

**Energy & Homeland Security**

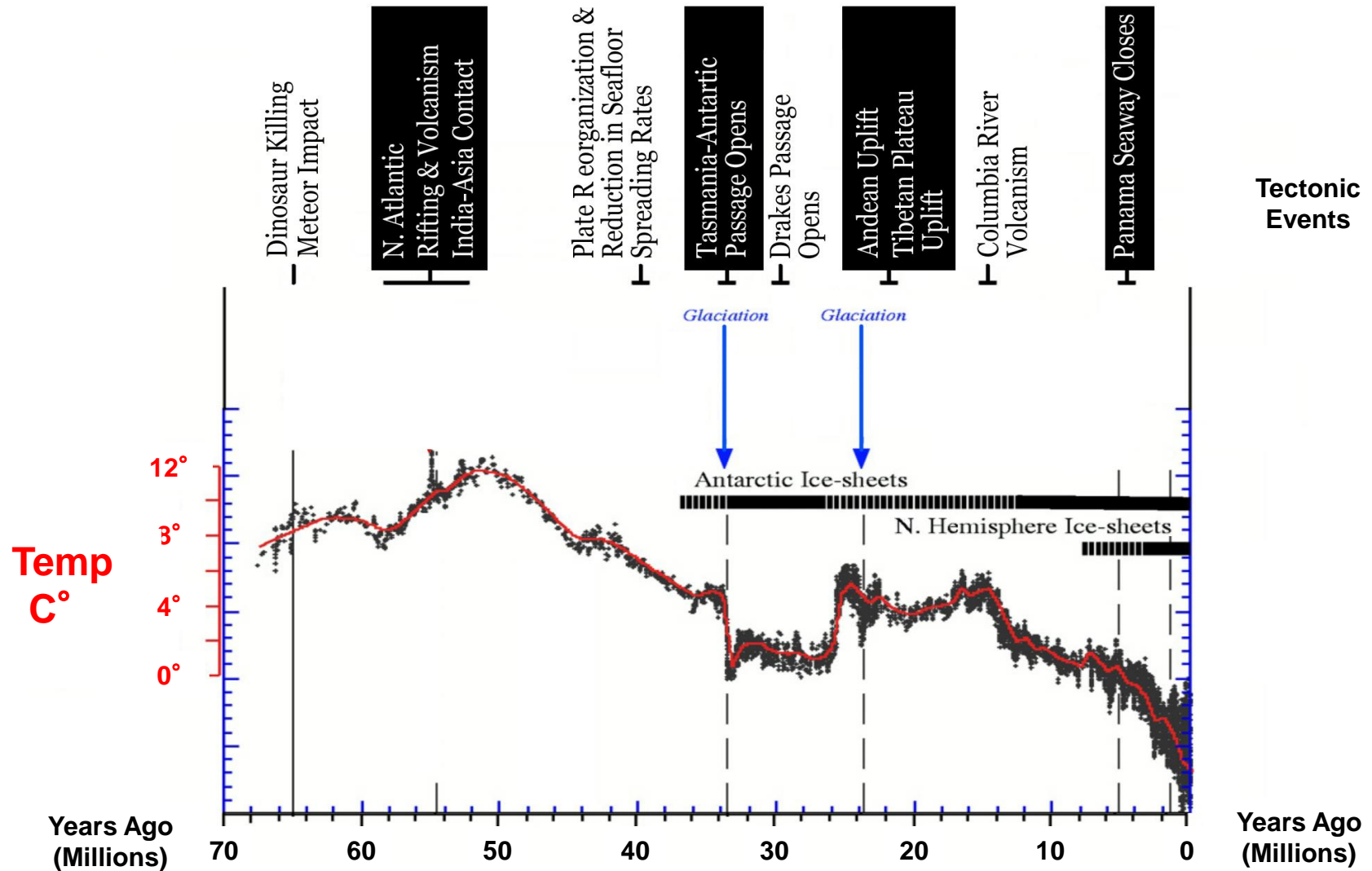
# NATIONAL SECURITY IN THE AGE OF ENERGY ABUNDANCE

**Steve Bohlen**

E Program Manager

May 7, 2019

# Earth Changes = Temperature Changes



# We face three major periods of climate mitigation – that overlap

Clean Up the Atmosphere

Mitigate Remaining Emissions

Eliminate  
Most  
Carbon  
Emissions

2010 2020 2030 2040 2050 2060 2070 2080 2090 2100



# To Achieve California 2045 and Paris 2° C Goals

## *We must remove atmospheric carbon dioxide*

### Renewable electricity will be cheap

We really can electrify everything.

Then we can use electricity to power new solutions to reduce atmospheric CO<sub>2</sub>.

### Carbon is not going away

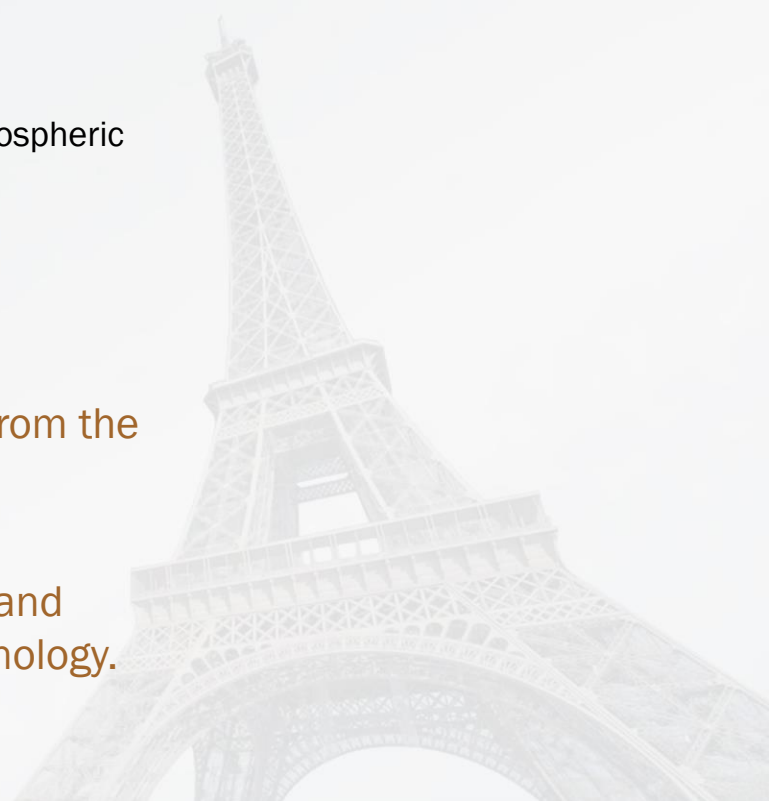
Fuels and carbon products from renewable energy sources.

A new carbon economy will emerge.

Up to 10 billion tons per year of CO<sub>2</sub> must be removed from the atmosphere after 2050.

Land stewardship will be vital.

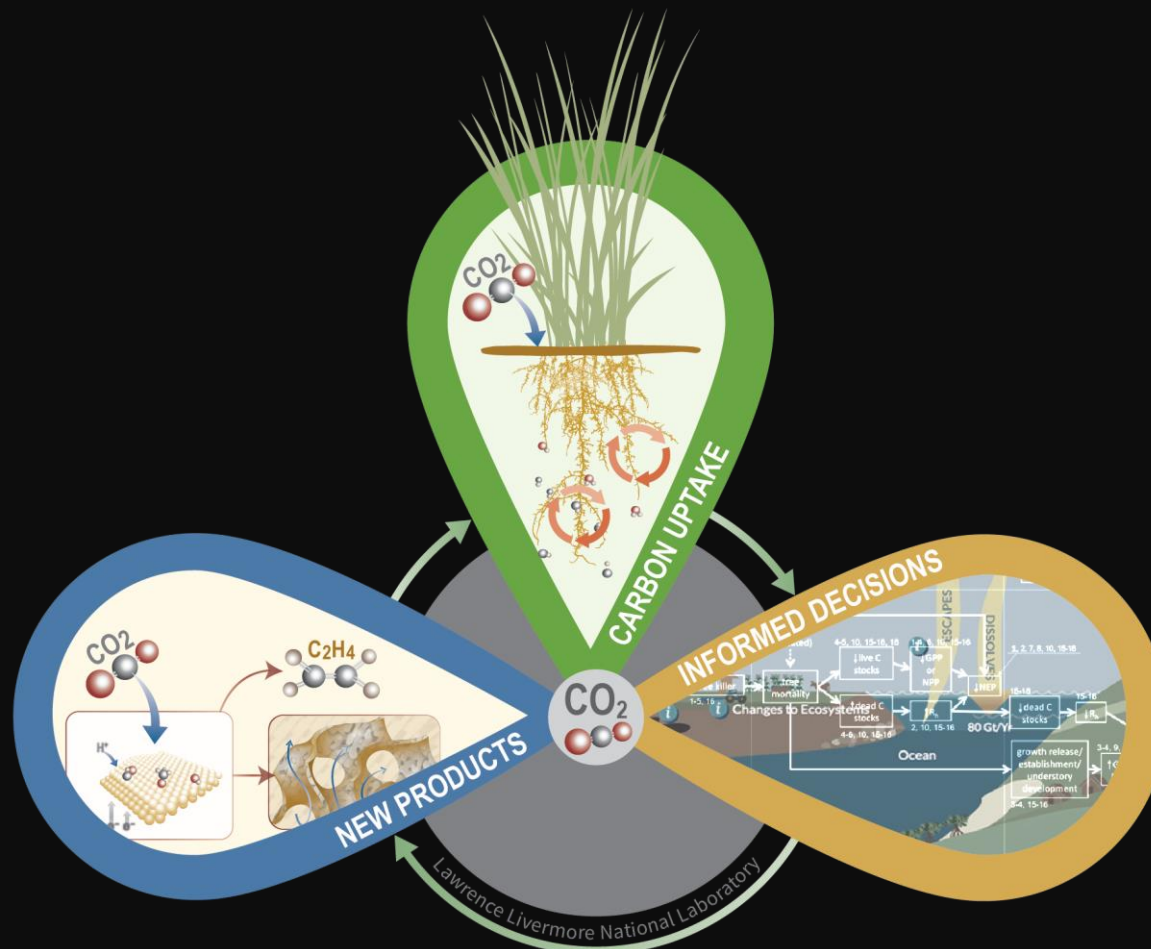
LLNL is working to understand the technology needed, and how we develop business and industry to use that technology.





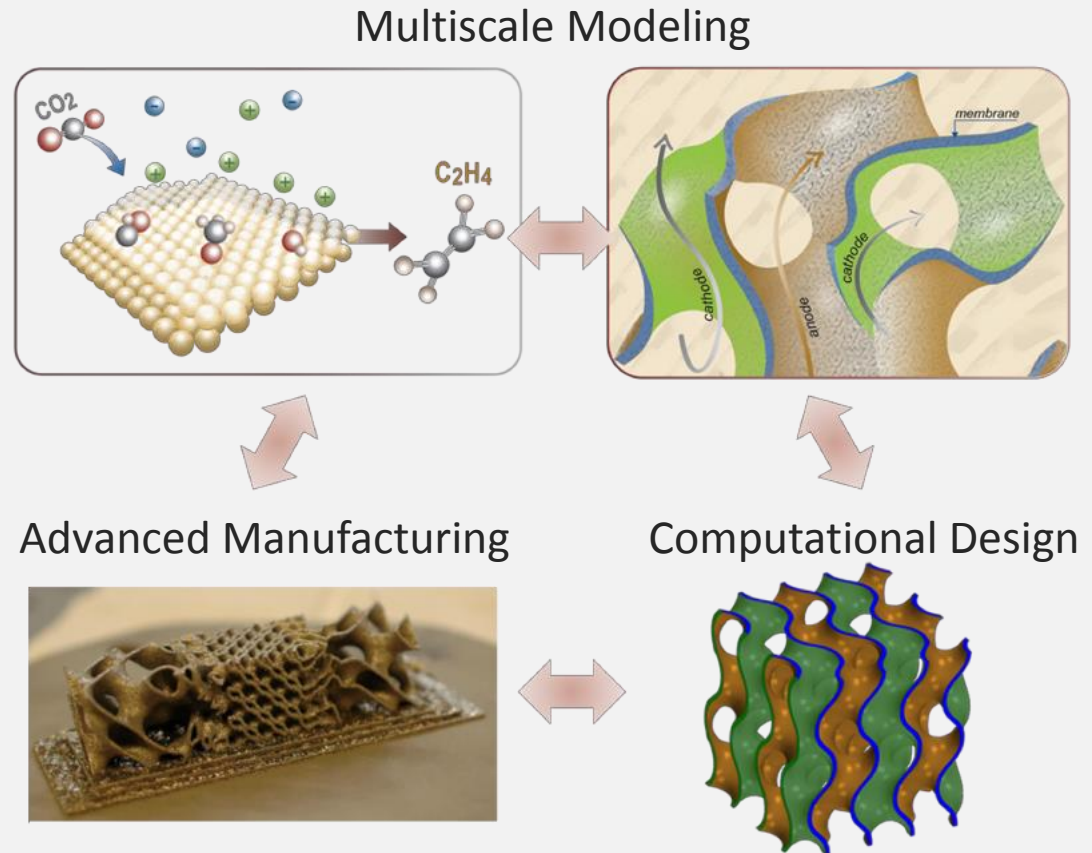
# ENERGY SECURITY

## Carbon Initiative



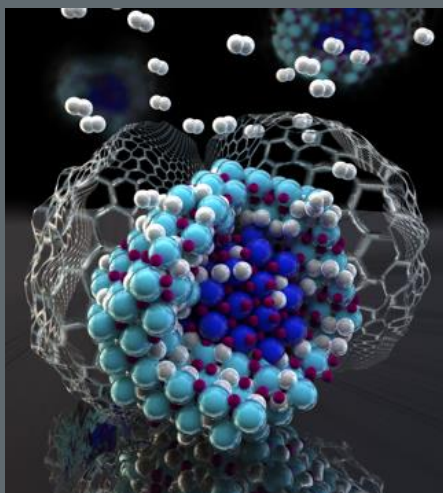
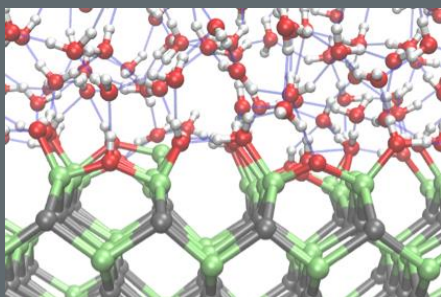


We are advancing  
energy materials  
through additive  
manufacturing,  
multiscale modeling  
and optimization



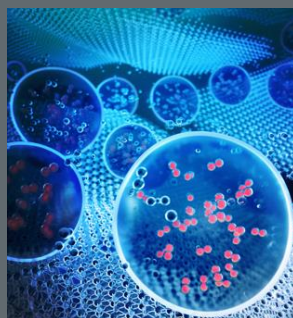
# LLNL focus areas for modeling and simulation

## Hydrogen technology



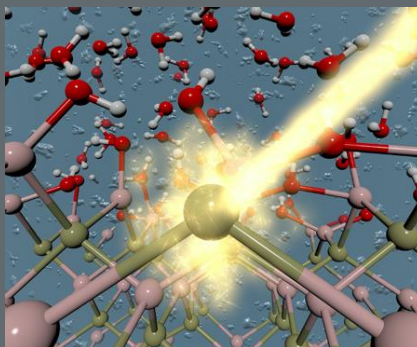
Materials for low-cost hydrogen production, storage, and distribution

## Carbon utilization



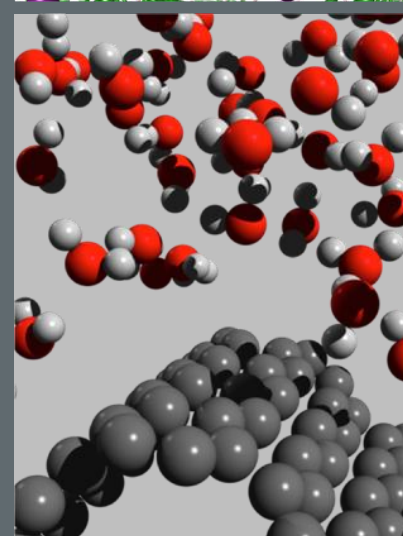
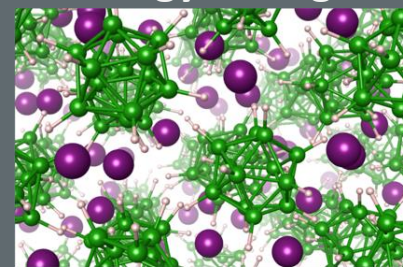
Catalysts for conversion of fuels and chemicals

## Energy infrastructure



Durable alloys for pipeline and power infrastructure

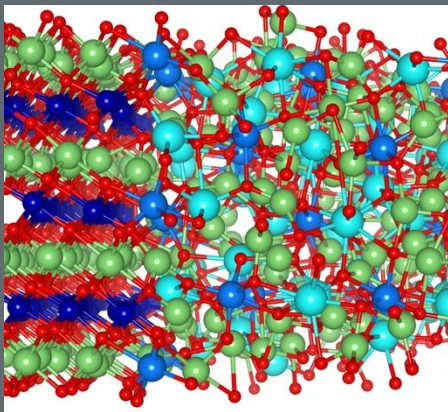
## Electrical energy storage



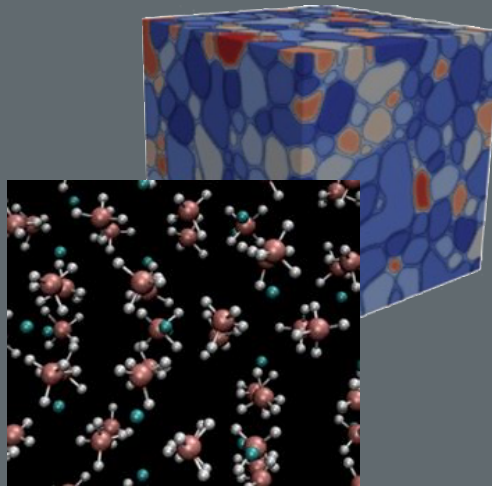
Safe, high-power, and high-capacity solid-state batteries and capacitors

# HPC modeling of materials interfaces utilizes approaches developed for core laboratory missions

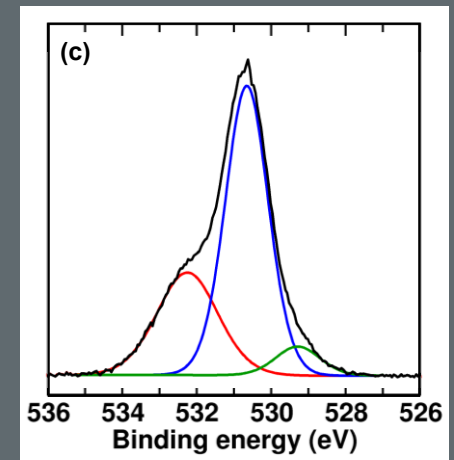
Real materials under  
real conditions



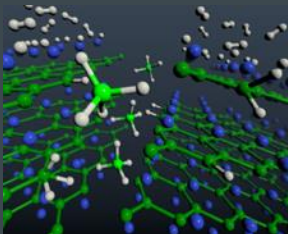
Multiscale modeling



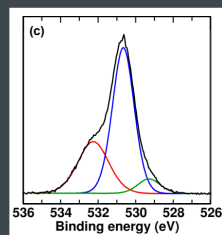
Experiment-theory  
integration



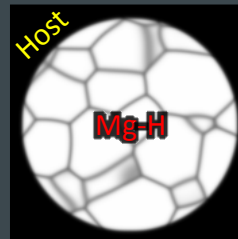
Assess



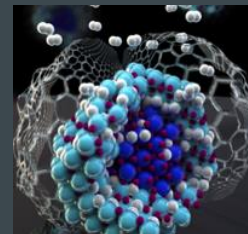
Interpret



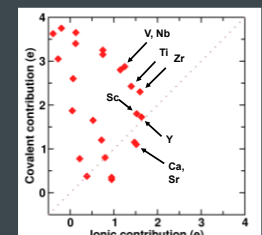
Model



Understand



Design

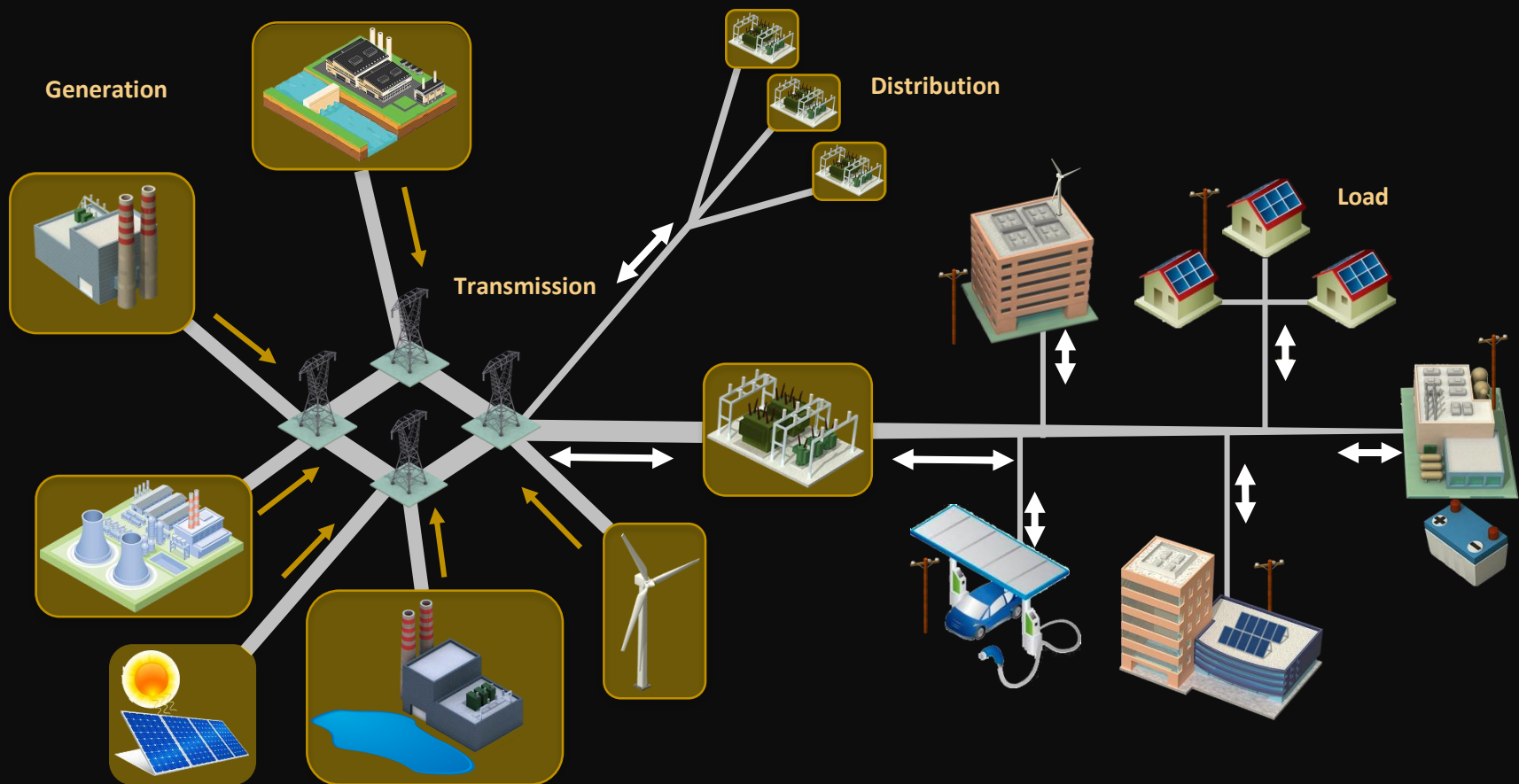




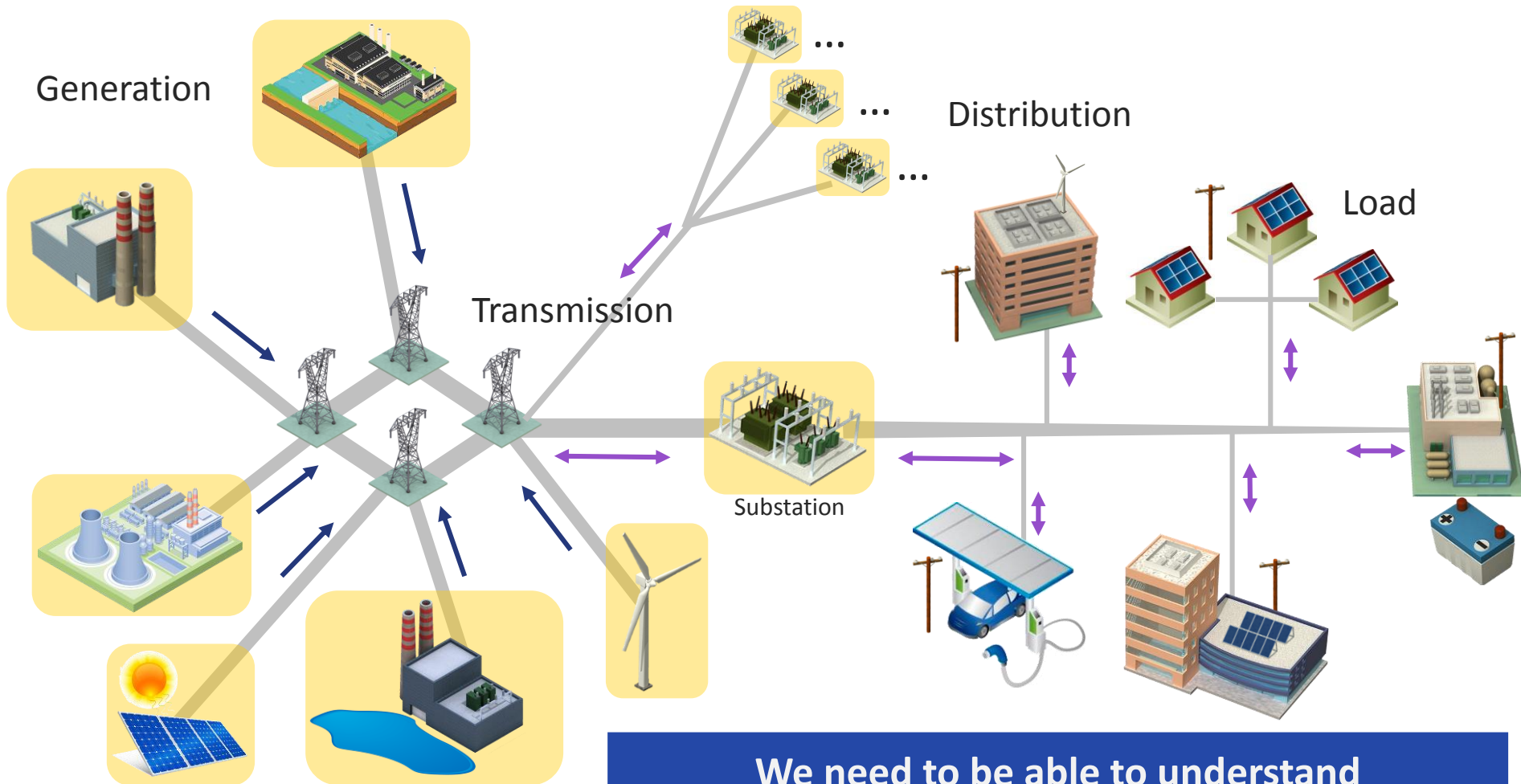


# ENERGY SECURITY

## Modeling & Simulation for Electric Infrastructure Modernization



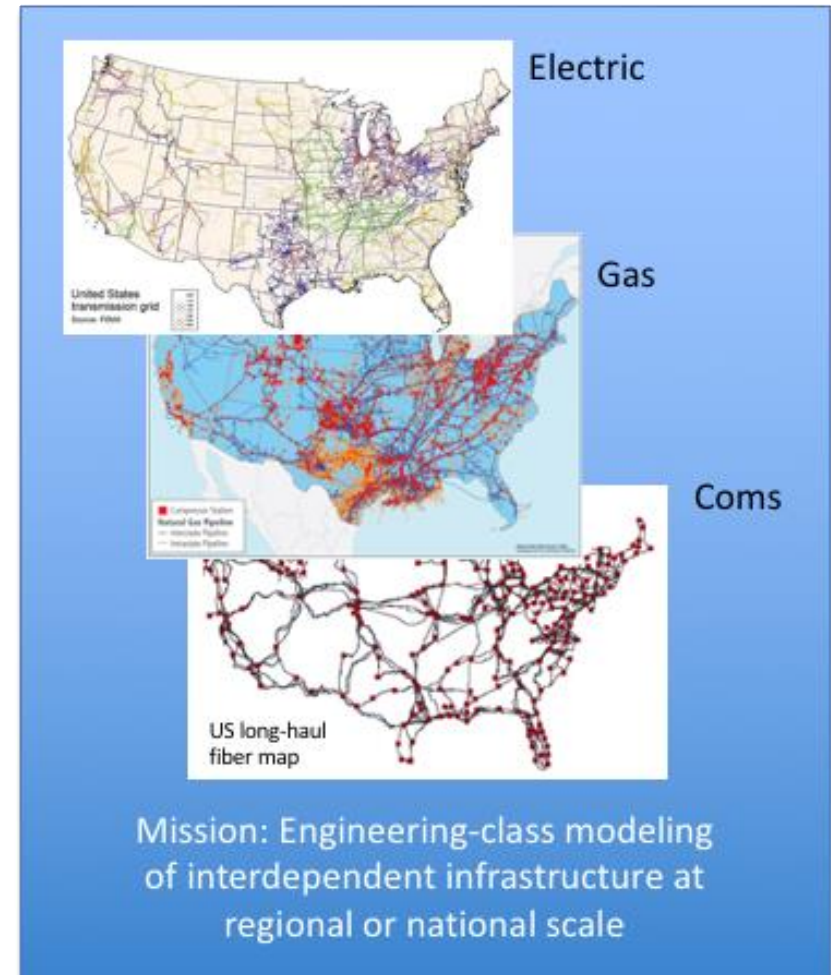
## Problem 2: Power flows both ways on the grid



**We need to be able to understand and control the flow of electrons**

# LLNL Approach: Advanced grid modeling

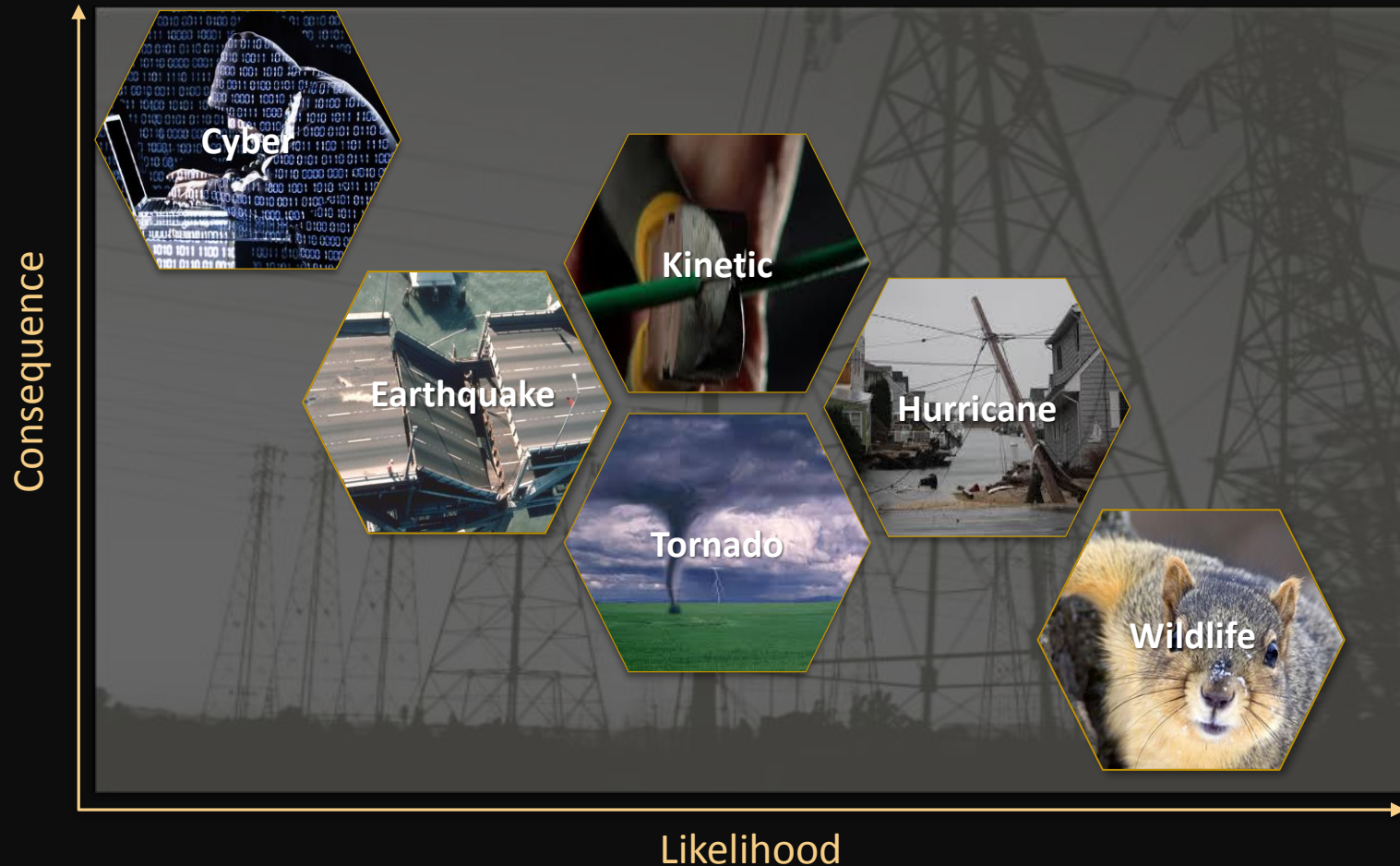
- Integrated transmission, distribution and communication co-simulation
- North American Energy Resilience Model (NAERM)
- Value of energy storage and demand response study
- Natural gas/electric grid interdependency model





# INFRASTRUCTURE AND HOMELAND SECURITY

## Quantitative Intelligent Adversary Risk Assessment

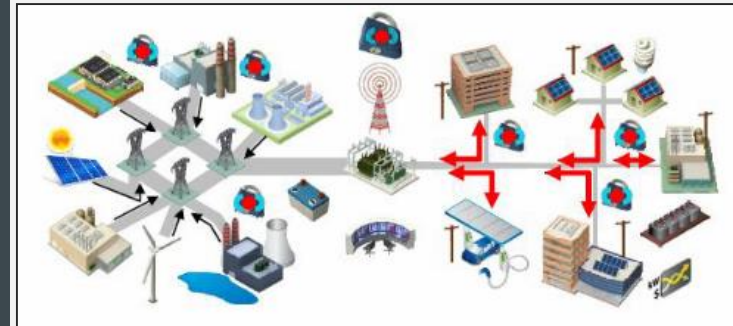




# Civilian Cybersecurity

We provide technology and solutions to enhance the security and resilience of the nation's critical infrastructure systems and networks to cyber hazards

- High-fidelity modeling and simulation of cyber-physical systems
- Machine learning and data analytics for threat detection and response
- Collaborative autonomy for cyber systems resilience
- Automated software assurance capabilities
- Network characterization and security
- Quantitative cyber risk assessment





# ENERGY DELIVERY SECURITY

## **Collaborative Autonomous Systems**



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US corporations would like to recycle CO<sub>2</sub>.

We need the technology to make these aspirations real.

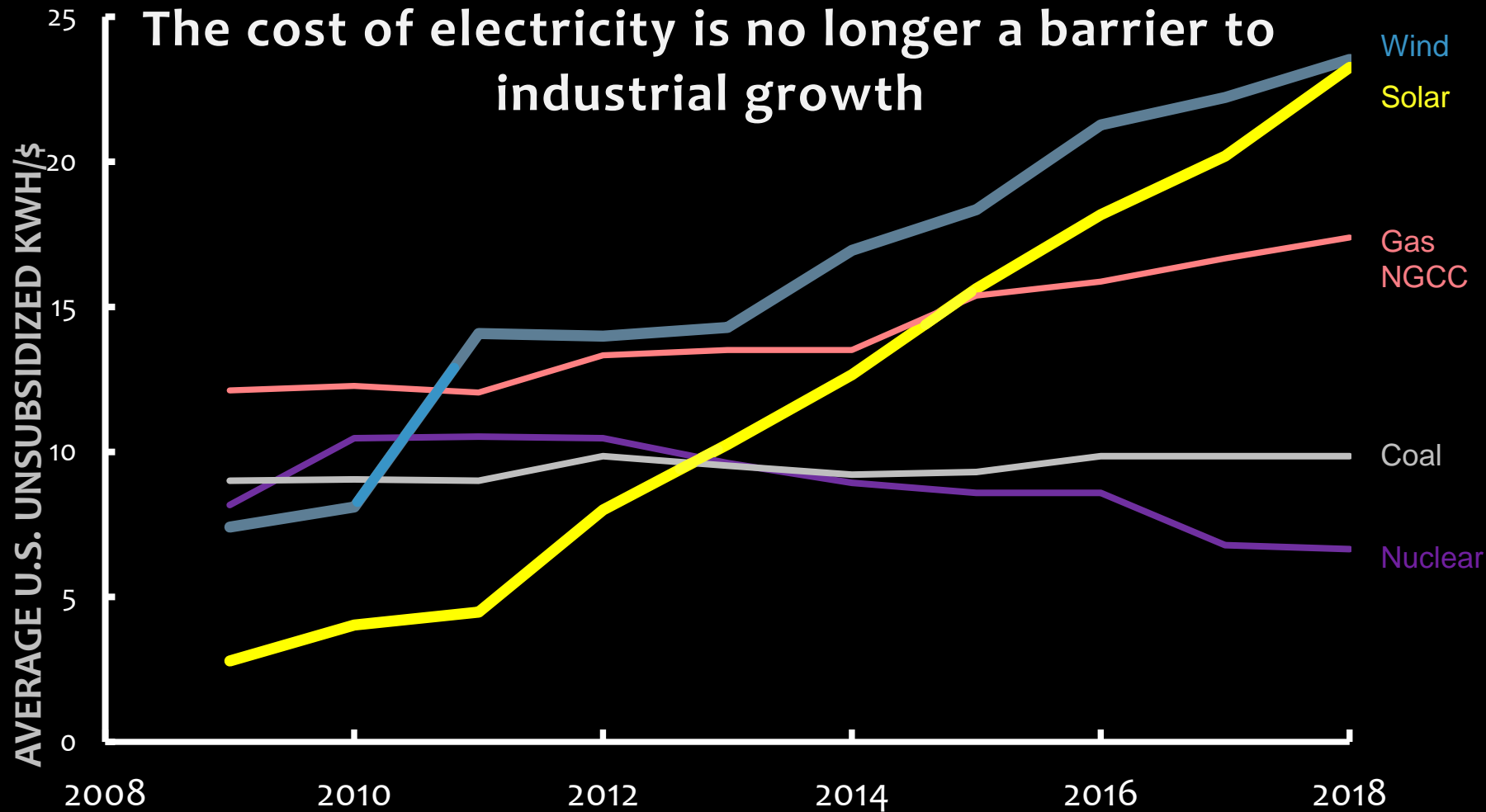


Booz | Allen | Hamilton





# The cost of electricity is no longer a barrier to industrial growth



# Recycling can use a lot of CO<sub>2</sub> – temporarily

	Carbonate Materials		Chemicals and Fuels		Durable Carbon Materials
	Binders/Cement	Aggregates	Commodity Chemicals	Fuels	Fiber, Nanotubes, Graphene
Market Size (Gt/y)	4 Portland cement (2016)	44 Non-metallic minerals (2017)	0.5 Upstream chemicals (2013)	2.5 Transport fuels (2016)	~0.0001 Carbon fibre (2018 est.)
CO <sub>2</sub> Demand (GtCO <sub>2</sub> /y)	0.1 - 1	1 Waste streams (2011)	1.4	7.7	?
CO <sub>2</sub> Abatement	Unclear - Indirect Benefits	Red. Likely – Neg. Possible	Red. Possible – Neg. Possible	Red. Possible	Unclear - Indirect benefits

Sean McCoy U Calgary

- Estimates of market size, CO<sub>2</sub> demand and abatement are *highly uncertain*
- Chemicals, fuels, and durable carbon materials also have large energy demand – i.e., high-temperature heat or electricity – which must be considered

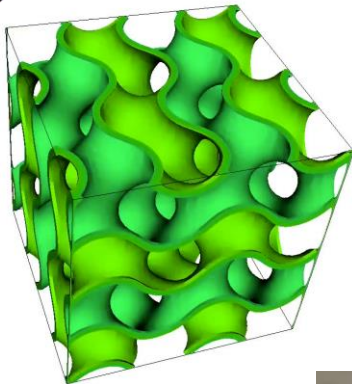
Chemical manufacturing today is a separations nightmare: *most of this \$18B Shell natural gas-to-products plant is refining and purifying.*



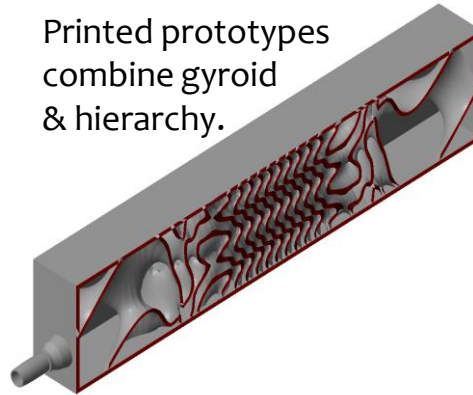
# New reactors with radically improved efficiency are getting attention



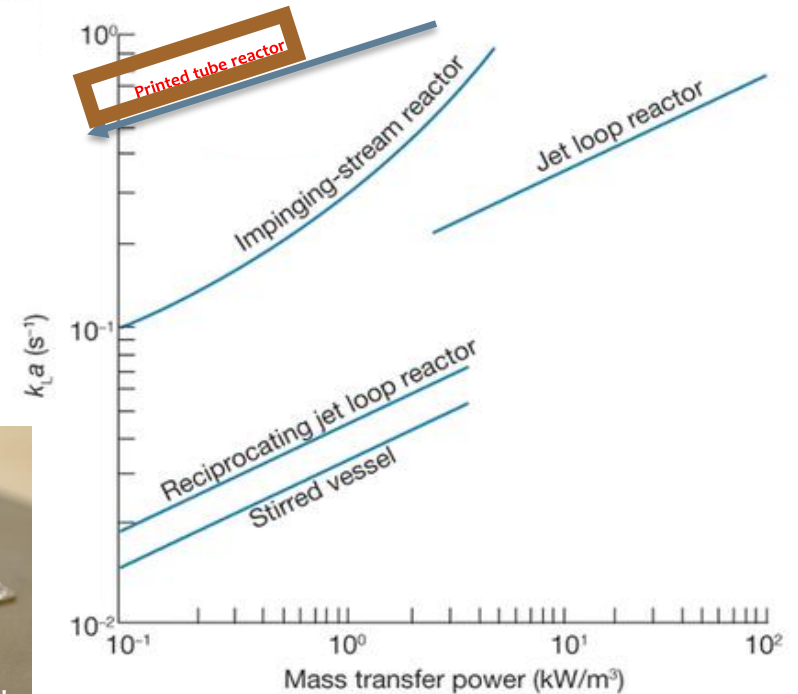
Gyroid



Printed prototypes  
combine gyroid  
& hierarchy.



First Inconel heat exchanger printed



Bio-inspired designs like gyroids and hierarchical flow paths can only be fabricated additively.