



HYDROGEN

Enabling The Solar Option

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DISCUSSION TOPICS

- Challenges of investing in hydrogen technologies
- Market opportunities for hydrogen technologies
- Filling the carbon-free energy gap
- Hydrogen - Enabling the Solar Option

ARETÊ HAS BEEN INVESTING IN SOLAR AND HYDROGEN TECHNOLOGIES FOR A LONG TIME

Company

Ballard Power (BLDP)

Proton Energy Systems
(now a unit of DESC)

Hydrogenics (HYGS)

H2Gen Innovations

Angstrom Power

CTP Hydrogen

Astropower (now GE)

Evergreen Solar (ESLR)

Northern Power Systems
(now a unit of DESC)

Technology

PEM FC

PEM electrolyzer, URFC

PEM FC, electrolyzers

SMR, PSA

Micro-FC

MEIC membrane

Silicon film poly-Si PV

String ribbon poly-Si PV

PV and wind system integrator

INVESTMENTS IN ENERGY TECHNOLOGIES ARE ENORMOUSLY CHALLENGING

- Getting to a commercial product always
 - Takes longer, and
 - Costs morethan investors expect
- It is critical to find near-term market opportunities
- Investors -- venture funds or corporations -- must have deep pockets and be very patient

NEAR-TERM MARKET OPPORTUNITIES FOR HYDROGEN TECHNOLOGIES

- Companies bringing new hydrogen technologies to market are looking for opportunities that can generate revenue today, i.e.
 - » Distributed hydrogen generation as an option to traditional merchant hydrogen
 - » Special niche applications, such as
 - Back-up power
 - Generator cooling
 - Laboratory hydrogen
 - Portable power: military, consumer
 - Metal annealing
- Pursuing these types of near-term opportunities helps to position them for large future markets

LONG-TERM MARKET OPPORTUNITIES FOR HYDROGEN TECHNOLOGIES

- Transportation is clearly one -- and it gets most of the attention, but
 - » It always seems to be some time in the future
 - » The near term opportunity is mostly in demonstrations
- Enabling Renewables -- and in particular, Solar -- is less discussed
 - » This is perhaps an even larger opportunity than transportation
 - » It is the topic of this conference, and the rest of my remarks

FILLING THE CARBON-FREE ENERGY GAP

- The slide shown at this point in the presentation was prepared by Argonne National Laboratory, based on data presented in a U.S. National Academy Report:
 - **“Energy and Transportation: Challenges for the Chemical Sciences in the 21st Century”**; The National Academies Press, 2003
- The data presented are being updated and Argonne has asked that the slide not be reproduced -- but they have authorized its being shown to facilitate discussion
- The critical points from the perspective of this presentation are
 - » The World “Carbon-Free Energy Gap” is 17 TW by 2050
 - » Solar Energy offers 600 TW of practically available resource world-wide to fill this gap

H2 ENABLING THE SOLAR OPTION

- At today's prices (\$6-8/watt installed), solar photovoltaics is not an economically viable option to fill the "energy gap" -- incentives are required
- But, at \$1-2/watt installed, solar PV would be the most attractive option
- Getting to \$1-2/watt requires scale in manufacturing -- fully integrated plants producing >1GW/year of PV modules and systems
- Even at that scale, the challenge is immense

H2 ENABLING THE SOLAR OPTION

- 17 TW (17,000,000,000,000 watts) by 2050 means
 - » 1GW (a very large 1000 MW power plant) of new solar power must be installed per day from now to 2050
 - » Today, the production of solar PV is about 1.7 GW per year worldwide -- so this growth rate is a huge challenge

But ...

- The U.S. produces >15 million cars per year, each with a 50kW power plant
 - » This is 750 GW of new power plants/year
 - » Or, about 2 GW per day
 - » So, an industry 1/2 the size of the US auto industry can meet the world's needs for solar to fill the “energy gap”

H2 ENABLING THE SOLAR OPTION...

- Solar photovoltaics alone cannot fill the 17 TW “Energy Gap”
 - » 10 TW at least must include some form of storage
 - » Using solar to produce H₂ is perhaps the most logical option
 - H₂ easily replaces carbon-based fuels in the established energy system
 - And can readily be used to generate electricity at times when there is no sunlight

THE MARKET OPPORTUNITY IS HUGE

<u>Market</u>	2000 - 2050 <u>Approx Size (Trillion \$)</u>
Grid-connected Solar	20 - 30
H2 Generators to enable Solar	15 - 20
H2 in Transportation	10 - 15
	<hr/> \$ 45 - 65 Trillion

SUMMARY

- H2 has an enormous role to play in containing the “Great Warming”
- The long term market opportunity for H2 systems in enabling solar PV is immense
- The H2 and the Solar communities need to work actively together to pursue this opportunity -- this conference is a great start!
- Time is not on our side