Company and Technology Overview

Hydrogen Technical Advisory Committee

14 October 2010

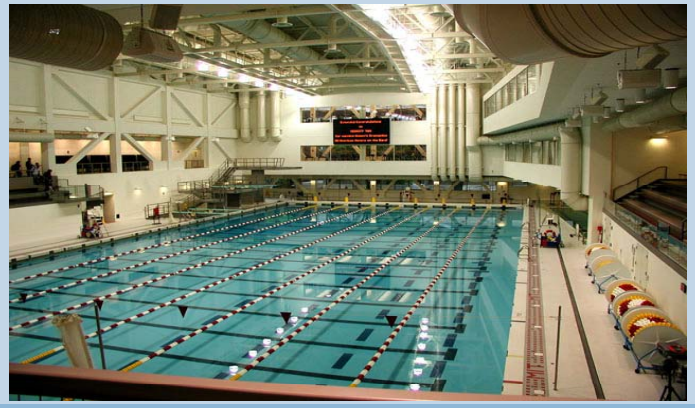
Transforming the Global Energy Paradigm

- **Vision: Sunlight + Water = Affordable, Accessible Energy**
  - *Sunlight:* Most Abundant Energy Source
  - *Water:* Most Abundant Liquid
  - *Sun Catalytix Technology:* Accessible and Inexpensive

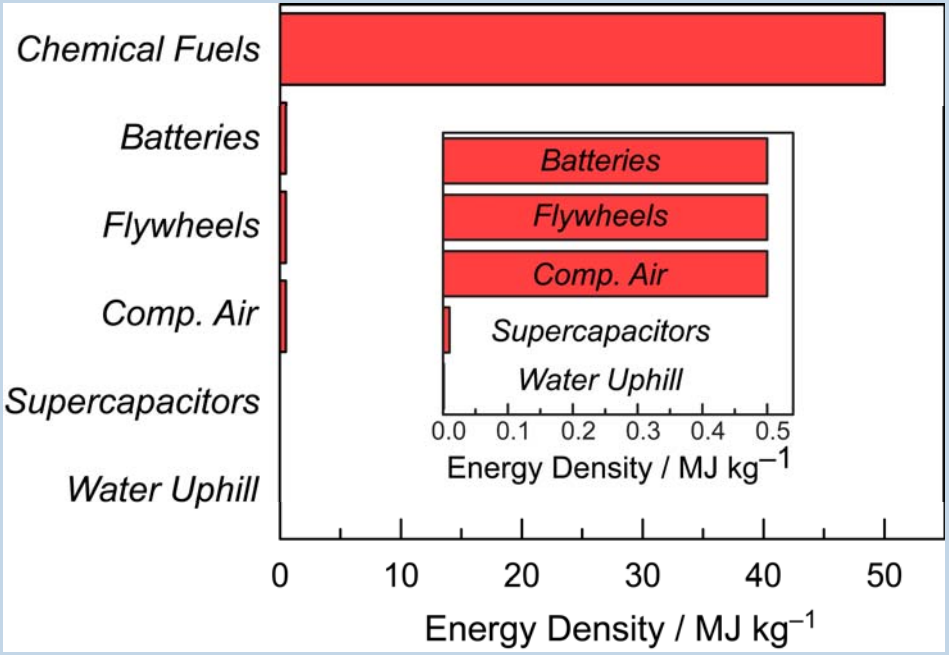
- **Impact**
  - *Affordable Energy Storage*
  - *Distributed Fuel Production*
  - *Every Home and Community Becomes an Energy Production Center*
    - Personalized energy paradigm consistent with prior shifts
      - Land lines to cell phones
      - Mainframes to personal computers

Sunlight + Water: Near Limitless Energy Supply

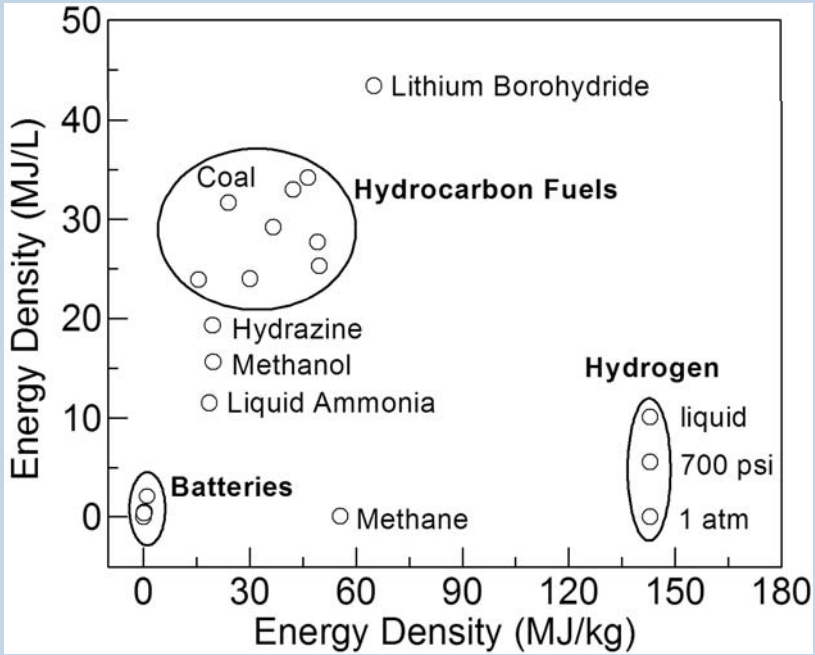
- Global energy usage likely to double to ~30TW by 2050
- 1.2 x 10^5 TW of Solar at Earth's surface; 800 TW practical
- Other renewables limited in scale
  - Biomass: 5-7 TW gross (with all arable land not used for food)
  - Wind: 2-4 TW total extractable
  - Geothermal: 12 TW gross over land small fraction recoverable
- *Volume of MIT pool → H_2 and O_2 per second = 43 TW*



Energy Storage in Chemical Fuels



Chemical fuels possess energy densities unmatched by any other storage means



Hydrogen is the most energy dense fuel by mass

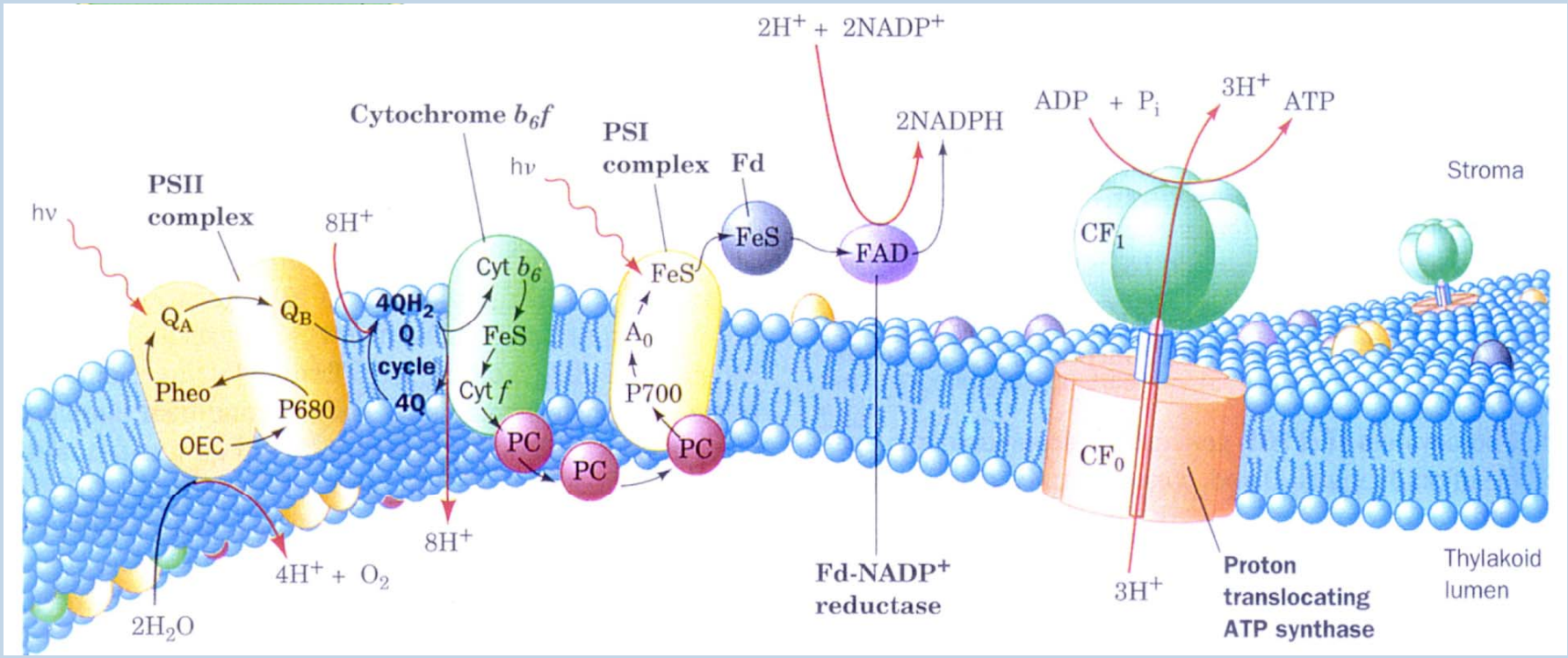
Target Applications

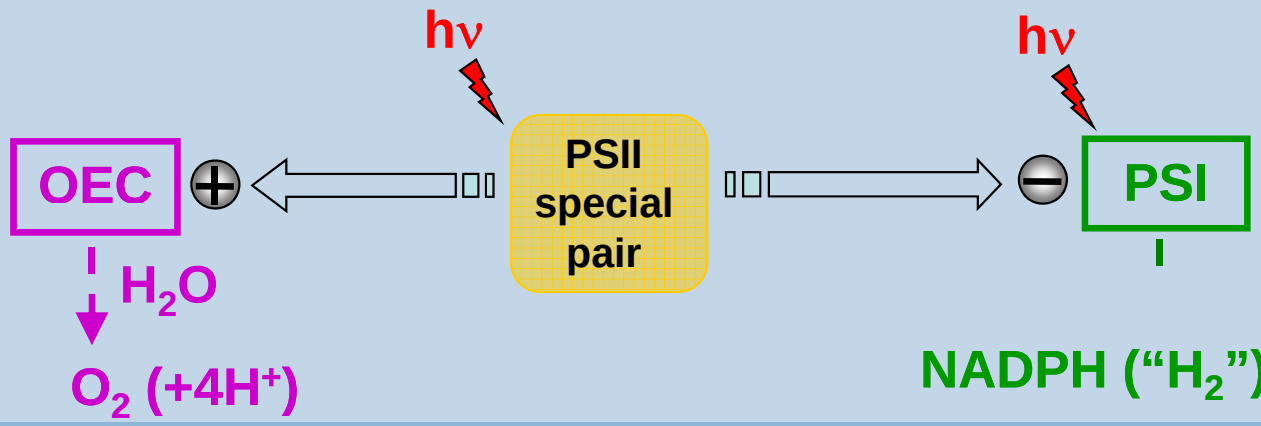
- **On-site industrial hydrogen**
  - For various applications: semiconductor fabrication, metal annealing, generator cooling, etc.

- **Energy storage**
  - Off grid power
  - On-grid storage

- **Fuels**
  - Automotive traction
  - Hydrogen as a fuel precursor (*e.g.,* renewable diesel)

Natural Photosynthesis



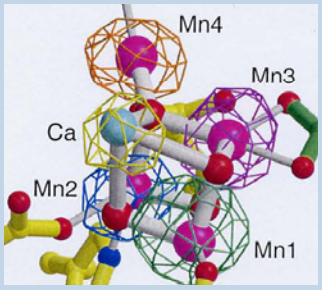
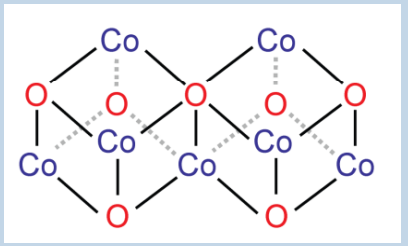


(1) catalysis is performed under benign conditions at neutral pH
(2) generation of OEC for water oxidation is key evolutionary step

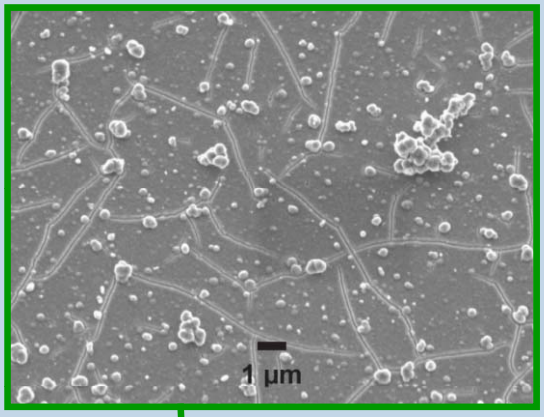
(3) photon sets up a (wireless) current within the leaf

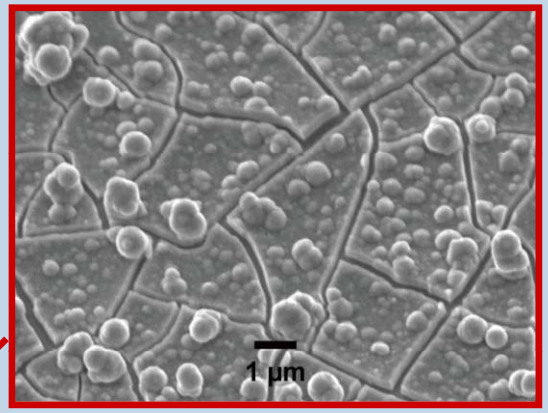
(4) separate light harvesting from energy storage

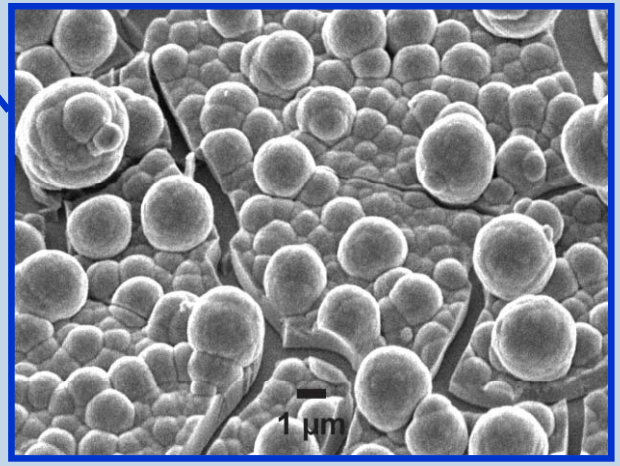
Our Technology Mimics Nature's Processes

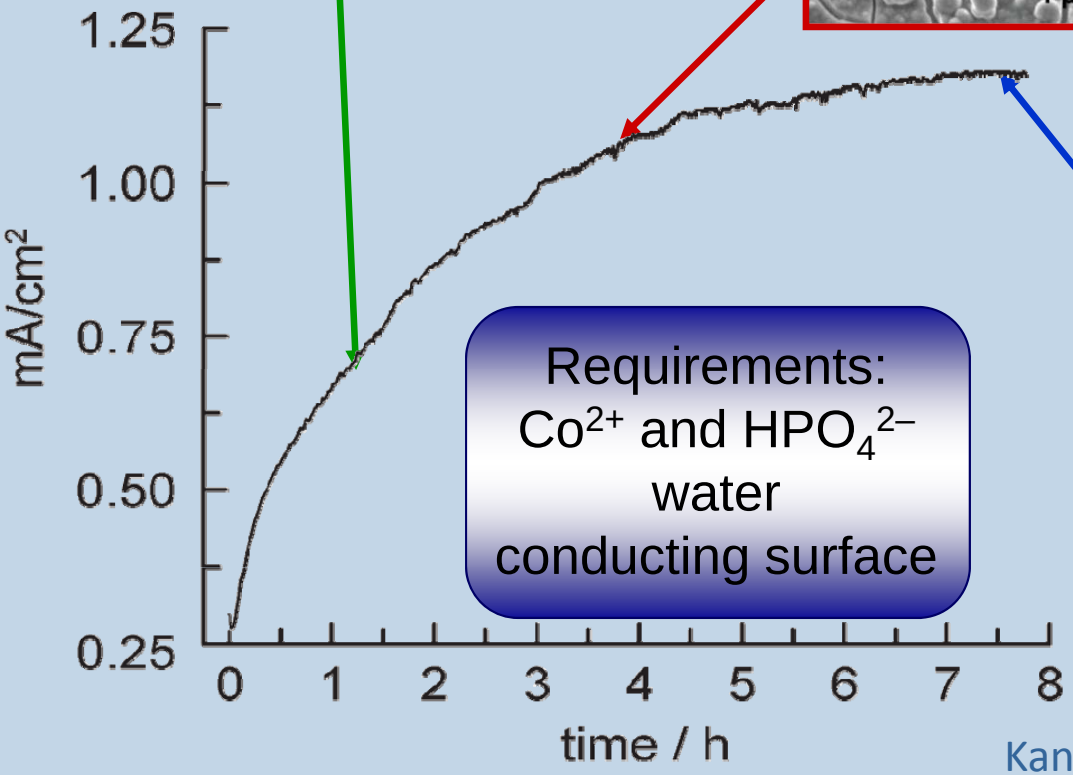
Design Criteria	Photo-system II	Cobalt-Phosphate
Conditions of operation	Neutral pH and STP Low over-potential	Neutral pH and STP Low over-potential
Repair	D1 protein	HPO_4^{2-}/Co^{3+} equilibrium
Water Supply	Fresh or Salt	Fresh or Salt
Stability	Regenerative	Regenerative
Abundant materials	Manganese	Cobalt
Structure		

In Situ Formation of an Oxygen-Evolving Catalyst







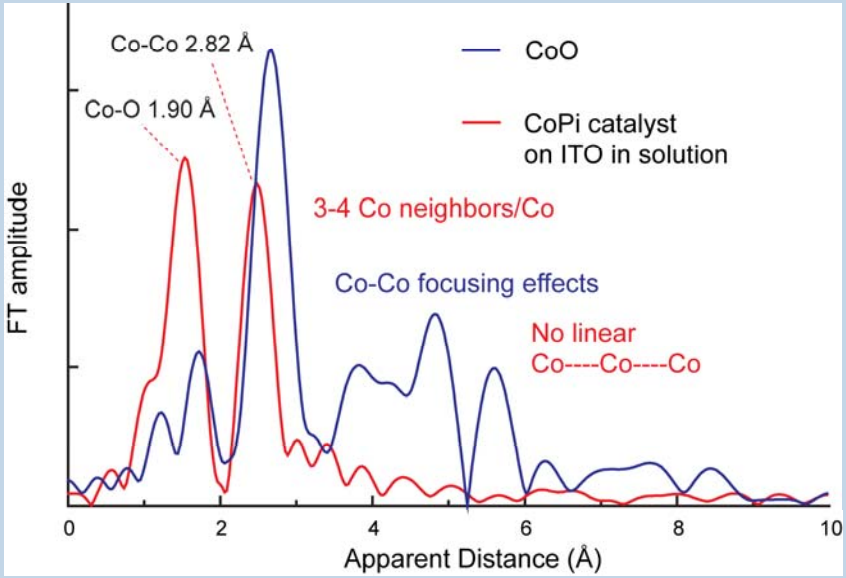


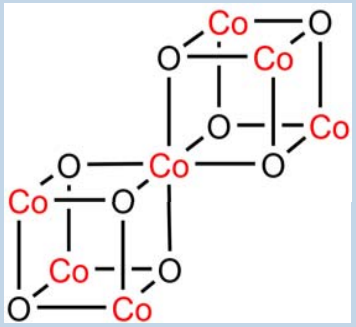
Requirements:
Co^{2+} and HPO_4^{2-}
water
conducting surface

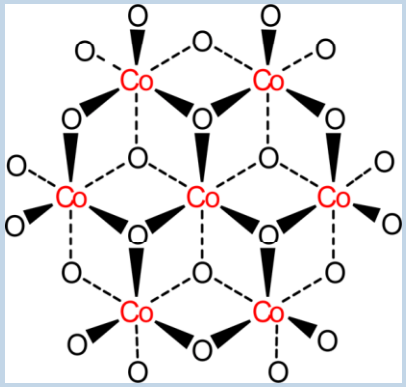
Kanan and Nocera, *Science* ***2008***, *321*, 1072.

Structural Insight from EXAFS

Not a typical Oxide material

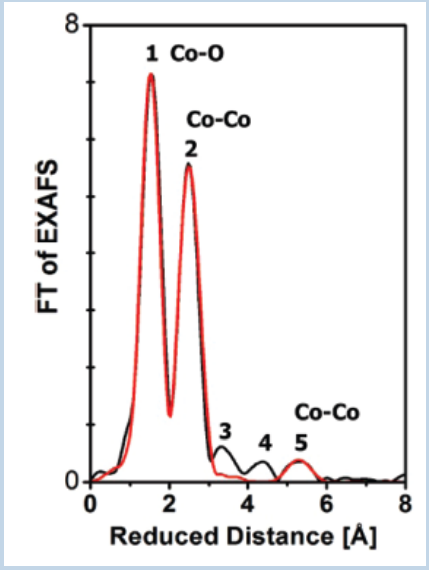


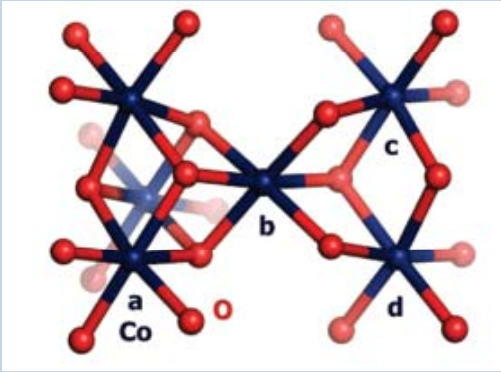




With Junko Yano and Vittal Yachandra at LBNL

Confirmed by a German group





Dau and coworkers *JACS* **2009**, *131*, 6936

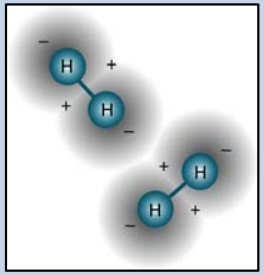
Two Modalities for Sun Catalytix Technology

1. Electrolyzer Modality

Solar, Wind or other electricity source

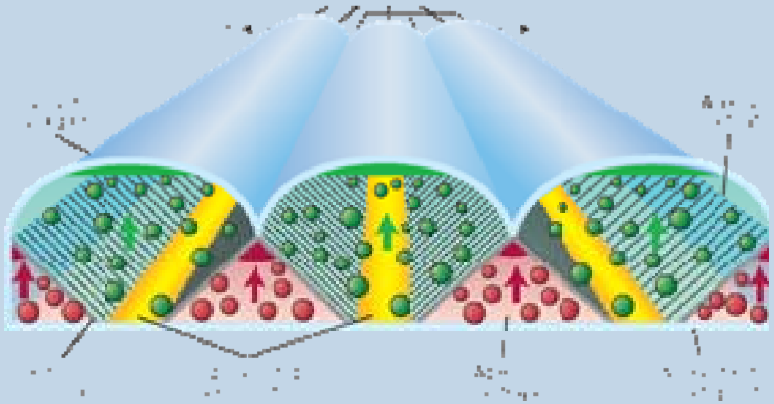
Sun Catalytix Electrolyzer

Hydrogen

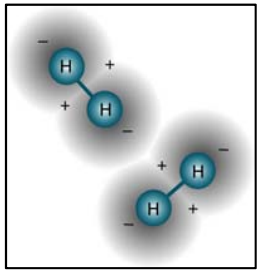


2. Photoelectrochemical (PEC) Modality

Sunlight



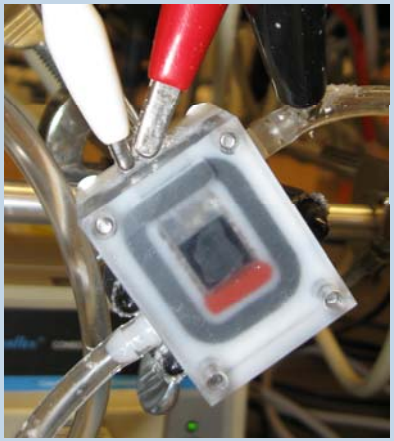
Hydrogen



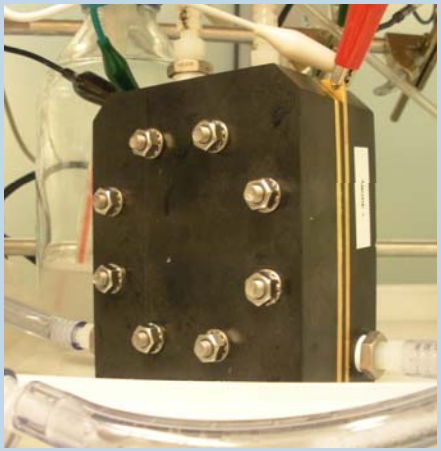
Electrolyzer Technology Status

- Anode catalyst performance meets initial target
- Cathode catalyst performance meets initial target
- Membrane / separator criteria defined, initial materials selected
- Integration of cell components, electrode design, performance enhancement underway

2008



2009

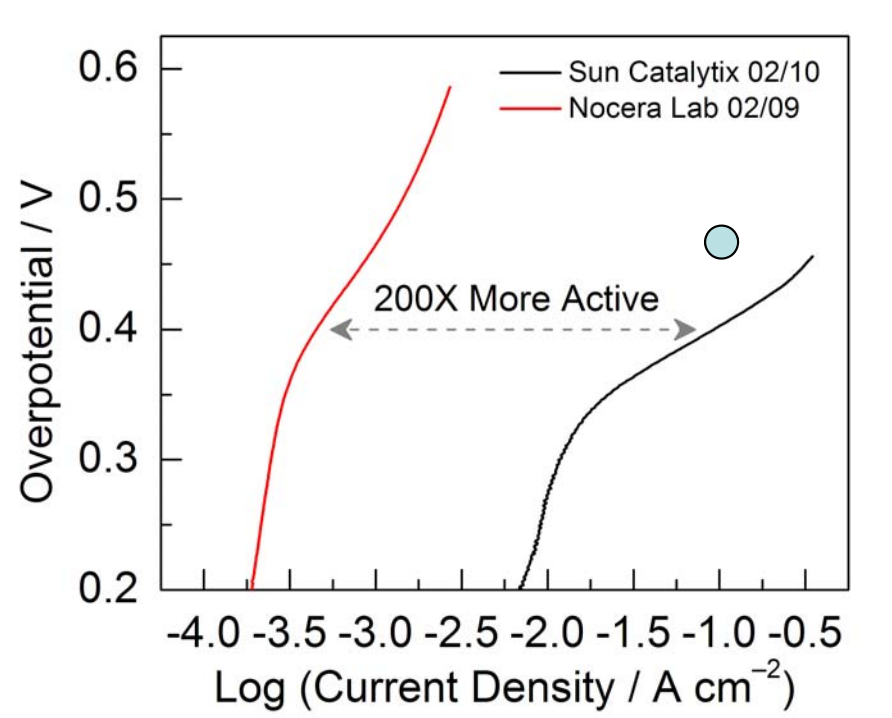


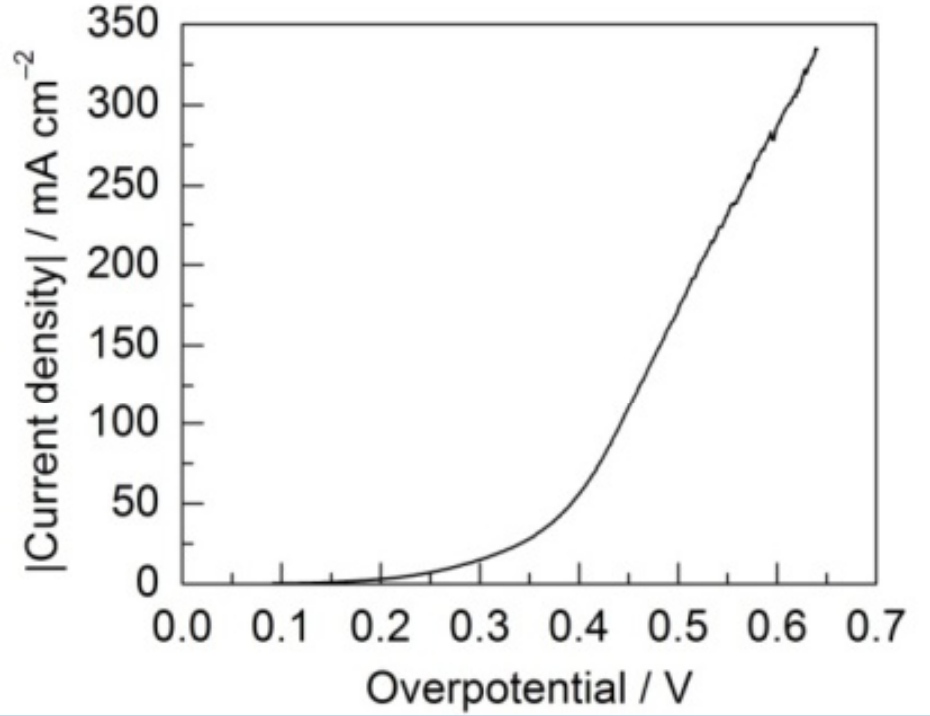
2010

Electrolysis Performance Enhancement

Electrode design has enabled ~200x current enhancement relative to results published in Kanan and Nocera, *Science* ***2008***, *321*, 1072.

Anode Activity Enhancement

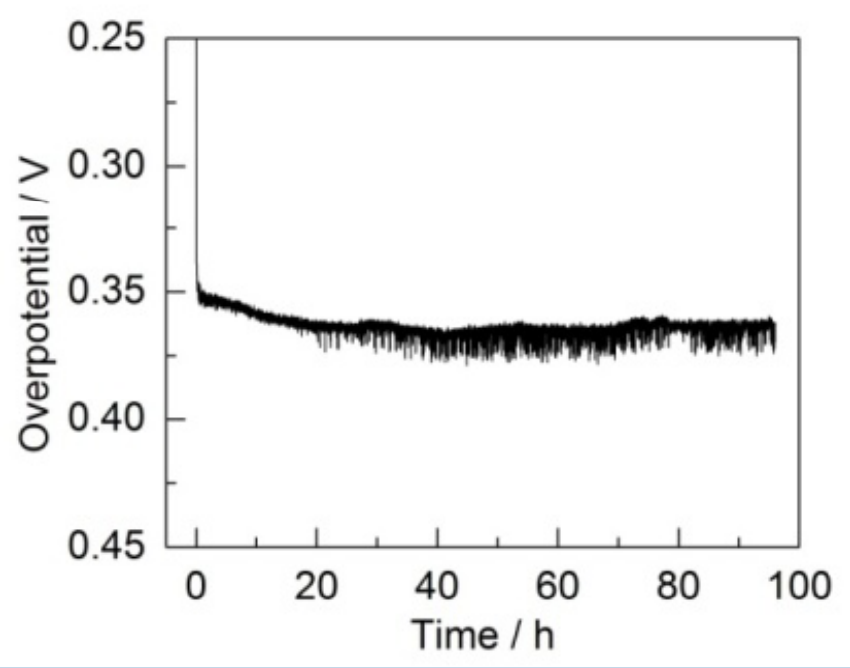




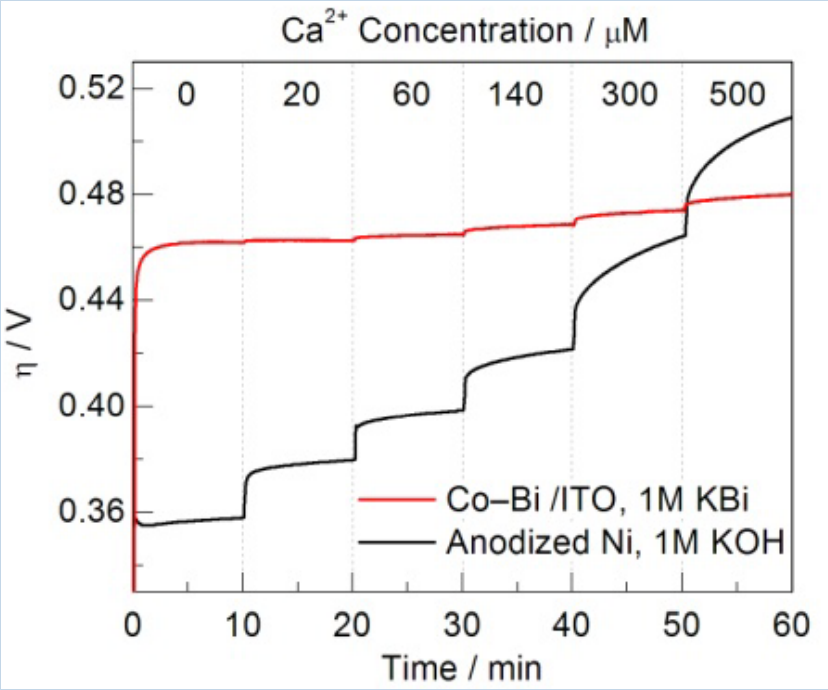
Esswein et. al., Submitted to *Energy and Environmental Science*

Anode Catalyst Capability

Anode Stability



Engineered Co-OEC catalysts exhibits high stability in untreated river water

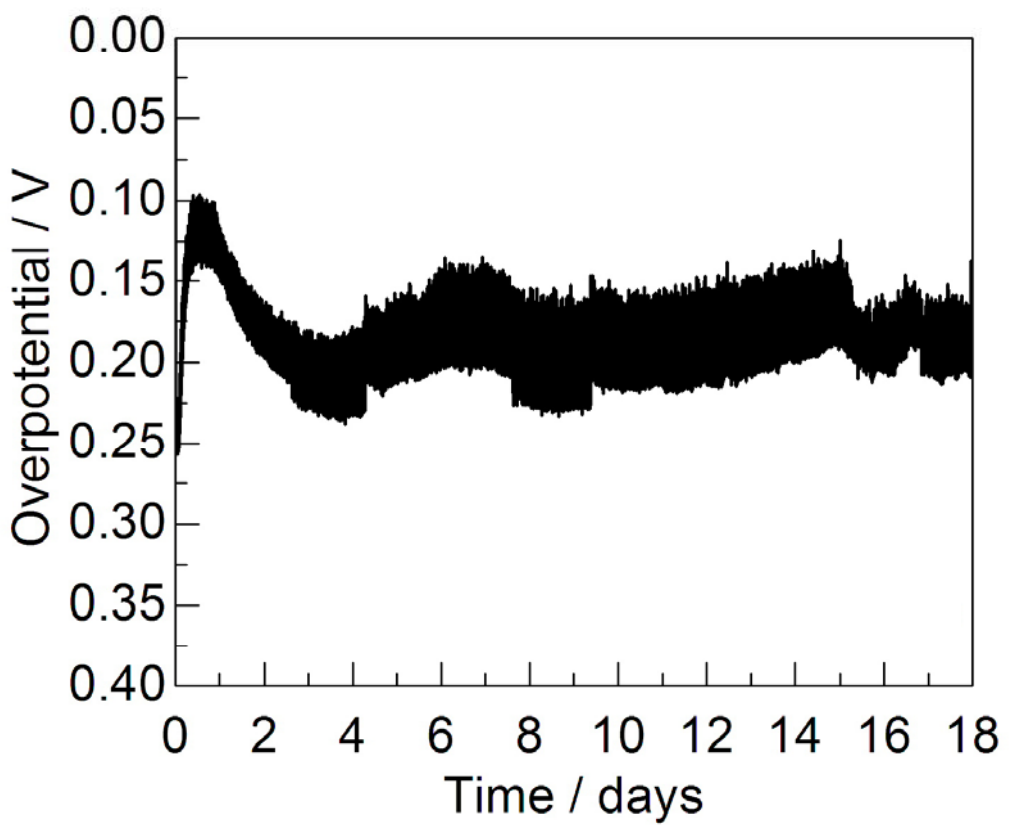


Engineered Co-OEC catalysts / conditions enable high resistance to poisoning

Esswein et. al., Submitted to *Energy and Environmental Science*

Earth-Abundant Cathode Catalyst

Cathode Stability



Sun Catalytix discovery -- cathode catalyst made of earth-abundant elements that exhibits stability in untreated river water

Full Cell Performance

- Initial results show progress toward ARPA-E goals (2V, 100 mA/cm^2)
- Cells constructed using earth-abundant catalyst materials (anode is Co-OEC, cathode is proprietary)
- Ongoing efforts to improve performance by component engineering efforts

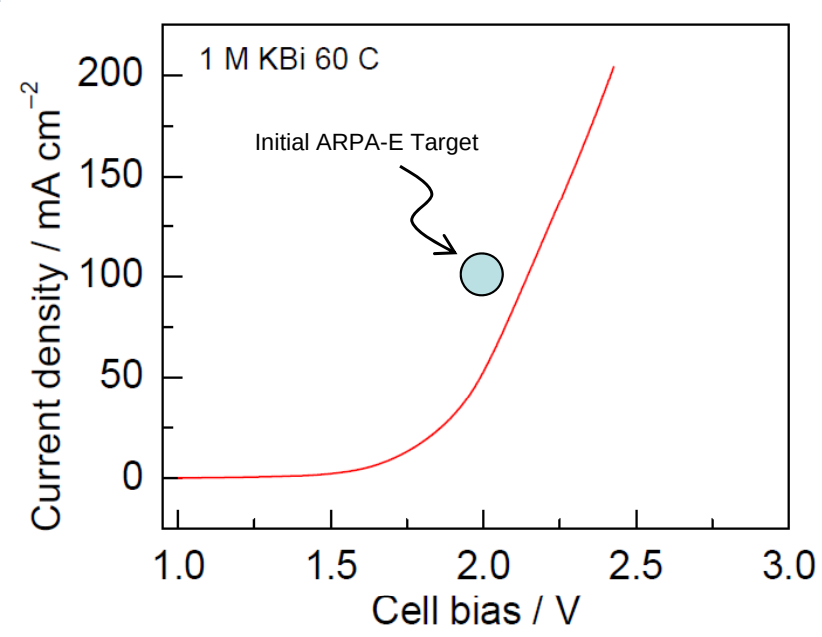


Photo-Electrochemical Cells

- Benign conditions suitable for Sun Catalytix catalysts increase the number of PV cells that can be used
- Operational current densities are limited by collecting solar photons
- Excellent match of system requirements with Sun Catalytix materials characteristics
- Several alternative configurations being explored

Photoanode/PV

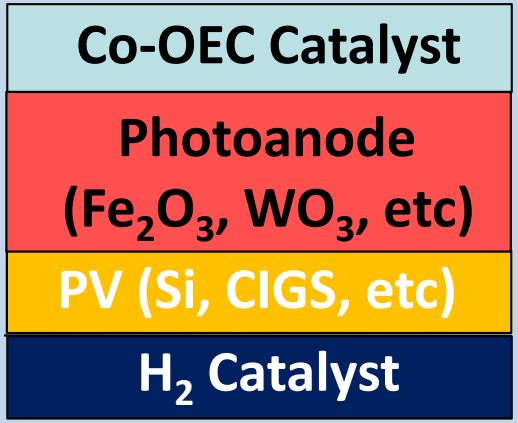
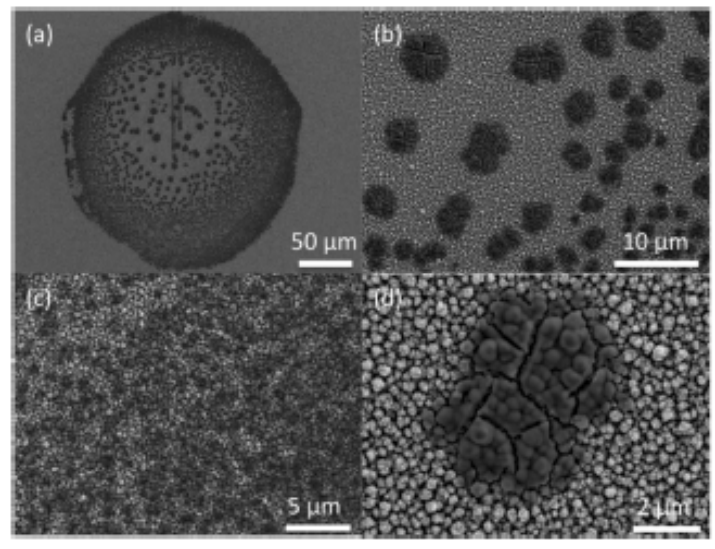
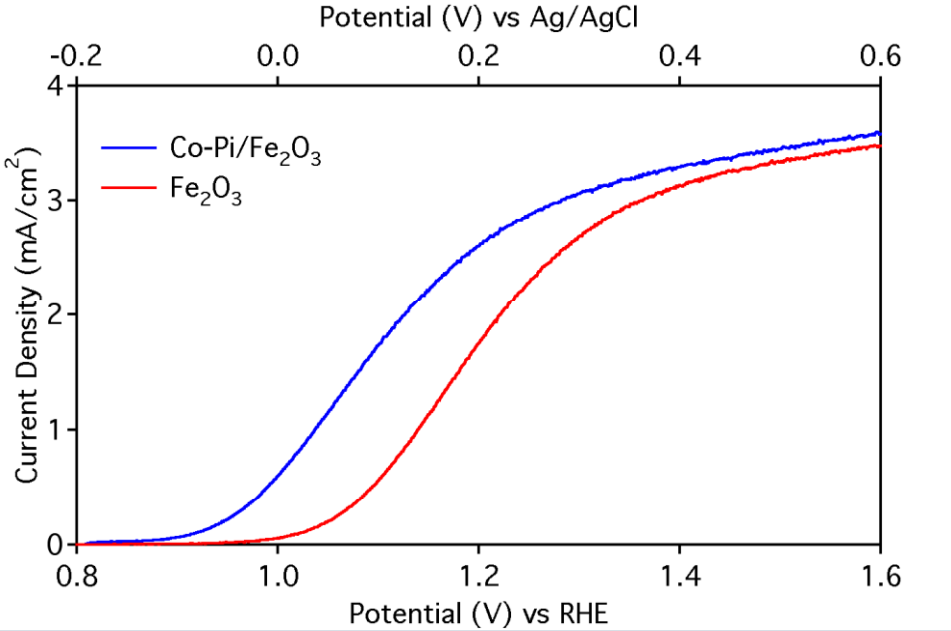


Photo-Anode Enhancement with Co-OEC





- **Sun Catalytix catalysts shown to enhance photo current for Fe_2O_3**
- **Demonstrates proof of concept of enhanced activity via Co-OEC**

Gamelin, D. R. and coworkers, Univ. of Wash.

Scientific and Strategic Leadership

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MIT

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Tom Jarvi
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Chief Technology Officer

Mark Barnett
CT Clean Energy Fund,
Foley Hoag Energy Technology

VP Business Development and General Counsel

Company Backing

- Polaris Venture Partners
  - Leading VC firm; >$3B assets under management
  - Founding investor; equity investments in series A and B rounds
- Tata
  - Global, visionary company and investor; $70B group revenue
  - Equity investment in B round
- ARPA-E
  - $4.1 M grant awarded in highly-competitive initial round

Sun Catalytix

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