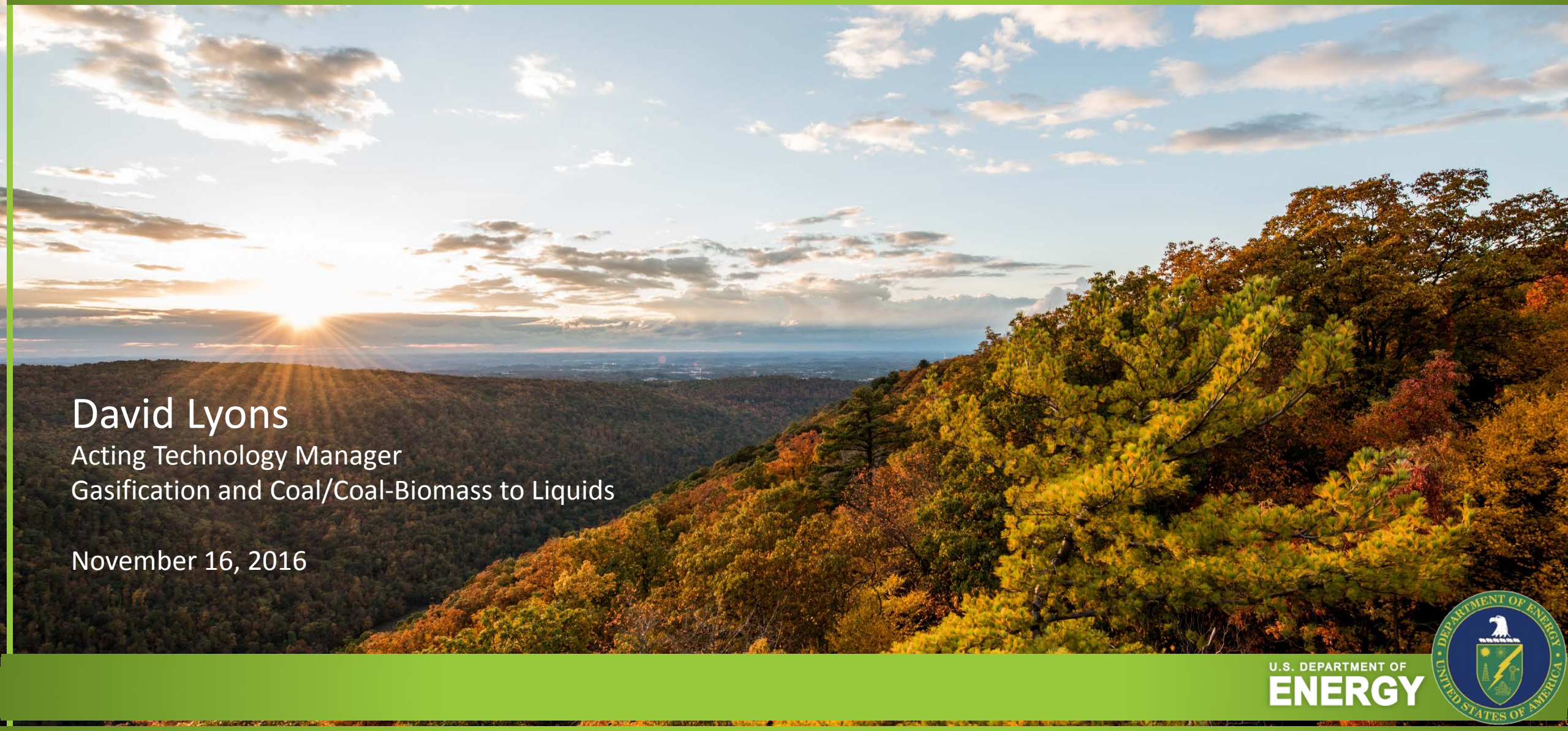
NETL/FE technologies for value-added applications in a deeply decarbonized economy

NATIONAL ENERGY TECHNOLOGY LABORATORY

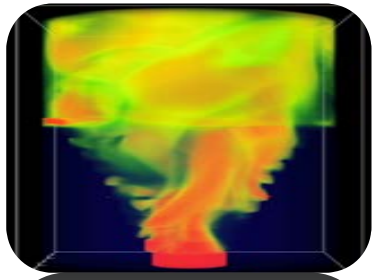


David Lyons
Acting Technology Manager
Gasification and Coal/Coal-Biomass to Liquids

November 16, 2016

U.S. DEPARTMENT OF ENERGY

NETL Core Competencies



Computational Science & Engineering

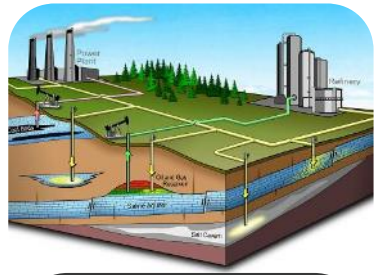
High Performance Computing

Data Analytics

Materials Engineering & Manufacturing

Structural & Functional

Design, Synthesis & Performance



Geological & Environmental Systems

Air, Water & Geology

Knowledge & Mitigation

Energy Conversion Engineering

Component & Device

Design & Validation

Systems Engineering & Analysis

Process & System

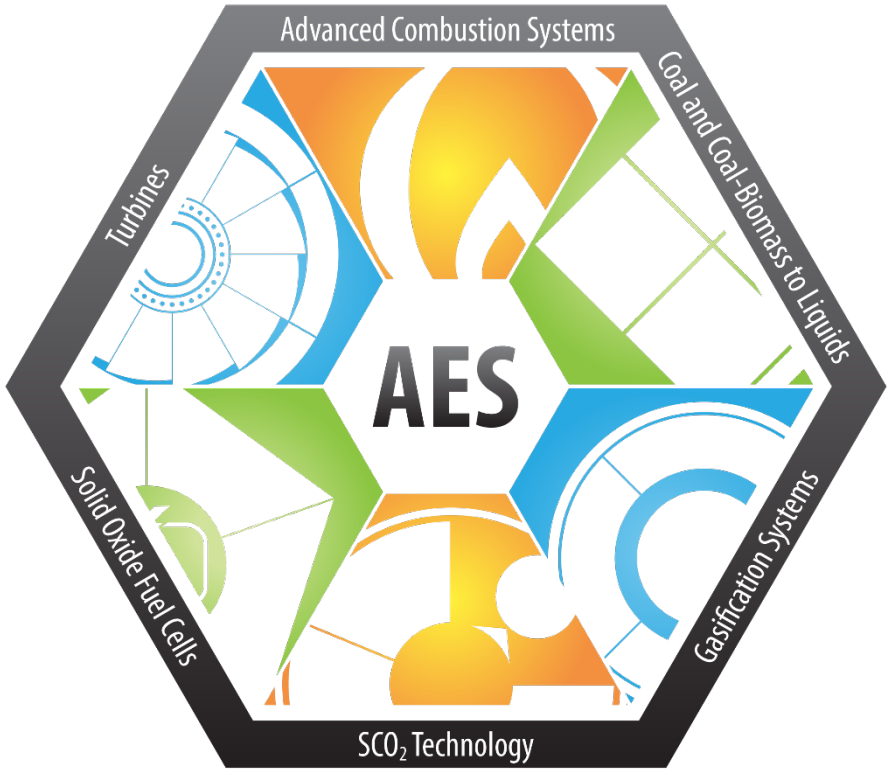
Optimization, Validation & Economics

Effective Resource Development • Efficient Energy Conversion • Environmental Sustainability

NETL Coal Program Technology Thrusts

Advanced Energy Systems		• Efficient Energy Conversion • Zero-Emissions Power Production • Minimize Water Use and Discharge
Carbon Capture		• Cost-Effective Capture Systems • Minimize Energy Penalty for Capture and Compression • Smaller Capture System Footprint
Carbon Storage		• Safe, Effective, Long-term Storage • Monitoring, Verification, Accounting, and Assessment • Demonstrate Storage Infrastructure
Crosscutting Research & Analysis		• High-performance Materials • Sensors and Controls • Enabling Technologies
STEP (Supercritical CO_2)		• High-efficiency Power Cycle • Reduced Water Consumption and Air Emissions • Reduced Power Cycle Footprint
Rare Earth Elements		• Efficient Rare Earth Element (REE) Recovery • Cost-Competitive Domestic Supply of REEs • Coal Byproduct Utilization

Advanced Energy Systems



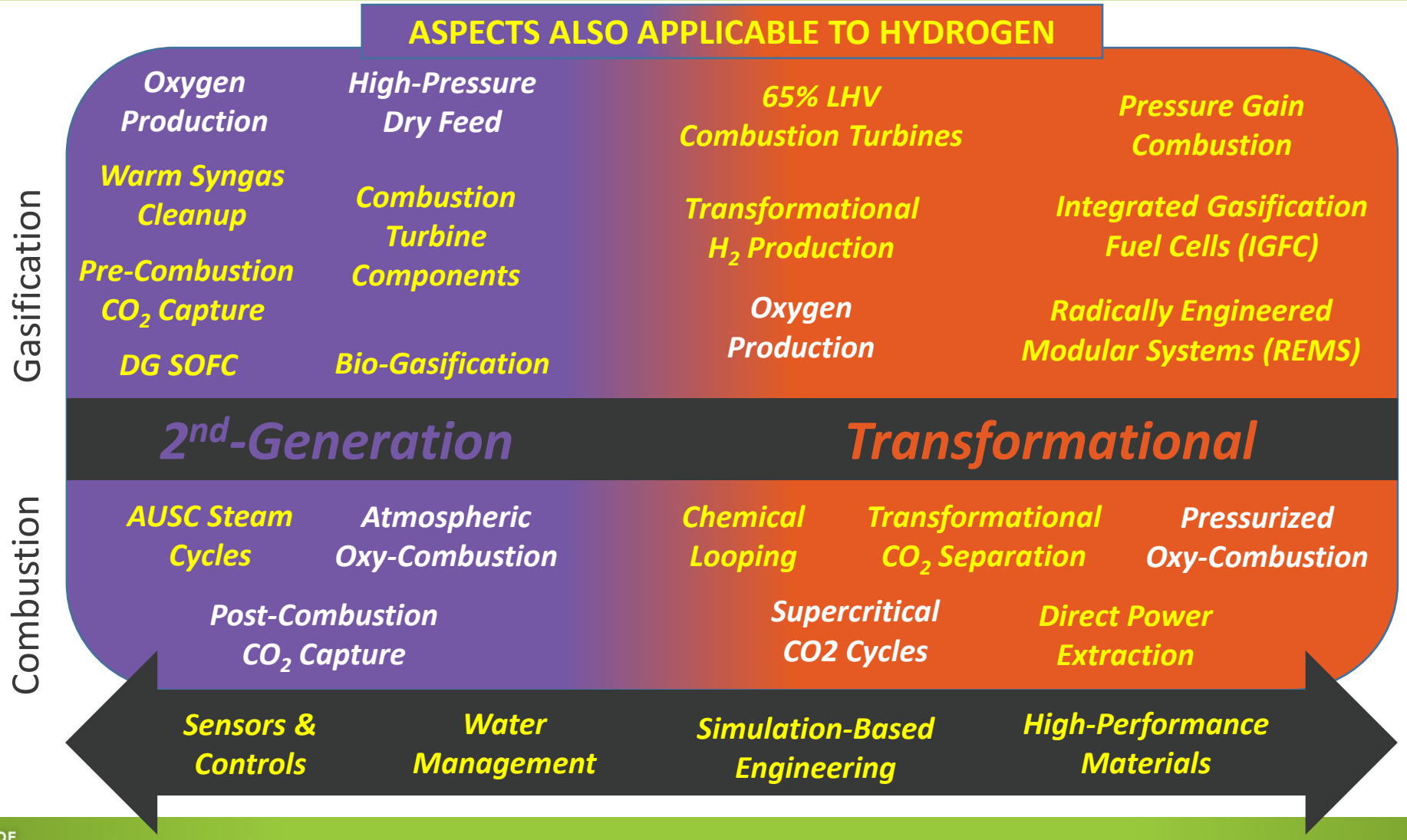
- **Advanced Combustion Systems**
  - Oxy-Combustion
  - Chemical Looping Combustion
  - Enabling Technologies/Innovative Concepts
- **Coal and Coal-Biomass to Liquids**
  - Biomass Feed and Gasification
  - Reactor Engineering Design
  - Advanced Fuels Synthesis
  - Site-Specific Coal Conversion
- **Gasification Systems**
  - Air Separation
  - Reactor Engineering Design
  - Site-Specific Coal Conversion
  - Novel Technologies to Advance Conventional Gasification
- **STEP (Supercritical CO_2)**
  - Turbomachinery
  - Recuperators
  - Advanced Concepts for Direct-Fired Cycles
  - Systems Integration and Optimization
- **Solid Oxide Fuel Cells**
  - Cell Technology
  - Core Technology
  - Systems Development
- **Advanced Turbines**
  - Advanced Combustion Turbines
  - Turbomachinery for sCO_2 Power Cycles
  - Pressure Gain Combustion

NETL Oil & Natural Gas Technology Thrusts

Advancing Technologies to Ensure Safe and Prudent Oil & Gas Development

	**Unconventional Oil & Gas**	*Developing technologies to maximize recovery and reduce environmental impact from unconventional oil & gas development.*
	**Transmission & Delivery**	*Developing technologies and practices to mitigate emissions from natural gas transmission, distribution, and storage facilities.*
	**Methane Quantification**	*Assessing current methane emissions data and addressing data gaps.*
	**Methane Hydrates**	*Unlocking the mysteries of methane hydrates and developing ways to tap their massive energy potential.*
	**Offshore**	*Minimizing the environmental impacts of deepwater and ultra-deepwater oil and natural gas production.*

NETL Supported Power Generation Technologies



Advanced Turbines
How H_2 is Playing a Role

NATIONAL ENERGY TECHNOLOGY LABORATORY

Solving Technology Challenges

- **Hydrogen combustion with low single digit NOx**
  - Solved for 2,650 °F turbine inlet temperature (TIT) (TRL 1 -> 7)
    - UTSR essentially identified & solved the basic science needed to understand ignition delay for H_2 combustion
    - Adv. mfg. applied to realize the design required by the physics
    - Approach will revolutionize low NOx combustion for H_2 & natural gas!

Advanced Turbine Program

- **Adv. combustion turbines for H_2 fuels (IGCC, NGCC) – 1 of 3 Key Technology Areas**
  - CC eff. ~ 65 % (LHV, NG bench mark), TIT of 3,100 °F
  - Components Approach TRL ~ 3 --- > TRL 6 - 7
  - Delivers transformational performance benefits by 2025 for coal based IGCC with CCS (ready for full-scale demonstration)
    - Delivers another $20/T reduction in CO_2 capture cost

2nd Generation targets met (H_2 Turbine Program)

- COE reduction of ~15% and cost of capture reduction of ~$19/tonne
- Eff. improvements of 3% pts. (4.3% pts. vs. 2003 IGCC with 7FA)

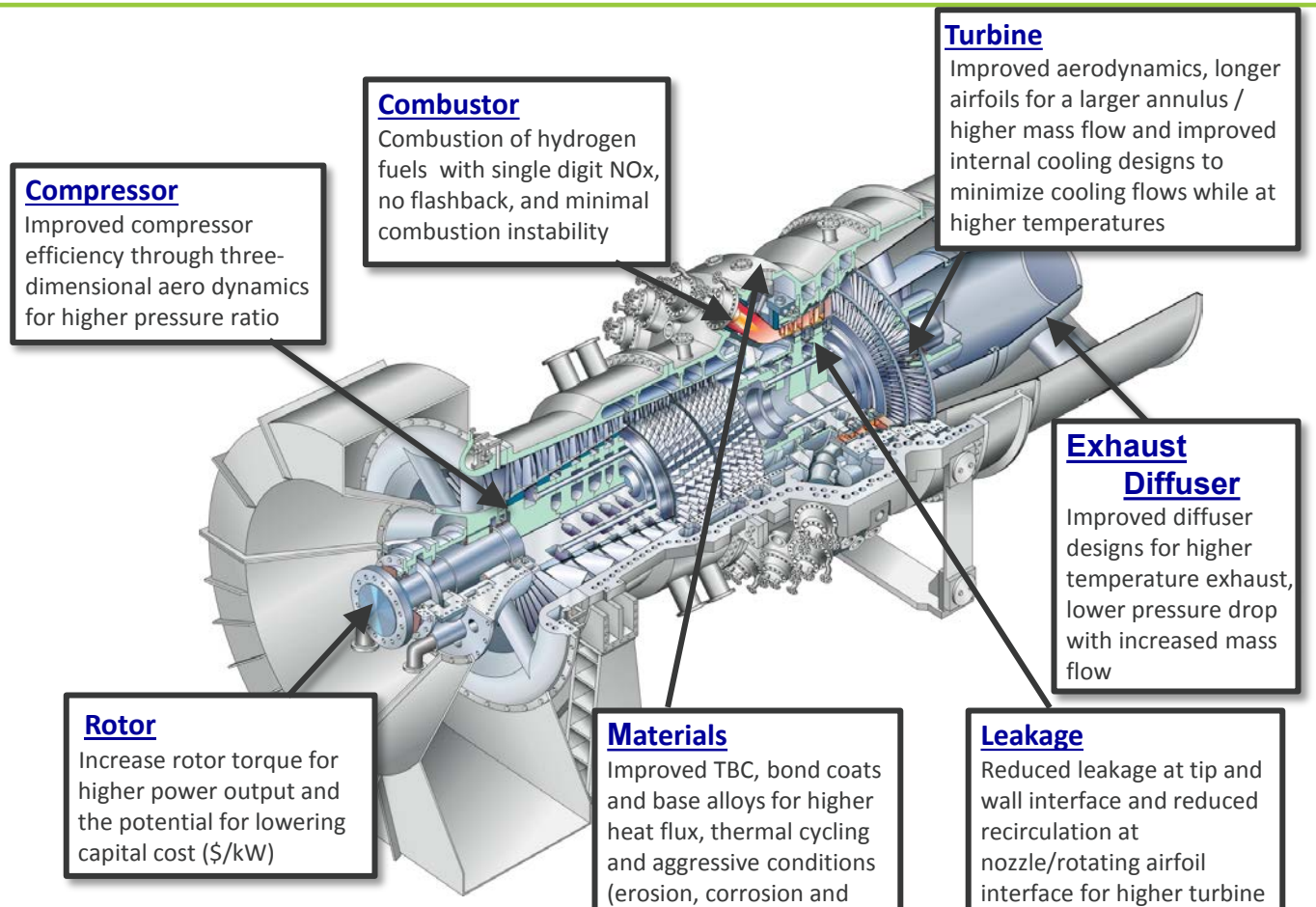
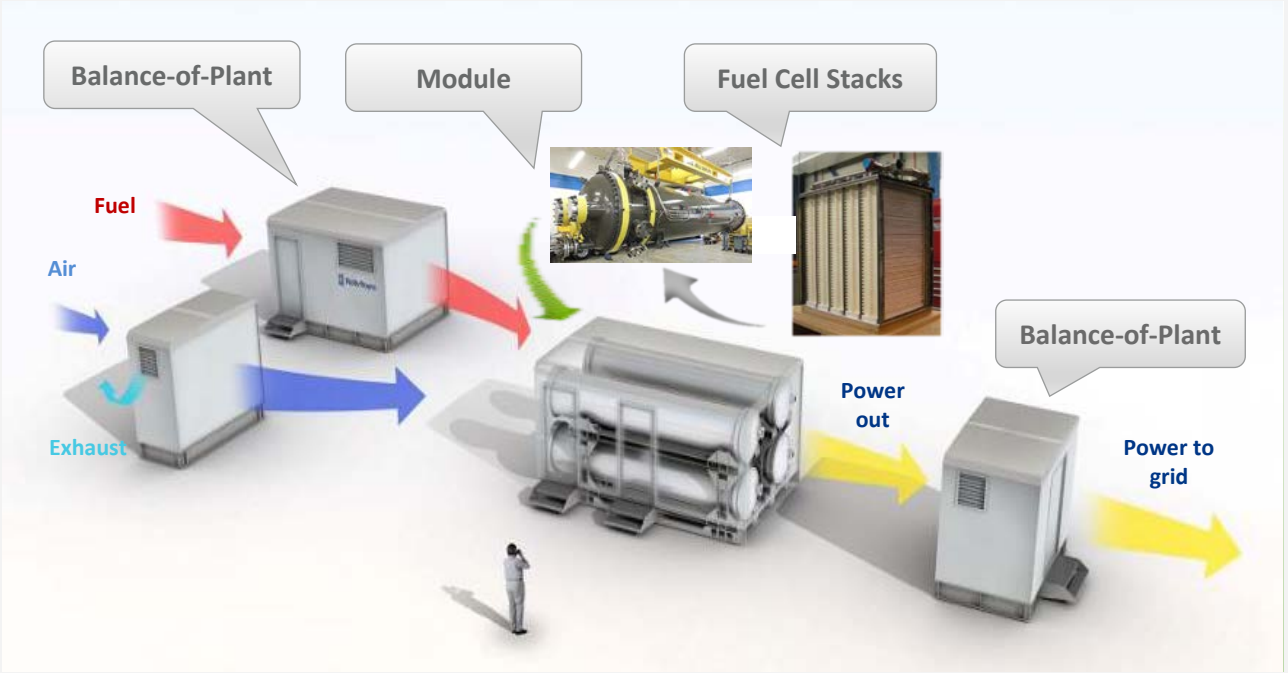


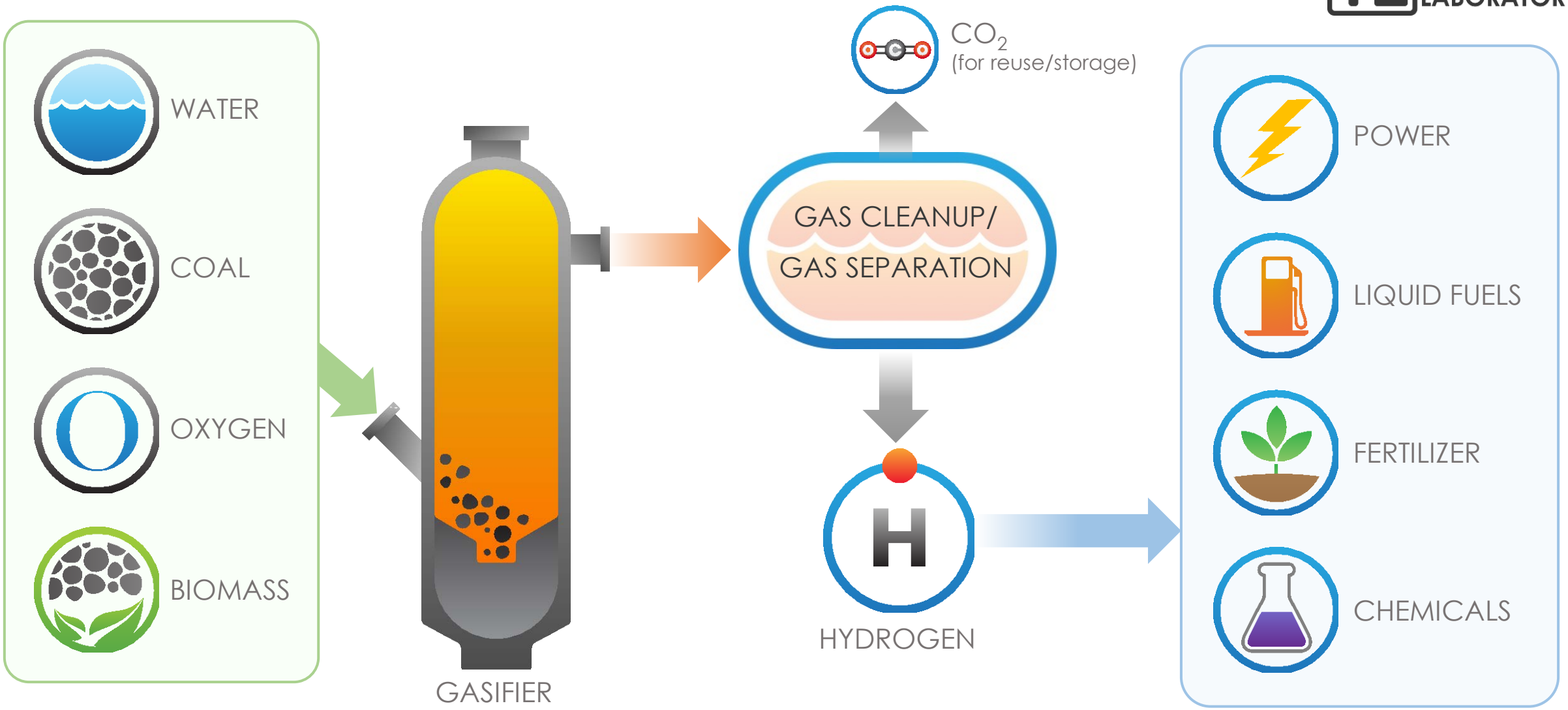
Photo courtesy of Siemens Energy

Solid Oxide Fuel Cells
provide many benefits …..

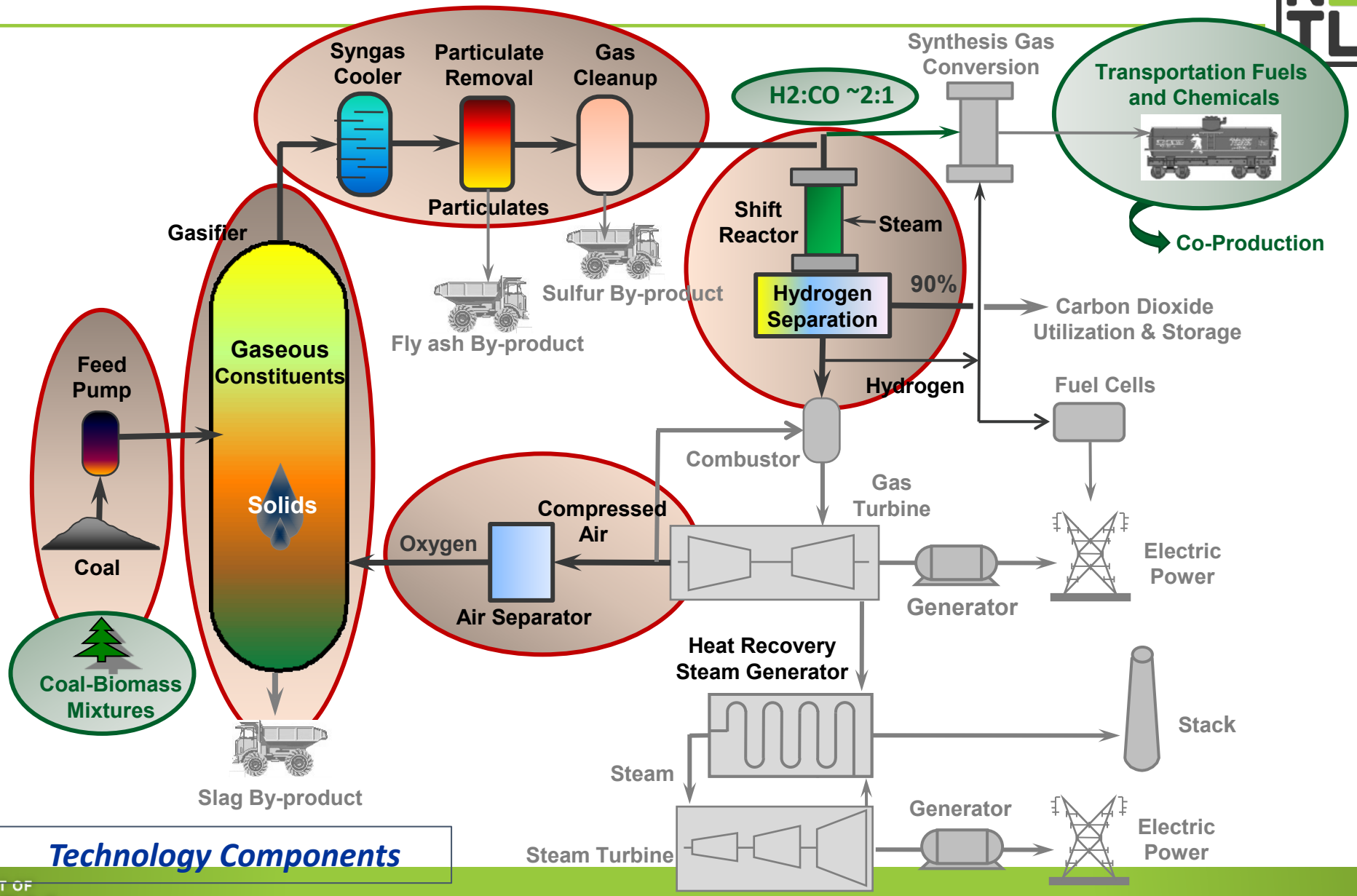
- Environmentally friendly
  - Intrinsic carbon capture (CCS) capability
  - Meet (without CCS) EPA Carbon Pollution Standards
    - Natural gas fueled: 1,000 lb. CO_2/MWh-gross
    - Coal fueled: 1,400 lb. CO_2/MWh-gross
  - Near-zero SOx and NOx
  - Minimal water consumption, ~1/3 of the amount relative to combustion processes
- High efficiency
  - >60% (HHV) electrical
  - >85% (HHV) combined heat and power
- Fuel Flexible
  - Natural gas, syngas, propane, biogas, logistics fuels, hydrogen
- Modular
  - Incremental capacity additions
  - Ideally suited for distributed generation applications



Enabling Gasification-based Technology

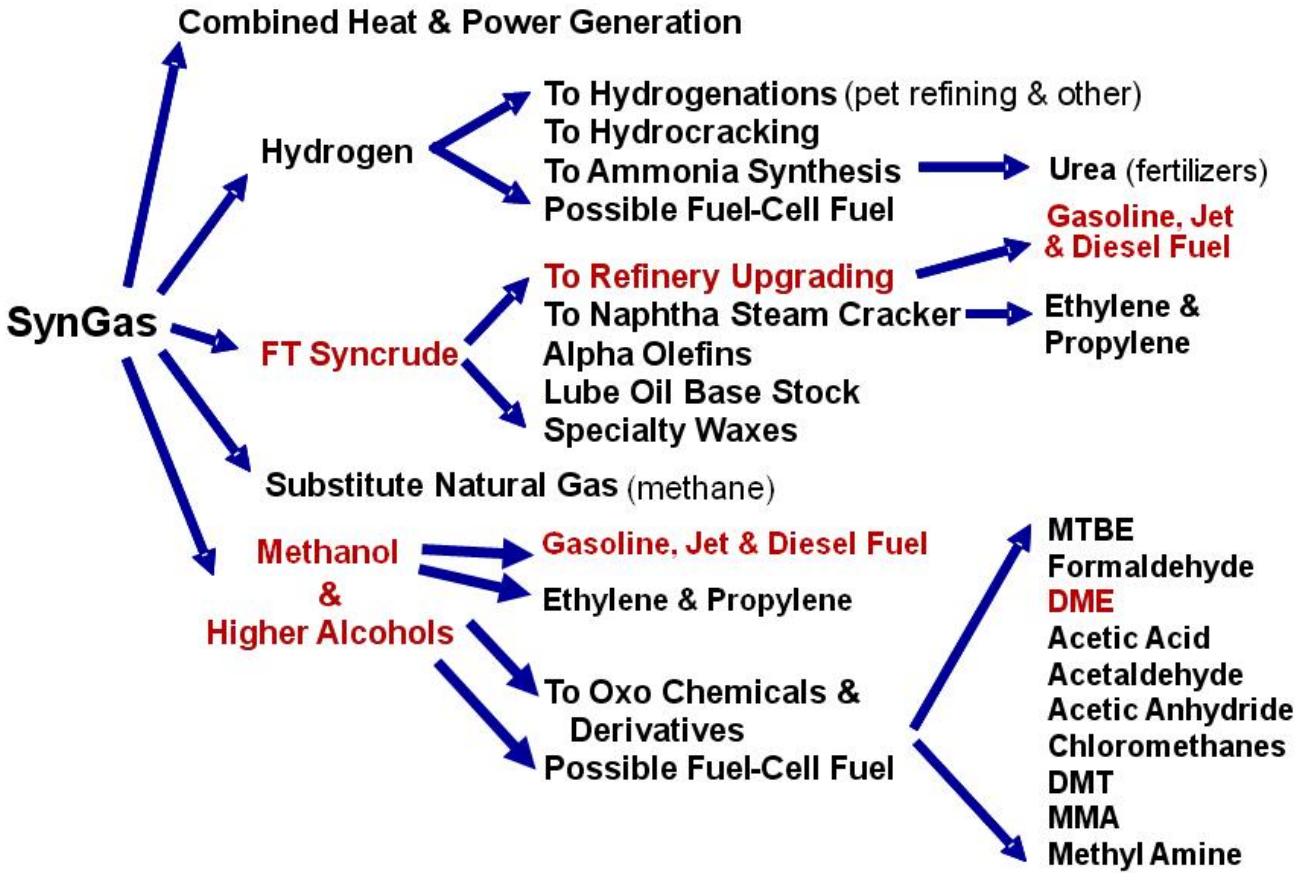


Gasification Systems/CBTL



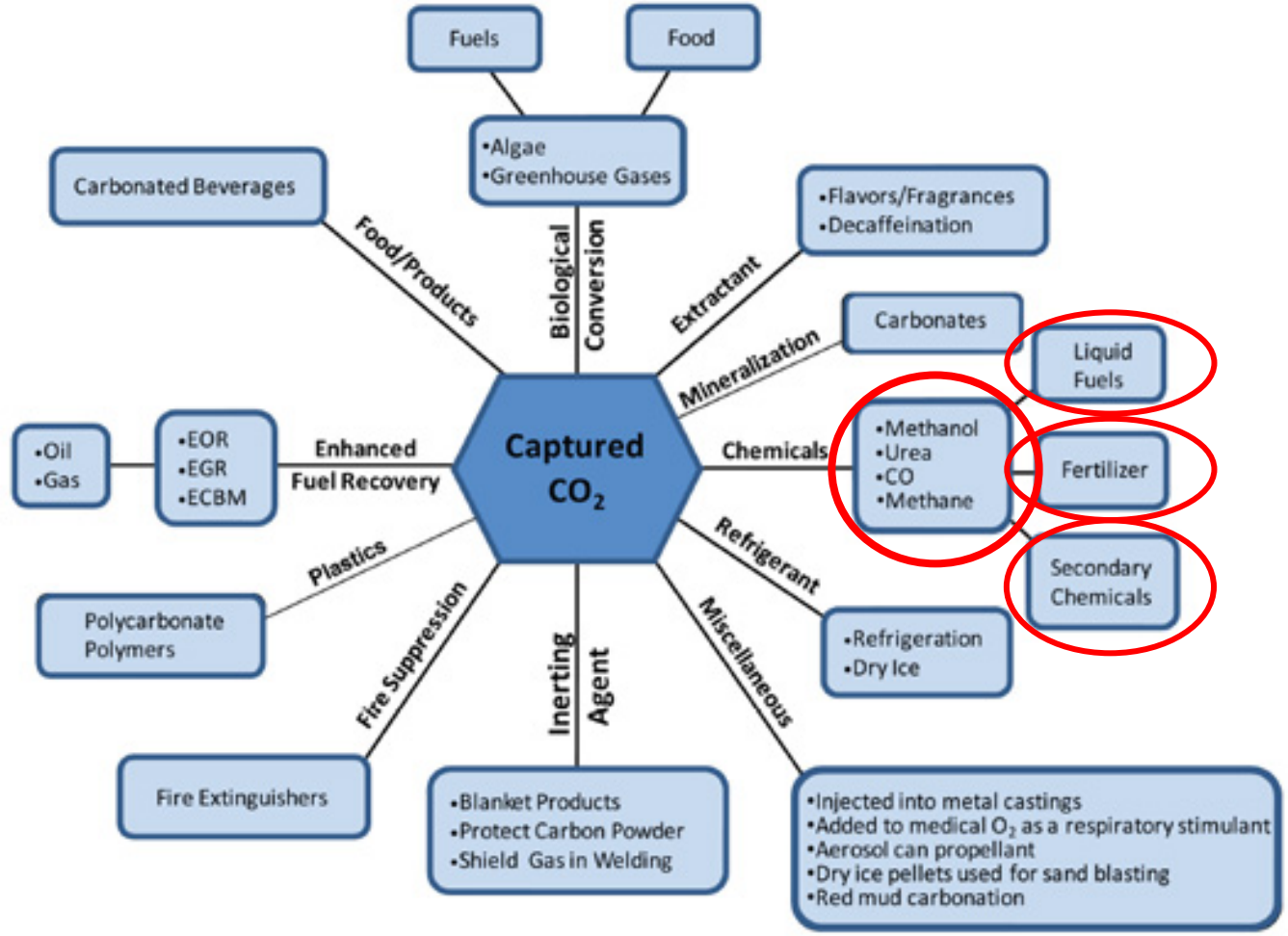
Technology Components

Products that can be made from syngas



Molecules of H_2 and CO contained in synthesis gas are building blocks that can be used to synthesize a wide variety of complex hydrocarbons & organic compounds

Utilization of CO_2 as a Raw Material



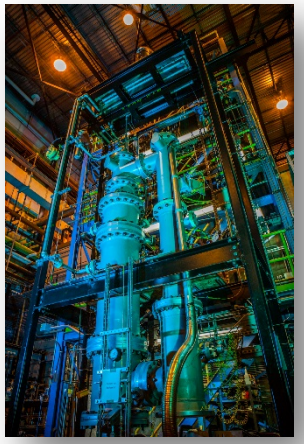
Chemical Looping Combustion

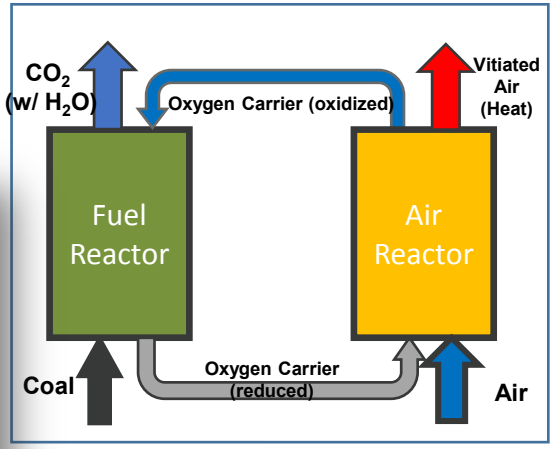
Benefits

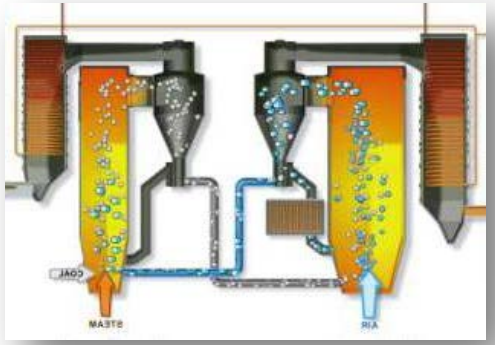
- Transformational cost reduction potential
- No need for O_2 production
- High CO_2 concentration in exhaust
- Uses conventional materials and fabrication techniques
- Leverages large-scale CFB experience, especially with limestone carriers

R&D Activities

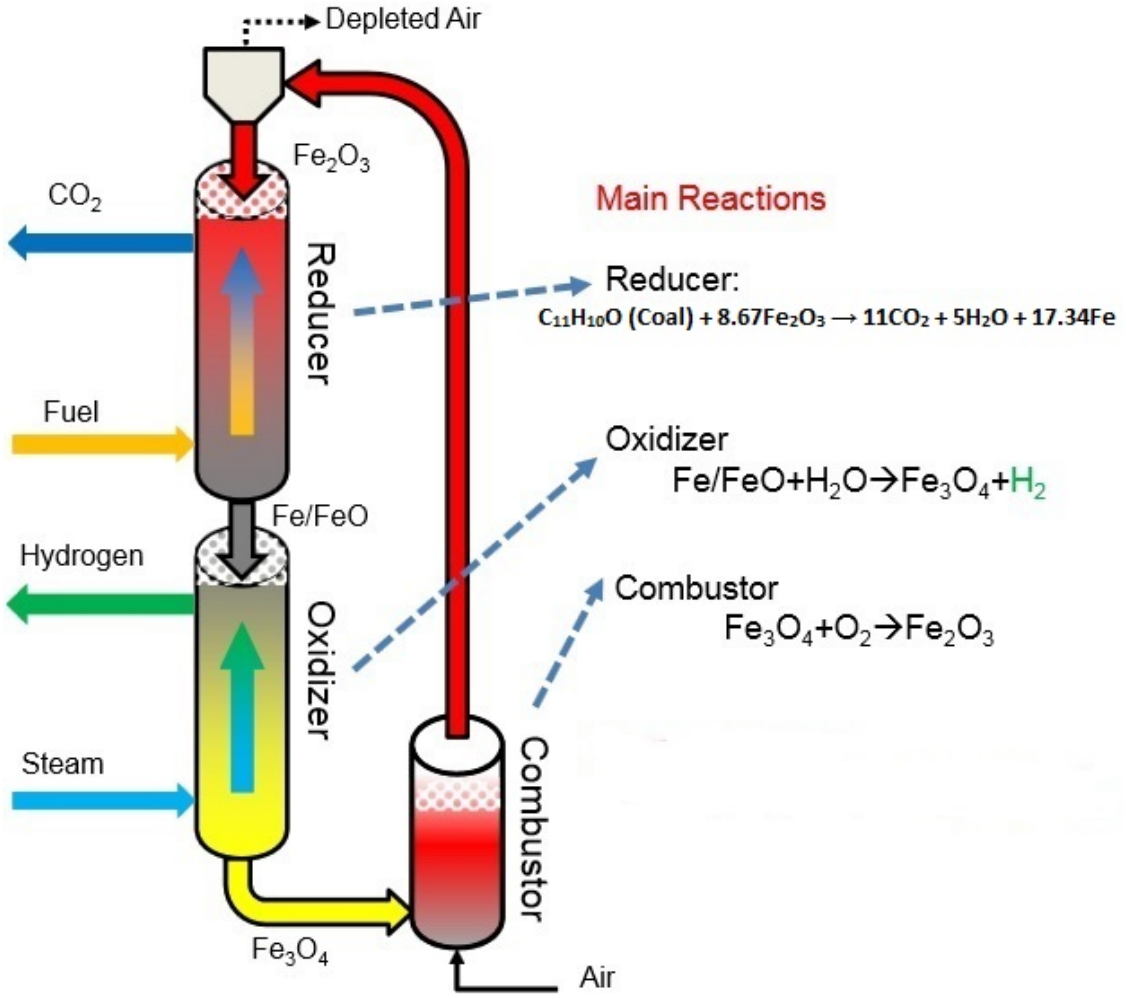
- Limestone-based chemical looping combustion
- Iron-based chemical looping combustion
- Chemical looping combustion with oxygen uncoupling
- Pressurized chemical looping
- H_2 production from syngas
- Chemical looping coal gasification
- Chemical looping oxygen carrier development



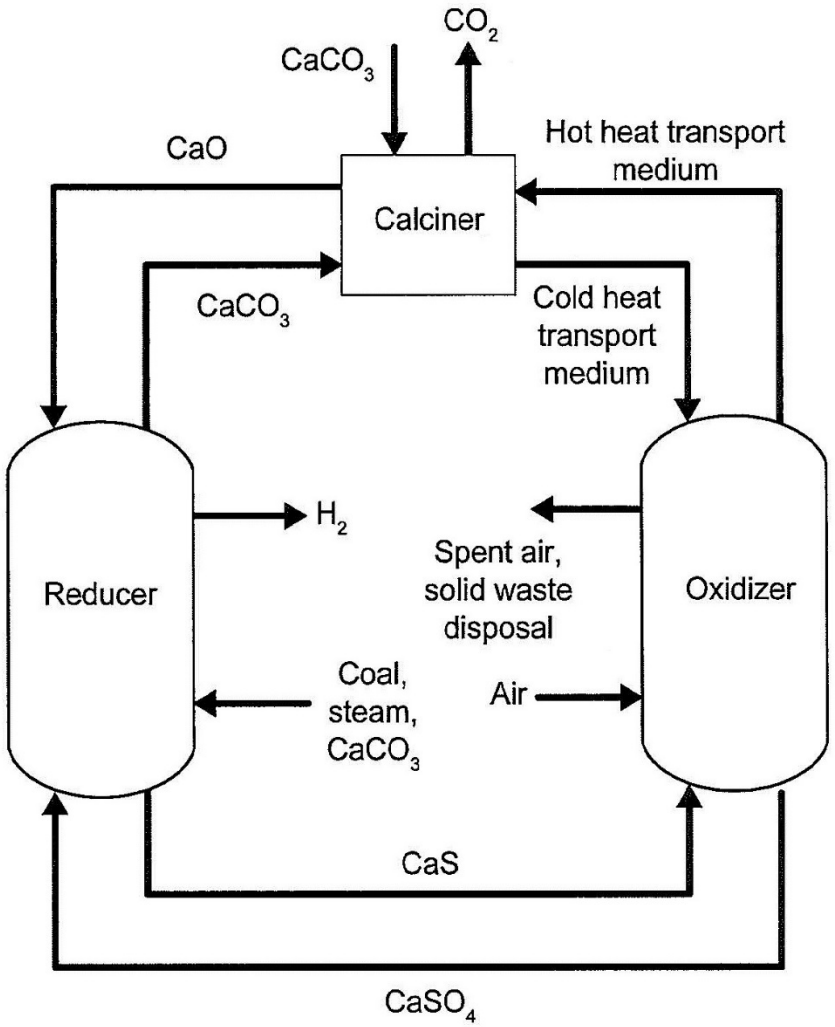




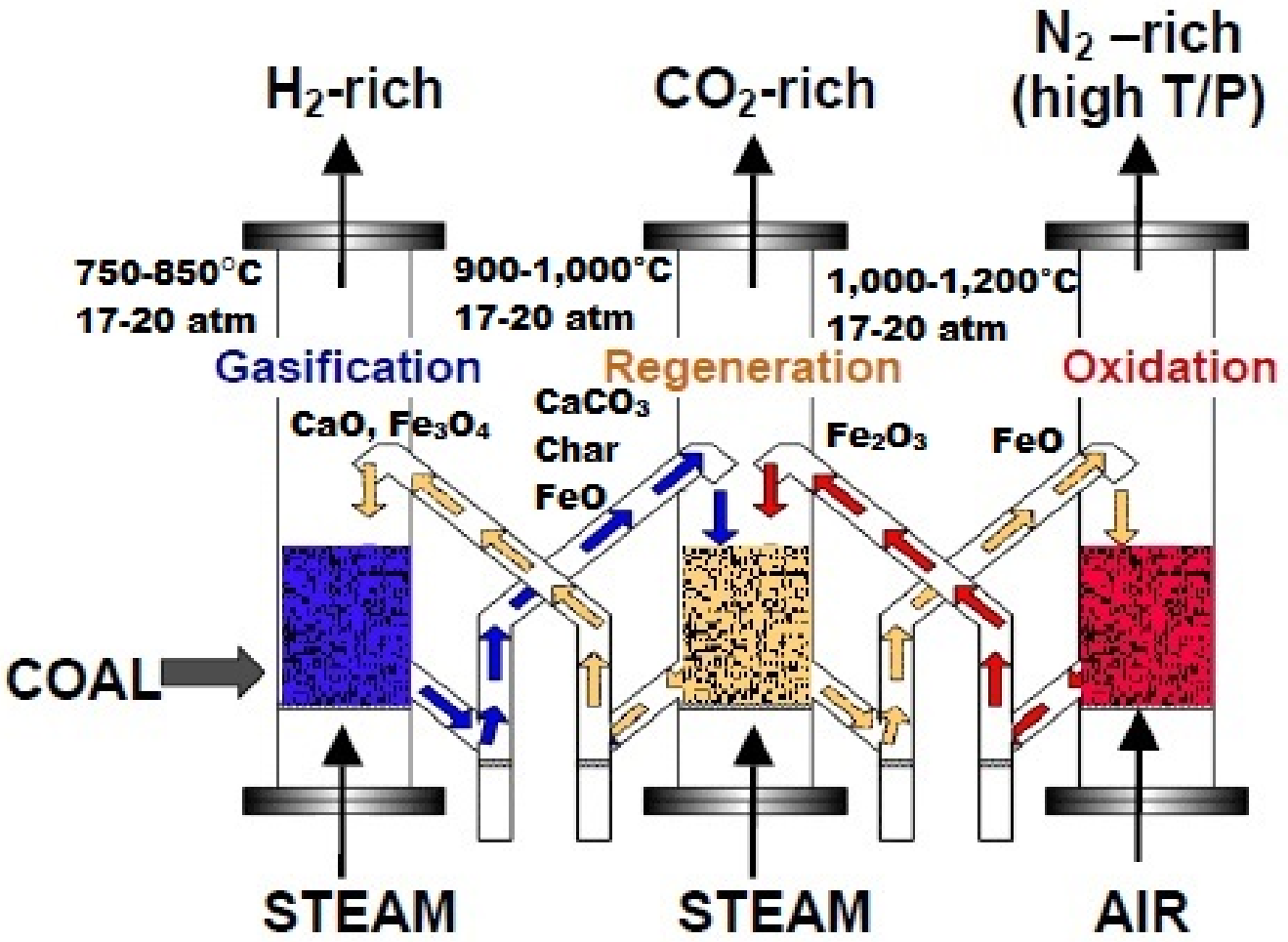
Chemical Looping Gasification – OSU



Chemical Looping Gasification – Alstom

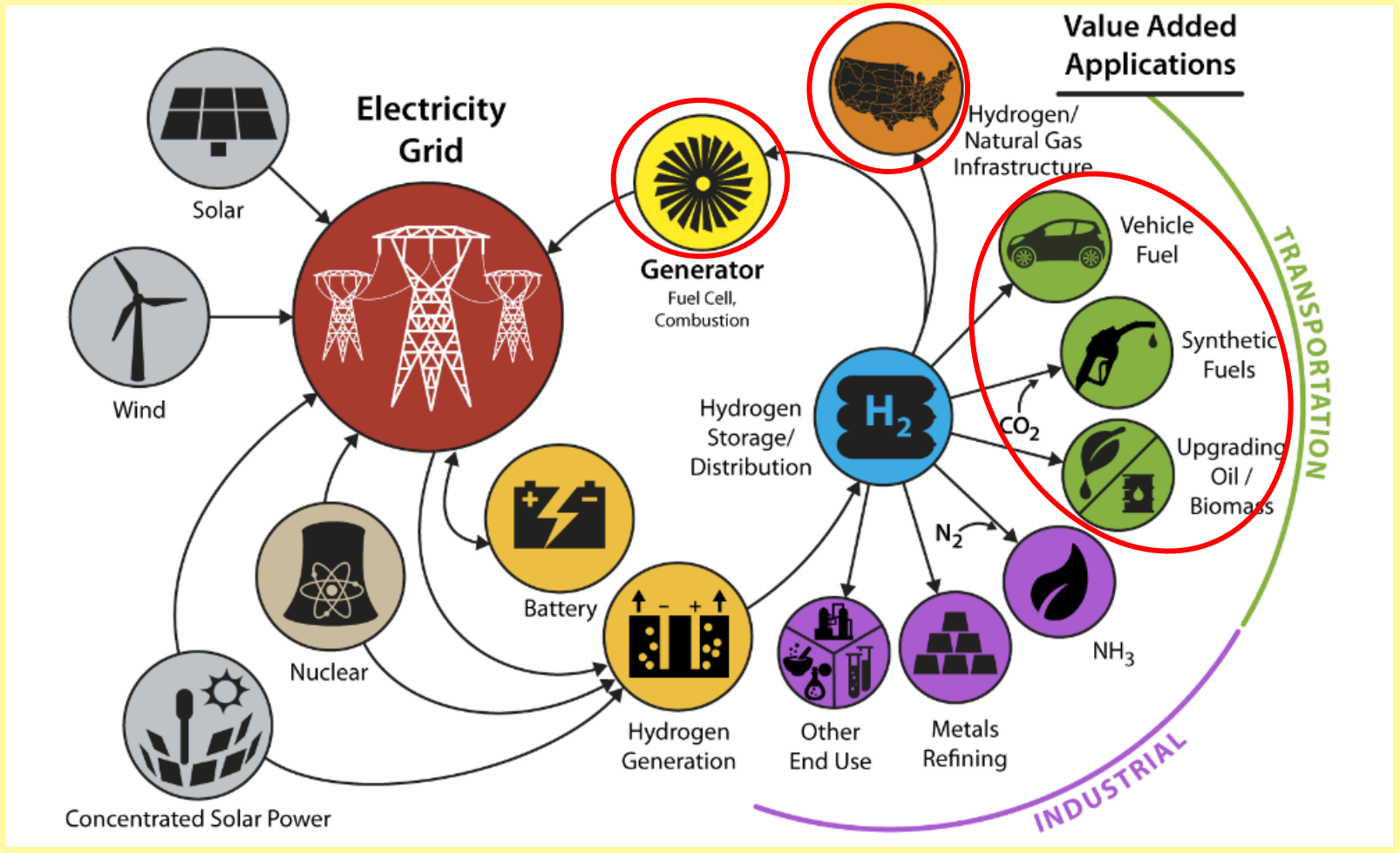


Chemical Looping Gasification – GE



Hydrogen Production and Use

NETL Mission Space



NETL Mission Space

Solutions for Today…Options for Tomorrow

For More Information

www.netl.doe.gov