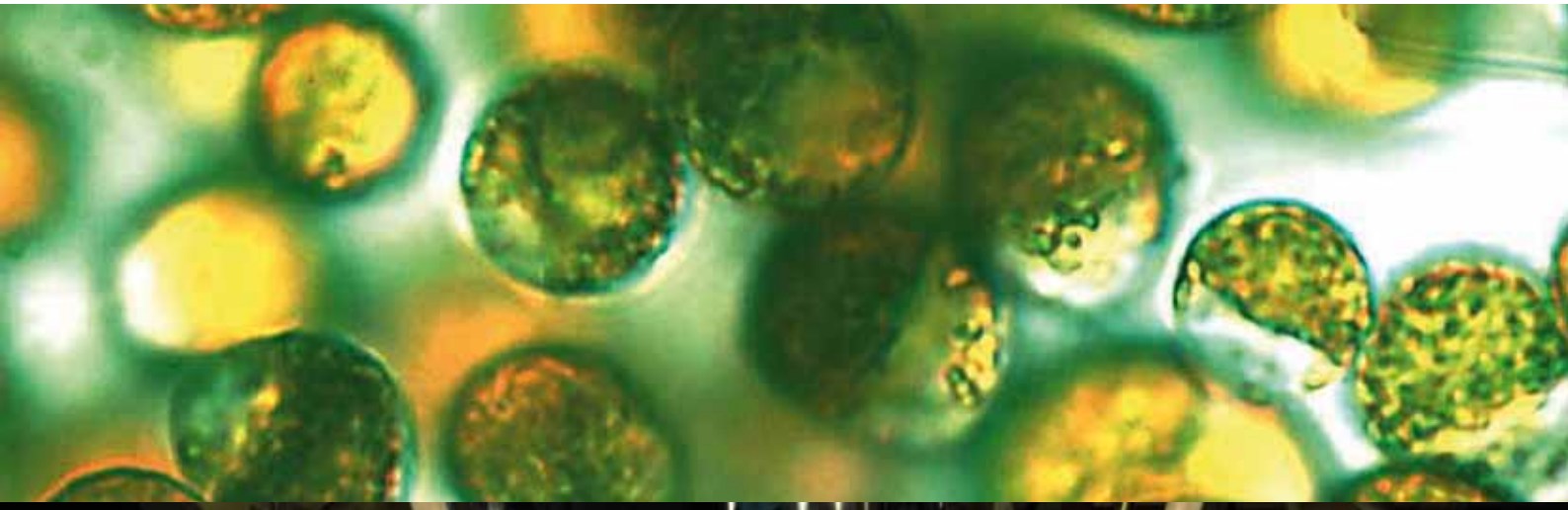
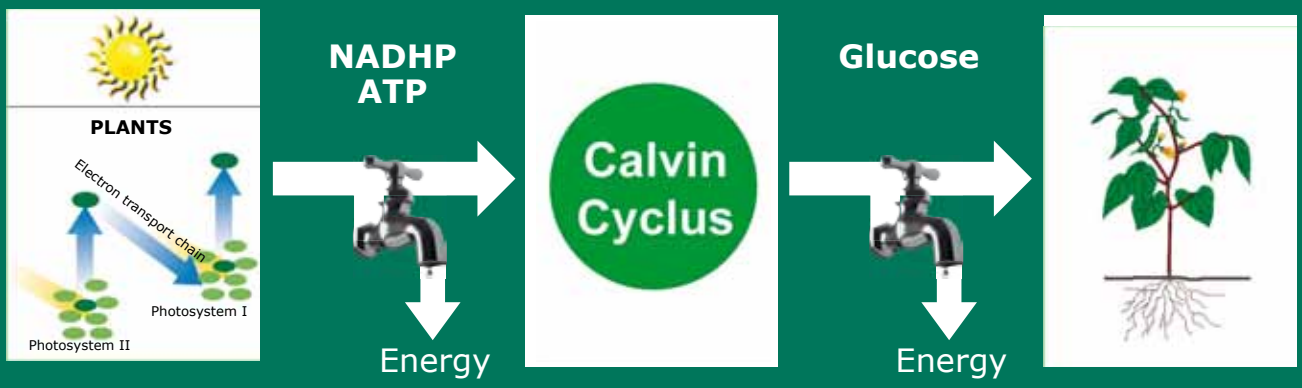
The BioSolar Cells project

Sustainable energy from photosynthesis



BioSolar Cells

Photosynthesis is a complex process that occurs in many variations. The BioSolar Cells Project initiative aims to specifically use this diversity to improve this process and enhance its potential as a source of energy, biomass, feed and food.



Energy

The world faces a rapidly increasing demand for sustainable energy. Man-caused changes that threaten the climate, together with oilsupplies that eventually will run short, forces us to rely on alternative biomass sources for products that now originate from oil. First and second generation biofuels cannot fulfill this need in a sustainable and societal acceptable manner. In addition, the world faces the challenge to increase agricultural production to adequately feed an increasing world population. Since the possibilities to increase the agricultural acreage are limited, this largely must be accomplished by improving the landproductivity.
The largest option available is the sun and it is our challenge to make the most of this incredible resource. While solar power currently revolves primarily around the application of photovoltaic cells, new options are available with photobiological cells or BioSolar Cells. These have various benefits:

- Production of these cells is in principle inexpensive;
- The biological materials used are not rare;
- The cells can produce liquid fuels directly.

An additional advantage is that BioSolar Cells can capture the greenhouse gas CO_2.

Photosynthesis

Photosynthesis is the key processes on this planet - the foundation for all (fossil) energy and therefore for life. Less well known is that photosynthesis is an enormous diverse process that occurs in many different organisms. This means that there is a great deal of biological variation that can be explicitly deployed to improve photosynthesis.

What are BioSolar Cells?

BioSolar Cells are natural systems or systems based on natural processes that use photosynthesis to convert sunlight into useable energy. This occurs in many ways, and the BioSolar Cells Project focuses on three options:

1 Increasing the photosynthetic efficiency of plants
Outcome: More biomass and higher yields per given surface area.
2 Direct production of fuels, bypassing the biomass phase. Outcome: Photosynthetic cyanobacteria or algae that produce butanol, for example.
3 Combining natural and technological components. Outcome: 'Artificial Leaves' that highly efficiently produce hydrogen gas or syn-gas from solar energy.

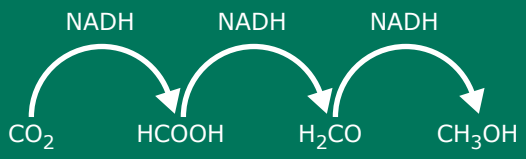
Results

There are many possible results. One example is the development of high production plants that are used for both food and feed. Another is the cultivation of micro-organisms on large patches of land or (sea) water that are currently unusable for biofuel production. And then there is the development of solar collectors that can refuel our cars at night.
There are already numerous possibilities and some applications are within reach. Further exploration of photosynthesis will result in new, unexpected options. Although true innovations cannot be predicted, they can be guided.

Solar energy
New solar cell

Electrical energy
$H_2O \longrightarrow H^+ + O_2 + e^-$

Chemical energy
$NAD^+ + H^+ \longrightarrow NADH$



Generation of methanol (CH_3OH) from CO_2

Initiators

The Netherlands has a rich tradition in the field of photosynthesis research and excellent research groups in all relevant subsectors. This has created a considerable background of photosynthesis know-how. We now face the challenge of combining and enhancing this knowledge so as to be able to use photosynthesis for sustainable energy supplies and for securing food production. Driven by the social relevance and scientific possibilities, a number of authoritative Dutch research groups decided to join forces in the BioSolar Cells Project:

- Wageningen UR (University & Research centre)
- Leiden University
- VU University Amsterdam
- University of Groningen
- Delft University of Technology
- University of Amsterdam

Public-private

The BioSolar Cells Project is a joint initiative of companies and knowledge institutions, supported by the Dutch government. The programme will last five years and has a total budget of 42 million euro. Companies and knowledge institutions will account for 17 million euro, whereas the government contributes the remaining 25 million euro.

Participating knowledge institutes
Plant Research International, part of Wageningen UR
Wageningen UR Food & Biobased Research
Wageningen University, part of Wageningen UR
University of Groningen
Delft University of Technology
Eindhoven University of Technology
University of Amsterdam
Leiden University
University of Twente
VU University Amsterdam
HAS Den Bosch

Room for new partners

The *BioSolar Cells Project* aims to bring together key-expertise in the photosynthesis sector and is always on the lookout for new partners and ideas. The participation of leading knowledge institutions and companies guarantees constant renewal and the utilisation thereof. We invite all national and international organisations that believe they can contribute to the project's success to contact us and join the project.

Information

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Participating companies
BASF Antwerpen N.V.
Bioclear B.V.
Biomethanol Chemie Nederland B.V.
Bruker Nederland B.V.
Drie Wilgen Development B.V.
DSM
ExxonMobil Research and Engineering Company
GEA Mechanical Equipment
Heliae Development LLC
Lionix B.V.
Neste Oil
Nijhuis Water Technology B.V.
Paques B.V.
Philips Electronic Nederland B.V.
Plant Dynamics B.V.
Proces-Groningen B.V.
Proviron Holding N.V.
Pursuit Dynamics PLC
Roquette Freres S.A.
Saudi Basic Industries Corporation
Simris Alg AB
Staatsolie Maatschappij Suriname N.V.
Stichting Waag Society
Synthetic Genomics Incorporated
Total
Unilever Research and Development Vlaardingen B.V.

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- Ministery of Economic Affairs, Agriculture and Innovation
- ALW (NWO Earth and Life Sciences)

Projects within BioSolar Cells	Project leader	University / Institute
Development of supramolecular catalysts	Joost Reek	University of Amsterdam
Development of fast, efficient and device compatible antenna	Ernst Sudhölter	Delft University of Technology
Development of device compatible charge separators.	Romano Orru	VU University Amsterdam
Functional assessment and characterization of artificial photosynthetic systems with time-resolved spectroscopy and spectroelectrochemistry	John Kennis/ Raoul Frese	VU University Amsterdam
Solid state NMR analyses of PCET and catalysis	Huub de Groot	Leiden University
Development of semiconductor tandem junctions and photocatalytic devices	Roel vd Krol/ Marc Koper	Leiden University
Characterization and predictive modeling of nanodevice components	Huub de Groot	Leiden University
BIOCOMET: Using Solar cells for the production of methanol from CO_2	Jules Beekwilder	Wageningen UR
S2FC: the Solar to Fuel Chip	Jurriaan Huskens	University of Twente
A Thylakoid Multiscale Engineering Platform	Agur Sevink	Leiden University
Defect engineering at oxide interfaces: Towards efficient ultra-thin absorber films	Roel van de Krol	Delft University of Technology
Nanostructured solar-to-fuel devices	Jurriaan Huskens	University of Twente
Photoelectrochemical water splitting in artificial nanostructured solar converters	René Janssen	Eindhoven University of Technology
Engineering surface electrical fields and charge separation in water-splitting perovskites	Rinke Wijngaarden	VU University Amsterdam
Nanowire solar energy conversion	Jos Haverkort	Eindhoven University of Technology
Photocatalytic water splitting in microfluidic devices	Joost Reek	University of Amsterdam
Selective photoreduction of CO_2 fuels in a microreactor platform	Elisabeth Bouwman	Leiden University
New photosynthetic cell factories for bio-butanol production	Klaas Hellingwerf	University of Amsterdam
Microalgae as photosynthetic cell factories for biofuel production	René Wijffels	Wageningen UR
From proteins to the thylakoid membrane	Rienk van Grondelle	VU University Amsterdam
Growth optimization of diatoms: antenna size of photosynthetic proteins and the role of stress and CO_2	Egbert Boekema	University of Groningen
Harvesting sunlight in a biodegradable polymer: Extracellular production of crystalline cellulose by Cyanobacteria	Klaas Hellingwerf	University of Amsterdam
A complementary photosystem for proton pumping in Synechocystis PCC 6803	Wim de Grip	Leiden University
Algae Pilot Production and Development Centre Research programme: Selection of algae strains based on the comparison of photosynthetic activity in different reactor production units	Maria Barbosa	Wageningen UR
Harvesting sunlight with microorganisms: metabolomics with microcoil fMRI	Huub de Groot	Leiden University
Photosynthesis and growth optimization of cold water diatoms for production of PolyUnsaturated Fatty Acids	Anita Buma	University of Groningen
High efficiency seaweed based photo-bioreactor	Willem Brandenburg	Wageningen UR
Application of on/off modulation and time-separated wavelength tuning for high yield phototrophic growth of the cyanobacterium Synechocystis PCC 6803	Hans Matthijs	University of Amsterdam
Studying the regulation of light harvesting in the green alga Chlamydomonas to improve its productivity under mass culture conditions	Herbert van Amerongen	Wageningen UR
Expanding society's toolbox to harvest solar energy: Creating multi-scale computational models to optimize oxygenic photosynthesis	Klaas Hellingwerf	University of Amsterdam
System-level integration of the process of photosynthesis in vivo. Application to various C3 plants	Jeremy Harbinson	Wageningen UR
Genetic variation in Arabidopsis thaliana of photosynthesis parameters in response to abiotic stress	Mark Aarts	Wageningen UR
Developing heuristic in silico models for C3 photosynthesis integrating electrochemical, biophysical and biochemical processes_	Paul Struik	Wageningen UR
Light Capturing Framework for Biosolar Cells	Gerie vd Heijden	Wageningen UR
Combined physiological and genetic analysis of photosynthetic regulation and plasticity in response to fluctuating environments and abiotic stress	Paul Struik	Wageningen UR
Dynamic LED lighting in greenhouse horticulture: controlling and monitoring photosynthesis, morphology and growth horticulture with LED light	Leo Marcelis	Wageningen UR
Maximizing crop photosynthesis by optimizing growth conditions	Leo Marcelis	Wageningen UR
Floriade Greenhouse	Piet Sonneveld	Wageningen UR
Phenotypic engineering of higher plants: Developing a new paradigm for improving photosynthetic efficiency	Alia	Leiden University
Societal Debates on GM Photosynthesis Research	Bart Gremmen	Wageningen UR
Constraints on large scale implementation of BioSolar Cells;Early-stage Assessment of Environmental Value Propositions (societal debate CML)/scenario building	Gjalt Huppes	Leiden University
Communication on GM Photosynthesis: Experts Reflecting on the Views of Consumers/Citizens	Bart Gremmen	Wageningen UR
Photosynthesis "at" School	Door Jonkers	Wageningen UR
Bachelor class photosynthesis	Jasper den Besten	HAS Den Bosch
Honors class Lorentz Center	Francesco Buda	Leiden University
Photobioreactor design	René Wijffels	Wageningen UR
Research minor	Jan Dekker	VU University Amsterdam
Research minor	Huub de Groot	Leiden University
Research minor	René Wijffels	Wageningen UR
Marie Curie ITN Harvest	Jan Dekker	VU University Amsterdam
Making a field of interpretation for BioSolar Cells	Rob Zwijnenberg/ Huub de Groot	Leiden University