Current Status and Perspectives of Clean Energy Research Development and Innovation Activities in CEA

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1. General context - French policy for Renewable Energy Deployment

Since the publication of the "Energy Transition and Green Growth law" in August 2015, the massive integration of low carbon footprint renewable energies into the French electrical mix has become a national goal together with the increase of energy efficiency in various sectors such as industry, transport or housing. Its implementation has been detailed in the "Multi-annual Energy Programming law" in December 2018 with priority given to decreasing the carbon footprint of energy systems. Quantified targets have been defined regarding in particular the share of Renewable Energy (RE) in the electrical mix (50% RE/50% Nuclear) and the deployment of electrical vehicles (1.2 Millions of EV with 100 000 reloading stations by 2023). National initiatives have been launched such as the Hydrogen Initiative for the Energy Transition in June 2018 aiming at deploying hydrogen based energy solution all over French territory. To support the expansion of electric mobility and the conversion of the automotive industry, France is also actively involved in the European Battery Alliance launched in Brussels in October 2017.

2. CEA research development and innovation activities in the field of renewable energies

In this general context, the official mandate of CEA has been reoriented in March 2016 towards producing research, development and innovation activities in the field of low carbon footprint energies including renewable energies together with nuclear energy.

Main research, development and innovation axis concern:

1. ***Decentralized solar energy production and development of photovoltaic solutions for housing and standalone systems***. Special attention is given to the development of very high yield photovoltaic cell technology and to its integration in a fully optimized photovoltaic energy system.
2. ***Grid flexibility and smart energies grid management***. Major attention is dedicated to energy storage and to convergence between electricity gas and heat together with digitalization and numerical interfaces. The production of low carbon footprint hydrogen using high yield electrolysis and its conversion for producing electricity or chemicals is in particular heavily studied. R&D on battery for transportation is turned towards reaching high capacity, high power and high safety. All solid state battery are studied in that context.
3. ***Energy efficiency, sustainability and circular economy.*** Special attention is given to thermal integration for taking advantage of fatal heat and to material and component eco-design with the aim of decreasing or replacing critical materials such as Platinum in fuel cell, Cobalt in batteries or Rare Earth in magnets. Chemical or electrochemical reduction of CO_2 are also studied in the perspective of establishing an environmentally virtuous "carbon cycle".

These research activities are mainly carried out by the CEA-Liten Institute in collaboration with several teams across CEA.

The research development and innovation activities of CEA-Liten cover a large TRL scale from proof of concept tested in CEA laboratories and analyzed operando in Large Scale Facilities together with national and international academic partners, up to real size

demonstrators produced on pilot lines (e.g. for PV cells, for batteries and for Solid Oxide Electrolysis stacks) and tested upon operation with industrial partners. For carrying out this ambitious approach CEA-Liten establishes partnerships with both, academic laboratories and industrial partners.

3. Specific Research activities in hydrogen, CCUS, and related technologies

CEA-Liten is heavily involved in the development of the high temperature steam electrolysis technology for producing hydrogen with high electrical efficiency by taking advantage of waste heat. After demonstrating its high potential at laboratory scale with electrical efficiency higher than 80%, R&D axis are centered on the one hand, on increasing lifetime and robustness of the system and on the other hand, on its scaling up to 300 kW.

The use of hydrogen for mobility is also considered by developing and integrating PEMFC systems in vehicles. Demonstration has for example been done with the 20 kW PEMFC system integrated in the "Energy Observer" boat that had covered more than 18000 km end of 2018 without any problem. In the coming years major R&D axis will concern i) the decrease of platinum catalyst to lower the cost and decrease the use of a critical material, ii) the increase of stack volume and mass power densities and iii) the comprehension of ageing mechanisms in order to develop mitigation strategies and increase the PEMFC system lifetime.

Hydrogen is also considered for converting CO_2 into methane or other high value chemical molecule like methanol thanks to methanation reaction. Specific micro-designed exchanger-reactors have been developed and demonstrated in France (Jupiter 1000 experimentation in Fos sur Mer) and in Poland (at the thermal power plant of Laziska). Further R&D axis will concern on the one hand, the control of high yield steady state operation and on the other hand, the conditions for intermittent operation without catalyst degradation or thermal excursions. To complement methanation in industrial processes, high temperature co-electrolysis of CO_2+H_2O is also studied.

Other related clean technologies are developed at CEA-Liten. It is in particular the case of batteries for transportation with a special attention given to hybridization with PEMFC fuel cell.

Related programs/projects conducted by the institute (further information on programs/projects are found in the template)

- Development and scaling up of High Temperature Steam Electrolysis (2019-2023)
- Development and integration of high compactness and low cost Proton Exchange Membrane Fuel Cells systems (PEMFC) - (2018-2025)
- Extension of CO_2 hydrogenation reactor operation conditions and thermochemical conversion of organic wastes for producing high value chemical molecules (2019 – 2023)

4. International collaboration

4-1 International alliance/networking development

CEA-Liten has established numerous international relationships in the field of renewable energy research and development. Many of them are long lasting European collaborations that include joint research projects, international workshop organizations and researcher exchanges. These are complemented by the regular contribution of CEA to various IEA tasks (especially on solar energy, hydrogen and fuel cells).

International partnerships have also been established between CEA and several governmental institutions for developing full size experimentations in the field of renewable energies. In addition, CEA has also concluded several MoUs with overseas research institutes like ITRI (Taiwan) or AIST (Japan) for strengthening relationships with these international renowned partners and conducting jointly research programs beneficial for both sides.

CEA is convinced that collaborations between G20 members in the field of clean energy technology, and more specifically joint research programs on energy cutting edge technologies will constitute a major asset for implementing energy transition worldwide.

4-2 International joint R&D activities

In the last five years, under the umbrella of European Framework programs, CEA-Liten has coordinated 6 new projects on hydrogen energy and participated to 15. In addition, the institute has participated to 4 new projects on carbon cycle essentially linked to "Power to Gas" implementation". In each of these projects Liten is in charge of one of the above mentioned scientific bottleneck, either regarding durability, scaling up or sustainability.

In addition, CEA-Liten has established collaborations worldwide with leading groups in high resolution Neutron Radiography (NR) of operating PEMFC, like Paul Scherer Institute (PSI) in Switzerland and National Institute of Standards Technology (NIST) along with the Los Alamos National Laboratory (LANL) in USA in order to combine imaging and scattering techniques. The first operando characterization of a fuel cell stack upon operation could be achieved in 2016 at NIST[1].

Related ongoing European H2020 programs coordinated by the institute:

- ID-FAST - Investigations on Degradation Mechanisms and Definition of Protocols for PEM Fuel cells Accelerated Stress Testing (2018-2020)
- PEGASUS - PEMFC based on Platinum Group Metal free Structured Cathodes (2018-2020)
- DOLPHIN - Disruptive PEMFC Stack with Novel Materials, Processes, Architecture and Optimized Interfaces (2019-2022)
- REFLEX - Reversible Solid Oxide Electrolyzer and Fuel Cell for Optimized Local Energy Mix (2018-2020)

5. Future perspectives

The optimization of electrolysis, fuel cell and methanation reactor technologies will continue deserving R&D activities as described above. More globally, future challenges in clean energy technologies, will essentially lie in their ability to scaling up and to massive deployment in a sustainable way. In that respect, eco-conception and carbon cycle should deserve major attention with global approaches and international contributions to protocols and standard definitions.

In addition, to increase the flexibility of energy grids and control high quality demand-response services, both technological and digital developments are still required. Indeed, renewable energies from solar of wind sources are intermittent and need to be stored and distributed "smartly". Combining electrical and gaseous grids by a "Power to Gas" or a Power to X" approach, involving low carbon footprint hydrogen is a solution that CEA-Liten will continue to investigate heavily. Numerical interfaces and digitalization of energy grids will also constitute a challenge for preparing the "smart cities" of tomorrow.

CEA Liten, aligned with the French energy policy, will dedicate a large share of its research activities to these hot topics and is ready to contribute actively to international initiatives in these area.

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[1] F. Nandjou et al, International Journal of Hydrogen Energy, (2016), 41, 15573

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Current Position:

2013 - Deputy Director of CEA-Liten in charge of scientific activities
2014 - Deputy Director of Institut Carnot Énergie du Futur[2]

Professional experience:

2007-2012: Hydrogen and Fuel Cell Program Manager, in charge of European partnership
2004-2006: Head of Fuel Cell and Hydrogen Laboratory of CEA-Liten
2002-2003: Deputy Head of Material and Processes Service in charge of coordinating research programs on renewable energies at CEA Grenoble
2000-2002: Research Scientist on Solid Oxide Fuel Cell development at CEA Grenoble
1991-1999: Research Scientist on nuclear materials, on zirconium alloy's metallurgy under irradiation at CEA Grenoble
1989-1990: Research Scientist on Aluminium and Magnesium alloys corrosion behaviour at PECHINEY research Centre in Voreppe (France)

Education:

2018 - Validation of the annual cycle of the Institute for Advanced Studies in Science and Society (IHEST)
1997 - Habilitation, INPG, in the field of Materials and Processing
1989 - PhD in Material Science, INSA Lyon, (cum laude)
1985 - Master of metallurgy, INPG, Grenoble, (cum laude)
1985 - Engineer Diploma INPG ENSEEG / PHELMA – Material science

Field of expertise:

Material science and electrochemistry applied to Hydrogen Energy (fuel cells, electrolysis, hydrogen storage and transport) and nuclear materials

Scientific productions and recent commission of trusts:

- 50 publications in peer-reviewed journals and 25 conference communications, h-index 20 (WOS)
- Supervision of 10 master thesis and 11 PhD thesis
- Coordination of 2 EU projects and WP leader in 4 EU projects

- Member of the Review Panel of the Helmholtz Center FZ Jülich "Research Field Energy" (2018)
- Member of the European Research Council review panel PE8 on « Materials and Processes Engineering » since 2012
- Member of the editorial board of the « Fuel Cell » journal (2014 to 2018)
- Chair of the « Scientific Committee » of the Fuel Cell & Hydrogen Joint Undertaking (JTI) –2013 (elected)
- Chair of the 10th European SOFC Forum, 26 – 29 June 2012, Lucerne, Switzerland
- Vice-Chair of the « Scientific Committee » du Fuel Cell & Hydrogen Joint Undertaking (JTI) 2009-2012 (elected)
- Member of the European road mapping exercise "Materials for the SET Plan" (2011) in charge of material needs for Hydrogen production, storage and conversion in fuel cells
- Title of International Expert of CEA in the field of Materials for Hydrogen Energy (2010)

[2] Alliance of 10 Academic Laboratories in Grenoble area with CEA-Liten in the field of renewable energies