EUROCORES Programme
European Collaborative Research

Networking / Dissemination Activity
Scientific Report Form

Form (Word or PDF file) to be completed and uploaded via the online system within two months of the completion of the event for the following activities: working group meetings, seminars, workshops, symposia, conferences, summer schools, training programmes and specialised courses (graduate-level and continuing education), EUROCORES programme invited sessions at larger conferences, working group meetings (e.g. publication meetings).

a) Summary

This is the second AMPEA workshop about solar fuels and artificial photosynthesis. The first workshop, held in Mülheim/Germany in October 2012, gathered *ca.* 40 participants from most of the major European groups in the field. The main outcomes were that artificial photosynthesis for solar fuels was identified as a core research area within the AMPEA JP agenda. This is the research topic of Eurosolarfuels. As an outcome of the workshop, a paper was published in the journal *Green* by a group of authors representing most countries involved in this research area in Europe and in the AMPEA JP. This paper provided the background for the discussions that were held in Wageningen. A second important suggestion of the Mülheim workshop was to create a society for research in artificial photosynthesis, which is currently headed by Holzwarth, who serves as a PI in the Eurosolarfuels Eurocores CRP Solarfueltandem. This point was estensively re-discussed during the Wageningen workshop. As a result of the Wageningen meeting, additonal groups have decided to commit to the AMPEA JP and the steering committee in AMPEA will meet again in Uppsala in October 2013.
The two-day workshop in Wageningen was hosted by the Dutch AMPEA member BioSolar Cells and with support from the dissemination budget of the EuroSolarFuels Eurocores program of the ESF.

b) Final programme of the event

Tuesday, June 11
Introduction and setting the stage
- 9.00 Introduction to the workshop (Huub de Groot);
-9.15 General presentation of the AMPEA JP (F. Chandezon);
-9.30 The Research Field of Artificial Photosynthesis: A general introduction S. Styring
-10.15 IRP as a possible funding scheme for the Artificial Photosynthesis (AP) activity in AMPEA (Ingo Bunzeck, EERA secretariat);
11.00 Coffee break

11.30 – 13.00 Perspectives on cross-linking between artificial photosynthesis and tools
11.30 Molecular catalysts and devices – Wolfgang Lubitz, Mülheim
12.00 Inorganic devices – Roel van de Krol, Berlin
12.30 Towards molecular devices for solar fuels – Leif Hammarstrom, Uppsala
13.00 – 14.30 Lunch. During lunch the workshop organization committee refines the organization and discusses the content of the group discussions. In addition the note-takers are recruited from the groups.

Road Mapping activities
14.30 – 16.30 Work groups sessions I: Priority research directions for catalysts, materials and devices
- **Group 1-4: New Materials (Robert, Fiechter, Styring, Kurz)**
- **Group 5: Physical Modeling (Messinger/de Groot)**
- **Group 6: Characterization (Chandezon)**

All groups deliver PRD forms with connections on a mid-term time scale with H2020
16.30 - 17.30 Reporting by the chairman of each group to all the audience and collecting feedback from the plenary by the note-takers of each group for the session on the 12th. 18:00 – 20:00 Buffet Dinner
Evening discussions about how to finalize the setup of the Artificial photosynthesis research society (Moderator A Holzwarth, prospective Chair).

Wednesday June 12
9.00 – 10.00 Out of the box thinking: Three short lectures presenting unconventional approaches:
Victor Batista: Oxomanganese complexes for natural and artificial photosynthesis
Joanna Kargul: Extremophile components for solar to fuel nanodevices
René Janssen: Ink over ink over ink over ink….multiple junctions solar to fuels with organic solar cells
10.00 – 12.30 Work group sessions II, Cross-linking of PRDs, the drafts of the previous day will be exchanged between groups, and the focus will be on preparation of future call texts.
- **Groups 1-4: New Materials (Robert, Fiechter, Styring, Kurz)**
- **Group 5: Physical Modeling (de Groot/Messinger)**
- **Group 6: Characterization (Chandezon)**

12.30 – 13.30 Lunch: In the lunch break the call texts prepared by the work groups will have to be available and will be collected.
Wrap-up
14.00 – 16.00 For the present organizing committee: Integrated Research Programme in the field of Artificial Photosynthesis: preparation of a tentative scheme and call text

c) Description of the scientific content of the event (abstracts can be provided)

It should provide a detailed picture of what went on during the meeting: brief summaries of presentations, synopsis of subsequent discussions (agreements/disagreements/highlights).

d) Assessment of the results and impact of the event on the EUROCORES programme.

During the workshop, limited number talks introduced the Ampea/Eurosolar fuel topics. This was followed by work group sessions that identified topics for the roadmap and with time scales for specific goals. The workgroup sessions with their participants were:

New materials: bio
Robert
Vass
Vermaas
Wegrzyn
Campus
Kargul
Leibl

Characterization
Chandezon
Holzwarth
Mackowski
Ocakoglu
Puntoriero
Klein Lankhorst
Lokstein

New Materials: device vehicles 1
Fiechter
Delgado
Janssen
Krol
Küppers
Linnekoski
Monllor-Satoca
Haverkort

New Materials: device vehicles 2
Styring
Llobet
Saracco
Schrantz
Maloney
Kaiser
Lubitz

New Materials: catalysts
Kurz
Dau
Hammarström
Lloret
Patzke
Pryce
Vlcek

Physical Modeling
Messinger
Sevink
Batista
Blumberger
Luo
Grondelle
Groot
Buda
Monti

Every work group delivered a protocol with priority research directions about their topic. These protocols were discussed and were summarized in a global vision document regarding the priority of research to be included in the Description of Work (DOW) of the AMPEA joint program at the next stage. A working concept of this document "EERA JP-AMPEA Workshop Wageningen - Merging_group_conclusions" is attached with this report in pdf.

e) List of speakers and participants

Name and affiliation are sufficient. The detailed list will be uploaded online directly.

Victor	Batista	Yale University	United States of America
Jochen	Blumberger	University College London	United Kingdom
Francesco	Buda	Leiden University, Leiden Institute of Chemistry	The Netherlands
Ingo	Bunzeck	ECN	Belgium
Paola	Campus	European Science Foundation	France
Frédéric	Chandezon	CEA	France
Alfonso Vidal	Delgado	CIEMAT-PSA Plataforma Solar de Almeria	Spain
Sebastian	Fiechter	Inst. Solar Fuels, Helmholtz Zentrum Berlin für Materialien und Energie	Germany
Huub	de Groot	Leiden University, Leiden Institute of Chemistry (LIC)	The Netherlands
Leif	Hammarström	Uppsala University	Sweden

Jos	Haverkort	Eindhoven University of Technology, Department of Applied Physics	The Netherlands
Alfred	Holzwarth	Max-Planck-Institut für Chemische Energieforschung	Germany
Khurram Saleem	Joya	Leiden University, Leiden Institute of Chemistry (LIC)	The Netherlands
Rene	Janssen	Technical University of Eindhoven	The Netherlands
Bernhard	Kaiser	TU Darmstadt, Materials Science	Germany
Joanna	Kargul	IMPERIAL	United Kingdom
René	Klein Lankhorst	BioSolar Cells, Plant Sciences Group	The Netherlands
Roel	van de Krol	Helmholtz Zentrum Berlin für Mat und Energie – Inst. Solar Fuels	Germany
Stephan	Küppers	Forschungszentrum Jülich GmbH	Germany
Philipp	Kurz	Christian-Albrechts-Universität Kiel	Germany
Winfried	Leibl	CEA Saclay, iBiTecS	France
Juha	Linnekoski	representative VTT	Finland
Antoni	Llobet	Institute of Chemical Research of Catalonia	Spain
Julio	Lloret	University Girona	Spain
Heiko	Lokstein	Glasgow Biomedical Research Centre, Univ. of Glasgow	United Kingdom
Wolfgang	Lubitz	Max Planck Institute for Chemical Energy Conversion	Germany
Kai	Luo	University of Southampton	United Kingdom
Sebastian	Mackowski	Nicolaus Copernicus University	Poland
Johannes	Messinger	Umeå University, Dept of Chemistry	Sweden
Damián	Monllor-Satoca	Institut de Recerca en Energia de Catalunya (IREC)	Spain
Adriano	Monti	Leiden University, Leiden Institute of Chemistry (LIC)	The Netherlands
Amelia	Montone	COST, ENEA, Material Technology Unit	Italy
Yuliya	Miloslavina	Leiden University, Leiden Institute of Chemistry (LIC)	
Kasim	Ocakoglu	Mersin University	Turkey
Greta	Patzke	Univerity of Zuerich	Switzerland
Mary	Pryce	Dublin City University	United Kingdom
Robin	Purchase	Leiden University, Leiden Institute of Chemistry (LIC)	
Bruno	Robert	Saclay institute of Biology and Technology	France
Guido	Saracco	Politecnico di Torino – Dept. Applied Science and Technology	Italy

Krisztina	Schrantz	Empa, Swiss Federal Laboratories for Materials Science and Technology	Switzerland
Stenbjörn	Styring	Molecular Biomimetics; Uppsala University	Sweden
Imre	Vass	BRC, Hungarian Academy of Science	Hungary
Wim	Vermaas	Arizona State University, School of Life Sciences, and Center for Bioenergy and Photosynthesis	USA
Tony	Vlcek	Queen Mary University London	United Kingdom
Grzegorz	Wegrzyn	University of Gdansk	Poland

AMPEA challenges and views on artificial synthesis and production of solar fuels

EERA JP-AMPEA cross-linking workshop on Artificial Photosynthesis
Wageningen (The Netherlands), June 11- 12th 2013

The present document discusses the challenges and presents the views of the AMPEA EERA-JP community in the field of Artificial Photosynthesis (AP) and production of Solar Fuels (SF) in connection with materials, modeling and advanced characterization issues and in line with the general philosophy of the AMPEA JP (see Figure 1). It is an outcome of the cross-linking workshop organized on June 11-12th in Wageningen (Netherlands). The workshop gathered approx. 40 participants from and outside Europe who presented and discussed their views on the bottlenecks and grand challenges in the field of AP/SF. Six work groups were constituted during the workshop to draw-out priority research directions in the following areas:

- Materials for AP/SF: bio-inspired approach (group 1), molecularly designed systems (group 2), solid-state approach (group 3);
- Device vehicles (group 4);
- Modeling (group 5);
- Characterization (group 6).

The present document summarizes in a synthetic way the main conclusions of these 6 work groups.

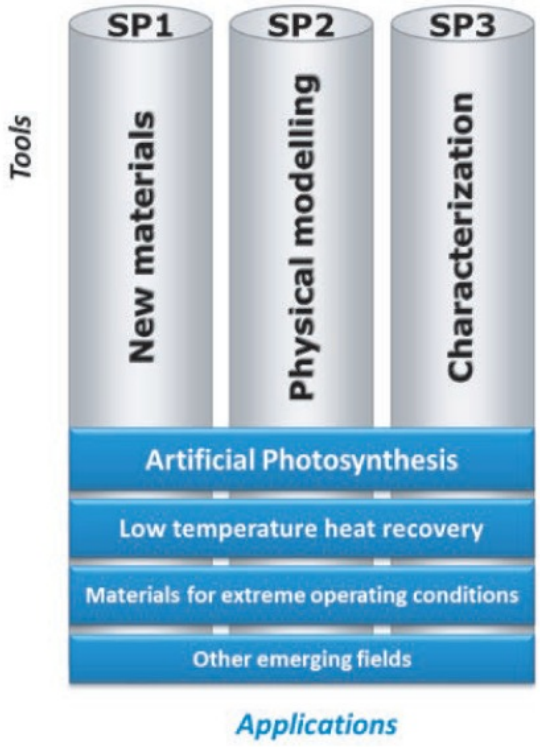

Figure 1: Structure of AMPEA and associated sub-programmes (SPs) with a matrix of tools and applications corresponding to emerging energy technology applications.

1. Priority research

1.1 Research Direction

Priority research should focus on the design of molecules, advanced materials and processes for artificial photosynthesis energy conversion and production of solar fuels exhibiting

- flexibility of solar fuel device designs
- energy transformation and fuel production efficiency
- long-term stability
- affordability

1.2 Potential Impact

Solar fuels produced from water oxidation and implemented at large scale would:

- increase the energy supply security in most of EU member states;
- allow to go far beyond the 2020 and 2050 CO_2 emission EU targets;
- seriously decrease the EU member states demand of fossil fuels;
- give the EU member states innovation and technological advantage in the energy production economy;
- outside the EU, solar fuel and solar power are likely to become very important factors in developing economies when they build their energy system;
- Early implementations of solar fuels in Europe could involve industrial sectors with large immediate needs to reduce their CO_2 footprint (*e.g.* fertilizers sector, cement and steel production plants).

All the above mentioned points (flexibility, efficiency, stability, affordability, see section 1.1) are crucial for solar fuels devices to make a wide economical, environmental and societal impact for a sustainable society.

2. Aims

2.1 Scientific Challenges

- **Challenges on materials for direct solar fuels production**:
  - → Durable catalysts and light absorbing systems based on abundant elements;
  - → Broadband spectrum light-harvesting systems for efficient fuel production;
  - → Immobilization strategies for catalysts and light absorbing systems;
  - → Control of proton and electron transfer;
  - → Catalysts for fuel production from CO_2 or N_2.

- **Challenges on processes and devices**:
  - → Light-driven fuel production devices comparing design concepts based on molecular, bio-inspired or bulk semiconductor platforms;
  - → For all concepts, the target is a monolithic architecture (artificial leaf) with high Solar-to-Fuel-Efficiency (SFE);
  - → Scalability of device design and engineering at all relevant levels;
  - → Light management at a higher level for improved performances (*e.g.* integration of solar light concentrators).
  - → Development of smart-responsive matrices (adapted to the working environment) and relevant characterization techniques for improved efficiencies and lifetimes.

- **Challenges on modelling**:
  - → Full modelling of devices *in silico* prior to making them
  - → Hierarchical modeling from the atomistic to the continuum level bridging time and length scales.

- **Challenges on characterization**:

  - → Network of advanced characterization platforms dedicated to studying materials and processes for energy (see below); develop *in situ* and *in operando* characterization methods at laboratory scale facilities and large scale instrument facilities.
    - Priority I: Development and characterization of devices for direct production of solar fuels;
    - Priority II: Material for extreme operating conditions at high temperatures;
    - Priority III: Connection to other JP programmes.

Infrastructure, 1- 5 years
Remark: connection with ESFRI (tbd).

  - → Development of single molecule sensitive techniques to study the dynamical processes on relevant time scales, and develop model systems.
  - → Specification and standardization of device vehicles.

2.2 Timescale:

What can be achieved in 1 year
What can be achieved in: 3 - 5 years
What can be achieved in 10-20 years

Matrix of the different challenges with a time scale to be included (Frédéric then updating by the Wageningen organizing committee).

3. Action points

3.1 Guiding coalition

Describe the coalition (Science, Business, Foundations) that you feel is suitable to address this. Identify the "champions" on your topic in industries as well, work from your personal contacts and mutual trust.

3.2 Action points with timescale for implementation, who is in charge

Point1: 1 years, names
Other steps to get there with names

Comments for addition/improvement of the document at a later stage

Characterization platform: connection with ESFRI ?

Data to keep in mind: investment in USA on AP/SF research: approx. 2 $/capita/5 years
Extrapolation to EU: approx. 1.2 b€

Bibliography:

[1] AMPEA EERA-JP webpage: http://www.eera-set.eu/index.php?index=78

[2] A. Thapper, S. Styring, G. Saracco, A. W. Rutherford, B. Robert, A. Magnuson, W. Lubitz, A. Llobet, Ph. Kurz, A. Holzwarth, S. Fiechter, H. de Groot, S. Campagna, A. Braun, H. Bercegol and V. Artero: "*Artificial photosynthesis for solar fuels – an evolving research field within AMPEA, a joint Programme of the European Energy Research Alliance*", *Green* **2013**, *3*, 43-57.