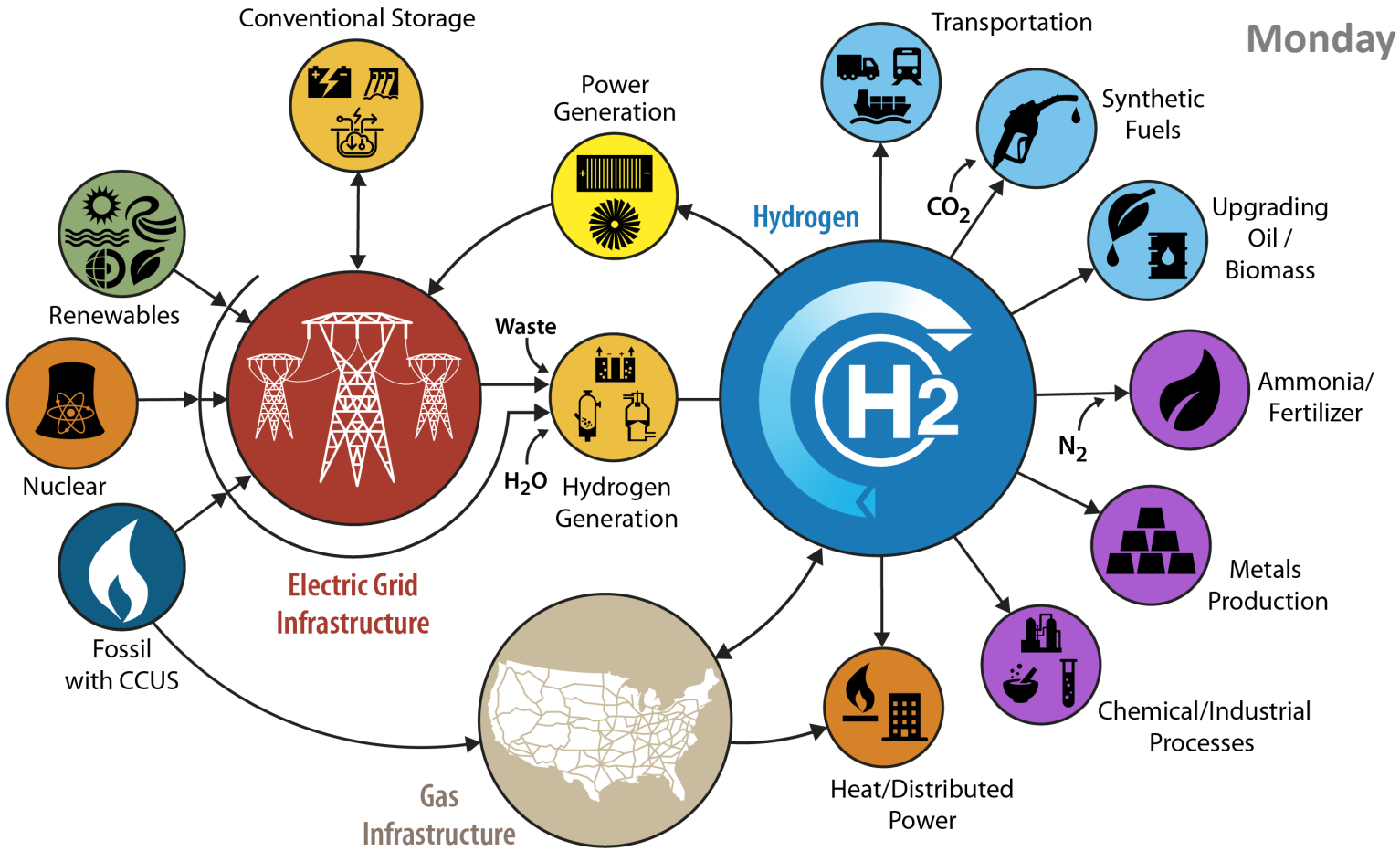
HFTO AMR Plenary Session – Experts Panel

U.S. DEPARTMENT OF ENERGY

Monday June 7th 3:45-4:30pm ET



Hydrogen's Role in Hybrid & Integrated Energy Systems

Hybrid/Integrated Energy Systems

Offering economic opportunities with environmental benefits across the U.S.

H_2 for Marine Application

California

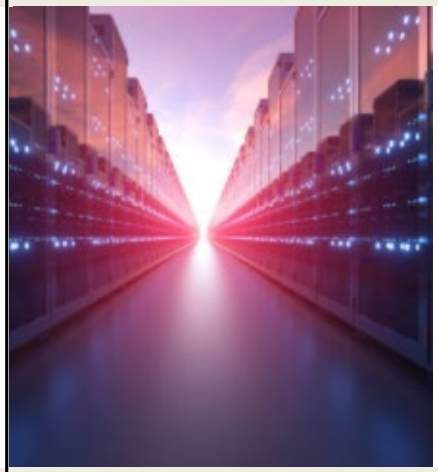
1st-of-its-kind maritime H_2 refueling on floating barge - up to ½ ton H_2/day

H_2 from Renewables

Texas

Integrates wind, solar, RNG from waste with onsite electrolysis and multiple end-uses

H_2 for Data Center



Washington

Integrates a 1.5MW fuel cell with a data center to provide reliable and resilient power

H_2 for Steel Production

Missouri

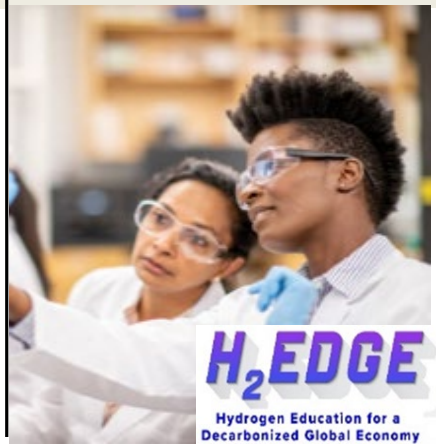
Reduction of 30% in energy and 40% emissions vs. conventional processes

H_2 from Nuclear

New York

Demonstrates a MW electrolyzer with a nuclear plant (collaboration with Nuclear Office)

Workforce Development



Multi-state

A Training, education and recruiting program to build skills needed in the H_2 industry

Hydrogen in Hybrid & Integrated Energy Systems

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Distinguished U.S. DOE Panel Experts

- **Eric Hsieh** – DOE Office of Electricity
  - *The DOE Energy Storage Grand Challenge*
- **Paul Spitsen** – DOE EERE Strategic Analysis
  - *Collaborative Opportunities in Hybrid Energy Systems*
- **Jian Fu** – DOE EERE Wind Energy Technologies Office
  - *Leveraging Wind/Renewable Resources – FlexPower*
- **Avi Shultz** – DOE EERE Solar Energy Technologies Office
  - *Leveraging Concentrated Solar Power & Heat*
- **Jason Marcinkoski** – DOE Office of Nuclear Energy
  - *Opportunities Leveraging Nuclear Power*
- **Bhima Sastri** – DOE Office of Fossil Energy
  - *Opportunities Leveraging Fossil Energy Resources*

Moderator: ***Eric Miller – DOE EERE Hydrogen and Fuel Cell Technologies Office***

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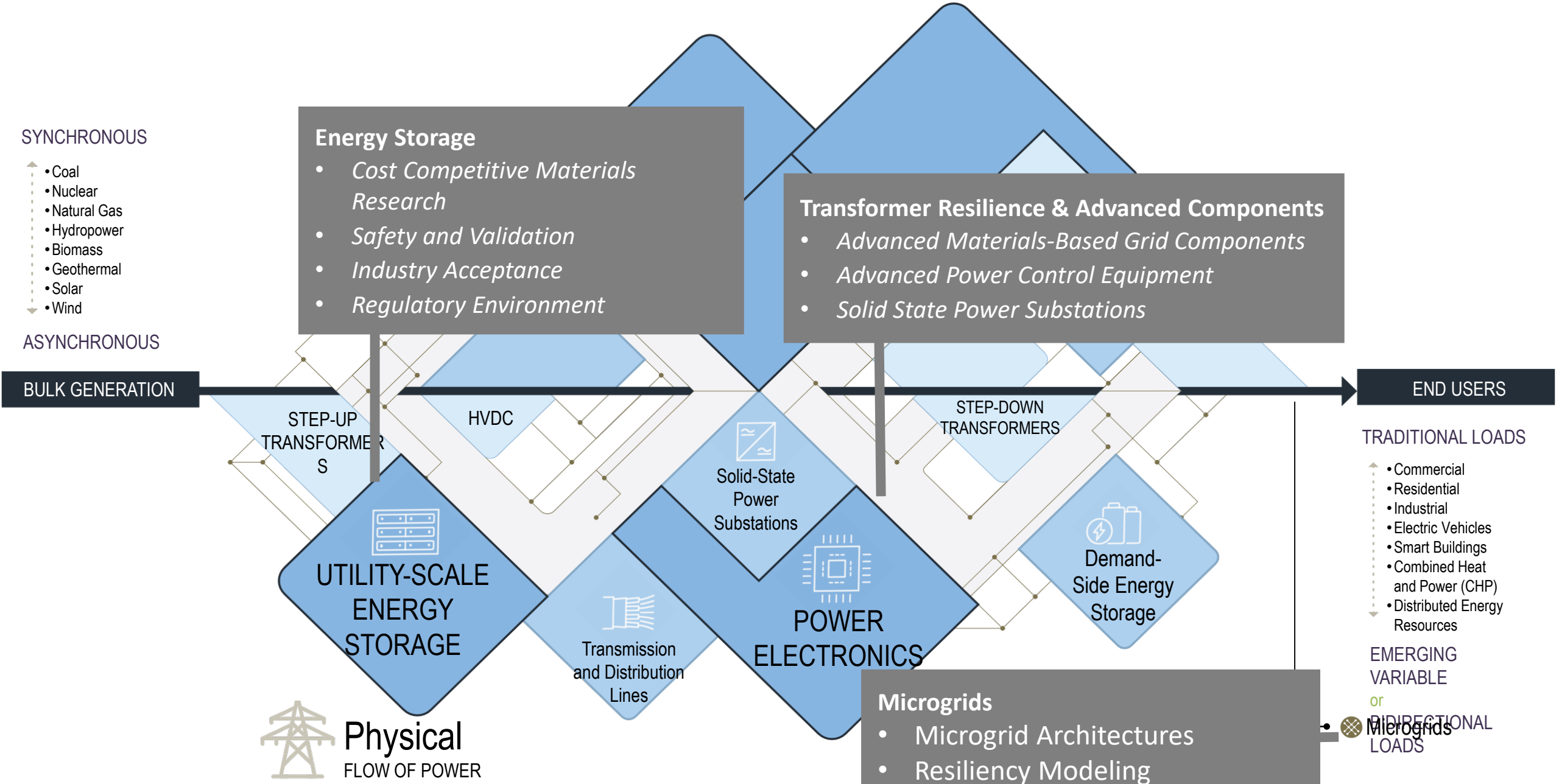
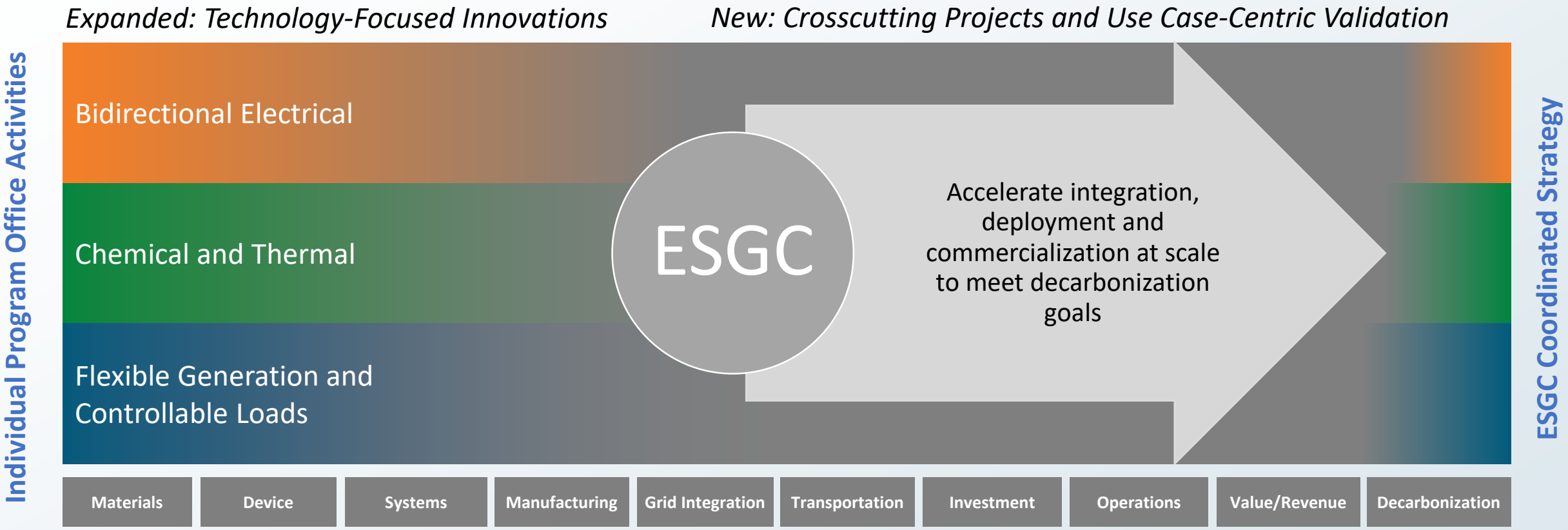
Eric Hsieh

Program Director– DOE Office of Electricity


SYNCHRONOUS
• Coal
• Nuclear
• Natural Gas
• Hydropower
• Biomass
• Geothermal
• Solar
• Wind
ASYNCHRONOUS
Energy Storage
• Cost Competitive Materials Research
• Safety and Validation
• Industry Acceptance
• Regulatory Environment
Transformer Resilience & Advanced Components
• Advanced Materials-Based Grid Components
• Advanced Power Control Equipment
• Solid State Power Substations
BULK GENERATION
STEP-UP TRANSFORMERS
HVDC
Solid-State Power Substations
STEP-DOWN TRANSFORMERS
END USERS
TRADITIONAL LOADS
• Commercial
• Residential
• Industrial
• Electric Vehicles
• Smart Buildings
• Combined Heat and Power (CHP)
• Distributed Energy Resources
EMERGING VARIABLE or BIDIRECTIONAL LOADS
• Microgrids
UTILITY-SCALE ENERGY STORAGE
Transmission and Distribution Lines
POWER ELECTRONICS
Demand-Side Energy Storage
Physical
FLOW OF POWER
Microgrids
• Microgrid Architectures
• Resiliency Modeling
• Microgrid Standards and Testing

Energy Storage Grand Challenge: Leveraging Later-Stage Commonalities



Identifying Diverse Storage Beneficiaries

The Use Cases form a technology neutral framework to ensure that storage technologies can cost effectively meet real needs.

Facilitating Grid Decarbonization

Ensure grid flexibility and the continued reliability, resilience, and security in a decarbonized electric power system.

$0.03-$0.05/kWh Levelized Cost of Storage

Serving Remote Communities

Support communities not connected to the bulk power and may be subject to high energy costs, supply disruption, and disaster events.

$65/MWh Delivered Energy Cost

Electrified Mobility

Support electrification of the transportation sector by minimizing charging impacts to the grid and promoting low-cost, high performance EVs.

$60/kWh manufactured battery cell cost

Independent Network Infrastructure

Infrastructure that is interdependent with the electric grid and requires reliable electricity delivery to maintain effective operations.

$77/yr storage capex

Critical Services

Maintain operations in facilities critical to public health/safety during major outage events

$77/kW-year storage capex

$1392/kW-year backup generator offset

Facility Flexibility, Efficiency, and Value Enhancement

Optimize energy production and/or usage to optimize value and enable flexible, efficient operations for the facility owner

$52/kW-yr residential & commercial

$20-$52/kW-yr large facilities.

Future Use Cases

Use Cases Link R&D to Policy Objectives

ESGC Roadmap envisions a periodic stakeholder process to update the use cases and cost targets

ENERGY STORAGE GRAND CHALLENGE
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Paul Spitsen

Technology and Policy Analyst – EERE Strategic Analysis

DOE Hybrid Energy Systems Opportunities Report

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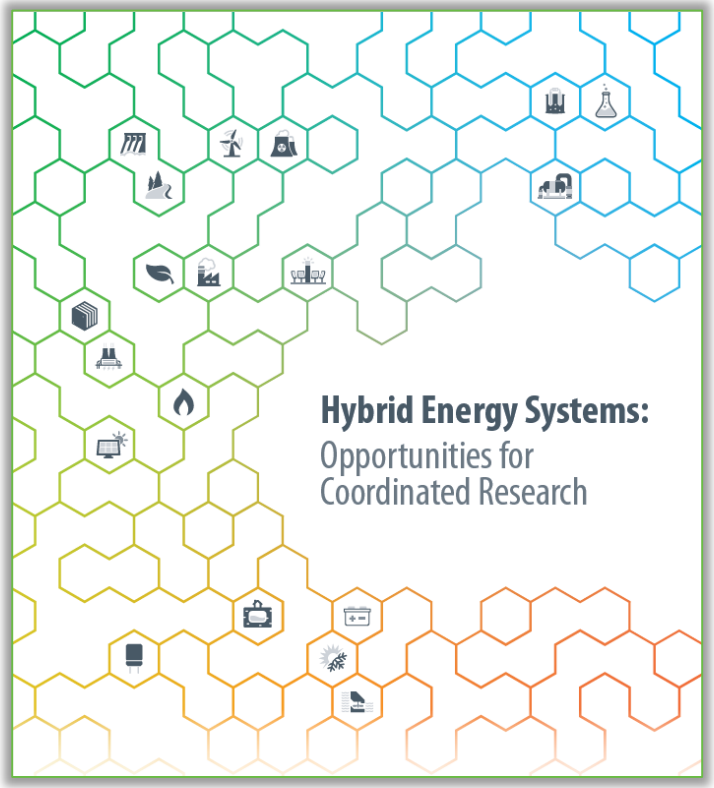

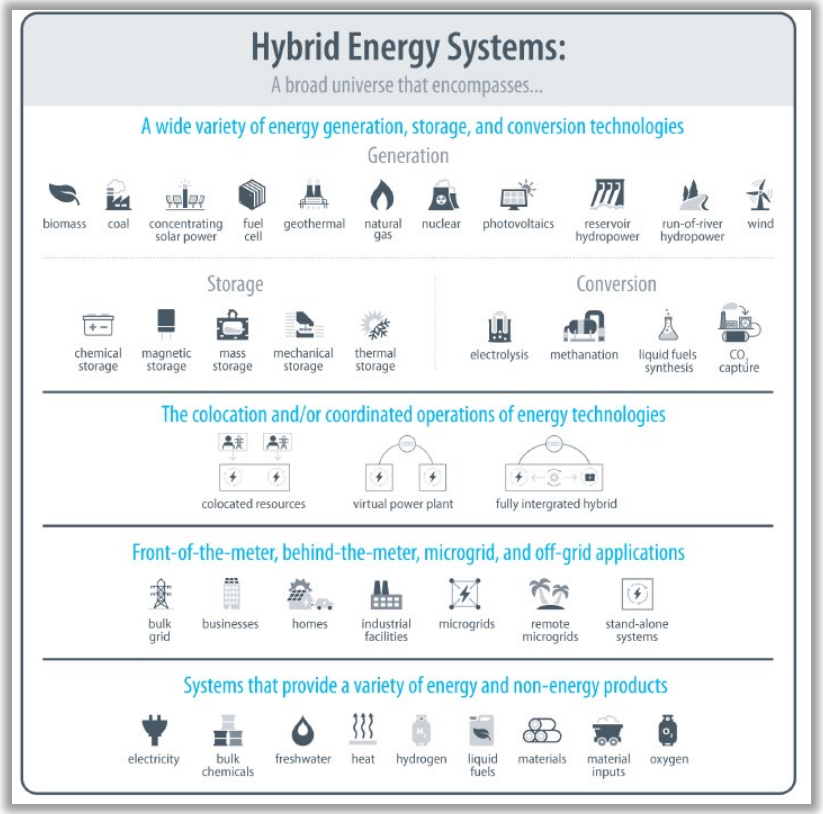

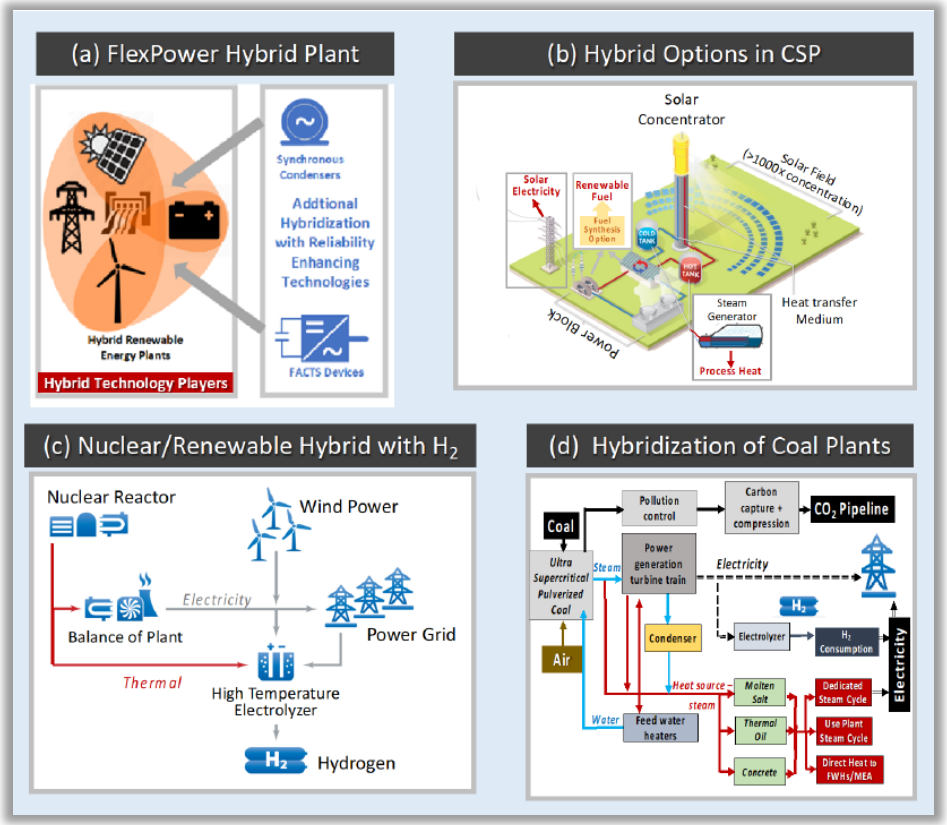

We define HES in this report as systems involving *multiple energy generation, storage, and/or conversion technologies that are integrated—through an overarching control framework or physically—to achieve cost savings and enhanced capabilities, value, efficiency, or environmental performance compared to the independent alternatives*.

DOE Hybrid Energy Systems Opportunities Report

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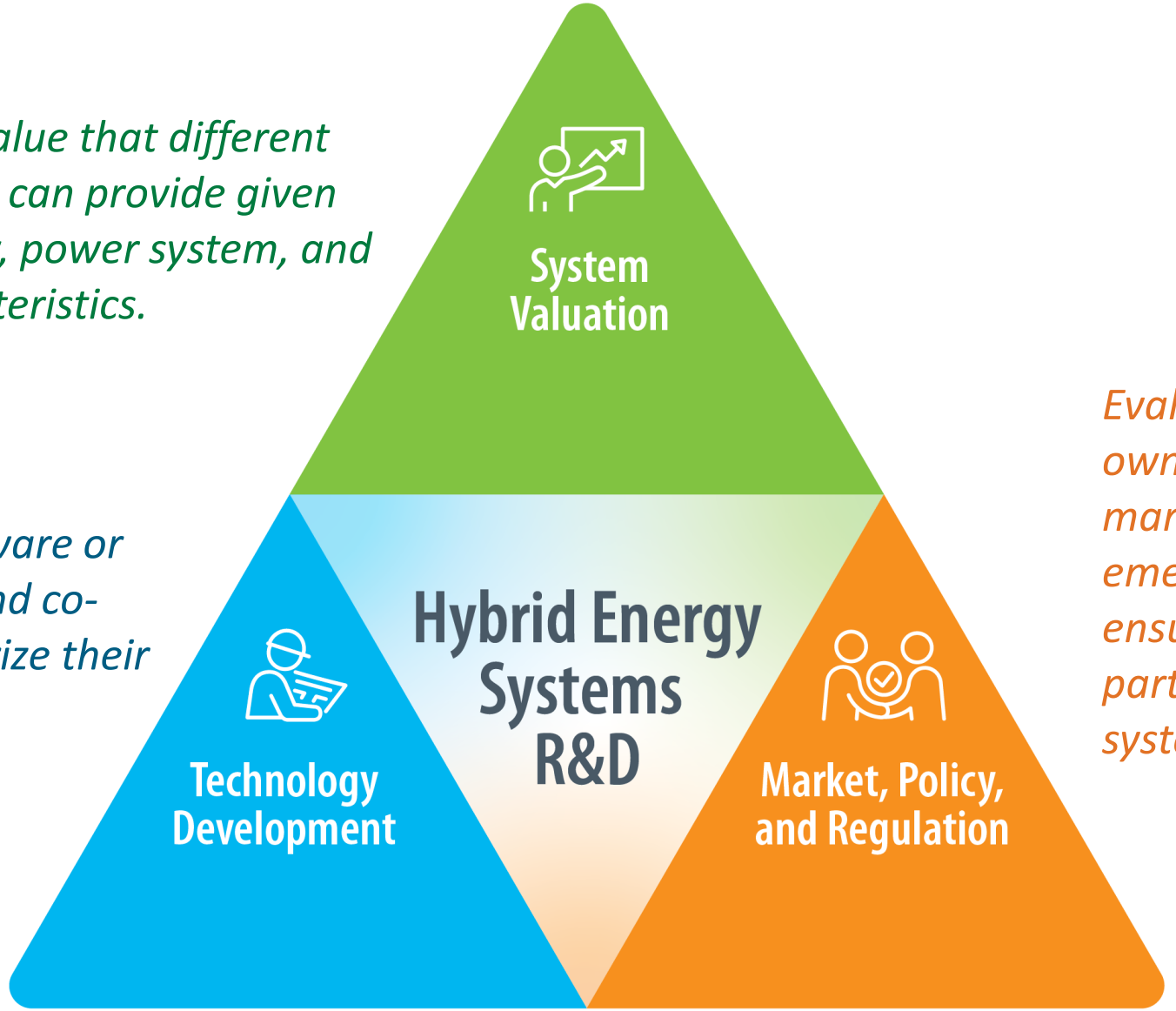
Quantify the value that different hybrid systems can provide given the technology, power system, and market characteristics.

Develop enabling hardware or software to be linked and co-optimize, and characterize their costs and performance.



Evaluate regulations, policies, ownership structures, and market products that are emerging and/or needed to ensure efficient dispatch and participation of hybrid systems.

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Jian Fu

Program Lead – EERE Wind Energy Technologies Office

Wind Office R&D Program Overview

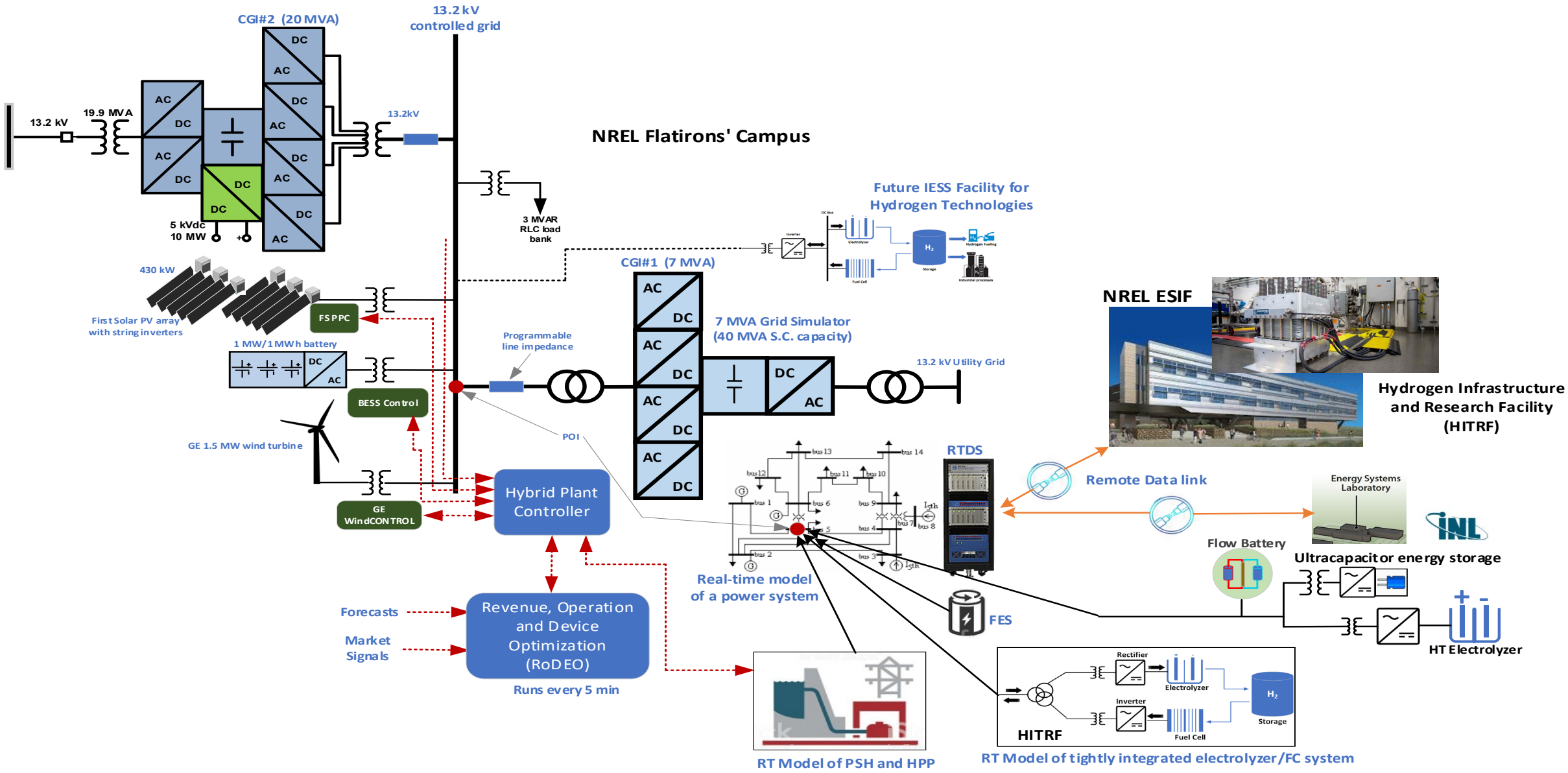
WETO R&D Focus Areas

- Offshore Wind
- Land-Based Wind
- Distributed Wind
- Systems Integration
- Data, Modeling & Analysis

Top-Line R&D Priorities

- Aggressive cost reduction
- Scaling and light-weighting
- Environmental & siting challenges
- Transmission access, grid services, hybrid systems, power electronics

FlexPower Hybrid Plant Demonstration Platform



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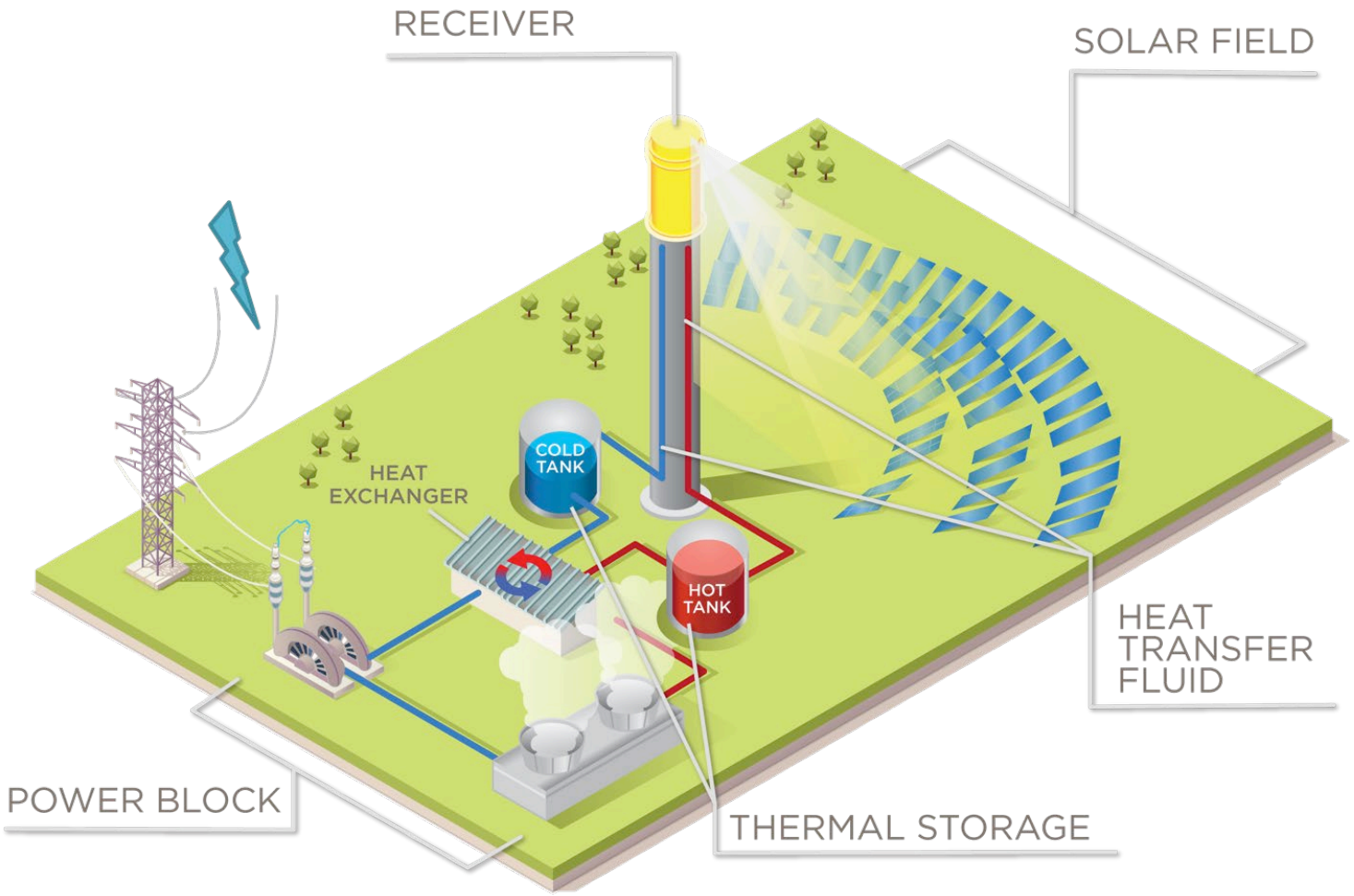
Avi Shultz

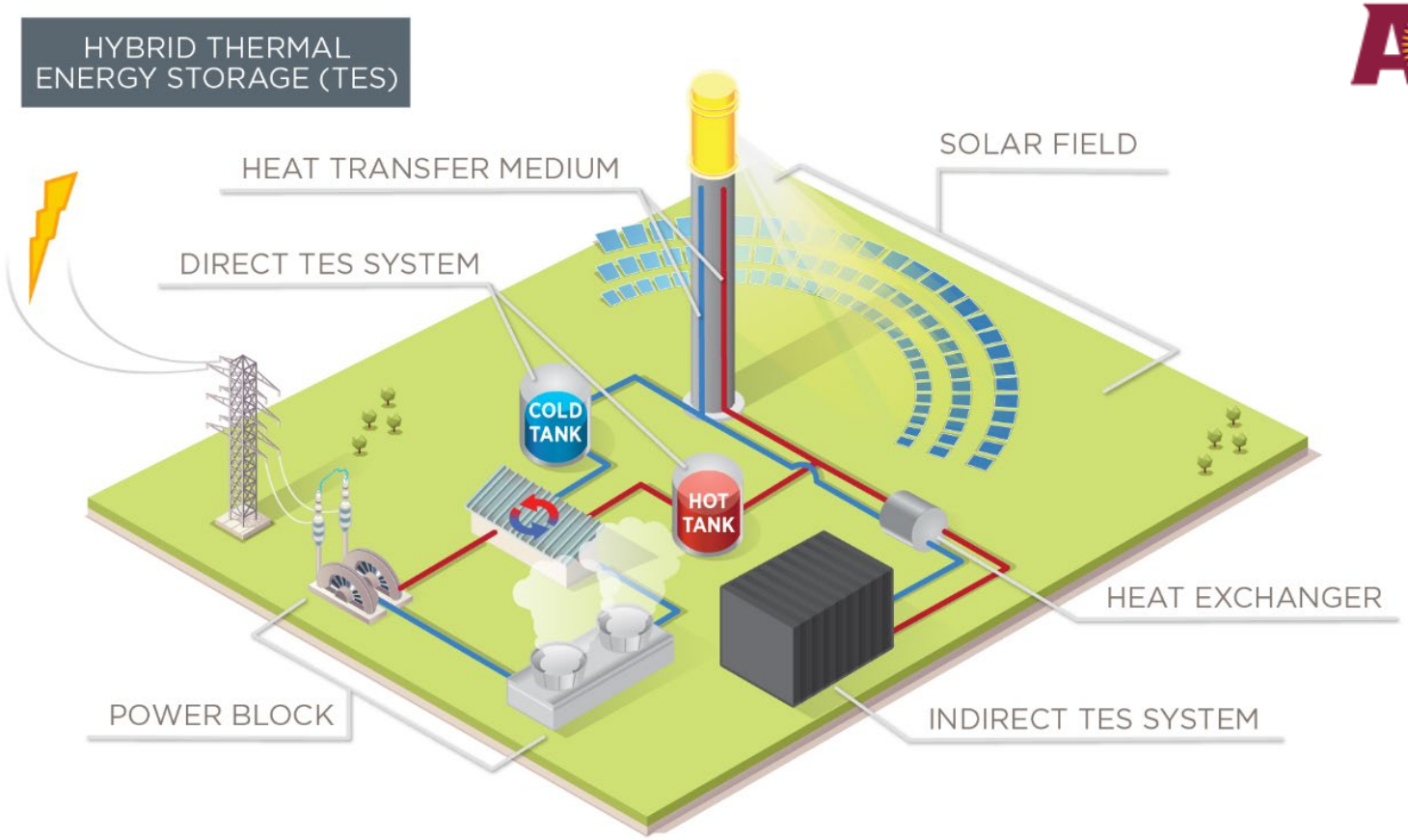
Program Manager – EERE Solar Energy Technologies Office

CSP with Storage is Solar Power or Heat On-Demand

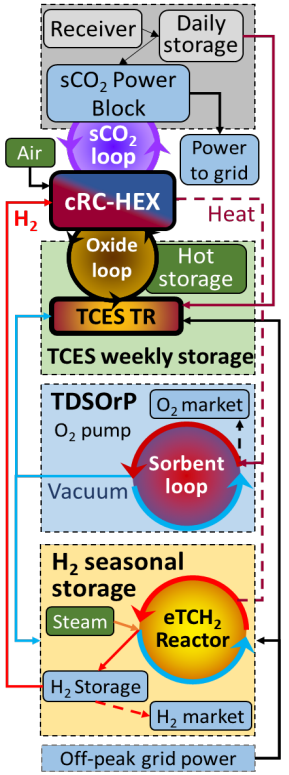


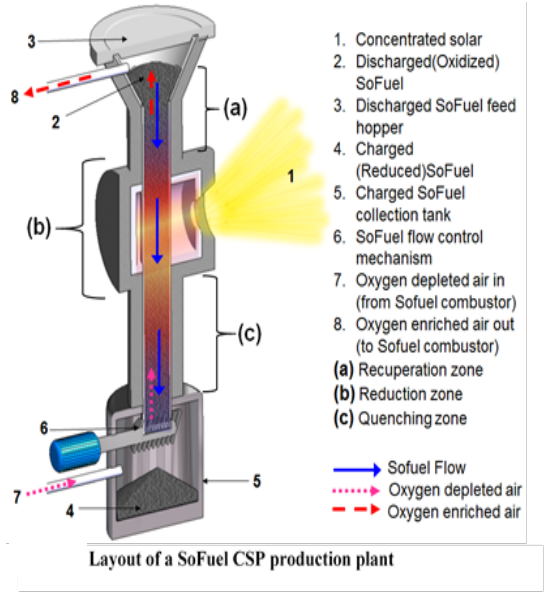
- **5.2 GW** of parabolic trough plants are operating or under construction – operating at **~400 °C**
- **1.3 GW** of tower plants are operating or under construction – operating at **~565 °C**
- CSP plants have been built with up to **17.5 hours** of storage
- Thermal energy storage allows 24/7 integration of **renewable heat and/or electricity** with chemical processes

Thermochemical Processes for Firm Energy Availability



Arizona State University





Layout of a SoFuel CSP production plant

$MgMn_2O_4 \leftrightarrow MnO + MgO + O_2$

$\Delta H = 370\text{-}392$ kJ/mol O_2

MICHIGAN STATE UNIVERSITY

Existing power block at a CSP plant can be leveraged for high value 'indirect' TES via long-duration thermochemical or (renewable) fuels

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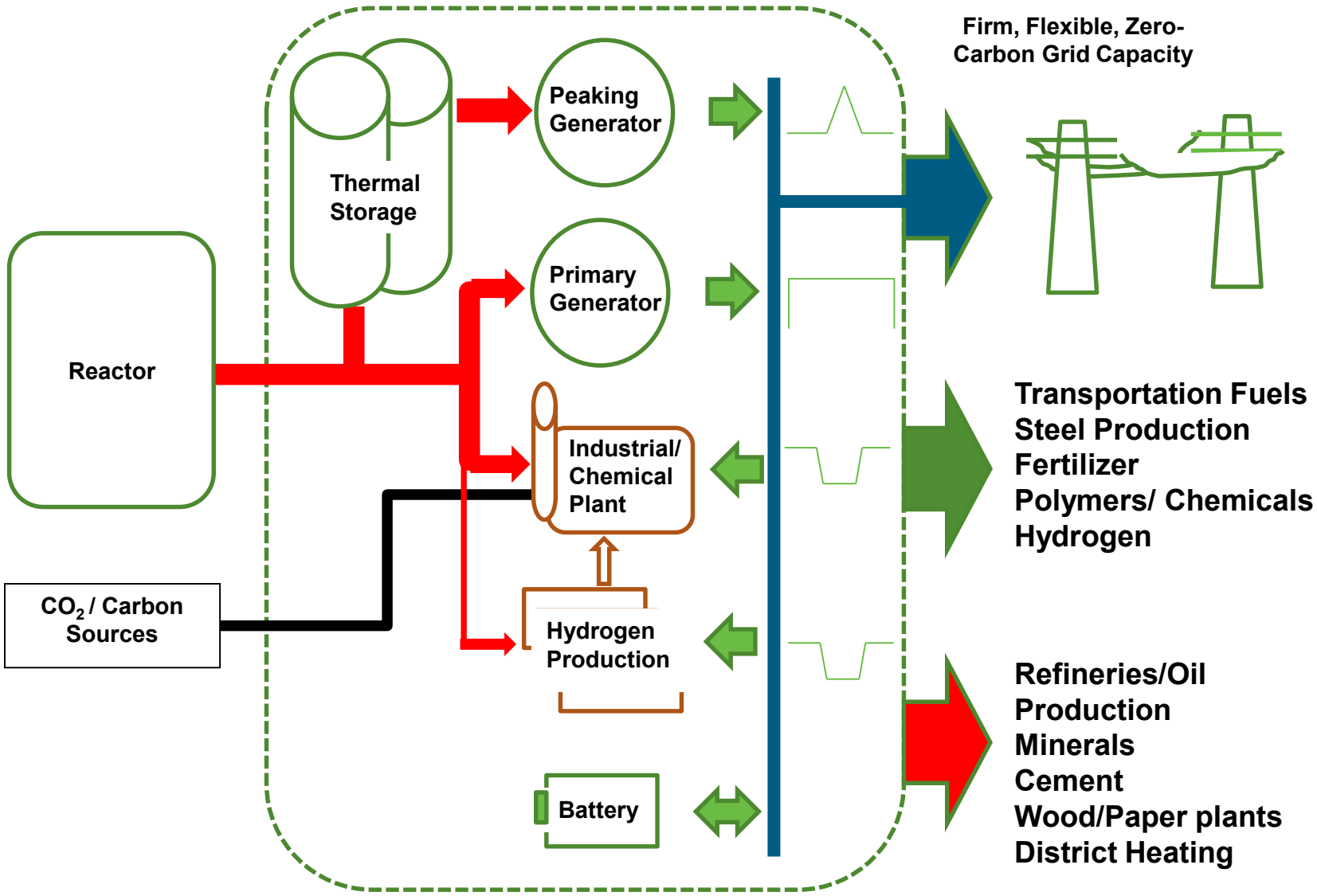
Jason Marcinkoski

Program Manager– Integrated Energy Systems

DOE Office of Nuclear Energy

Nuclear Integrated Energy Systems Strategy



Integrating Nuclear Technologies with Renewables

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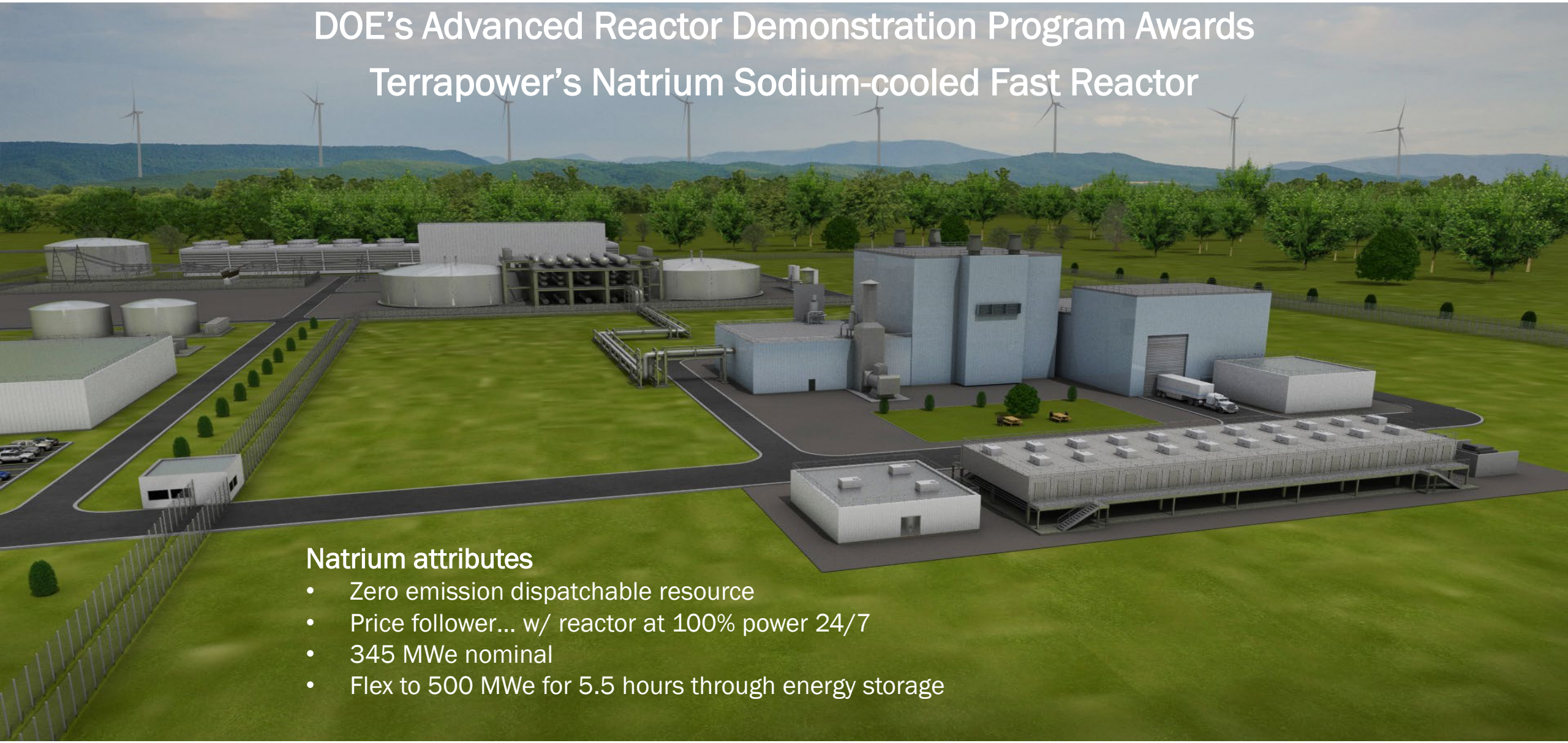
DOE's Advanced Reactor Demonstration Program Awards

Terrapower's Natrium Sodium-cooled Fast Reactor



Natrium attributes

- Zero emission dispatchable resource
- Price follower… w/ reactor at 100% power 24/7
- 345 MWe nominal
- Flex to 500 MWe for 5.5 hours through energy storage

Envisioning Future Nuclear Energy:
Microreactor Powered Hydrogen Fueling Station

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Notional Specs*

MW Total (15 MW modules)	60
kg / day trucks	50
kWh / kg hydrogen generation	50
kWh / truck / day	2500
trucks / station / day	576
fueling positions	~12

***not associated with images**

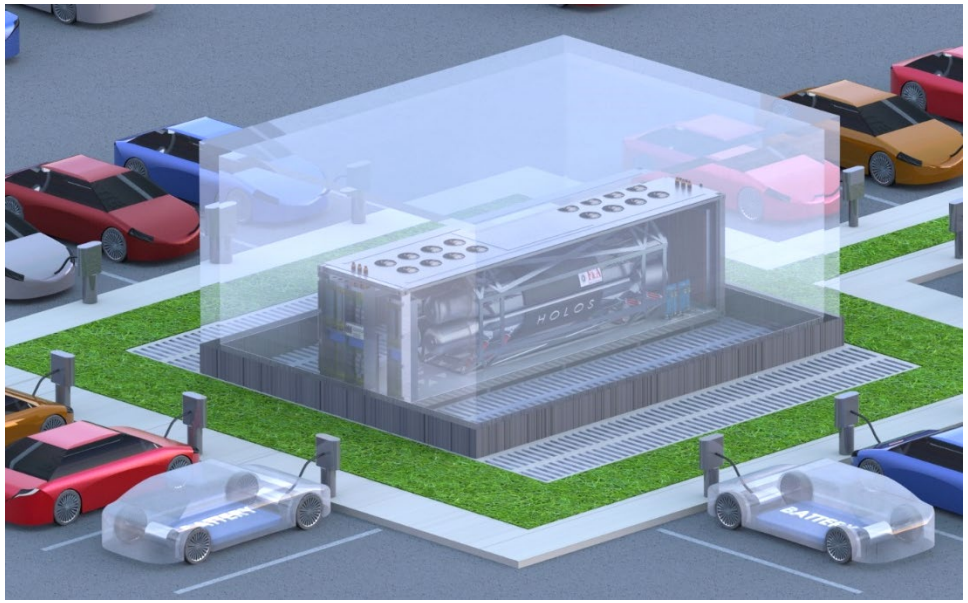

Image courtesy of HolosGen

Image courtesy of Nikola Motor Company

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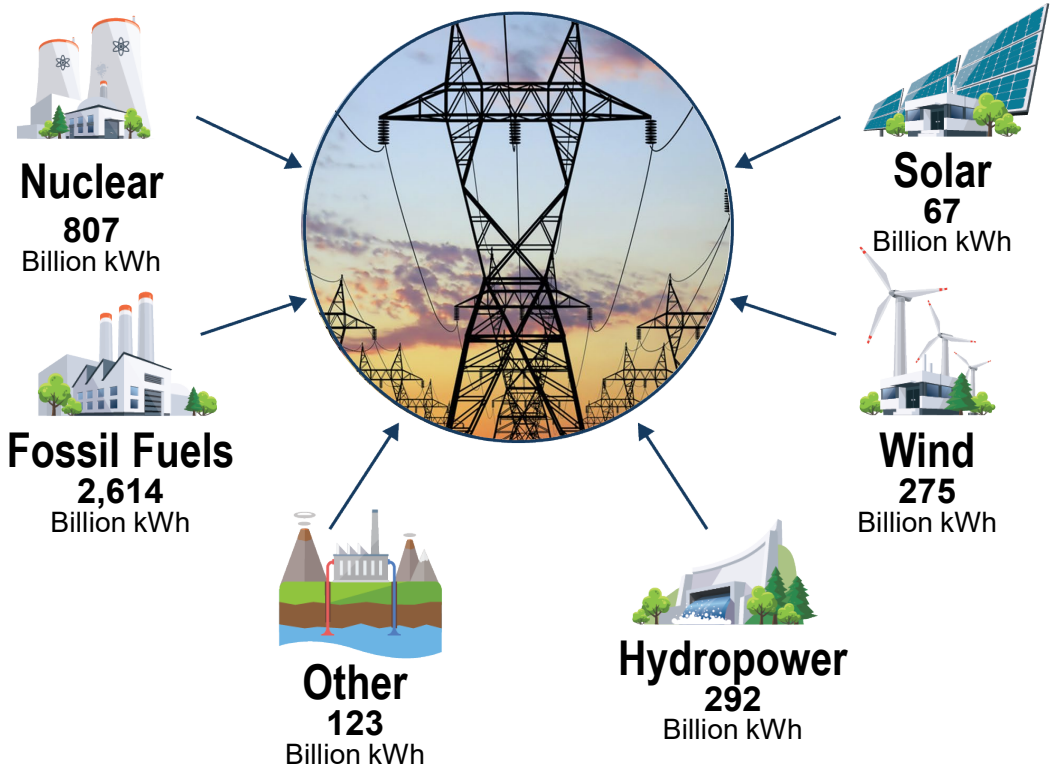
Bhima Sastri

Director– Crosscutting R&D and Systems Integration

DOE Office of Fossil Energy and Carbon Management

IES Effort to Enable New Technologies

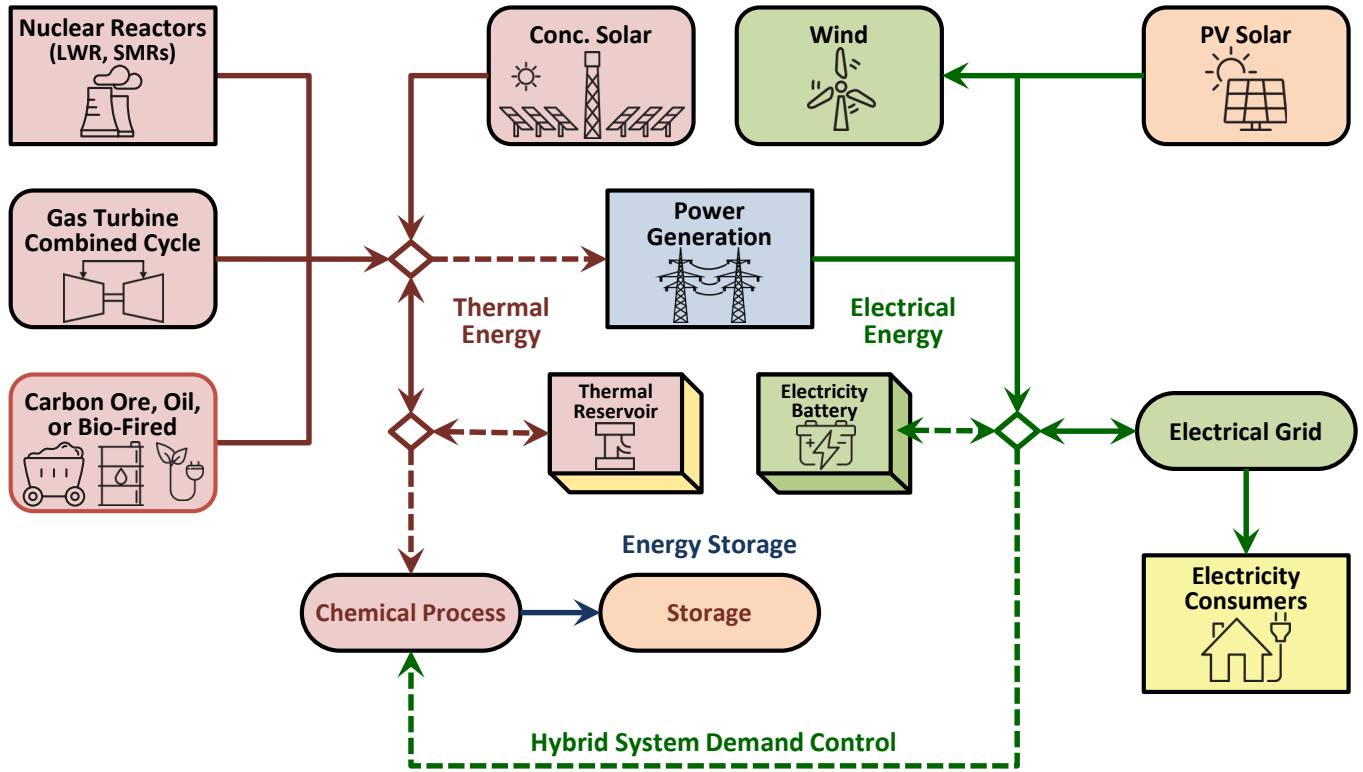
Coordinated Energy Systems



Total: 4,178 Billion kilowatt-hours (kWh)

Data source: EIA, 2018

Tightly Coupled Hybrid Energy Systems



Question to the Distinguished Panelists:

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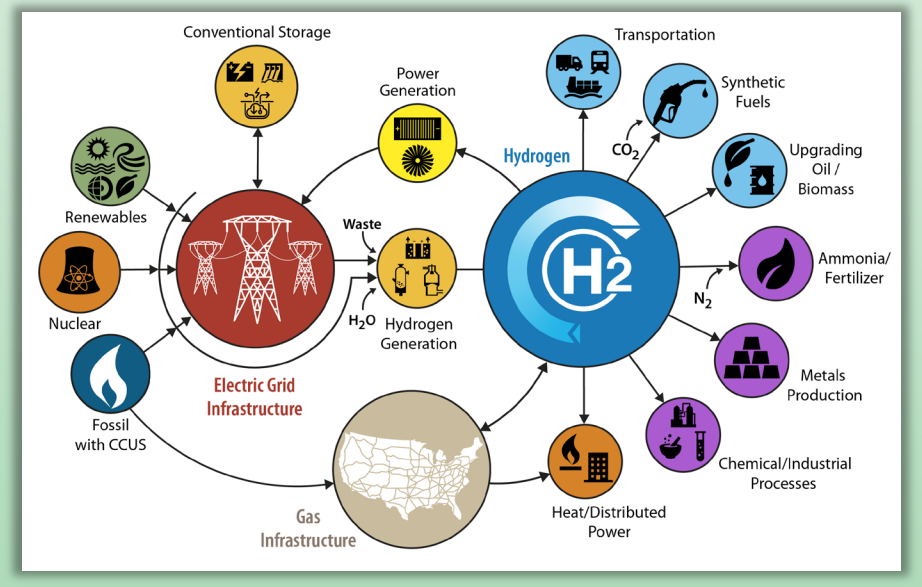
- Where do you see the major challenges and opportunities for collaborative RD&D in hybrid/integrated systems comprising power generation, energy storage, and value-add co-products: *specifically ones leveraging hydrogen and fuel cell technologies?*



Thank you!

More info on the DOE Hydrogen Program:

www.hydrogen.energy.gov