

# Final report

## 1.1 Project details

<b>Project title</b>	IEA Hydrogen Implementing Agreement
<b>Project identification (program abbrev. and file)</b>	64016-0066
<b>Name of the programme which has funded the project</b>	EUDP
<b>Project managing company/institution (name and address)</b>	DGC / Jan K Jensen Dr. Neergaards Vej 5B, 2970 Hørsholm
<b>Project partners</b>	DGC
<b>CVR</b> (central business register)	12105045
<b>Date for submission</b>	08-03-2019

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## **General**

### **2017-2018: Hydrogen at the international energy agenda**

The landscape for Hydrogen has changed dramatically during the last 2 years and both IEA and other international organisations and international energy companies have pointed out Hydrogen as a key component in the CO<sub>2</sub> neutral energy system.

During the last 2 years IEA Hydrogen has supported IEA analysts with data on hydrogen technologies and validation of IEA publications.

Hydrogen Highlights during the project period:

#### Davos/World Economic Forum

- 2017: Creation of Hydrogen Council
- 2019: Session devoted to Hydrogen with Fatih Birol, IEA Executive Director

#### IEA International Energy Agency

- IEA Renewables Division 2017: Publication of report on hydrogen for industry
- IEA EC workshop on Electro fuels, September 2018, Brussels
- World Energy Outlook: A role for hydrogen
- Energy Business Council: Hydrogen topic in EBC, 21. November 2018

#### Mission Innovation

- Hydrogen adopted as 8<sup>th</sup> Innovation Challenge, Malmø and Copenhagen, Maj 2018
- IC#8 October workshop in Berlin
- MI summit Vancouver: Hydrogen project, 27.-29. May 2019

#### European Ministries

- Linz declaration on hydrogen, 18. September 2018

#### New Hydrogen Ministerial meeting on hydrogen in Japan

- 1<sup>st</sup> on 23. October 2018
- 2<sup>nd</sup> fall 2019

### **1.2 Short description of project objective and results**

The aim of the project is to participate in IEA Hydrogen TCP, in order to stimulate hydrogen R&D activities in Denmark and to co-ordinate Danish and international scientific work on hydrogen and related subjects. At the end of 2018, HIA had 29 members from countries, international organisations and industrial sponsors. Four additional members are expected to be formally approved by IEA as members in the beginning of 2019.

The work includes:

- DGC participation in IEA Hydrogen Executive Committee
- Facilitate Danish participation from Industry and Academia in IEA Hydrogen tasks (Working groups)
- Communication and outreach on IEA Hydrogen activities and task results via web, papers, workshops and conferences

Furthermore, to coordinate the Danish HIA participation with the Danish Energy Agency (the formal Danish HIA representative).

Results during the period 2017-2018:

- Growth in IEA Hydrogen members
- New tasks on Hydrogen in the maritime, Hydrogen storage and Hydrogen data and modelling
- Steady and effective participation of ExCo Members and task experts
- CERT Chairman present at ExCo meeting (Napoli, December 2017)
- Substantial presentations at the WHEC2018 in Rio de Janeiro
- Active collaboration with- and support to the IEA Paris office
- Development of draft work programme 2020-2025
- Development of call for tender for IEA Hydrogen secretariat 2020-2025

### **1.3 Executive summary**

The main HIA activities and the strategic directions during 2017-2018 are given by the HIA Strategic Plan 2015-2020. HIA Strategic Plan 2015-2020 is based on:

#### *Vision:*

A hydrogen future based on a clean sustainable energy supply of global proportions that plays a key role in all sectors of the economy

#### *Mission:*

To accelerate hydrogen implementation and widespread utilization to optimize environmental protection, improve energy security and promote economic development internationally while establishing the HIA as a premier global resource for expertise in hydrogen

#### *Strategy:*

To facilitate, coordinate and maintain innovative research, development and demonstration activities through international cooperation and information exchange

#### Themes

The main themes in the work programme are:

##### *Collaborative RD&D*

- Hydrogen production
- Hydrogen storage
- Integrated hydrogen systems
- Integration of hydrogen in existing infrastructure

##### *Analysis*

- Technical progress and optimization
- Market preparation and deployment
- Support in political decision-making

##### *Understanding, Awareness and Acceptance*

- Information dissemination
- Safety
- Outreach

##### *Work programme overview*

Created 6 October 1977													
Membership – 21 countries, the EC, UNIDO, 6 Sponsors Participating Experts – 200-350													
40 tasks approved to date – production is most frequent task topic													
NR	NAME	13	14	15	16	17	18	19	20	21	22	23	STATUS
32	H2Based Energy Storage												completing
34	BioH2 for Energy & Environment (Successor to Task 21)												completing
35	Renewable Hydrogen (Super Task)												completing
36	Life Cycle Sustainability Assessment (LCSA) (Successor Task 30)												completing
37	Safety (Successor to Task 31)												current
38	Power-to-Hydrogen and Hydrogen to X												current
39	Hydrogen in Marine Transport												current
40	Energy Storage and Conversion based on Hydrogen												approved
i	Analysis and modeling – a reference database (likely to become a “standing task”)												in definition
ii	Market Deployment and Pathways to Scale												In definition
iii	Biological production & conversion of H2 for energy and chemicals (Successor Task 34)												In definition
iv	Hydrogen Export Supply Chains												In definition
v	Hydrogen Applications In Primary Sectors (mining, resources and agriculture)												In definition
vi	Industrial Use of Hydrogen in Middle Income Developing countries												Proposed new
vii	Successor tasks for renewable electrolysis, photoelectrochemical water-splitting (PEC), and solar thermochemical hydrogen production												Proposed successor

Danish Task participation:

- Task 32: Torben R. Jensen, iNANO and Tejs Vegge, DTU
- Task 33: John, Bøgild Hansen, Haldor Topsøe
- Task 35: Begrænset DTU deltagelse
- Task 37: Frank Markert, DTU
- Task 38: Henrik Iskov, DGC
- Task 39: Ballard Europe
- Task 40: Torben R. Jensen, iNANO and Tejs Vegge, DTU

I (approved Feb. 2019):

Possible Danish participation by Energinet and/or DGC and xxx (tbd).

*Actual work programme by themes:*

Hydrogen production

Task 33: Local H2 Supply

- Platform for evaluation and harmonization of various technologies for local H2 supply for reduced costs and increased employment
- Expands research on supply to include electrolyzers as well as reformers

Task 34: BioH2 for Energy & Environment

- BioHydrogen production
  - Dark Fermentation and Bioelectrolysis
  - Light-driven BioHydrogen production
  - Enzymatic and Bio-inspired Molecular Systems
- Subtask 2 – Applied Research and Biohydrogen Production

Task 35 Renewable Hydrogen Production

- Subtask 1 – Renewable Electrolysis
- Subtask 2 – Photoelectrochemical Solar Water-Splitting
- Subtask 3 – Solar High Temperature Thermochemical Cycles

## Hydrogen Storage

### Task 32: Hydrogen-based energy storage (2013-2019)

- Project based: further research needed for new and improved compounds; Demonstration of solid storage systems for both stationary and mobile applications needed
- Objectives: Develop reversible or regenerative H<sub>2</sub> storage materials fulfilling the technical targets for mobile and stationary applications; develop the fundamental and engineering understanding of H<sub>2</sub> storage; develop materials and systems that have the capacity to fulfill these targets
- Develop materials and systems for H<sub>2</sub> based energy storage for use in stationary, mobile and portable applications, and electrochemical storage

### Task 40: Energy storage and conversion based on hydrogen (2019-2022)

- Develop reversible or regenerative hydrogen storage materials (solid or liquid) fulfilling the technical targets for mobile and stationary applications.
- Develop the fundamental and engineering understanding of hydrogen storage materials and systems that have the capacity of fulfilling Target I.
- Develop materials and systems for energy storage and conversion based on hydrogen, including hydrogen storage for use in stationary, mobile and portable applications, electrochemical storage, and solar thermal heat storage.

## Integration and hydrogen in Existing Energy systems

### Task 38: Power to Hydrogen and Hydrogen-to-X. System analysis of the techno-economic, legal and regulatory conditions (2015-2018)

- Subtask 1 - Management and Communication
- Subtask 2 – Mapping and analysis of existing demo projects
- Subtask 3 – Deliverables
- Subtask 4 – Specific Case Studies

### Task 39: Hydrogen in Marine Applications

- Hydrogen and fuel cell suppliers
- Shipping companies
- Advisory and assurance institutions
- Research institutions

## Analysis

### Task 36: Life Cycle Sustainability Assessment (LCSA) of H<sub>2</sub> Energy Systems

- Environmental challenges
- Economic Analysis
- Social Indicators and Integrative approaches for LCSA

### Task 41 (I): Data and Modeling Task

The new Hydrogen TCP Task includes the following four subtasks:

- Data collection of parameters describing the Hydrogen technologies, such as investment costs, efficiencies, lifetimes, learning curves etc.

- Develop knowledge of how to model Hydrogen in the value chain and improve current methods
- Collaboration with analysts in IEA HQ Analytics and the ETSAP community
- Applications and interactions for providing data for IEA, ETSAP and Hydrogen TCP tasks

## Hydrogen Safety

### Task 37 Safety

- Physical Phenomena
- Storage/Materials Issues
- Early Markets
- Knowledge Analysis
- Dissemination and Global Relevance / Integrative approaches for LCSA

### **1.4 Project objectives**

The main objectives (for DGC) have been an active Danish participation in the relevant HIA tasks, contact to the IEA Hydrogen secretariat, Information dissemination and Information outreach. Most of the DGC resources have been spend on:

- Regular contact to the HIA secretariat
- Preparation for Executive Committee meetings
- Ensure progress in the task work
- Recruitment of new HIA members
- Represent HIA at relevant workshops and conferences
- IEA Hydrogen involvement in the IEA activities relevant for Hydrogen
- Create a new and up-dated IEA Hydrogen programme 2020-2025
- DGC newsletters on IEA Hydrogen and project reports to the Danish Energy Agency and the Danish Gas Companies

### **1.5 Project results and dissemination of results**

The results from each project (task) are summarized in an End of Task report, which are approved by the Executive Committee.

Results are also presented during the task period by the task members at workshops and scientific conferences and at internal IEA seminars (with other Implementing Agreements and IEA experts).

Furthermore, overview presentations and HIA newsletters are prepared by the HIA secretariat.

During the 5 years' program period (to be reported in details in the End of Term Report 2020) the number of publications and presentations for the tasks are expected to be approx. 2000 each.

Task papers and presentations are given at relevant international conferences and workshops – not necessary specific for hydrogen, but on Safety, Energy Storage, LCA etc.

## Conference Scorecard & Participation

### Internal IEA Hydrogen TCP Meetings (2018-2019)

- 78th ExCo Meeting Part I in London, UK (May 2018)
- 78th ExCo Meeting Part II in Rio de Janeiro (June 2018)
- 79th ExCo Meeting in Cadarache, France (November 2018)
- 80th ExCo Meeting in Rotorua, New Zealand

#### Internal IEA Meetings

- TCP Universal Meeting October 2018
- REWP Meeting February 2018
- CERT Meeting March 2018
- IEA Electrofuels Workshop Brussels (EU host)
- REWP Meeting October 2018
- IEA Hydrogen Workshop February 2019

#### External Task workshops

- Task 38 – two workshops
- IEA Hydrogen Safety Workshop (Europe) October 2017
- Task 28 – end of task workshop at Topsector
- Task 32 – end of task workshop – China

#### IEA Hydrogen External presentations

- WHTC Prague – presentation and exhibit July 2017
- IEA Hydrogen Safety Workshop (Europe) October 2017
- WHEC Rio de Janeiro – keynote workshop July 2018
- WHEC Rio de Janeiro – 6 task presentations
- IEA H2 Awareness building event – New Zealand February 2019 (multiple presentations) at IEA Hydrogen Forum
- WHTC Tokyo – presentation 2019
- IEA Hydrogen Awareness building event Brussels 2019 with Hydrogen Council

### **1.6 Utilization of project results**

The Danish energy systems are facing large changes and challenges during the conversion from fossil fuels to a decentralized energy system based on renewable energy.

The Danish HIA participation offers a great opportunity to be at the forefront of the hydrogen energy research, which might be an advantage, as hydrogen is one of the tools in the implementation of the national energy policy.

The feedback from HIA participants is that HIA offers an excellent opportunity for international collaboration, creation of project consortia and exchange of scientific results.

The Main Danish interests are: Conversion of electricity to hydrogen (electrolysis, power-to-gas issues, energy storage, integration of energy systems); roll out of hydrogen infrastructure; hydrogen refuelling stations, hydrogen vehicles and hydrogen regulatory conditions (legal and safety).

### **1.7 Project conclusion and perspective**

During the last 2 years there has been an increasing global interest for hydrogen as an enabler for a carbon free energy system. Driven by a greener energy supply of biomass and wind there is a need for:

- Hydrogen from Renewable Energy Resources
- Energy conversion via hydrogen
- Energy storage via hydrogen
- Hydrogen as a CO<sub>2</sub> free energy carrier

The HIA participation of both countries and sponsors are increasing and so are the expert task participation, indicating the importance of the HIA work and the great opportunity offered for international collaboration on the challenges of the future energy systems. More than 200 hydrogen experts participate in the HIA tasks making the IEA HIA network a unique platform for hydrogen knowledge.

The HIA core business on Hydrogen production, Hydrogen storage, Hydrogen infrastructure systems and hydrogen safety are all issues of great importance for the future energy systems, which is why they also are the main issues in the actual Strategic Plan (2015-2020), formally approved by IEA in February 2015.

The Strategic plan 2020-2025 will also include a topic on Hydrogen end use.

Overarching Objectives for the period 2015–2020:

- Broaden the perspective on the transformative role of H<sub>2</sub> by articulating and communicating its functions and value as a highly flexible energy vector in an integrated future multi-sector energy system.
- Strengthen analysis activities with a special focus on IEA analysis & publications and the competitive global energy technology environment.
- Focus on the development and implementation of the H<sub>2</sub> infrastructure, highlighting storage, safety and cost reduction.
- Raise the profile of the IEA HIA
- Formulate messages from IEA HIA technical and analytic activities in order to guide and inform IEA's policy making activities.
- Foster productivity and progress through growth in membership, closer relationships and cooperation with other H<sub>2</sub> organizations, and a broader business orientation.
- Cultivate and deepen industry participation at the task and ExCo levels

## Links

HIA homepage

<http://ieahia.org/>

HIA Strategic Plan (2015-2020) and HIA End of Term report (2009-2014)

[http://ieahia.org/pdfs/IEAHIA\\_SP\\_2015\\_2020.aspx](http://ieahia.org/pdfs/IEAHIA_SP_2015_2020.aspx)

[http://ieahia.org/RESEARCH-PORTFOLIO/Tasks/IEAHIA\\_EOT\\_2009\\_2015.aspx](http://ieahia.org/RESEARCH-PORTFOLIO/Tasks/IEAHIA_EOT_2009_2015.aspx)

HIA: Global trends and outlook, December 2017

[http://ieahydrogen.org/pdfs/Global-Outlook-and-Trends-for-Hydrogen\\_WEB.aspx](http://ieahydrogen.org/pdfs/Global-Outlook-and-Trends-for-Hydrogen_WEB.aspx)

HIA Annual report 2017

[http://ieahydrogen.org/pdfs/2017\\_Annual\\_Report\\_WEB.aspx](http://ieahydrogen.org/pdfs/2017_Annual_Report_WEB.aspx)

HIA newsletters 2017-2018

Summer 2017: [http://ieahydrogen.org/pdfs/HIANews\\_Spring\\_2017\\_WEB-\(4\).aspx](http://ieahydrogen.org/pdfs/HIANews_Spring_2017_WEB-(4).aspx)

Winter 2017: [http://ieahydrogen.org/pdfs/Winter2017Newsette\\_FINAL\\_A4-\(6\).aspx](http://ieahydrogen.org/pdfs/Winter2017Newsette_FINAL_A4-(6).aspx)

Summer 2018: [http://ieahydrogen.org/pdfs/2018\\_Summer\\_Newsletter\\_WEB-\(6\).aspx](http://ieahydrogen.org/pdfs/2018_Summer_Newsletter_WEB-(6).aspx)

HIA summary presentations

*Hydrogen at the international agenda, Hydrogen Forum 20<sup>th</sup> February 2019, NZ*

<http://ieahydrogen.org/pdfs/1-Lucchese-ExCo-meeting-Rotorua-New-Zealand-Forum.aspx>



*IEA Hydrogen, Global Hub for Collaboration, Hydrogen Forum, 20<sup>th</sup> February 2019, NZ*  
<http://ieahydrogen.org/pdfs/0-Mary-Rose-IEA-Hydrogen-Global-Hub-for-Colla.aspx>  
*Hydrogen-based Energy Storage, SYMP.ON METAL-HYDROGEN SYSTEMS, 1<sup>st</sup> Nov, China*  
[http://ieahydrogen.org/pdfs/MH2018\\_Hirscher\\_PDF.aspx](http://ieahydrogen.org/pdfs/MH2018_Hirscher_PDF.aspx)  
*Hydrogen: Premium electrofuel, IEA Electrofuels Workshop, 10<sup>th</sup> Septber 2018, Brussels*  
[http://ieahydrogen.org/pdfs/IEA-H2-pres-for-IEA-Electrofuels-2018\\_-short.aspx](http://ieahydrogen.org/pdfs/IEA-H2-pres-for-IEA-Electrofuels-2018_-short.aspx)  
*Fuel Cell Technologies in Germany, WHEC, Rio de Janeiro, June 21, 2018*  
[http://ieahydrogen.org/pdfs/WHEC-2018\\_Bonhoff\\_20180621.aspx](http://ieahydrogen.org/pdfs/WHEC-2018_Bonhoff_20180621.aspx)  
*Power-to-Hydrogen and Hydrogen-to-X; WHEC, Rio de Janeiro, June 21, 2018*  
[http://ieahydrogen.org/Activities/Task-in-Definition-Hydrogen-in-Marine-Applicatio/Power-to-Hydrogen-and-Hydrogen-to-X\\_Robinius.aspx](http://ieahydrogen.org/Activities/Task-in-Definition-Hydrogen-in-Marine-Applicatio/Power-to-Hydrogen-and-Hydrogen-to-X_Robinius.aspx)  
*Hydrogen in Maritime Transport, WHEC, Rio de Janeiro, June 21, 2018*  
[http://ieahydrogen.org/pdfs/WHEC\\_Sepideh\\_Jafarzadeh\\_IEA\\_HIA\\_Task\\_39.aspx](http://ieahydrogen.org/pdfs/WHEC_Sepideh_Jafarzadeh_IEA_HIA_Task_39.aspx)  
*Hydrogen in international energy scenarios, WHEC, Rio de Janeiro, June 21, 2018*  
<http://ieahydrogen.org/pdfs/20190615-WHEC-Paul-Lucchese-Plenary-lecture.aspx>

Links to DGC news on IEA Hydrogen and Hydrogen R,D&D during 2017-2018

2018

<https://www.dgc.dk/nyhed/2018/nyt-fra-iea-hydrogen-0>  
<https://www.dgc.dk/nyhed/2018/nyt-fra-iea-hydrogen-0>  
<https://www.dgc.dk/nyhed/2018/minikonference-om-lovgivning-brint-og-braendselsceller>  
<https://www.dgc.dk/nyhed/2018/nyt-fra-iea-hydrogen>  
<https://www.dgc.dk/nyhed/2018/videnskabelig-artikel-i-bioresource-technology-journal>  
<https://www.dgc.dk/nyhed/2018/termisk-og-biologisk-forgasning-kan-blive-et-fint-makkerpar>  
<http://www.biopress.dk/PDF/nyt-fra-iea-hydrogen>

2017

<https://www.dgc.dk/nyhed/2017/nyt-fra-iea-hydrogen>  
<https://www.dgc.dk/nyhed/2017/connecting-electrons-and-molecules-role-energy-infrastructure>  
<https://www.dgc.dk/nyhed/2017/iea-hydrogen-safety-workshop-ichs2017-ny-formand-og-nyhedsbrev>  
<https://www.dgc.dk/nyhed/2017/iea-samarbejde-om-hydrogen>  
<https://www.dgc.dk/nyhed/2017/vi-foerer-paa-brint-men-halter-bagud-med-metangas>  
<https://www.dgc.dk/nyhed/2017/workshop-om-gassens-fremtid>  
<http://www.dgc.dk/nyhed/2016/nyhedsbrev-fra-iea-hydrogen>