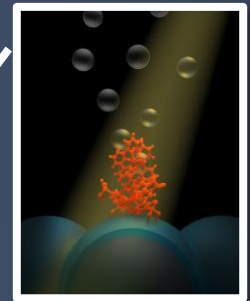


# Fuel Choices. The Long Term Future

**Panel. Innovation and Technology**

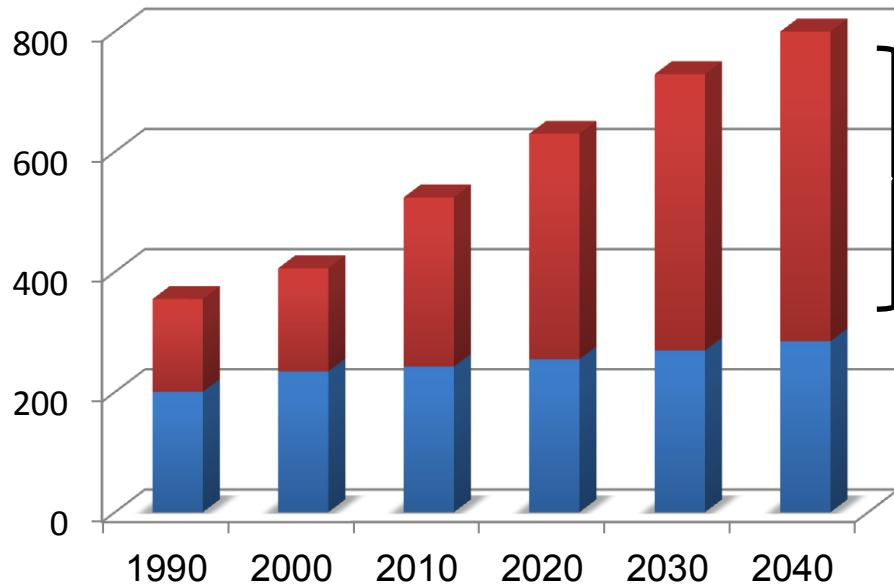
**December 4, 2014**

**UNC Energy Frontier Research Center  
Solar Fuels**



“Artificial Photosynthesis and Solar Fuels”  
PNAS (US) 9/25/12

## World energy demand, 1990-2040<sup>1</sup>



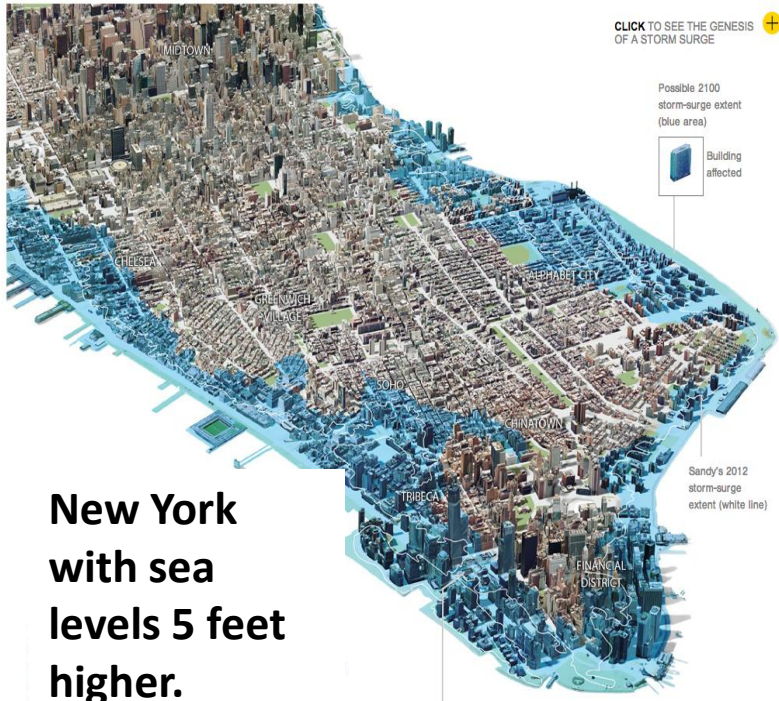
- 85% of the increase in global energy demand will come from developing nations

- Currently: >85% of energy supply is from hydrocarbons.

<sup>1</sup>Source: US Energy Information Administration

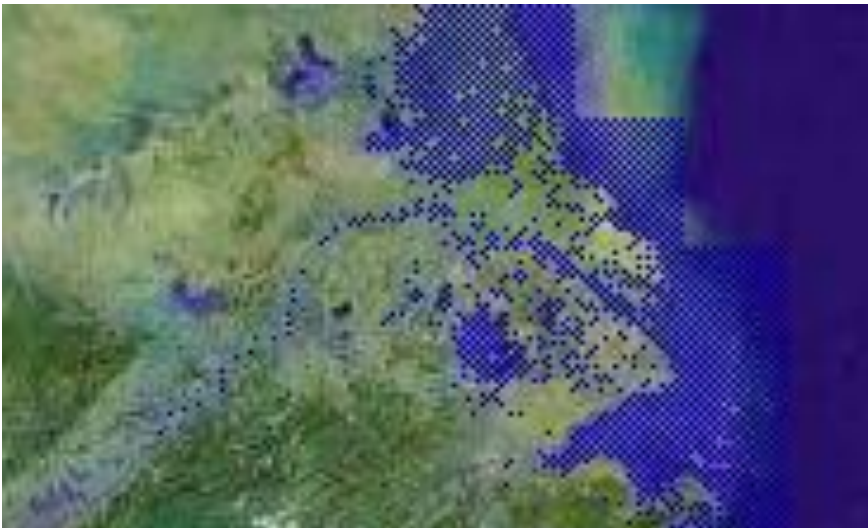
# Energy Issues.

## *Hydrocarbons and Climate Change*



- May 2013: Atmospheric CO<sub>2</sub> levels reached 400 ppm, highest in 3 million years
- By 2100, sea levels could be up to 6-7 feet higher
- By 2070, 150 million people in port cities would be displaced, losing \$35 trillion worth of property (9% global GDP)

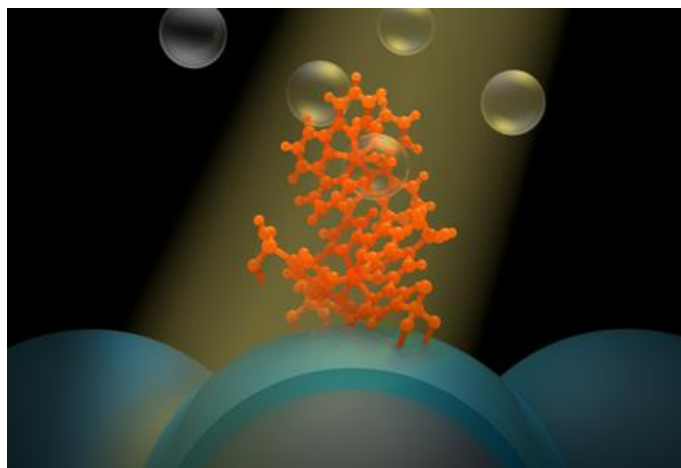
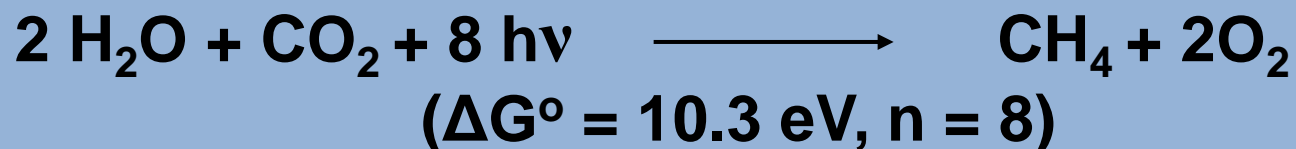
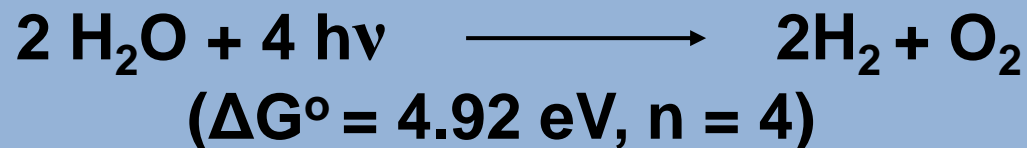
Shanghai  
+2 meters





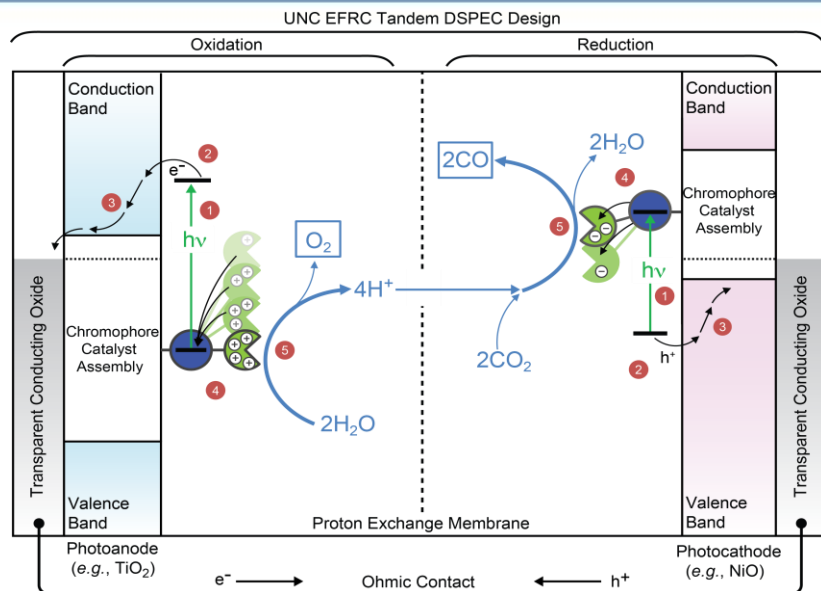
# Energy Conversion and Storage with Solar Fuels. *Artificial Photosynthesis*

- Hydrogen, CO, natural gas, liquid hydrocarbons and oxygenates
- Use the existing energy infrastructure



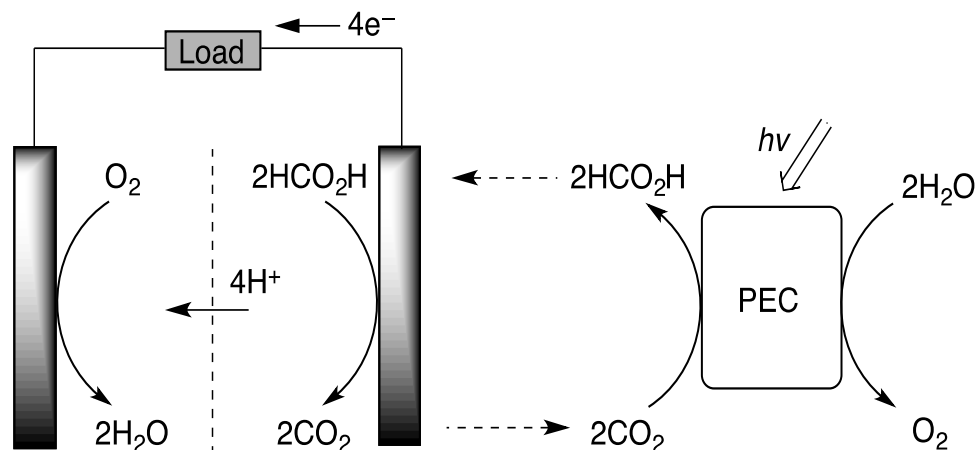
# Tandem 2e<sup>-</sup> Reduction of Carbon Dioxide.

## *Syngas (2H<sub>2</sub>:CO) and Formate (HCO<sub>2</sub><sup>-</sup>)*



- **CO<sub>2</sub>/H<sub>2</sub>O/H<sup>+</sup> reduction to syngas (2H<sub>2</sub>:CO).**  
Syngas → CH<sub>3</sub>OH → hydrocarbons by Fischer-Tropsch synthesis

- **Tandem, DSPEC for CO<sub>2</sub> reduction.**
- **Integrated PEC/formate-oxygen fuel cell.**



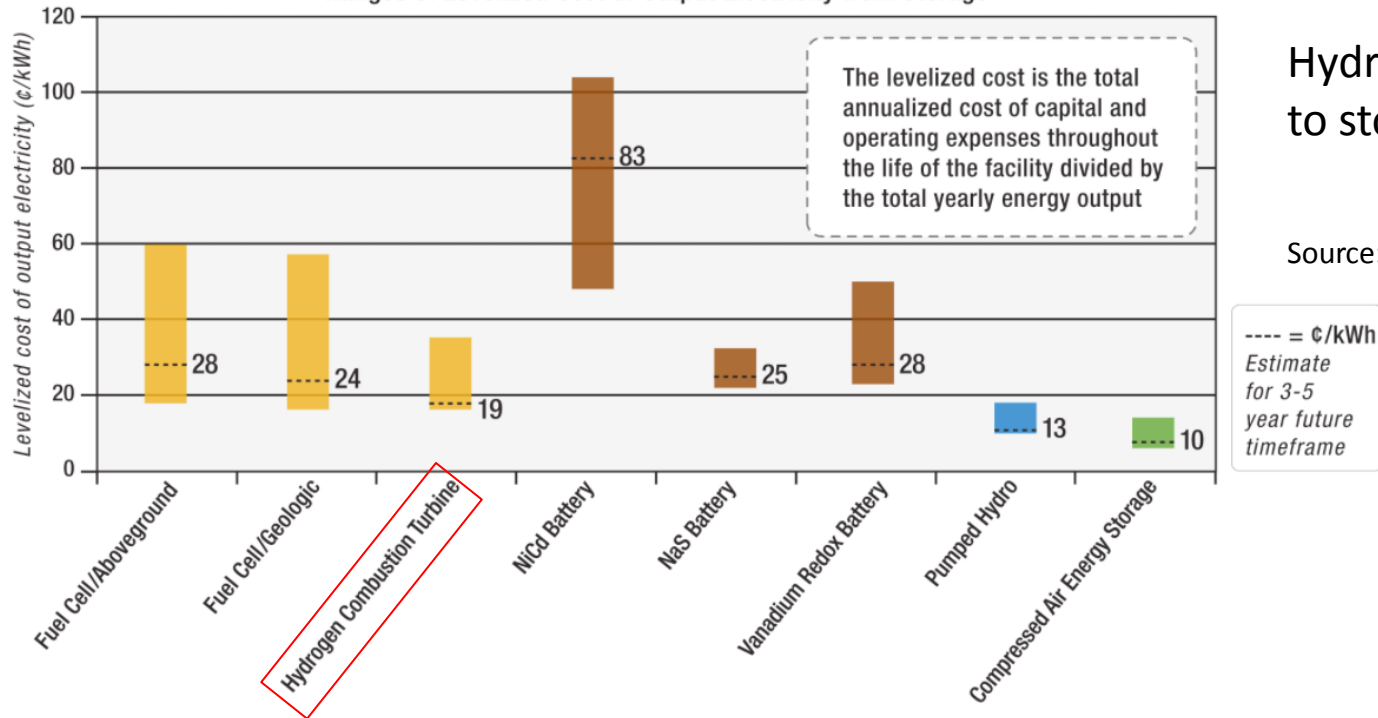
Direct Formic Acid  
Fuel Cell

Photoelectro-  
chemical Cell

# Market Potential.

## Technoeconomic analysis

Ranges of Levelized Cost of Output Electricity from Storage



Hydrogen: less expensive to store than electricity.

Source: NREL- Hydrogen for Energy Storage



Solar

Wind

Electrolyzer



Renewable electrolysis (First Step):

Wind: \$3.64/kg H<sub>2</sub>

Solar: \$7.62/kg H<sub>2</sub>

PEC H<sub>2</sub> production still too high. Goal is ~\$5/kg H<sub>2</sub>

Electrocatalytic syngas production

# Initial Target Markets



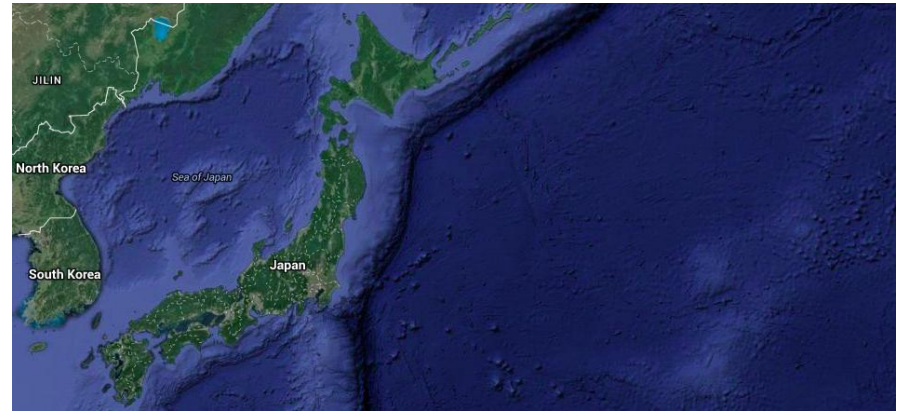
Deployable electrolyzers for military applications.



Clean energy for remote islands and off-grid communities.



Clean energy for the third world.



Energy independence for island nations.