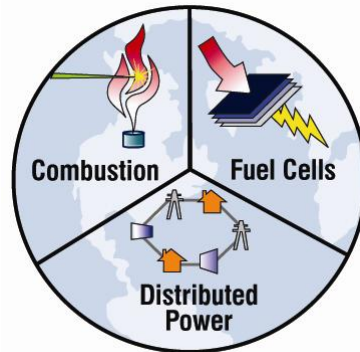


POWERING THE FUTURE OF TRANSPORTATION

National Fuel Cell Research Center Advanced Power and Energy Program



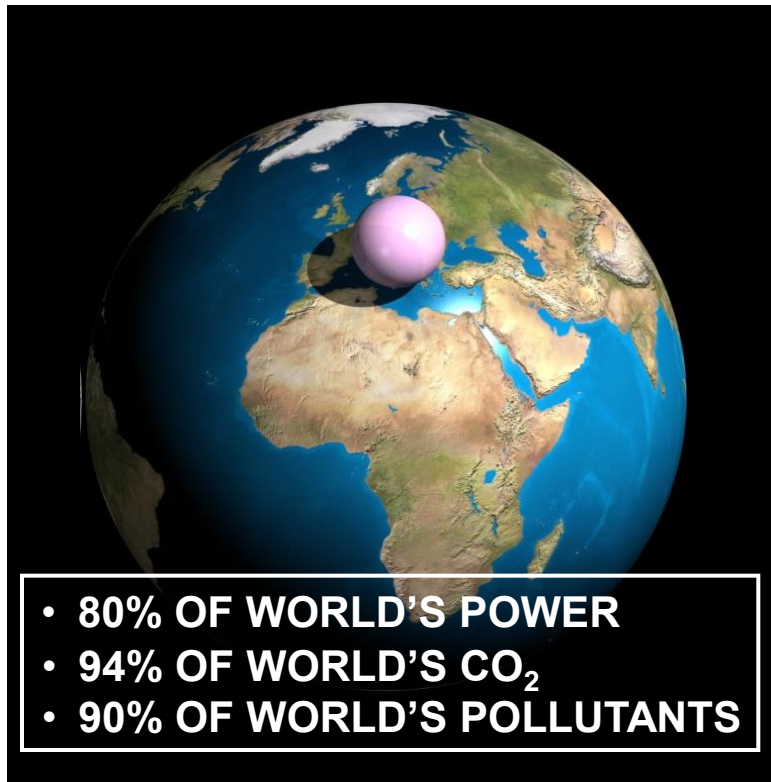
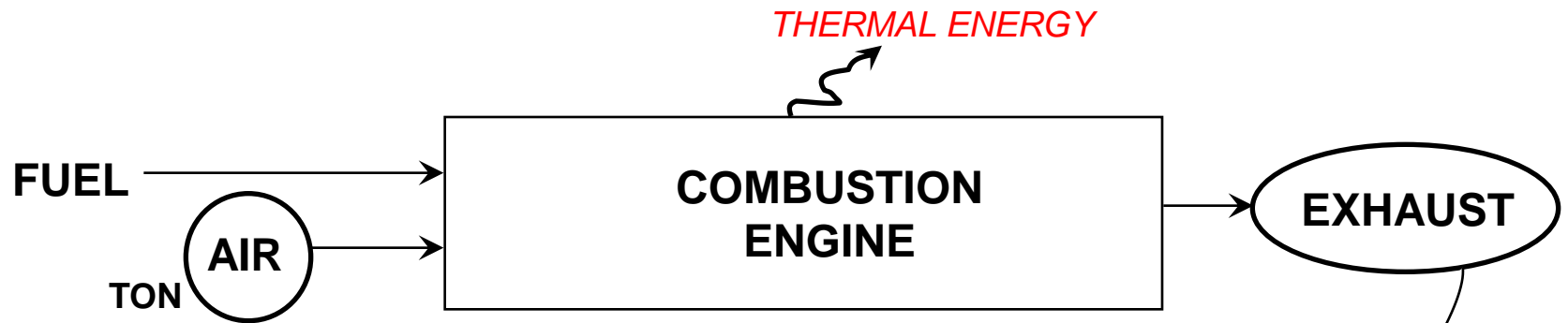
University of California, Irvine
<http://www.apep.uci.edu>

Scott Samuelsen, Director

Oregon Transportation Research and Education Consortium
April 10, 2009

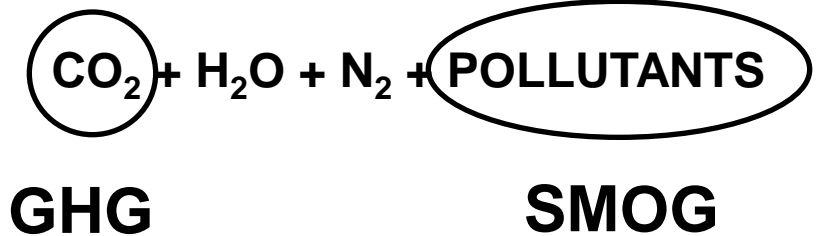


COMBUSTION



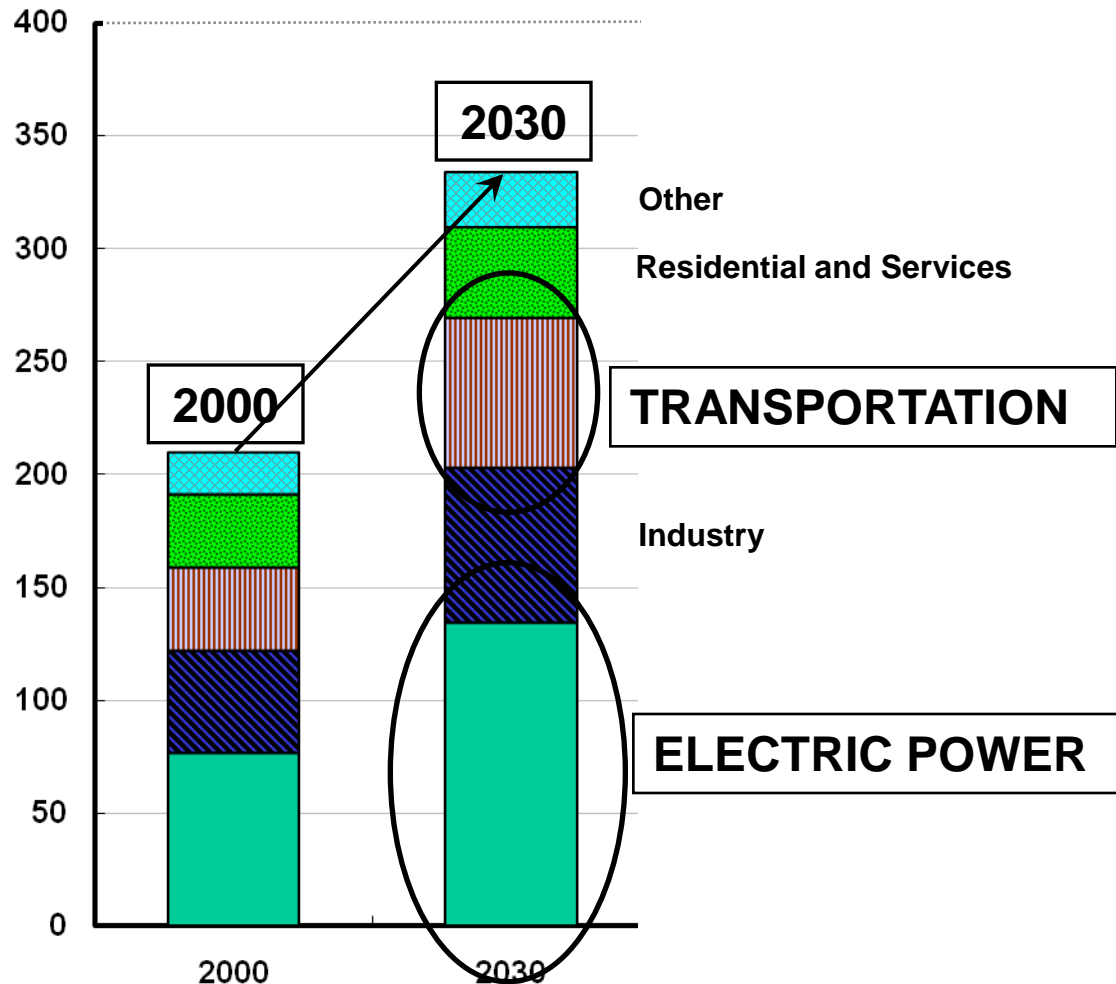
- 80% OF WORLD'S POWER
- 94% OF WORLD'S CO₂
- 90% OF WORLD'S POLLUTANTS

SOURCE: SCIENCE PHOTO LIBRARY



ENERGY DEMAND

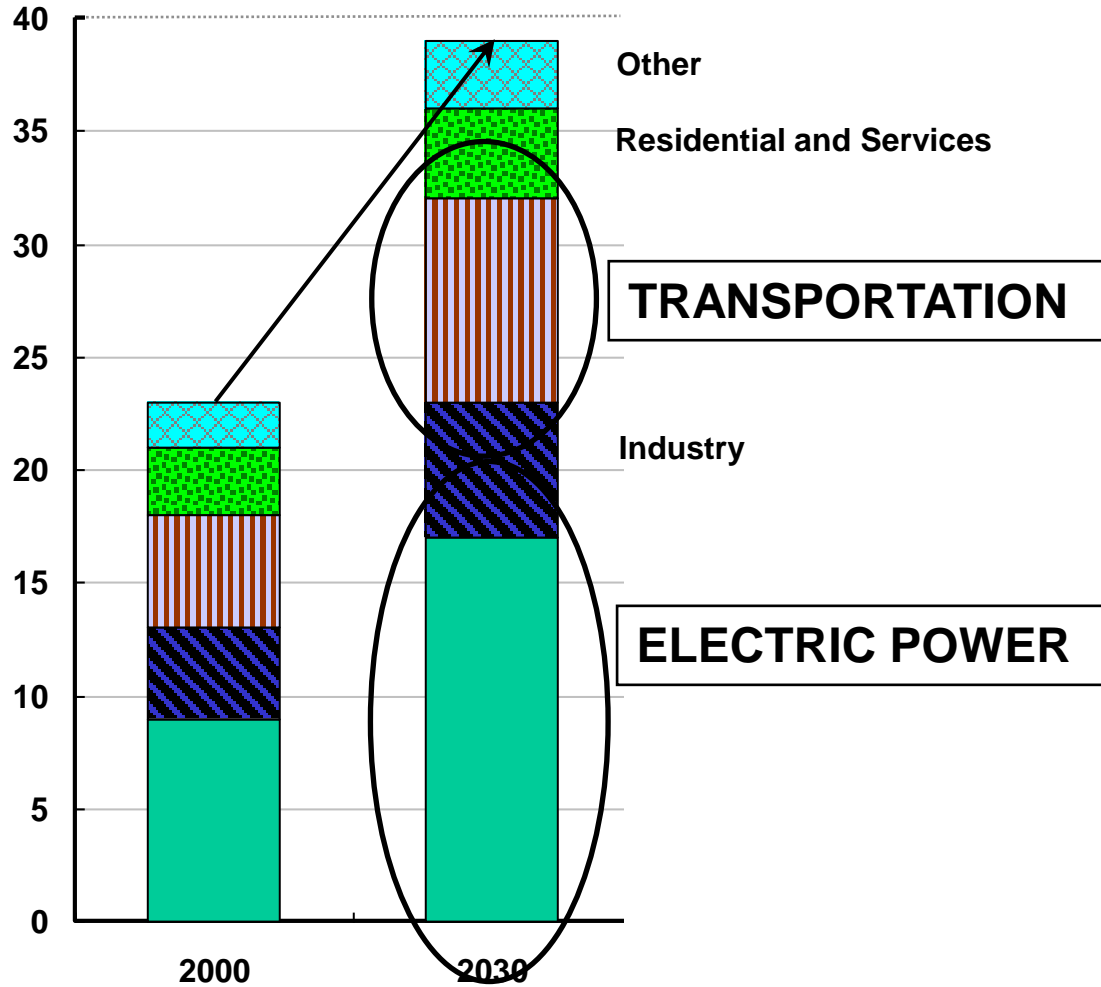
WORLD ENERGY DEMAND
[Million B/D Oil Equivalent]



SOURCE: IEA WORLD ENERGY OUTLOOK

GHG INTENSITY

WORLD GHG INTENSITY [Billion Metric T/Y]



SOURCE: IEA WORLD ENERGY OUTLOOK



FORCES FOR CHANGE

#1 GREEN HOUSE GAS INTENSITY (1990)

#2 POLLUTANT IMPACTS (1940)

#3 HUBBERT'S CURVE (1980)

#4 FUEL INDEPENDENCE (9/11)

#5 NATIONAL SECURITY (9/11)

FORCES FOR CHANGE

#1 GREENHOUSE GAS INTENSITY (1990)

#2 POLI

#3 HUB

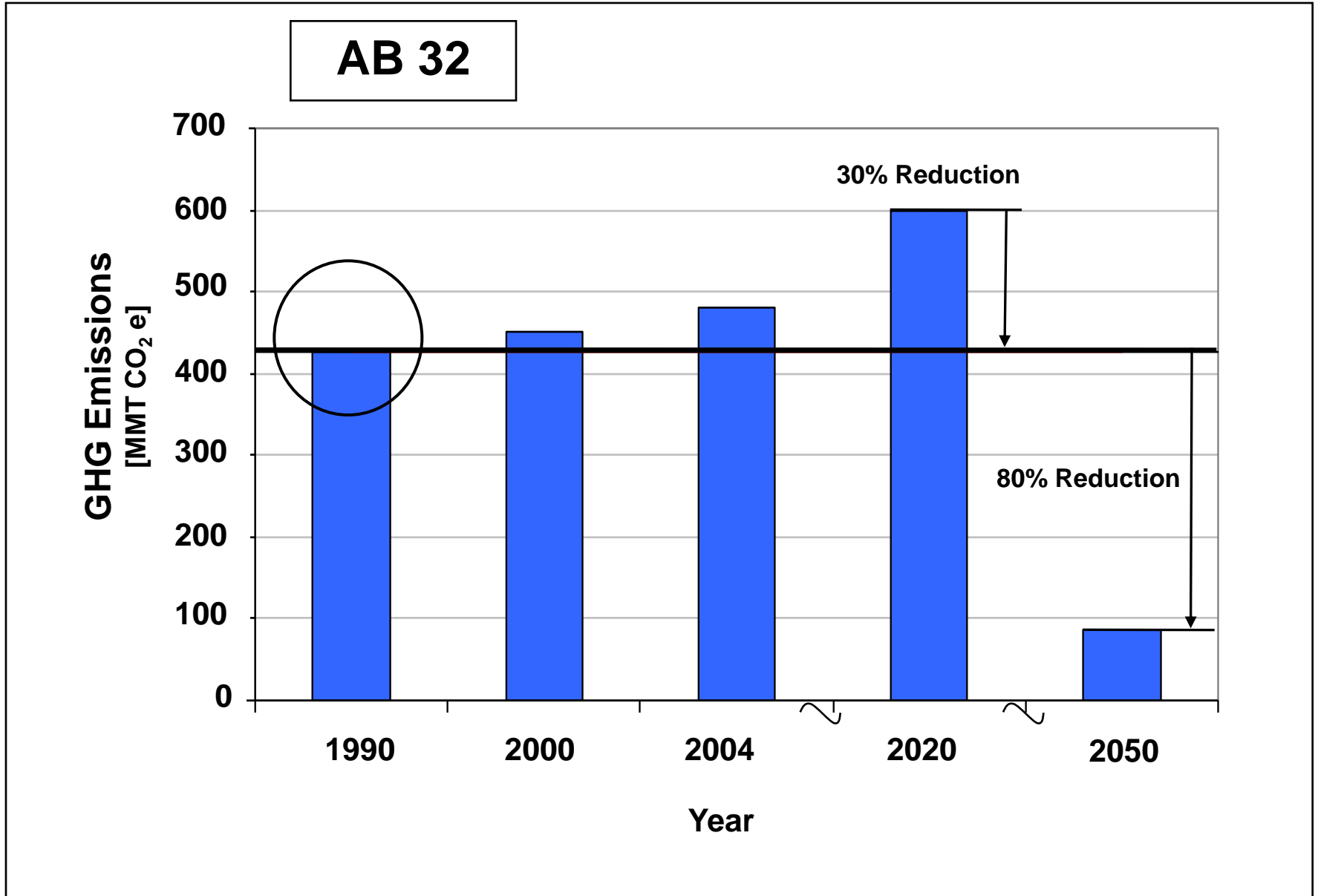
#4 FUEL

#5 NATI

PARADIGM SHIFTS

- **ELECTRIC POWER**
- **TRANSPORTATION**
 - **FUEL**
 - **ENGINE**
- **CONSERVATION**
 - **ELECTRICAL POWER**
 - **PERSONAL VEHICLE**
 - **PUBLIC TRANSPORTATION**
- **BUILDING DESIGN**
- **URBAN DESIGN**

CALIFORNIA



FORCES FOR CHANGE

#1 GREENHOUSE GAS INTENSITY (1990)

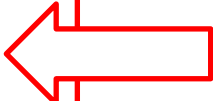
#2 POLI

#3 HUB

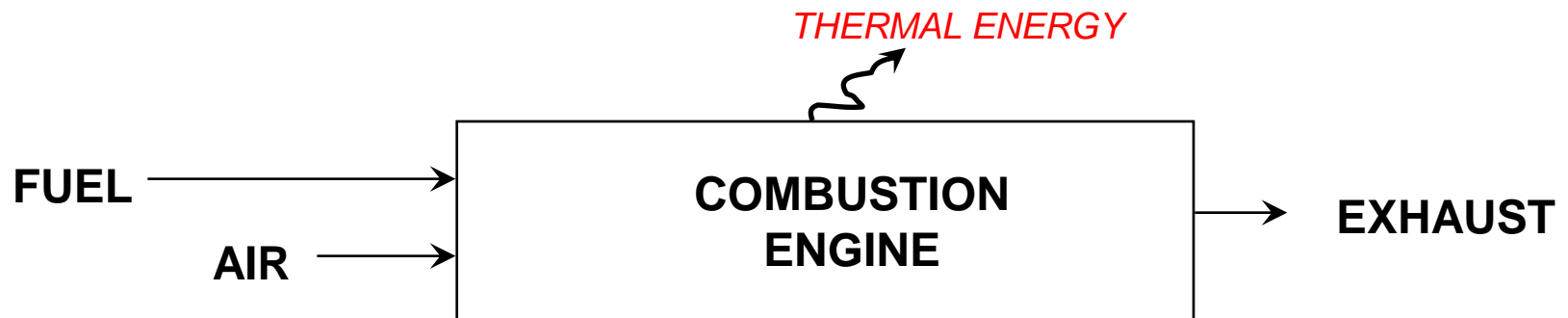
#4 FUEL

#5 NATI

PARADIGM SHIFTS

- **ELECTRIC POWER**
- **TRANSPORTATION** 
 - **FUEL**
 - **ENGINE**
- **CONSERVATION**
 - **ELECTRICAL POWER**
 - **PERSONAL VEHICLE**
 - **PUBLIC TRANSPORTATION**
- **BUILDING DESIGN**
- **URBAN DESIGN**

COMBUSTION



- **COMBUSTION**

FOSSIL FUEL

COMBUSTION



- 80% OF WORLD'S POWER
- 94% OF WORLD'S CO₂
- 90% OF WORLD'S POLLUTANTS

EXPANSION

PISTON

GENERATOR

ELECTRICITY

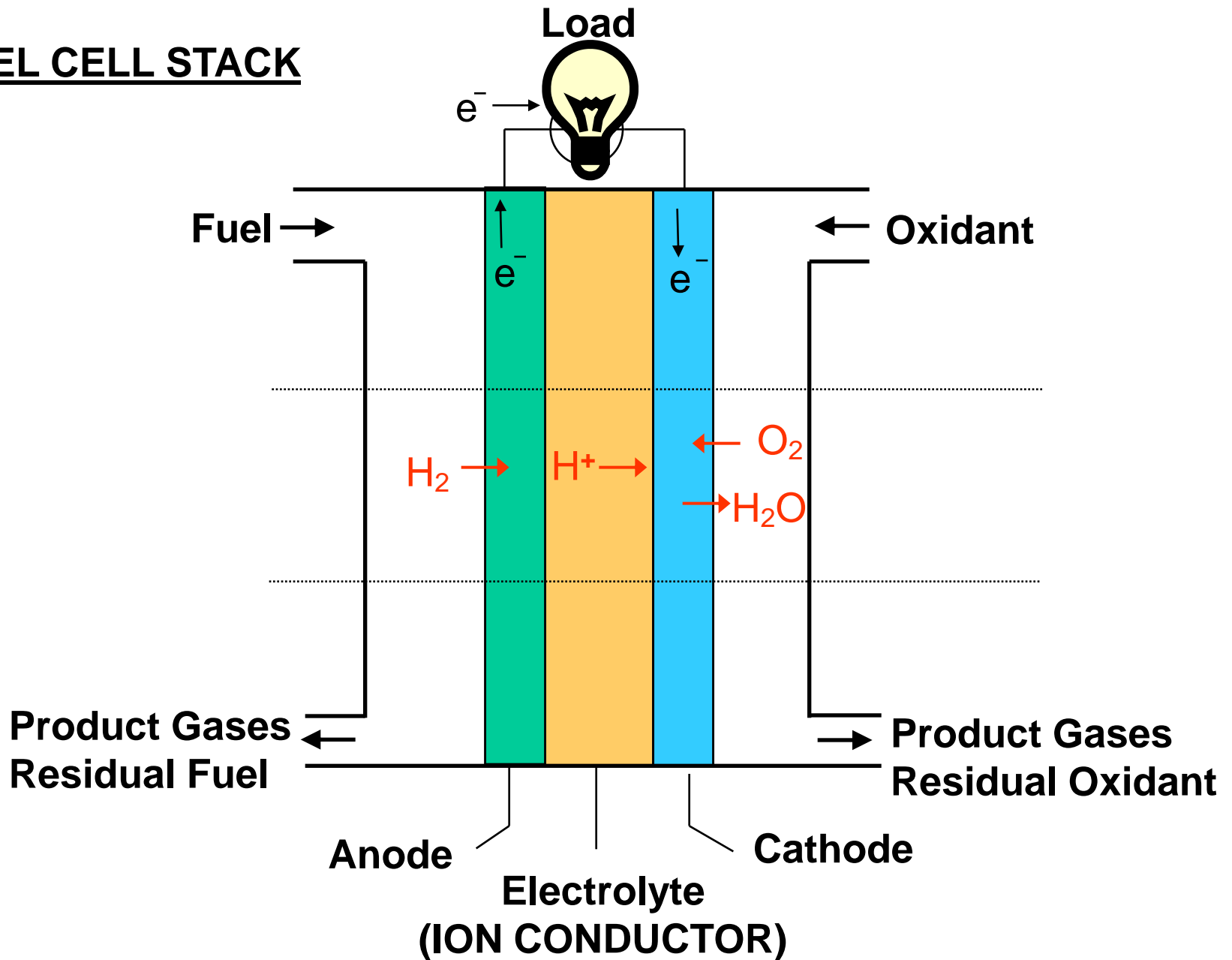
- **FUEL CELLS**

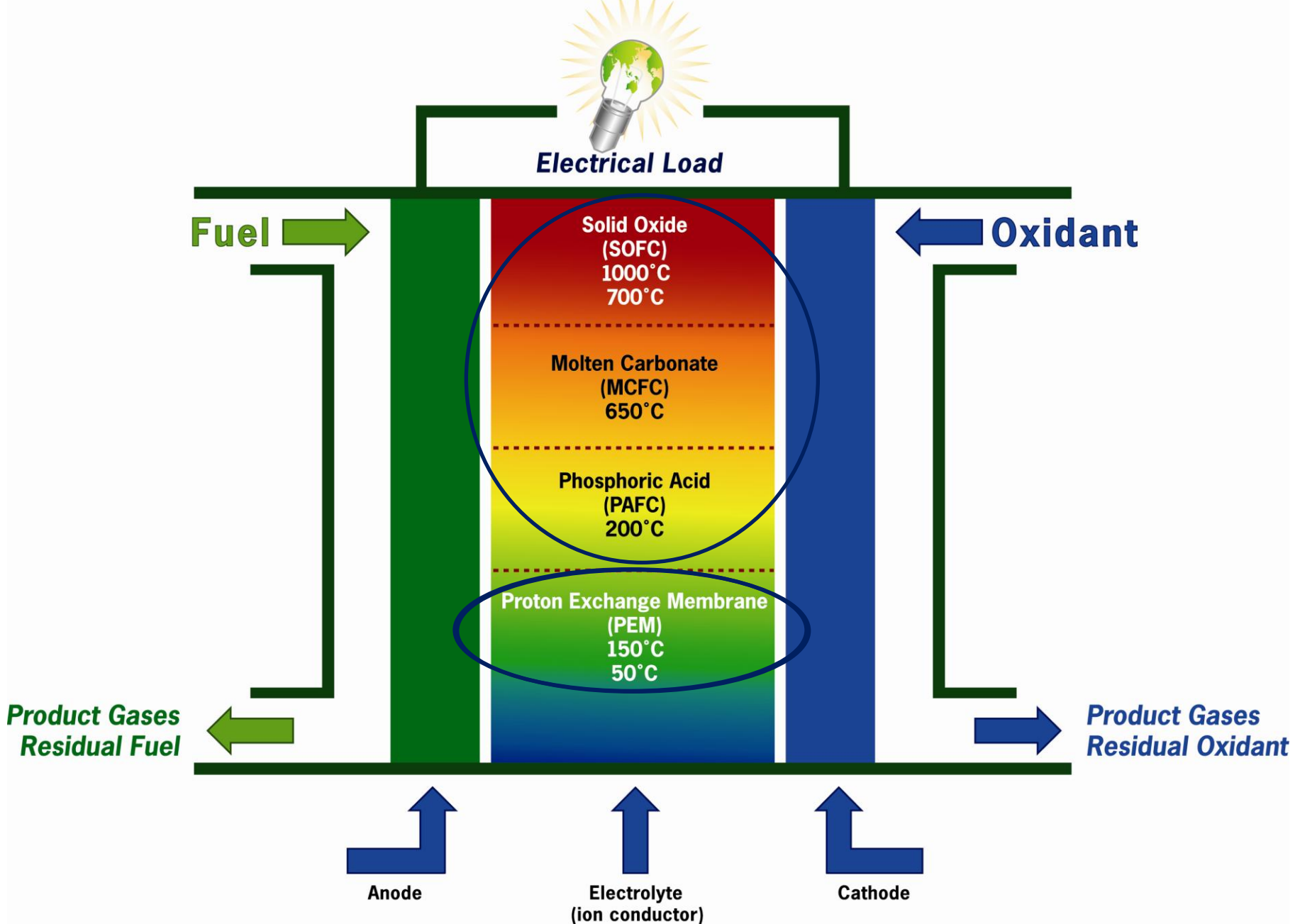
FOSSIL FUEL

ELECTROCHEMISTRY

ELECTRICITY

FUEL CELL STACK

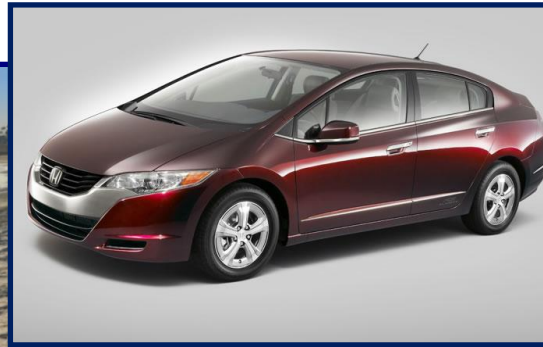




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Fuel Cell Vehicle

60 %

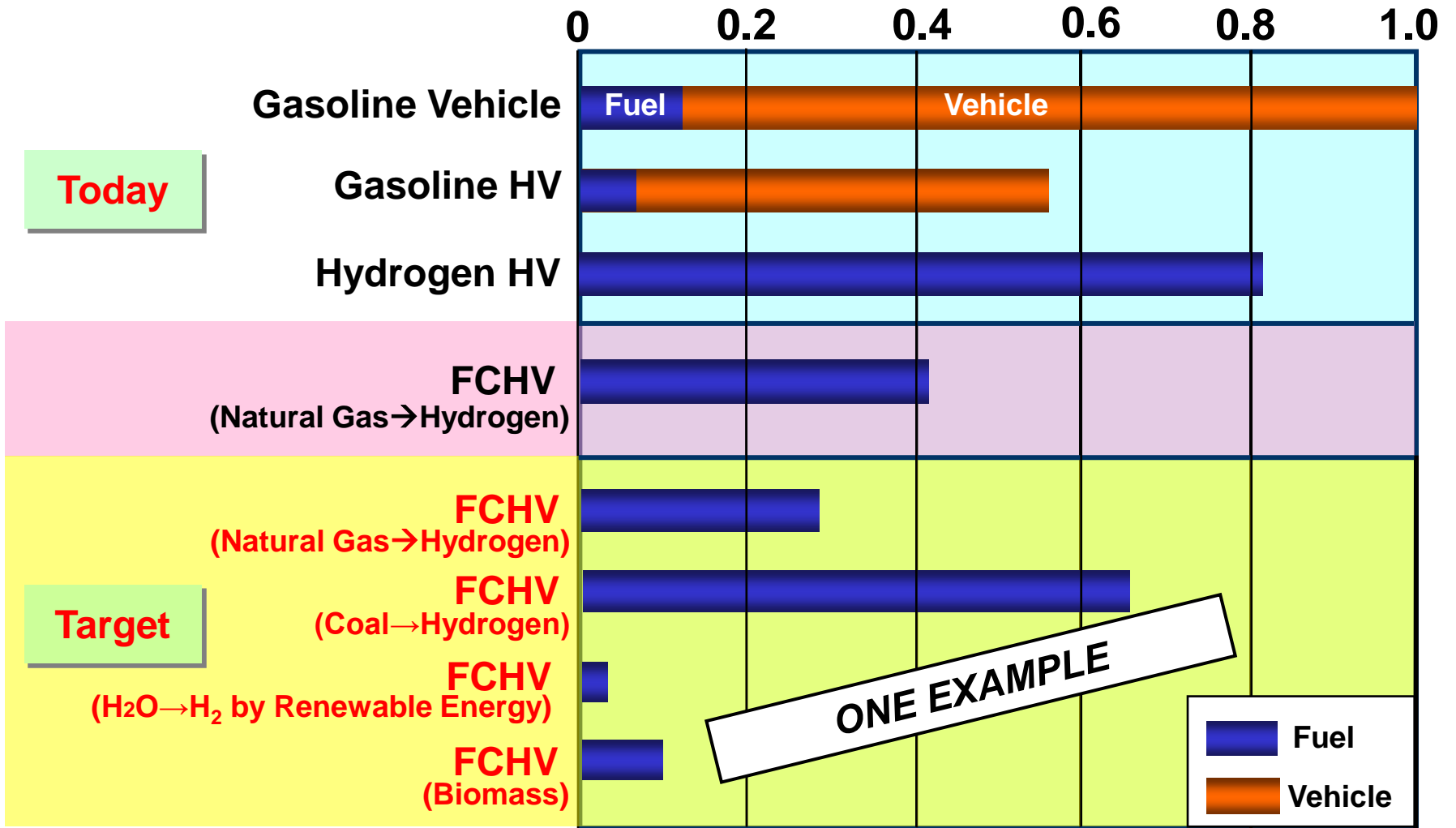


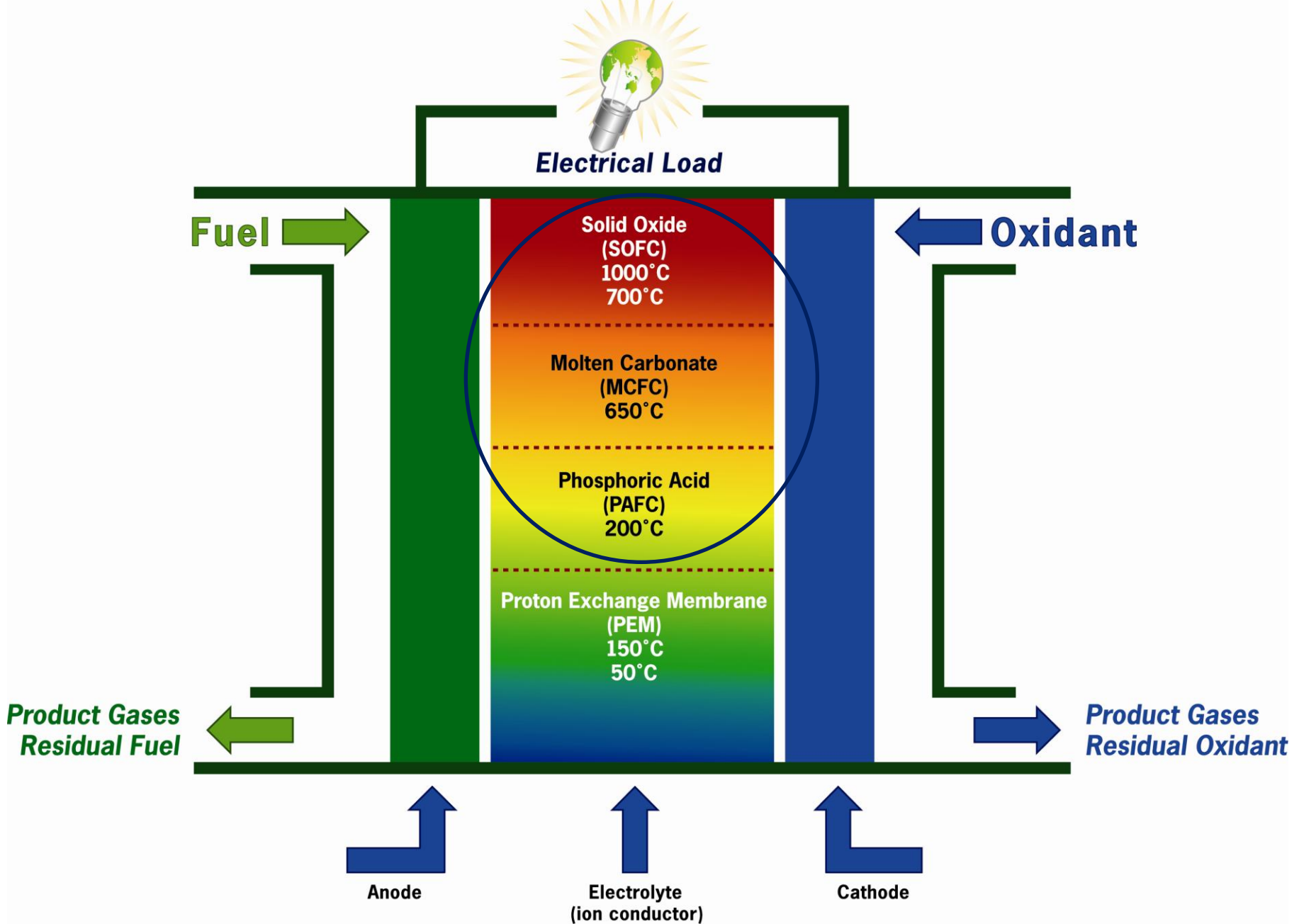
Fuel Cell Vehicle



National Fuel Cell Research Center
University of California, Irvine

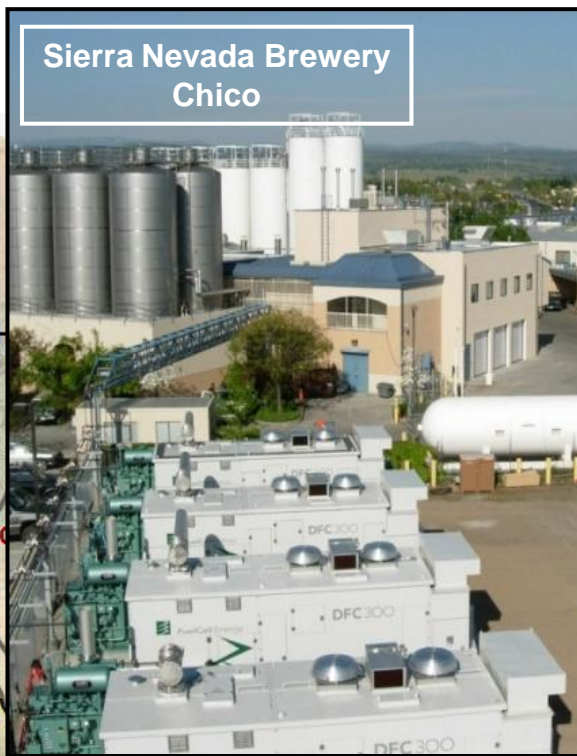
CO₂ EMISSION: FUEL and VEHICLE



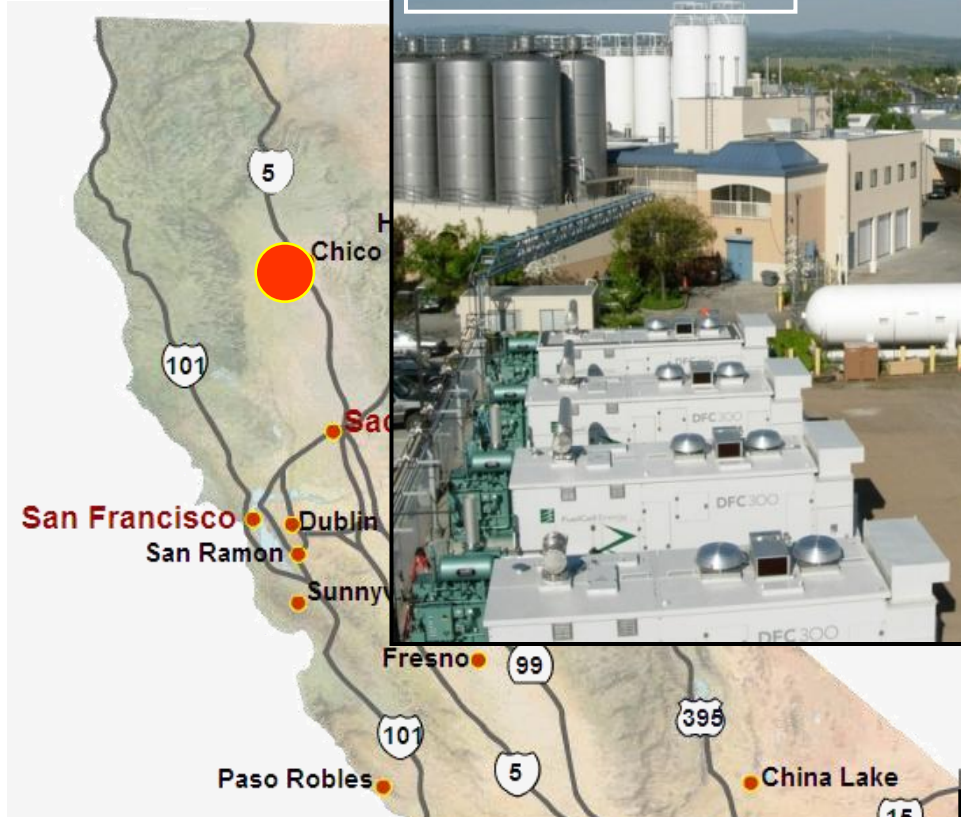


© National Fuel Cell Research Center

Sierra Nevada Brewery
Chico



WASTEWATER TREATMENT	6.10
MOBILE RENEWABLES	3.90
HOTELS	2.75
GOVERNMENT	2.25
UNIVERSITIES	1.00
BREWERIES	1.00
INDUSTRIAL	1.20
MANUFACTURING	0.50
FOOD PROCESSING	0.50
UTILITIES	0.25
TOTAL =	19.45 MW



SOURCE: WWW.CASFCC.ORG



California State University
Northridge



Sheraton Hotel
San Diego

ENERGY STATION

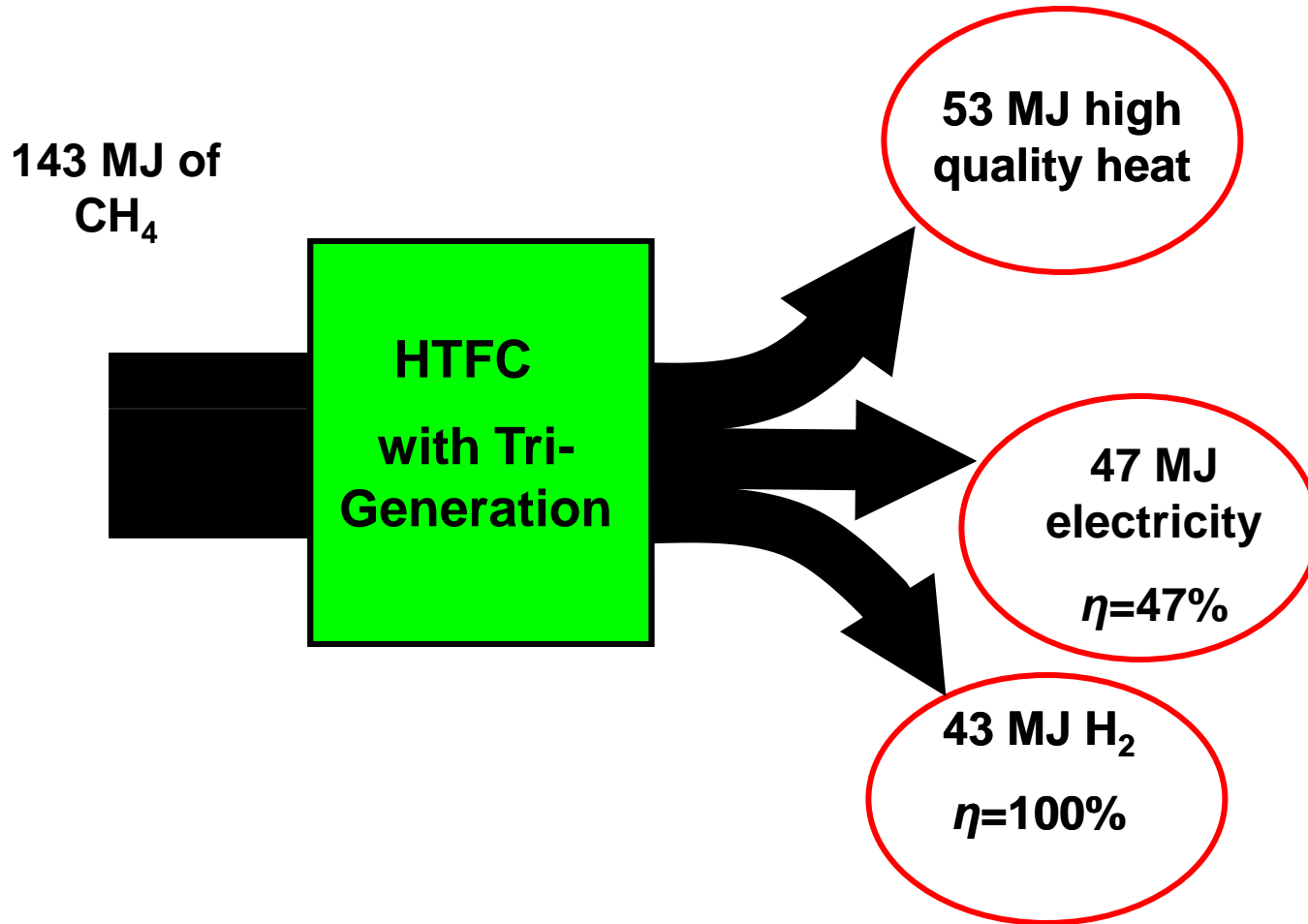
- Electric Power Generation
- Thermal Power Generation
- Hydrogen Generation



NATURAL GAS

National Fuel Cell Research Center
University of California, Irvine

High-Temperature Fuel Cell with H₂ Tri-Generation



ENERGY STATION

- Electric Power Generation
- Thermal Power Generation
- Hydrogen Generation

“GREEN ENERGY STATION”

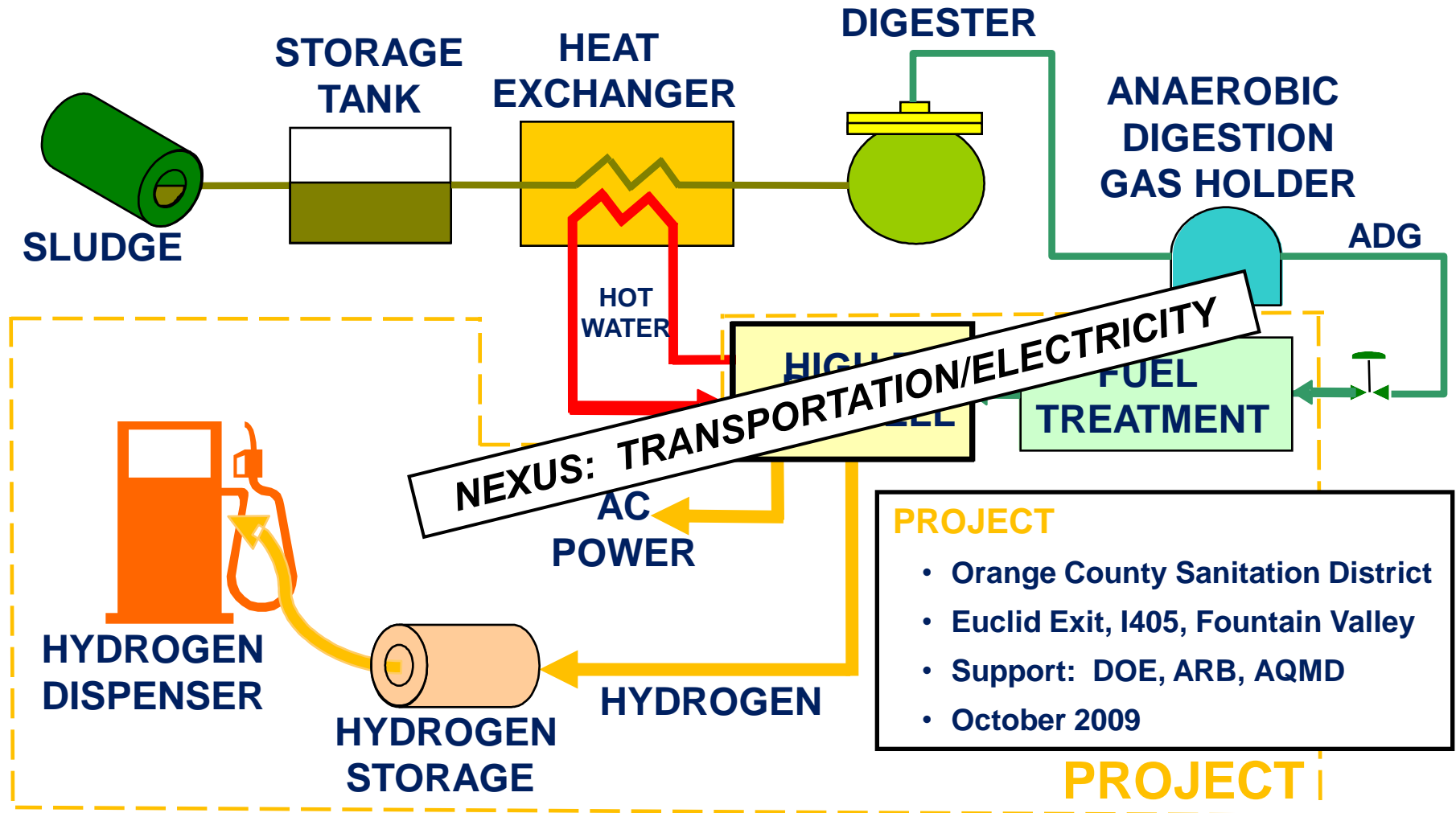
- Green Electricity
- Green Thermal Power
- Green Hydrogen



DIGESTER GAS
LAND-FILL GAS

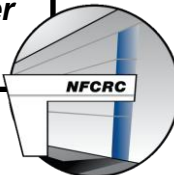
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University of California, Irvine

High-Temperature Fuel Cell with H₂ Tri-Generation



FuelCell Energy

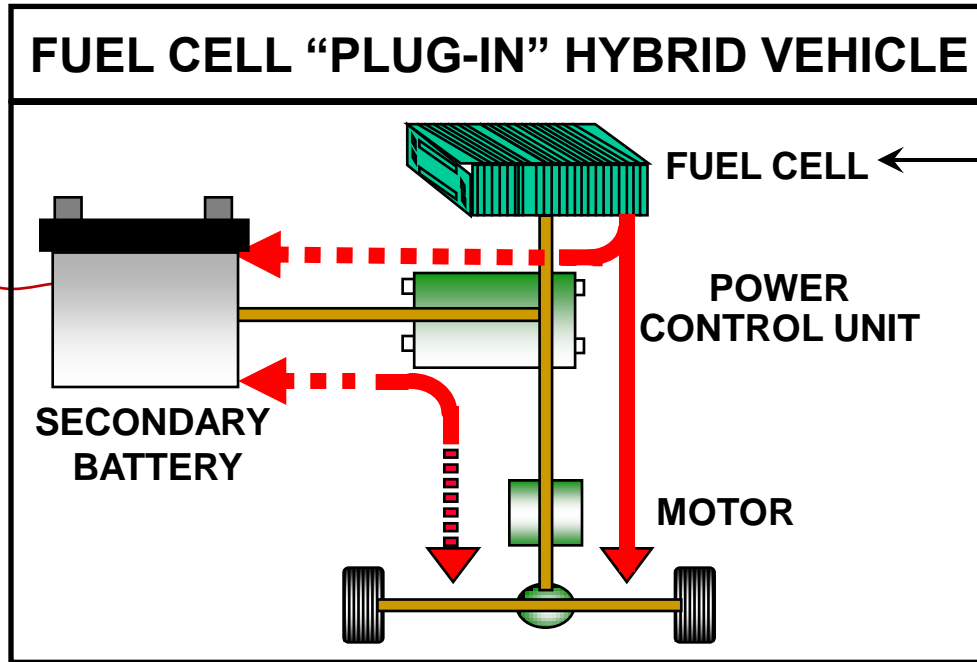
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University of California, Irvine



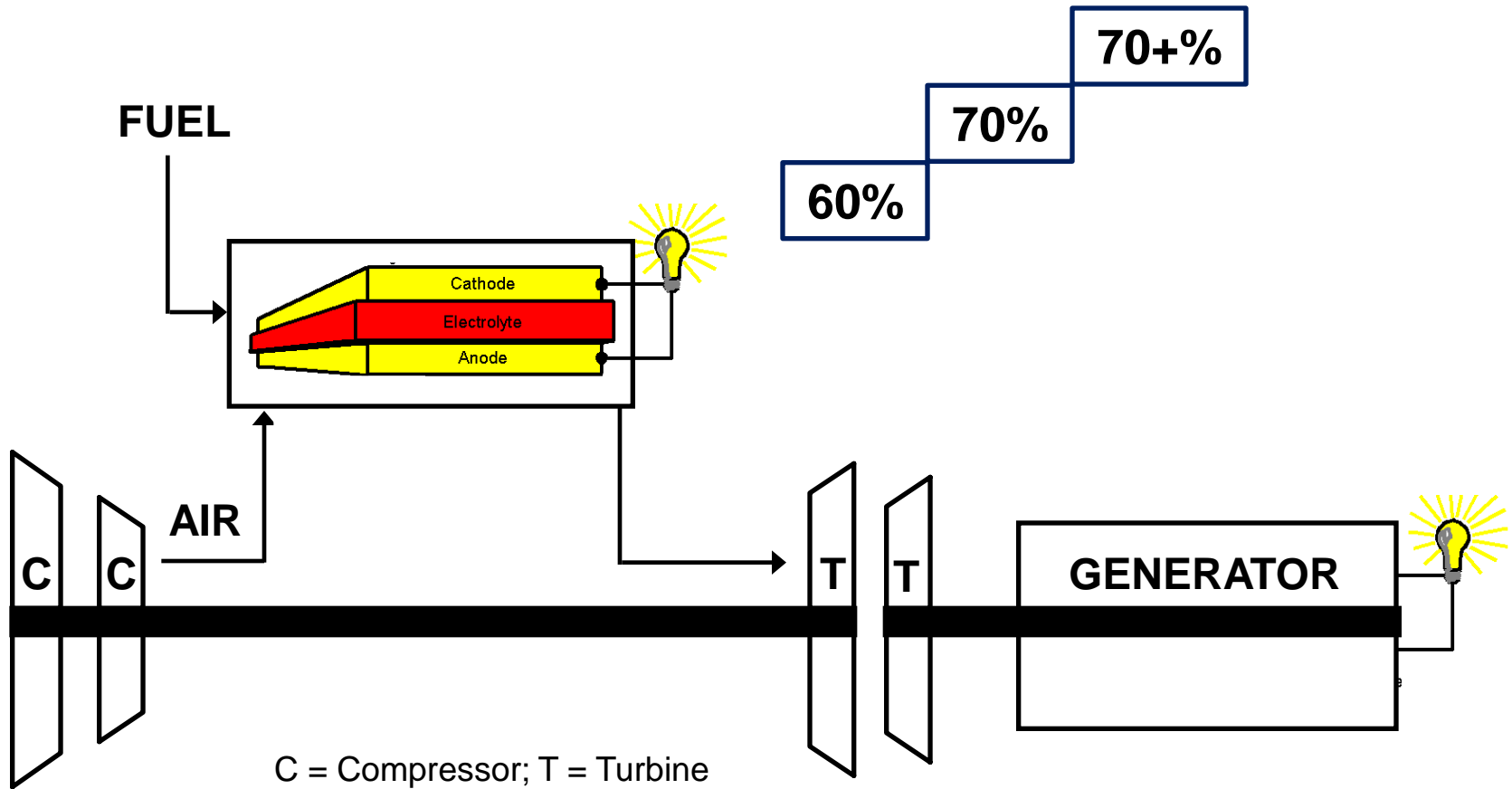
DUAL FUEL



NEXUS: TRANSPORTATION/ELECTRICITY



EMERGING TECHNOLOGY



HYBRID FUEL CELL/GAS TURBINE SYSTEMS

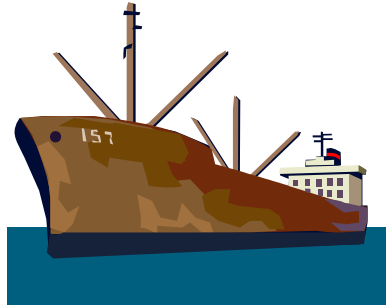
HYBRID FC/GT

- **Locomotives**



HYBRID FC/GT

- **Ships**



HYBRID FC/GT

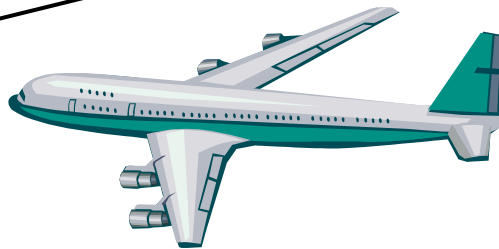
- **Trucks**



NEXUS: TRANSPORTATION/ELECTRICITY

HYBRID FC/GT

- **Aircraft**



HYBRID FC/GT

GHGs
POLLUTANTS
CONSUMPTION OF OXYGEN
NEXUS: TRANSPORTATION and ELECTRICITY
NEXUS: TRANSPORTATION and WATER
NEXUS: ELECTRICITY and WATER

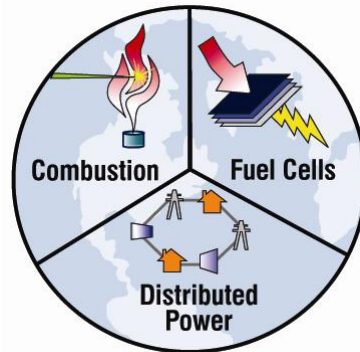


SOURCE: SCIENCE PHOTO LIBRARY

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