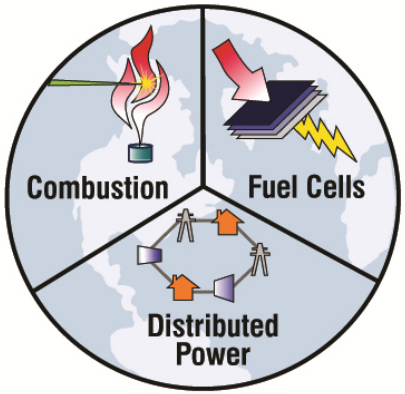
Overview of Energy R&D at the University of California Irvine

The Future of Clean Technology

Advanced Power and Energy Program

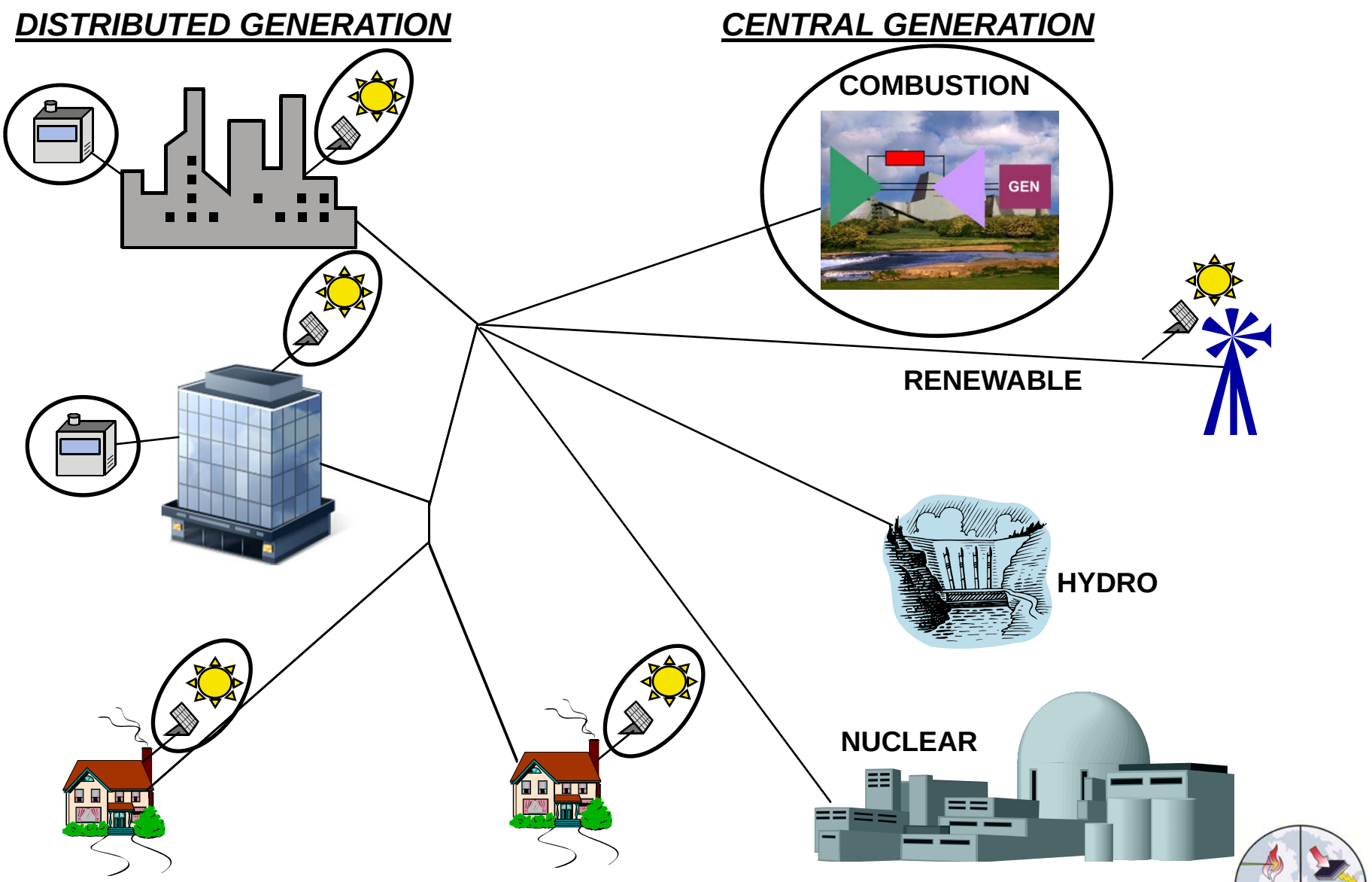
National Fuel Cell Research Center



University of California, Irvine
http://www.apep.uci.edu

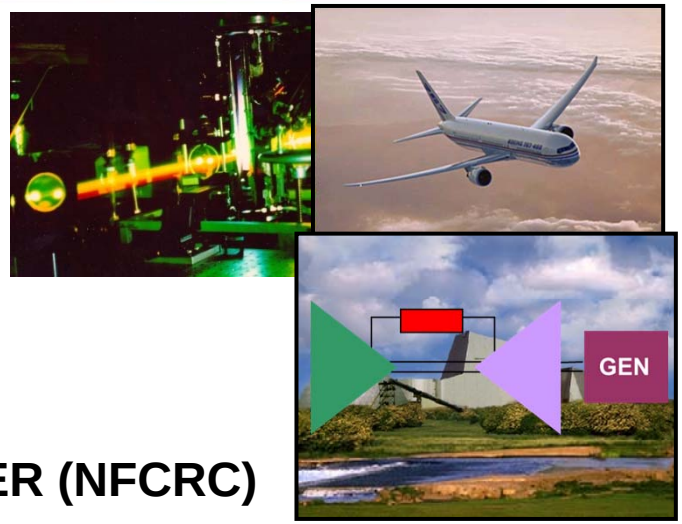
Scott Samuelsen
October 2, 2012

ELECTRIC GRID

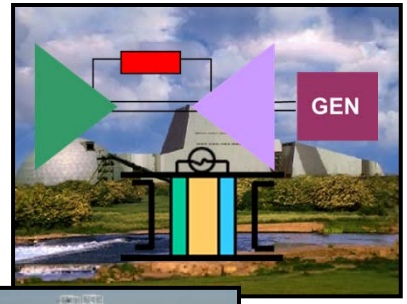


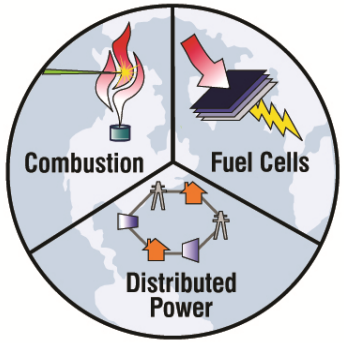
ADVANCED POWER AND ENERGY PROGRAM

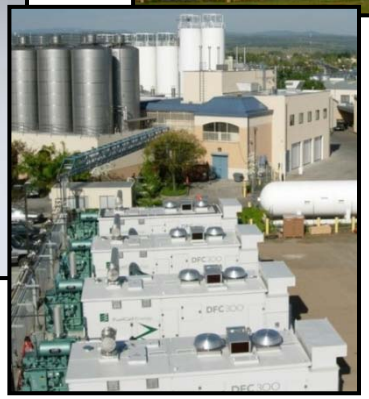
- **UCI COMBUSTION LABORATORY (UCICL)**
  - **1970**
  - **Gas Turbine Combustion**



- **NATIONAL FUEL CELL RESEARCH CENTER (NFCRC)**
  - **1998**
  - **U.S. Department of Energy**
  - **California Energy Commission**





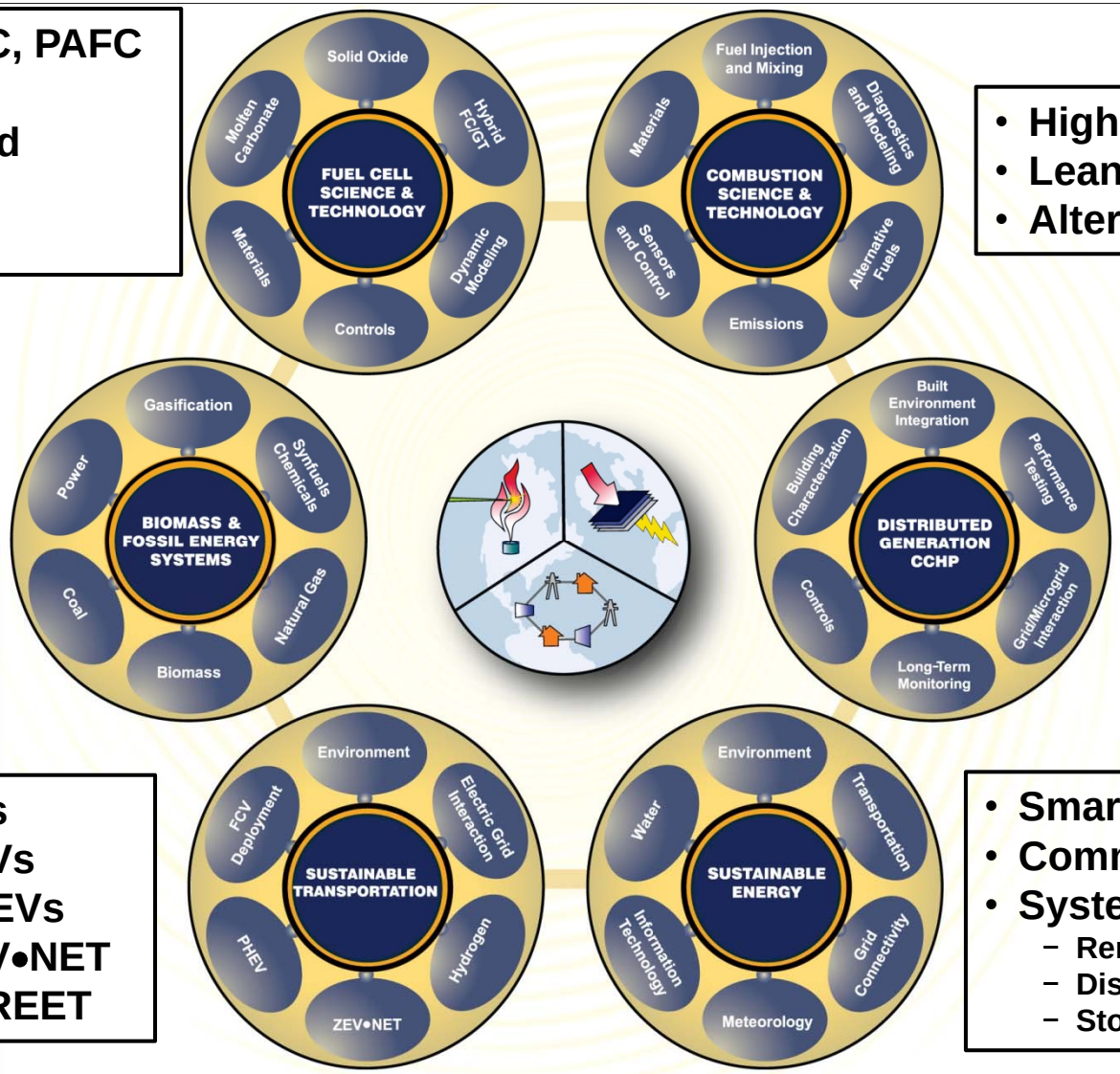


ADVANCED POWER AND ENERGY PROGRAM

- SOFC, MCFC, PAFC
- PEMFC
- FC/GT Hybrid
- Deployment
- CaSFCC

- High Performance
- Lean Combustion
- Alternative Fuels

- Natural Gas
- Bio Gas
  - ADG
  - Land Fill
  - SynGas
- Coal
- Bio Hydrogen

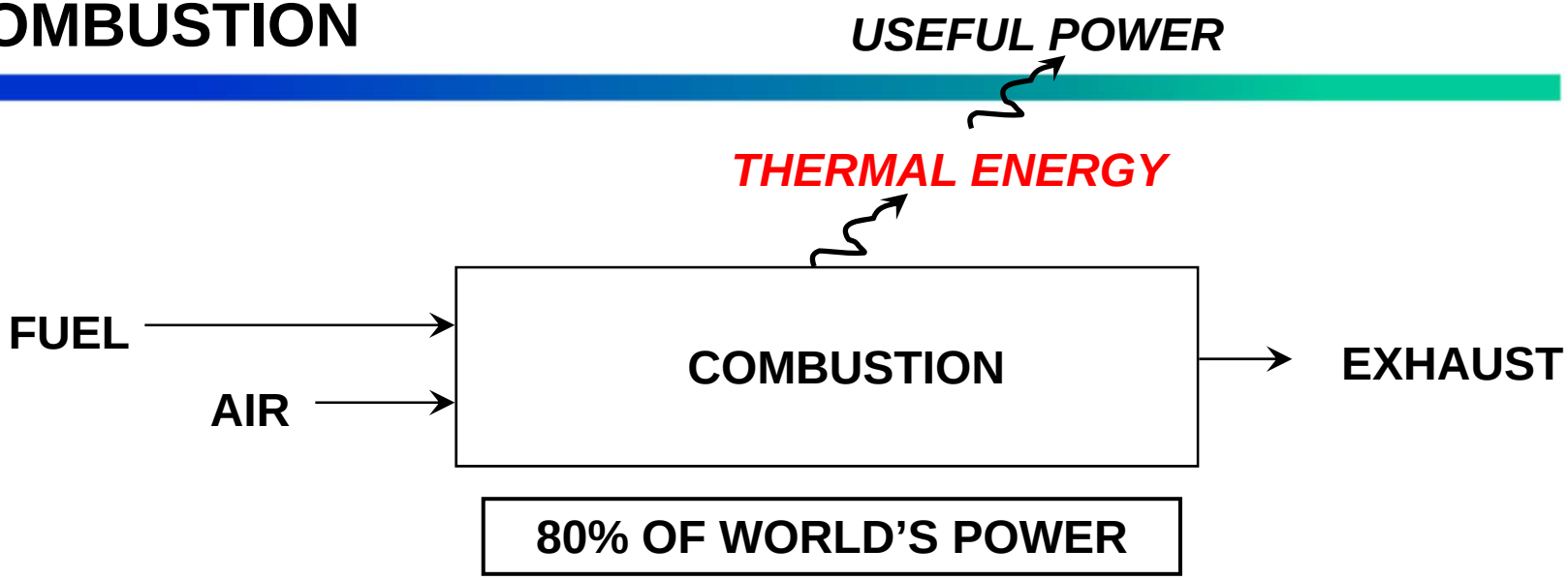


- EVs
- FCVs
- PHEVs
- ZEV•NET
- STREET

- Gas Turbines
- Fuel Cells
- Photovoltaic
- Wind
- CCHP
- Storage

- Smart Grid
- Community Design
- Systems Integration
  - Renewables
  - Distributed Generation
  - Storage

COMBUSTION



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Forces for Change

- Urban Air Quality
- Climate Change
- Petroleum Resources
- Fuel Independence
- National Security

POWER GENERATION

- **COMBUSTION**

FUEL/AIR

COMBUSTION CHEMISTRY

THERMAL ENERGY

EXPANSION

PISTON or TURBINE

GENERATOR

ELECTRICITY

LIMITED EFFICIENCY
POLLUTANT EMISSION

- **FUEL CELL**

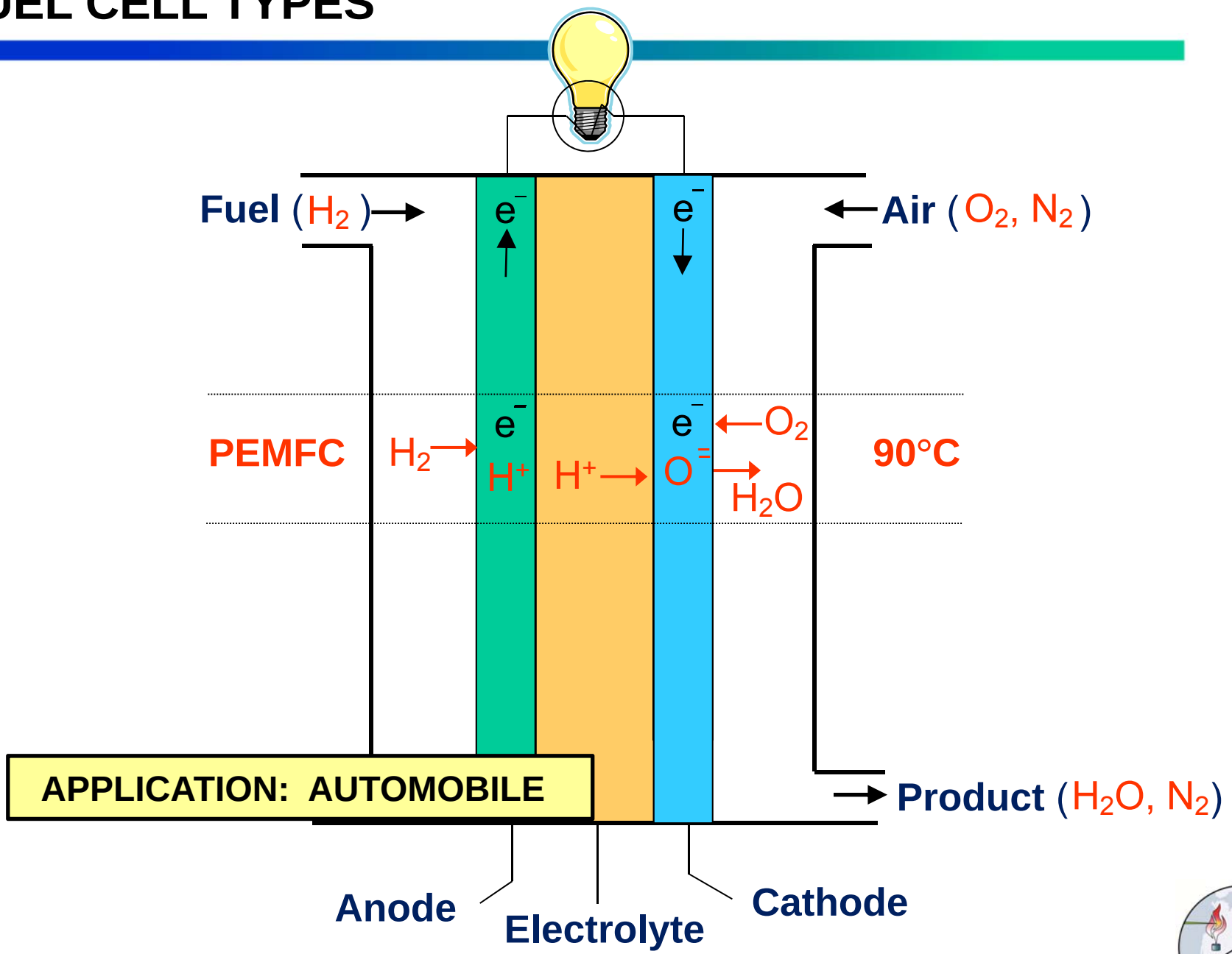
FUEL/AIR

ELECTROCHEMISTRY

ELECTRICITY

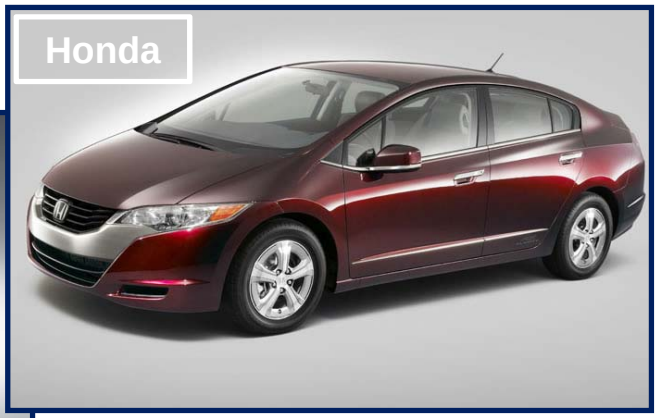
HIGH EFFICIENCY
NO POLLUTANT EMISSION
HIGH QUALITY HEAT
ACOUSTICALLY BENIGN

FUEL CELL TYPES



FUEL CELL POWER PLANT

2015



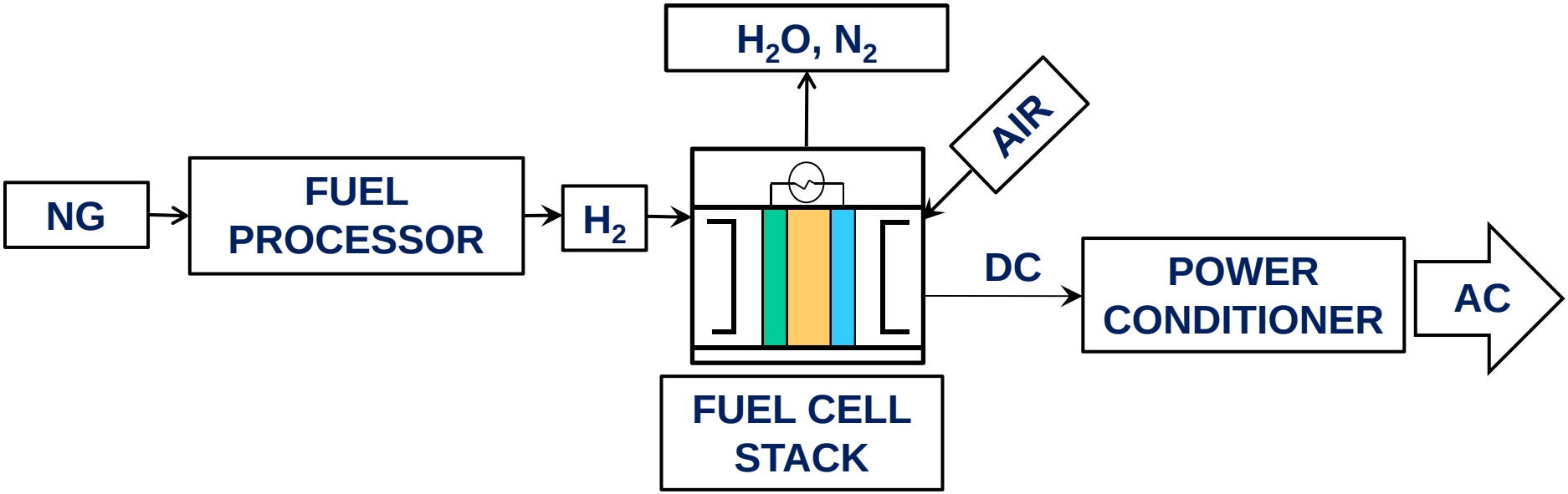
APPLICATION: AUTOMOBILE

APPLICATION: BUS

APPLICATION: LIFT TRUCK

NOW

FUEL CELL POWER PLANT



APPLICATION: STATIONARY

STATIONARY FUEL CELLS

APPLICATION: STATIONARY

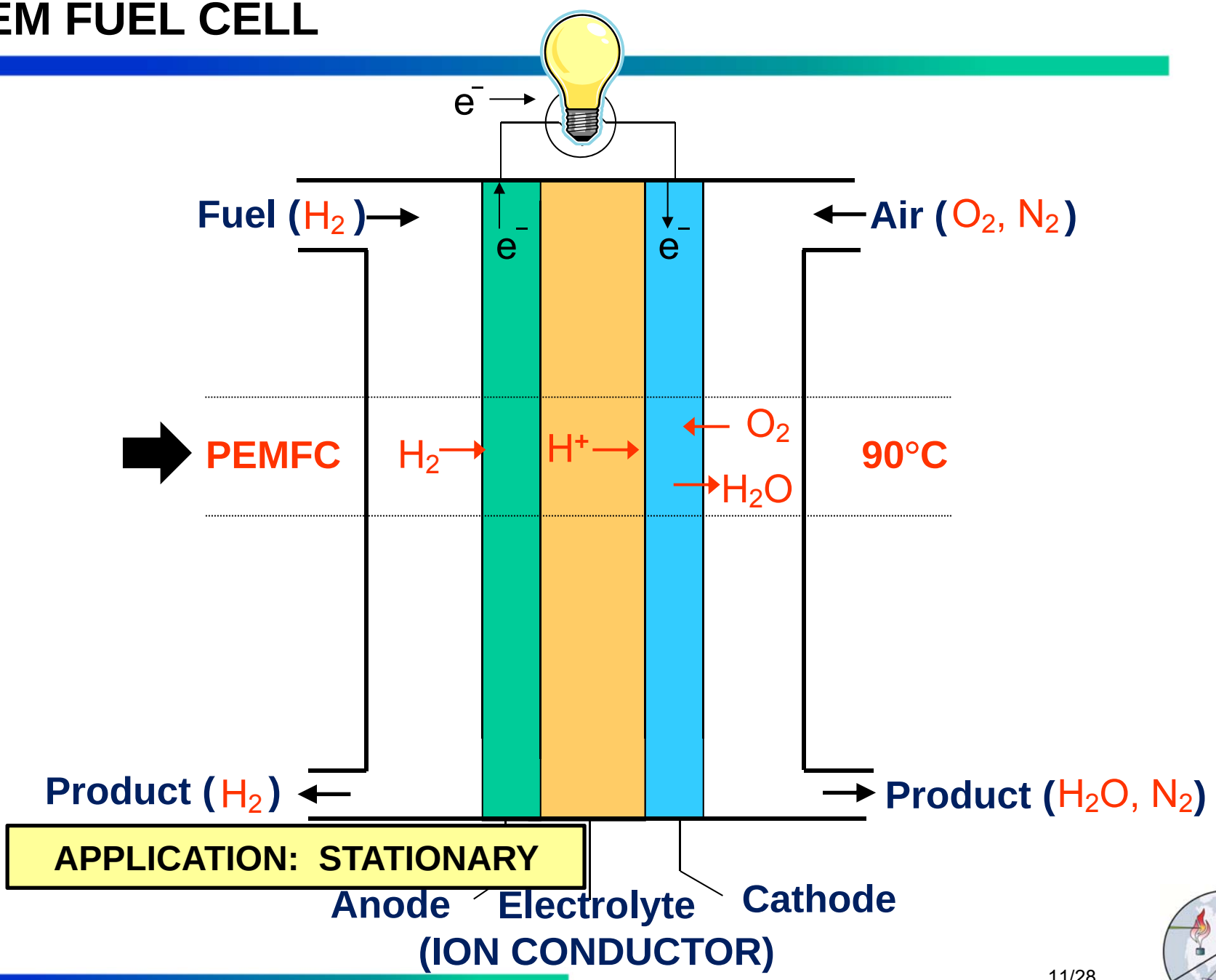
STATIONARY FC DEPLOYMENTS

• WASTEWATER TREATMENT	9.10
• MOBILE RENEWABLES	3.90
• HOTELS	2.75
• GOVERNMENT	2.25
• HOSPITALS	1.00
• COMMUNICATIONS	0.50
• GROCERY STORES	1.00
• UNIVERSITIES	5.00
• BREWERIES	1.00
• INDUSTRIAL	4.20
• MANUFACTURING	0.50
• FOOD PROCESSING	0.50
• UTILITIES	0.25
TOTAL =	33.00 MW

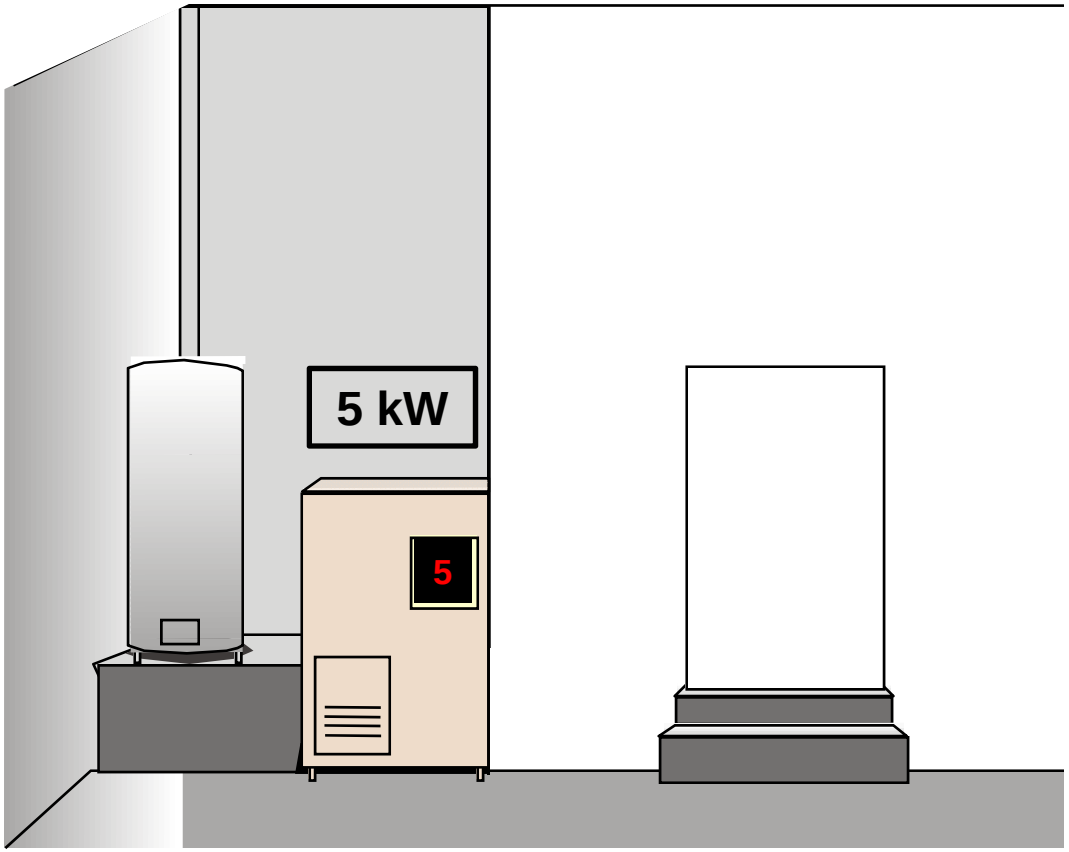
CaSFCC California Stationary Fuel Cell Collaborative

SOURCE: CASFCC.ORG

PEM FUEL CELL



FUEL CELL POWER PLANT



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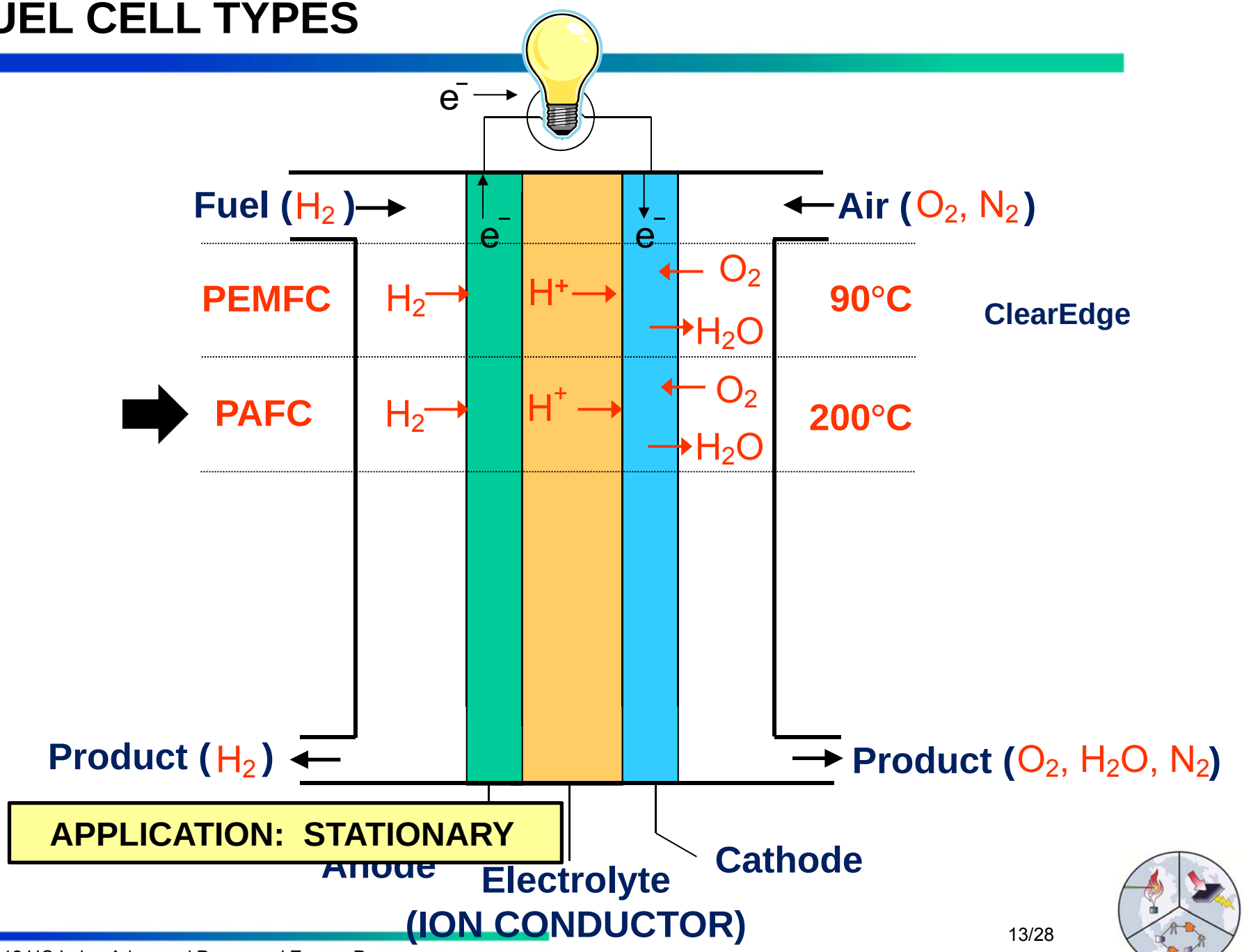
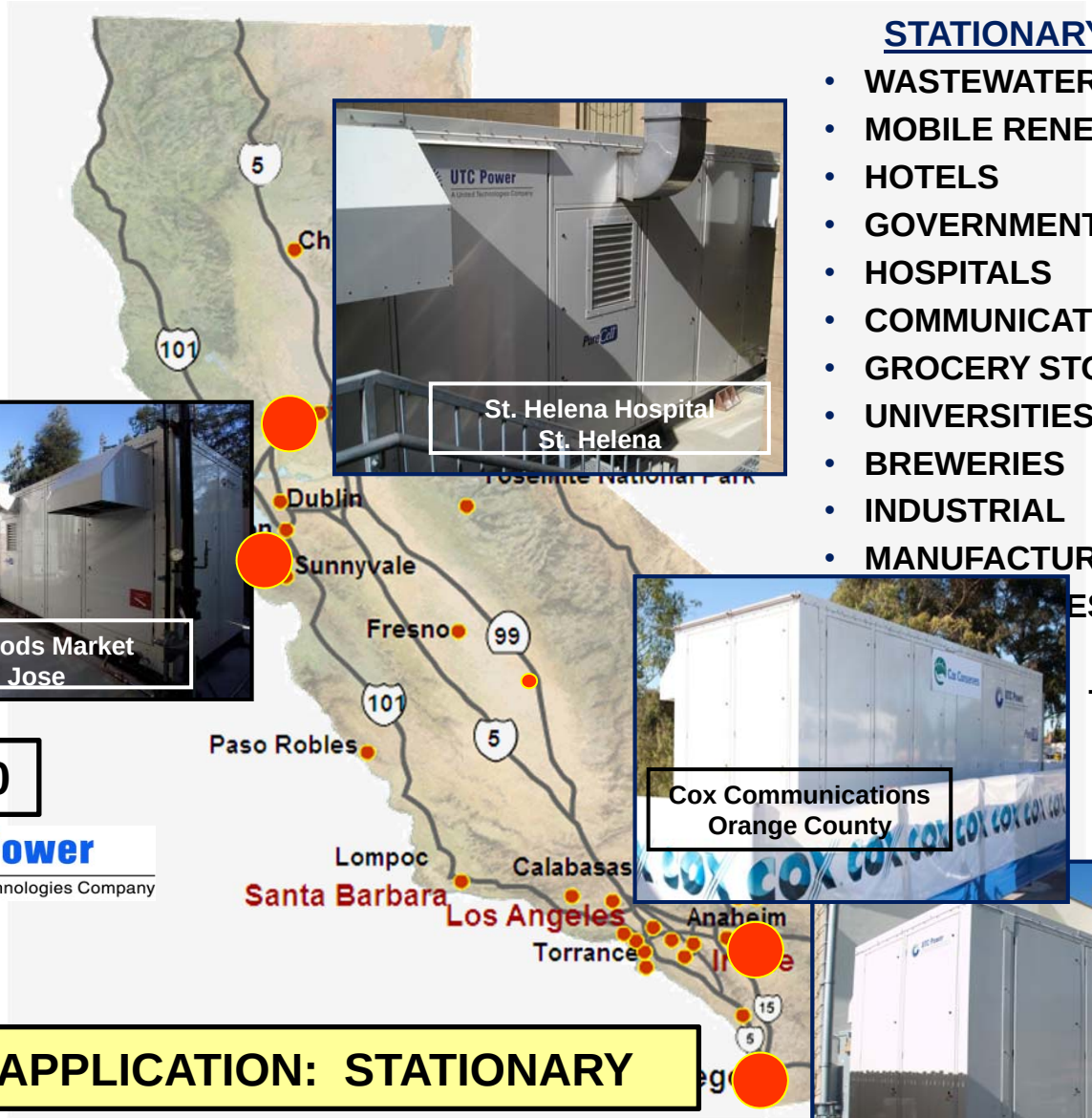
Delivering Smart Energy Today™

EARLY STAGE

FUEL CELL TYPES



PHOSPHORIC ACID FUEL CELLS



St. Helena Hospital
St. Helena

Whole Foods Market
San Jose

Cox Communications
Orange County

Albertson's
San Diego

STATIONARY FC DEPLOYMENTS

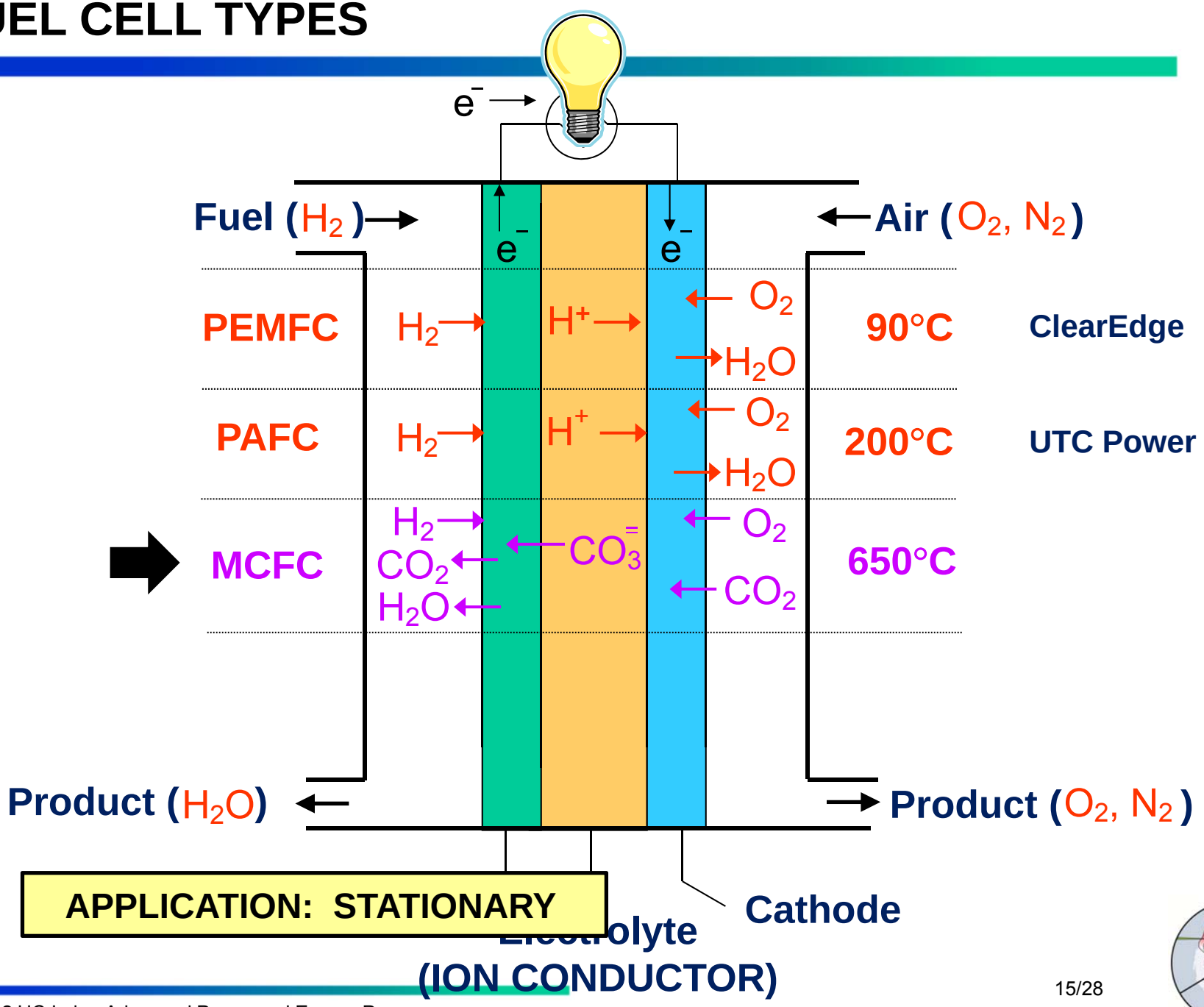
• WASTEWATER TREATMENT	9.10
• MOBILE RENEWABLES	3.90
• HOTELS	2.75
• GOVERNMENT	2.25
• HOSPITALS	1.00
• COMMUNICATIONS	0.50
• GROCERY STORES	1.00
• UNIVERSITIES	5.00
• BREWERIES	1.00
• INDUSTRIAL	4.20
• MANUFACTURING	0.50
ESSING	0.50
	0.25
TOTAL =	33.00 MW

1990

UTC Power
A United Technologies Company

APPLICATION: STATIONARY

FUEL CELL TYPES



MOLTEN CARBONATE FUEL CELLS

2003

FuelCell Energy

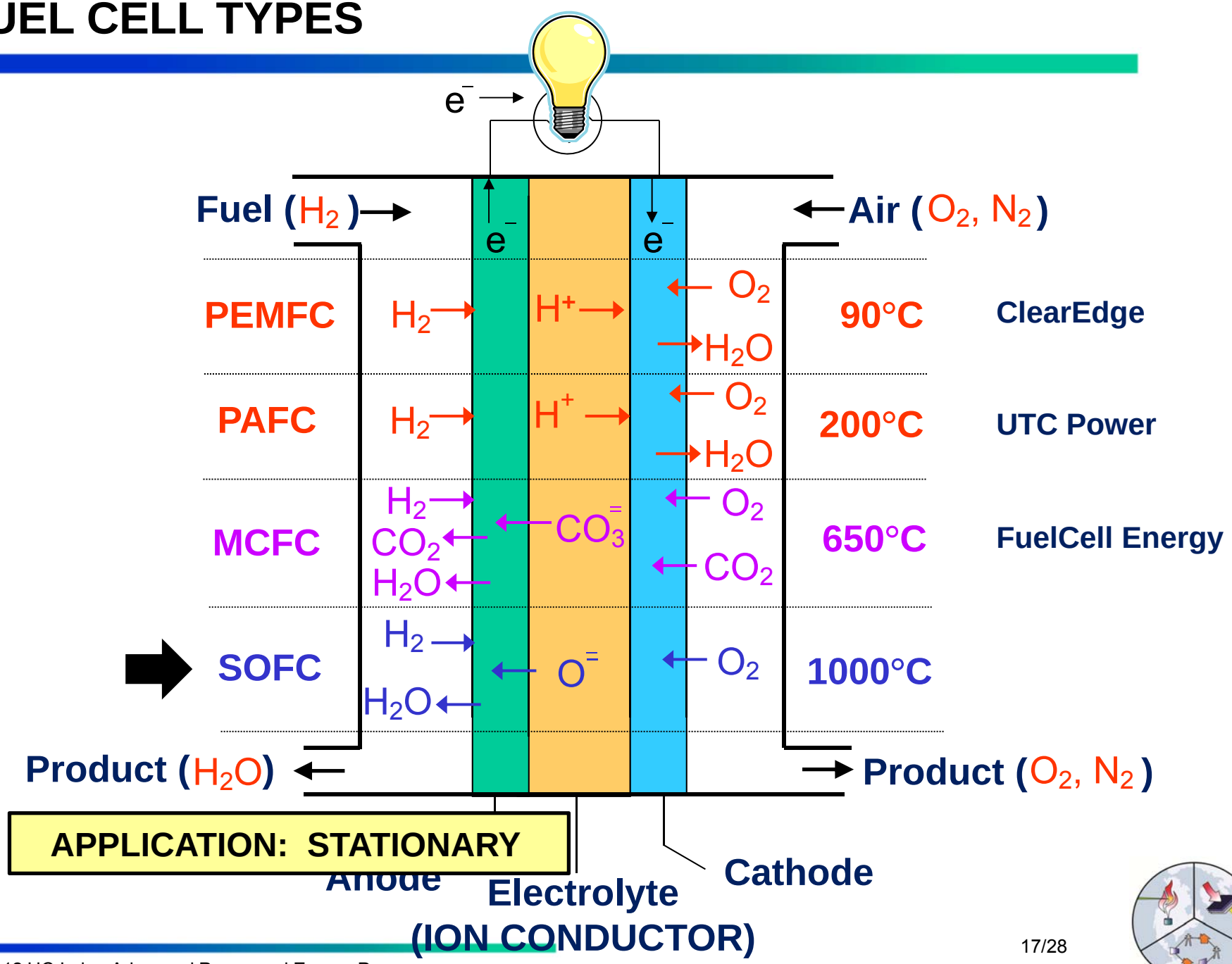
STATIONARY FC DEPLOYMENTS

- WASTEWATER TREATMENT 9.10
- MOBILE RENEWABLES 3.90
- HOTELS 2.75
- 25
- 00
- 50
- 00
- 00
- 00
- 20
- 50
- 50
- 25

0 MW

APPLICATION: STATIONARY

FUEL CELL TYPES



SOLID OXIDE ACID FUEL CELLS

2009

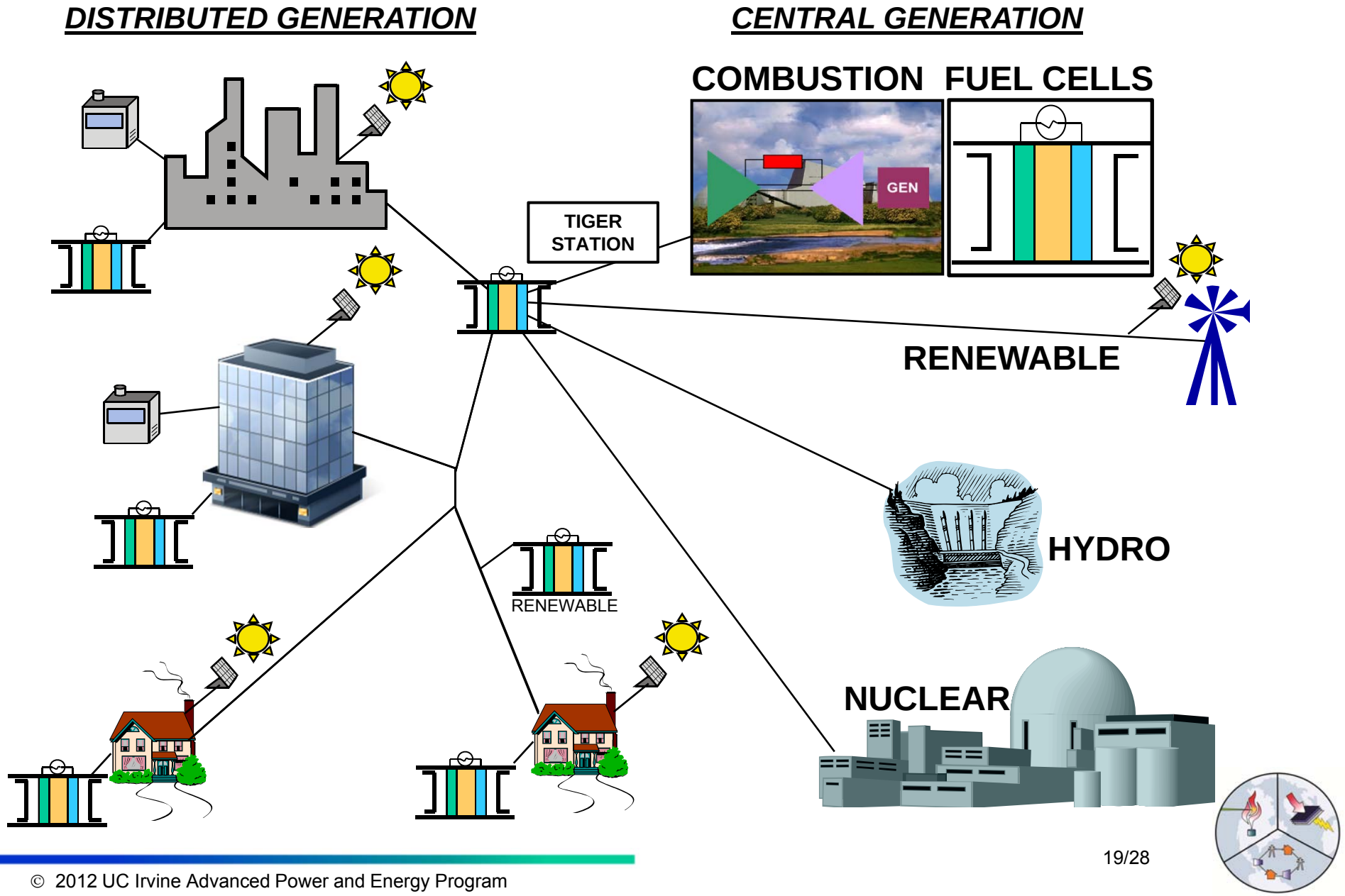
Bloomenergy

STATIONARY FC DEPLOYMENTS

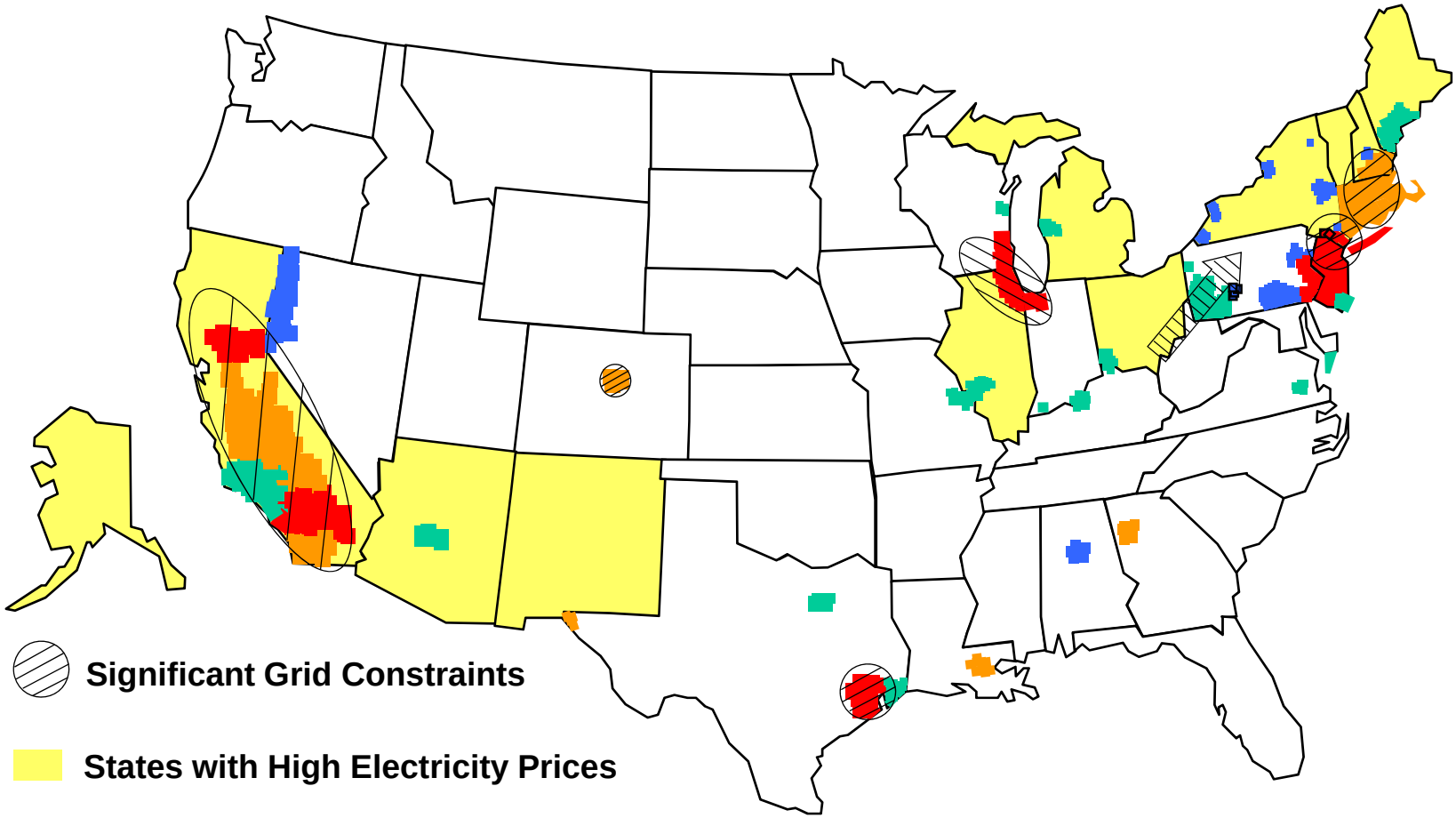
• WASTEWATER TREATMENT	9.10
• MOBILE RENEWABLES	3.90
	2.75
	2.25
	1.00
NS	0.50
ES	1.00
	5.00
	1.00
	4.20
• MANUFACTURING	0.50
• FOOD PROCESSING	0.50
• UTILITIES	0.25
TOTAL =	33.00 MW

APPLICATION: STATIONARY

FUEL CELL MARKETS



MARKET DRIVERS



Source: Energy Information Administration

CALIFORNIA STATIONARY FUEL CELL COLLABORATIVE

Co-Chairs

Mary Nichols, Chair
California ARB

Dr. Scott Samuelsen, Director
National Fuel Cell Research Center

Executive Director

Mike Tollstrup

Industry Advisory Panel

Matt Heling, Chair
PG&E

www.stationaryfuelcells.org

Established 2001

CA Air Resources Board
CA Department of General Services
CA Energy Commission
CA Environmental Protection Agency
CA Public Utilities Commission
CA Resources Agency
CA Trade and Commerce Agency
CA Transportation and Housing Agency
CA Food and Agriculture

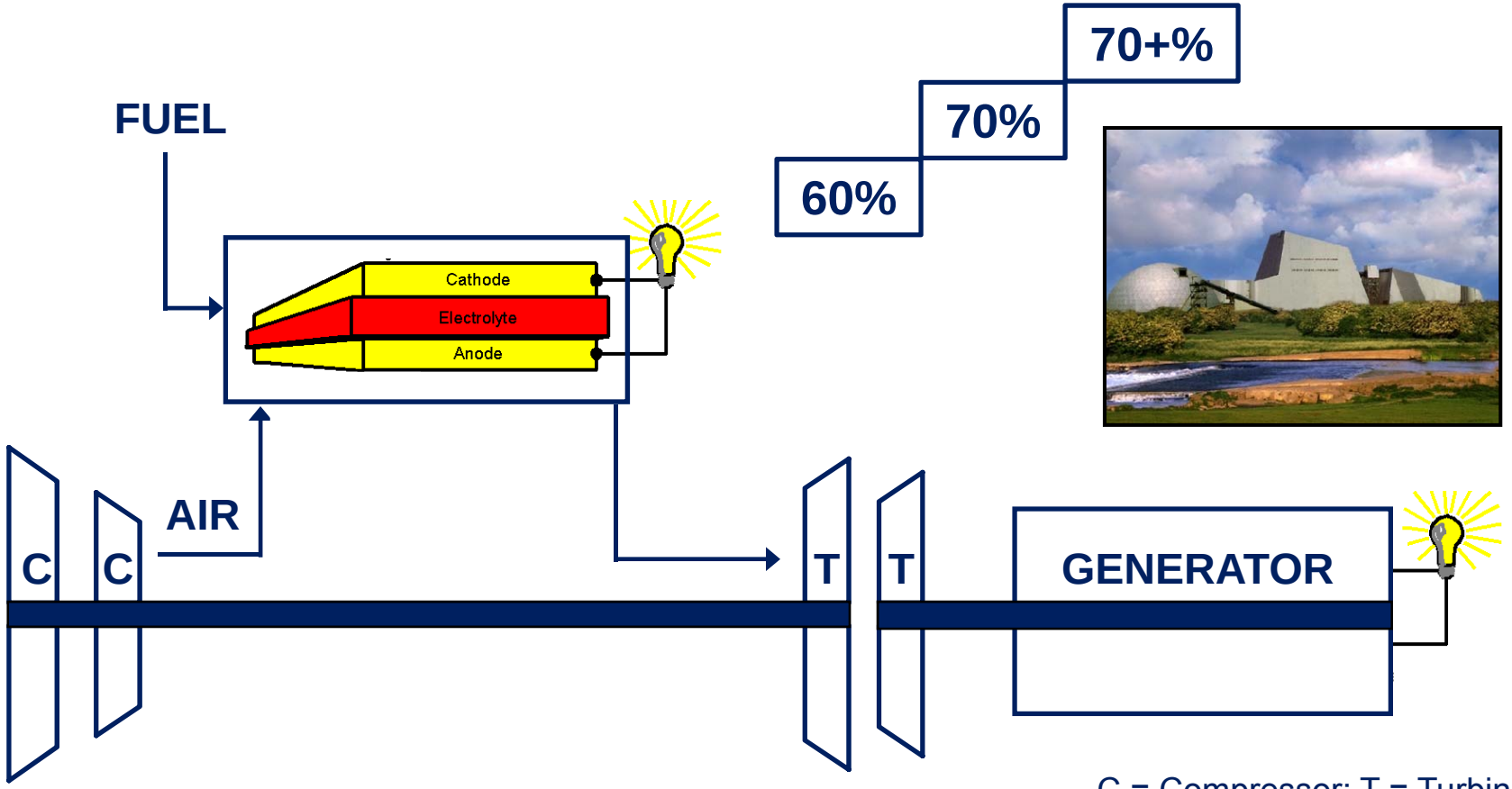
U.S. Department of Energy
U.S. Department of Defense
U.S. General Service Administration
U.S. Environmental Protection Agency

National Fuel Cell Research Center
LA Department of Water and Power
South Coast Air Quality Mgt District
Bay Area Air Quality Mgt District

TAKEAWAYS

- **Natural Gas Powered**
  - Most Energy Efficient
  - Most Environmentally Sensitive
- **Bio Gas Powered**
  - 24/7 Renewable
- **GHG Reduction**
  - High Efficient Fuel-to-Electricity
  - High-Quality Heat
- **Emissions Reduction**
- **Reliability and Power Quality**
  - Enable Islanding
- **"Fortuitous Fit"**
  - Distributed Generation
  - RPS Partner for Renewable Solar and Wind
  - Renewable 24/7 Baseload Power and Heat
  - AB-32
  - Market Demand

HYBRID FUEL CELL/GAS TURBINE

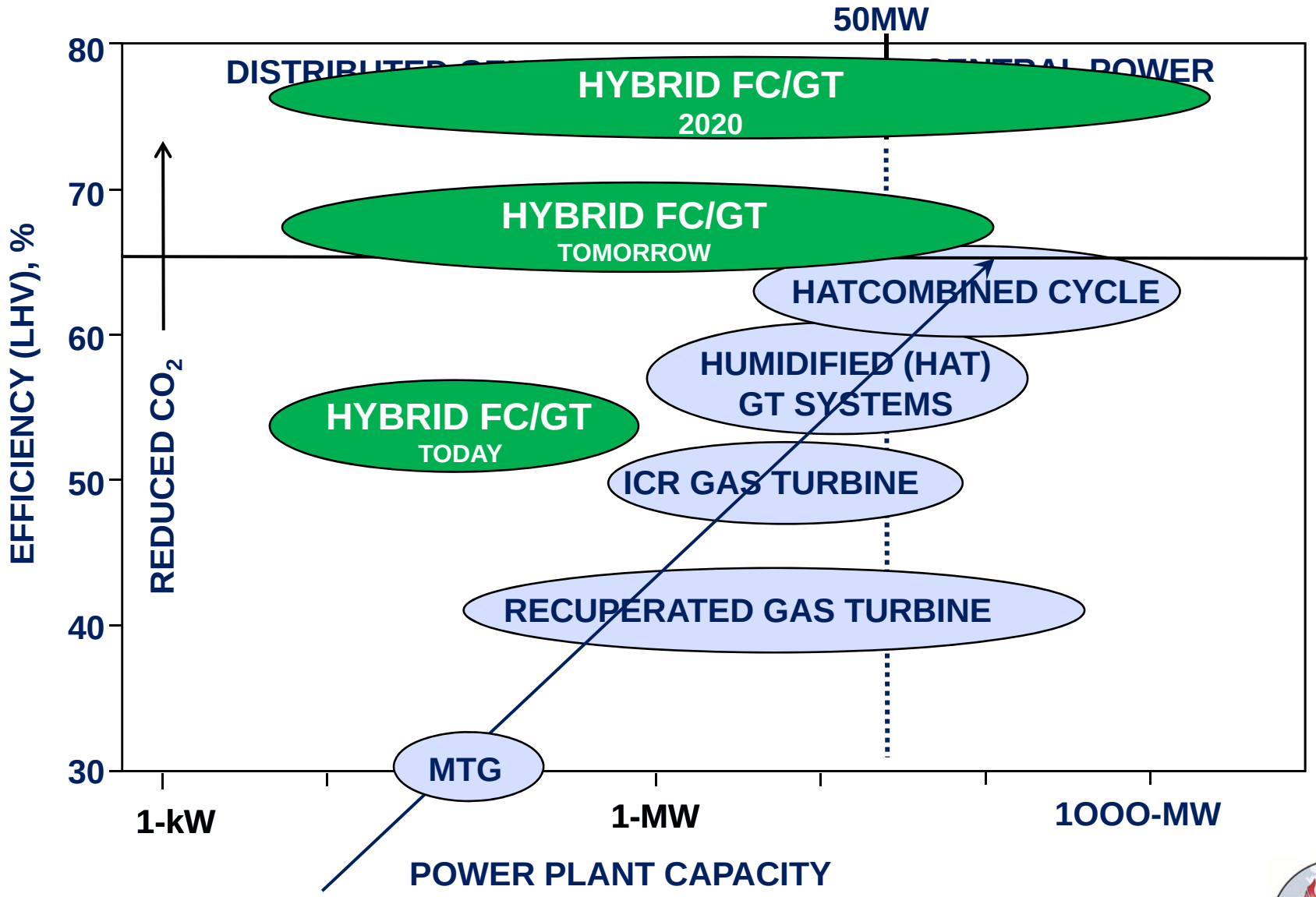


C = Compressor; T = Turbine

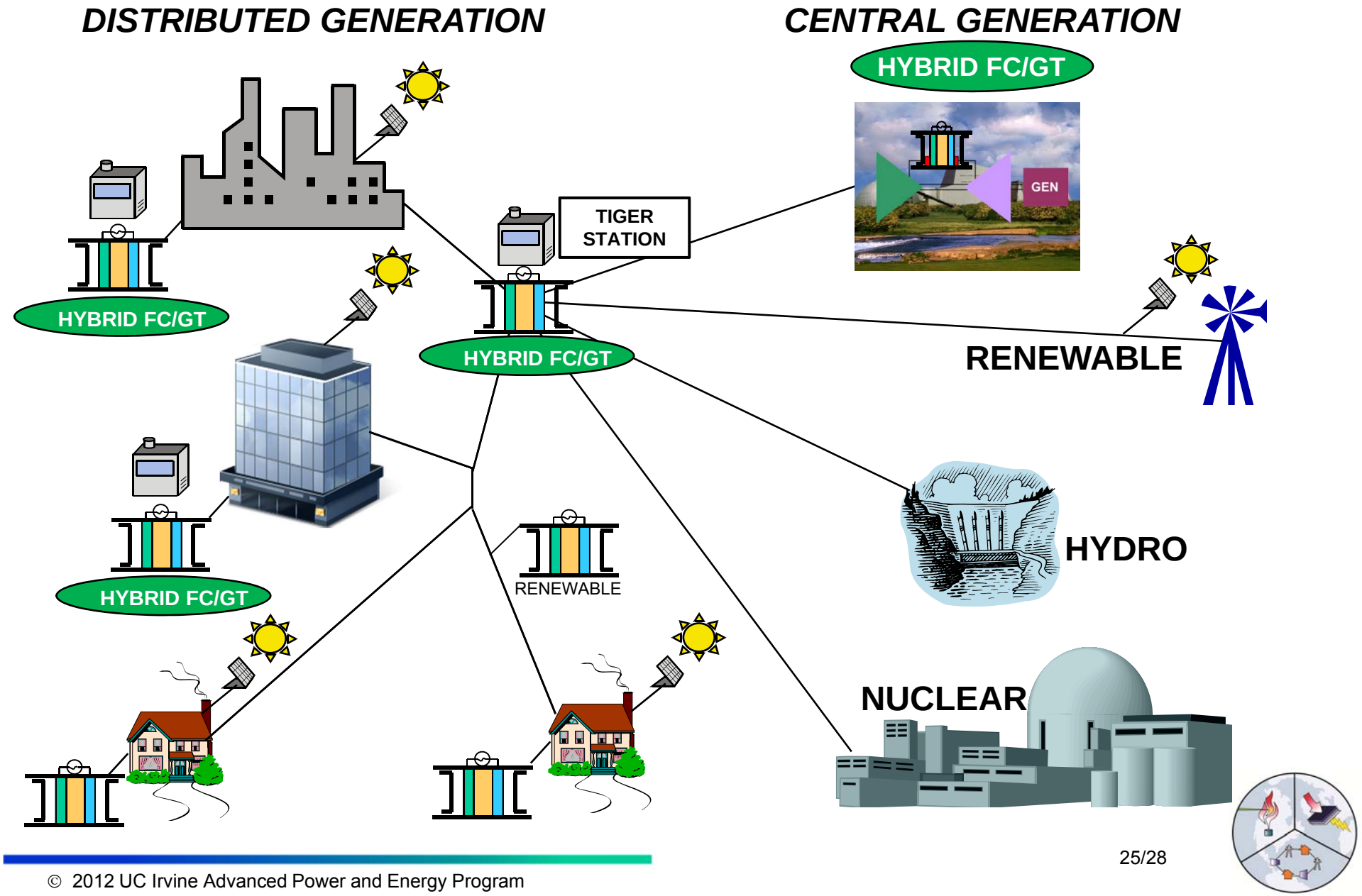
HYBRID FUEL CELL/GAS TURBINE

HYBRID FC/GT

HYBRID FUEL CELL/GAS TURBINE

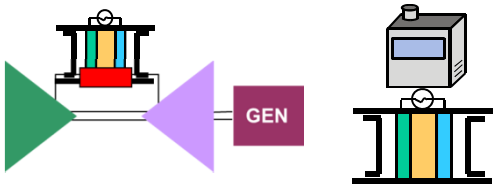


HYBRID FUEL CELL/GAS TURBINE



HYBRID FUEL CELL/GAS TURBINE

√ • **Electricity**



HYBRID FC/GT

√ • **Locomotives**

HYBRID FC/GT

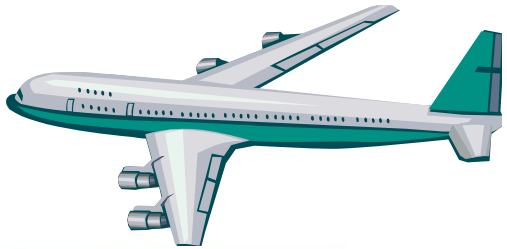
• **Ships**

HYBRID FC/GT

• **Trucks**

HYBRID FC/GT

√ • **Aircraft**



HYBRID FC/GT

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- **SOFC, MCFC, PAFC**
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- **FC/GT Hybrid**
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- CaSFCC

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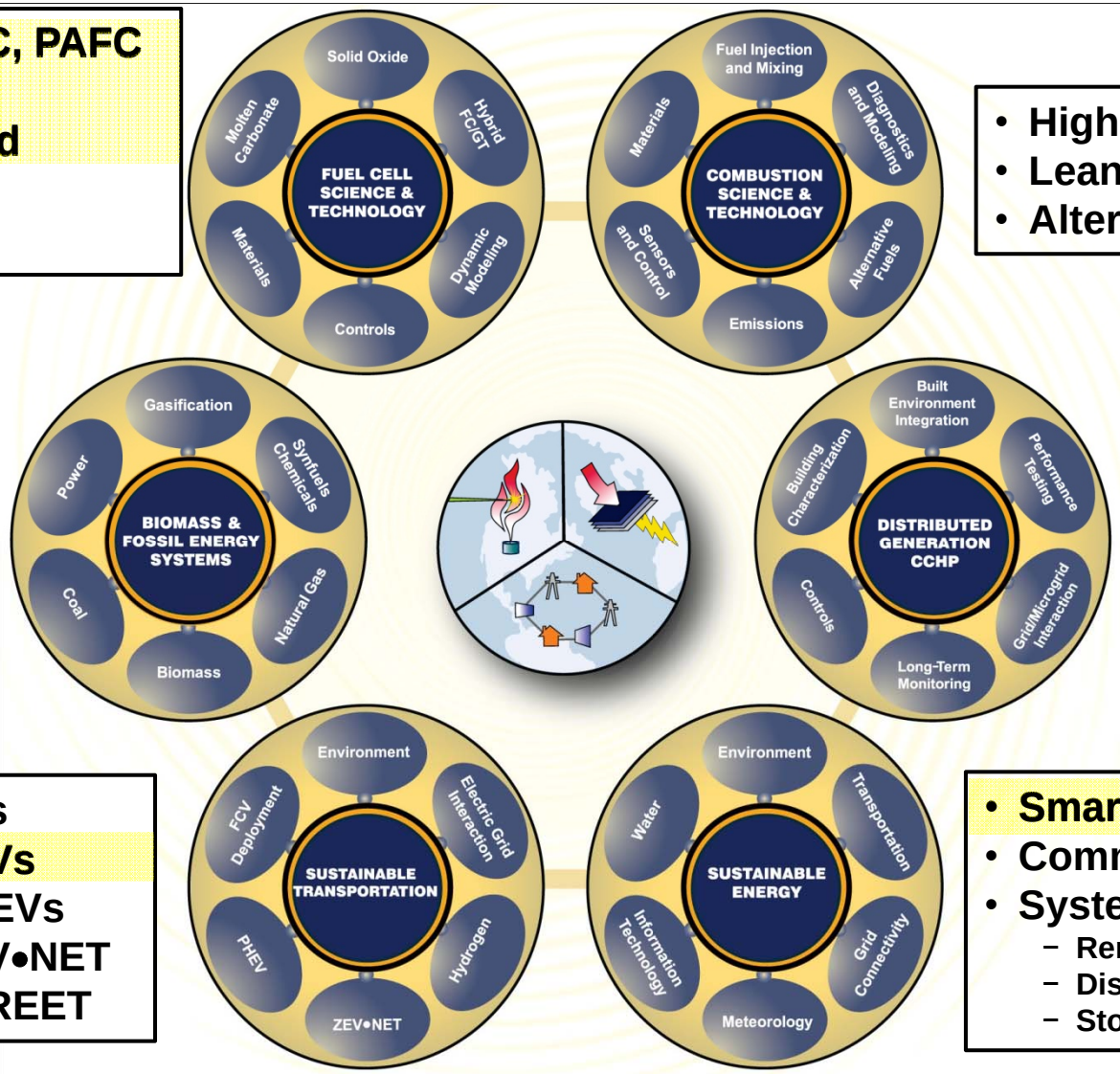

- EVs
- **FCVs**
- PHEVs
- ZEV•NET
- STREET

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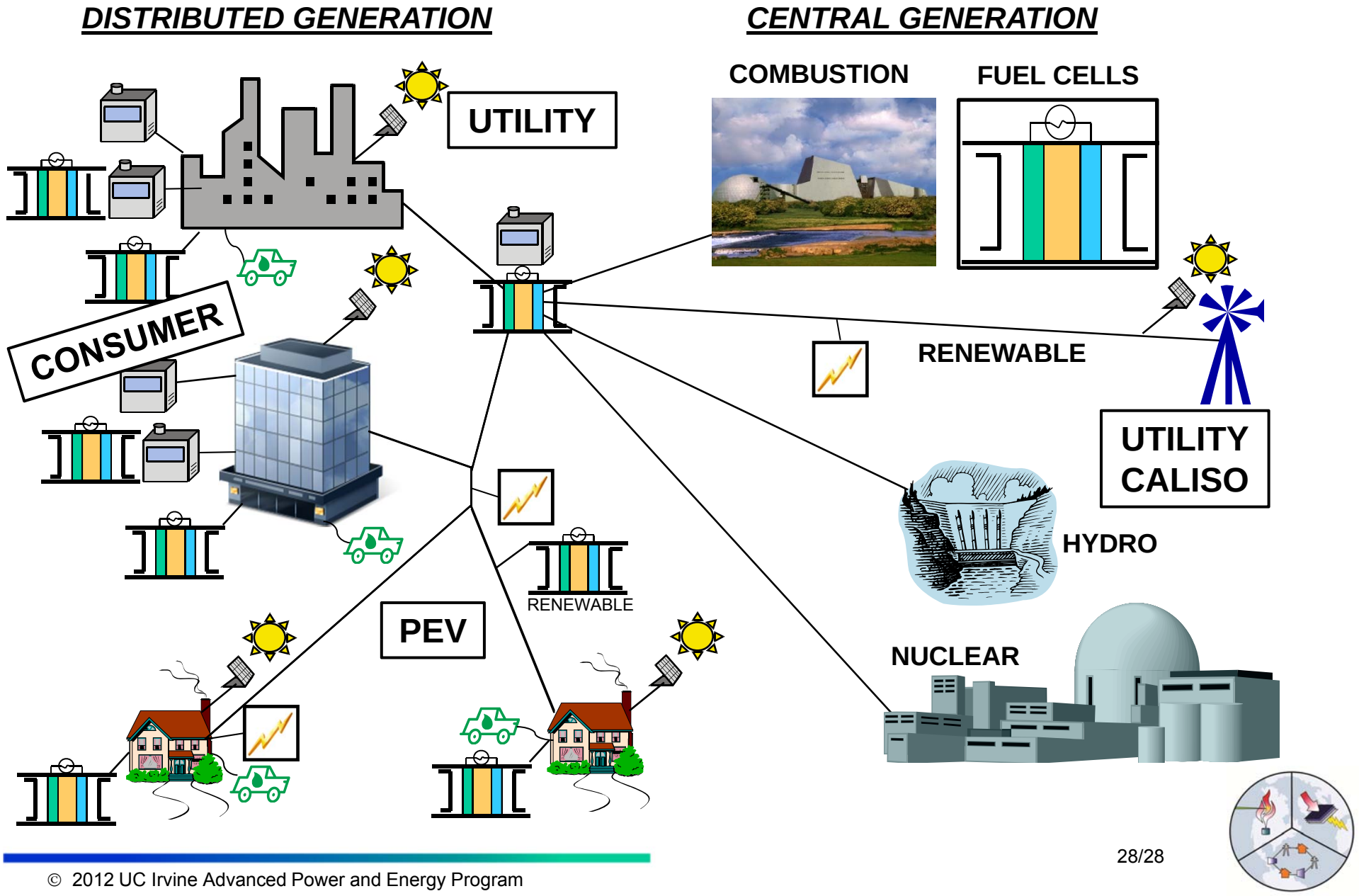
- **Fuel Cells**
- **Photovoltaic**
- **Wind**
- **CCHP**
- **Storage**

- **Smart Grid**
- **Community Design**
- **Systems Integration**
  - Renewables
  - Distributed Generation
  - Storage

SMART GRID



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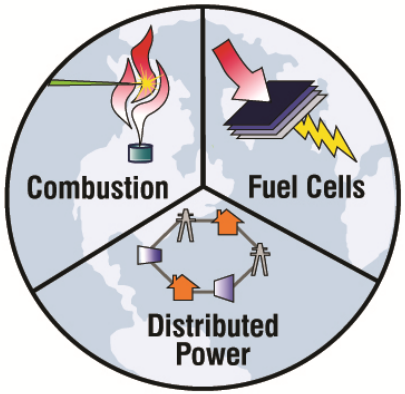

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October 2, 2012