



# HYDROGEN

## *Enabling The Solar Option*

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# DISCUSSION TOPICS

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- 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

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## 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

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- 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

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- 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

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- 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

*Where can carbon-free energy come from?*

## Solar

$1.2 \times 10^5$  TW at Earth surface  
600 TW practical

Energy Gap  
17 TW by 2050  
33 TW by 2100

## Wind

2-4 TW extractable

## Tide/Ocean Currents

2 TW gross

## Geothermal

12 TW gross over land  
small fraction recoverable



## Biomass

5-7 TW gross  
all cultivatable  
land not used  
for food

## Hydroelectric

4.6 TW gross  
1.6 TW technically feasible  
0.9 TW economically feasible  
0.6 TW installed capacity

## Nuclear Power

17 TW = 17,000 1-GW reactors

## H2 ENABLING THE SOLAR OPTION

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- 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

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- 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...

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- Solar photovoltaics alone cannot fill the 17 TW “Energy Gap”
  - » 10 TW at least must include some form of storage
  - » Using solar to produce H<sub>2</sub> is perhaps the most logical option
    - H<sub>2</sub> 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

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<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/> <b>\$ 45 - 65 Trillion</b>

# SUMMARY

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- 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