Free Energy for the North

Executive Summary

Summary

This is a proposal to implement hydrogen storage and utilization facilities based entirely on renewable energy sources and suitable for northern regions. The technology is based on existing products and has been successfully tested and implemented in Europe.

Background

The promise of hydrogen economy [WP] has been pursued for a number of years as an alternative to fossil fuels [FT]. One roadblock of its realization has been high costs of hydrogen production [RE] and distribution [AF]. However, a recent development from Sweden showed that this does not have to be the case [FW, MN]. It was demonstrated in several pilot projects [AT, PC, PV] that solar energy can be captured in Summer and used during long Winter months [RM, ZS]. The solution is based on using electricity from solar panels to produce hydrogen from excess sun light and then convert it to electricity in fuel cells [FW]. Commercial distributors of the technology are currently based in Europe [BE].

Technologies

This development has become possible through the combination of three existing technologies: renewable energy (wind/solar) [EA], hydrogen storage [HS], and fuel cells [FC]. In particular, PEM fuel cells [PM] are best suited to produce electricity from hydrogen. They can also operate in reverse, producing hydrogen from water. Thus, a single fuel cell unit can produce hydrogen in summer from excess sunlight and produce electricity in winter. The proposed solution alleviates the problem of creating hydrogen distribution infrastructure since all production and utilization of hydrogen happens on the same site.

Compared to a conventional battery storage solution, this technology can be used to mitigate seasonal variation in sunlight since hydrogen can be stored indefinitely. Battery storage time is limited due to an inherent discharge rate which makes long-term storage impractical.

Hydrogen Production and Utilization

Hydrogen can be produced by means of electrolysis [EG]. One way to accomplish this is to run a fuel cell in reverse, that is, by supplying electricity and water and generating hydrogen and oxygen [RF]. There are a number of PEM fuel cell [PM] manufacturers who can supply suitable systems [FM, HC].
Considering fuel utilization and other parasitic losses the efficiency of a fuel cell stack can be around 50%. Commodity fuel cells can be obtained at $4,500 per kW power generated.

Hydrogen Storage

Hydrogen storage systems available today are subdivided into pressurized storage, and material based storage systems [HC, HE, HS]. For the purposes of this project commercially available systems can be used as was already demonstrated in Sweden [HF].

Cost Estimates

Based on commercially available components such as fuel-cell stacks [FM], hydrogen storage [PS], compressor [CO], and electrolyser [HG] a preliminary capital cost estimates for the system can be made for a single household consuming **1.25kW** of energy on the average:

Component	**Price**	**Life span (hrs)**	**Cost per hour**
Fuel cell stack	$7,140.00	40,000.00	$0.18
Hydrogen storage	$28,000.00	438,000.00	$0.06
Compressor	$19,500.00	262,800.00	$0.07
Electrolyser	$3,280.00	40,000.00	$0.08
Solar panels	$12,000.00	219,000.00	$0.05
Misc Mechanical	$3,500.00		
Misc Electrical	$8,000.00		
Installation	$13,000.00		
Total	**$94,420.00**		**$0.45**
Cost per kw-hr			**$0.36**

In these estimates prices of commercially available solar panels [SP], fuel-cell stacks [FS] were used and a 4 months winter season was assumed when the household runs solely on produced hydrogen. In estimating the amount of hydrogen needed it was assumed that the fuel cell stack is operating at 60% efficiency [HZ]. The miscellaneous mechanical and electrical components include valves, gauges, wiring, monitoring and control systems.

It should be noted that these costs can be reduced with a choice of a low-power compressor specifically tuned for a slow operating mode and electrolyser based on non-noble metal catalysts. Another alternative is to operate fuel cells in reversible mode [RF] in which case in which case no electrolyse is necessary. Also with a wider adoption of this technology cost gains can be expected with the economy of scale.

To compare the cost of operating the system with conventional sources an estimate is done of costs per kWh generated which is provided in the last column of the table.
This costs will primarily consist of initial capital expenses spread over the lifetime of various components. Energy costs are zero, since energy is provided by renewable sources (solar, wind). The last row of the table shows the estimates of the costs per 1kWh, which is obtained by dividing the total hourly costs by the power delivered by the system (i.e.1.25kW).
Extra power consumption due to compressor work will result in a 7% increase from the average

of 1.25 kW. This cost was already accounted for by respective increase in hydrogen storage capacity.

Conclusion

The technology is becoming available to provide a cost effective solution for renewable energy systems in northern regions. Cost estimates obtained from commercially available components can be reduced with an expected increase in purchase volume and customization of components for a particular system. Also, a steady progress in fuel cell and electolyser technologies should bring the costs further down. In addition to that, an increasing possibility of monetary penalties for carbon pollution will favor the introduction of zero-emission systems.

Considering the great promise offered by this system and a growing importance of mitigating climate change it is worthwhile to explore this opportunity of implementing on-site hydrogen production and utilization based on renewable energy sources.

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