



Science & Technology

**FORESIGHT**

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## Executive Summary

“Promoting a Sustainable Future through a Large-scale Utilisation of Renewable Fuels”

8-10 July, 2019 - Rome

**WG ENERGY**



F2F Workshop on

**Promoting a Sustainable Future through a Large-scale Utilisation of Renewable Fuels**

*Rome (Italy), 8<sup>th</sup>-10<sup>th</sup> July 2019*

## **EXECUTIVE SUMMARY**

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## ***Table of Contents***

<i>1. Introduction</i>	<i>P.3</i>
<i>2. Main outcomes and recommendations</i>	<i>P.3</i>
<i>3. Action items</i>	<i>P.5</i>
<i>4. Conclusions</i>	<i>P.7</i>
<i>6. ANNEX I – Meeting Agenda</i>	<i>P.8</i>
<i>7. ANNEX II – List of participants</i>	<i>P.12</i>
<i>8. ANNEX III –Background document</i>	<i>P.13</i>

## **1. Introduction**

In July 2019, a face-to-face workshop on *Promoting a Sustainable Future through a Large-scale Utilisation of Renewable Fuels* was organized in Rome. The workshop focused on Energy Storage according to the Foresight CNR project.

In the workshop background document, the urgent need to address climate change and its related issues by individuating both short- and especially long-term solutions was considered.

The decarbonisation of the energy sector was recognised at the workshop as a major challenge in the energy roadmap to 2050. In this regard, alternative and renewable fuels are considered necessary in order to reduce GHG emissions and to achieve the challenging 2050 objectives in energy, transport, climate and economic and social policies. Accordingly, the activities of the workshop were essentially focused on “*Carbon Dioxide Management and Valorisation*” and “*Green Hydrogen Generation and Use on a Wide-scale*”.

After a brainstorming session, the activities of the F2F workshop aimed at identifying specific research directions as foresight priorities, to carry out a down-selection and to suggest a road map for their implementation.

This executive summary provides a list of the specific recommendations for prioritising specific research programs in this field.

A complete description of the workshop contents, methodology, activities, outcomes and conclusions is provided in the full report.

## **2. Main outcomes and recommendations**

A general vision resulting from this workshop possibly sees the future energy system partially shifting from a centralised to a distributed energy generation. The latter one will rely on a full set of renewable energy sources and related technologies, which should be efficient, reliable, smart, and cost effective, and characterised by an extremely low environmental impact. This scenario will involve all energy sectors, i.e., conversion, storage and distribution. However, centralised processes will coexist with distributed generation especially in those contexts where economy of scale is relevant.

Long-term society needs include sustainable processes, energy security, independence and saving, low environmental impact, strong reduction of greenhouse gas emissions, widely available cost-effective technologies. New research directions should address these goals but will require an interdisciplinary approach including economic models for the possible future scenarios, health considerations, and an analysis of their impact on environment and society.

Electricity as an energy carrier will still be key in a carbon neutral energy system, as it enables an expanded use of renewables in a diversity of sectors of energy consumption, and improves overall efficiency of the energy system because of the intrinsic characteristics of many electric technologies and because it supports digitalization and related benefits.

Specific issues and necessary step changes in relation to energy storage through renewable fuels were analysed in a broad sense by covering the most relevant subjects such as electrolysis, co-electrolysis, photo-electrolysis, hydrogen and fuel cells, power to gas and to liquid fuels, CO<sub>2</sub> recycling, photoelectrochemical and photocatalytic processes, and distributed energy generation. Processes addressing sequestration of CO<sub>2</sub> (carbon-negative cycle) through biologic pathways (such as biochar and microalgae) were analysed as possible parallel or alternative routes to renewable fuel production. Data treatment for energy storage using renewable fuels as well as socio-economic, financial and environmental aspects concerning newly emerging technologies were additional relevant topics discussed at the workshop.

*The long-term vision of the energy system that has emerged from this workshop indicates the deployment of renewable gas and liquid fuel networks as complementary and strongly interconnected to the electricity grid and the electrochemical energy storage, while parallel innovative photosynthetic approaches for CO<sub>2</sub> sequestration could also contribute to a significant extent to address environmental issues, but are still limited to an early stage of development.*

Following an overview of all planned solutions and related challenges, the focus shifted towards a prioritization of future research directions based on long-term society needs. In this regard, the participants have underlined all possible positive outcomes and the possible issues of the proposed approaches.

The discussions clearly showed that a single technology solution to achieve all these goals does not exist, in fact a holistic approach is necessary. The transition to efficient and clean energy solutions necessarily needs to be supported by public financing. This is intended to provide subsidies and incentives in order to speed up the transformation of the energy technologies towards a sustainable and environmentally benign system at local and global level. Microscale-operating energy technologies should be also supported by advanced data processing, with sensors and Internet connection.

The main outcomes are summarised as follows:

- ✓ The problem of energy storage should be considered, taking into account three main aspects: economy, equality and climate mitigation. Although climate change is perceived as the most important issue, it is connected to other aspects (food, water quality and security etc.) which should not be neglected. Currently, there is no individual technology that can be seen as the winner in the long term, also because breakthroughs cannot be predicted. However, hydrogen and renewable organic fuels, obtained from CO<sub>2</sub> and water using the surplus of renewable energy, and

transformation of CO<sub>2</sub> in biochar through photosynthesis or in additives for cement production are recognised as important players for the future energy system.

- ✓ A common, “global”, development path should be identified to give all countries the possibility to contribute to the energy system change, but each area will definitely require a different approach.
- ✓ In the shorter term, we will need to emphasize support for more mature technologies (such as power-to-gas solutions and electrolyzers) while other solutions (power-to liquid fuels) will need more time to be developed. In parallel, we will also need to introduce fundamental changes in the infrastructures needed for energy supply.
- ✓ A possible approach would be to test more advanced, breakthrough solutions in some restricted systems, such as islands. That can provide useful data to be expanded to more general applications.
- ✓ For the development of CO<sub>2</sub> related technologies, it is very important to find an efficient way to capture CO<sub>2</sub> and release it in concentrated form in order to make its transformation feasible. It is also very important to develop catalysts able to tolerate poisoning. Regarding the use of the captured CO<sub>2</sub>: solid oxide co-electrolysis to syngas following by methanation appears as one of the most promising routes.
- ✓ It is very important to develop a proper regulatory framework especially for the production of liquid fuels from renewable energy. Providing a suitable legal framework is as important as giving incentives. Furthermore, rules should be introduced to promote sustainable practices and penalize those resulting in increased emissions.
- ✓ The role of ICT will be very important in two regards: first, to collect and process the huge amount of data on energy generation (e.g., through “smart” power meters), and to use data in order to allow politicians and consumers to make informed decisions. Second, to help demand and offer solutions in a more efficient way.
- ✓ Energy efficiency is a key factor. No technology for energy storage will be successful in reducing GHG emissions if a reduction in energy consumption is not implemented first.

### 3. Action items

A list of action items and recommendations is indicated below with the aim of suggesting the research areas that need to be prioritised:

- ***Target disruptive innovations in parallel with incremental research providing practical and rapid solutions:***
  - ✓ *Consider research as driven primarily by human needs*
  - ✓ *Consider the urgency to address global warming and climate change*
  - ✓ *Consider the urgency to address local and global pollution effects on health*
- ***Green hydrogen as energy vector***
  - ✓ *H<sub>2</sub> should be produced from renewables using sustainable processes (e.g. electrolysis) not from fossil fuels*

- ✓ *Green H<sub>2</sub> should contribute to wide-scale decarbonisation of the energy system (sustainable mobility, domestic uses) but also to decarbonisation of specific industry segments (metallurgy, cement production etc.). Green hydrogen should be also widely used as feed stock chemical*
- ✓ *H<sub>2</sub>O –H<sub>2</sub> cycle (from water to water) is sustainable and has a much lower impact on the environment and in terms of water availability for other relevant uses (e.g. agriculture).*
- **CO<sub>2</sub> as a possible resource and not a waste: renewable energy-assisted CO<sub>2</sub> reduction as means to produce renewable fuels**
  - ✓ *Production of sustainable chemical products (e.g., through co-electrolysis) especially high energy density chemicals such as DME or syngas, as base for synthesizing organic compounds and fuels (hydrocarbons, etc.) in a carbon neutral cycle.*
  - ✓ *Develop carbon negative solutions based on photosynthesis processes (e.g. biochar, microalgae) and chemical (e.g., catalytic) processes, and enhanced rock weathering.*
  - ✓ *Carbon capture should be characterised by low costs and not based on energy intensive processes, especially when CO<sub>2</sub> is diluted in the atmosphere (efforts should be addressed to adsorption and membrane processes).*
  - ✓ *Carbon-neutral processes are not enough to address global warming; these should be complemented by hydrogen technologies and CO<sub>2</sub> sequestration (carbon negative cycles)*
- **Combination of different energy solutions and energy saving**
  - ✓ *A global approach is required for decarbonisation*
  - ✓ *It is necessary to identify each country and region's energy and environmental requirements and offer specific solutions to favour integration*
  - ✓ *Diversity in local approaches should be pursued*
  - ✓ *Shifting from supply smart management to demand smart management (ICT technologies)*
- **Functional materials:**
  - ✓ *Developing more efficient, better-performing, smart, functional and new materials for energy conversion based on non-critical raw materials and obtained through cost-effective processes. This applies especially to the development of efficient (electro)catalysts not based on Pt-group metals.*
  - ✓
- **Main drivers for the energy transition**
  - ✓ *Environment, energy security, accessibility and independence.*
  - ✓ *Social, economics, and system approach.*
  - ✓ *Energy saving: efficiency, life-style change (mobility, energy saving, prosumers), impact of ICT technologies, smart grids, internet of energy*
  - ✓ *Costs to benefits ratio is important; alternative benefits will mitigate cost increase.*

- ✓ *Energy return on investment (EROI): the amount of energy that has to be expended in order to produce a certain amount of energy should be > 1.*
- ✓ *Life-cycle analysis (LCA) and/or life cycle cost analysis (LCCA) methodology should be widely used to assess novel processes including the “human factor”.*
- ✓ *Social awareness and public acceptance (in need of raising).*

#### **4. Conclusions**

Renewable fuels such as hydrogen, methanol, ethanol, dimethyl ether, and ammonia, obtained from water splitting, electrochemical or catalytic processes, or from recycling of CO<sub>2</sub> using the surplus of renewable power, will complement the electrochemical storage. Those can also represent a proper solution for transportation by extending the driving range of electric vehicles and for domestic use to produce heat and power in micro-distributed generation through CHP systems. However, efforts in developing appropriate infrastructures for alternative fuels are also required.

Beside investing in transmission technologies to avoid congestion from increasing renewable energy facilities, alternative energy vectors will provide an efficient link between sustainable energy generation, distribution and use. CO<sub>2</sub> valorisation will provide an efficient tool to reduce greenhouse gas emissions. Water electrolysis supplied by renewable energy appears as the foremost technology for producing "green" hydrogen for fuel cell vehicles in the next future. Co-electrolysis of CO<sub>2</sub> and water sustained by renewable energy, photo-electrolysis and photocatalytic conversion processes also appear as key technologies for an efficient recycling of CO<sub>2</sub>. These technologies will facilitate the wide implementation of carbon-neutral processes. Such new carbon-neutral processes could contribute to achieve a smooth transition towards a complete decarbonisation of the energy system.

Research programs should be addressed to innovative, efficient and sustainable electrochemical and catalytic processes to achieve high conversion efficiency, using non-critical raw materials and cost-effective technologies to favour large-scale deployment.

The specific challenge for all these areas is to develop disruptive approaches, which can overcome the issues currently limiting the wide-scale sustainable technologies use. Breakthrough research should be supported in parallel with technology optimisation and upscaling while society and environment impact should be carefully analysed. The overall approach in developing or improving sustainable processes should be systemic and cover interdisciplinary aspects.

*This executive summary has been circulated among and agreed with the experts participating to the workshop before being made available to the public through the Foresight web site.*

*Giuseppe Montesano has actively participated in the workshop, but he does not necessarily agree with all the statements included in this report.*



# AGENDA

## Face-to-Face (F2F) Workshop “Promoting a Sustainable Future through a Large-scale Utilisation of Renewable Fuels”

8-10 July 2019

Venue: Crowne Plaza Rome St. Peter's

Via Aurelia Antica 415, Aurelio - 00165 Rome, Italy

### 8<sup>th</sup> July 2019 Afternoon – Workshop Context, Topics and Objectives

13:00 – 14:20 Get Together and Light Lunch

#### **Session 1. Introduction about the S&T Foresight Project and the Workshop Context**

*Moderator G. Einaudi* - Scientific Director of the CNR Science and Technology Foresight Project (IT)

14:20 -14:30 **Welcome and introduction of participants**

14:30 – 14:40 **Introduction to the CNR Science and Technology Foresight Project**

Giorgio Einaudi – Scientific Director of the CNR Science and Technology Foresight Project (IT)

14:40 – 14:50 **The energy storage context in the framework of the S&T Foresight project and the sustainable fuels pathway: Introduction and objectives for the F2F workshop**

Antonino Salvatore Aricò - Responsible of the Energy working group (IT)

14:50 – 15:05 **Questions and Answers (Session 1)**

15:05 -15:25 Coffee break

#### **Session 2. Focus on Green Hydrogen generation and use, CO<sub>2</sub> Recycling on a wide scale and related Socio-economic aspects:**

*Moderator A. S. Aricò*

**15:25 – 15:55 Introductory speeches** (10 min each)

- ✓ Piotr Zelenay - FECS-FLANL, Professor of Chemistry Materials Physics and Applications, Los Alamos National Laboratory, Los Alamos (USA)
- ✓ Anne Hauch – Professor at the Denmark Technical University, Copenhagen (DK)
- ✓ Marco Frey – Professor at Scuola Superiore Sant'Anna, Pisa (IT)

**15:55 – 16:15 Questions and Answers**

**16:15 - 18:00 Discussion and possible interventions by the other participants (Session 2)**

20:00 – Dinner

**9<sup>th</sup> July 2019 Morning – Workshop Context, Topics and Objectives**

**Cont'd**

***Session 3. Focus on innovative routes for Hydrogen and Carbon Dioxide Management and Valorisation***

*Moderator E. Einaudi*

**9:00 – 9:40 Arguing and completing the discussions from the previous session, addressing specific issues** (10 min each)

Nicholas van Dijk - Chief Operating Officer, PV3 Technologies Ltd, London (UK)

Samir Bensaïd – Professor at Politecnico di Torino (IT)

Franco Miglietta – Senior Researcher at CNR-IBIMET, Florence (IT)

Simelys Hernández - Assistant Professor, Politecnico di Torino, Turin (IT)

**9:40 – 10:10 Questions and Answers**

**10:10 - 11:00 Discussion and possible interventions by other participants (Session 3)**

11:00 – 11:20 Coffee break

***Session 4. Analysis of relevant scenarios for the energy system at 2050: challenges, approaches and policy aspects***

*Moderator C. Bartolucci*

**11:20 – 11:50 Focus on global policy and economics for the energy storage and implementation of energy policy objectives** (10 min each)

Giuseppe Montesano - Deputy Director Enel Foundation (IT)

Megan Bettilyon - Director, Renewable Energy and Special Projects, Global Good (USA)

Daria Vladikova - Chair of the Bulgarian Hydrogen, Fuel Cell and Energy Storage Association, Bulgarian Academy of Sciences (BG)

11:50 – 12:10 **Questions and Answers**

12:10 - 13:00 **Discussion and possible interventions by other participants (SESSION 3)**

13:00 – 14:30 Light Lunch

## 9<sup>th</sup> July 2019 Afternoon – INTEDISCIPLINARY BRAINSTORMING

**14:30 – 16:30 Parallel sessions: open and guided discussion.**

*Moderators E. Einaudi, A.S. Aricò, C. Bartolucci (Foresight)*

*Rapporteurs: Daria Vladikova (BAS); Lorenzo Zani (CNR)*

- How to address challenges and priorities in the field of energy storage?
- Which technologies and processes can better support the energy transition?
- Which aspects are the most urgent to address?
- What could be the impact of the proposed technologies in addressing sustainable development and future energy needs, and how can these benefit the environment?
- Analysis of the proposed scenarios for both the transition period and an envisaged complete decarbonisation at 2050.
- Discuss common denominators for hydrogen technologies and CO<sub>2</sub> management and valorisation
- Discuss socio-economic challenges of an economy based on "Renewable Fuels".

16:30 – 17:00 Coffee break

**17:00 – 18:00 Plenary: Report from parallel sessions and reflections**

*Moderators E. Einaudi, A.S. Aricò*

- Points of view: commonalities and diversities
- Propose holistic solutions to address human needs at 2050
- Analyse the specific impacts

20:00 – Dinner

09:00 – 10:30 **Select research priorities**

*Moderators E. Einaudi, A.S. Aricò*

10:30 – 11:00 **Coffee break**

11:00 – 11:30 **Analyse next steps**

*Moderators E. Einaudi, A.S. Aricò*

11:30 – 13:00 **Implement research priorities into concrete actions**

*Moderators E. Einaudi, A.S. Aricò*

- Discuss the role of academia, research organization, industry and foundations in promoting the selected research priorities
- Discuss how to implement the identified research priorities in the next topics of various calls in different organisations, countries etc.
- Discuss how policy makers should support the transition towards a sustainable energy system
- Drafting the general scheme and the contents of the workshop report to be finalized by the WG responsible and approved by the experts participating to the F2F.

13:00 – 14:00 **Light Lunch**

*End of the meeting*

# F2F\_Workshop “Promoting a Sustainable Future through a Large-scale Utilisation of Renewable Fuels”

## LIST OF PARTICIPANTS

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# FULL REPORT

Available at the Foresight web site:

<http://www.foresight.cnr.it/>

## BACKGROUND DOCUMENT

*(document circulated before the meeting)*

Available at:

[http://www.foresight.cnr.it/images/EVENTS/Sept\\_2018\\_energy/AArico\\_BCK\\_doc\\_on\\_Energy\\_settembre\\_2018.pdf](http://www.foresight.cnr.it/images/EVENTS/Sept_2018_energy/AArico_BCK_doc_on_Energy_settembre_2018.pdf)