Organic PV Cells, Electricity Collected from Plant Photosynthesis - Feasibility and Demonstration

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Abstract

The main objective of this project is to demonstrate and develop new potential source of natural energy (electricity) by photosynthesis, and directly from living (inedible) plant. The electricity capacity will be evaluated based on various plants nature, and time for sunlight exposure. In this project, a new method for electricity current collection, based on micro-electrophysiology patches "on plant", will be devolved and tested to optimize for the selected plant crop. A new genetic engineered plant, for high quality electricity current release, will be selectively tested and developed for best choice of growing line at in the field. The project combines information science, chemical and electric engineering, microbiology, plant cell and molecular biology, plant breeding, and integrates research with industrial R&D, to develop a novel, sustainable, renewable energy technology. The principle of the breakthrough is a photosynthetic plant extract, incubated in the sunlight, in which a genetically improved electron transport chain (E-chain) linked into a semiconductor element via an electron carrier protein (E-protein) will transport sunlight-excited electrons to generate electricity. The input of the planned system is sunlight, soil and water, while its output is electric power. The by-products, oxygen and hydrogen, will be collected for industrial use, and discharged plant extracts will be transformed to a fertiliser for crop farming. Thus, the project is characterised not only by its innovative technology, but also by its **sustainability** – completely free from any pollutants – and its circular economy. The **scientific outcome** of the project is a new concept and knowledge of solar energy conversion via the E-chain.

State-Of –the-Art and Future Directions

Light energy is cheap, clean, and essentially inexhaustible. With limited supplies of fossil fuel and increasing concern about CO_2 emissions, further development of technologies that make use of solar energy is inevitable. Current silicon-based technologies for the harvesting of solar energy require a very energy-intensive production process and even though they have improved significantly over the years in their efficiency, further development of photosynthesis-based technologies for energy collection is certainly warranted. However, photosynthesis and related processes can be applied to many more areas than just solar energy conversion, and novel designs and applications of light-mediated processes have enormous promise and potential in the next decade and beyond. The goal of the initiative is to capitalize on research progress and ideas in this area, and to more effectively interface academia, where many of the discoveries are made, with the private sector, where such discoveries are worked out further and applied.

Electrons drained from the photosynthetic electron transport chain represent a form of electricity. The technology for draining-off electrons from the photosynthetic chain has long been available in the academic domain. The use of various electron acceptors, characterized by distinct binding sites in the photosynthetic chain, has been extensively exploited in the past to study the process of photosynthesis. Typical, well-characterized compounds capable of accepting electrons are ferricyanide, p-phenylenediamine, silicomolybdate and 3,6 diaminodurol. Methylviologen in particular is known to effectively catalyze the transfer of electrons from a binding site near PS I to the electron acceptor molecular oxygen, in the process regenerating itself. Often these artificial compounds accept electrons from molecular sites that have evolved to accommodate native electrons transport compounds that are an intrinsic part of the electron transport chain. We will take advantage of this capability of the photosynthetic system to transfer electrons to mobile carriers, and we will select the most efficient electron shuttles and study their capability in terms of transferring electrons to electricity conducting elements (**Fig. 5**).

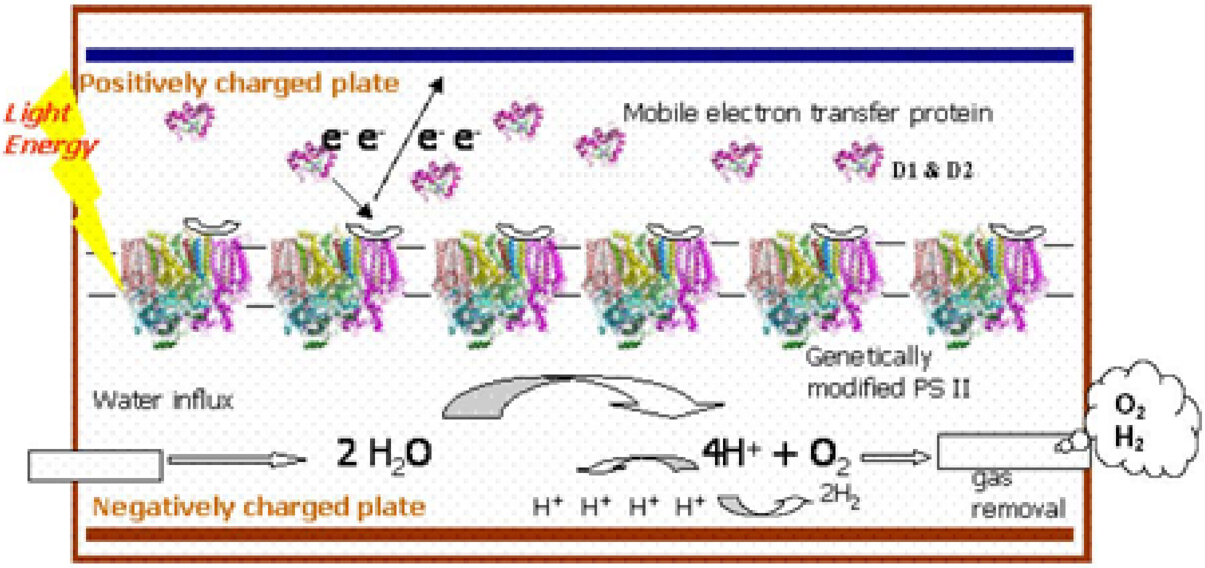

Fig. 5. The design of the artificial system for making electricity connecting leaves cells as PV cells of transgenic plants. Transgenic tobacco plants will be produced in which the thylakoid photosystem II proteins (D1 and D2) will be genetically modified in such a way that a high binding affinity site will be introduced in a closed vicinity to the plastoquinone binding site. A crude thylakoid leaves cells of these plants will be connected in strings between two large electrode patches and supplied also with a high efficient soluble electron carrier protein (E-protein). Upon charging the electrodes and turning on light (which could be sun light) electron transfer will take place between the patches.

The photosynthetic working rate is very different depending on species, light composition (thus climate), and plant health etc. To synthesize a single sucrose molecule, a simple formula of photosynthesis is as following (in which **E** is energy of sunlight):

.(1

$$E + 6CO_2 + 12H_2O \Rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

The energy stored in light establishes a flow of electrons from water (Em = 0.82V) to ferredoxin (Em = -0.42V). Formed NADPH is a strong mobile electron carrier that diffuses freely through the stroma to drive the subsequent reduction of CO_2 into C3-sugars. Some 690 kJ of light energy are required to drive the transfer of a mole pair of electrons from H_2O to NADP+, some 30% of that energy are conserved in NADPH, and a smaller amount as ATP.

The voltage range of such photosynthetic compounds are presented in Table 1:

Table 1. Voltage range of photosynthetic compounds

Oxidized Reduced Number of Electrons			Transferred Redox		Potential (Volts)
X(Fe_4S_4)		X�		1	-0.73
1/2$0_2$	+	H_2	H_20	2	+0.82

Thus, **<u>a potential difference between -0.73 and +0.82 = 1.55 volt in any single step is significantly higher than in any photovoltaic cell available, whose potential difference is about only 0.5 volt per cell.</u>**

From an environmental protection point of view, the proposed renewable energy system will not produce any net CO_2, on the contrary, it will produce oxygen and hydrogen, and both of these gases can be collected and utilized for other energy dependent processes, ending up with a production of water. The exhausted PS II and E-chain extracts will be collected and transformed to a fertilizer that will be used for crop farming (**Fig. 6**). Thus, this system is more environmentally friendly than any chemical energy conversion known nowadays.

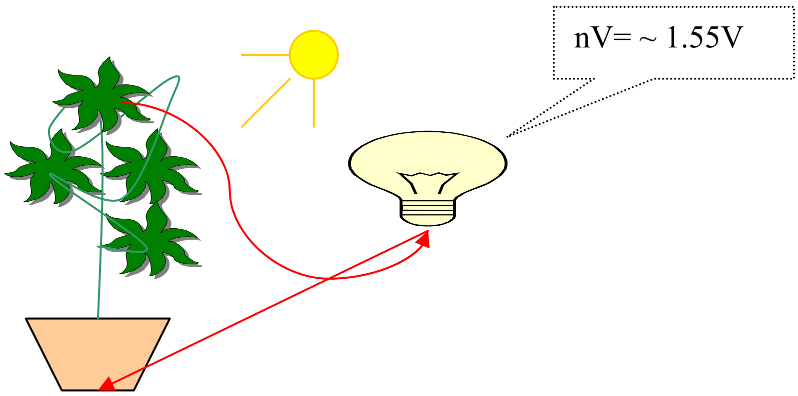

Fig 6. Reuse of exhausted PS II and E-chain as a fertilizer.

If, two units or **n** units leaves or leaves cells or small plants are setting in series (not in parallel…), then the enter crop potential, is accumulating per unit of surface (**patch size)**, per one leave, per one plant and per the entire the plant field or orchard.

.(2

[unit] + [unit] + *n*[unit] = n {Xn x 1.55Volt }

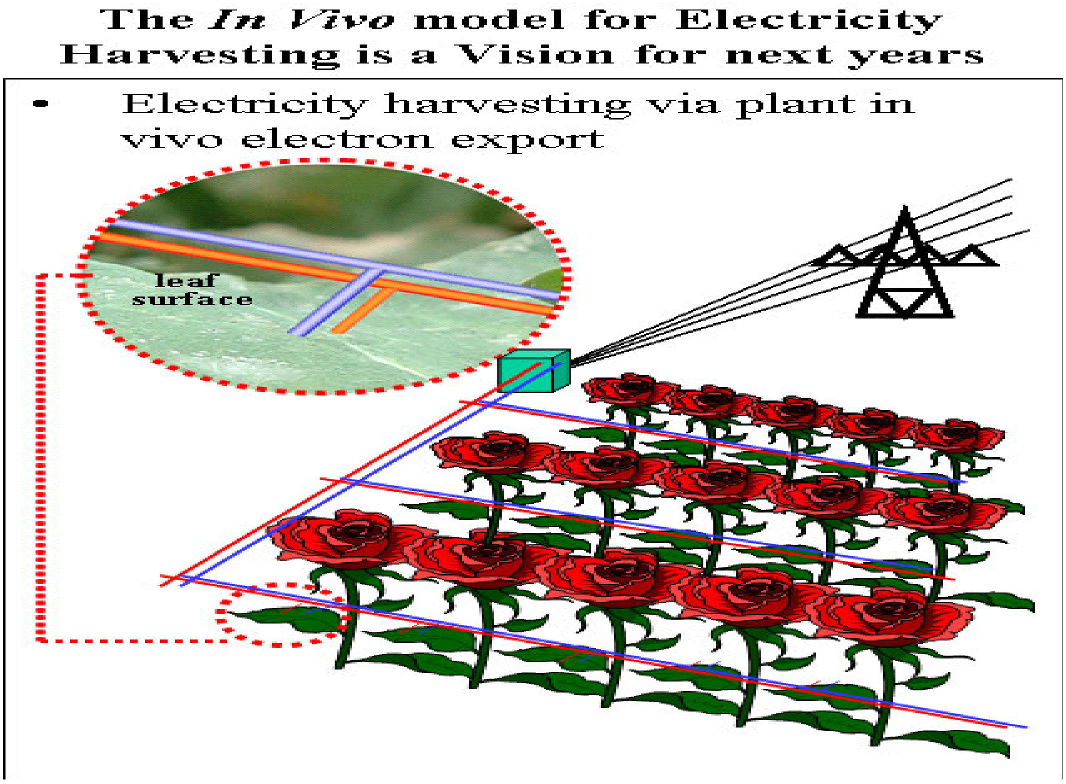

Fig. 7. Energy of tomorrow -in vivo model of electron harvesting plant (EHP) will be the next generation of the present product, in which electricity will be obtained directly from plants in the fields. Knowledge obtained from the present project will be a fundament of the EHP improvement in the future. Plant overall ability to generate energy, so far is based on a spinach plant which is extremely efficient, churning out a lot of energy relative to its size and weight. But combining biological with non-biological materials in one device has stymied researchers in the past. The present project proposed is the first exploitation of biological materials in solar energy conversion in a large scale, cheap and sustainable fashion. However, the success of the project would result in further improvement, i.e., the innovation of a next generation of solar energy excited electron harvesting plant that will target phyto-electron field based on field plant production As (Fig. 7).