MISSION INNOVATION
Accelerating the Clean Energy Revolution
INDIA

सत्यमेव जयते
Ministry of Science and Technology
Government of India

Mission Innovation
Converting Sunlight IC#5
Country Workshop

Mission Innovation Challenge IC# 5 "Converting Sunlight"

Workshop Date: September 14th, 2017

Venue: International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi

Conference Report

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 area of converting sunlight to usable fuels, and roadblocks hindering these breakthrough technologies. The list of participants of the workshop is enclosed as Annexure I.

Participants of MI-India Workshop on Converting Sunlight Innovation Challenge

Dr. Sangita Kasture, Joint Director DBT (Department of Biotechnology) gave a welcome address and also provided a brief view about the Mission Innovation program. The participants were addressed by Dr. Renu Swarup, Senior Adviser, DBT. She highlighted the importance of Mission Innovation for development of new technologies to meet the challenge of climate change and to meet the commitments made in Paris agreement for low carbon economy. Dr. Dinkar Salunke, Director, International Centre for Genetic Engineering and Biotechnology in his brief address highlighted need to develop game changing technologies for clean energy development. Dr. S.S. Yazdani, Coordinator, DBT-ICGEB, Centre introduced the structure of the interactive workshop and also listed the expected deliverables.

The presentations were made by three experts in three major areas under Converting Sunlight Innovation Challenge 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 II.

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:

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 photographs of participants involved in group discussion are enclosed in Annexure III. The recommendations from the two groups are discussed in the following section:

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

1. Photocatalysis

Current status of Technology:

- Many materials that have been evaluated in laboratory and are available but yet many of 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.

R&D gap areas/suggestions:

Photocatalysis for water splitting as well as CO_2 capture-conversion is a multi-facet 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.

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 actions:

- 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 actions:

- Consider setting up a virtual center of R&D
- Process up-scaling.
- Collaboration and theme/consortium based projects with scientific experts in key knowledge areas.

Long-term actions:

- 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

Current status of Technology:

- Basic materials are being researched for H_2 production.
- At least one Technology transfer in progress
- IOC R&D has setup facilities at bench scale and required collaborations.
- Currently at TRL 3.

R&D gap areas/suggestions:

- 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.

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 actions:

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

Mid-term actions:

- Process up-scaling.

Long-term actions:

- Commercialization efforts.

3. Photo-bioelectrochemical CO_2 reduction

Current status of Technology:

- 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.

R&D gap areas/suggestions:

- 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.

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 actions:

- National/International collaboration.
- Basic research on electrode, biocatalysts and process intensification efforts.

Mid-term actions:

- Process up-scaling and demonstration of technology.

Long-term actions:

- Commercialization efforts.

II. Recommendations of Group B on Cyanobacteria and Micro algal based fuels

1. Cyano-bacteria and Micro algal based fuels

Current status of Technology

- Selection of robust strains-Capability exists in:
  - 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.

R&D gap areas/suggestions:

- 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.

Types of projects to be taken up

Short-term actions:

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

Short-term to mid-term actions:

- 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 actions:

- 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 actions:

- 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.

Annexure-I: List of Participants

Sl. No.	Name	Organization/ Institution Name
1.	Dr. Renu Swarup	Department of Biotechnology, New Delhi.
2.	Dr. Sanjay Bajpai	Department of Science & Technology, New Delhi.
3.	Dr. Prabhat Ranjan	TIFAC, New Delhi.
4.	Dr. Sangita Kasture	Department of Biotechnology, New Delhi.
5.	Dr. Shams Yazdani	ICGEB, New Delhi.
6.	Dr. Pramod Wangikar	DBT Pan IIT Centre for Bioenergy, IIT Mumbai.
7.	Dr. Ninand Gujarathi	Reliance Industries Ltd., Mumbai.
8.	Dr. Narendra M. Gupta	BARC, Mumbai.
9.	Dr. D. K. Tuli	DBT Energy Bio-Sciences Chair, Faridabad.
10.	Dr. Neelima Alam	Department of Science & Technology, New Delhi.
11.	Dr. S. Venkata Mohan	CSIR-IICT, Hyderabad.
12.	Dr. L. Giribabu.	CSIR-IICT, Hyderabad.
13.	Dr. Sunil. A. Patil	IISER, Mohali.
14.	Dr. Sahab Dass	Dayalbagh Educational Institute India, Agra.
15.	Dr. Satishchandra B. Ogale	NCL, Pune.
16.	Dr. Narayan Pradhan	IACS, Kolkota.
17.	Dr. Vivek Polshettiwar	TIFR, Mumbai.
18.	Dr. Reena Pandit	DBT-ICT-CEB, Mumbai.
19.	Dr. Alok Sharma	IOCL (R&D), Faridabad.
20.	Dr. S K Puri	IOCL, Faridabad.
21.	Dr. Manoj Kumar	IOCL, (R&D), Faridabad.
22.	Dr. Mrinal R. Pai	BARC, Mumbai.
23.	Dr. Shilpi Gupta	BIRAC, New Delhi.
24.	Dr. Brajesh Barse	ICGEB, New Delhi.
25.	Dr. Deepika Singh	Mission Innovation- India, New Delhi.
26.	Dr. Ayashaa Ahmad	Mission Innovation- India, New Delhi.
27.	Dr. Umashankar Sagaram	Reliance Industries Ltd., Mumbai.
28.	Dr. Sanjukta Subudhi	TERI, New Delhi.
29.	Dr. Dheeban Chakravarthi	TERI, New Delhi.
30.	Dr. Snehangshu Patra	IIEST, Shibpur.
31.	Dr. Shireesh Srivastava	ICGEB, New Delhi.

32.	Dr. Shashi Kumar	ICGEB, New Delhi.
33.	Dr. Pavan Jutur	ICGEB, New Delhi.
34.	Dr. Yatendra S. Chaudhary	CSIR-IMMT, Bhubaneswar.
35.	Dr. Srikanth Sanipam	IOC (R&D), Faridabad.
36.	Ms. Padmini Raju	DBT-ICT-CEB, Mumbai.
37.	Dr. Preeti Mehta	IOC (R&D), Faridabad.
38.	Dr. Dilip Singh	IOC (R&D), Faridabad.
39.	Dr. Archita Bhatta	DBT Communication Cell, New Delhi.

Annexure-II: 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.

Annexure-III: Photographs of participants during panel and group discussion

Dr. Renu Swarup, Senior Adviser, DBT; Dr Sanjay Bajpai, Adviser, DST; Dr. Sangita Kasture, Joint Director, DBT, Ministry of Science & Technology, Government of India along with Dr. Dinkar Salunke, Director, and Dr. S.S. Yazdani, Coordinator, DBT-ICGEB Centre addressed the participants of MI-India Workshop on Converting Sunlight Innovation Challenge

Group A- Discussed on Photocatalysis, Photoelectrochemical cells, Photo-bioelectrochemical CO_2 reduction

Group B- Discussed on Cyanobacteria and Micro algal based fuels