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# Fermentative biohydrogen production: Evaluation of net energy gain

*Karnayakage Rasika J. Perera* [a], *Balachandran Ketheesan* [a], *Venkataramana Gadhamshetty* [b], *Nagamany Nirmalakhandan* [a,*]

[a] *Civil Engineering Department, New Mexico State University, Las Cruces, NM 88011, USA*
[b] *Civil & Environmental Engineering Dept., Rensselaer Polytechnic Institute, Troy, NY 12180, USA*

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ABSTRACT

Most dark fermentation (DF) studies had resorted to above-ambient temperatures to maximize hydrogen yield, without due consideration of the net energy gain. In this study, literature data on fermentative hydrogen production from glucose, sucrose, and organic wastes were compiled to evaluate the benefit of higher fermentation temperatures in terms of net energy gain. This evaluation showed that the improvement in hydrogen yield at higher temperatures is not justified as the net energy gain not only declined with increase of temperature, but also was mostly negative when the fermentation temperature exceeded 25 °C. To maximize the net energy gain of DF, the following two options for recovering additional energy from the end products and to determine the optimal fermentation temperature were evaluated: methane production via anaerobic digestion (AD); and direct electricity production via microbial fuel cells (MFC). Based on net energy gain, it is concluded that DF has to be operated at near-ambient temperatures for the net energy gain to be positive; and DF + MFC can result in higher net energy gain at any temperature than DF or DF + AD.



## 1. Introduction

Rapidly increasing global demand for the limited fossil fuel reserves on one hand, and the need to control greenhouse gas effects due to $CO_2$ emissions from fossil fuel usage on the other, are driving the search for sustainable and carbon-free or carbon-neutral energy carriers for the well-being of future generations. Hydrogen has been identified as a potential substitute for fossil fuels because it has high calorific value, which can be converted to electrical energy at higher efficiencies than current fuel-to-energy conversion technologies. In addition, it is also carbon-free, non-polluting, and recyclable.

Currently, world hydrogen production is around $5 \times 10^6$ N $m^3$, 96% of which is derived from fossil fuels [1] with net negative energy gain. Production of hydrogen, for example, by methane-steam reforming at best yields 2.95 mol $H_2$ per mole of methane, with a negative net energy gain of −16 MJ/kg of $H_2$; production by electrolysis of water using electricity generated by a natural gas-fired combined cycle power plant at best yields 1.37 mol $H_2$ per mole of methane, with a negative net energy gain of −172 MJ/kg of $H_2$ [2]. If hydrogen is to be widely accepted as a sustainable substitute for fossil fuels, it has to be produced from renewable feedstock other than the fossil fuels it is intended to replace via processes with a net positive energy gain.

* *Corresponding author.*
E-mail address: nkhandan@nmsu.edu (N. Nirmalakhandan).
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