Governance for Global Artificial Photosynthesis

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ECI Open Day
December 2015
Stromatolites-at Zebra River in Namibia
PHYSICAL AND CHEMICAL CHARACTERISTICS OF CHLOROPLAST FRAGMENTS

Applied Research Concerning Artificial Photosynthesis

TECHNICAL DOCUMENTARY REPORT NO. AMRL-TDR-62-146
December 1962

Biomedical Laboratory
6570th Aerospace Medical Research Laboratories
Aerospace Medical Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

Contract Monitor: Paul A. Lachance, 1st Lt., USAF
Project No. 7164, Task No. 716403

[Prepared under Contract No. AF 33(616)-7255 by
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Armour Research Foundation, Chicago, Illinois]
1.9 Å PS II resolution data collected at SPring-8, Japan –Kamiya et al- breakthrough Nature paper

Mar225HE CCD detector, BL44XU, SPring-8
Purple = Mn ions in the “London” structure
   Barber et al. *Science* 2004, 303, 1831

Yellow = Mn ions in the “Berlin” structure

Blue = the “Osaka” structure

• **LIGHT utilises only this one catalytic structure** for facilitating sustained water oxidation catalysis

• **WHY?**

• If this structure were present in a non-biological species, would it catalyse water oxidation?

• What is the relationship between the cubane core structure and the facilitation of water oxidation catalysis?
Light harvesting

Reaction center

Oxidative catalysis

Reductive catalysis

H_2O

H_2

CO_2

N_2

NH_3

CH_3OH/C_{nH_m}

H^+

O_2

ANU

THE AUSTRALIAN NATIONAL UNIVERSITY
To make an efficient, cheap, durable, and scalable solar fuel device, scientists first have to develop at least three key components: a light absorber, a catalyst to trigger the reduction of water to hydrogen, and a catalyst for the oxidation reaction.

The light absorber would convert light into energetic electrons and holes, while the catalysts have to make sure that these charge carriers can be effectively used to drive the electrochemical reactions that convert cheap resources such as water and/or CO2 into chemical fuels such as hydrogen and hydrocarbons.
Experimental catalysts

- Iridium, ruthenium - efficient but expensive rare earth metals

- Manganese - the catalyst of choice for plants - abundant, safe but chemistry is complex

- Bismuth vanadate (BiVO4) holds the efficiency record among metal oxide light absorbers, and is fairly cheap and easy to make. Researchers are modifying it by doping, nanostructuring, coating to enhance the stability

- Cobalt -

- Doped iron oxide, nickel and molybdenum
GAP leaders—bold, positive visions for engineering sustainability using light

• **10-year JCAP Goal, 2010:** To demonstrate a manufacturably scalable solar fuel generator, using earth-abundant elements, that, with no wires, robustly produces fuel from the sun, 10 times more efficiently than (current) crops.

Photosynthesis

Artificial Photosynthesis

"...they're developing a way to turn sunlight and water into fuel for our cars. ..." President Obama's State of the Union remarks

Jan. 2011
GAP conference, Lord Howe Island 2011

SOLAR-H2

Bioreactors
Artificial Systems
Photosynthetic Organisms
Function of Hydrogenases & Photosystems
Genetics
Regulation
Metabolism

Saclay
Cadarache
Max-Planck-Institut für Bioanorganische Chemie
UNIVERSITÉ PARIS-SUD 11
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
ICIQ
UNIVERSITÉ DE GENEVE

WAGENINGEN UR
For quality of life

UNIVERSITET I HUMLESTAD, HUBBLENDT-Universitet

Turun yliopisto University of Turku
The first conference dedicated to the creation of a Global Artificial Photosynthesis Project is being held on Lord Howe Island, a beautiful world heritage-listed site in the South Pacific.

Artificial photosynthesis, if promoted globally, could assist crop production on marginal lands, reduce atmospheric CO2 levels, lower geopolitical and military tensions over fossil fuel, food and water scarcity and create carbon-neutral hydrogen fuel for domestic, community and industrial storage.

The aim of this conference is to foster international collaboration and strategies for funding through a global effort in five key areas of artificial photosynthesis:

- global collaborations, governance and policy structures and models
- energy capture — including photovoltaic systems
- energy conversion and storage — including quantum coherence in electron transfer and hydrogen production for fuel cells
- carbon fixation, and
- modified and synthetic biological processes.
Do we need a global project on artificial photosynthesis (solar fuels and chemicals)?

9 am, Tuesday 8 July – 5 pm, Thursday 10 July 2014

The Royal Society at Chicheley Hall, home of the Kavli Royal Society International Centre, Buckinghamshire

Enquiries & Registration
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Register: royalsociety.org/events/2014/artificial-photosynthesis-global-project/
Interface Focus (April 2015) unique collection of interdisciplinary papers in artificial photosynthesis (AP) science and policy derived from presentations at the Royal Society Chicheley Hall meeting in July 2014 on the theme ‘Do we need a global project in artificial photosynthesis’.

Explore the vision that there is a growing ethical responsibility on humanity in general to ensure that every road, pavement, building and vehicle on the Earth’s surface performs photosynthesis.

Common theme is that a global AP project is not just an issue of enhancing AP technological capacity but of thereby facilitating an expansion of moral sympathy; the promoted good intention being not just to make renewable human fuel and food, but help sustain the biosphere by sustainable principles.
Kara Bren’s Global AP Model

- Global AP project would fund single-principal investigator (PI) grants, multi-PI grants and centres of excellence.

- Single-PI grants fund focused research on the individual components using specific approaches to capitalize on the recognized expertise of individual PIs and their laboratories.

- Multi-PI grants fund interface efforts, for example testing compatibility between the modules of AP research and testing performance.

- Feedback modifications towards practical device development coordinated in centres of excellence that organized sources of specialized equipment, technical expertise, benchmarking, testing product development strategies and scale-up of most successful systems for AP from the multi-PI efforts.

- Centres of excellence hold an annual conference for current PIs and other interested researchers and policy-makers.
Funding under Bren’s Global AP Model

- Global AP project funds drawn internationally from government sources initially and distributed internationally (i.e., European Research Council).

- Supplemented by funds from large philanthropic organizations provided a mutually agreeable mechanism for distribution of the funds could be developed.

- Fund distributed according to equity criteria among the different participating nations

- Global AP project to support principle that photosynthesis in its natural form is ‘common heritage of humanity.’
Funding Distribution under Bren’s GAP Model

• Funding distribution coordinated by an international governing board advised by peer reviewers.
• Funding criteria include principles such as diversity, quality of science and geography (socio-political context) so that the taxpayers could expect a direct benefit to their region as well as to humanity and the environment in general.
• Criteria encourage collaboration and rapid development of functional systems rather than decades long study of a single, isolated component.
• Single-PI grants for limited time periods (i.e. 3 years) with one renewal after which only multi-PI grants could be accessed (encouraging individual PIs to coalesce their AP research projects in order to maintain funding.
Propose nine factors likely to be critical to global uptake of AP technology.

(i) strong institutional capacity, (ii) political commitment, (iii) favourable legal and regulatory frameworks, (iv) competitive installation financing, (v) mechanisms for information and feedback, (vi) access to financing, (vii) prolific community and/or individual ownership and use, (viii) participatory project siting, and (ix) recognition of externalities or positive public image.

(ii) Once AP systems are ready to be piloted, quantitative case studies could be done to determine market segments and social barriers unique to AP.
Global AP Ethics at Chicheley Hall

- Ethical importance of a global AP project having a defined challenge at the levels of both fundamental science and benchmarking as well as an ethical mission statement.

- Proposed that benchmarking in this context to include not just technological efficiency and competitive advantage, but precautionary life cycle risk analysis and cost-effectiveness assessment.

- Importance of making the activities of such a global AP project express a narrative relevant to the concerns of the general populace in both developed and developing nations.
Photosynthesis as Common Heritage of Humanity

• Wide-spread support for the view that photosynthesis in its natural form should be considered to fall within the concept of ‘common heritage of humanity’ under international law

• Knowledge of its fundamental processes could not be owned entirely by profit-making interests, militarized or manipulated to promote social inequality or environmental degradation.

• Governance of a global AP project would need to comprise a highly qualified scientific committee capable of evaluating single and multi-investigator grants as well as a policy-oriented board capable of lobbying for, securing and coordinating recurrent funding and other resources.
‘Our goal is to work cooperatively and with respect for basic ethical principles to produce the scientific breakthroughs that allow development and global deployment of artificial photosynthesis an affordable, equitably accessed, economically and environmentally sustainable, non-polluting energy, food and fertilizer system that also contributes positively to our biosphere’
Engineering Artificial Photosynthesis Globally for the Sustainocene
Moral Vision - Global AP Roadways

Glass Surface

WATER SPLITTING

Support Structure

AMDONIA and BIOCHAR

LED

Nitrogen AND CO2 REDUCTION

Base Layer/Recyclable Materials

Water Collecting Basin
a world without GAP

population: 1 billion

population: 857 million

a GAP-powered future

compare the pair
‘Sustainocene’ coined by Furnass 2012
Technology (GSP) powering revolution in moral sympathy and consciousness - towards environmental sustainability and local governance-
Rights for ecosystems and other species
Preserving legacy fuels for future generations
All human structures sustaining biosphere
Sustainocene must last over 1 billion years, if the human species is to repay its ethical debt to life

Faunce TA (ed). *Nanotechnology Toward the Sustainocene (Pan Stanford 2014)*
Conclusion

Global AP and Nanotechnology

At this perilous point in human history, the moral culmination of nanotechnology is global Artificial Photosynthesis.

Global AP as Common Heritage

The natural process of photosynthesis should be declared ‘common heritage,’ not just of humanity but of life on the Earth.

Unravelling the details of AP should be a reciprocal gift from humanity to all life on this planet rather than a source of profit to corporations.
Solar-driven water splitting also powers CO$_2$ and Nitrogen Reduction in Human Structures
Global AP Homes in Sustainocene

Faunce TA (ed)
Nanotechnology
Toward the Sustainocene
(Pan Stanford 2014)
International Conference
Global Artificial Photosynthesis for the Sustainocene
Sept 17-20 2016
Lord Howe Island Aug-Sept
Australia

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