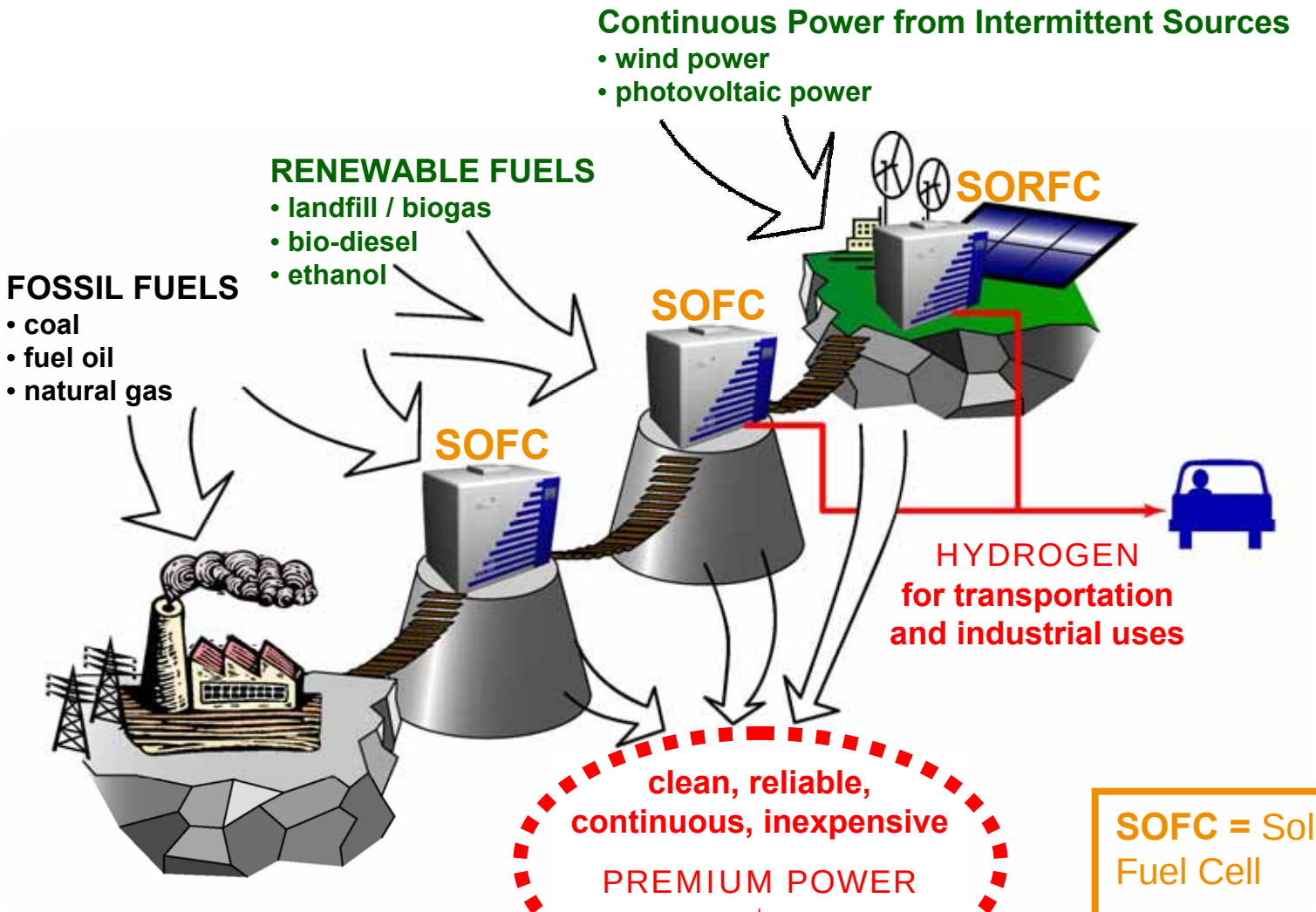
Ion America

a distributed generation company

September 2005

New Energy Vision

A Logical Pathway



SOFC = Solid Oxide Fuel Cell

SORFC = Solid Oxide Regenerative Fuel Cell

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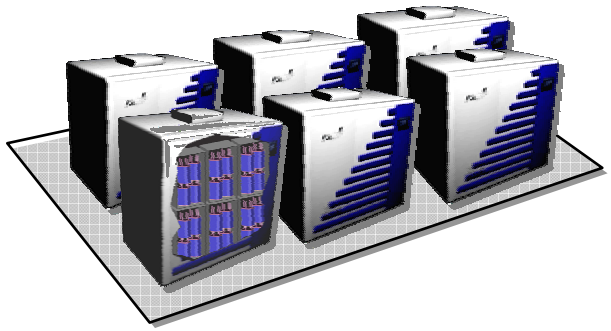
Capabilities – Variety of Inputs/Outputs

Ion America's SOFC generator

Fuel
- Coal-Gas
- Liquid Fuels
- Natural Gas
- Bio-fuels / Ethanol

Ambient Air



SOFC Cluster

Reliable Electric Power

Efficiency 45-60%

High Quality Heat Cooling

Combined Efficiency 80-85%

Hydrogen

Hydrogen is produced within the generator as a result of reforming and water-gas shift reactions

$$C_nH_{2m} + 2nH_2O \rightarrow nCO_2 + (2n+m)H_2$$

(Example: $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$)

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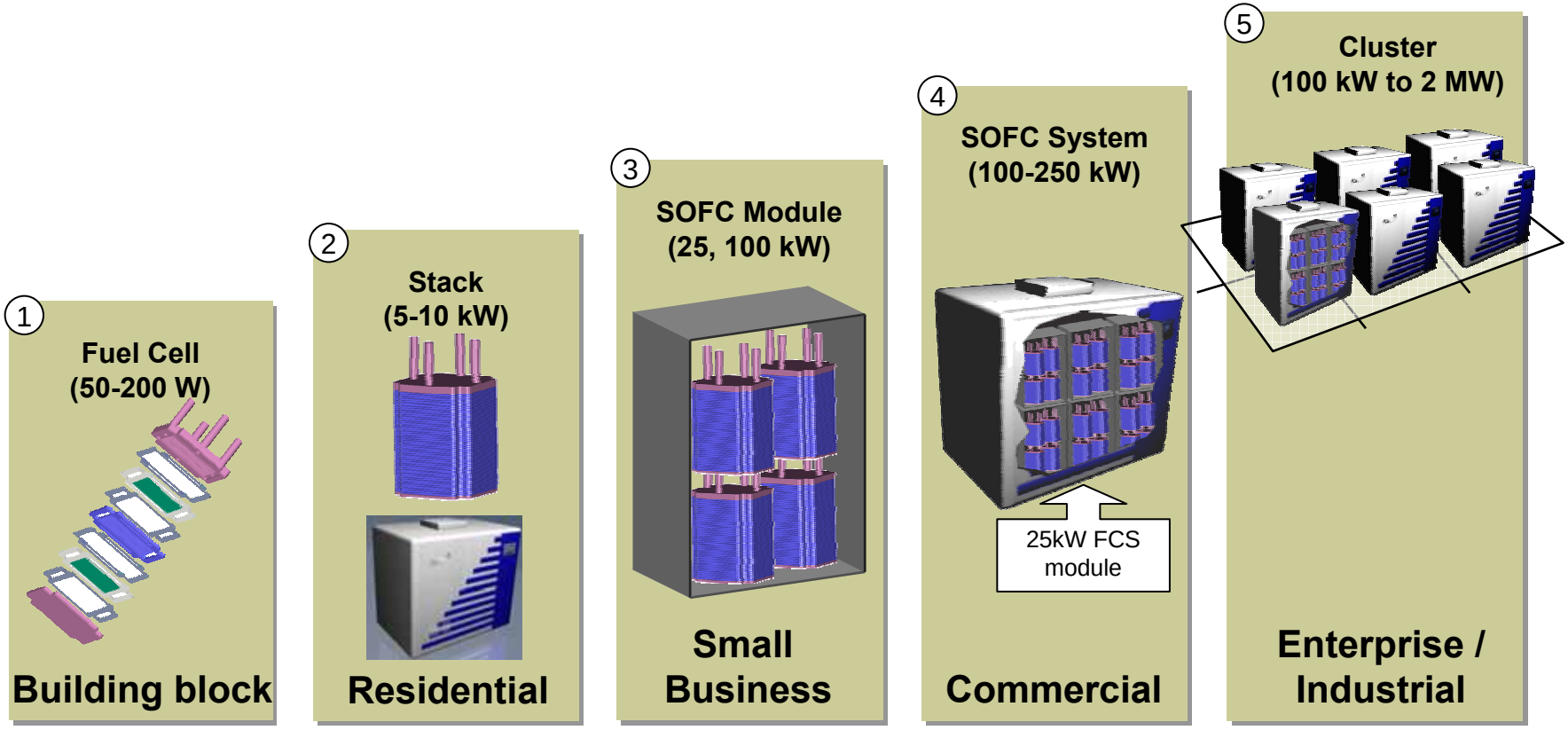
Capabilities – Premium Power

Built in redundancies create a reliable, “always-on” system



- Modularity creates redundancy and reliability.
- Systems are not failure proof but fault tolerant (“always-on”).

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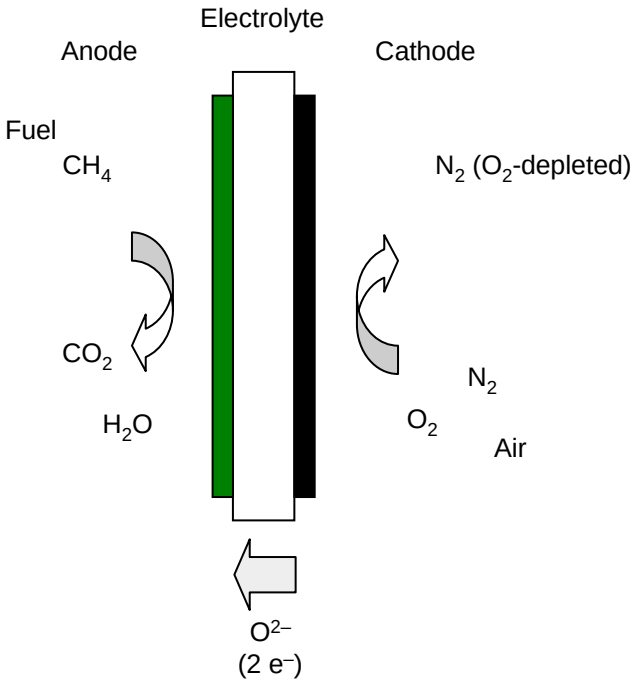
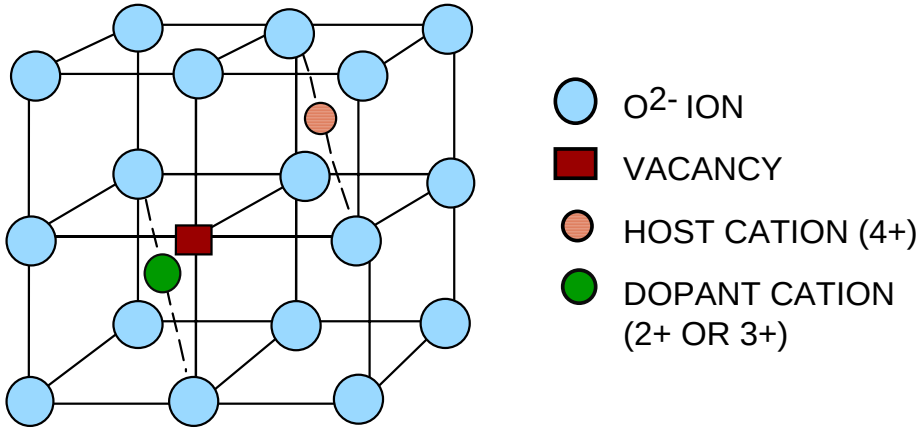
Why SOFC?

Solid Oxide Fuel Cell

Planar Solid Oxide Fuel Cell



Crystal Structure of Stabilized Zirconia Electrolyte



$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + 8e^- + \text{Heat}$$

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Why SOFC?

Solid Oxide Fuel Cell Differentiation

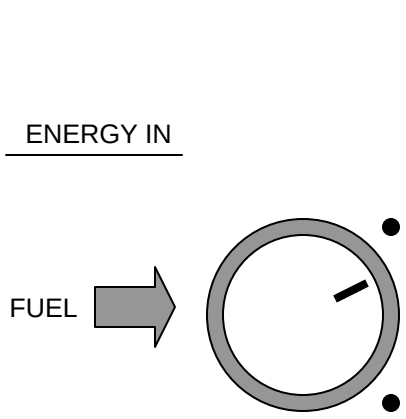
Attribute	PEMFC	SOFC
Charge carrier	Hydrogen	Oxygen (Air)
Fuel Requirements	Requires pure hydrogen • Natural gas must be pre-processed • Carbon Monoxide is a poison	Does not require pure hydrogen • Direct or close-coupled fuel use • Carbon Monoxide is a fuel
Startup Time	Rapid (Well suited for automotive)	Slow (Base-load applications)
System Design	Complex • Management of liquids	Simple • All gas phase
Core Building Blocks	High cost materials • Platinum catalysts	Low cost materials • Zirconia, Nickel Oxide, etc.
Waste Heat	Low temperature (Not useful – liability)	High temperature (Useful - asset)
Efficiency (LHV of natural gas in)	30 - 40%	55 - 60%
Technology Maturity	Medium-high	Low

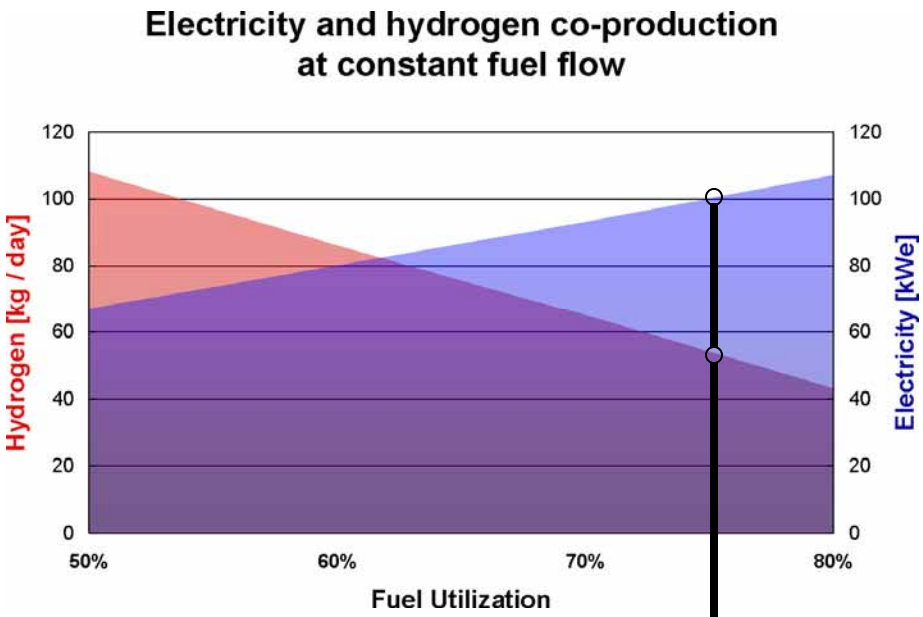
Pollutant / Emission	National Fossil Fuel Average	SOFC
NO_x (lb/MW-hr)	5.1	0.01
So_x (lb/MW-hr)	11.6	0.00
Particulate Matter (lb/MW-hr)	0.27	0.00
CO_2 (lb/MW-hr)	2031	665 - 725

Capabilities – Hydrogen production

Hydrogen and Power Cogeneration

- **Optimum capital utilization: single system capable of electricity and hydrogen co-production**





Example: 100 kWe SOFC generator at 75% fuel utilization

A hydrogen production rate of **50 kg / day** corresponds to

- a gasoline energy equivalent of 47 gallons / day (equal energy basis)
- support for a fleet of 25 fuel cell vehicles

$1.50/kg ~ $1.50/gallon gasoline equivalent

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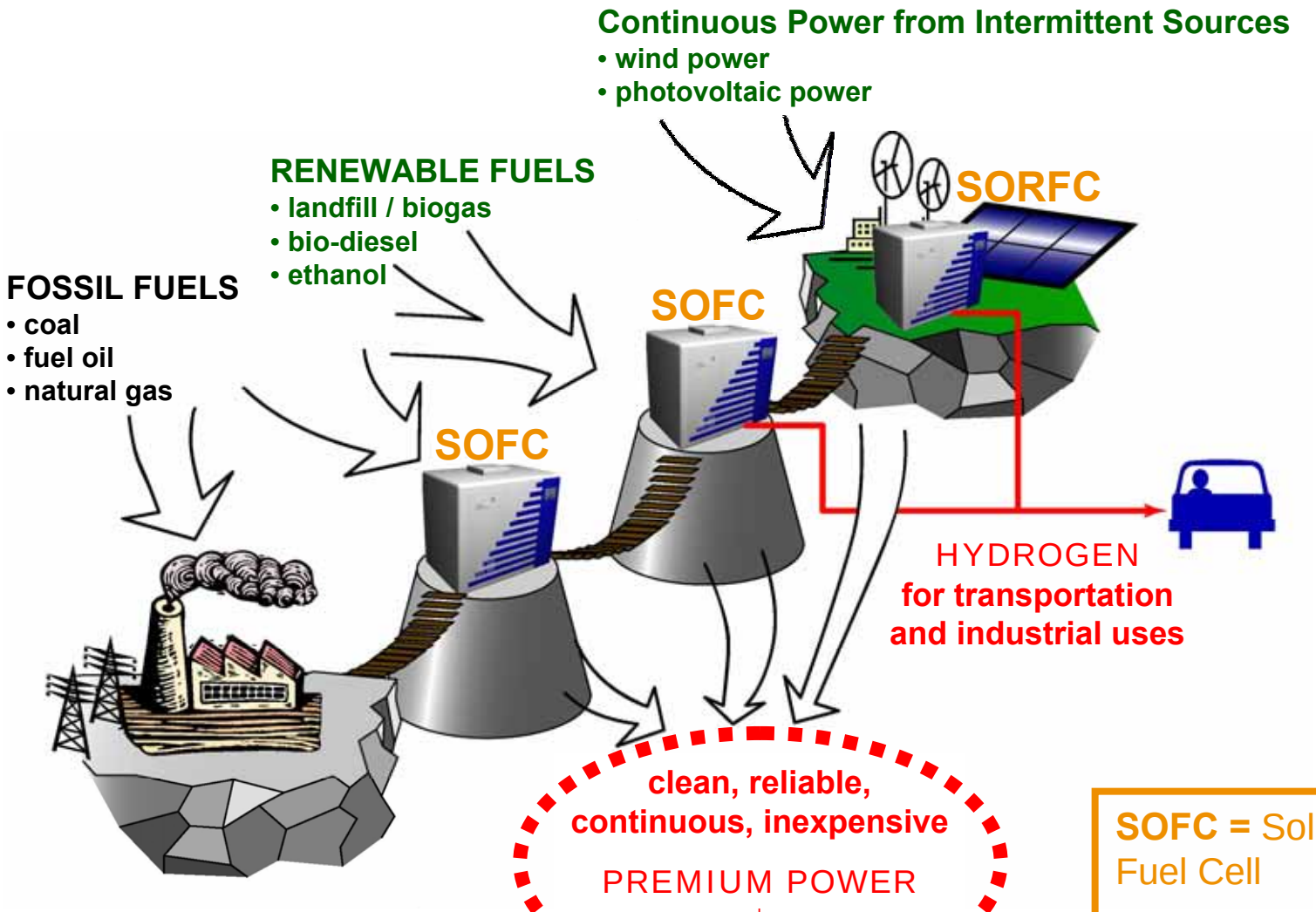

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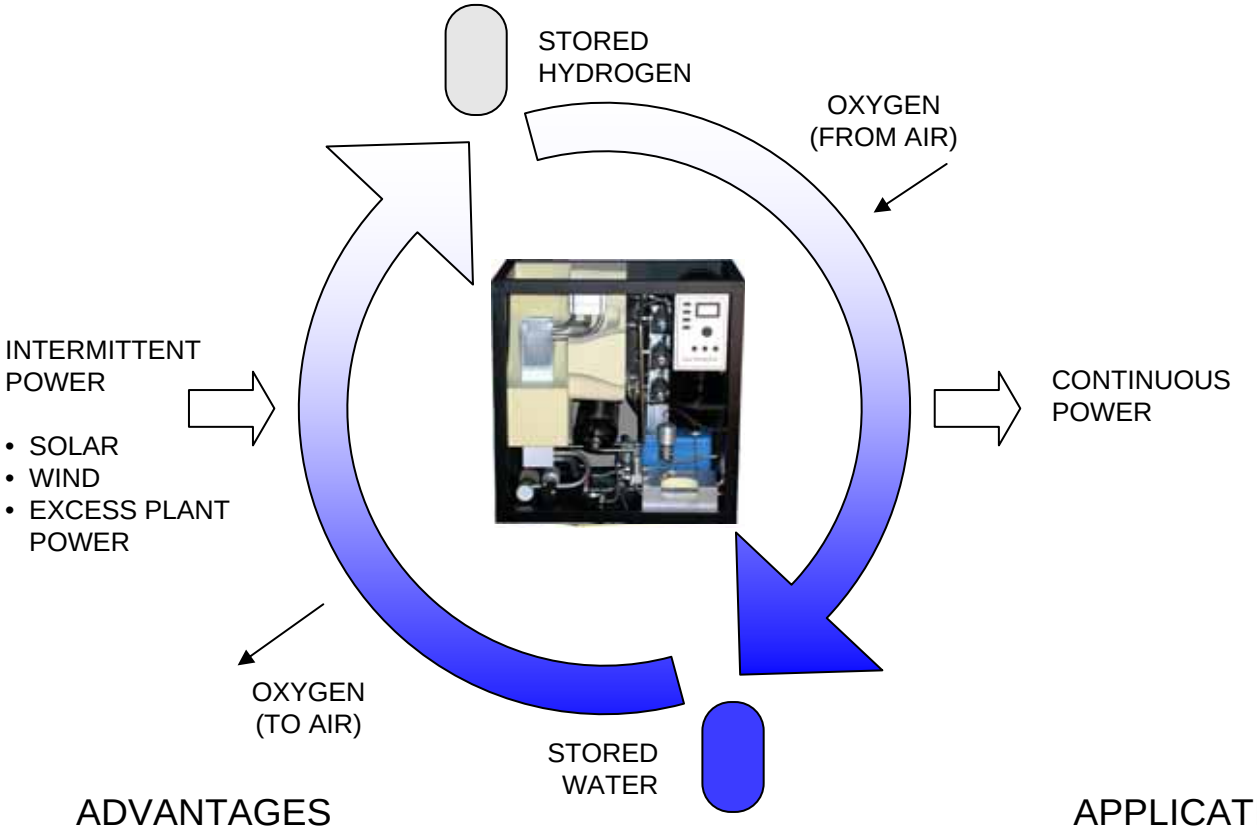
Capabilities - SORFC

Solving the Energy Storage Problem



ADVANTAGES

- High round-trip efficiency.
- Single reversible cell.
- High energy density.
- No oxygen storage required.

APPLICATIONS

- Continuous power from intermittent renewables.
- Peak shaving and load leveling.
- Extends capabilities of T&D systems.
- Coproduction of hydrogen as a commodity.

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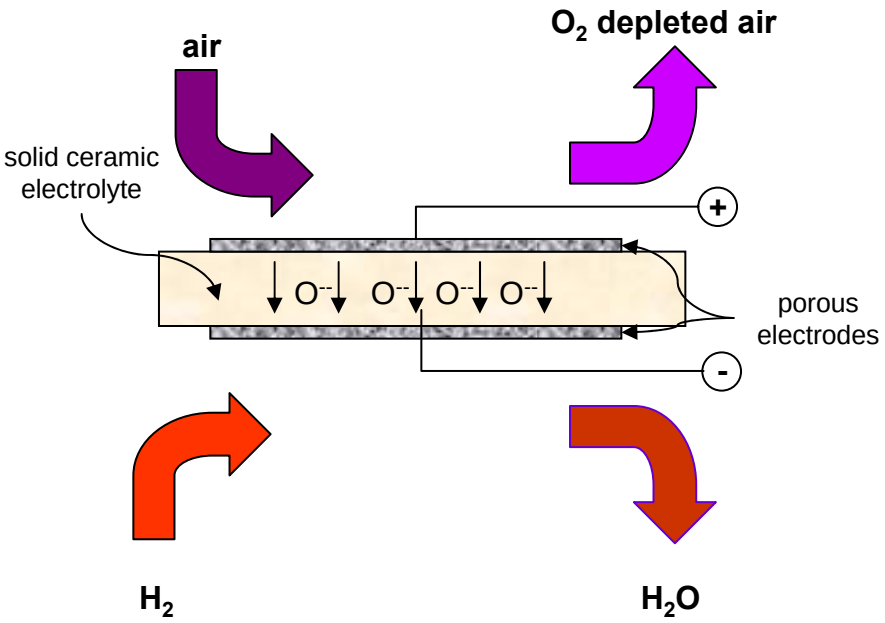
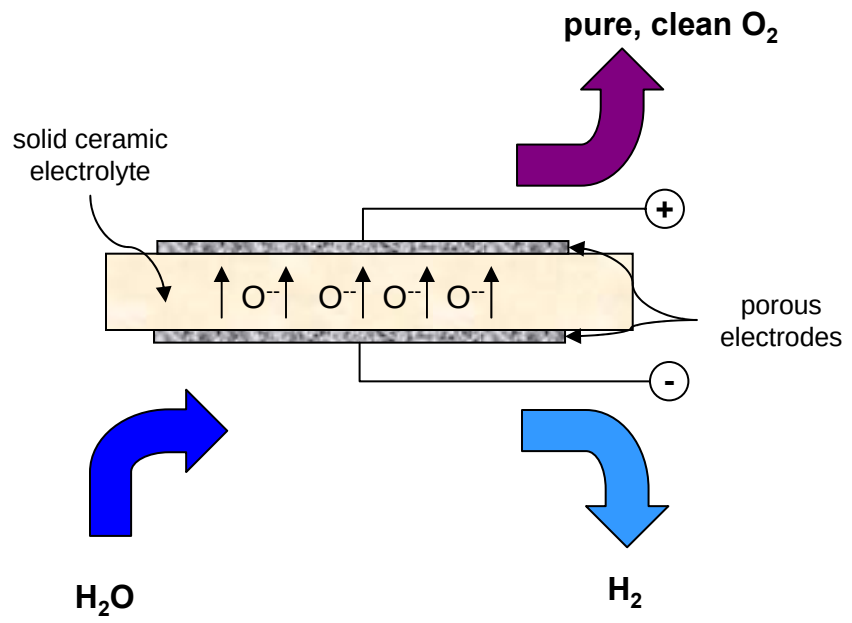
Capabilities - SORFC

Solid Oxide Regenerative Fuel Cell (SORFC)

Solid Oxide Fuel Cell (SOFC) operation



Solid Oxide Electrolyzer Cell (SOEC) or Oxygen Pump operation



- In charge mode the SORFC functions as an electrolyzer and regenerates reactants (e.g., hydrogen and oxygen) from stored products (e.g., water)
- In discharge mode the SORFC functions as a fuel cell which generates electrical energy from reactants (e.g., hydrogen and oxygen from ambient air)

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Capabilities - SORFC

Comparison of SORFC Performance with other Battery Systems

Battery System	Theoretical Specific Energy [Wh/kg]	Packaged Specific Energy [Wh/kg]	Comments
H_2/O_2 RFC	3660	**400-2000**	**RFC with lightweight pressure vessels**
Li-SPE/MO_x	735	**220**	**Novel packaging for unmanned system**
Ag/Zn	450	**200**	**Excess Zn required, low charge rate**
Li/$LiCoO_2$	735	**150**	**Poor cycle life, high capacity fade**
Li/$AlFeS_2$	515	**150**	**≥400°C thermal management**
Na/S	1180	**150**	**~350°C thermal management**
Li/TiS_2	470	**130**	**~50% DOD for high cycle life (900 cycles)**
Li/ion	700	**100 (200)[a]**	**Projection revised September 2005**
Ni/Zn	305	**90**	**Excess Zn required, low specific energy**
Ni/MH_x	470	**70 (90)[b]**	**Projection revised September 2005**
Ni/H_2	470	**60**	**Low specific energy**
Ni/Cd	240	**60**	**Low specific energy**
Pb/acid	170	**50**	**Low specific energy**

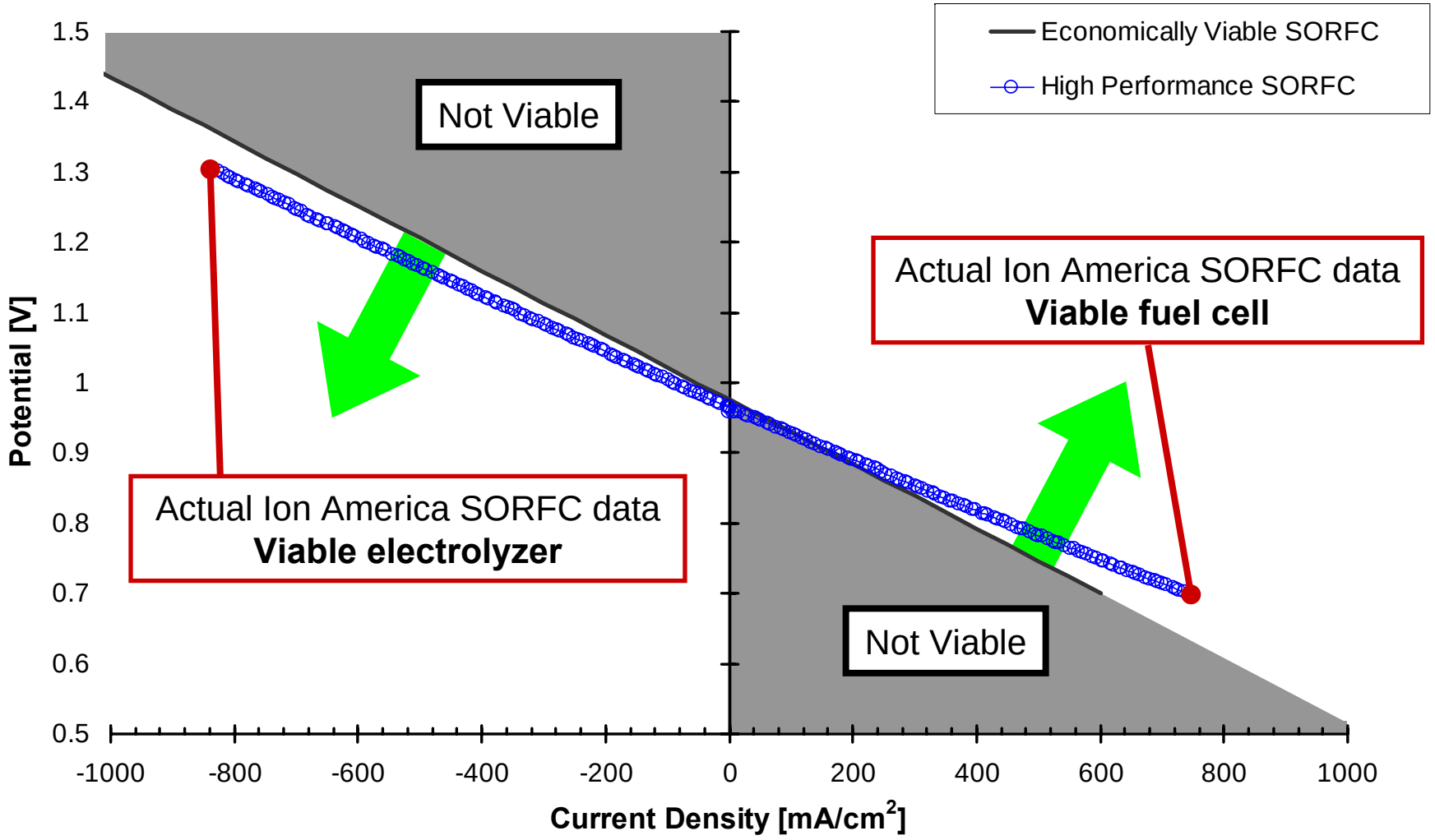
Survey by A.D. Little, Inc., July 1993 for LLNL, excluding RFCs

[a] Projection revised September 2005 (J. Gleeson)

[b] Projection revised September 2005 (DoE/EERE)

Capabilities - SORFC

High Performance SORFC Exceeds Economically Viable Performance



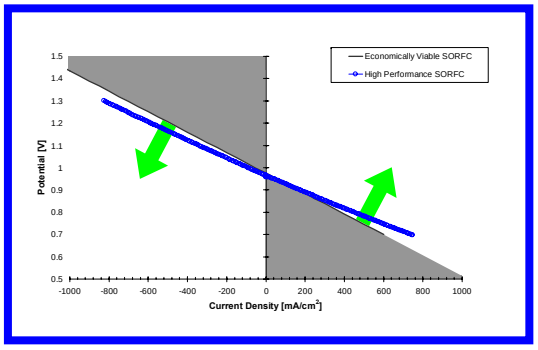
Capabilities - SORFC

Method for Calculating SORFC Economic Viability

Inputs: - SORFC operating characteristics
- Duty cycle and application scenarios

Model: - Iterative calculations
- DOE cost of hydrogen target constraint

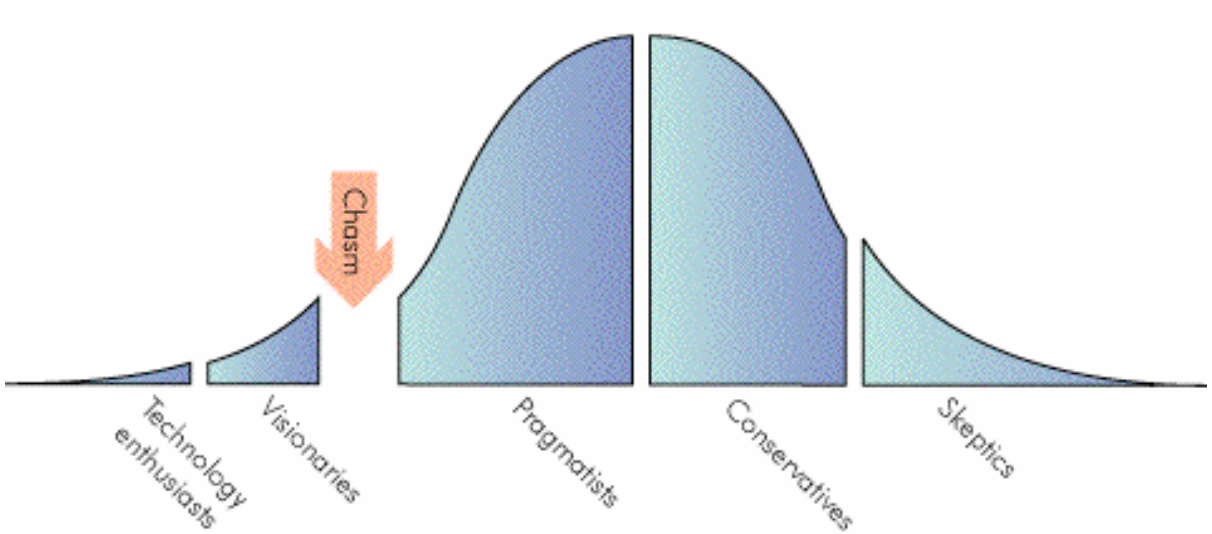
Output: - SORFC V-I curve required for economic viability



Bringing New Solutions to the Market

The Venture Capital Model

- Mainstream Venture Capitalists have recently begun making investments in new energy technology companies, with the hopes of making an impact as they have in :
  - Telecom
  - Biotech
  - Semiconductors
  - Internet
  - Software
- Unlike these industries, however, new energy technologies face special policy and regulation challenges.
- New energy technologies are similar in that they also face the problem of “crossing the chasm”:



The key question is now to initiate widespread market adoption for a new-to-the-world technology?

Bringing New Solutions to the Market

An Alternative Solution

Existing Model

Gov't funded basic science research

R&D in large companies funded by gov't

National labs and academia

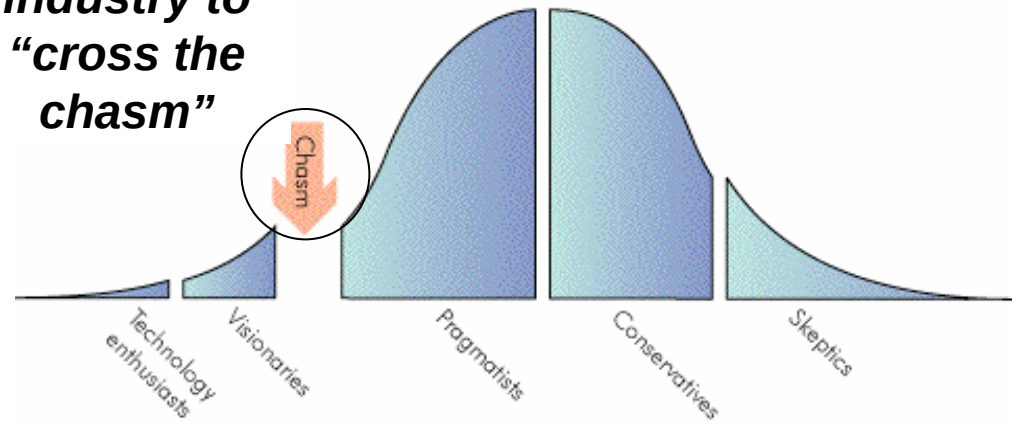
Gov't is attempting to pick winners and losers

Our Recommendation

Gov't funded basic science research

R, D & E to commercialize products of social value, funded by private capital (or internal corporate R&D dollars)

Gov't helps industry to "cross the chasm"



Bringing New Solutions to the Market

How Government Can Help: Recommendations

Government as an early adopter / buyer of new energy technologies:

- Customer that has traditionally functioned effectively as an early adopter
- Process to expedite installations prior to commercial certifications
- Leverage government installations to “cross chasm” to commercial sales

Government rebate program:

- Replicate the Energy Star program
- Government rebates for high-impact new energy technologies
- Guaranteed subsidy for a specified capacity/ time and well defined eligibility criteria
- Adapts to market conditions (i.e size of rebate can decline with the costs of production)
- Pool of funds sufficient to initiate sizeable market demand

Include VC backed energy entrepreneurs in the traditional energy policy and road-mapping activities

- Injects new thinking and insight necessary for revolutionary changes
- Representation instills confidence to VCs and entrepreneurs.

Conclusions

The Future is Here and Now

- **Technology solutions that are also economically viable are rolling in now with the following benefits:**
  - **Significantly higher efficiency of utilization of fossil fuels**
  - **Dramatic reduction in emission of global warming gases**
  - **Energy independence**
  - **Energy security**
  - **Eliminates need for expensive infrastructure**
  - **Most viable pathway to a hydrogen economy**

- **Important for the government to provide a helping hand for these technologies to take off and become commercial successes with huge positive impact to the environment and economy.**