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Invited review

Photobiological hydrogen production: Bioenergetics and challenges for its practical application

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ABSTRACT

Photobiological production of hydrogen is considered to be one of the most promising technologies for replacing or complementing fossil fuel-derived energy. This review focuses on the bioenergetics of photobiological hydrogen production by various phototrophs, namely purple non-sulfur bacteria, green sulfur bacteria, cyanobacteria, and green algae. We discuss the improvements in hydrogen production efficiency and the advances in related technologies that are needed before phototrophs can be used for economically-viable hydrogen production. We also discuss some technological aspects such as the cost of nutrients and bioreactors, which should be taken into consideration in designing future plans for the application of photobiological hydrogen production.

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Contents

Abbreviations: BChl, bacteriochlorophyll; Chl, chlorophyll; Fd, ferredoxin; Fld, flavodoxin; FNR, ferredoxin-NADP$^+$ reductase; H_2ase, hydrogenase; N_2ase, nitrogenase; Ndh, NADH dehydrogenase; MQ, menaquinone; MQH_2, menaquinol; pmf, proton-motive force; PNS, purple non-sulfur; PQ, plastoquinone; PQH_2, plastoquinol; PS I, photosystem I; PS II, photosystem II; PTOX, plastoquinol terminal oxidase; RC, reaction center; UQ, ubiquinone; UQH_2, ubiquinol.

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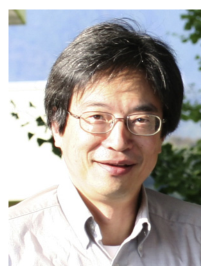

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1. Introduction

The global human population has an acute need for renewable energy sources in order to mitigate the global climate change caused by increasing green-house gases in the atmosphere and to keep up with the dwindling fossil fuel supplies. According to one of the scenarios presented in the Intergovernmental Panel on Climate Change's (IPCC) 4th Assessment Report "Climate Change" [327], in order to mitigate the dangerous effects of anthropogenic warming, we must reduce global CO_2 emission from fossil fuels by about 50% of present levels by 2050. The more economically-advanced countries will be required to achieve more severe reductions. An upcoming 5th Assessment Report by the IPCC is scheduled to be published in 2014 and will provide more in-depth analyses. In order to achieve the significant reductions of CO_2 emissions called for in the IPCC report, the adoption of large-scale solar energy-based technologies seems to be among the most promising strategies (Table 1) in terms of meeting energy demands.

Considering that our current consumption of fossil fuels is about 20 times greater than our energy derived from foods, we cannot expect much additional energy production from agricultural land-based energy crops. Even if we had additional arable land available to produce energy crops alongside food crops, and energy crops were as productive as food crops in terms of the quantity of available energy, this theoretical energy crop production would meet only 5% of our current fossil fuel energy demand. Therefore, even with new crops grown exclusively for energy production, the amount of energy feasibly produced from our agricultural lands

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