BACKGROUNDs

IEA HIA Task 21 covers integrated areas of R&D, technological/economic evaluations, and societal acceptance issues, which are of mutual interest to the 11 countries currently participating in Task 21. Task 21 provides the foundation for cooperation within the task, which promotes substantial collaborative research projects amongst the member countries and transfer of Task 21 technologies into industry (particularly in developing countries, where the economics are more favorable than in the developed world) to facilitate the commercial production of hydrogen. The member countries are: Finland, France, Germany, Italy, Japan, Korea, Norway, Sweden, The Netherlands, Turkey, and United Kingdom. It is anticipated that China will participate in the near future.

STATUS OF TECHNOLOGY

Subtasks A—D have major Basic Research, Applied Research, and Critical Function elements; Subtasks B and D in addition have Laboratory Testing and Prototype System Verification elements; Subtask B has an Integrated Pilot System Demonstration element; and Subtask E has a Program Management and Market Development element.

TECHNOLOGY READINESS LEVEL

Dark biohydrogen fermentation systems are at the Technology Readiness Level (TRL) 7 (Integrated Pilot System Demonstration) level and biological electrochemical systems are at the TRL 6 (Prototype System Verification) level. All other projects in Subtasks A-D are at the TRL 1–3 (Basic Research, Applied Research, and Critical Function, respectively) levels with the exception of Subtask E, which is a TRL 10 (Market Analysis) task.

ACTIVITIES AND ACCOMPLISHMENTS

In a strong expression of member interest in task extension, a proposal for the one year extension for Task 21 was submitted to the ExCo for consideration at the ExCo meeting held in Paris on March 12-14, 2013. The ExCo approved the proposal. The extended task is a continuation of the present task; a full-scale change will be made in the next task.

The first task meeting was held in August, 2013 at the Marriott Hotel in Montreal, Canada. The meeting was held along with BioH2 (Chair Prof. P. Hallenbeck). The members agreed that Prof. Alan Guwy would become the new Operating Agent.

The second task meeting was held in Osaka on November 22-24, 2013. The meeting was coupled with the Asia BioHydrogen-Link meeting (ABHL2013) (Chair Prof. J. Miyake). The members discussed the extension proposal, analyzed the current situation and agreed on the current trends faced by the task: 1) Rapid changes on the situation of bio-based renewable energy; 2) Eco-community based positioning of bioHydrogen; 3) Growing...
research activities and researcher populations in Asia; and 4) Impact of the Brazil-Sapporo Brewery project on bioHydrogen. Over the next decade, bioHydrogen should adapt to the situation of renewable bioenergy development, for which eco-community and social system will be the leading concepts.

**SUBTASK MILESTONES**

**SUBTASK A (INTEGRATION OF BIOHYDROGEN FERMENTATION SYSTEMS FOR ENHANCED ENERGY PRODUCTION)**

*Milestone*: Conduct a metabolic analysis on exceeding the currently achievable yields of \( \text{H}_2 \) production from substrates and a system analysis on reaching the optimized yields of \( \text{H}_2 \) production from real world substrates.

**SUBTASK B (ENLARGED BIOHYDROGEN SYSTEMS)**

*Milestone*: Develop and optimize an integrated system incorporating a sequential, dark, anaerobic, and photo-fermentation process to enhance \( \text{H}_2 \)-production efficiency from biomass waste.

**SUBTASK C (LIGHT-DRIVEN BIOHYDROGEN PRODUCTION)**

*Milestone*: Develop and test innovative concepts for photobioreactor design and sustained exploitation of the metabolic potential of advanced strains for \( \text{H}_2 \) production.

**SUBTASK D (INTEGRATION OF BIO-INSPIRED AND PHOTO-ELECTROCHEMICAL HYDROGEN SYSTEMS)**

*Milestone*: Identify and develop promising applications of microbial/enzymatic electrochemical cells for \( \text{H}_2 \)-production processes.

**SUBTASK E (ENVIRONMENTAL AND ECONOMICAL FEASIBILITY)**

*Milestone*: Develop novel ways of combining technologies developed from the subtasks with other renewable and recyclable energy systems in a perspective of application and deployment, especially for the developing countries where the economics will be more favorable than in the developed countries.

**EFFECTIVENESS OF TASK PARTICIPATION**

In 2013, three countries (Canada, Iceland and Turkey) withdrew or began the process of withdrawing from the IEA HIA. The Experts from these countries could not attend Task 21 meetings, which is unfortunate since they have been very active in participating task activities and making significant progress towards reaching task milestones in Subtasks B, C, and E. Some tasks are led by the new Operating Agents, Prof. Jun Miyake of Japan and Prof. Alan Guwy, UK.
MATTERS REQUIRING EXCO ATTENTION

The funding difficulty in the USA did not allow Dr. Mike Seibert to continue in the role of OA, so Dr. Jun Miyake, Japan, the former OA (2005-2010), took the role for the remaining period of the 2012-2013 term and the extension period (January 2013-March 2014). The three-year period for the task will end in 2013, and a one-year extension was approved by ExCo in Paris, 2013. A majority of the members strongly supported the term extension. The extended task is expected to be a continuation of the present task, reflecting the withdrawal of some member countries whose experts had functioned as subtasks leaders. The full-renewal of the task will be discussed in the extension period and a new plan for 2014-2016 will be presented at the end of 2013.

A bioHydrogen boom occurred despite the withdrawal of some countries. In 2013, a large-scale bioHydrogen conference was held in Japan. Many Asian countries joined the research. Apart from Japan and Korea, China will become the third country member from Asia. Some other countries—Thailand, Singapore, Hong Kong, Indonesia, and Taiwan—are also the candidates to join the task. In general, we can see that the bioHydrogen development is still in the process of growing to maturity.

Brazil, which has large-scale production Petrobras and Sapporo Beer bioHydrogen projects, also expressed the intention in joining the task.

We have to take into consideration some new systems that are needed to enhance the efficiency of cooperation in geographically diverse areas, mainly in Europe and Asia (and possibly South America). Since 2010, Task 21 has a regional coordinator system (Europe: P. Lindbrad; America: P. Hallenbeck; and Asia: J. Miyake). This mechanism aims to advance the information exchange and also accelerate the cooperation. Operating Agents could consult with the regional coordinators to get detailed information. Due to the loss of participants in North America, the use of a regional coordination system in the two remaining regions, Europe and Asia, has become more important for task operations.

ACHIEVEMENTS:

SUBTASK A (INTEGRATION OF BIOHYDROGEN FERMENTATION SYSTEMS FOR ENHANCED ENERGY PRODUCTION)

Reported by The Netherlands (Subtask Leader)

In the Netherlands, research work is underway on both the electricity-mediated H₂ production by mixed microbial communities, and the fundamental and applied aspect of dark bioHydrogen production by the extreme thermophilic bacterium, *Caldicellulosiruptor saccharolyticus*. The research input in the Netherlands is declining due to funding constraints.

The effect of the hydrogen partial pressure on the fermentation pattern during growth of *Caldicellulosiruptor saccharolyticus* on glucose has been researched in continued efforts (Bielen et al 2013). Genome-wide transcription analysis revealed upregulation of hydrogenases and certain dehydrogenases. A bioinformatic analysis was conducted to find out putative transcriptional regulators.

Hydrogen formation by the hyperthermophilic *Thermotoga martina* from glycerol was researched (Maru et al 2013).
Hydrogen production and production of other compounds from complex substrates have been studied, and the potential use of *C. saccharolyticus* has been explored Panagiotopoulos et al (2013a;2013b). Microbial ecological and operational aspects of hydrogen production and methane production in bioelectrical systems were researched and published (Croese et al 2013; van Eerten-Jansen et al 2013).

**Reported by Norway**

Researches have been conducted on the production of bioHydrogen from Palm Oil Mill Effluent (POME). Thermophilic fermentative hydrogen production and genome sequence of Thermoanerobacterium thermosaccharolyticum were performed. Production of bioHydrogen and biomethane from waste materials were studied in a process involving hyperthermophilic bacteria.

**Subtask B (Enlarged BioHydrogen Systems)**

**Reported by UK (Subtask Leader)**

University of South Wales focused on exploration of real time gas production data for more accurate comparison between continuous single-stage and two-stage fermentation (Massanet-Nicolau, J., Dinsdale, R., Guwy, A., Shipley, G., 2013. Exploration of real time gas production data for more accurate comparison between continuous single-stage and two-stage fermentation. Bioresource technology 129, 561–7.)

![Fig 1. Methane production rate from different digestion systems.](image)

Researchers developed an integrated, two-stage continuous anaerobic digestion process for producing hydrogen and methane sequentially from wheat feed (flour milling co-product). Parallel digestion experiments were carried out to compare conventional single-phase digestion system with the two-stage system which is being evaluated, and to research the effect of operating the two-stage system at shorter hydraulic retention times as well. It was demonstrated that using a two-stage digestion system produced significantly more methane, resulting in a 38% increase in energy yields compared with single stage digestion, while also producing hydrogen (Figure 1). Researchers also found out that a two-stage system could also be operated at much shorter HRTs, improving the overall energy efficiency of the digestion process.

The authors of this article tested the integration of anaerobic digestion producing hydrogen and methane with emerging bioelectrochemical methodologies for the production of hydrogen or electrical energy. The advantages of this integration are evaluated to increase energy yields from substrate, increase process efficiency and reduce process residues. The authors tested the concatenation of hydrogen producing fermentation systems that produce high levels of organic acids such as acetate and butyrate with bioelectrochemical systems, which can convert these acids into energy (Figure 2). The authors also cited several important economic driving factors for this strategy including the need to accelerate the conversion of biomass to target products, as well as the importance to meet statutory requirements when recycling anaerobic digestion residues. A specific case was presented where a two-stage anaerobic digestion (ad) system was used to increase energy yields and process efficiency; this was then coupled with a microbial fuel cell in order to reduce the soluble COD in the residue from the digestion process and increase the overall energy yields from the biomass. The authors concluded that integration of this strategy has great potential for upgrading existing ad processes, but challenges still remain, such as effective scaling up of bioelectrochemical systems and removal of residuals such as phosphorus for those residuals which are discharged to water bodies.

Fig 2. Schematic of an acidogenic hydrogen producing digester combined with a microbial electrolysis cell.

• Cambridge University: The purification of crude glycerol derived from biodiesel manufacture and its use as a substrate by Rhodopseudomonas palustris to produce hydrogen (Pott, R.W.M., Howe, C.J., Dennis, J.S., 2013. The purification of crude glycerol derived from biodiesel manufacture and its use as a substrate by Rhodopseudomonas palustris to produce hydrogen. Bioresource Technology.)


Reported by Italy

In order to achieve the economic feasibility of biological H₂-production processes that combines dark and photofermentation, it is necessary to enhance the conversion efficiency of substrates into hydrogen so that a value close to the theoretical limit of 12 moles of H₂ production per glucose equivalent can be reached.

The success of photobiological hydrogen production with microalgae depends on the ability to develop a cost-effective process and select strains with high hydrogen output rates. At the present time, the efficiency of this process in most cases is below 1% under laboratory conditions which will be further reduced when hydrogen production is carried out outdoors.

Both the Dark fermentation carried out by Thermotoga neapolitana, and the photofermentation carried out by Rhodopseudomonas palustris, were studied. The main aim of this activity was the optimization of culture conditions in order to increase the conversion rate of glucose into hydrogen by the integrated H₂-producing process.

Experiments on large scale have been continued by testing a new photobioreactor design (110 liters) for the biological production of hydrogen with the microalga Chlamydomonas reinhardtii. The photobioreactor (PBR) was made up of 64 tubes (i.d., 27.5 mm, length, 2 m) arranged on an 8 x 8 square pitch cell connected by 64 U-bends for a total length of 133 m. The PBR was contained in a rectangular parallelepiped tank (2.5 x 2 x 2 m) made with isotactic polypropilene, except for the opposite square faces which were made of transparent Plexiglas. The tubes were immersed in a thermostatic water bath and continuously illuminated with artificial lights. The culture was circulated with a peristaltic pump. To attain a uniform distribution of light to the cells, they used a suspension of silica nanoparticles that scattered the light supplied by the light bulbs (2 x 2000 W) from the opposite square sides of the photobioreactor. Growth experiments carried out
with *C. reinhardtii* CC124 strain, showed a 23% net increase in the final chlorophyll concentration when the nanoparticle suspension was used.

Relative to the milestone *Examine and optimize an integrated system incorporating a sequential dark anaerobic and photo-fermentation process to enhance H₂-production efficiency from biomass waste* the conversion efficiency achieved was by far the highest reported in literature.

**Reported by Norway**

Hydrogen production by sulfur deprivation from species of green algae was cultivated under autotrophic conditions.

Hydrogen production from green algae was also cultivated under autotrophic conditions using flue gas as a CO₂ source.

Production of cancer inhibiting biomolecules from hydrogen producing green algae was also observed.

**Reported by Turkey**

- Activities during 2012-2013 are related to Subtask B (and C) supported by the following national and international projects. The Production of 5-Aminolevulinic Acid (5-ALA) and BioHydrogen Using Molasses in a Biorefinery Concept (TÜBİTAK-3501-111T523, Coordinator Asist. Prof. Dr G. Kars 2011-2013.)
- Optimization Of 1,3-Propanediol Production Using Proteomic Analysis And Metabolic Profiles (TUBITAK-BIDEB 2214- Researcher: M. GUNGORMUSLER; Director: Assoc. Prof. Dr. David B. LEVIN-12 months, 10/2012 – 10/2013, University of Manitoba, Winnipeg, MB, CANADA).
- From laboratory to outdoors, Microalgal bioHydrogen production in photobioreactors (TUBITAK-CNR bilateral project 111M609) Coordinators: Prof. Dr. F. Vardar Sukan, G. Torzillo, Researchers: S. Oncel, E. Imamoğlu, C. Faraloni, Consultant: Prof.Dr. M. Elibol (2012-2014.)
- Development of Enzymes and Microorganisms for Efficient Hydrolysis of Agricultural Wastes and Lignocellulosic Raw Materials. (TÜBİTAK 1003-113O123, 2013-2016 Coordinator Assoc.Prof. Dr. Y. Öztürk.)
SUBTASK C (LIGHT-DRIVEN BIOHYDROGEN PRODUCTION)

Reported by Turkey

Bio-Hydrogen Production with Immobilized photofermentative bacteria: A novel entrapment material, LentiKat®, used for entrapment of new isolates and magnetic particles, was used for biofilm formation surface. Even at low HRT conditions higher biomass concentrations were achieved in reactors and at 18 hours HRT 0.69 mmol/L/h production rate was observed (which is 60% of the theoretical value) by LentiKat® entrapment method.

Photosynthetic Hydrogen Production on Sucrose and Molasses: Several sustainable and renewable substrates like sugar beet molasses and waste barley are being investigated for both bioHydrogen and high value added compound productions in a biorefinery concept.

Photobiological hydrogen production on pure sucrose and sucrose-rich sugar beet molasses has been conducted using different strains of PNSB, on different initial substrate concentrations.

Transcriptomic and Proteomic Analysis of Hydrogen Production Rhodobacter capsulatus at Different Conditions: the photofermentative hydrogen production is significantly affected by conditions such as temperature, type and concentration of the carbon and nitrogen source in the medium. For a deeper understanding of the effects of these conditions at the cellular level, transcriptomic analysis has been carried out in PNS bacterium R. capsulatus.

Evolutionary Engineering of Rhodobacter capsulatus: To overcome the temperature fluctuations problem of outdoor closed photobioreactors, temperature-resistant mutants (up to 42°C) of R. capsulatus were generated by a directed evolution approach. Eleven mutant strains of R. capsulatus DSM 1710 were obtained by initial ethyl methane sulfonate (EMS) mutagenesis of the wild-type strain, followed by batch selection at gradually increasing temperatures up to 42°C under respiratory conditions.

Modeling and simulation of photobioreactors for biological hydrogen production: Outdoor production of hydrogen using photosynthetic bacteria is strongly influenced by fluctuations in temperature and light intensity, which vary seasonally and according to the geographic locations. In order to forecast hydrogen productivity and estimate its cost-effectiveness, models describing the dependency of hydrogen production on the natural parameters have been developed.

Imperial College London: Process and reactor design for biophotolytic hydrogen production. (Tamburic, B., Dechatiwongse, P., Zemichael, F.W., Maitland, G.C.,

Figure 3. Flat plate photo bioreactor design developed by researchers at Imperial College London.

The research described here concerned the optimization of biophotolytic hydrogen production. In this research biophotolysis is carried out by photosynthetic microbes under of the species Chlamydomonas reinhardtii (a type of green algae) under sulphur limited conditions.

Researchers sought to develop a practical and scalable hydrogen production technology based on a flat plate photobioreactor design (Figure 3). Several process design parameters were evaluated including sulphur feeding and dilution regimes to encourage both algal growth and photolytic hydrogen production. Continuous operation of a hydrogen-producing photobioreactor was demonstrated at laboratory scale with production rates and yields of 1.52 ml H$_2$ l$^{-1}$ h$^{-1}$ and 119.8 ml H$_2$ l$^{-1}$ h$^{-1}$ respectively. Based on these findings, researchers presented a conceptual design for a scaled up semi-continuous photobioreactor. Currently, the process is susceptible to changes in algal metabolism which over time affect the stability of the bioreactor. Researchers believe that these limitations will ultimately be overcome by genetic engineering of the algae together with novel engineering approaches to improve process efficiency.

SUBTASK D (INTEGRATION OF BIO-INSPIRED AND PHOTO-ELECTROCHEMICAL HYDROGEN SYSTEMS)

Reported by Sweden

Currently the successful sequencing of eight Frankia genomes showed that the genomes were of different sizes in Frankia, which revealing a relationship between genome size and geographical distribution. The Frankia bacteria are GC-rich soil organisms with the ability to fix nitrogen in free-living conditions as well as in symbiosis. During nitrogen fixation by Frankia where atmospheric nitrogen is converted to ammonia, hydrogen is produced and, in the absence of an uptake hydrogenase, the hydrogen production can be measured (Sellsyedt and Richau, 2013). Our results showed that in Frankia strain ACN14a, the expression patterns of the large (HupL1) and small (HupS1) uptake hydrogenase subunits
depend on the abundance of oxygen in the external environment. The structural models of the membrane-bound hydrogenase subunits of ACN14a showed that both subunits can resemble the structures of known [NiFe] hydrogenases (Richau et al., 2013).

Photosystem II: They have continued to characterize the substrate water binding sites in photosystem II by time-resolved membrane inlet mass spectrometry (TR-MIMS) and by electron double resonance detected NMR spectroscopy (EDNMR). Both techniques involve rapid labeling with either H$_2^{18}$O (TR-MIMS) or H$_2^{17}$O (EDNMR). These experiments allowed the identification of the binding site of the slow substrate water as one of the bridging oxygen’s (O$_5$ in the Umena et al structure).

The team that established the free-electron X-ray laser as a tool in photosynthesis research has successfully developed the required technology and demonstrated the feasibility of the experiments. Now improvements in resolution will be required to reach the final goal, which is the structure determination of reaction intermediates during photosynthetic water oxidation. Together these data narrow significantly the options for mechanistic proposals, so it’s expected that mechanism of water oxidation will be established completely within the next few years.

Artificial Photosynthesis: The artificial Leaf and Solar Fuels projects have been started up successfully by recruiting postdocs and PhD students, and by establishing structures for the interactions between all partners involved. Experiments have been started up, and first data are close to publication in some of the subgroups.

Sweden has concluded that metabolic and genetic engineering of native cyanobacterial hydrogen metabolism can significantly increase hydrogen production. Introduction of custom-designed non-native capacities opens up new possibilities to further enhance cyanobacterial-based hydrogen production (Khetkorn et al. 2013). They have also found a new valuable production route that indicated potential for green microalgae to produce hydrogen, pharmaceuticals and other high value products in a combined process (Skjanes et al. 2013).

Sweden has reported on the development of engineered TetR-regulated promoters with a wide dynamic range of transcriptional regulations. An optimal 239 (±16) fold induction in darkness (white-light-activated heterotrophic growth, 24 h) and an optimal 290 (±93) fold induction in red light (photoautotrophic growth, 48 h) were observed with the L03 promoter in cells of the unicellular cyanobacterium Synechocystis sp. strain ATCC27184 (i.e., glucose-tolerant Synechocystis sp. strain PCC 6803). By altering only few bases of the promoter in the narrow region between the -10 element and transcription start site, significant changes in the promoter strengths, and consequently in the range of regulations, were observed. It is concluded that the non-native inducible promoters developed are ready to be used to further explore the notion of custom designed cyanobacterial cells in the complementary frameworks of metabolic engineering and synthetic biology (Huang and Lindblad, 2013).

Sweden has overexpressed, isolated, and characterized the small subunit of the cyanobacterium Nostoc punctiforme (Raleiras et al. 2013).
SUBTASK E (ENVIRONMENTAL AND ECONOMICAL FEASIBILITY)

Reported by Japan (Subtask Leader)

For the discussion of the application of bioHydrogen, a large regional scientific meeting for bioHydrogen, ABHL2013, was held in Osaka Japan (Chair J. Miyake, Osaka), during Nov 22-24, 2013 by Asia BioHydrogenLink (ABHL) and attended by 150 researchers from Asian countries (50 from Japan, 30 from China, 30 from Taiwan, 12 from Thailand, and more Korea, Hong Kong, Singapore, Turkey, etc). Two kinds of special issues are going to be published in regular journals. The first significant fact noted about the meeting was the increasing number of researchers in Asia, and the second is the expansion of the field covering the community-based bio/eco/safety system. In the meeting, Japanese Ministry of Economy, Trade and Industry presented a Smart-City project which included the possible use of bio-renewable energy. Decentralized energy supply is suitable for bioenergy application. This is especially true of bioHydrogen due to its flexibility (solar-biomass-hydrogen-electricity-chemical).

Reported by UK

Life cycle assessment of bioHydrogen and biomethane production and utilization as a vehicle fuel (Patterson, T., Esteves, S., Dinsdale, R., Guwy, A., Maddy, J., 2013. Life cycle assessment of bioHydrogen and biomethane production and utilisation as a vehicle fuel. (Bioresource Technology 131, 235–245.)

Researchers undertook a lifecycle analysis of two experimental systems producing biomethane and bioHydrogen from biomass. The single-phase digestion system producing solely methane was compared with the two-phase digestion system producing hydrogen and methane sequentially. These digestion systems were evaluated using two different substrates, food waste and flour milling co-product (wheat feed). The environmental burden of using the biogas produced from these substrates as vehicular transport fuel...
formed the basis of comparison. In the case of food waste a high hydrogen yield (84.2 l H₂ kg⁻¹ VS) with lower energy output was obtained when using two-stage system, and the diversion of food waste from landfill prove that the environmental burdens of this process compared favorably with diesel. When wheat feed was used as a substrate, lower energy yields were obtained (7.5 l H₂ kg⁻¹ VS) but a higher energy output was observed. The resulting process efficiencies meant that this form of digestion had lower CO₂ burdens when compared with diesel. Researchers concluded that, in particular, two-stage fermentation is an attractive use of wheat feed for energy production, if process efficiencies can be maintained at full scale.

Newcastle University: Fueling the future, researchers at Newcastle University revealed that they have carried out the first trials of a microbial electrolysis cell at a sewage treatment that works in Tyneside. The MEC converts organic material in the sewage to hydrogen using anaerobic microorganisms. The research was funded by the Engineering and Physical Sciences Research Council (EPSRC). The team at Newcastle headed by Professor Tom Curtis is now planning to install the next generation of the device at a sewage treatment that works in County Durham.

**OTHER ACTIVITIES**

**INTERNATIONAL COOPERATIONS**

Imperial College London: *UK and Korea sign agreement today to advance fuel cell technology*

Professor James Stirling, of Imperial College London, and Professor Taihyun Chang, Executive Vice President of Pohang University of Science and Technology in Korea, signed a ‘Memorandum of Understanding’ which facilitates collaboration of fuel cell development between the UK and Korea. The Energy Futures Lab (EFL) at Imperial College is headed by Professor Nigel Brandon and leads Hydrogen and Fuel Cell SUPERGEN Hub (H2FC SUPERGEN) which will play an important role in the planned collaborative research. The partnership builds on a history of collaboration between the UK and Korea involving companies such as Ceres Power, K D Navien, Rolls-Royce Fuel Cells Systems, and the Korean manufacturer LG.

**Book Publications:**

A book for bioHydrogen should be published in Germany (Editor M. Roegner et al.).

Three books in the field of bioHydrogen are under edition in Japan (Editor J. Miyake et al).

Special issue on BioHydrogen of International Journal of Hydrogen Energy (IJHE) is going to be published for Asia BioHyLink (ABHL) 2013 (Editor J. Miyake et al).

**New Projects**

In EU, “CyanoFactory,” a recently started (Dec 1, 2012) EU-FP7/Energy project with 10 partners from seven countries. CyanoFactory is coordinated by Peter Lindblad, Uppsala University (Sweden).

In Japan, the CyanoFactory project was also launched in 2012 as a part of CREST/JST (the main project name is “Creation of Basic Technology for Improved Bioenergy Production through Functional Analysis and Regulation of Algae and Other Aquatic Microorganisms,” led by Prof. T. Matsunaga of TUAT).
## RELATED PUBLICATIONS

Task 21 Article Publication Table

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The complete list of publications may be found on the IEA HIA website ([www.ieahia.org](http://www.ieahia.org)) under Task 21.