13 June 2019. On the occasion of this regions-and-cities-focused edition of the SET-plan conference, the FCH 2 JU organised a series of outreach activities which benefitted from wide exposure in Romania's local and national media. Participants and representatives from the press were able to try out a hydrogen bus, observe the refuelling process, and test drive two hydrogen cars.

> Workshop on Hydrogen Mobility in the Visegrad countries

This was organised within the Newmatech conference in Slovakia. During the event, participants were able to test drive two hydrogen vehicles, while top officials from the Visegrad countries also tried out the cars. Furthermore, the FCH 2 JU took part in a popular TV show to present the technology.

> Hydrogen mobility workshop in Ostrava, Czechia

This workshop took place on 23 September 2019 and brought together policy and industry from the Visegrad regions and Central Europe to inform them about best-practice examples of hydrogen mobility for public transport. The FCH 2 JU provided information about strategies, purchase, operation, maintenance of hydrogen buses as well as HRS.

> Hydrogen for green Slovakia

During this workshop to promote the technology towards regions and cities, held on 24 September 2019, the FCH 2 JU informed Slovak cities and regions about clean hydrogen public transport and infrastructure. The aim was to motivate them to start bilateral discussions about hydrogen bus and hydrogen energy projects.

The above events proved successful in achieving the targeted outreach towards national and local policymakers and the general public.

2.1.3 PUBLIC OUTREACH ACTIVITIES – CAMPAIGNS

For the FCH 2 JU, 2019 marked a milestone in terms of outreach and brand recognition through a campaign which aimed to:

- Increase FCH 2 JU's brand awareness
- Promote FCH utilisation as Europe's best available option to store clean energy on a large scale
- Raise awareness on the benefits of clean hydrogen for the economy and the environment and as a clean fuel for clean mobility
- Highlight the FCH 2 JU's mission and achievements among EU influencers in Brussels and beyond.

The #CleanHydrogen campaign targeted the broader public, the EU and national policymakers present both in Brussels and in other EU countries. The two-week campaign, which took place in the first weeks of November around the FCH 2 JU Stakeholder Forum, included two promotional 6' videos demonstrated in two of the main metro (Schuman) and railway (Gare du Midi train station) hubs and in the Brussels Airport departures terminal. The campaign was also adapted for social media where the videos featured on both Twitter and LinkedIn. It was also carried forward in Politico, Brussels' top media outlet.

The aim was to raise awareness among a mixed, English-speaking audience comprising EU policymakers and bureaucrats from different areas of EU activity, experts and representatives of the EU Member States (and beyond) travelling to/in Brussels, young people and influencers. The objective was to go beyond the hydrogen industry and research community, communicating simple messages focusing on hydrogen.

The outreach generated by the campaign was significant and contributed directly to one of the objectives identified by the GB in its assessment as one the major issues to be continued in 2019 and beyond.

Advertising campaign in high traffic transportation hubs in Brussels

Promo video

The video-centred campaign made a good impact during its two-week duration, reaching 67 % of the target group. The campaign reached out over 650 thousand viewers at the Airport and generated 188 thousand viewers at Gare du Midi. At Schuman metro station, 145 thousand viewers saw the campaign.

Media Campaign – Politico.eu

The main tactics were to:

- Showcase hydrogen's substantial socio-economic and environmental benefits to Europe through an informative article written by FCH 2 JU Executive Director, Bart Biebuyck.

- Take over the POLITICO.eu homepage for 24 hours to promote FCH 2 JU's brand and redirect users to the FCH 2 JU's homepage
- Increase FCH 2 JU brand promotion through online banners on the FCH 2 JU article.

Key takeaways from the campaign:

- Online article promotion and engagement results were far beyond average, highlighting the interest of Politico's audience in the topic
- Significantly above the engagement rate for FCH 2 JU's banner promotion both in the article and during the takeover of Politico's homepage
- The informative article – published on 13 November 2019 – generated 1 826 views, while the homepage and in-story promotion associated with the article generated 210 000+ impressions (views) and 507 clicks

The homepage was 'taken over' for 24 hours on 21 November – the same day as the Stakeholder Forum; it generated the following results:

> 282 000 impressions

> 367 clicks

> 69 000 page views

> Average time spent on the page: 10min 40s

Campaigns and events driving website and social media traffic

Social media campaign 'Let's talk #CleanHydrogen'

By creating a social media campaign around the FCH flagship events – the Stakeholder Forum and the Awards – programme visibility was significantly enhanced.

The social media campaigns run from 24 October 2019 to 25 November 2019 produced significantly more impressions and higher engagement rates on both Twitter and LinkedIn than were produced last year over the same time period.

The LinkedIn posts achieved 10 times more impressions compared to last year. Visitors to the LinkedIn page increased by 91 % during that period, leading to a gain of 463 new followers, 411 more than the previous year.

On Twitter, posts gathered 67 000 more impressions than during the same period last year. For all types of engagement (clicks, retweets, likes, replies), 2019 coverage of the FCH 2 JU event did better than 2018 coverage.

Sponsored advertisements on Twitter led to 135 807 impressions and an engagement rate of 2.09 % which is considered to be very high.

The hashtags used during the event were #cleanhydrogen, #FCH_JU #PRD2019 #SF2019 and #FCH_Awards19.

The #cleanhydrogen hashtag started trending on Belgium Twitter during the morning of 21 November 2019, testifying to the high visibility of the campaign.

The visuals designed for both LinkedIn and Twitter included banners reminding people of the forthcoming events (Figure 22) as well as banners revealing the Awards winners (Figure 23).

FIGURE 22. (LEFT) BANNER PROMOTING THE FCH 2 JU EVENTS (POSTED ON BOTH LINKEDIN AND TWITTER)

FIGURE 23. (RIGHT) BANNER ANNOUNCING THE WINNER OF THE 2019 FCH AWARDS FOR THE 'BEST INNOVATION' (POSTED ON BOTH LINKEDIN AND TWITTER)

FIGURE 24. (LEFT) POST PREPARED IN ADVANCE TO REMIND PEOPLE ABOUT THE 2019 FCH AWARDS AND TO GIVE THEM DIRECTIONS TO THE VENUE

FIGURE 25. (RIGHT) SPONTANEOUS POST REPORTING ON A SPEECH BY NOÉ VAN HULST DURING THE FCH STAKEHOLDER FORUM

LinkedIn

During the campaign, there were 35 posts on LinkedIn, the first post being published on 28 October 2019 and the last on 25 November 2019. These posts achieved a total of 16 599 impressions, 10 times more than last year (1 647).

The campaign and the promotion of various events resulted in new users targeting the FCH 2 JU website and social media channels.

Social media participation increased significantly in 2018 – for example, the number of Twitter followers increased from 2 241 in January 2019 to around 3 700 in December 2019 (a rise of about 70 %).

Activity on LinkedIn has more than doubled since 2018, with 3 184 current followers compared to 1 265 at the end of 2018.

2.1.4 COMMUNICATION ON PROJECT RESULTS

Success stories

In 2019, the FCH 2 JU aimed to update and increase the number of projects presented by means of success stories and results packs. The communication efforts continued to highlight the enormous progress that FCH technology has made in Europe through the results of various FCH 2 JU projects. The **success stories** presented in the new, updated success stories publication illustrate the continuous learning approach exemplified by the FCH 2 JU projects, from creating low-carbon and sustainable solutions, enabling market entry for new products, developing 'next-generation' products based on previous research, to opening new markets for European expertise in FCH technology. Each of the stories shows how collaboration between research, industry and policymakers in a European partnership delivers the best innovation and accelerates the transition to a greener world.

Collaboration with the CORDIS website

Collaboration with CORDIS continued in 2019, including the publication of a series of news articles featuring the FCH 2 JU-funded project H2ME (https://cordis.europa.eu/article/id/124282-taking-hydrogen-mobility-forward-in-europe), https://cordis.europa.eu/article/id/124941-hydrogen-mobility-from-clean-energy-gaining-momentum-in-europe; https://cordis.europa.eu/article/id/406958-emissions-free-transport-speeding-up-in-europe.

Other projects featured in CORDIS news throughout the year were:

- H2Future: https://cordis.europa.eu/article/id/411733-major-step-towards-producing-carbon-neutral-steel-with-green-hydrogen.
- JIVE: https://cordis.europa.eu/article/id/406599-zero-emission-double-decker-buses-to-join-public-bus-fleets-in-aberdeen
- FLAGSHIPS: https://cordis.europa.eu/article/id/125380-hydrogenpowered-river-vessel-to-turn-zeroemission-shipping-into-reality

The HEATSTACK project was published in the 'Results in Brief' section of the CORDIS website, alongside:

- BIONICO: https://cordis.europa.eu/article/id/394984-bionico-a-pilot-plant-for-turning-biomass-directly-into-hydrogen and:
- HyLAW: https://cordis.europa.eu/article/id/395015-identifying-legal-and-administrative-barriers-and-solutions-for-hydrogen-technology/en.

Synergies with project communications

Overall, the FCH 2 JU's **communication with project partners** set out to increase synergies and amplify the outcome of its communication activities.

The following events benefited from joint communication and inputs from the FCH 2 JU:

- **H2ME – mid-term conference**

The 'Hydrogen for Clean Transport' conference took place on **25 October 2019** in Hamburg during which discussions focused on opportunities around hydrogen in the transition to a sustainable energy future and the conclusions emerging from the H2ME projects were shared. The programme was complemented by the arrival of a rally of FC electric vehicles and a press event on 24 October to promote the advances made in creating a European network of HRS.

- **Fuel Cell Buses Workshop: Clearing the Way for Zero Emission Transport**

The FCH 2 JU moderated the workshop Fuel Cell Buses: Clearing the Way for Zero Emission Transport, organised during the European Week of Regions and Cities on 8 October 2019 in Brussels. The Undertaking provided, via one of its projects, a hydrogen shuttle bus for participants attending the European Week of Regions and Cities.

2.1.5 PUBLICATIONS

Throughout 2019, the FCH 2 JU produced the following publications which were made available both online on the FCH 2 JU website and through the distribution of printed copies at various events. It promoted the publications through its newsletter and social media channels.

An updated edition of the Success Stories Brochure was released ahead of the Programme Review Days/Stakeholder Forum. Individual projects are presented in a new, easy-to-read format enabling the clear presentation of results plus the impact of each project on the clean energy transition.

The **Study on the use of fuel cells and hydrogen in a railway environment** was launched in May 2019 during a joint workshop organised with the Shift2Rail Joint Undertaking. A joint press release was sent out to promote the study results to the specialised media.

2.1.6 MEDIA

Amplifying impact

The FCH 2 JU strengthened its engagement with stakeholders and the public in 2019 by expanding its media and social media presence through a more frequent distribution of relevant content, alongside regular news updates sent to the subscribers' database. Several opportunities were pursued throughout the year, illustrating greater media interest in topics covering green, sustainable energy and transport. Media coverage was generated mainly through earned media, with a media partnership set up with Politico for the awareness campaign (see 2.1.3 above).

Highlights

The Stakeholder Forum was particularly well presented, with Vice-President Timmermans' messages picked up by a variety of European media.

- https://www.euractiv.com/section/energy-environment/news/timmermans-sees-pivotal-role-for-hydrogen-in-meeting-eu-climate-goals/
- https://www.neweurope.eu/article/eu-sees-important-role-for-clean-hydrogen-in-europes-energy-transition/
- https://www.h2-view.com/story/hydrogen-is-ready-to-forge-a-zero-emission-economy-fch-ju-stakeholder-forum-confirms/
- https://www.energy-reporters.com/transmission/eu-to-lead-world-in-clean-hydrogen-timmermans/
- https://www.governmenteuropa.eu/hydrogen-energy-adoption/95597/

The Northern Netherlands ' successful bid to create a hydrogen valley has also received media attention, well ahead of the start day of the HEAVENN project.

The deployment of bus and car fleets around Europe was another topic of interest throughout the entire year, with the latest being the inauguration of the first hydrogen bus in France, at Pau, which was picked up by the French media in both France and Belgium.

The joint FCH 2 JU and S2R JU study on the use of FCH in the railway environment was picked up in a news article in the Italian newspaper, *La Stampa*, among others. Another FCH 2 JU study, Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition, has also been followed by the specialised media.

Below is a non-exhaustive list of articles published by European, technical and national media, in which FCH 2 JU was specifically mentioned:

- European Energy Innovation – Autumn 2019 edition: Fuel Cells and Hydrogen (FCH) Technologies in Europe: Looking towards 2020
- Government Europe quarterly: Carbon neutral rail travel of the future (rail study)
- Government Europa: Hydrogen energy adoption key to Europe's green transition
- H2View: Exclusive interview with FCH 2 JU Executive Director
- H2View: A roadmap to realise hydrogen's potential for Europe
- H2View: More hydrogen cars for London car service
- T&D World: EU Makes a New Bet on Green Hydrogen
- Manmonthly.com (Australia): Austrian metal manufacturer utilises hydrogen for green steel – on November 27, 2019
- Politico (paid contribution): Hydrogen power for Europe's green energy transformation

- National media in Romania and Slovakia also featured FCH 2 JU on several occasions during the events that took place (SET-Plan conference in Bucharest, Newmatech conference in Bratislava). It should be highlighted that the FCH 2 JU demonstrations were widely covered by the mainstream media (national TV channels with large audiences) and the investment made has paid off in terms of promotion at the national level.

  > http://stiri.tvr.ro/autobuzul-cu-hidrogen--prezentat-in-premiera-in-romania_846494.html

  > https://www.realitatea.net/autobuzul-cu-hidrogen-a-circulat-prin-bucure-ti-cum-func-ioneaza_2200216.html

  > https://a1.ro/news/auto/autobuzul-cu-hidrogen-la-bucuresti-poate-fi-alimentat-in-doar-sapte-minute-id874142.html

  > https://www.libertatea.ro/stiri/autobuzul-revolutionar-care-a-circulat-prin-bucuresti-este-alimentat-cu-hidrogen-2667748

  > https://www.digi24.ro/stiri/sci-tech/auto/autobuzul-revolutionar-care-a-circulat-timp-de-doua-zile-prin-bucuresti-1147080

  > TV programme (SK)

Additional exposure was achieved through FCH 2 JU-funded projects (in particular H2ME, BigHIT, ZEFER, etc.). Media database: a comprehensive media database has been updated with both European and national media.

2.1.7 GDPR – COMPLIANT COMMUNICATION

In preparation for compliance with the General Data Protection Regulation (which entered in force in October 2018) the communications team updated the existing lists of contacts and subscribers and carried out the necessary modifications to the website, in line with the new privacy laws.

2.2 LEGAL AND FINANCIAL FRAMEWORK

During 2019, the following procedures were drafted or updated and adopted:

- **Adoption of the Code of Good Administrative Behaviour**

To enable the FCH 2 JU to meet its obligations concerning good administrative behaviour and in particular in the dealings it has with the public, the FCH 2 JU undertakes to observe the standards of good administrative behaviour set out in the corresponding Code (as adopted also by the EC) and to be guided by these in its daily work.

The Code of Good Administrative Behaviour was adopted by the Executive Director of the FCH 2 JU on 27 September 2019.

- **Adoption of the Financial Rules of the Fuel Cells and Hydrogen 2 Joint Undertaking**

By Delegated Regulation (EU) 2019/887[174], the Commission adopted the model financial regulation for public-private partnership bodies to ensure sound financial management of Union funds and to enable public-private partnership bodies like FCH 2 JU to adopt their own financial rules. The model financial regulation ensures consistency with the provisions of Regulation (EU, Euratom) 2018/1046[175] and allows for additional simplification and clarification.

In view of this legal and financial context, the FCH 2 JU has adopted its new financial rules, following the model financial regulation for public-private partnerships.

The Decision was adopted by the FCH 2 JU GB on 18 December 2019.

174 Commission Delegated Regulation (EU) 2019/887 of 13 March 2019 on the model financial regulation for public-private partnership bodies referred to in Article 71 of Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council, C/2019/1875, OJ L 142, 29.5.2019, pp. 16-42.

175 Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council of 18 July 2018 on the financial rules applicable to the general budget of the Union, amending Regulations (EU) No 1296/2013, (EU) No 1301/2013, (EU) No 1303/2013, (EU) No 1304/2013, (EU) No 1309/2013, (EU) No 1316/2013, (EU) No 223/2014, (EU) No 283/2014, and Decision No 541/2014/EU and repealing Regulation (EU, Euratom) No 966/2012, OJ L 193, 30.7.2018, pp. 1-222.

- **Other rules and procedures**

Other rules were adopted, mainly implementing rules on governing the engagement of contract staff (see section 2.6).

A procedure for the adoption of a document management policy was also launched at the end of 2019, with the final document to be adopted in early 2020.

in addition, in view of the future adoption of internal rules for applying restrictions in terms of data subjects' rights and obligation, as provided for under Article 25 of Regulation (EU) 2018/1725[176], the FCH 2 JU, together with the other JUs (S2R, BBI, Clean Sky, ECSEL, IMI and SESAR), prepared a set of draft internal rules and launched a consultation with the European Data Protection Supervisor. The results of the consultation, adoption of the final set of rules and publication in the *Official Journal of the European Union* will take place during 2020.

2.3 BUDGETARY AND FINANCIAL MANAGEMENT

2.3.1 BUDGET

The FCH 2 JU budget comprises revenue and expenditure. On the expenditure side, the budget is divided into three titles:

- Title 1 covers staff expenditure, such as salaries, training, costs associated with the recruitment procedure, missions, medical expenses and representational costs;
- Title 2 covers the costs associated with the functioning of the FCH 2 JU, such as renting premises, IT needs, expenses related to external communications, experts' fees and the cost of *ex-post* audits;
- Title 3 covers operational activities of FCH 2 JU for both FP7 and H2020 programmes.

Compared to 2018, the 2019 commitment appropriations increased by 33 % whereas payment appropriations were reduced by 10 %.

There were two amendments and five budget transfers in 2019. The first amendment, which was adopted by the FCH 2 JU GB on 10 May 2019, introduced unused administrative and operational payment appropriations carried over from 2018. The second amendment was adopted by the FCH 2 JU GB on 13 December 2018 following the reduction in operational payment appropriations, as accepted in the context of the EC's global transfer procedure.

An overview of the initial budget, the amendments and transfers are presented below:

TABLE 2.3.1: 2019 BUDGET EVOLUTION

BUDGET 2019 (IN EUR)									
	VOTED BUDGET		AMENDMENTS		TRANSFERS		ASSIGNED REVENUES	FINAL BUDGET	
	CA	PA	CA	PA	CA	PA	CA+PA	CA	PA
EU operational FP7		4 750 000		-4 500 000				**0**	**250 000**
EU administrative	2 684 775	2 684 775						2 684 775	2 684 775
Hydrogen Europe	2 308 907	2 308 907						2 308 907	2 308 907
Hydrogen Europe Research	375 869	375 869						375 869	375 869
EU operational H2020	81 723 069	105 618 082		-7 000 000				81 723 069	98 618 082
Reactivations from previous years	3 799 175	269 954		8 509 604				3 799 175	8 779 558
JTI revenues							838 790	838 790	838 790
Total revenue	**90 891 795**	**116 007 587**	**0**	**-2 990 396**	**0**		**838 790**	**91 730 585**	**113 855 981**

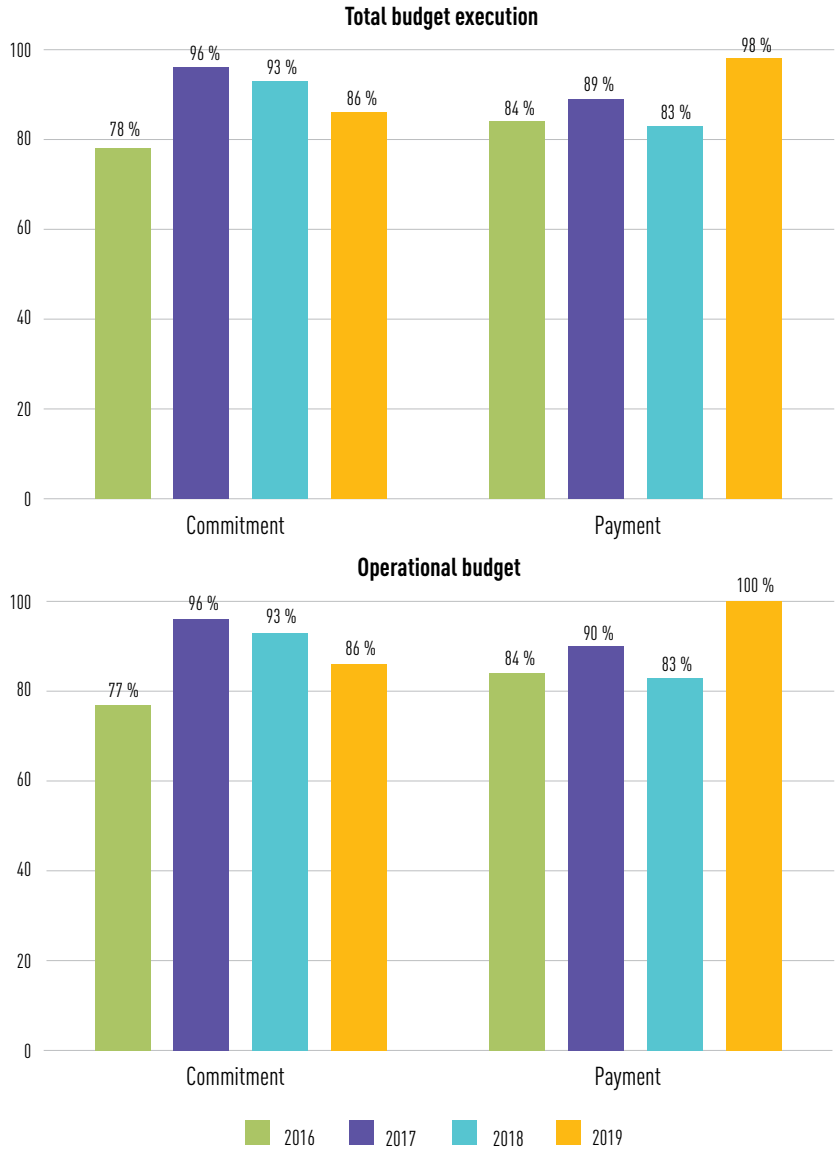
176 Regulation (EU) 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies and on the free movement of such data, and repealing Regulation (EC) No 45/2001 and Decision No 1247/2002/EC.

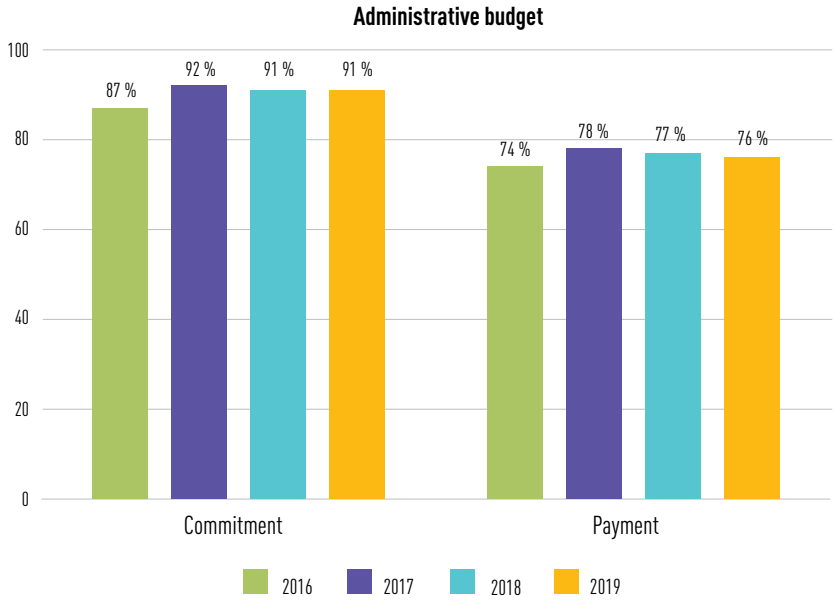
BUDGET 2019 (IN EUR)									
	VOTED BUDGET		AMENDMENTS		TRANSFERS		ASSIGNED REVENUES	FINAL BUDGET	
	CA	PA	CA	PA	CA	PA	CA+PA	CA	PA
Expenditure									
Title 1	3 547 600	3 547 600		139 518				3 547 600	3 687 118
Title 2	2 091 905	2 091 905		674 827				2 091 905	2 766 732
Title 3 – FP7		4 750 000		575 755		15 184		0	5 340 939
Title 3 – H2020	85 252 290	105 618 082		-4 380 496		-15 184	838 790	86 091 080	102 061 191
Total expenditure	**90 891 795**	**116 007 587**	**0**	**-2 990 396**	**0**	**0**	**838 790**	**91 730 585**	**113 855 981**

2.3.2 BUDGET EXECUTION

In 2019, the level of executed payments recorded the best performance in FCH history (98 %), surpassing the previous record by far. This reveals the accuracy of the budget forecast and is the outcome of closely monitoring project spending and time to pay (TTP). The commitment execution rate dropped by 7 percentage points compared to 2018, as explained in sections 1.3 and 1.6 above.

GRAPH 2.3.1: BUDGET EXECUTION





The execution rates for the operational budget reached 86 % and 100 % for commitments and payments, respectively, as shown in graph 2.3.1. The utilisation rates for administrative commitments and payments were consistent for a third year in a row.

Further details on budget execution:

Revenues

FCH 2 JU revenue for 2019:

TABLE 2.3.2: IMPLEMENTATION OF REVENUES

REVENUE (IN EUR)		
HEADING	INCOME APPROPRIATION (IN BUDGET)	CASHED IN 2019
Operational expenditure, Union	98 868 082	98 868 082
Administrative expenditure, Union	2 684 775	2 684 775
Administrative expenditure, IG	2 308 907	2 308 907
Administrative expenditure, RG	375 869	375 869
Recoveries[177]	838 790	847 441
Reactivation of appropriations	8 779 558	
TOTAL	**113 855 981**	**105 085 074**

177 Difference between amount inscribed in expenses budget and amount cashed is due to liquidated damages that are cashed but do not constitute a revenue that automatically increases the budget.

Expenditure

TABLE 2.3.3: IMPLEMENTATION OF EXPENDITURE

Title Chapter Article Item	Heading	Commitment				Payment			
		Commitment appropriations (CA) (1)	Commitments (2)	Non-used appropriations (3)=(1)-(2)	%committed (4)=(2)/(1)	Payment appropriations (PA) (5)	Payments (6)	Non-used payment appropriations (7)=(5)-(6)	%paid (8)=(6)/(5)
1	STAFF EXPENDITURE								
1 1 0 0	Staff costs	3 213 019	3 137 163	75 856	97.6%	3 348 260	3 131 151	217 109	93.5%
1 2 0 0	Expenditure related to recruitment	107 000	13 843	93 157	12.9%	107 000	13 843	93 157	12.9%
1 3 0 0	Mission expenses	180 000	180 000	0	100%	181 467	157 550	23 916	86.8%
1 4 0 0	Socio-medical infrastructure	42 000	39 533	2 467	94.1%	44 809	35 865	8 945	80.0%
1 5 0 0	Entertainment and representation expenses	5 600	3 338	2 262	59.6%	5 600	3 338	2 263	59.6%
TOTAL TITLE 1		**3 547 619**	**3 373 877**	**173 742**	**95.1%**	**3 687 137**	**3 341 747**	**345 390**	**90.6%**
2	INFRASTRUCTURE								
2 0 0 0	Rentals	357 606	353 563	4 042	98.9%	388 832	347 109	41 723	89.3%
2 1 0 0	IT costs operational	388 242	354 473	33 770	91.3%	597 889	291 122	306 767	48.7%
2 2 0 0	Movable property and associated office equipment costs	0	0	0	0%	0	0	0	0%
2 3 0 0	Current administrative expenditure	4 500	3 322	1 178	73.8%	5 701	3 388	2 313	59.4%
2 4 0 0	Correspondence, postage and telecommunications	13 000	10 660	2 340	82.0%	20 359	7 297	13 061	35.8%
2 5 0 0	Meetings in general	92 299	48 184	44 114	52.2%	95 010	46 431	48 579	48.9%
2 6 0 0	Communication costs	633 705	569 720	63 985	89.9%	872 541	508 306	364 235	58.3%
2 7 0 0	Service contracts	231 923	119 250	112 673	51.4%	392 836	81 126	311 710	20.7%
2 8 0 0	Expert contracts and meetings	403 860	321 259	82 601	79.6%	426 794	316 475	110 319	74.2%
TOTAL TITLE 2		**2 125 134**	**1 780 432**	**344 703**	**83.8%**	**2 799 962**	**1 601 255**	**1 198 707**	**57.2%**
TOTAL TITLE 1+2		**5 672 753**	**5 154 309**	**518 444**	**90.9%**	**6 487 099**	**4 943 002**	**1 544 097**	**76.2%**
3	OPERATIONAL EXPENDITURE								
3 0 0 1	**FP7**	764 153	0	764 153	0.00%	6 105 092	5 805 092	300 000	95.1%
3 0 0 2	**H2020**	85 293 679	73 642 035	11 651 644	86.3%	101 263 790	101 263 790	0	100%
TOTAL TITLE 3		**86 057 832**	**73 642 035**	**12 415 797**	**85.6%**	**107 368 882**	**107 068 882**	**300 000**	**99.7%**
TOTAL		**91 730 585**	**78 796 344**	**12 934 241**	**85.9%**	**113 855 981**	**112 011 884**	**1 844 097**	**98.4%**

Administrative expenditure

The FCH 2 JU's administrative budget execution remained at the same level as 2018 (91 %). Unused appropriations coming from the 2019 budget totalled EUR 518 444, of which EUR 148 688 had already been reactivated in the 2020 budget. The remaining EUR 369 756 could be reactivated in 2020 or in 2021 in accordance with FCH 2 JU financial rules.

Unused commitment appropriations came mainly from service contracts as, in the absence of an agreement with the CAS regarding the payment modalities, there was no charge for audits ordered by the FCH, as provided for in the initial budget. Furthermore, budget line 1200 (expenditure related to recruitment) included provision for two seconded national experts (SNEs). However only one SNE was recruited in November, hence the observed unused appropriations. In addition, the cost of evaluators in 2019 fell by nearly EUR 40 000 compared to 2018 costs, which explains the lower execution in this budget line (2800).

Operational expenditure

As regards the **H2020 operational costs** (call, studies, JRC and EHSP), the commitment execution rate reached 86.3 %. The total unused appropriations are due to the fact that two topics from Call 2019 were not covered, as explained in sections 1.3 and 1.7. The majority of the unused appropriations (in total EUR 11 651 644) had already been reactivated in 2020 budget. A small balance resulting from the Mission Innovation study (EUR 10 000) will be reactivated in the 2020 budget through an amendment.

The entire budget for H2020 payments was used (100 % execution), which is by far the best result in FCH 2 JU history.

As regards **FP7 operational costs**, the execution rate on the payment appropriations reached 95.1 %, which also constitutes the PO's best performance.

Overview of programme implementation

The following tables provide an overview of FP7 and H2020 implementation:

TABLE 2.3.4: IMPLEMENTATION OF FP7 PROGRAMME

FP7 (IN EUR)			
TYPE	EXECUTION UNTIL 31.12.2019	SUBSEQUENT YEARS	TOTAL
Commitments (operational costs)	450 851 384		450 851 384
Payments (operational costs)	415 313 265	10 825 034	426 138 299
Cumulative execution (operational costs)	**92.1 %**	**94.5 %**	**94.5 %**
Commitments (administrative costs)	30 658 610		30 658 610
Payments (administrative costs)	30 658 610		30 658 610
Cumulative execution (administrative costs)	**100.0 %**	**100.0 %**	**100.0 %**
Overall FP7 execution	**92.6 %**	**94.9 %**	**94.9 %**

As regards operational costs:

For **FP7**, the execution rate reached 92.6 % at the end of 2019. The commitments under operational costs refer to individual commitments for grants and studies. In total, there were 155 grant commitments and 13 operational commitments referring to procurement activities. Until 31 December 2019, from 155 grant agreements signed, 1 project was cancelled, final payments were made for 149 projects, and 5 projects remain open. The amount shown under 'subsequent years' refers to the interim and final payments for these 5 projects. It should be noted that the execution rate on the closed projects reached 93 %.

TABLE 2.3.5: IMPLEMENTATION OF H2020 PROGRAMME

H2020 (IN EUR)			
TYPE	EXECUTION UNTIL 31.12.2019	SUBSEQUENT YEARS	TOTAL
Commitments (operational costs)	550 624 578	95 375 422	646 000 000
Payments (operational costs)	402 450 870	243 549 130	646 000 000
Cumulative execution (operational costs)	**73.1%**	**100.0%**	**100.0%**
Commitments (administrative costs)	11 341 355	26 658 645	38 000 000
Payments (administrative costs)	10 471 669	27 528 331	38 000 000
Cumulative execution (administrative costs)	**92.3 %**	**100.0 %**	**100.0 %**
Overall H2020 execution	**73.5 %**	**100.0 %**	**100.0 %**

For **H2020**, the amount committed until the end of 2019 refers to the 109 individual commitments for H2020 projects, 18 studies contracted, 2 annual commitments for the European Hydrogen Safety Panel, 4 commitments for the JRC's annual work as well as 1 commitment for acquisition of the registry in certificates.

As regards the **administrative costs**, an amount of EUR 869 686 was committed in 2018 and 2019 but not paid (as services are ongoing and/or invoices pending); therefore, this will be carried forward to meet remaining obligations.

Amendments signed in 2019

Besides assessing the periodic reports, FCH financial management also includes the processing of project amendments.

In 2019, the Executive Director signed 4 FP7 and 51 H2020 amendments.

2.3.3 TIME TO PAY

Operational payments

In 2019, 9 FP7 and 52 H2020 reports (interim and final) were assessed (63 in 2018). The overall TTP for FP7 and H2020 combined remained at the 2018 level (71 days). The gross TTP (including any suspensions due to requests for clarifications and amendments) was only 40 days which is an improvement of nearly 70 % compared to the 2018 suspension time (127 days).

In more detail:

FP7

9 reports were assessed in 2019 (29 in 2018), of which 6 were final and 3 interim.

The average TTP of these reports was 67 days (64 days in 2018). The gross TTP (162 days) remained at the 2018 level.

H2020

The average Time To Grant (TTG) for the 17 signed projects from Call 2019 was 230 days, a consistent performance with 2018.

In 2019, 44 interim and 8 final reports were assessed with an average TTP of 71 days (76 in 2018). The gross time to assess was 101 days (96 in 2018).

Administrative payments

The average TTP for administrative payments (invoices from suppliers of goods, service providers and cost claims from experts/staff) was 16.3 days (18.2 in 2018). The number of late payments (3.4 %) was another best performance in FCH records, slightly improving on the previous one in 2017 (3.6 %). Strong monitoring measures on the open invoices helped to achieve this record.

2.4 PROCUREMENT AND CONTRACTS

The tender and contract management has been simplified as far as possible by following the inter-institutional procurement procedures launched by the EC and using the resulting multi-annual Framework Contracts. FCH 2 JU also cooperates with other Joint Undertakings in tendering needs in order to minimise the administrative effort.

As in previous years, most of FCH 2 JU's contracting was carried out under existing multi-annual Framework Contracts, except for operational procurement activities (see procurement studies under section 1.4 Call for tenders). In terms of volume, procurement of studies and the managed IT services were the most significant procedures launched.

Launching a call for tender and receiving and opening tenders was greatly simplified by the introduction of eTendering and eSubmission modules at the beginning of 2019.

The table below gives an overview of the contracts awarded in 2019, including the procedure used in each case and the name of the contractor(s). Only those contracts with a value exceeding EUR 15 000 are listed below:

TABLE 2.4.1: CONTRACTS AWARDED IN 2019 (> EUR 15 000)

TYPE OF CONTRACT	CONTRACT TITLE	CONTRACT REFERENCE	SELECTION PROCEDURE (IF APPLICABLE FOR CONTRACT AWARDS)	NAME OF CONTRACTOR	AMOUNT (IN EUR)
Direct service contract	PDA study	FCH/OP/Contract 242	Open procedure	Spilett New technologies GmbH	742 080
Direct service contract	Mission Innovation platform study	FCH / OP / Contract 249	Open procedure	Roland Berger GmbH	490 000
Framework Contract for services	Event organisation	FCH / Contract 243	Open procedure	Teamwork	400 000
Direct service contract	Study on Opportunities arising from the inclusion of Hydrogen Energy Technologies in the National Energy & Climate Plans	FCH/OP/Contract 234	Open procedure	Trinomics B.V. Ludwig-Bolkow-Systemtechnik GmbH	270 000
Specific contract	PRD/SF 2019	FCH/Contract 243-1	Specific contract under framework	Teamwork	189 675
Framework Contract for services	Editing, writing and proof-reading	FCH/Contract 227	Negotiated procedure for middle value contracts	European Service Network SA	143 000
Agreement	Construction of kiosk	Amendment No3 to Usufruct Agreement	Agreement under Usufruct Contract	ES Finance AS	83 676
Specific contract	Managed IT services 2020	Specific contract No 3	Specific contract under framework	Realdolmen N.V.	81 387
Specific contract	Managed IT services 2019	Specific contract No1	Specific contract under framework	Realdolmen N.V.	74 797
Specific contract	Editorial work 2019	FCH/Contract 227-1	Specific contract under framework	European Service Network SA	44 536
Direct service contract	Mobile HRS supply 2019	FCH/ Contract 223	Negotiated procedure for middle value contracts	Air Liquide Advanced Technologies	44 196

TYPE OF CONTRACT	CONTRACT TITLE	CONTRACT REFERENCE	SELECTION PROCEDURE (IF APPLICABLE FOR CONTRACT AWARDS)	NAME OF CONTRACTOR	AMOUNT (IN EUR)
Specific contract	12th batch	Specific contract No 2019-12-LB	Specific contract under framework	Lubbock Fine	37 800
Specific contract	Interim staff	FCH/Contract 225		Start People N.V.	37 747
Specific contract	Interim services – Knowledge Management support	FCH JU 2019 PO103	Specific contract under framework	Randstad Belgium NV	36 022
Specific contract	Interim services – Communication support	FCH JU 2019 PO104	Specific contract under framework	Randstad Belgium NV	30 430
Specific contract	Interim staff	FCH JU 2019 PO115	Specific contract under framework	Randstad Belgium NV	29 962
Direct service contract	Sponsorship to Energy Observer	FCH / Contract 246	Negotiated procedure for low value contracts	Energy Observer	25 000
Direct service contract	Publicity campaign 2019 metros/airport	FCH / Contract 256	Negotiated procedure for low value contracts	JCDecaux	23 643
Direct service contract	Privacy management tool	FCH/CONTRACT 236	Negotiated procedure for low value contracts	OneTrust Technology Ltd.	21 330
Specific contract	TESTA-ng II Ongoing services 2020	TESTA-ng II SC 95	Specific contract under framework	T-System International GMBH	20 096
Specific contract	Multimedia awareness campaign	**AV0054**	Specific contract under framework	European Service Network SA	17 095
Specific contract	Layout posters for PRD 2019 + App Android 8.1 update	**PO/2017-06/A2-9**	Specific contract under framework	Pomilio Blumm Srl	17 031

2.5 IT AND LOGISTICS

The year 2019 was driven by the monitoring and continuous improvement of the IT managed services provided by RealDolmen for support services and CANCOM for hosting services. FCH 2 JU also supported the setting up of a second secured data communication line (Testa line) from Hamburg to the EC and a back-up line between Brussels and Hamburg, to secure access to the infrastructure as a service community cloud set-up in 2018 for the Joint Undertakings. The year was also marked by the appreciated upgrade of audio-visual equipment in some of the meeting rooms. During the second semester, a lot of activities and improvements were carried out on the website and computers in relation to the entry into force of the EUPR.

Support to FCH core business

As in previous years, FCH staff were assured adequate access to the complete set of EC applications for grant management, with an improved monitoring system of access rights, in line with prior audit recommendations. The roles of the Single Point of Contact for COMPASS (SPOC) and Local Authorisations Manager for ABAC (LAM) were again useful to deal with workload and blocking situations in workflows. Close contacts were maintained with the CIC to ensure the successful implementation of H2020 Call 2019. New functionalities were introduced, including:

- The workflow for Audit Report Implementation (AURI) already in use was adapted for the new task Letter Paper Sending;
- Audit Process In-Housed (AUPI), and Audit Process Outsourced (AUPO) workflows were adapted to the business practices and proper allocation of actors for the various steps set in February;
- The workflow Grant Outbound Formal Notification (GOFN) was released in May;
- The new letter paper sending task for the 'recovery order' workflow was adopted in May;
- The experts LE/BA workflows for validation services was announced in October and proper allocation of actors for the various steps has already been communicated.

Business support tools

The FCH 2 JU continued to adopt more common EU systems. Amongst them, following e-Prior[178] in 2018, e-Tendering and e-Submission provided by DIGIT were implemented for a paperless procurement cycle that simplifies manual interactions and saves time.

All staff members now use ARES, the registration and document management system used by the EC on a daily basis. This allows FCH 2 JU to apply by analogy the same document management policy as the EC known under the acronym e-Domec (electronic archiving and document management in the EC).

The FCH 2 JU continued to use the shared Innovative Medicines Initiative Joint Undertaking (IMI JU) cloud application platform for time-management and selection procedures while in parallel preparing for the SYSPER implementation, in collaboration with DG HR and DIGIT, to support this two-year transition.

The FCH 2 JU website is hosted by DIGIT under the Next-Europa services to ensure the stability and continuity of this essential tool for the external communication and visibility of the FCH programme. In this context, the dissemination of results related to studies and project-related information was supported by new sections:

- SOA and future targets (KPIs) as derived from the MAWP;
- TIM, an IT tool to monitor and better understand the different facets of FCH innovation and technological development.

As regards EUDPR implementation and its implications for the website:

- Procurement and deployment of a dedicated tool for cookies and consent management (Onetrust) is expected to be in production in the first quarter of 2020;
- Integration of the online data protection register procured jointly with other JUs and expected to be in production in the first quarter of 2020;
- Use of Europa Analytics to analyse the traffic and usage statistics on the FCH 2 JU website;
- Updated maps for FCH 2 JU projects, regions' initiatives, value chain study using the map web tools as corporate and interactive services tailored for europa.eu sites.

FCH internal support

The specific contract under the EC Framework Contract TESTA NG II for the provision of the secured telecommunications line in the first half of 2020 was signed during the last quarter of 2019 to enable the continuation of services in all Joint Undertakings. This contract includes a second access from Hamburg to the European Commission IT services (Testa@Cancom) for business continuity consideration. BEREC Office is sharing this solution and associated costs with the 6 JUs from the White Atrium building. This link will be assessed as potential main solution during the first quarter 2020 and the European Institute of Innovation and Technology (EIT) has already expressed interest in sharing the investments, too.

FCH 2 JU is the leading authority for the Framework Contract for the IT Managed Services provided for the six JUs hosted in the White Atrium building. The second specific contract for the associated services entered into force on 1 January 2020. It includes a revision of the service level agreement, provision for the Windows 10 long-term service support and VPN service as well as preparations for the migration towards Microsoft Office 365 cloud solutions and support services.

The renewal of the wired and wireless network to cover the announced obsolescence, the current needs and, in particular, future expectations (wireless/mobile offices, future/digital workplace, etc.) is a common project under the IT annual work plan for the six JUs. The best financial and technical option was selected during the third quarter 2019 and orders for new equipment were placed under the EC Framework Contracts in December 2019. The IT service provider will carry out the installation and configuration during the first quarter of 2020.

Support was also provided at events using video broadcasting, such as Info Day, project reviews and studies.

178 e-PRIOR is a free open source e-Procurement platform that allows public administrations to implement interoperable electronic services.

Logistics

In addition, logistical support has been provided in the context of general administration. This encompasses the management of supply and maintenance of equipment, namely stationery, goods and services for administration, and includes the monitoring of services provided in particular through the Office des Infrastructures de Bruxelles, the translation centre and the publications office (OPOCE).

In 2019, one special achievement was the implementation of new equipment for the meeting room covering the required audio-visual and web-conference services. The SCIC AV&C-2 Framework Contracts available to the JU were used in this context. Implementation was carried out during the first quarter of 2019 in two of the four common meeting rooms on the first floor. Given the success of this, similar equipment was installed in meeting rooms of the third and fourth floors during the second quarter for the direct benefit of the JUs concerned (FCH 2 JU, Clean Sky 2 JU and BBI JU). The same upgrade was also adopted for FCH 2 JU's three mobile interactive screens. Given its success, it has also been adopted in the common IT AWP for 2020 to equip the rest of the common meeting room on the first floor with similar equipment.

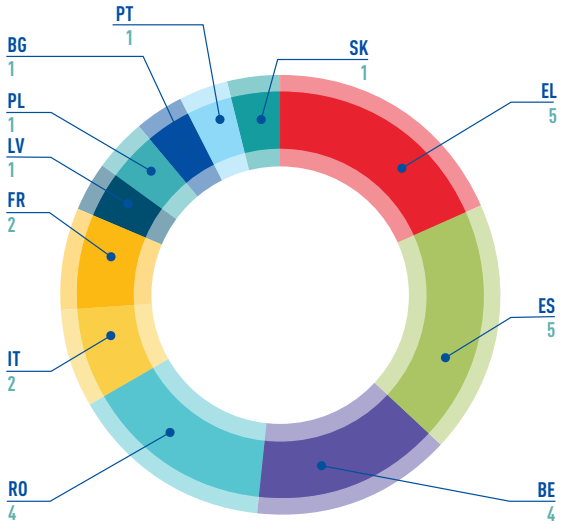
Furthermore, FCH 2 JU led the project for a new reception desk in the White Atrium, financed by the six JUs and Coopernic and aiming to improve the security/reception agents' working environment. The contract was signed in October 2019 and work should be completed by the end of January 2020.

2019 was also marked by a number of 'go-green' initiatives, including replacing single-use plastic bottles and cups with glass jars and glasses, better rubbish sorting and use of eco-friendly catering, among others.

2.6 HUMAN RESOURCES

By the end of 2019, the FCH 2 JU PO comprised 27 team members (24 temporary agents and 3 contract agents) representing 10 different EU Member States.

GRAPH 2.6.1: FCH 2 JU STAFF BY NATIONALITIES



The team is well balanced in terms of gender distribution (51 % men and 49 % women) and ages range from 31 to 62 years (average 44.6).

Details of the Staff Establishment Plan are shown in Annex 2.

Following the launch in September 2018 of a selection procedure for two SNE posts, one was filled in November 2019 for an initial period of two years. An open-end call for SNE was published in December 2019 with the aim of filling the second position.

To provide support to the PO in communication and knowledge management and to cover the long-term sick leave of an assistant, short-term contracts for interim services were used in 2019. The PO also benefited from the contribution of the two paid trainees who each spent six months in the office supporting the work in the operations and communications unit.

The PO depends on the expertise and motivation of its staff to achieve its goals. In 2019, in accordance with the FCH 2 JU Framework for Learning and Development adopted by the GB in January 2018 and with the **learning and development** policy adopted by the Executive Director in December 2018, emphasis on learning and development was pursued by identifying training needs and promoting professional development through training opportunities.

Individual training needs were identified during the annual appraisal exercise in order to manage talents and ensure consistency in the professional and personal development of all staff in line with the PO's mission and tasks. This included both classroom and online training in languages, general soft skills and H2020 training, as well as on specific topics related to individual staff members' current jobs.

In addition to individual training, horizontal sessions were organised, including a training course on personal effectiveness attended by all staff and followed by individual coaching sessions, and a workshop on procurement aiming to increase awareness and knowledge of procurement rules and the procedures developed internally.

An away day was organised in September 2019 with a visit to the site of a beneficiary which manufactures hydrogen-powered garbage trucks. It was an opportunity for the whole team to learn about the company, the constraints of this application of the technology and the challenges it faces.

The Reclassification Exercise 2019 was carried out and the decision on staff reclassified (one temporary agent) was adopted with reclassification taking effect retroactively on 1 January 2019.

In accordance with notifications from the EC, new implementing rules on staff regulations were adopted by the FCH 2 JU GB during 2019:

> on provisions governing the engagement of contract staff (14/02/2019)

> on type of posts and post titles (10/05/2019).

In addition, the following implementing rules adopted by the EC were notified to the FCH 2 JU and will apply by analogy nine months after the notification date:

- Decision on Drivers C(2019)7822 of 30/10/2019 – notified 12/11/2019
- Decision on dealing with professional incompetence (officials) C(2019) 6855 of 4 October 2019 – notified 9/10/2019
- Decision amending max duration of non-permanent staff in EC services C(2019)2548 of 5 April 2019 – notified 30/09/2019
- Decision re conduct of administrative inquiries and disciplinary proceedings C(2019)4231 of 12.06.2019 – notified 17/06/2019

03
GOVERNANCE

3.1 GOVERNING BOARD

The FCH 2 JU GB comprises three representatives from the EC representing the EU, six representatives from Hydrogen Europe and one from Hydrogen Europe Research. The chair of the GB is Valérie Bouillon-Delporte, president of Hydrogen Europe and the vice-chair is Patrick Child, Deputy Director-General of DG R&I. At the end of 2019, one representative from Hydrogen Europe was replaced by Oliver Weinmann from Vattenfall.

During the year, the FCH 2 JU GB had three meetings: 22 March, 27 June and 7 November. The first was mainly dedicated to discussions on AWP 2020 as well as agreement on the change in the organisation chart proposed by the Executive Director. The June meeting included a presentation on the outcome of Call 2019 evaluations, which were subject to a written procedure for adoption of the call results by the FCH 2 JU GB (see below), a follow-up on the preparation of AWP 2020, a discussion on the new model financial rules, and a presentation of the Innovation fund by DG CLIMA. In November, discussions covered finalisation of the AWP 2020 (which was followed by a written procedure for adoption – see below) as well as the possible role of the FCH 2 JU in the IPCEI. All the meetings focused on strategic issues and discussions on the progress of the programme and included updates from the members on policy developments and preparations for Horizon Europe.

The FCH 2 JU GB also adopted major decisions by written procedure, including the following:

- FCH-GB-2019-01 Approval on 9 April 2019 of the AAP 2019
- FCH-GB-2019-02 Decision on 22 March 2019 on extension of the Executive Director's contract
- FCH-GB-2019-03 Adoption on 10 May 2019 of the 1st amendment to the budget for 2019
- FCH-GB-2019-04 Approval on 10 May 2019 of the assessment of the level of in-kind contributions (FP7)
- FCH-GB-2019-05 Adoption on 10 May 2019 of types of post and post titles in FCH 2 JU
- FCH-GB-2019-06 Adoption on 29 July 2019 of the minutes of the FCH 2 JU GB meeting of 22 March 2019
- FCH-GB-2019-07 Assessment and approval on 24 June 2019 of the AAR 2018
- FCH-GB-2019-08 Opinion on 1 July 2019 of FCH 2 JU 2018 final accounts
- FCH-GB-2019-09 Adoption on 29 August 2019 of the minutes of the FCH 2 JU GB meeting of 27 June 2019
- FCH-GB-2019-10 Adoption on 5 August 2019 of the list of actions selected for funding – Call 2019
- FCH-GB-2019-11 Adoption on 14 August 2019 of the general implementing provisions governing the engagement of contract staff
- FCH-GB-2019-12 Adoption on 15 January 2020 of the minutes of the FCH 2 JU GB meeting of 7 November 2019
- FCH-GB-2019-13 Approval on 13 December 2019 of the FCH 2 JU AAP for 2020
- FCH-GB-2019-14 Adoption on 13 December 2019 of the AWP and budget for 2020

- FCH-GB-2019-15 Adoption on 13 December 2019 of the 2nd amendment to the budget for 2019
- FCH-GB-2019-16 Adoption on 18 December 2019 of the FCH 2 JU financial rules

More information on the role and composition of the GB is available at: http://www.fch.europa.eu/page/governing-board

3.2 EXECUTIVE DIRECTOR

According to Article 9 of the FCH 2 JU statutes, the Executive Director is the legal representative and the chief executive responsible for the day-to-day management of the FCH 2 JU in accordance with the decisions of the GB.

Bart Biebuyck was appointed as Executive Director by the FCH 2 JU GB and took up his duties on 16 May 2016. In 2019, his contract was extended until May 2023.

3.3 STATES REPRESENTATIVES GROUP

During 2019, the States Representatives Group (SRG) met on 28 January, 28 May and 18 November. Among other things, its activities focused on monitoring FCH 2 JU's achievements and results, with particular attention being paid to the following:

- In the January meeting, the main topics included a presentation by industry representatives of the HyLAW[179] project which aimed at boosting the market uptake of FCH technologies and giving market developers a clear view of the applicable regulations whilst calling the attention of policymakers to the legal barriers to be removed; a presentation by the FCH 2 JU's strategy and market development officer on the Hydrogen Europe Roadmap[180] study and a discussion on the SRG's draft position paper regarding the support for FCH technologies in the next Framework Programme.
- During the May meeting, the SRG members were updated on the status of Call 2019 and on progress on AWP 2020 preparations, and a presentation was given on the results of the joint FCH-Shift2Rail study on hydrogen for railway applications[181].
- In the November meeting, a Commission representative gave a presentation on the status of preparations for Horizon Europe and on a possible Clean Hydrogen partnership. The JRC presented its report[182] on the analysis of collaboration mechanisms with European Structural and Investment Funds in an S3 context. A representative from Hydrogen Europe presented the vision of Hydrogen Europe and Hydrogen Europe Research on the Clean Hydrogen Partnership and invited SRG members to participate in the consultation on the full Strategic Research & Innovation Agenda published on its website[183]. The mandate of the chair and the two vice-chairs was extended for one year until the end of 2020.

During 2019, the SRG was consulted on developing call topics and documents and on AWP 2020. In November, the GB validated a set of answers provided by the Coordinators' Group to the questions/comments raised by the SRG. The SRG chair and/or vice-chair participated in the FCH 2 JU GB meetings.

179 https://www.hylaw.eu/about-hylaw

180 https://www.fch.europa.eu/news/hydrogen-roadmap-europe-sustainable-pathway-european-energy-transition

181 https://www.fch.europa.eu/sites/default/files/01-Roland-Berger-Public.pdf

182 https://s3platform.jrc.ec.europa.eu/documents/20182/322704/Joint+Undertakings+analysis+of+collaboration+mechanisms+with+ESI+Funds/40d43c03-00d6-453c-8025-484e2261177e

183 www.cleanhydrogenforeurope.eu

3.4 SCIENTIFIC COMMITTEE

The Scientific Committee (SC) is an advisory body to the GB and comprises a maximum of nine members reflecting a balanced representation of globally renowned expertise from academia, industry and regulatory bodies. The role of the SC is to provide: (a) advice on scientific priorities to be addressed in the annual work plans; and (b) advice on scientific achievements described in the annual activity reports. The SC held a teleconference (in March) and a meeting (in May) to give the GB advice on both the above-mentioned actions. The chairperson attended the board meetings (in March, June and November 2019) and took part in discussions but had no voting rights. An additional informal meeting was held during the PRD event in Brussels (November 2019).

3.5 STAKEHOLDERS FORUM

The Stakeholders Forum is one of the FCH 2 JU key governance bodies, which ensures the transparency and openness of the FCH 2 JU programme for all stakeholders, including the public. It also provides opportunities to enhance FCH 2 JU communication activities as it brings together a large number of policymakers and EU stakeholders.

The 2019 edition of the Stakeholder Forum 'Racing towards a clean hydrogen economy' took place on 21 November 2019 in Brussels.

It brought together the European FCH community and facilitated an open discussion on the impact, achievements and strategic direction of the FCH 2 JU programme, as well as on the latest developments in the sector.

For more information on the Stakeholders Forum in 2019 (including the awards), please see section 2.1.2.

04
INTERNAL CONTROL FRAMEWORK

In August 2018, the GB adopted the revised FCH 2 JU Internal Control Framework (ICF). The new framework is based on the revised EC framework and consists of five internal control components and 17 principles based on the COSO 2013 Internal Control-Integrated Framework.

The internal control component[184] underpin the structure of the ICF and support the FCH 2 JU in its efforts to achieve its objectives.

To facilitate the implementation of the ICF and management's assessment of whether each component is present and functioning, and whether the components function well together, each component consists of a set of principles. Assessments based on these principles help to provide reasonable assurance that the FCH 2 JU's objectives are being met. The principles specify the actions required for internal control to be effective. The characteristics of each principle are defined to assist the management in implementing internal control procedures and in assessing whether the principles are present and functioning.

In addition, the FCH 2 JU ICF provides for handover reports, briefings, monthly reporting on specific topics (such as budget execution, financial management, and monitoring KPIs) and reporting at weekly management meetings. A yearly review and declaration of assurance by each head of unit are included in their input into the AAR and in a review by the internal control coordinator of the state of the internal control system (see sections 4.6 and 5.2).

4.1 FINANCIAL PROCEDURES

The financial procedures guide FCH 2 JU operations and set out how it uses and manages its funds and resources.

Effective implementation of new COMPASS workflows (such as formal notification) brought further improvement in managing grants.

Preparation of calls for tenders, managing the calls (for instance, replying to questions), submission of offers and opening of tenders was improved and simplified to a great extent through the adoption of eTendering and eSubmission in Q1 2019. In particular, eSubmission enables tenders to be submitted only electronically even for open procedures, significantly increasing the efficiency of the PO.

4.2. *EX-ANTE* CONTROLS ON OPERATIONAL EXPENDITURE

Ex-ante controls are essential to prevent errors and avoid the need for *ex-post* corrective action. In 2019, the FCH 2 JU continued to apply the provisions of Article 66 of the Financial Regulation and Article 18 of FCH 2 JU Financial Rules: *'each operation shall be subject at least to an ex-ante control based on a desk review of documents and on the available results of controls already carried out relating to the operational and financial aspects of the operation'.*

Therefore, the main objective of *ex-ante* controls is to ascertain that the principles of sound financial management have been applied.

The FCH 2 JU has developed and continues to apply well-developed procedures defining the controls to be performed by project and finance officers for every cost claim, invoice, commitment and payment, taking into account risk-based and cost-effectiveness considerations.

For operational expenditure, the processing and recording of transactions in the IT accounting system (ABAC) are mainly performed via the corporate Horizon 2020 IT tools (Sygma/COMPASS), which ensures a high degree of automation, and the controls are embedded in each workflow.

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184 Control environment, risk assessment, control activities, information and communication, and monitoring activities.

Ex-ante control activities in 2019 included:

- Assessing 61 periodic reports;
- Checks during the Grant Agreement Preparation (GAP) phase for the 17 projects under Call 2019;
- Participation of project and finance officers in H2020 project kick-off meetings in order to clearly communicate the financial reporting requirements;
- Targeted webinars focused on the specificities of each project;
- Reinforced monitoring and targeted checks during *ex-ante* controls for interim and final payments in accordance with the H2020 *ex-ante* control strategy, last updated on 18 December 2019.

4.3 *EX-POST* CONTROL OF OPERATIONAL EXPENDITURE AND ERROR RATES IDENTIFIED

The main objectives of the *ex-post* controls are to ensure that legality, regularity and sound financial management (economy, efficiency and effectiveness) have been respected and to provide the basis for corrective and recovery activities, if necessary.

H2020 programme – *ex-post* controls, H2020 audit strategy and cooperation with the Common Implementation Centre (CIC)

Ex-post controls of operational expenditure for H2020 are designed and implemented in line with the Horizon 2020 *Ex-Post* Audit Strategy[185]. For Horizon 2020, CIC developed this audit strategy in cooperation with all of its clients (i.e. the entities that implement the Horizon 2020 budget: EC services, executive agencies and joint undertakings).

The B2 unit of the CIC Common Audit Service (CAS) ensures harmonised implementation of the H2020 *Ex-Post* Audit Strategy for the EU's research and innovation expenditure, serving all 20 H2020 stakeholders. The CAS uses the IT tool AUDEX for audit process management. Its mission is to deliver a corporate approach for the audit cycle: audit selection, planning, application of rules, relations with beneficiaries, and management information on the audit process.

The main objective of the audit strategy is to provide the individual authorising officers with the necessary elements of assurance in a timely manner, thereby allowing them to report on the budget expenditure for which they are responsible. *Ex-post* controls on operational expenditure contribute in particular to:

- Assessing the legality and regularity of expenditure on a multi-annual basis;
- Providing an indication of the effectiveness of the related *ex-ante* controls;
- Providing the basis for corrective and recovery mechanisms, if necessary.

The FCH 2 JU is effectively integrated in this control chain: it participates in the audit process definition and in the monitoring of its implementation in close cooperation with the CAS and its clients. The main objectives of this cooperation are to align operations and exploit synergies on the common audit effort. The efficiency gains will reduce audit costs and the administrative burden on auditees, always in line with the specific objectives explained above for *ex-post* controls.

The implementation of all *ex-post* audit results remains the responsibility of the FCH 2 JU.

The FCH 2 JU also ensures the implementation of the research community's common anti-fraud strategy. The main actions derived from the strategy include the organisation of awareness-raising sessions within the JU and cooperation with the European Anti-Fraud Office (OLAF) (in the case of risk-based audits conducted by the CAS or outsourced contractors). Implementation of the action plan derived from the strategy is monitored by the Fraud and Irregularity Committee (FAIR) – see also section 4.1.

185 Ref. Ares(2016)981660 – 25/02/2016, endorsed by the CIC Steering Board.

In 2019, the following main achievements were reached:

- Selection of 22 new corrective and representative H2020 *ex-post* audits in cooperation between FCH 2 JU and CAS (CIC, B2 unit) for execution of the audits in 2019-2020 with expected results (Letter of Conclusion sent) by 31 December 2020;
- Formal endorsement of the JUs' sampling methodology, after a successful application and lessons learnt from the first two years of H2020, by the CIC Executive Committee on 19 July 2019;
- Closure of the first 18 representative audits by 31 December 2019 allowing for more precise calculation of the FCH 2 JU specific representative error rate at the rate of -0.94 % on the total FCH 2 JU contribution of EUR 194.26 million, accepted by 31 December 2019;
- Participation of the FCH 2 JU in the extension of the audit findings exercise, common for all H2020 stakeholders, enabling further cleaning of the representative error rate down to -0.70 % of the residual error rate.

H2020 *ex-post* audit methodology and error rates – corporate approach

The Common Representative Sample (CRaS) provides an estimate, via a representative sample of cost claims across the research and innovation family, of the **overall level of error** in the research FPs, across all services involved in its management. All of these grants follow the same homogeneous overall control system set out in this report.

The H2020 *ex-post* audit strategy builds upon different layers of audits:

- A corporate layer consisting of a CRaS[186] complemented by risk-based samples;
- An additional sample for entities with specific GAs or a separate discharge procedure and Article 10 audits on the demand of the JUs.

In H2020, all 20 implementing entities are expected to follow the same homogeneous overall *ex-ante* control system[187].

The Horizon 2020 audit campaign started in 2016. By June 2020 there will be three CRaS (with a total of 467 expected results) selected. By the end of 2019, cost claims amounting to EUR 16.2 billion had been submitted by the beneficiaries to the services. The error rates at 31 December 2019 were:

- Representative detected error rate: 2.78 % , expected to rise to 3.30 % taking into account the results of draft audit reports.
- Cumulative residual error rate for the R&I Family of DGs: 2.15 % (2.24 % for DG R&I), expected to rise to around 2.31 % (2.40 % for DG R&I) when taking into account the results of the draft audit reports.

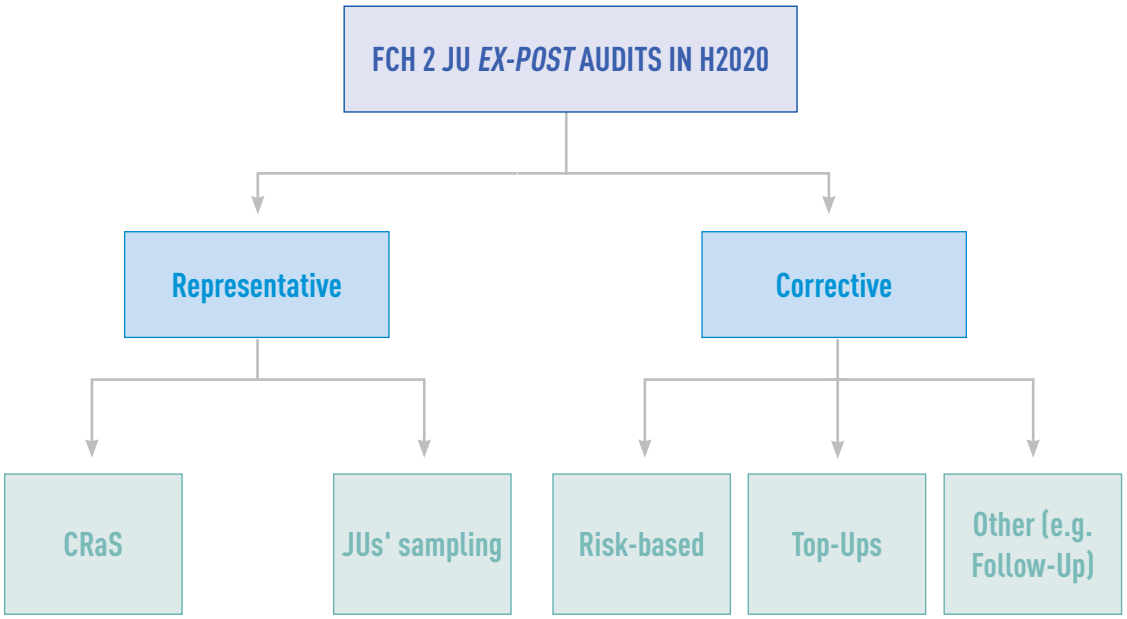
H2020 *ex-post* audit methodology and error rates – FCH 2 JU approach

For classification, reporting and error-rate calculation purposes, FCH 2 JU distinguishes between representative and corrective audits. Corrective FCH 2 JU audits are defined as all audits which were not selected by statistically representative sampling.

186 Taken biannually for 162 participations; MUS sampling is applied; population is determined by the costs declared and paid by the beneficiaries through financial statements which form the basis for calculating the EU contribution.

187 Guidance H2020 *ex-ante* controls on interim and final payments, version 1.0.

CHART 4.3.1: H2020 *EX-POST* AUDIT STRATEGY AT FCH 2 JU – CLASSIFICATION OF THE *EX-POST* AUDITS



Given the relatively small share of the FCH 2 JU's budget (target H2020 overall FCH 2 JU contribution of EUR 665 million: 1 %) compared to the overall H2020 target budget (EUR 63 584 million[188]: 100 %), the number of participations selected for *ex-post* audit by the CAS via the CRaS is very limited.

This observation was further confirmed by the fact that none of the FCH 2 JU participations were selected in the first CRaS. In the second round of CRaS, two FCH 2 JU participations were directly hit by Monetary-unit (MUS) sampling in 2018. The items hit by CRaS are considered as representative for calculation of the FCH 2 JU specific error rates. The results of these two hits by CRaS 2 were available by 31 December 2019 and were incorporated into the -0.94 % error rate calculation[189].

Selection of the third round of CRaS is expected in Q1 of 2020.

Therefore, in line with Annex 1 to the H2020 *ex-post* audit strategy, the FCH 2 JU planned for additional audit sampling (i.e. JUs' specific sample) in order to ensure sufficient *ex-post* audit coverage and enable a representative error rate on FCH 2 JU expenditure to be calculated over time. This is necessary to provide reasonable assurance to the JU Executive Director in view of his declaration of assurance and the separate discharge procedure for the JU.

By 31 December 2019, the FCH 2 JU had selected 76 participations for *ex-post* audits (compared to the estimated target of 295 participations audited for the whole H2020 programme). As observed in the table and graphs below, the FCH 2 JU in its H2020 ex-post audit campaign follows closely the payment patterns of H2020 projects.

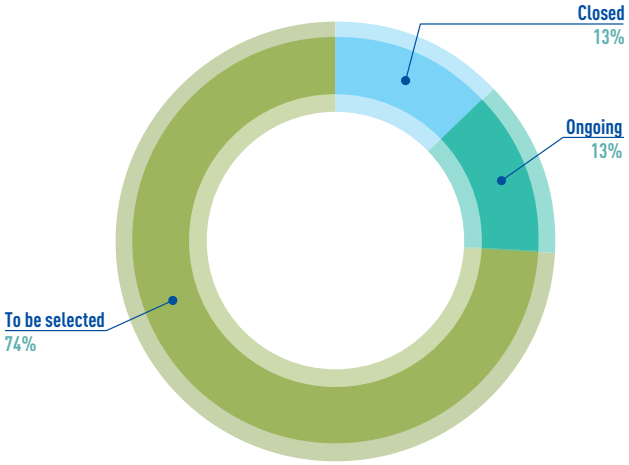
188 H2020 operational budget of EUR 70.280 million less EUR 6.696 million related to the EIT financial instruments and others.

189 As these two audit results came from the MUS sampling from the whole research family, in order to incorporate them into FCH 2 JU's specific representative error rate calculation the identical weighting factor was assigned as to those results (the same as for those from FCH 2 JU's representative audits).

TABLE 4.3.1: *EX-POST* AUDITS IN-PROGRESS TABLE AT 31 DECEMBER 2019 – COMPLETENESS STATUS

H2020 AUDITS WITH FCH 2 JU PARTICIPATIONS	NUMBER OF PARTICIPATIONS			
	CLOSED	ONGOING	TO BE SELECTED	H2020 OVERALL TARGET
Total at 31 December 2019	38	38	219	295

FCH 2 JU H2020 *EX-POST* AUDITS – COMPLETNESS STATUS



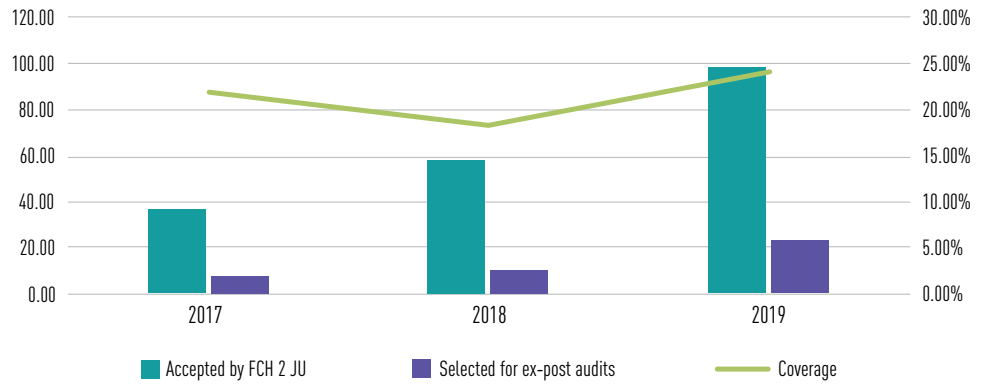
In 2019, the FCH 2 JU validated cost claims totalling EUR 102.58 million (EUR 72.32 million in 2018), of which EUR 98.53 million represented the EU contribution (EUR 58.65 million in 2018).

Of this EUR 98.53 million, throughout the year the FCH 2 JU selected corrective and representative audits to target overall audit coverage of around 20 % of H2020 expenditure, as per the table below.

TABLE 4.3.2: *EX-POST* AUDITS IN-PROGRESS TABLE AS AT 31 DECEMBER 2019 – AUDIT COVERAGE

	FCH 2 JU CONTRIBUTION IN EUR MILLION			COSTS IN EUR MILLION		
YEAR	ACCEPTED BY FCH 2 JU	SELECTED FOR *EX-POST* AUDITS	COVERAGE	ACCEPTED BY FCH 2 JU	SELECTED FOR *EX-POST* AUDITS	COVERAGE
2017	37.09	8.14	21.96%	53.93	13.52	25.08 %
2018	58.65	10.80	18.41%	72.32	12.55	17.35 %
2019	**98.53**	**23.71**	**24.06%**	**102.58**	**32.59**	**31.78 %**
Total as at 31 December 2019	**194.26**	**42.65**	**21.95%**	**228.82**	**58.67**	**25.64 %**

COVERAGE OF FCH 2 JU CONTRIBUTION BY H2020 *EX-POST* AUDITS SELECTED IN 2017 – 2019



Representative audits were selected following the common JU sampling methodology. This methodology was built on the principles of stratified random sampling (which is similar to the method used by the FCH 2 JU in FP7) with the following objectives:

- Efficient use of resources
- Focusing on large-value cost claims
- Providing an overview of the full range of projects and beneficiaries in the FCH 2 JU programme
- Ensuring representability of the results, as per the International Standards on Auditing.

Risk-based audits in 2019 were selected by applying an analytical approach of reviewing the inherent risk and exposure profiles of FCH 2 JU beneficiaries (first step). In the second step, the selected beneficiaries were assessed internally by the project and financial officers to validate a rationale and specific risks involved in projects signed with those beneficiaries.

As a result of this approach, six beneficiaries were selected for the risk-based audits, following a discussion with the operational services.

For efficiency purposes, all available cost claims validated by the FCH 2 JU until the audit was launched, if available, were added to the selection.

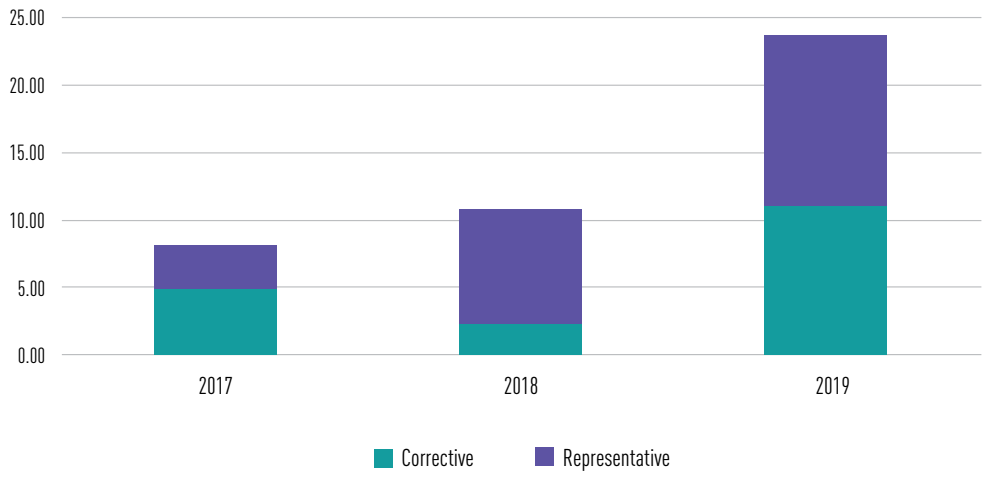
In addition to risk-based audits, in the course of FCH 2 JU representative selection and during separate sampling exercises for other H2020 stakeholders done in 2019, FCH 2 JU identified additional 4 participations which could be added to the audits already initiated by the JU or by other stakeholders of the H2020 family in order to increase efficiency and provide an overall cost-benefit of *ex-post* controls in the H2020 family. We refer to such additional participations as "top-ups".

Distribution of the coverage of two main audit streams is captured in the table and graph below.

TABLE 4.3.3: *EX-POST* AUDITS IN-PROGRESS TABLE AS AT 31 DECEMBER 2019 – CLASSIFICATION OF AUDITED PARTICIPATIONS

	FCH 2 JU CONTRIBUTION IN EUR MILLION		
YEAR	CORRECTIVE	REPRESENTATIVE	TOTAL
2017	4.98	3.16	8.14
2018	2.38	8.42	10.80
2019	**11.11**	**12.59**	**23.71**
Total as at 31 December 2019	**18.47**	**24.17**	**42.65**

AUDITED FCH 2 JU CONTRIBUTION UP TO 31 DECEMBER 2019 COVERED BY *EX-POST* CONTROLS



FCH 2 JU specific error rates for H2020

For the calculation of the FCH 2 JU's representative error rate, only results coming from the items either directly hit by JU sampling or by MUS sampling of the CRaS are taken into consideration.

Results of 18 representative items were used to calculate **an indicative cumulative representative error rate on H2020 expenditure specific to the FCH 2 JU, as at 31 December 2019**:

Representative error rate on FCH 2 JU contribution: -0.94 %

Residual error rate on FCH 2 JU contribution: –0.70 %

FP7 programme

The FCH 2 JU *ex-post* controls of FCH FP7 grants included financial audits carried out by external audit firms.

The main activities of *ex-post* controls include management of FP7 *ex-post* audits of beneficiaries via a contract with external audit firms, and implementation of the FP7 *ex-post* audit strategy to ensure appropriate audit coverage of the cost claims validated.

At the same time, a primary aim of FP7 *ex-post* controls was to achieve performance efficiency, i.e. trying to minimise the costs of audits while maintaining targeted and appropriate audit coverage.

In 2019, in line with the FCH 2 JU's multi-annual FP7 *ex-post* audit strategy, the following new audits were launched:

- Four representative audits, covering the FCH 2 JU's top beneficiaries not previously audited under the FP7 programme.

For execution of the FP7 audits in 2019, the FCH 2 JU used the new Framework Contract concluded with two other JUs in the course of 2018 (cascade system).

After conflict of interest and capacity checks, it signed a specific contract for batch audits with the external audit firm Lubbock Fine.

Because of its multi-annual nature, the effectiveness of the FCH 2 JU's control strategy can only be fully measured and assessed during the final stages of the JU's programme, once the *ex-post* control strategy has been fully implemented and systematic errors have been detected and corrected.

During this stage, the main legality and regularity indicator is the 'error rate' detected by *ex-post* audits. The following two aspects must be considered when providing information on error rates and inferring conclusions from such errors:

- Due to the multi-annual perspective of *ex-post* audits, their effectiveness must be measured by presenting '**cumulative**' information on the errors detected;

- **Two types of *ex-post* audits** must be distinguished with **two different objectives**: 'representative' audits with a goal of producing a representative estimate of the error rate present in the population, and 'corrective' audits (e.g. 'risk-based' audits) with the aim of detecting and correcting as many errors as possible.

Bearing in mind these two aspects, three types of cumulative error rates are calculated to provide a comprehensive overall view of the results of *ex-post* audits (see Table 4.3.3). For each type of error, the rate is calculated at both the 'total cost' and at the 'FCH 2 JU contribution' level. This distinction is necessary as not all errors detected at total cost level have a financial impact on the FCH 2 JU contribution[190].

190 For example, an error detected in indirect costs (at total-cost level) for a beneficiary using the 'actual' indirect cost method but with a maximum reimbursement rate of 20 % could have no impact on the FCH 2 JU contribution if 'declared' and 'eligible' indirect costs are above the 20 % reimbursed by the JU.

Overall error rate

This is the error rate derived from all audits, comprising both 'representative' and 'risk-based' audits. It is calculated as a percentage of the value[191] of the errors detected divided by the value of total costs accepted by the JU.

It provides information on the importance of the errors detected, but it cannot be used as a reference for inferring conclusions on the expected error in the non-audited population, for the following reasons: i) it is the result of representative and risk-based audits with two different objectives; and ii) as it is based on values, it is easily influenced by the error rates resulting from the individual audits of the cost claims of the highest values, which may not necessarily be those most representative for inferring conclusions.

Residual error rate

This is the level of error remaining in the population after corrections and recoveries made by the FCH 2 JU. This includes the extrapolation of audit results to non-audited contracts and the correction of errors. The formula for the calculation of the residual error rate, in line with the *ex-post* strategy and shown in Annex 9, is based on the following assumptions: i) all the errors detected will be corrected; and ii) the residual error rate for participations subject to extrapolation is estimated to be equal to the non-systematic error rate.

Ex-post audit resources

The lean structure of the FCH JU does not allow for the setting up of an internal *ex-post* audit section, therefore all *ex-post* audits are outsourced to external audit firms.

Whereas the execution of the audit work is externalised, some of the JU's staff (*ex-post* audit team) are responsible for managing ex-post audits, in particular the following three processes:

- Planning (i.e. selection of representative and risk-based audits, coordination with EC audits and preparation of audit input files);
- Monitoring (i.e. regular follow-up of audit status, interaction with audit firms on technical questions, and more importantly, quality checks of audit reports);
- Evaluation/implementation of audit results (i.e. inferring conclusions on the basis of identified error rates, extrapolation procedures and initiation of recovery orders/offsetting with future payments to correct errors detected).

The following table gives an overview of the resources devoted to *ex-post* audits:

TABLE 4.3.4: RESOURCES DEVOTED TO *EX-POST* AUDITS

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Internal resources *ex- post* audits[192]	1 FTE	15 FTE	2 FTE	2 FTE	1.5 FTE	2 FTE	2 FTE	1 FTE	1 FTE
Cost of externalised audits (commitments, in EUR)	77 820	208 665	161 082	245 081	315 716	206 762	194 949	75 600	37 800

Ex-post audits – coverage

The FCH JU FP7 *ex-post* audit strategy was adopted by the GB on 6 January 2011 and its implementation began in September 2011.

191 When considering the value of errors detected, three calculations are provided: i) with only the errors in favour of the JU (i.e. ineligible costs detected by the auditors; the JU has to recover the unduly paid funds, and these errors are expressed in negative values); ii) with only the errors in favour of the beneficiary (i.e. additional eligible costs identified by the auditors and not declared by the beneficiary, who can submit an additional cost claim, and additional payment by the JU is subject to certain conditions; these errors are expressed in positive values); and iii) with the total net value of errors (in favour of both the JU and the beneficiary).

192 Due to the lean structure of the FCH JU, and for cost-efficiency reasons, there is no single function in the JU fully dedicated to the management of *ex-post* audits. The reported figure in 'FTE: full-time equivalent' is therefore an estimation of the time devoted by various members of the JU staff to *ex-post* audits to manage the three processes under the JU's responsibility (i.e. planning, monitoring/quality checks, and evaluation/implementation of audit results).

The following table gives an overview of the number of *ex-post* audits and their audit coverage:

TABLE 4.3.5: NUMBER OF AUDITS AND AUDIT COVERAGE, CUMULATIVE

BATCH	YEAR	TO BE LAUNCHED	ONGOING	FINALISED	TOTAL	OF WHICH REPRESENTATIVE	RISK-BASED
1 to 11	2011 to 2018	0	6	135	141	116	25
12	2019	0	4	0	4	4	0
Total (audits)		**0**	**10**	**135**	**145**	**120**	**25**
Total (cost claims)					**574**		

Total costs accepted by FCH 2 JU (*cumulative*) (in €) **(A)**	820,869,168
Total costs of audits launched (*cumulative*) (in €) **(B)**	189,657,854
Total costs of audits finalised (**cumulative**) (in €) **(C)**	160,086,632
Direct audit coverage of total audits (in %) **(B/A)**	23 %
Direct audit coverage of finalised audits (in %) **(C/A)**	20 %
Total FCH 2 JU beneficiaries **(D)**	561
FCH 2 JU beneficiaries audited **(E)**	143
Audit coverage (number of benef.) of total audits (in %) **(E/D)**	25 %

In conclusion, since starting the FP7 *ex-post* audits, 145 have been launched of which 120 were representative and 25 risk-based, covering in total EUR 189.66 million of accepted costs declared by the beneficiaries, with an average sum of EUR 1.31 million of accepted costs per individual audit.

This resulted in direct audit coverage of 23 %, from all validated costs claims by the FCH for all 155 projects totalling EUR 820.87 million since the beginning of the FP7 Programme (at 31 December 2019).

Ex-post audits – error rates

The error rates resulting from the 135 finalised audits (of which 113 are representative and 22 are risk-based) are as follows:

TABLE 4.3.6: INDICATORS OF ERROR

	ACHIEVED CUMULATIVE PERIOD (AS OF 31/12/2019)	
	TOTAL COST	FCH 2 JU CONTRIBUTION
Costs accepted by FCH 2 JU financial officers (FO) (in €) **(A)**	123,422,135	57,094,641
Overall errors (in €) in favour of the FCH 2 JU **(B)**	-5,618,494	-2,077,602
'Overall Error rate' (only in favour of the FCH 2 JU) **(B/A)**	**-4.55 %**	**-3.64 %**
Overall errors (in €) in favour of the beneficiary **(C)**	3,700,047	1,155,810
'Overall Error rate' (only in favour of the beneficiary) **(C/A)**	**3.00 %**	**2.02 %**
Total Overall errors (in €) (in favour of the FCH 2 JU and in favour of the beneficiary **(D)**	-1,918,447	-921,792
'Overall Error rate' (netting off errors in favour of the JU and of the beneficiary **(D/A)**	**-1.55 %**	**-1.61 %**
'**Representative error rate**' (formula in Annex 9) (%)	**-2.59 %**	**-2.08 %**
'**Residual error rate**' (formula in Annex 9) (%)	**-1.13 %**	**-1.08 %**

The difference between the 'representative error rate' and the 'residual error rate' is the result of the following: i) the correction of errors in an important part of the population due to the high audit coverage; and ii) the effect of extrapolation of audit results to non-audited cost claims of audited beneficiaries.

Based on the calculation formula (derived from the FP7 *ex-post* audit strategy and coherent with the overall R&I FP7 *ex-post* audit strategy – see Annex 9), for the representative error rates, where all positive audit adjustments (i.e. adjustments in favour of the beneficiaries) appear as zero adjustments, whereas all negative audit adjustments appear as their exact value, the representative error rate on total costs audited remains at the same level as the previous year (-2.59 % in 2019 compared to -2.64 % in 2018). The representative error rate on the FCH contribution (following the same calculation formula) remains unchanged (from 2.09 % in 2018 to 2.08 % in 2019.

In 2019, the **residual error rate** (following the materiality criteria of 2 % threshold for AAR reservation) remains stable: **–1.13 % on the total costs audited** (compared to -1.15 % in 2018) and **–1.08 % on the FCH contribution** (compared to -1.10 % in 2018).

Further analysis of the error rates and whether or not a reservation is necessary in the declaration of assurance concerning the accuracy of the cost claims is addressed in section 5.3.

Most common audit findings

For direct costs, most of the findings in the audits related to an incorrect calculation of the hourly rates applied by the beneficiaries to calculate personnel costs.

The FCH 2 JU has learnt lessons from the most common audit errors and, as part of the preventive measures, during the *ex-ante* process the FCH team is focusing on proper explanations of correct interpretations of the applicable financial rules for the beneficiaries.

For indirect costs, the findings related mainly to incorrect calculations (inclusion of ineligible costs) or to the use of budgeted rather than actual indirect cost figures. These errors are completely avoided in the H2020 programme, which introduces a 25 % flat rate on indirect costs.

Implementation of audit results

As a result of errors identified during the FCH 2 JU *ex-post* audits, JU funds paid unduly must be recovered. The FCH 2 JU has implemented the necessary controls and monitoring mechanisms to ensure that all errors detected in favour of the JU are corrected in due course (either through a recovery order or by offsetting a future payment).

The detailed situation on the implementation (at project level) of *ex-post* audit results is given below:

TABLE 4.3.7: IMPLEMENTATION OF *EX-POST* AUDIT RESULTS IN FAVOUR OF THE FCH 2 JU (IN EUR)

SUMMARY OF NEGATIVE AUDIT ADJUSTMENTS. BENEFICIARIES WITH PFAR APPROVED BY 31/12/2018						
AUDIT LAUNCHING YEAR	AUDIT ADJUSTMENT (IN FAVOUR OF FCH 2 JU)		ADJUSTMENTS PENDING IMPLEMENTATION		ADJUSTMENTS IMPLEMENTED	
	ON TOTAL COSTS	ON FCH 2 JU CONTRIBUTION	ON TOTAL COSTS	ON FCH 2 JU CONTRIBUTION	ON TOTAL COSTS	ON FCH 2 JU CONTRIBUTION
2011	824,960	214,492			824,960	214,492
2012	629,111	346,512			629,111	346,512
2013	138,734	66,592			138,734	66,592
2014	1,096,153	486,361			1,096,153	486,361
2015	1,443,873	340,234			1,443,873	340,234
2016	324,005	102,066			324,005	102,066
2017	1,159,250	445,806	878,040	316,729	281,209	129,077
2018		29,278.98		29,278.98		
TOTAL	**5,616,086**	**2,031,342**	**878,040**	**346,008**	**4,738,046**	**1,685,334**

NOTE: The total amount of negative adjustments (5,616,086) does not match the same total in Table 4.3.3 (5 618 494) because in this table the information is at the level of project (in order to indicate afterwards the amount implemented, which is always by project), whereas in table 4.3.3 the information is given at the level of beneficiary.

At the cut-off reporting date (i.e. 31 December 2019), the percentages of total adjustments effectively implemented are close to 100 % at both total cost and FCH 2 JU contribution level. These percentages prove the continuous timely implementation of audit results and, consequently, the effective correction of errors detected by the FCH 2 JU. Indeed, the vast majority of the adjustments with pending implementations are not due to JU delays but can simply be explained by the fact that the audits have been finalised recently and implementation will follow shortly.

As can be seen in the table above, the FCH 2 JU has implemented the results from all the audits launched before 2017.

To date, the FCH 2 JU has focused its *ex-post* audit effort on finalising a representative number of audits in order to have sufficient information for the calculation of a representative error rate in preparation for the 2019 AAR.

Implementation of extrapolation/'extension of audit findings'

Extension of the audit findings (formerly known as 'extrapolation') is the process whereby 'systematic' errors detected in audited cost claims are 'extrapolated' to all other non-audited FCH 2 JU claims from the same audited beneficiary. The timely implementation of extension of audit findings relies on beneficiaries preparing and submitting revised cost claims from which the effect of any systematic error(s) detected in audits has been eradicated.

The overall situation on the implementation of the extension of audit findings is given below:

TABLE 4.3.8: IMPLEMENTATION OF 'EXTENSION OF AUDIT FINDINGS' OF *EX-POST* AUDIT RESULTS

	BENEFICIARIES	COST CLAIMS
Audits finalised	135	
Letters of conclusion sent as of reporting date	135	
Of which potentially concerned by extrapolation	43	
Extrapolation feedback not received from beneficiary	0	
Extrapolation feedback received from beneficiary	43	153
Of which projects not affected		73
Of which projects affected		80
Of which non-implemented		2
Of which implemented		78

At the cut-off reporting date (31 December 2019), 43 of the 135 finalised audits were potentially affected by extrapolation. Feedback was received from all the beneficiaries who provided the necessary information for 153 cost claims. Of these, 80 were affected by an extension of audit findings and the FCH 2 JU implemented the extrapolation in 78 of them (97 %).

Conclusions

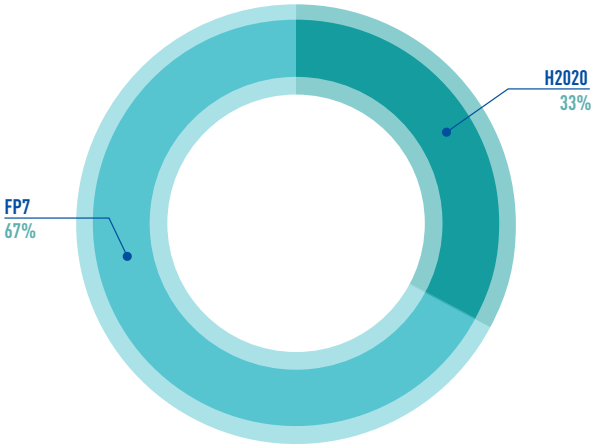
Cumulative FP7 error rates show a stable but declining trend, especially in residual error rates, which are constantly below 2 %, providing a robust indicator of the legality and regularity of the underlying transactions.

For the H2020 programme, sufficient audit coverage was ensured via the selection of the *ex-post* audits in 2017-2019.

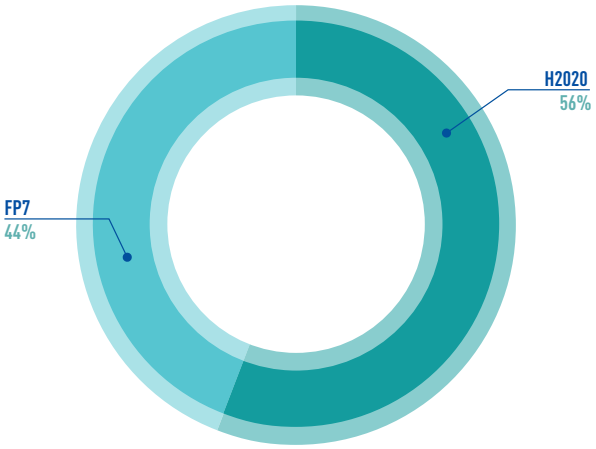
2019 was the last year when FCH 2 JU launched FP7 *ex-post* audits because of the declining amount of FP7 expenditure validated vs. H2020 expenditure validated.

To support this observation, the graph below shows the trend observed in the previous three years, whereby H2020 validated expenditure slowly outweighed FP7 expenditure. In 2020, this trend is expected to continue, with H2020 expenditure most likely representing more than 95 % of yearly validated expenditure.

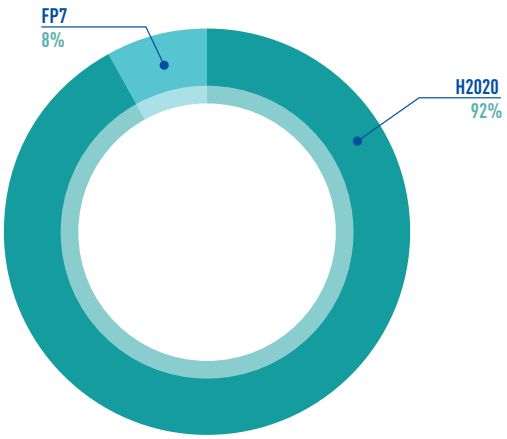
FP7 VS. H2020 VALIDATED EXPENDITURE **IN 2017**



FP7 VS. H2020 VALIDATED EXPENDITURE **IN 2018**



FP7 VS. H2020 VALIDATED EXPENDITURE **IN 2019**



The preliminary audit results from H2020 point to a downward trend for the error rates in H2020, mainly thanks to the simplification of the lump sum of 25 % applicable for indirect costs (as compared to the FP7 programme, where the most common errors were found in the calculation of indirect costs).

The positive trend in the error rates under H2020 can only be confirmed when more audit results become available.

As part of an internal control, all lessons learnt and observations from the *ex-post* audits (applicable for both the FP7 and H2020 programmes) feed back into the system of *ex-ante* checks in order to improve their effectiveness and efficiency.

This is an ongoing process, where close cooperation between FCH 2 JU operational units is facilitating the achievement of synergies between technical and financial knowledge, applied in practice.

4.4 AUDIT OF THE EUROPEAN COURT OF AUDITORS

In 2019, the FCH 2 JU:

- Continued its cooperation with an independent auditor to audit FCH 2 JU accounts, as required by the FCH 2 JU financial rules;
- Provided support for the ECA auditors in the framework of their audit on the 2018 accounts;
- Followed up and implemented the recommendations made in the European Court of Auditors' reports on the FCH 2 JU annual accounts.

4.5 INTERNAL AUDIT

The internal audit is carried out according to Article 20 of the FCH 2 JU financial rules.

Based on Council Regulation (EU) No 559/2014 of 6 May 2014 establishing the FCH 2 JU, the internal audit operation is under the authority and responsibility of the EC's IAS, succeeding the previous role taken on by the FCH 2 JU's IAC.

Within the FCH 2 JU, the new role of internal control and audit manager was established in 2015 to act as a main contact point for the IAS and coordinate the execution and follow-up of the annual internal audits carried out by the IAS.

In 2019, the FCH 2 JU provided answers to the draft and final report on a new Strategic Internal Audit Plan (SIAP) for 2019-2021 prepared by the IAS team.

In agreement with the IAS team, a new IAS audit as per SIAP 2019-2021 will only be launched in 2020.

The FCH 2 JU was consulted and provided input to the IAS in the context of a consulting engagement in the existing process of research and innovation policy feedback carried out by the IAS at the request of the CIC. The process and implementation actions will be concluded in early 2020.

At 31 December 2019, all recommendations and action plans coming from the previous IAS audits were successfully implemented and closed.

4.6 RISK MANAGEMENT AND CONFLICT OF INTEREST

Risk management

During the annual risk assessment workshop, held in October 2019, the FCH 2 JU team reflected on the status of the significant risks and action plans that had been identified in the previous year and assessed their adequacy and relevance for 2019 and 2020.

In addition, consolidated input was gathered and discussed in order to establish a list of new significant risks for 2020, and the respective action plans were drawn up.

The full list of important risks and related action plans identified can be found in the AWP 2020.

A complete risk matrix for 2020 (including lower-priority risks) is regularly assessed and discussed by management, as part of an ongoing risk assessment process, to reflect on any changes in the organisation's internal and external environment. This exercise, part of the internal control system, is designed to capture, in a timely way, any new and emerging risks that could potentially influence the achievement of the FCH 2 JU's objectives, as well as to provide timely reflection on the rating and relevance of the existing risks to ensure that appropriate actions and mitigating measures are put in place.

The FCH 2 JU will report on the fulfilment of the action plans and relevance of these risks in the 2020 AAR.

Managing potential conflict of interest

The PO has developed a comprehensive set of rules and procedures that are effectively implemented across its entire governance structure, as follows:

- When joining the PO team, each staff member agrees to the application of the Staff Regulation and signs a declaration of honour on the management of conflicts of interest.
- With ED decision of 27/09/2019[193], FCH 2 JU applies by analogy 'mutatis mutandis' the 'Code of Good Administrative Behaviour for Staff of the European Commission in their Relations with the Public'.
- Conflict of interest procedures are in place for the members of both the FCH 2 JU GB and the advisory bodies.
- Specific measures have been implemented for the prevention and management of conflicts of interest of experts in charge of the evaluation of grant applications and of the review of projects and tenders.

In addition, the FCH 2 JU implements the common Research Anti-Fraud Strategy. In March 2019, the CIC adopted the revised Strategy (RAFS 2019) and the associated action plan. The implementation of the action plan is monitored through regular meetings of FAIR in which the FCH 2 JU participates.

Furthermore, for areas of expenditure other than grants, the FCH 2 JU applies *mutatis mutandis* by analogy the anti-fraud strategy of DG R&I. This is relevant in particular for expert management, procurement and internal fraud and the risk analysis leads to the conclusion that the residual risks (after mitigating actions) are low.

4.7 COMPLIANCE AND EFFECTIVENESS OF INTERNAL CONTROL

The FCH 2 JU internal control framework is designed to provide reasonable assurance regarding the achievement of the following five objectives:

- Effectiveness, efficiency and economy of operations;
- Reliability of reporting;
- Safeguarding of assets and information;
- Prevention, detection, correction and follow-up of fraud and irregularities, and
- Adequate management of the risks relating to the legality and regularity of the underlying transactions.

In line with the objectives and priorities described in the AWP 2019, the robustness of the internal control system was monitored throughout the year. Internal control matters, such as *ex-ante* and *ex-post* controls, segregation of duties, documented processes and procedures and sound financial management, were discussed at least on a weekly basis during unit meetings and on an ad-hoc basis when preparing new processes (e.g. COMPASS workflows) or revising existing operating processes. Risks identified through the annual risk assessment exercise (see sections 1.1 and 4.6), which might pose a threat to achieving the FCH 2 JU's mission and objectives, were also systematically assessed and managed through appropriate controlling and mitigating actions. Throughout the year, particular efforts were made to monitor the KPIs, which led to the record-breaking results in terms of budget execution and TTP.

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In addition, DG BUDG carried out its annual evaluation of the Undertaking's local financial by reviewing the information on changes in the local systems and/or in the control environment. The DG BUDG team also verified a sample of transactions for the operations authorised by the FCH 2 JU during the 2018 financial year. The evaluation did not identify any weaknesses in the internal control systems which would materially affect the accuracy, completeness and timeliness of the information required to draft the annual accounts and produce reliable reporting.

The 2018 self-assessment of the internal control framework resulted in an action plan that was included in AWP 2019. In November 2019, the manager in charge of risk management and internal control carried out an assessment that ensured that the action plan was followed (e.g. staff were informed about implementing rules and procedures through the FCH intranet, and the Common Business Continuity Plan was presented to the staff in January 2019).

In conclusion, it can be confirmed that the FCH 2 JU is in compliance with all the principles, the controls in place are working as intended, and the internal control system is providing an effective framework for managing any risks to the JU's ability to achieve its objectives.

05
MANAGEMENT ASSURANCE

5.1 ASSESSMENT OF THE ANNUAL ACTIVITY REPORT BY THE GB

This section will be provided separately.

5.2 ELEMENTS SUPPORTING ASSURANCE

Reasonable assurance is the personal judgement of the JU's Executive Director – as the JU's authorising officer at the date of signature of this Annual Activity Report – based on all the information at his disposal.

The main elements supporting the assurance are based on the JU's management assessment of the robustness of the JU's Internal Control Framework, the results of audits from the ECA and the IAS, the reporting from the internal control and audit manager, and the reporting from the heads of unit.

No significant weaknesses were identified or reported under Section 2 ('Support to Operations') and Section 4 ('Internal Control Framework'). Furthermore, based on their review, the heads of unit consider that, given the scope of the statement of assurance and taking into account the controls and monitoring system in place, there are no weaknesses that could call into question the reasonable assurance as to the use of resources for their intended purpose, in accordance with the principles of sound financial management, and the fact that the implemented control procedures provide the necessary guarantees on the legality and regularity of the underlying transactions.

5.3 RESERVATIONS

H2020 programme

The indicative **representative error rate** resulting from the 18 representative audits finalised is **-0.94 %** (2018: -0.50 %) at FCH 2 JU contribution level.

The **residual error rate** (i.e. error remaining in the population after corrections and recoveries) calculated at this point is **-0.70 %** (2018: -0.46 %) at FCH 2 JU contribution level. This rate should develop as more audits are closed and more corrections and recoveries undertaken.

Taking into consideration:

- The residual error rates below 2 % at this point in time
- The adequate audit coverage, comprising a representative number of finalised audits
- The experience gained by JU staff in the *ex-ante* validation of costs claims
- The JU's strong *ex-ante* controls (financial webinars, etc.)

no reservation is necessary. In the opinion of the Executive Director, considering the aspects above and with the information available at this stage, it is possible to state with reasonable assurance that by the end of the programme the residual error rate will be below the materiality threshold (i.e. 2 %) established in Annex 9 ('Materiality criteria').

FP7 programme

The **representative error rate** resulting from the 114 representative audits finalised is **–2.59 %** (2018: -2.64 %) at the total-cost level and **–2.08 %** (2018: -2.09 %) at the FCH 2 JU contribution level.

The **residual error rate** (i.e. error remaining in the population after corrections and recoveries) calculated at this point is **–1.13 %** (2018: -1.15 %) at total-cost level and **–1.08 %** (2018: -1.10 %) at FCH 2 JU contribution level. This rate should remain stable and final as 2019 was the last year during which the very few remaining FP7 audits were launched.

FCH 2 JU actions towards an acceptable level of residual error rate

The declaration of assurance in 2018 did not include a reservation, as is the case in 2019. This is the result of the FCH 2 JU's firm commitment to maintain a robust internal control system where *ex-post* audits play a significant role. The residual error rate is a key indicator of the legality and regularity of the JU's transactions. In this context, in 2012, the FCH 2 JU set out an action plan with the aim of achieving an acceptable level of residual error rate, which should provide sufficient assurances to the Executive Director, while at the same time respecting cost-benefit principles (i.e. the cost of controls have to be measured against the benefits that those additional controls can bring to the organisation – auditing 100 % of the cost claims is not cost-efficient).

The FCH 2 JU action plan includes a combination of **preventive, detective and corrective measures** and is closely monitored. The measures/actions can be grouped around three main axes, as follows:

For H2020

- Organisation of financial webinars to explain key aspects of the financial provisions of the H2020 Model Grant Agreement and of financial reporting with a focus on specificities and business models pertinent to the FCH 2 JU and aiming to prevent errors. Since 2016, for all new signed grants, specific targeted financial webinars have been organized within the first year following the start of the action, which are available to all members of the consortia (see also section 4.2).

- Greater involvement by the financial officers during grant agreement preparations and in project kick-off meetings in order to check the financial aspects and clarify financial reporting requirements.

- Ad-hoc financial webinars for individual projects, depending on the complexity of the project and needs of the beneficiaries.

- *Ex-ante* controls consistent with the guidelines on *ex-ante* controls in H2020, adopted by the CIC, which are predominantly risk-based and/or justified by deviations from the budget.

- *Ex-post* audits: as indicated in the sections on H2020 *ex-post* audits above, the FCH 2 JU will ensure that, in line with Annex 1 to the H2020 Audit Strategy, the audit effort is sufficient to allow for adequate coverage and the calculation of a representative error rate on FCH 2 JU expenditure.

- Participation by the financial officers in the *ex-post* audits as observers to further improve the system of *ex-ante* controls.

The FCH 2 JU has a clear control strategy which is multi-annual in nature and combines ex-ante and *ex-post* controls while taking cost-efficiency into consideration. Since this strategy has proved its effectiveness from an assurance point of view, the FCH 2JU is fully committed to continuing its work along the same control principles.

For FP7

- Organisation of **communication campaigns** to prevent financial errors in cost reporting by improving awareness among the beneficiaries of the regulatory framework. In total, seven campaigns were organised by the FCH 2 JU (2012-2015). The communication campaigns were highly appreciated by the participants and their positive impact has been visible since 2013, through improvements in the quality of beneficiaries' cost reporting.

- Maintaining strong FCH 2 JU ***ex-ante* controls** to enable greater detection and correction of errors before validating cost claims (e.g. JU's scrutiny of the CFS, and its thorough *ex-ante* checklists).

- Continuation of the FCH 2 JU *ex-post* audit efforts while phasing out the programme to cover FP7 expenditures validated until 31 December 2019. The combination of appropriate audit coverage (25 % for FP7) and a relatively low detected error rate has resulted in a residual error rate constantly below 2 %.

The positive feedback loop generated by the combination of the three actions above is of particular importance. For example, the (preventive) communication campaigns provided a very useful platform on which to share experiences among beneficiaries and JU actors. In addition, *ex-post* audits have a multiplying effect: lessons learned from the results of *ex-post* audits provide very valuable information not only for the audited beneficiary but also for the JU's *ex-ante* controllers for future cost claims and other beneficiaries in the same project.

5.4 OVERALL CONCLUSIONS

The purpose of this section is to provide an overall conclusion on the declaration of assurance as a whole (section 6).

It is important to note that only material weaknesses/risks lead to any reservation concerning the assurances in section 6. The concept of 'materiality' provides the Executive Director with the basis for assessing the importance of the weaknesses/risks identified. Deciding whether something is material involves making a judgement in both qualitative and quantitative terms (see details on the Materiality criteria in Annex 9).

Based on the information provided in the sections above, the following conclusions can be drawn.

- Concerning the FCH2 JU's policy activities, no qualification needs to be made. Likewise, there is no reservation in the procedures relating to the selection of contractors and beneficiaries for FCH2 JU projects and their underlying financial operations (legal and financial commitments). This is also the case for JU's payments relating to administrative expenditure and procurement, as well as for pre-financing payments in the case of grants.

- The amounts with a greater risk of being affected by errors are the expenditures incurred against cost statements. Based on the analysis of error rates and the effectiveness of the preventive, detective and corrective actions presented in section 5.3, no reservation is necessary in this area either.

In conclusion, the JU's management has reasonable assurance that, overall, suitable controls are in place and are working as intended, risks are being properly monitored and mitigated, and necessary improvements noted by the auditors (i.e. the EC's IAS and the ECA) are being implemented. Therefore, the Executive Director, in his capacity as authorising officer, has signed the declaration of assurance presented in section 6.

06
DECLARATION OF ASSURANCE

I, the undersigned, Bart Biebuyck

Executive Director of the FCH 2 JU

In my capacity as authorising officer

Declare that the information contained in this report gives a true and fair view[194].

State that I have reasonable assurance that the resources assigned to the activities described in this report have been used for their intended purpose and in accordance with the principles of sound financial management, and that the control procedures put in place give the necessary guarantees concerning the legality and regularity of the underlying transactions.

This reasonable assurance is based on my own judgement and on the information at my disposal, such as the results of the self-assessment, ex-post controls, the work of the internal control and audit manager, the observations of the Internal Audit Service and the lessons learnt from the Court of Auditors' reports for the years prior to the year of this declaration.

Confirm that I am not aware of anything not reported here which could harm the interests of the Joint Undertaking.

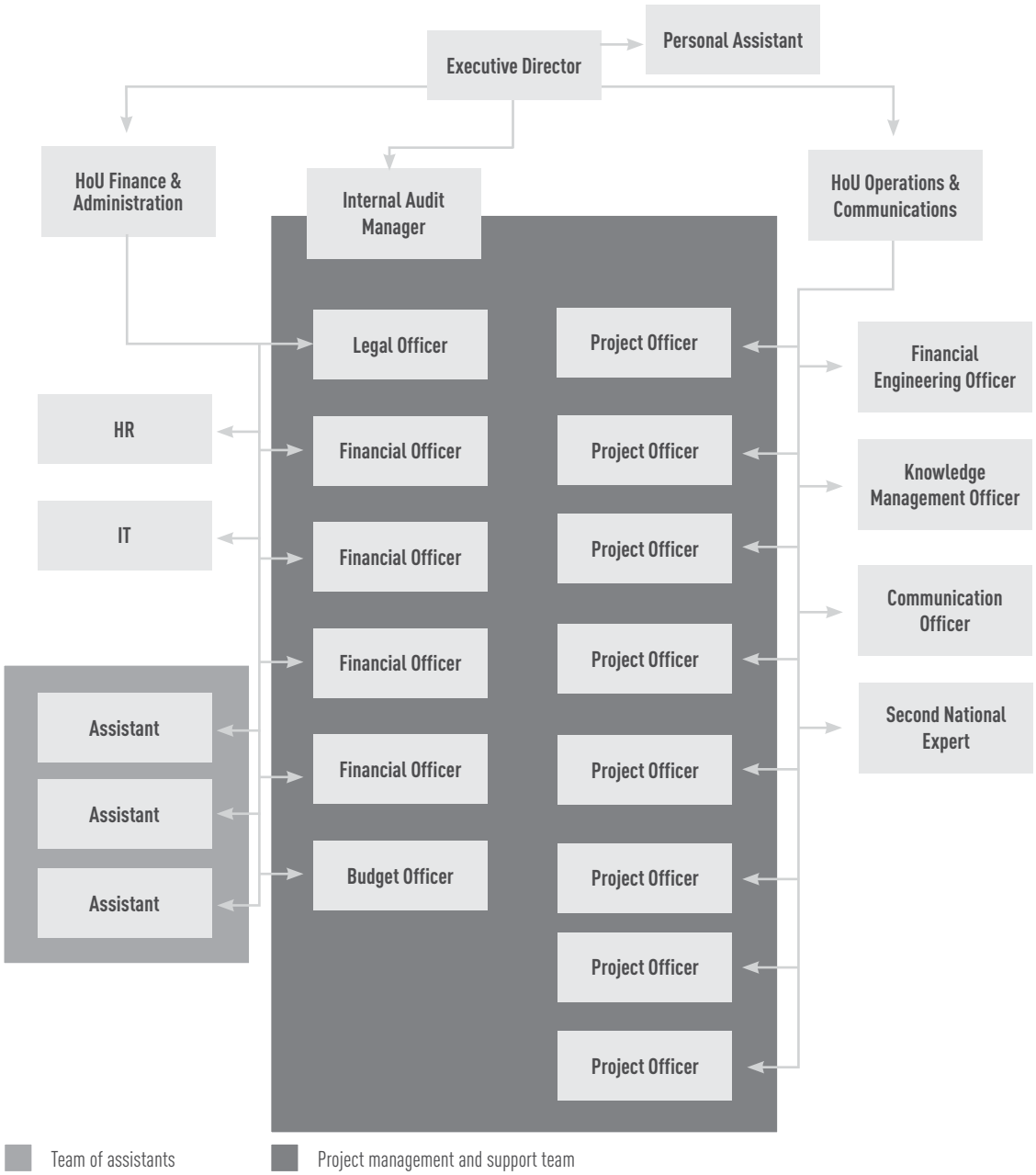
Place ..... date: 28 February 2020

Bart Biebuyck

194 True and fair in this context means a reliable, complete and correct view on the state of affairs in the Joint Undertaking.

07
ANNEXES

ANNEX 1
Organisation chart



ANNEX 2
Staff establishment plan

The JU team of statutory staff consists of 27 members (24 temporary agents and 3 contract agents). In addition, staff resources include two Seconded National Experts (SNE).

The 2018-2019 Staff establishment plan is shown below.

GRADE	2018 BUDGET	2018 FILLED	2019 BUDGET	2019 FILLED
AD 16	-	-		
AD 15	-	-		
AD 14	1	1	1	1
AD 13	-	-		
AD 12	-	-		
AD 11	2	2	2	2
AD 10	-	-		
AD 9	2	2	2	2
AD 8	6	6	6	6
AD 7	-	-		
AD 6	3	3	4	4
AD 5	1	1		
Total AD[195]	**15**	**15**	**15**	**15**
AST 11	-	-		
AST 10	-	-		
AST 9	-	-		
AST 8	2	2	2	2
AST 7	1	1	1	1
AST 6	1	1	1	1
AST 5	1	1	1	1
AST 4	4	4	4	1
AST 3	-	-		
AST 2	-	-		
AST 1	-	-		
Total AST[196]	**9**	**9**	**9**	**9**
Function Group IV	1	1	1	1
Function Group III	1	1	1	1
Function Group II	1	1	1	1
Function Group I	-	-		
Total contract agents	3	3	3	3
Total Seconded National Experts	**2**	**0**	**2**	**1**

195 AD stands for administrator.

196 AST stands for assistant.

ANNEX 3
Publications from projects

The list of publications related to both FP7 and H2020 projects is given below[197]:

Project number	Project acronym	Publication title	Authors
303485	SWARM	(Proposed paper) Vibration Analysis of Fuel Cell Stack Mounting in Automotive Applications	J. Shang, M. Apicella, J. Jostins, P. Jostins
325325	ONSITE	Experimental and numerical analysis of a SOFC-CHP system with adsorption and hybrid chillers for telecommunication applications	Valeria Palomba, Marco Ferraro, Andrea Frazzica, Salvatore Vasta, Francesco Sergi, Vincenzo Antonucci
325335	Auto-Stack CORE	Characteristic Time Constants Derived from the Low Frequency Arc of Impedance Spectra of Fuel Cell Stacks	Stefan Keller, Tansu Özel, Anne-Christine Scherzer, Dietmar Gerteisen, Ulf Groos, Christopher Hebling, Yiannos Manoli
621173	SOPHIA	Optimal design of solid-oxide electrolyzer based power-to-methane systems: A comprehensive comparison between steam electrolysis and co-electrolysis	Ligang Wang, Mar Pérez-Fortes, Hossein Madi, Stefan Diethelm, Jan Van herle, François Maréchal
621196	FluidCELL	A comprehensive model of a fluidized bed membrane reactor for small-scale hydrogen production	S. Foresti, G. Di Marcoberardino, G. Manzolini, N. De Nooijer, F. Gallucci, M. van Sint Annaland
621196	FluidCELL	Direct route from ethanol to pure hydrogen through autothermal reforming in a membrane reactor: Experimental demonstration, reactor modelling and design	V. Spallina, G. Matturro, C. Ruocco, E. Meloni, V. Palma, E. Fernandez, J. Melendez, A.D. Pacheco Tanaka, J.L. Viviente Sole, M. van Sint Ann
621196	FluidCELL	Enhancing Pt-Ni/CeO 2 performances for ethanol reforming by catalyst supporting on high surface silica	Vincenzo Palma, Concetta Ruocco, Eugenio Meloni, Fausto Gallucci, Antonio Ricca
621196	FluidCELL	Optimization of PEM Fuel Cell Operation with High-purity Hydrogen Produced by a Membrane Reactor	S. Foresti, G. Manzolini
621196	FluidCELL	Oxidative steam reforming of ethanol in a fluidized bed over CeO 2-SiO 2 supported catalysts: effect of catalytic formulation	Vincenzo Palma, Concetta Ruocco, Antonio Ricca
621196	FluidCELL	Three-dimensional modeling of PEMFC with contaminated anode fuel	M. Abdollahzadeh, P. Ribeirinha, M. Boaventura, A. Mendes
621210	HELMETH	CO_2 methanation over Ni catalysts based on ternary and quaternary mixed oxide: A comparison and analysis of the structure-activity relationships	Chalachew Mebrahtu, Salvatore Abate, Siglinda Perathoner, Shiming Chen, Gabriele Centi
621218	PEMBeyond	Power ramp rate capabilities of a 5 kW proton exchange membrane fuel cell system with discrete ejector control	K. Nikiforow, J. Pennanen, J. Ihonen, S. Uski, P. Koski
621218	PEMBeyond	Pressure swing adsorption for hydrogen purification using a copper modified activated carbon – High recovery and low carbon monoxide content	Frederico Relvas, Roger D. Whitley, Carlos Silva, Adélio Mendes
621237	INSIDE	Degradation of Proton Exchange Membrane (PEM) Electrolysis: The Influence of Current Density	Aldo Saul Gago, Jörg Bürkle, Philipp Lettenmeier, Tobias Morawietz, Michael Handl, Renate Hiesgen, Fabian Burggraf, Pilar Angel Valles Beltra
621237	INSIDE	Highly active nano-sized iridium catalysts: synthesis and operando spectroscopy in a proton exchange membrane electrolyzer	P. Lettenmeier, J. Majchel, L. Wang, V. A. Saveleva, S. Zafeiratos, E.R. Savinova, J.-J. Gallet, F. Bournel, A.S. Gago, K.A. Friedrich
621237	INSIDE	Structure, Properties, and Degradation of Nanothin Ionomer Films in Fuel Cell Catalytic Layers	Michael Handl, Tobias Morawietz, Devproshad K Paul, Kaspar Andreas Friedrich, Kunal Karan, Renate Hiesgen
621237	INSIDE	Structure, Properties, and Degradation of Ultrathin Ionomer Films in Catalytic Layers of Fuel Cells	Tobias Morawietz, Michael Handl, Kaspar Andreas Friedrich, Renate Hiesgen
671396	AutoRE	Analysis of a fuel cell combined heat and power plant under realistic smart management scenarios	Andrea L. Facci, Stefano Ubertini
671396	AutoRE	AUTomotive deRivative Energy system (AutoRE): power plant modeling and optimization	G. Loreti, A.L. Facci, S. Ubertini
671396	AutoRE	AutoRE (Automotive deRivative Energy system)	G.J. Kelsall

197 The table has been devised from the patents query in CORDA databases for H2020 and FP7 projects. As part of the TRUST annual exercise collecting data from the year-minus 1, the list contains publications covering both 2018 and 2019. For the full list of previous publications, please refer to previous versions of the Annual Activity Report.

Journal title	Relevant pages	ISSN/Publication frequency[1]	Publisher	Publication year	Open Access[2]
JVC/Journal of Vibration and Control	TBC	Dec. 25	SAGE Publications Inc.	2019	
Applied Energy	620-633	Vol. 216	Elsevier BV	2018	
Journal of Fuel Cell Science and Technology	1-38	15	American Society of Mechanical Engineers (ASME)	2018	No
Applied Energy	1060-1079	Vol. 211	Elsevier BV	2018	
Chemical Engineering and Processing	136-144	Vol. 127	Elsevier	2018	No
Energy	666-681	Vol. 143	Elsevier Limited	2018	Yes
Catalysis Today	175-188	Vol. 307	Elsevier	2018	No
Fuel Cells	335-346	Vol. 18/Issue 3	John Wiley & Sons Ltd.	2018	No
Renewable Energy	356-364	Vol. 125	Elsevier BV	2018	No
Energy	939-959	Vol. 152	Elsevier Limited	2018	No
Catalysis Today	181-189	Vol. 304	Elsevier	2018	No
Journal of Power Sources	30-37	Vol. 381	Elsevier	2018	Yes
Industrial and Engineering Chemistry Research	-	-	American Chemical Society	2018	
ECS Transactions	695-700	Vol. 86/Issue 13	The Electrochemical Society	2018	No
Chemical Science	3570-3579	Vol. 9/Issue 14	Royal Society of Chemistry	2018	Yes
ECS Transactions	889-903	Vol. 85/Issue 13	The Electrochemical Society	2018	No
ECS Transactions	179-191	Vol. 86/Issue 3	The Electrochemical Society	2018	No
Applied Energy	60-72	3062619	Pergamon Press Ltd.	2018	Yes
Poster at International Workshop Noon-to-Noon with Energy and Environmental Challenges			International Workshop Noon-to-Noon with Energy and Environmental Challenges	2018	No
Presentation at Programme Review Days 2018 of FCH 2 JU			FCH 2 JU	2018	Yes

Project number	Project acronym	Publication title	Authors
671396	AutoRE	Combined heat, cooling, and power systems based on half effect absorption chillers and polymer electrolyte membrane fuel cells	Gabriele Loreti, Andrea L. Facci, Ilaria Baffo, Stefano Ubertini
671396	AutoRE	Formation of hydrogen bubbles in Pd-Ag membranes during H2 permeation	T.A. Peters, P.A. Carvalho, M. Stange, R. Bredesen
671396	AutoRE	Meta-heuristic optimization for a high-detail smart management of complex energy systems	Andrea L. Facci, Stefano Ubertini
671396	AutoRE	Numerical modeling of an automotive derivative polymer electrolyte membrane fuel cell cogeneration system with selective membranes	Gabriele Loreti, Andrea Luigi Facci, Thijs Peters, Stefano Ubertini
671396	AutoRE	Pd-Based Membranes: Overview and Perspectives	Thijs Peters, Alessio Caravella
671396	AutoRE	Selective membranes for hydrogen production in a realistic energy management scenario	G. Loreti, A.L. Facci, S. Ubertini
671458	ELYntegration	A Powder Metallurgy Route to Produce Raney-Nickel Electrodes for Alkaline Water Electrolysis	Christian Immanuel Bernäcker, Thomas Rauscher, Tilo Büttner, Bernd Kieback, Lars Röntzsch
671458	ELYntegration	Potential of new business models for grid integrated water electrolysis	Patrick Larscheid, Lara Lück, Albert Moser
671458	ELYntegration	Techno-economic modelling of water electrolysers in the range of several MW to provide grid services while generating hydrogen for different applications: a case study in Spain applied to mobility with FCEVs	Guillermo Matute, José María Yusta, Luis Carlos Correas
671459	BIONICO	Green Hydrogen Production from Raw Biogas: A Techno-Economic Investigation of Conventional Processes Using Pressure Swing Adsorption Unit	Gioele Di Marcoberardino, Dario Vitali, Francesco Spinelli, Marco Binotti, Giampaolo Manzolini
671459	BIONICO	Life Cycle Assessment and Economic Analysis of an Innovative Biogas Membrane Reformer for Hydrogen Production	Gioele Di Marcoberardino, Xun Liao, Arnaud Dauriat, Marco Binotti, Giampaolo Manzolini
671459	BIONICO	On concentration polarisation in a fluidized bed membrane reactor for biogas steam reforming: Modelling and experimental validation	Niek de Nooijer, Fausto Gallucci, Emma Pellizzari, Jon Melendez, David Alfredo Pacheco Tanaka, Giampaolo Manzolini, Martin van Sint Annaland
671459	BIONICO	Potentiality of a biogas membrane reformer for decentralized hydrogen production	Gioele Di Marcoberardino, Stefano Foresti, Marco Binotti, Giampaolo Manzolini
671461	HySEA	A simple model for calculating peak pressure in vented explosions of hydrogen and hydrocarbons	Anubhav Sinha, Jennifer X. Wen
671461	HySEA	Blind-prediction: Estimating the consequences of vented hydrogen deflagrations for homogeneous mixtures in 20-foot ISO containers	T. Skjold, H. Hisken, S. Lakshmipathy, G. Atanga, M. Carcassi, M. Schiavetti, J.R. Stewart, A. Newton, J.R. Hoyes, I.C. Tolias, A.G. Venetsanos, O.R. Hansen, J. Geng, A. Huser, S. Helland, R. Jambut, K. Ren, A. Kotchourko, T. Jordan, J. Daubech, G. Lecocq, A.G. Hanssen, C. Kumar, L. Krumenacker, S. Jallais, D. Miller, C.R. Bauwens
671461	HySEA	Blind-prediction: estimating the consequences of vented hydrogen deflagrations for inhomogeneous mixtures in 20-foot ISO containers	Trygve Skjold, Helene Hisken, Laurence Bernard, Lorenzo Mauri, Gordon Atanga, Sunil Lakshmipathy, Melodia Lucas Pérez, Marco Carcassi, Martino Schiavetti, Vendra Chandra Madhav Rao, Anubhav Sinha, Ilias C. Tolias, Stella G. Giannissi, Alexandros G.Venetsanos,James R. Stewart, Olav Roald Hansen, Chenthil Kumar, Laurent Krumenacker, Florian Laviron, Romain Jambut, Asmun Huser,
671461	HySEA	Blind-prediction: Estimating the consequences of vented hydrogen deflagrations for inhomogeneous mixtures in 20-foot ISO containers	Trygve Skjold, Helene Hisken, Laurence Bernard, Lorenzo Mauri, Gordon Atanga, Sunil Lakshmipathy, Melodia Lucas Pérez, Marco Carcassi, Martino Schiavetti, Vendra Chandra Madhav Rao, Anubhav Sinha, Jennifer X. Wen, Ilias C. Tolias, Stella G. Giannissi, Alexandros G. Venetsanos, James R. Stewart, Olav Roald Hansen, Chenthil Kumar, Laurent Krumenacker, Florian Laviron, Romain Jambut, Asmund Huser
671461	HySEA	Comparison of Engineering and CFD Model Predictions for Overpressures in Vented Explosion	Sinha Anubhav, Vendra Chandra Madhav Rao, Jennifer X. Wen
671461	HySEA	Consequence models for vented hydrogen deflagrations: CFD vs. engineering models	S. Lakshmipathy, T. Skjold, H. Hisken, G. Atanga
671461	HySEA	Duct-vented hydrogen–air deflagrations: The effect of duct length and hydrogen concentration	Fuqiang Yang, Jin Guo, Changjian Wang, Shouxiang Lu

Journal title	Relevant pages	ISSN/Publication frequency[1]	Publisher	Publication year	Open Access[2]
Applied Energy	747-760	3062619	Pergamon Press Ltd.	2019	Yes
International Journal of Hydrogen Energy		3603199	Pergamon Press Ltd.	2019	Yes
Energy Conversion and Management	341-353	1968904	Pergamon Press Ltd.	2018	Yes
International Journal of Hydrogen Energy	4508-4523	3603199	Pergamon Press Ltd.	2019	Yes
Membranes	25	20770375	Molecular Diversity Preservation International	2019	Yes
Presentation at Ph.D. Summer School AIMSEA			AIMSEA	2018	No
Journal of The Electrochemical Society	F357-F363	134651	Electrochemical Society, Inc.	2019	Yes
Renewable Energy	599-608	9601481	Pergamon Press Ltd.	2018	Yes
International Journal of Hydrogen Energy		0360-3199	Pergamon Press Ltd.	2019	Yes
Processes	19	22279717	MDPI – Processes	2018	Yes
Processes	86	22279717	MDPI – Processes	2019	Yes
Chemical Engineering Journal	232-243	13858947	Elsevier BV	2018	Yes
Chemical Engineering and Processing – Process Intensification	131-141	2552701	Elsevier BV	2018	Yes
International Journal of Hydrogen Energy		3603199	Pergamon Press Ltd.	2019	Yes
International Journal of Hydrogen Energy	8997-9008	3603199	Pergamon Press Ltd.	2019	Yes
Proceedings Twelf[th] International Symposium on Hazards, Prevention and Mitigation of Industrial Explosions (XII ISHPMIE)	875-898	978-1-5323-8443-1	Fike Corporation	2018	Yes
Journal of Loss Prevention in the Process Industries		9504230	Elsevier BV	2019	Yes
Comparison of engineering and CFD model predictions for overpressures in vented explosions	860-874	978-1-5323-8443-1	Fike Corporation	2018	Yes
International Journal of Hydrogen Energy	8699-8710	3603199	Pergamon Press Ltd.	2019	Yes
International Journal of Hydrogen Energy	21142-21148	3603199	Pergamon Press Ltd.	2018	Yes

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671461	HySEA	Explosion venting of hydrogen-air mixtures from a duct to a vented vessel	Hongwei Li, Jin Guo, Fuqiang Yang, Changjian Wang, Jiaqing Zhang, Shouxiang Lu
671461	HySEA	Fluid structure interactions modelling in vented lean deflagrations	V.C.M. Rao, J.X. Wen
671461	HySEA	Fluid structure interactions modelling in vented lean deflagrations	Vendra C. Madhav Rao, Jennifer X. Wen
671461	HySEA	Modelling approach for vented lean deflagrations in non-rigid enclosures	V.C.M. Rao, J.X. Wen
671461	HySEA	Modelling Flow Past Obstacles in Vented Explosions	Anubhav Sinha, Jennifer Wen
671461	HySEA	Modular phenomenological model for vented explosions and its validation with experimental and computational results	Anubhav Sinha, Vendra C. Madhav Rao, Jennifer X. Wen
671461	HySEA	Non-homogeneous hydrogen deflagrations in small scale enclosure. Experimental results	M. Carcassi, M. Schiavetti, T. Pini
671461	HySEA	Numerical investigation of venting through roof for an ISO containers	V.C.M. Rao and J.X. Wen
671461	HySEA	Numerical modelling of vented lean hydrogen deflagrations in an ISO container	Vendra C. Madhav Rao, Jennifer X. Wen
671461	HySEA	Performance evaluation of empirical models for vented lean hydrogen explosions	Anubhav Sinha, Vendra C. Madhav Rao, Jennifer X. Wen
671461	HySEA	Phenomenological Modelling of External Cloud Formation in Vented Explosions	Anubhav Sinha, Jennifer X. Wen
671461	HySEA	Simulating vented hydrogen deflagrations: improved modelling in the CFD tool FLACS-Hydrogen	M. Lucas, H. Hisken, T. Skjold
671461	HySEA	Small scale experiments and Fe model validation of structural response during hydrogen vented deflagrations	T. Pini, A.Grønsund Hanssen, M. Schiavetti, M. Carcassi
671461	HySEA	Structural response for vented hydrogen deflagrations: Coupling CFD and FE tools	G. Atanga, S. Lakshmipathy, T. Skjold, H. Hisken, A.G. Hanssen
671461	HySEA	Structural response of 20-foot shipping containers during vented hydrogen deflagrations	T. Skjold, H. Hisken, L. Bernard, A.G. Hanssen
671461	HySEA	The effect of vent burst pressure on a vented hydrogen-air deflagration in a 1 m3 vessel	Shengchao Rui, Jin Guo, Gang Li, Changjian Wang
671461	HySEA	The effect of venting process on the progress of a vented deflagration	M. Schiavetti, T. Pini, M. Carcassi
671461	HySEA	Vented hydrogen deflagrations in 20-foot ISO containers	Trygve Skjold
671461	HySEA	Vented hydrogen deflagrations in containers: Effect of congestion for homogeneous and inhomogeneous mixtures	T. Skjold, H. Hisken, S. Lakshmipathy, G. Atanga, L. Bernard, M. van Wingerden, K.L. Olsen, M.N. Holme, N.M. Turøy, M. Mykleby, K. van Wingerden
671461	HySEA	Vented hydrogen deflagrations in weak enclosures: experimental results and implications for industrial practice	T. Skjold
671465	VOLUMETRIQ	Design of Heterogeneities and Interfaces with Nanofibers in Fuel Cell Membranes	Marta Zatoń, Sara Cavaliere, Deborah J. Jones, Jacques Rozière
671465	VOLUMETRIQ	New perfluorinated ionomer with improved oxygen permeability for application in cathode polymeric electrolyte membrane fuel cell	Andrea Rolfi, Claudio Oldani, Luca Merlo, Daniele Facchi, Riccardo Ruffo
671470	DEMOSOFC	Life Cycle Assessment of a Biogas-Fed Solid Oxide Fuel Cell (SOFC) Integrated in a Wastewater Treatment Plant	Marta Gandiglio, Fabrizio De Sario, Andrea Lanzini, Silvia Bobba, Massimo Santarelli, Gian Andrea Blengini
671470	DEMOSOFC	Techno-economic assessment of biogas-fed CHP hybrid systems in a real wastewater treatment plant	M. MosayebNezhad, A.S. Mehr, M. Gandiglio, A. Lanzini, M. Santarelli
671470	DEMOSOFC	Techno-economic assessment of biogas-fed solid oxide fuel cell combined heat and power system at industrial scale	Sara Giarola, Ornella Forte, Andrea Lanzini, Marta Gandiglio, Massimo Santarelli, Adam Hawkes
671481	SElySOs	A continuum model for yttria-stabilized zirconia incorporating triple phase boundary, lattice structure and immobile oxide ions	Petr Vágner, Clemens Guhlke, Vojtěch Miloš, Rüdiger Müller, Jürgen Fuhrmann

Journal title	Relevant pages	ISSN/Publication frequency[1]	Publisher	Publication year	Open Access[2]
International Journal of Hydrogen Energy	11307-11313	3603199	Pergamon Press Ltd.	2018	Yes
Proceedings Twelfth International Symposium on Hazards, Prevention and Mitigation of Industrial Explosions (XII ISHPMIE)	899-914	978-1-5323-8443-1	Fike Corporation	2018	Yes
Journal of Loss Prevention in the Process Industries		9504230	Elsevier BV	2019	Yes
Proceedings Ninth International Seminar on Fire and Explosion Hazards (ISFEH9), 21-24 April 2019	393-402	978-5-7422-6496-5	St. Petersburg Polytechnic University Press	2019	Yes
Seventh International and Forty-fifth National Fluid Mechanics and Fluid Power Conference (FMFP 2018)			IIT Bombay	2018	Yes
Journal of Loss Prevention in the Process Industries	Aug. 23	9504230	Elsevier BV	2019	Yes
International Journal of Hydrogen Energy	19293-19304	3603199	Pergamon Press Ltd.	2018	Yes
Proceedings Twenty-Seventh International Colloquium on the Dynamics of Explosions and Reactive Systems (27 ICDERS)	6 pp		Institute for Dynamics of Explosions and Reactive Systems	2019	Yes
International Journal of Hydrogen Energy	8767-8779	3603199	Pergamon Press Ltd.	2019	Yes
International Journal of Hydrogen Energy	8711-8726	3603199	Pergamon Press Ltd.	2019	Yes
Proceedings Twelfth International Symposium on Hazards, Prevention and Mitigation of Industrial Explosions (XII ISHPMIE)	847-859	978-1-5323-8443-1	Fike Corporation	2018	Yes
Proceedings Eighth International Conference on Hydrogen Safety (ICHS 2019)			ICHS 2019	2019	Yes
International Journal of Hydrogen Energy	9063-9070	3603199	Pergamon Press Ltd.	2019	Yes
International Journal of Hydrogen Energy	8893-8903	3603199	Pergamon Press Ltd.	2019	Yes
Proceedings Twenty-Seventh International Colloquium on the Dynamics of Explosions and Reactive Systems (27 ICDERS)			Institute for Dynamics of Explosions and Reactive Systems	2019	Yes
International Journal of Hydrogen Energy	21169-21176	3603199	Pergamon Press Ltd.	2018	Yes
International Journal of Hydrogen Energy	9080-9088	3603199	Pergamon Press Ltd.	2019	Yes
Proceedings Twelfth International Symposium on Hazards, Prevention and Mitigation of Industrial Explosions (XII ISHPMIE)	823-846	978-1-5323-8443-1	Fike Corporation	2018	Yes
International Journal of Hydrogen Energy	8819-8832	3603199	Pergamon Press Ltd.	2019	Yes
Chemical Engineering Transactions			Italian Association of Chemical Engineering	2019	Yes
Handbook of Nanofibers	1-37	978-3-319-42789-8	Springer International Publishing	2018	No
Journal of Power Sources	95-101	3787753	Elsevier BV	2018	Yes
Energies	1611	19961073	Multidisciplinary Digital Publishing Institute (MDPI)	2019	Yes
Applied Thermal Engineering	1263-1280	13594311	Pergamon Press Ltd.	2018	Yes
Applied Energy	689-704	3062619	Pergamon Press Ltd.	2018	Yes
Journal of Solid State Electrochemistry		14328488	Springer Verlag	2019	Yes

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671481	SElySOs	Affecting the H_2O electrolysis process in SOECs through modification of NiO/GDC; experimental case of Au-Mo-Ni synergy	Ch. Neofytidis, E. Ioannidou, L. Sygellou, M. Kollia, D.K. Niakolas
671481	SElySOs	Au-doped Ni/GDC as an Improved Cathode Electrocatalyst for H_2O Electrolysis in SOECs	E. Ioannidou, Ch. Neofytidis, L. Sygellou, D.K. Niakolas
671481	SElySOs	Experimental Clarification of the RWGS Reaction Effect in H_2O/CO_2 SOEC Co-Electrolysis Conditions	Evangelia Ioannidou, Stylianos Neophytides, Dimitrios Niakolas
671481	SElySOs	High Performance LSC Infiltrated LSCF Oxygen Electrode for High Temperature Steam Electrolysis Application	V. Vibhu, S. Yildiz, I. C. Vinke, R.-A. Eichel, J.-M. Bassat, L. G. J. de Haart
671481	SElySOs	High temperature electrolysis cells with the use of solid oxide fuel cell state-of-the-art electrode materials	K.M. Papazisi, M.E. Farmaki, D. Tsiplakides, S. Balomenou
671481	SElySOs	La2Ni1-Co O4+δ (x = 0.0, 0.1 and 0.2) based efficient oxygen electrode materials for solid oxide electrolysis cells	V. Vibhu, I.C. Vinke, R.-A. Eichel, J.-M. Bassat, L.G.J. de Haart
671481	SElySOs	Thermodynamic analysis of high temperature steam and carbon dioxide systems in solid oxide cells	Petr Vágner, Roman Kodým, Karel Bouzek
671486	HEALTH-CODE	Fault Characterization of a Proton Exchange Membrane Fuel Cell Stack	Samuel Simon Araya, Fan Zhou, Simon Lennart Sahlin, Sobi Thomas, Christian Jeppesen, Søren Knudsen Kær
671486	HEALTH-CODE	Generalized scaling-up approach based on Buckingham theorem for Polymer Electrolyte Membrane Fuel Cells impedance simulation	Pierpaolo Polverino, Giovanni Bove, Marco Sorrentino, Cesare Pianese
699892	ECo	A Comparative Study of Durability of Solid Oxide Electrolysis Cells Tested for Co-Electrolysis under Galvanostatic and Potentiostatic Conditions	M. Rao, X. Sun, A. Hagen
699892	ECo	Electricity from renewable sources must be stored efficiently	A. Hagen
699892	ECo	Experimental validation of a La 0.6 Sr 0.4 Co 0.2 Fe 0.8 O 3-δ electrode model operated in electrolysis mode: Understanding the reaction pathway under anodic polarization	F. Monaco, V. Tezyk, E. Siebert, S. Pylypko, B. Morel, J. Vulliet, T. Le Bihan, F. Lefebvre-Joud, J. Laurencin
699892	ECo	Infiltrated mesoporous oxygen electrodes for high temperature co-electrolysis of H 2 O and CO 2 in solid oxide electrolysis cells	E. Hernández, F. Baiutti, A. Morata, M. Torrell, A. Tarancón
699892	ECo	Microstructural correlations for specific surface area and triple phase boundary length for composite electrodes of solid oxide cells	H. Moussaoui, R.K. Sharma, J. Debayle, Y. Gavet, G. Delette, J. Laurencin
699892	ECo	Optimal design of solid-oxide electrolyzer based power-to-methane systems: A comprehensive comparison between steam electrolysis and co-electrolysis	Ligang Wang, Mar Pérez-Fortes, Hossein Madi, Stefan Diethelm, Jan Van herle, François Maréchal
699892	ECo	Power-to-fuels via solid-oxide electrolyzer: Operating window and techno-economics	Ligang Wang, Ming Chen, Rainer Küngas, Tzu-En Lin, Stefan Diethelm, François Maréchal, Jan Van herle
699892	ECo	Power-to-methane via co-electrolysis of H_2O and CO_2: The effects of pressurized operation and internal methanation	Ligang Wang, Megha Rao, Stefan Diethelm, Tzu-En Lin, Hanfei Zhang, Anke Hagen, François Maréchal, Jan Van herle
699892	ECo	Solid Oxide Electrolysis Cells electrodes based on mesoporous materials	Elba María Hernández Rodríguez
699892	ECo	Stochastic geometrical modeling of solid oxide cells electrodes validated on 3D reconstructions	H. Moussaoui, J. Laurencin, Y. Gavet, G. Delette, M. Hubert, P. Cloetens, T. Le Bihan, J. Debayle
699892	ECo	Trade-off designs of power-to-methane systems via solid-oxide electrolyzer and the application to biogas upgrading	Guillaume Jeanmonod, Ligang Wang, Stefan Diethelm, François Maréchal, Jan Van herle
700008	HPEM2GAS	Electrochemical Impedance Spectroscopy as a Diagnostic Tool in Polymer Electrolyte Membrane Electrolysis	Stefania Siracusano, Stefano Trocino, Nicola Briguglio, Vincenzo Baglio, Antonino Aricò
700092	BIG HIT	Life cycle assessment of hydrogen production and consumption in an isolated territory	Guangling Zhao, Allan Schrøder Pedersen
700092	BIG HIT	Life cycle cost analysis: A case study of hydrogen energy application on the Orkney Islands	Guangling Zhao, Eva Ravn Nielsen, Enrique Troncoso, Kris Hyde, Jesús Simón Romeo, Michael Diderich
700101	Giantleap	Ageing integration in PEMFC stack simulator for onboard prognostic purposes in electrical bus applications	Raffaele Petrone, Nadia Yousfi Steiner, Daniel Hissel
700101	Giantleap	Catalyst degradation diagnostics of proton exchange membrane fuel cells using electrochemical impedance spectroscopy	Ivan Pivac, Dario Bezmalinović, Frano Barbir
700101	Giantleap	Control and prognostics for flexible hybrid battery-hydrogen buses	Federico Zenith

Journal title	Relevant pages	ISSN/Publication frequency[1]	Publisher	Publication year	Open Access[2]
Journal of Catalysis	260-275	219517	Academic Press	2019	Yes
Applied Catalysis B: Environmental	253-264	9263373	Elsevier BV	2018	Yes
Catalysts	151	20734344	Multidisciplinary Digital Publishing Institute (MDPI)	2019	Yes
Journal of The Electrochemical Society	F102-F108	134651	Electrochemical Society, Inc.	2019	Yes
Materials Today: Proceedings	27536-27542	22147853	Elsevier	2018	Yes
Journal of Power Sources	227292	3787753	Elsevier BV	2019	Yes
Sustainable Energy & Fuels	2076-2086	23984902	Royal Society of Chemistry	2019	Yes
Energies	152	19961073	Multidisciplinary Digital Publishing Institute (MDPI)	2019	Yes
Energy Procedia	1514-1520	18766102	Elsevier	2019	Yes
Journal of The Electrochemical Society	F748-F755	134651	Electrochemical Society, Inc.	2018	Yes
www.openaccessgovernment.org	digital publication		openaccessgovernment	2019	Yes
Solid State Ionics	234-246	1672738	Elsevier BV	2018	Yes
Journal of Materials Chemistry A	9699-9707	20507488	Royal Society of Chemistry	2018	Yes
Journal of Power Sources	736-748	3787753	Elsevier BV	2019	Yes
Applied Energy	1060-1079	3062619	Pergamon Press Ltd.	2018	Yes
Renewable and Sustainable Energy Reviews	174-187	13640321	Elsevier BV	2019	Yes
Applied Energy	1432-1445	3062619	Pergamon Press Ltd.	2019	Yes
			Universitat de Barcelona	2018	Yes
Computational Materials Science	262-276	9270256	Elsevier BV	2018	Yes
Applied Energy	572-581	3062619	Pergamon Press Ltd.	2019	Yes
Materials	1368	19961944	MDPI Open Access Publishing	2018	Yes
			ScienceDirect	2018	Yes
International Journal of Hydrogen Energy	9517-9528	3603199	Pergamon Press Ltd.	2019	Yes
Hydrogen & Fuel Cells Conference 2018			H2FC2018	2018	Yes
International Journal of Hydrogen Energy	13512-13520	3603199	Pergamon Press Ltd.	2018	Yes
Hannover Messe, Hydrogen & Fuel Cells Technical Forum			Hannover Messe	2019	Yes

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700101	Giantleap	Diagnostics of PEMFC Degradation	Frano Barbir, Gjomir Radica, Dario Bezmalinović, Boris Šimić, Željko Penga, Nikolina Pivac, Ivan Pivac
700101	Giantleap	Diagnostics, Prognostics and Control of Low-Temperature PEM Fuel Cells	Federico Zenith
700101	Giantleap	Electrochemical low-frequency impedance spectroscopy algorithm for diagnostics of PEM fuel cell degradation	Ivar J. Halvorsen, Ivan Pivac, Dario Bezmalinović, Frano Barbir, Federico Zenith
700101	Giantleap	Electrochemical Low-Frequency Impedance Spectroscopy for Diagnostics of Fuel Cells	Federico Zenith, Ivar J. Halvorsen, Ivan Pivac, Dario Bezmalinović, Frano Barbir
700101	Giantleap	Fuel cell performance prediction using an Auto-Regressive Moving-Average Model	A. H. Detti, N. Yousfi Steiner, L. Bouillaut, A. B. Same, S. Jemei
700101	Giantleap	Increasing Reliability of Fuel-Cell Buses: The Giantleap Project	Federico Zenith
700101	Giantleap	Integration of Ageing in a PEMFC range extender model for on-board prognostic applications	R. Petrone, N. Yousfi Steiner, D. Hissel, M.-C. Péra, N. Zerhouni, S. Jameï, S. Hemmer, R. Bouwman
700101	Giantleap	Low-Frequency EIS for PEM Fuel-Cell Diagnostics	Ivar Johan Halvorsen, Ivan Pivac, Dario Bezmalinović, Frano Barbir, Federico Zenith
700101	Giantleap	Proton Exchange Membrane Fuel Cell Model for Prognosis	A.H. Detti, S. Jemeï, N. Yousfi Steiner
700101	Giantleap	Relay feedback excitation for identification of Fuel Cell performance parameters	Ivar J. Halvorsen, Federico Zenith
700101	Giantleap	The Giantleap Project: Improving reliability of hydrogen buses	Federico Zenith
700127	INSPIRE	A comparison of rotating disc electrode, floating electrode technique and membrane electrode assembly measurements for catalyst testing	Sladjana Martens, Ludwig Asen, Giorgio Ercolano, Fabio Dionigi, Chris Zalitis, Alex Hawkins, Alejandro Martinez Bonastre, Lukas Seidl, Alois C. Knoll, Jonathan Sharman, Peter Strasser, Deborah Jones, Oliver Schneider
700127	INSPIRE	Controlling Near-Surface Ni Composition in Octahedral PtNi(Mo) Nanoparticles by Mo Doping for a Highly Active Oxygen Reduction Reaction Catalyst	F. Dionigi, C. Cesar Weber, M. Primbs, M. Gocyla, A. Martinez Bonastre, C. Spöri, H. Schmies, E. Hornberger, S. Kühl, J. Drnec, M. Heggen, J. Sharman, R. Edward Dunin-Borkowski, P. Strasser
700127	INSPIRE	Electrodeposition of Platinum Catalyst from Ionic Liquids	Jonathan Diederich, Sladjana Martens, Ludwig Asen, Oliver Schneider
700127	INSPIRE	Electrodeposition of Pt and Gd from the Same Ionic Liquid	Ludwig Asen, Sladjana Martens, Ueli Heiz, Alois C. Knoll, Oliver Schneider
700127	INSPIRE	Impact of Carbon Support Corrosion on Performance Losses in Polymer Electrolyte Membrane Fuel Cells	Friedemann Hegge, Jonathan Sharman, Riko Moroni, Simon Thiele, Roland Zengerle, Matthias Breitwieser, Severin Vierrath
700127	INSPIRE	Preparation of Ni@Pt core@shell conformal nanofibre oxygen reduction electrocatalysts via microwave-assisted galvanic displacement	Giorgio Ercolano, Filippo Farina, Lorenzo Stievano, Deborah J. Jones, Jacques Rozière, Sara Cavaliere
700127	INSPIRE	Recent developments in electrocatalyst design thrifting noble metals in fuel cells	Giorgio Ercolano, Sara Cavaliere, Jacques Rozière, Deborah J. Jones
700127	INSPIRE	Revealing the nature of active sites in electrocatalysis	Batyr Garlyyev, Johannes Fichtner, Oriol Piqué, Oliver Schneider, Aliaksandr S. Bandarenka, Federico Calle-Vallejo
700266	Cell3Ditor	Continuous hydrothermal flow synthesis of Gd-doped CeO 2 (GDC) nanoparticles for inkjet printing of SOFC electrolytes	Yu Xu, Nicholas Farandos, Massimo Rosa, Philipp Zielke, Vincenzo Esposito, Peter Vang Hendriksen, Søren Højgaard Jensen, Tao Li, Geoffrey Kelsall, Ragnar Kiebach
700266	Cell3Ditor	Gd0.2Ce0.801.9/Y0.16Zr0.8401.92 nanocomposite thin films for low temperature ionic conductivity	Giovanni Perin, Christophe Gadea, Massimo Rosa, Simone Sanna, Yu Xu, Ragnar Kiebach, Antonella Glisenti, Vincenzo Esposito
700266	Cell3Ditor	Impact of cation redox chemistry on continuous hydrothermal synthesis of 2D-Ni(Co/Fe) hydroxides	Massimo Rosa, Debora Marani, Giovanni Perin, Søren Bredmose Simonsen, Philipp Zielke, Antonella Glisenti, Ragnar Kiebach, Andreas Lesch, Vincenzo Esposito
700266	Cell3Ditor	Printing of NiO-YSZ nanocomposites: From continuous synthesis to inkjet deposition	Massimo Rosa, Philippe Zielke, Ragnar Kiebach, Victor Costa Bassetto, Andreas Lesch, Vincenzo Esposito
700266	Cell3Ditor	Zirconia UV-curable colloids for additive manufacturing via hybrid inkjet printing-stereolithography	M. Rosa, C. Barou, V. Esposito
700300	GrInHy	Design and characterization of novel glass-ceramic sealants for solid oxide electrolysis cell (SOEC) applications	Hassan Javed, Antonio Gianfranco Sabato, Kai Herbrig, Domenico Ferrero, Christian Walter, Milena Salvo, Federico Smeacetto
700300	GrInHy	Elastic properties of multi-layered ceramic systems for SOCs	Alessia Masini, Filip Šiška, Oldřich Ševeček, Zdeněk Chlup, Ivo Dlouhý

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Vehicle Power and Propulsion Conference 2017			IEEE	2018	Yes
Fundamentals and Development of Fuel Cells 2019			FDFC2019	2019	Yes
International Journal of Hydrogen Energy		3603199	Pergamon Press Ltd.	2019	Yes
Vehicle Power Propulsion Conference			IEEE	2019	Yes
Vehicle Power Propulsion Conference			IEEE	2019	Yes
Hydrogen Days			HyTEP	2019	Yes
Vehicle Power and Propulsion Conference 2018			IEEE	2018	Yes
Hydrogen & Fuel Cells Conference 2018			H2FC2018	2018	Yes
Vehicle Power and Propulsion Conference 2018			IEEE	2018	Yes
Nordic Process Control Workshop			DTU	2019	Yes
Hydrogen Innovation Festival			MedioTejo21	2018	Yes
Journal of Power Sources	274-284	3787753	Elsevier BV	2018	Yes
Nano Letters	6876-6885	15306984	American Chemical Society	2019	Yes
ECS Transactions	533-546	19385862	Electrochemical Society, Inc.	2019	Yes
ECS Transactions	475-487	19385862	Electrochemical Society, Inc.	2018	Yes
Journal of The Electrochemical Society	F956-F962	134651	Electrochemical Society, Inc.	2019	Yes
Catalysis Science & Technology	6920 – 6928	20444753	Royal Society of Chemistry	2019	Yes
Current Opinion in Electrochemistry	271-277	24519103	Elsevier BV	2018	Yes
Chemical Science	8060-8075	20416520	Royal Society of Chemistry	2019	Yes
International Journal of Applied Ceramic Technology	315-327	1546542X	American Ceramic Society	2018	Yes
Journal of Physics and Chemistry of Solids		223697	Pergamon Press Ltd.	2019	Yes
Reaction Chemistry & Engineering		20589883	Royal Society of Chemistry	2019	Yes
Journal of the European Ceramic Society	1279-1286	9552219	Elsevier BV	2018	Yes
Materials Letters	214-217	0167577X	Elsevier BV	2018	Yes
International Journal of Applied Ceramic Technology	999-1010	1546542X	American Ceramic Society	2018	Yes
International Journal of Applied Ceramic Technology	370-379	1546542X	American Ceramic Society	2018	Yes

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700300	GrInHy	Electrolyte-Supported Fuel Cell: Co-Sintering Effects of Layer Deposition on Biaxial Strength	Alessia Masini, Thomas Strohbach, Filip Šiška, Zdeněk Chlup, Ivo Dlouhý
700300	GrInHy	Shear Performance at Room and High Temperatures of Glass–Ceramic Sealants for Solid Oxide Electrolysis Cell Technology	Hassan Javed, Antonio Sabato, Ivo Dlouhy, Martina Halasova, Enrico Bernardo, Milena Salvo, Kai Herbrig, Christian Walter, Federico Smeacetto
700339	PACE	Status on Demonstration of Fuel Cell Based Micro-CHP Units in Europe	E. R. Nielsen, C. B. Prag, T. M. Bachmann, F. Carnicelli, E. Boyd, I. Walker, L. Ruf, A. Stephens
700359	ELY4OFF	ELY4OFF – PEM ElectroLYsers FOR operation with OFFgrid renewable installations – H2020	Pedro Casero
700359	ELY4OFF	Sistema Híbrido de Almacenamiento (H2 y baterías) para instalación aislada	Lorién Gracia, Pedro Casero
700359	ELY4OFF	Sustainable and efficient off-grid production of Hydrogen. Demo Project on-going in Spain	Rubén Galvéz, Logan Lopéz, Estanis Oyarbide, Lorién Gracia, Pedro Casero, Edgar Bueno
700359	ELY4OFF	Use of Hydrogen in Off-Grid Locations, a Techno-Economic Assessment	Lorién Gracia, Pedro Casero, Cyril Bourasseau, Alexandre Chabert
700667	SOSLeM	Analysis of High Temperature Degradation of Alloys in Solid Oxide Fuel Cell	Manuel Bianco, Jan Van herle, Stefan Diethelm
700667	SOSLeM	Ex-situ experimental benchmarking of solid oxide fuel cell metal interconnects	Manuel Bianco, Johan Tallgren, Jong-Eun Hong, Shicai Yang, Olli Himanen, Jyrki Mikkola, Jan Van herle, Robert Steinberger-Wilckens
700667	SOSLeM	Identification of Solid Oxide Cell Elementary Processes by Electrochemical Impedance	Priscilla Caliandro, Jan Van herle, Stefan Diethelm
700667	SOSLeM	Model-assisted identification of solid oxide cell elementary processes by electrochemical impedance spectroscopy measurements	P. Caliandro, A. Nakajo, S. Diethelm, J. Van herle
735160	qSOFC	Artificial intelligence for automatic optical inspection of multilayered solid oxide membranes	Anton Litke, Petrus Martens, Ronald van Olmen, Greg Norsworthy, Roderik Höppener
735160	qSOFC	Long term stability of a Mn-rich precoated AISI 441 for Solid Oxide Fuel Cell Interconnects at 650 °C in air	Carlos Bernuy-Lopez, Robert Berger, Jörgen Westlinder
735160	qSOFC	Mass-manufacturing and quality assurance of SOFC stacks in FCH 2 JU projects qSOFC and INNO-SOFC	Markus Rautanen, Olli Himanen, Jyrki Mikkola, Johan Tallgren, Enn Õunpuu, Sergii Pylypko, Matti Noponen, Paul Hallanoro, Jukka Göös, Anton Litke, Roderik Höppener, Simon Hailer, Uwe Maier, Robert Berger, Stephen McPhail, Lars Steckkönig
735160	qSOFC	Sandvik surface technology: a solution for mass production of fuel cells	Carlos Bernuy-Lopez, Robert Berger, Mikael Stenström, Jörgen Westlinder
735218	PECSYS	Applicability of a New Sulfonated Pentablock Copolymer Membrane and Modified Gas Diffusion Layers for Low-Cost Water Splitting Processes	S. Filice, G. Urzì, R.G. Milazzo, S.M.S. Privitera, S. A. Lombardo, G. Compagnini, S. Scalese
735218	PECSYS	Characteristics of a New Polymer Electrolyte Electrolysis Technique with Only Cathodic Media Supply Coupled to a Photovoltaic Panel	M. Müller, W. Zwaygardt, E. Rauls, M. Hehemann, S. Haas, L. Stolt, H. Janßen and M. Carmo
735218	PECSYS	Effect of Morphology and Mechanical Stability of Nanometric Platinum Layer on Nickel Foam for Hydrogen Evolution Reaction	Rachela G. Milazzo, Stefania M. S. Privitera, Silvia Scalese, Salvatore A. Lombardo
735218	PECSYS	Impedance Spectroscopy Modeling of Nickel–Molybdenum Alloys on Porous and Flat Substrates for Applications in Water Splitting	İlknur Bayrak Pehlivan, Miguel A. Arvizu, Zhen Qiu, Gunnar A. Niklasson, Tomas Edvinsson
735218	PECSYS	Impedance spectroscopy of water splitting reactions on nanostructured metal-based catalysts	G.A. Niklasson, Z Qiu, I. Bayrak Pehlivan, T. Edvinsson
735218	PECSYS	Optimum Band Gap Energy of ((Ag),Cu)(InGa)Se2 Materials for Combination with NiMo–NiO Catalysts for Thermally Integrated Solar-Driven Water Splitting Applications	İlknur Bayrak Pehlivan, Marika Edoff, Lars Stolt, Tomas Edvinsson
735218	PECSYS	Prospects for Hermetic Sealing of Scaled-Up Photoelectrochemical Hydrogen Generators for Reliable and Risk Free Operation	Sonya Calnan, Stefan Aschbrenner, Fuxi Bao, Erno Kemppainen, Iris Dorbandt, Rutger Schlatmann
735218	PECSYS	Spontaneous galvanic displacement of Pt nanostructures on nickel foam: Synthesis, characterization and use for hydrogen evolution reaction	Rachela G. Milazzo, Stefania M.S. Privitera, Daniele D'Angelo, Silvia Scalese, Salvatore Di Franco, Francesco Maita, Salvatore Lombardo
735485	QualyGridS	Integration of demand-side response in the Swiss ancillary service markets through the ENTSO-E central settlement model	A. Chacko, C. Imboden, R. Kummer, T. Reithofer

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Materials	306	19961944	MDPI Open Access Publishing	2019	Yes
Materials	298	19961944	MDPI Open Access Publishing	2019	Yes
Fuel Cells	340-345	16156846	John Wiley & Sons Ltd.	2019	Yes
Impact	74-76	23987073	Science Impact Ltd	2018	Yes
Congreso Iberoamericano de Hidrógeno y Pilas de Combustible 2017	227-231	978-84-697-6342-1	APPICE	2018	Yes
XVIII International Congress of the Mexican Hydrogen Society	307-315	2448-71202018	CSMH 18	2018	Yes
Energies	3141	19961073	Multidisciplinary Digital Publishing Institute (MDPI)	2018	Yes
			EPFL	2019	No
Journal of Power Sources	226900	3787753	Elsevier BV	2019	Yes
			EPFL	2018	No
Journal of Power Sources	226838	3787753	Elsevier BV	2019	Yes
European SOE & SOFC Forum			European SOE & SOFC Forum	2018	Yes
European SOE & SOFC Forum			European SOE & SOFC Forum	2018	Yes
European SOE&SOFC Forum			European SOE&SOFC Forum	2018	Yes
International Hydrogen and Fuel Cells Conference			International Hydrogen and Fuel Cells Conference	2018	Yes
Energies	2064	19961073	Multidisciplinary Digital Publishing Institute (MDPI)	2019	Yes
Energies	4150	1996-1073	Multidisciplinary Digital Publishing Institute (MDPI)	2019	Yes
Energies	3116	19961073	Multidisciplinary Digital Publishing Institute (MDPI)	2019	Yes
The Journal of Physical Chemistry C	23890-23897	19327447	American Chemical Society	2019	No
IOP Conference Series: Materials Science and Engineering	12005	1757899X	IOP Publishing Ltd.	2019	Yes
Energies	4064	19961073	Multidisciplinary Digital Publishing Institute (MDPI)	2019	Yes
Energies	4176	19961073	Multidisciplinary Digital Publishing Institute (MDPI)	2019	Yes
International Journal of Hydrogen Energy	7903-7910	3603199	Pergamon Press Ltd.	2018	Yes
15. Symposium Energieinnovation, Gratz			HSLU	2018	Yes

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735485	QualyGridS	QualyGridS – Standardized qualifying tests of electrolysers for grid services	Regine Reissner, Marius Bornstein, Ben Green, Laura Abadía, Cyril Bourasseau, Shi You, Chresten Træholt, Francoise de Jong, Pablo Marcuello, Christoph Imboden, M. Spirig et al.,
735533	MEMPHYS	An Engineering Toolbox for the Evaluation of Metallic Flow Field Plates	Uwe Reimer, Dieter Froning, Gert Nelissen, Leonard F. J. M. Raymakers, Shidong Zhang, Steven B. Beale, Werner Lehnert
735533	MEMPHYS	Engineering toolbox for flowfield plates with automated mesh generation	U. Reimer, D. Froning, S. B. Beale, W. Lehnert
735533	MEMPHYS	Fault detection of fuel cell systems based on statistical assessment of impedance data	Martin Stepančič, Đani Juričić, Pavle Boškoski
735533	MEMPHYS	Membrane based purification of hydrogen system	L. Schorer, S. Schmitz, A. Weber
735533	MEMPHYS	Membrane based purification of hydrogen system (MEMPHYS)	Linda Schorer, Sven Schmitz, Alexandra Weber
735692	CH2P	A Cogeneration System Based on Solid Oxide and Proton Exchange Membrane Fuel Cells with Hybrid Storage for Off-Grid Applications	Francesco Baldi, Ligang Wang, Mar Pérez-Fortes, François Maréchal
735692	CH2P	Characterization of the local morphology at triple-phase boundaries after SOFC/SOEC operation	G. Rinaldi, A. Nakajo, M. Cantoni, W.K.S. Chiu, J. Van herle
735692	CH2P	Design of a Pilot SOFC System for the Combined Production of Hydrogen and Electricity under Refueling Station Requirements	M. Pérez-Fortes, A. Mian, S. Srikanth, L. Wang, S. Diethelm, E. Varkaraki, I. Mirabelli, R. Makkus, R. Schoon, F. Maréchal, J. Van herle
735692	CH2P	Process optimization of a SOFC system for the combined production of hydrogen and electricity	M. Pérez-Fortes, A. Mian, S. Diethelm, L. Wang, F. Maréchal, J. Van herle, S. Santhanam, M.P. Heddrich, S.F. Au, E. Varkaraki, Z. Wuillemin, R. Makkus, I. Mirabelli, R. Schoon, M. Grippa, M. Testi, L. Crema
735692	CH2P	Thermo-mechanical reliability of SOFC stacks: impact of component tolerances and operating conditions	F. Greco, A. Nakajo, Z. Wuillemin, J. Van herle
735918	INSIGHT	Carbon Deposition Diagnostics for Reliability and State-of-Health Assessment of SOFC	Alexandra Ploner, Anke Hagen, Anne Hauch
735918	INSIGHT	Experimental validation of a La 0.6 Sr 0.4 Co 0.2 Fe 0.8 O 3-δ electrode model operated in electrolysis mode: Understanding the reaction pathway under anodic polarization	F. Monaco, V. Tezyk, E. Siebert, S. Pylypko, B. Morel, J. Vulliet, T. Le Bihan, F. Lefebvre-Joud, J. Laurencin
735918	INSIGHT	Impact of Nickel agglomeration on Solid Oxide Cell operated in fuel cell and electrolysis modes	M. Hubert, J. Laurencin, P. Cloetens, B. Morel, D. Montinaro, F. Lefebvre-Joud
736290	DIGIMAN	Automatic PLC Code Generation Based on Virtual Engineering Model	Mohammad Jbair, Bilal Ahmad, Mus'ab H. Ahmad, Daniel Vera, Robert Harrison, Tony Ridler
736290	DIGIMAN	Uncertainty in Measurement	Carlo Ferri
736648	NET-Tools	Blast wave after hydrogen storage tank rupture in a tunnel fire	V. Shentsov, D. Makarov, and V. Molkov
736648	NET-Tools	Blast wave and fireball after hydrogen tank rupture in a fire	V. Molkov, D.M.C. Cirrone, V. Shentsov, W. Dery, W. Kim, and D. Makarov
736648	NET-Tools	Blast wave and fireball after hydrogen tank rupture in a fire	V. Molkov, D.M.C. Cirrone, V. Shentsov, W. Dery, W. Kim, and D. Makarov
736648	NET-Tools	Deflagrations of localised homogeneous and inhomogeneous hydrogen-air mixtures in enclosures	D. Makarov, P. Hooker, M. Kuznetsov, V. Molkov
736648	NET-Tools	Effect of a heat release rate on reproducibility of fire test for hydrogen storage cylinders	Sergii Kashkarov, Dmitriy Makarov, Vladimir Molkov
736648	NET-Tools	Hands-on session on e-Laboratory and lectures on Hydrogen Safety	V. Shentsov, D. Makarov, and V. Molkov
736648	NET-Tools	Modelling of Hydrogen Tank Fuelling	M. Dadashzadeh, D. Makarov, V. Molkov
736648	NET-Tools	Modelling of Hydrogen Tank Fuelling	M. Dadashzadeh, D. Makarov, V. Molkov

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European Grid Service Markets Symposium 2018, Lucerne, Switzerland, 5. July 2018			Lucerne University of Applied Science & Arts and European Fuel Cell Forum	2018	Yes
ChemEngineering	85	23057084	MDPI AG	2019	Yes
15th Symposium on Modeling and Validation of Electrochemical Energy Devices. ModVal 2018	156-157		Paul Scherrer Institut	2018	Yes
Energy Conversion and Management	76-85	1968904	Pergamon Press Ltd.	2019	Yes
EHEC 2018: Proceedings		978-84-09-01620-4	EHEC	2018	No
International Journal of Hydrogen Energy	12708-12714	3603199	Pergamon Press Ltd.	2019	Yes
Frontiers in Energy Research	Jan. 18	2296598X	Frontiers in Energy Research	2019	Yes
Proceedings of 13th European SOFC & SOE Forum 2018 (B0304)		978-3-905592-23-8	European Fuel Cell Forum AG	2018	Yes
Fuel Cells	389–407	16156846	John Wiley & Sons Ltd.	2019	Yes
Proceedings of 13th European SOFC & SOE Forum 2018 (Chapter 06, Session A13)	106-117	978-3-905592-23-8	European Fuel Cell Forum AG	2018	Yes
Proceedings of 13th European SOFC & SOE Forum 2018 (A1403)		978-3-905592-23-8	European Fuel Cell Forum AG	2018	Yes
ECS Transactions	25-32	19385862	Electrochemical Society, Inc.	2018	No
Solid State Ionics	234-246	1672738	Elsevier BV	2018	Yes
Journal of Power Sources	240-251	3787753	Elsevier BV	2018	No
2019 IEEE International Conference on Industrial Cyber Physical Systems (ICPS)	675-680	978-1-5386-8500-6	IEEE	2019	Yes
Intelligent System and Computing			Intechopen	2019	Yes
Presentation at International Symposium on Tunnel Safety and Security 2018			ISTSS	2018	Yes
11th International Colloquium on Pulsed and Continuous Detonations (ICPCD)			ICPCD	2018	Yes
Presentation at 11th International Colloquium on Pulsed and Continuous Detonations (ICPCD)			ICPCD	2018	Yes
International Journal of Hydrogen Energy	9848-9869	3603199	Pergamon Press Ltd.	2018	Yes
International Journal of Hydrogen Energy	10185-10192	3603199	Pergamon Press Ltd.	2018	Yes
Presentations at Joint European Summer School 2018			JESS2018	2018	Yes
Presentation at Ninth International Seminar on Fire and Explosion Hazards			Saint Petersburg Peter the Great St. Petersburg Polytechnic University 2019	2019	Yes
Proceedings of the Ninth International Seminar on Fire and Explosion Hazards	1396	978-5-7422-6498-9	Saint Petersburg Peter the Great St. Petersburg Polytechnic University 2019	2019	Yes

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736648	NET-Tools	Near Field Thermal Dose of Cryogenic Hydrogen Jet Fires	D. Cirrone, D. Makarov, V. Molkov
736648	NET-Tools	Near Field Thermal Dose of Cryogenic Hydrogen Jet Fires	D. Cirrone, D. Makarov, V. Molkov
736648	NET-Tools	Pressure peaking phenomenon: Model validation against unignited release and jet fire experiments	D. Makarov, V. Shentsov, M. Kuznetsov, V. Molkov
736648	NET-Tools	Risk assessment methodology for onboard hydrogen storage	Mohammad Dadashzadeh, Sergii Kashkarov, Dmitriy Makarov, Vladimir Molkov
736648	NET-Tools	Scientific Principles of e-Laboratory of Hydrogen Safety	V. Shentsov, D. Makarov, V. Molkov
736648	NET-Tools	Scientific Principles of e-Laboratory of Hydrogen Safety	V. Shentsov, D. Makarov, V. Molkov
736648	NET-Tools	Similitude analysis and critical conditions for spontaneous ignition of hydrogen release into the atmosphere through a tube	Liang Gonga, Qiangling Duana, Jinhua Suna, Vladimir Molkov
736648	NET-Tools	Simulation of thermal hazards from hydrogen under-expanded jet fire	D.M.C. Cirrone, D. Makarov, V. Molkov
736648	NET-Tools	Stand-Alone Hemisphere-Tank Rupture in Tunnel Fire: Effect of Hydrogen Inventory on Blast Wave Strength in Far Field	V. Shentsov, D. Makarov, W. Dery
736648	NET-Tools	Stand-Alone Hemisphere-Tank Rupture in Tunnel Fire: Effect of Hydrogen Inventory on Blast Wave Strength in Far Field	V. Shentsov, D. Makarov, W. Dery
736648	NET-Tools	The progress in hydrogen safety research	V. Molkov
736648	NET-Tools	The progress in hydrogen safety research	V. Molkov
736648	NET-Tools	Thermal radiation from cryogenic hydrogen jet fires	D.M.C. Cirrone, D. Makarov, V. Molkov
779366	CRESCENDO	Accurate Evaluation of Active-Site Density (SD) and Turnover Frequency (TOF) of PGM-Free Metal–Nitrogen-Doped Carbon (MNC) Electrocatalysts using CO Cryo Adsorption	Fang Luo, Chang Hyuck Choi, Mathias J.M. Primbs, Wen Ju, Shuang Li, Nathaniel D. Leonard, Arne Thomas, Frédéric Jaouen, Peter Strasser
779366	CRESCENDO	Toward Platinum Group Metal-Free Catalysts for Hydrogen/Air Proton-Exchange Membrane Fuel Cells	Frédéric Jaouen, Deborah Jones, Nathan Coutard, Vincent Artero, Peter Strasser, Anthony Kucernak
779469	Haeolus	Hydrogen Export to Svalbard: Exploiting Stranded Wind in Finnmark	Federico Zenith
779469	Haeolus	Large-Scale Hydrogen Production from Wind Power in Arctic Conditions	Federico Zenith
779469	Haeolus	Large-Scale Hydrogen Production from Wind Power in Arctic Conditions	Federico Zenith
779469	Haeolus	Non-Technical Obstacles for Power-to-H2: Hydrogen from Wind Power in Arctic Conditions	Federico Zenith
779478	PRETZEL	A modular design approach for PEM electrolyser systems with homogeneous operation conditions and highly efficient heat management	F.J. Wirkert, J. Roth, S. Jagalski, P. Neuhaus, U. Rost, M. Brodmann
779478	PRETZEL	Webpage of the project	Consortium of PRETZEL project
779486	GAMER	Mixed proton and electron conducting double perovskite anodes for stable and efficient tubular proton ceramic electrolysers	Einar Vøllestad, Ragnar Strandbakke, Mateusz Tarach, David Catalán-Martínez, Marie-Laure Fontaine, Dustin Beeaff, Daniel R. Clark, Jose M. Serra, Truls Norby
779540	NEPTUNE	Chemically stabilised extruded and recast short side chain Aquivion® proton exchange membranes for high current density operation in water electrolysis	Stefania Siracusano, Claudio Oldani, Maria Assunta Navarra, Stefano Tonella, Lucia Mazzapioda, Nicola Briguglio, Antonino S. Aricò
779540	NEPTUNE	Flammability reduction in a pressurised water electrolyser based on a thin polymer electrolyte membrane through a Pt-alloy catalytic approach	Nicola Briguglio, Stefania Siracusano, Giuseppe Bonura, David Sebastián, Antonino S. Aricò

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Presentation at Ninth International Seminar on Fire and Explosion Hazards			Saint Petersburg Peter the Great St. Petersburg Polytechnic University 2019	2019	Yes
Proceedings of the Ninth International Seminar on Fire and Explosion Hazards	1361	978-5-7422-6498-9	Saint Petersburg Peter the Great St. Petersburg Polytechnic University 2019	2019	Yes
International Journal of Hydrogen Energy	9454-9469	3603199	Pergamon Press Ltd.	2018	Yes
International Journal of Hydrogen Energy	6462-6475	3603199	Pergamon Press Ltd.	2018	Yes
Presentation at Ninth International Seminar on Fire and Explosion Hazards			Saint Petersburg Peter the Great St. Petersburg Polytechnic University	2019	Yes
Proceedings of the Ninth International Seminar on Fire and Explosion Hazards	1306	978-5-7422-6498-9	Saint Petersburg Peter the Great St. Petersburg Polytechnic University 2019	2019	Yes
Fuel – The Science and Technology of Fuel and Energy	413-419	0016-2361	Elsevier BV	2019	Yes
International Journal of Hydrogen Energy		3603199	Pergamon Press Ltd.	2018	Yes
Presentation at Ninth International Seminar on Fire and Explosion Hazards			Saint Petersburg Peter the Great St. Petersburg Polytechnic University 2019	2019	Yes
Proceedings of the Ninth International Seminar on Fire and Explosion Hazards	1315		Saint Petersburg Peter the Great St. Petersburg Polytechnic University 2019	2019	Yes
8th International Symposium on Non-equilibrium Processes, Plasma, Combustion, and Atmospheric Phenomena			Torus Press	2018	Yes
Presentation at 8th International Symposium on Non-equilibrium Processes, Plasma, Combustion, and Atmospheric Phenomena			Torus Press	2018	Yes
International Journal of Hydrogen Energy		3603199	Pergamon Press Ltd.	2018	Yes
ACS Catalysis	4841-4852	21555435	American Chemical Society	2019	Yes
Johnson Matthey Technology Review	231-255	20565135	Johnson Matthey plc.	2018	Yes
Input meeting for Svalbard's future energy supply			Norway's Ministry for Oil and Energy	2018	Yes
IEA HIA Task 38 5th Plenary Meeting			IEA HIA Task 38	2018	Yes
Nordic Hydrogen & Fuel Cell Conference			Nordic Hydrogen & Fuel Cell Conference	2018	Yes
Workshop on Power-to-X Demonstrations			IEA HIA Task 38	2018	Yes
International Journal of Hydrogen Energy		3603199	Pergamon Press Ltd.	2019	Yes
			Consortium of PRETZEL project	2018	Yes
Nature Materials	752-759	14761122	Nature Publishing Group	2019	Yes
Journal of Membrane Science	136-148	3767388	Elsevier BV	2019	Yes
Applied Catalysis B: Environmental	254-265	9263373	Elsevier BV	2019	Yes

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779577	REFLEX	DC-DC DAB converter with high voltage-ratio transformation for smart-grids and automotive application	Guillermo Perez Vazquez, Eduardo Galvan, Juan M. Carrasco
779577	REFLEX	Optimization of Solid Oxide Cells and Stacks for reversible operation	Alexandra Ploner, Anne Hauch, Sergii Pylypko, Stéphane Di Iorio, Géraud Cubizolles, Julie Mougin
779591	MAMA-MEA	Review of Catalyst-deposition Techniques for PEMFC Electrodes	Paolo Santangelo, Maria Cannio, Marcello Romagnoli
779613	PRESLHY	CFD Validation against large scale liquefied helium release	A.G. Venetsanos, S. Giannissi, C. Proust
779613	PRESLHY	Choked two-phase flow with account of discharge line effect	A.G. Venetsanos
779613	PRESLHY	Cryogenic hydrogen jets: calculation of hazard distances.	D. Cirrone, D. Makarov, V. Molkov
779613	PRESLHY	Homogeneous non-equilibrium two-phase choked flow modeling	Alexandros G. Venetsanos
779613	PRESLHY	How to see and quantify hydrogen concentration (and cryogenic hydrogen) using optical diagnostics	E. Hecht, B. Roy Chowdhury, S. Bisson, A. McDaniel
779613	PRESLHY	Introduction to PRESLHY	T. Jordan
779613	PRESLHY	Near field thermal dose of cryogenic hydrogen jet fires	D. Cirrone, D. Makarov, V. Molkov
779613	PRESLHY	Numerical predictions of cryogenic hydrogen vertical jets	S.G. Giannissi, A.G. Venetsanos, E.S. Hecht
779613	PRESLHY	R&D for Safety Codes and Standards: Hydrogen Behavior	E. Hecht, B. Roy Chowdhury, A. McDaniel, S. Bisson
779613	PRESLHY	Regulations, Codes and Standards (RCS) Analysis	A.V. Tchouvelev
779613	PRESLHY	Results of the Phenomena Identification and Ranking Table Exercise	S. Jallais
779613	PRESLHY	State-of-the-Art Combustion	S. Jallais et al.
779613	PRESLHY	State-of-the-Art Dispersion	A. Venetsanos
779613	PRESLHY	State-of-the-Art Ignition.	P. Hooker
779613	PRESLHY	Status of the pre-normative research project PRESLHY for the safe use of LH2	T. Jordan, L. Bernard, S. Jallais, A. Venetsanos, S. Coldrick, D. Cirrone
779613	PRESLHY	Thermal radiation from cryogenic hydrogen jet fires	D. Cirrone, D. Makarov, V. Molkov
779644	TAHYA	Monte-Carlo-analysis of minimum load cycle requirements for composite cylinders for hydrogen	G.W. Mair, B. Becker, B. Wang, S. Gesell
826161	WASTE2GRIDS	Balancing wind-power fluctuation via onsite storage under uncertainty: Power-to-hydrogen-to-power versus lithium battery	Yumeng Zhang, Ligang Wang, Ningling Wang, Liqiang Duan, Yi Zong, Shi You, François Maréchal, Jan Van herle, Yongping Yang
826161	WASTE2GRIDS	Data-driven flexibility requirements for current and future scenarios with high penetration of renewables	Karen Pardos Olsen, Yi Zong, Shi You, Henrik Bindner, Matti Koivisto, Juan Gea-Bermúdez

Journal title	Relevant pages	ISSN/Publication frequency[1]	Publisher	Publication year	Open Access[2]
			IEEE Industrial Electronics Society	2019	No
ECS Transactions			The Electrochemical Society	2019	No
TECNICA ITALIANA-Italian Journal of Engineering Science	65-72	401846	Tecnica Italiana	2019	Yes
8th International Conference on Hydrogen Safety			HySafe	2019	Yes
8th International Conference on Hydrogen Safety			HySafe	2019	Yes
8th International Conference on Hydrogen Safety, 24th-26th September 2019			n/a	2019	Yes
International Journal of Hydrogen Energy	22715-22726	3603199	Pergamon Press Ltd.	2018	No
			Sandia National Lab	2018	Yes
LH2 Research Priorities Workshop			HySafe	2018	Yes
International Seminar on Fire and Explosion Hazards	1361-1367		n/a	2019	No
8th International Conference on Hydrogen Safety			HySafe	2019	Yes
			Sandia National Lab	2018	Yes
			HySafe	2018	Yes
LH2 Research Priorities Workshop			HySafe	2018	Yes
LH2 Research Priorities Workshop			HySafe	2018	Yes
LH2 Research Priorities Workshop			HySafe	2018	Yes
LH2 Research Priorities Workshop			HySafe	2018	Yes
8th International Conference on Hydrogen Safety			HySafe	2019	Yes
International Journal of Hydrogen Energy	Pages 8874-8885	0360-3199	Pergamon Press Ltd.	2019	Yes
International Journal of Hydrogen Energy	8833-8841	3603199	Pergamon Press Ltd.	2019	No
Renewable and Sustainable Energy Reviews	109465	13640321	Elsevier BV	2019	Yes
International Conference on Applied Energy 2019			none	2019	No

ANNEX 4
Patents from projects.

The patents are related to H2020 projects.

Project Number	Project Acronym	Patent Application Title	Patent Application Name	Patent Application Date	Patent Awarded
671403	INNO-SOFC	Protection arrangement and method of solid oxide cells	ELCOGEN OY	14/03/18	No
671403	INNO-SOFC	Sealing arrangement and method of solid oxide cell stacks	ELCOGEN OY	17/07/14	Yes
700101	Giantleap	Inrichting voor het koppelen van een trekkend voertuig met een te trekken voertuig	VDL ENABLING TRANSPORT SOLUTIONS BV	6/02/18	Yes
700667	SOSLeM	Method for determining an operating state of an electrochemical system	AVL LIST GMBH	7/12/18	Yes
700667	SOSLeM	Recursive, time-series based method for determining the state of an electrochemical reactor	AVL LIST GMBH	27/11/18	Yes

The patents statistics are related to both H2020 and FP7 projects[198]

Project Number	Project Acronym	Patent Application Title
Cross Cutting	3	5%
Energy	72	20%
Transport	18	13%
Total JU	**93**	**14 %**

198 The full list of patents is available upon request.

199 The full list of patents is available upon request.

ANNEX 5
Scoreboard of Horizon 2020 common KPIs

H2020 priority	H2020 KPI number	Key Performance Indicator	Type of data required	Results H2020 up to 31 December 2018 (calls 2014–2018)
INDUSTRIAL LEADERSHIP	12	SME – Share of participating SMEs introducing innovations new to the company or the market (covering the period of the project plus three years)	Number of SMEs that have introduced innovations;	62 SMEs
	13	SME – Growth and job creation in participating SMEs	Turnover of company, number of employees	Turnover of SMEs at most recent reporting: EUR 749,377.467 No of employees at SMEs at most recent reporting: 7492
SOCIETAL CHALLENGES	14	Publications in peer-reviewed high-impact journals	Publications from relevant funded projects (DOI: digital object identifiers); journal impact benchmark (ranking) data to be collected by commercially available bibliometric databases	228 publications in peer-reviewed high-impact journals
	15	Patent applications and patents awarded in the area of the JTI	Patent application number	1 patent application and 4 patents awarded
	16	Number of prototypes testing activities and clinical trials	Reports on prototypes, and testing activities, clinical trials	No of prototypes: 238 No of testing activities: 195 No of clinical trials: N/A
	17	Number of joint public-private publications in projects	Properly flagged publications data (DOI) from relevant funded projects	67 joint public-private publications
	18[200]	New products, processes and methods launched on the market	Project count and drop-down list enabling choice of the type processes, products and methods	No of projects with: New products: 0[201] New processes: 25 New methods: 14
EVALUATION	N/A	Time to inform (TTI) all applicants of the outcome of the evaluation of their application from the final date for submission of completed proposals	Number and % of information letters sent to applicants within target Average TTI in calendar days Maximum TTI in calendar days	109 information letters with an average of 109 days (100 % within target)
	N/A	Redress after evaluations	Number of redresses requested	11
GRANTS	N/A	Time to grant (TTG) measured (average) from call deadline to signature of grants	Number and % of grants signed within target Average TTG in calendar days Maximum TTG in calendar days	109 grant agreements signed (80 % within target) Average TTG: 242 days Maximum TTG: 589 days

200 This indicator is not a legally compulsory one, but it covers several additional specific indicators requested for more societal challenges by the services in charge.

201 Not Available

H2020 priority	H2020 KPI number	Key Performance Indicator	Type of data required	Results H2020 up to 31 December 2018 (calls 2014-2018)
	N/A	Time to sign (TTS) grant agreements from the date of informing successful applicants (information letters)	Number and % of grants signed within target Average TTS in calendar days Maximum TTS in calendar days	109 grant agreements signed Average TTS: 131 days Maximum TTS: 463 day
PAYMENTS	N/A	Time to pay (TTP) (% made on time) - pre-financing - interim payment - final payment	Average number of days for pre-financing, interim payments and final payments	Average number of days for pre-financing: 7 (92 % on time) Average number of days for interim payments: 77 (100 % on time) Average number of days for final payments: 88 (100 % on time) Average number of days for administrative payments in 2018: 16
HR	N/A	Vacancy rate (%)	% of post filled in	100 %
JU EFFICIENCY	N/A	Budget implementation/ execution: 1. % commitment appropriation (CA) to total budget 2. % payment appropriation (PA) to total budget	% of CA and PA	In 2019 CA: 86 % PA: 98 %
	N/A	Administrative budget: Number and % of total of late payments	Number of delayed payments % of delayed payments (of the total)	In 2019 31 late payments 3.4 % late payments (of the total)

ANNEX 6
Indicators for monitoring cross-cutting issues[202]

NUMBER	DEFINITION/RESPONDING TO QUESTION	TYPE OF DATA REQUIRED	AAR 2019 (CALLS 2014-2019)[203]
2.1	Total number of participations by EU-28 Member State	Nationality of Horizon 2020 applicants and beneficiaries (number)	Applications: 2653 applications, 1115 applicants from EU-28 Grants: 1027 participations, 531 participants from EU-28
2.2	Total amount of EU financial contribution by EU-28 Member State (EUR millions)	Nationality of Horizon 2020 beneficiaries and corresponding EU financial contribution	In EUR per country: AT 17755813.56; BE 20455420.26; BG 389125; CZ 1440206.25; DE 141838625.9; DK 22491881.29; EE 502675; EL 5431010; ES 17144269.4; FI 18463041; FR 79984124.04; HR 380000; HU 21000; IE 65000; IT 43789012.07; LT 130530.28; LU 1537281.94; LV 176311.25; MT 32999; NL 44547563.22; PL 526342.5; PT 580352.76; RO 243250; SE 9084321.06; SI 1920672.5; UK 72269008.92; Grand Total 501266512.2
N/A	Total number of participations by Associated Countries	Nationality of Horizon 2020 applicants & beneficiaries (number)	Applications: 284 applications, 124 applicants from Associated Countries Grants: 121 participations, 63 participants from Associated Countries
N/A	Total amount of EU financial contribution by Associated Country (EUR millions)	Nationality of Horizon 2020 beneficiaries and corresponding EU financial contribution	In EUR per country: CH 12,071,153.81; IL 238750; IS 1845075; NO 25503582.99; UA 55125; Grand Total 39,713,686.8
3.1	Share of EU financial contribution going to SMEs (Enabling & industrial tech and Part III of Horizon 2020)	Number of Horizon 2020 beneficiaries flagged as SMEs % of EU contribution going to beneficiaries flagged as SMEs	SME participations: 288/1146 (25 %) SME participants: 143/602 (23.7 %) SME funding: EUR 170,405,291.1/ EUR 541,047,924 (31.5 %)
6.1	Percentage of women participants in Horizon 2020 projects	Gender of participants in Horizon 2020 projects	According to continuous reporting: 23,562 / 88,729 (27 %)
6.2	Percentage of women project coordinators in Horizon 2020	Gender of MSC fellows, ERC principle investigators and scientific coordinators in other Horizon 2020 activities	26/109 (23.8%)
6.3	Percentage of women in EC advisory groups, expert groups, evaluation panels, individual experts, etc.	Gender of members of advisory groups, panels, etc.	Scientific Com. 3/9 (33.3 %) on 31/12/2019
7.1	Share of third-country participants in Horizon 2020	Nationality of Horizon 2020 beneficiaries	Grants: 8 participations, 8 participants from third countries whith EU Funding: 67,725 mil EUR
7.2	Percentage of EU financial contribution attributed to third-country participants	Nationality of Horizon 2020 beneficiaries and corresponding EU financial contribution	0.01 %
9.1	Share of projects and EU financial contribution allocated to Innovation Actions (IAs)	Number of IA proposals and projects properly flagged in the WP; follow-up at grant level	No: 28/109 (25.6 %) Funding: EUR 316,740,610.2/EUR 541,047,924 (58.54 %)
9.2	Within the IAs, share of EU financial contribution focused on demonstration and first-of-a-kind activities	Topics properly flagged in the WP; follow-up at grant level	1.9 %

202 Based on Annex III to Council Decision 2013/743/EU.

203 The figures include 109 projects

NUMBER	DEFINITION/RESPONDING TO QUESTION	TYPE OF DATA REQUIRED	AAR 2019 (CALLS 2014-2019)[203]
N/A	Scale of impact of projects (High Technology Readiness Level)	Number of projects addressing TRL between (2-3, 4-6, 5-7)	Based on TRL specified in the topic (project start) TRL 2 : 6 topics – 9 grants, TRL 2-3: 1 topic – 1 grant; TRL <3: 1 topic –1 grant; TRL 3: 23 topics – 22 grants; TRL 3-4: 4 topics – 3 grants; TRL 4: 23 topics – 18 grants; TRL 4-5: 5 topics – 7 grants; TRL 5: 8 topics – 7 grants; TRL 4-6: 1 topic – 0 grants; TRL 5-6: 1 topic – 1 grant; TRL 6: 9 topics – 4 grants; TRL >6: 1 topic – 0 grants; TRL 6-7: 5 topics – 5 grants; TRL 7: 10 topics – 7 grants; TRL >7: 1 topic – 1 grant; TRL 8: 1 topic-1 grant; na: 26 topics -21 grants (cross-cutting projects) and TRL 8-9 for FCVs and TRL 7-8 for HRS: 1 topic – 1 grant
11.1	Percentage of Horizon 2020 beneficiaries from the private-for-profit sector	Number of and % of the total Horizon 2020 beneficiaries classified by type of activity and legal status	Participations: 411/1156 (36 %) Participants: 269/602 (45 %)
11.2	Share of EU financial contribution going to private-for-profit entities (Enabling & industrial tech and Part III of Horizon 2020)	Horizon 2020 beneficiaries classified by type of activity; corresponding EU contribution	EUR 374,823,641.6/ EUR 541,047,924 (62.98%)
12.1	EU financial contribution for public-private partnerships (PPP) (Art. 187)	EU contribution to PPP (Art. 187)	Cumulative EU contribution to administrative and operational budget for the period 2014-2019: CA: EUR 570,821,430 PA: EUR 420,066,954
12.2	PPPs leverage: total amount of funds leveraged through Art. 187 initiatives, including additional activities, divided by the EU contribution	Total funding made by private actors involved in PPPs - in-kind contribution already committed by private members in projects selected for funding - additional activities (i.e. research expenditures/investment of industry in the sector, compared to previous year)	1.96 (see section 1.1, Formula B)
13.3	Dissemination and outreach activities other than peer-reviewed publications [conferences, workshops, press releases, publications, flyers, exhibitions, training, social media, websites, communication campaigns (e.g. radio, TV)]	A drop-down list allows the type of dissemination activity to be selected. Number of events, funding amount and number of persons reached thanks to the dissemination activities	Based on manual extraction from 19 projects which had reported within 2019 (including data from 2014-2019 calls,) as well as research on the web: 86 websites, 22 Twitter accounts, 15 LinkedIn profiles, 10 videos, 60 press releases, 22 newsletters, 8 brochures, 11 posters, 7 flyers, 250 presentations at conferences or seminars, 15 trade fairs, 11 public handover ceremonies of vehicles, 10 HRS opening ceremonies, 8 radio interviews, 6 awards received, 1 TV film, 29 workshops, 48 events (scientific, dissemination, showcase, etc.)
14.2	Proposal evaluators by country	Nationality of proposal evaluators	Austria (6), Belgium (1), Canada (2), Switzerland (3), Germany (17), Greece (8), Spain (22), Finland (5), France (15), Hungary (1), Ireland (5), India (4), Italy (23), Lithuania (2), Netherlands (1), Poland (2), Portugal (3), Romania (2), Sweden (3), Turkey (2), United Kingdom (13), United States of America (9)
14.3	Proposal evaluators by organisations' type of activity	Type of activity of evaluators' organisations	Type of activity: No of expert participations (%) • Higher education establishments (49) – 34.5 % • Others/not defined (26) – 18.3 % • Private-for-profit organisation (32) – 22.5 % • Public organisation (25) – 17.6 % • Research organisation (12) – 8.5 %

NUMBER	DEFINITION/RESPONDING TO QUESTION	TYPE OF DATA REQUIRED	AAR 2019 (CALLS 2014-2019)[203]
N/A	Participation of RTO[3]s and universities in PPPs (Art. 187 initiatives)	Number of RTOs participating in funded projects and % of the total	232/1165 (20 %)
		Number of universities participating in funded projects and % of the total	165/1156 (14 %)
		% of budget allocated to RTOs and to universities	RTO: EUR 79,937,049.25 (14.8 %) HES: EUR 39,298,734.17 (7.26 %)
N/A	The objective is to ensure that research projects funded are efficiently compliant with provisions on ethics	% of proposals not granted because of non-compliance with ethical rules/proposals invited to grant (target 0 %); time to ethics clearance (target 45 days)	N/A
N/A	Error rate	% of common representative error; % residual error	See section 4.3
N/A	Implementation of ex post audit results	Number of cases implemented; in total EUR million; of cases implemented/total cases	H2020: # closed audits: 26 Percentage of implementation: 100 % FP7: see section 4.3.

ANNEX 7
Scoreboard of KPIs specific to FCH 2 JU

NO	KEY PERFORMANCE INDICATOR	RESULTS
1	Share of the fund allocated to the following research activities: • renewable energy • end-user energy efficiency • smart grids • storage	Renewable energy: EUR 73.7 million (14 %)[204] End-user energy efficiency: EUR 109.4 million (20 %) Smart grids: EUR 33 million (6 %) Storage: EUR 57.5 million (11 %)
2	Demonstrator projects hosted in MSs and regions benefiting from EU structural and investment funds	The FCH 2 JU has made considerable progress towards the KPI of having demonstrator projects hosted in MSs and regions benefiting from EU structural and investment funds[205]: the HyBalance, JIVE, JIVE 2 and DEMOSOFC projects have used additional EU funding schemes in parallel with that of the FCH 2 JU

204 Projects addressing topics related to renewable energy integration (KPI 1) and storage (KPI 4) are interrelated, typically covering both aspects. Complementarily, a common KPI of 25 % is reported for KPIs 1 and 4.

205 https://ec.europa.eu/info/funding-tenders-0/european-structural-and-investment-funds_en
FCH 2 JU projects work mainly with the following funds: European Regional Development Fund (ERDF), European Social Fund (ESF) and Cohesion Fund (CF).

ANNEX 8

Draft annual accounts

		EUR '000
	31.12.2019	31.12.2018
NON-CURRENT ASSETS		
Intangible assets	45	43
Property, plant and equipment	104	135
Pre-financing	98 854	79 805
	99 003	**79 983**
CURRENT ASSETS		
Pre-financing	53 694	79 076
Exchange receivables and non-exchange recoverables	22 784	25 687
	76 478	**104 763**
TOTAL ASSETS	**175 481**	**184 746**
CURRENT LIABILITIES		
Payables and other liabilities	(70 985)	(57 588)
Accrued charges and deferred income	(42 331)	(43 454)
	(113 317)	**(101 042)**
TOTAL LIABILITIES	**(113 317)**	**(101 042)**
NET ASSETS		
Contribution from members	1 300 886	1 183 489
Accumulated deficit	(1 099 785)	(981 465)
Economic result for the year	(138 937)	(118 320)
NET ASSETS	**62 165**	**83 704**

ANNEX 9
Materiality criteria

The '**materiality**' concept provides the Executive Director with a basis for assessing the importance of the weaknesses/risks identified and thus whether those weaknesses should be subject to a formal reservation to his/her declaration. The same materiality criteria are applicable to the FP7 and H2020 programmes.

When deciding whether or not something is material, **qualitative and quantitative** terms have to be considered.

In **qualitative** terms, when assessing the significance of any weakness, the following factors are taken into account:

- the nature and scope of the weakness;
- the duration of the weakness;
- the existence of compensatory measures (mitigating controls which reduce the impact of the weakness);
- the existence of effective corrective actions to correct the weaknesses (action plans and financial corrections) which have had a measurable impact.

In **quantitative** terms, in order to make a judgement on the significance of a weakness, the potential maximum (financial) impact is quantified.

Whereas the FCH 2 JU control strategy is of a multi-annual nature (i.e. the effectiveness of the JU's control strategy can only be assessed at the end of the programme, when the strategy has been fully implemented and the errors detected have been corrected), the Executive Director is required to sign a declaration of assurance for each financial year. In order to determine whether to qualify his declaration of assurance with a reservation, the effectiveness of the JU's control system has to be assessed, not only for the year of reference but, more importantly, with a multi-annual outlook.

The **control objective** for FCH 2 JU is to ensure that the '**residual error rate**', i.e. the level of errors which remain undetected and uncorrected, does not exceed 2 % by the end of the JU's programme. Progress towards this objective is to be (re)assessed annually, in view of the results of the implementation of the ex post audit strategy. As long as the residual error rate is not (yet) below 2 % at the end of a reporting year within the programme's life cycle, a reservation would (still) be made. Nevertheless, apart from the residual error rate, the Executive Director may also take into account other management information at his/her disposal to identify the overall impact of a weakness and determine whether or not it leads to a reservation.

If an adequate calculation of the residual error rate is not possible, for reasons not involving control deficiencies, the consequences are to be assessed quantitatively by estimating the likely exposure for the reporting year. The relative impact on the declaration of assurance would then be considered by analysing the available information on qualitative grounds and considering evidence from other sources and areas (e.g. information available on error rates in more experienced organisations with similar risk profiles).

Considering the crucial role of ex post audits in the JU's control system, its effectiveness needs to check whether the scope and results of these audits are sufficient and adequate to meet the control objectives.

EFFECTIVENESS OF CONTROLS

The **starting point** to determine the effectiveness of the controls in place is the 'representative error rate', expressed as a percentage of errors in favour of the FCH 2 JU detected by ex post audits measured with respect to the amounts accepted after ex ante controls.

According to the FCH 2 JU ex post audit strategy approved by the Governing Board, the representative error rate will be based on the simple average error rate (AER) for a stratified population, from which a representative sample has been drawn, according to the following formula:

$$AER\% = \frac{\Sigma\,(err)}{r} = RepER\%$$

Where:

Σ (err) = sum of all individual error rates of the sample (in %). Only those errors in favour of the JU will be taken into consideration.

n = sample size

Second step: calculation of **residual error rate**:

To take into account the impact of the *ex* post controls, this error level is to be adjusted by subtracting:

- errors detected and corrected as a result of the implementation of audit conclusions;
- errors corrected as a result of the extrapolation of audit results to non-audited contracts with the same beneficiary.

This results in a residual error rate, which is calculated by using the following formula:

$$RepER\% = \frac{(RepER\% * (P\text{-}A) - (RepERsys\% * E)}{P}$$

Where:

ResER% = residual error rate, expressed as a percentage.

RepER% = representative error rate, or error rate detected in the representative sample, in the form of the AER, expressed as a percentage and calculated as described above (AER%).

RepERsys% = systematic portion of the RepER% (the RepER% is composed of complementary portions reflecting the proportion of 'systematic' and 'non-systematic' errors detected) expressed as a percentage.

NB: Only systematic errors higher than 2 % actually implemented via an extension of audit finding exercise were taken into consideration for cleaning of the FCH 2 JU population.

P = total amount in EUR of the auditable population.

A = total of all audited amounts, expressed in EUR.

E = total non-audited amounts of all audited beneficiaries. This will comprise the total amount, expressed in EUR, of all non-audited validated cost statements for all audited beneficiaries, excluding those beneficiaries for which an extrapolation is ongoing.

This calculation will be performed on a point-in-time basis, i.e. all the figures will be provided as at a certain date.

ANNEX 10
List of acronyms

AAR	Annual Activity Report
ACEA	European Automobile Manufacturers' Association
APU	Auxiliary power unit
ARES	Advanced REcord System
AST	Accelerated stress testing
AWP	Annual Work Plan
CAPEX	Capital expenditure
CAS	Common Audit Service
CFS	Certificate of financial statements
CHP	Combined heat and power
CIC	Common Implementation Centre
CMR	Catalytic membrane reactor
COSO	Committee of Sponsoring Organizations of the Treadway Commission
CRaS	Common representative sample
CSA	Coordination and support actions
CIC	Common Implementation Centre
DG	Directorate-General
DIGIT	Directorate-General for Informatics
EC	European Commission
EC	European Commission
ECA	European Court of Auditors
ED	Executive Director
EDA	European Defence Agency
EHSP	European Hydrogen Safety Panel
EIB	European Investment Bank
EU	European Union
EUSEW	European Sustainable Week
FAIR	Fraud and Irregularity Committee
FC	Fuel cells
FCEV	Fuel cell electric vehicle
FCH	Fuel cells and hydrogen
FCH 2 JU	Fuel Cells and Hydrogen 2 Joint Undertaking
FP7	European Union's Seventh Framework Programme
FCS	Fuel cell system
GA	Grant agreement

GAP	Grant agreement preparation
GB	Governing Board
GHG	Greenhouse gas
H	Hours
H2020	Horizon 2020
HIAD	Hydrogen Incidents and Accidents Database
HRS	Hydrogen refuelling station
IA	Innovation Action
IAS	Internal Audit Service
ICE	Internal combustion engine
ICF	Internal Control Framework
ICHS	International Conference on Hydrogen Safety
IEA	International Energy Agency
IKAA	In-kind contributions in additional activities
IKOP	In-kind contributions in operational activities
IMO	International Maritime Organization
IPHE	International Partnership for Hydrogen into the Economy
IT	Information technology
JRC	Joint Research Centre
JTI	Joint Technology Initiative
KPI	Key performance indicator
Kg	Kilogram
Km	Kilometre
kW	Kilowatt
kWe	Kilowatt electric
kWh	Kilowatt hour
LCA	Life Cycle Assessment
LDV	Light-duty vehicle
MAWP	Multi-Annual Work Programme
mCHP	Micro combined heat and power
MEA	Membrane electrode assembly
MHV	Material handling vehicles
MW	Megawatt
MWe	Megawatt electric
MWth	Megawatt thermal
NECP	National Energy and Climate Plans
OEM	Original equipment manufacturer
OLAF	European Anti-Fraud Office
OPEX	Operating expenses
PDA	Project development assistance
PEM	Proton exchange membrane

PEMFC	Proton exchange membrane fuel cell
PGM	Platinum group metals
PNR	Pre-normative research
PO	Programme office
PPP	Public-private partnership
PRD	Programme Review Days
PV	Photovoltaic
Q&A	Questions and answers
QC	Quality and control
RAT	Ram air turbine
R&D	Research and development
RCS SC	Regulations, Codes and Standards Strategy Coordination
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RIA	Research and innovation actions
RSOC	Reversible solid oxide cell
RTD	Research, technological development and demonstration
SC	Scientific Committee of the Fuel Cells and Hydrogen Joint Undertaking
SET-Plan	European Strategic Energy Technology Plan
SIAP	Strategic Internal Audit Plan
SF	Stakeholders Forum
SME	Small and medium-sized enterprise
SNE	Seconded national expert
SoA	State-of-the-art
SOEC	Solid oxide electrolyser cell
SOFC	Solid oxide fuel cell
SRG	States Representatives Group
SSERR	Support Services for Exploitation of Research Results
SWD	SYStème de gestion du PERsonnel
SYSPER	SYStème de gestion du PERsonnel
TIM	Tools for innovation monitoring
TRL	Technology readiness level
TRUST	Technology Reporting Using Structured Templates
TTG	Time To Grant
TTI	Time To Inform
TTP	Time To Pay
TTS	Time To Sign
VC	Venture capital
w	Watt

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