Department of BioTechnology, Government of India

MISSION INNOVATION
Accelerating the Clean Energy Revolution

Mission Innovation Challenge IC# 5: Converting Sunlight Innovation

Report on Meeting of MI-India Workshop on "Converting Sunlight Innovation" Challenge on 14th September, 2017 at ICGEB, New Delhi INDIA

Recommendations of First MI workshop on Converting Sunlight Innovation, IC#5

IC#5 workshop was held on 14th September, 2017 at the International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi. The workshop was aimed at identifying key technological advances in the field, and roadblocks hindering breakthrough technologies. The list of participants and agenda of the workshop is enclosed.

Inaugural lecture in the Workshop was delivered by Dr. Sangita Kasture, Joint Director DBT (Department of Biotechnology), and participants were addressed by Dr. Renu Swarup, Senior Adviser, DBT and Dr. Dinkar Salunke, Director, International Centre for Genetic Engineering and Biotechnology.

The presentations were made by three experts in three major areas under Converting Sunlight Innovation to discuss the R&D gaps and current developments in the specified field. The details of experts and the topics of discussion is enclosed in Annexure I. After 3 main talks which were helpful in setting the context, the participants were divided into 2 groups (Group A and Group B) to discuss about the topic with the following deliverables:

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1. What is the current status of Technology in India?
2. What are the R&D gap areas?
3. What type of R&D projects should be taken?
4. Need for National/International collaborations.
5. Short, Mid and Long term strategies.
6. Which other stakeholders/groups to be included in future discussions?

The first group (Group A) discussed:

1. **Photocatalysis**
2. **Photoelectrochemical cells**
3. **Photo-bioelectrochemical CO_2 reduction**

The second group (Group B) discussed

1. **Cyano-bacteria and Micro algal based fuels**

The recommendations from the two groups are discussed in the following section:

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Recommendations of Group A on Photocatalysis, Photoelectrochemical cells, Photo-bioelectrochemical CO_2 reduction.

1. Photocatalysis

a. Current R&D status

- Many materials that have been evaluated in laboratory are available but these do not meet industrial requirements.
- Basic know-how related to photocatalysis is available in India but is limited to laboratory level. Current at TRL 2.

b. Gap areas

Photocatalysis for water splitting as well as CO_2 capture-conversion is a multi-faceted process with large number of unanswered questions, regarding mechanism, reaction pathways, effect of photocatalyst size/shape/ morphology on its efficiency, etc. Some of the gap areas are:

- Solar-to-Hydrogen (STH) efficiency is low.
- Materials with STH > 5% and stability in long term operation required.
- Availability of stable and recyclable materials, with better adsorption capacity for water and CO_2.
- Use of noble metal as co-catalysts/use of sacrificial agents (to be avoided).
- No scale-up studies and efficient reactor designs.
- Process economics not studied.
- Scattered infrastructure and lack of collaboration.
- Issues related to sacrificial agent.

c. Types of projects to be taken up

- Development of stable materials with STH > 5% and stability in long term operation.
- Development of hetero-structured type materials.

- Optimization of process considering the industry needs.
- Efficient reactor design.
- Studies on process economics and LCA.

Short-term:

- Enhancing scientific collaboration (national/international) is priority.
- Emphasis on developing collaborations by building cross-functional teams (chemists, engineers, spectroscopists, theoreticians etc.).
- Develop new efficient material.

Mid-term:

- Virtual center: Process up-scaling.
- Collaboration and theme/consortium based projects with scientific experts in key knowledge areas.

Long-term:

- Establishment of dedicated Institute e.g. National Centre for Energy and Environment with modern facilities and high quality research/ infrastructure.
- Implement research and exchange collaborations, evaluate the success of these measures, develop new measures based on lessons learnt.

2. Photoelectrochemical cells

a. Current R&D status

- Basic materials are being researched for H_2 production.
- At least one Technology transfer in progress.
- Currently at TRL 3.

b. Gap areas

- Availability of stable and cost-effective materials.
- No scale-up studies and efficient reactor designs.
- Process economics not studied.
- Scattered infrastructure and lack of collaboration.

c. Types of projects to be taken up

- Development of stable materials.
- New strategies for enhancing efficiency (molecular catalysts, heterojunction, plasmon, etc.).
- Optimization of process considering the industry needs.
- Efficient reactor design.
- Study of Process economics and LCA.

Short-term:

- National/International collaboration.
- New efficient material development.

Mid-term:

- Process up-scaling.

Long-term:

- Commercialization efforts.

3. Photo-bioelectrochemical CO_2 reduction

a. Current R&D status

- Basic R&D at initial stage.
- Effective and energy efficient process for CO_2 reduction into multi-carbon high energy chemicals/fuels.
- Being researched globally & in a few laboratories in India.
- Currently at TRL 2.

b. Gap areas

- Limited fundamental knowledge.
- Availability of biocompatible, stable and cost-effective electrode materials is a constrain.
- Selectivity and stability of microbial catalysts.
- No efficient reactor designs.
- Process economics not studied.
- Studied only with pure CO_2.

c. Types of projects to be taken up

- Development of biocompatible electrode materials.
- Fundamental research on biocatalyst-electrode interactions.
- Strain/biocatalyst improvement with synthetic biology.
- Process optimization in context of Industry needs.
- Efficient and integrated reactor design.
- Focus to also include the downstream processes.
- Research on Bioinorganic hybrid materials.
- Studies on Process economics and LCA.
- Studies with flue gas. (e.g. with membranes in thermal power plants/ industries).

Short-term:

- National/International collaboration.

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- Basic research on electrode, biocatalysts and process intensification efforts.

Mid-term:

- Process up-scaling and demonstration of technology.

Long-term:

- Commercialization efforts.

Recommendations of Group B on Cyanobacteria and Micro algal based fuels

Cyano-bacteria and Micro algal based fuels

a. Current status of R&D in the area

- Selection of robust strains
  - Marine microalgae and cyanobacteria.
  - Fresh water microalgae and cyanobacteria tolerant to waste water.
  - Photosynthetic bacteria.
- DBT Repositories IBSD and NFMC store thousands of algal species.
- Algal network programme of DBT - four bio-energy centers and other institutes.
- RIL and ABAN working extensively in the area with current TRL 5.
- Use of waste water for algae cultivation.
- Bench scale efforts have not been translated outside laboratory.

b. Gap Areas

- Considerable emphasis on lipid content of algae instead of biomass productivity.
- Translation of laboratory achievements to outdoor cultivation.
- Domestication of strains to improve robustness, which involves tolerance to environmental stress & efficient sunlight capture.
- Crop rotation based on seasons and locations.

- Knowledge sharing for GMO strain cultivation and bio-safety.
- Harvesting and downstream processing of biomass.

c. Types of projects to be taken up

Short-term:

- Detailed characterization of biomass of potential strains for bio-chemicals and fuels.

Short-term to mid-term:

- Domestication of robust algae.
- Design of CAPEX and OPEX friendly bioreactor systems and material development.
- Multiple medium scale cultivation programmes across the country at multiple locations.
- Harvesting of biomass using economically viable technologies.
- Downstream processing of biomass for identified products.
- LCA and evaluation of process engineering.
- Solutions to address evaporative water loss in large scale algal systems.
- Develop methods of lipid recovery from wet algae without the need for drying.
- Development of diverse value addition pathways such as platform chemical production and novel material synthesis.

Mid-term to Long-term:

- Host engineering/strain improvement of micro algae and cyanobacteria for improvement of photosynthetic efficiency, production of bio-chemicals, secretory biofuel molecules and precursors.
- Majority of the final value-added products obtained from micro-algal farming end up being overall carbon negative (e.g. bio fuel). This results in carbon build-up in the environment, and needs to be addressed in mid to long-term strategies.

Long term:

- Metabolic flux analysis to improve biochemical potential.

Collaborations:

- International labs working in cultivation and harvesting of algal biomass
- Public and private partnership starting from R&D.

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Annexure I: List of Experts and topics for Thematic Presentation and Discussion

1. Current Status of R&D in the area of semiconductor-mediated solar-light-driven water splitting to produce H_2 by Dr. Narendra M. Gupta, Ex: Bhabha Atomic Research Centre, Mumbai
2. Algae-to-Oil at RIL, Dr. Ninad Gujarathi, Reliance Biofuels R&D, Jamnagar
3. Solar Fuel Generation- PEC Pathway, Dr. Yatendra S. Chaudhary, CSIR-IMMT, Bhubaneswar