GLOBAL CLIMATE AND ENERGY PROJECT | STANFORD UNIVERSITY

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Climate Change: What Can We Do?

Stanford Women's Club of San Francisco

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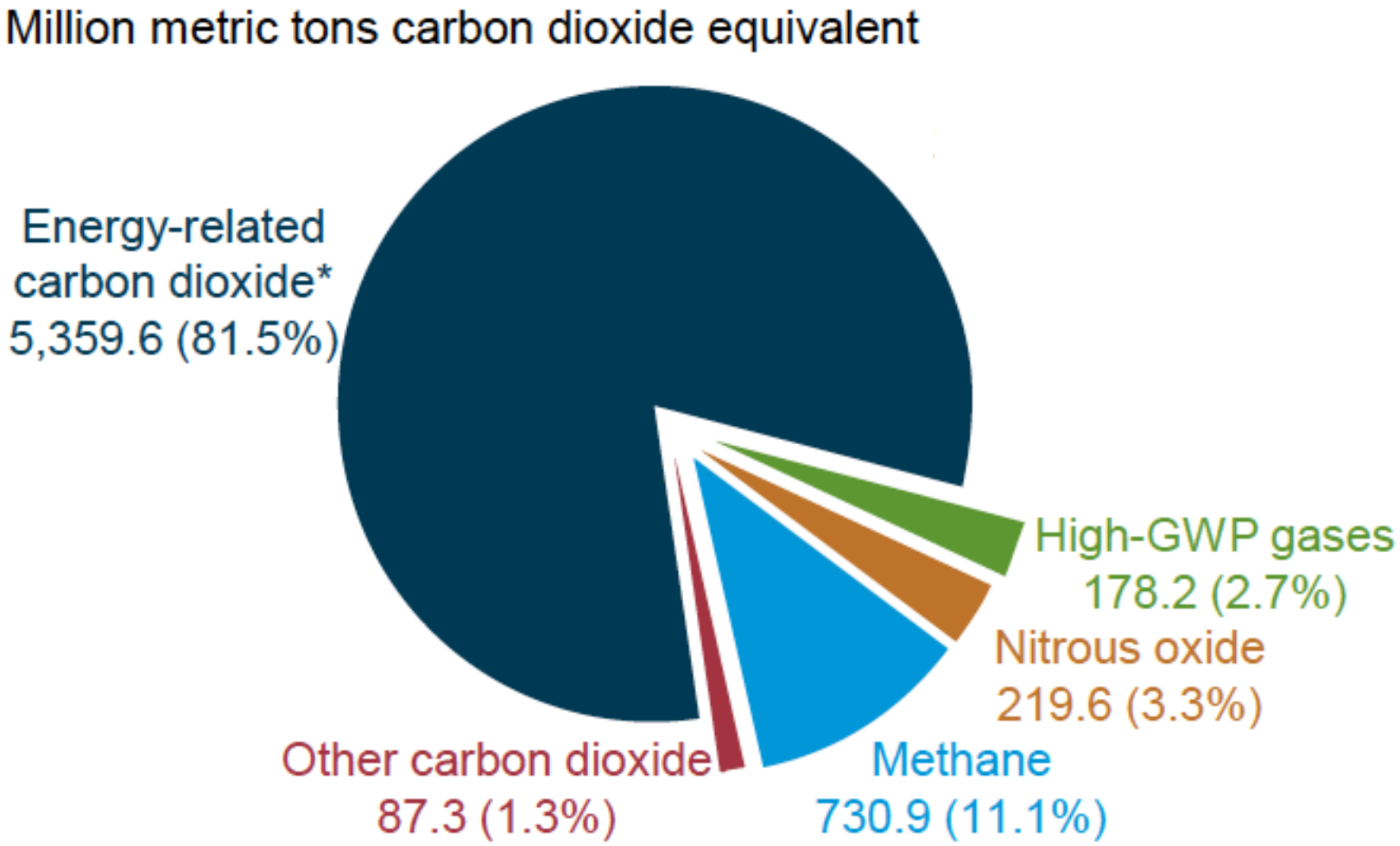
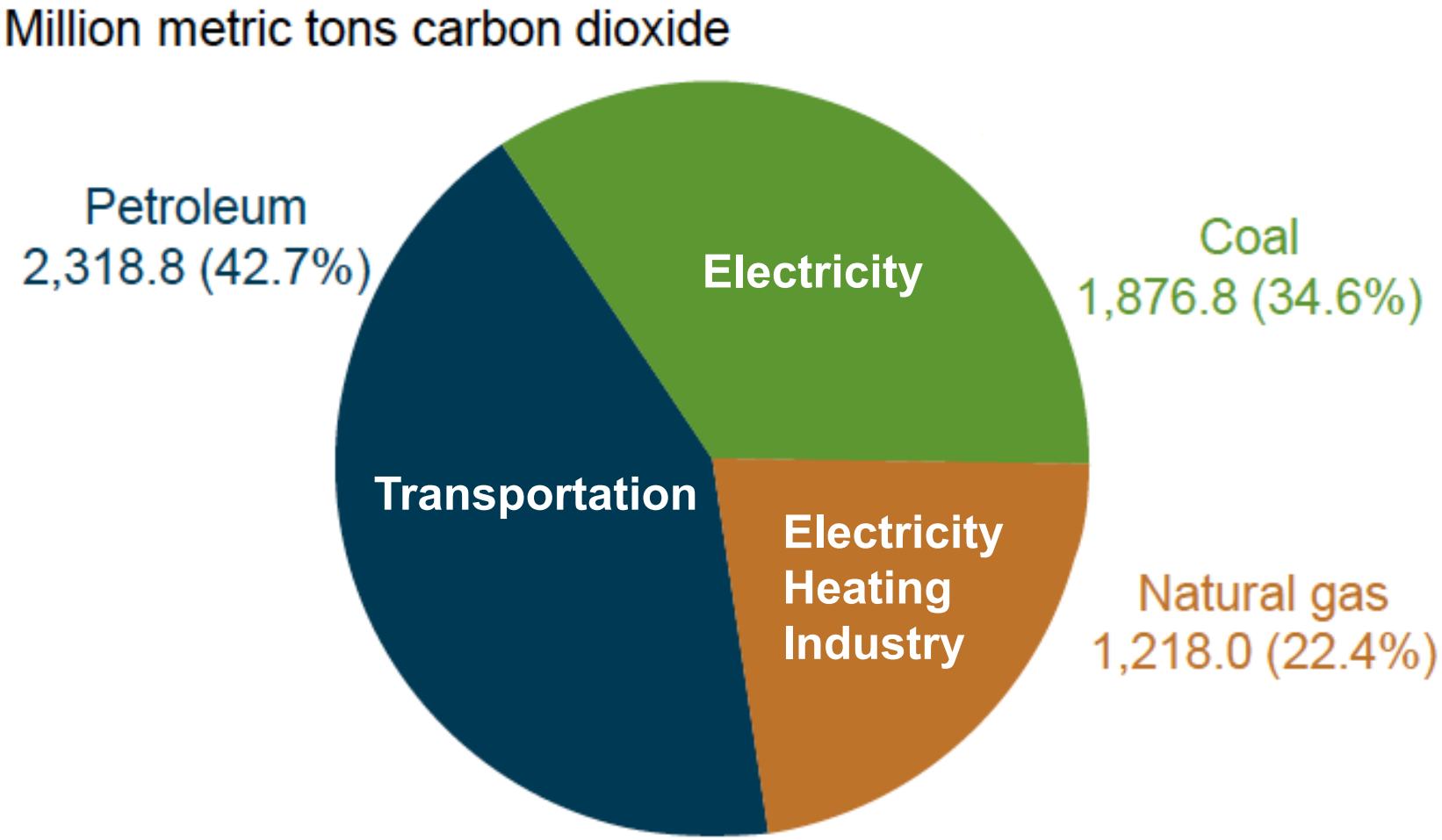
GLOBAL CHALLENGES – GLOBAL SOLUTIONS – GLOBAL OPPORTUNITIES

Over 80% of Greenhouse Gas Emissions Come from Energy Use



Source: EIA GHG Emissions Report, 2011

Energy Related CO_2 Emissions Come From Oil, Coal, and Natural Gas



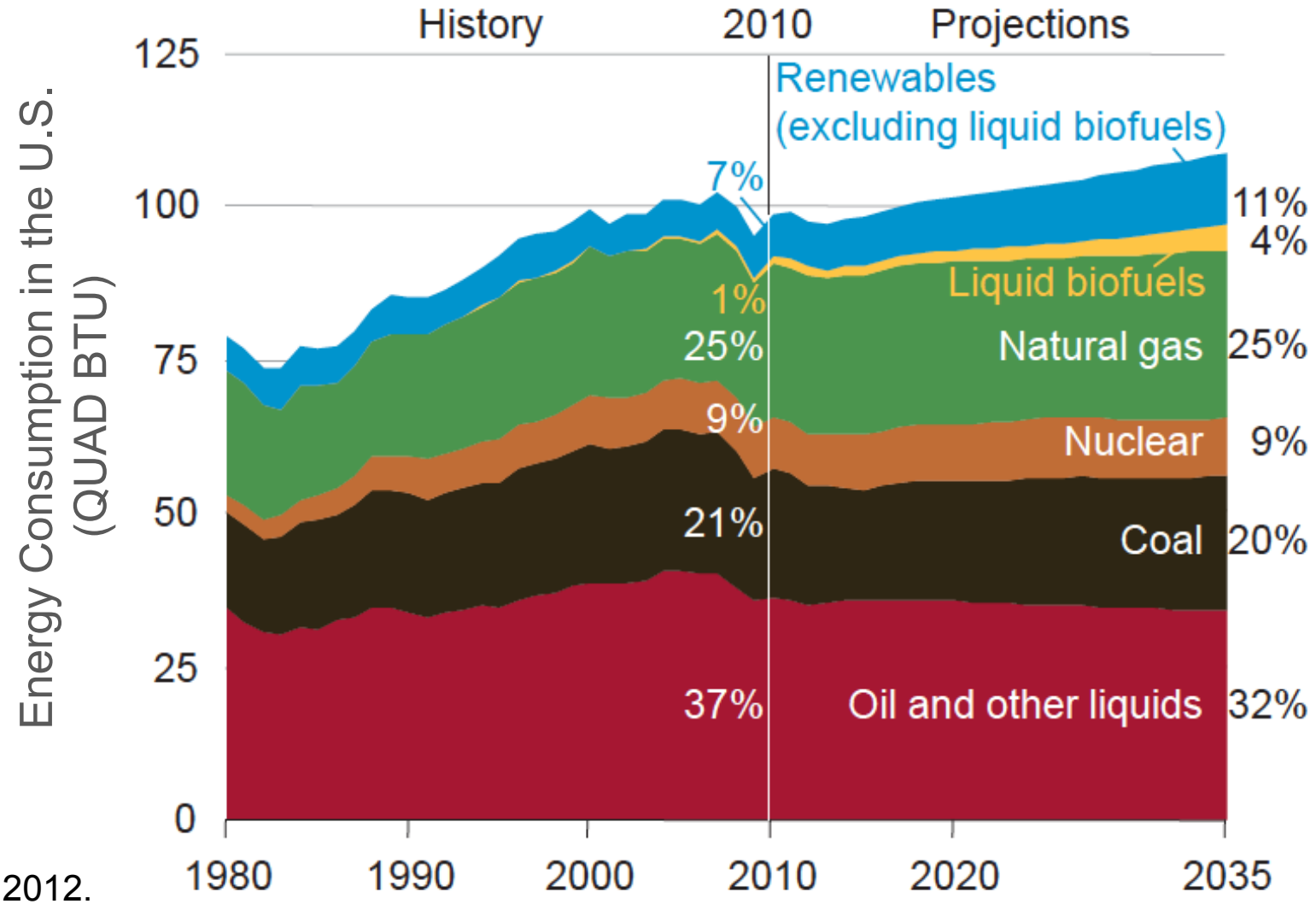
Source: EIA GHG Emissions Report, 2011

Limiting Climate Change Requires Dramatic Reduction in Greenhouse Gas Emissions

50-80% by 2050

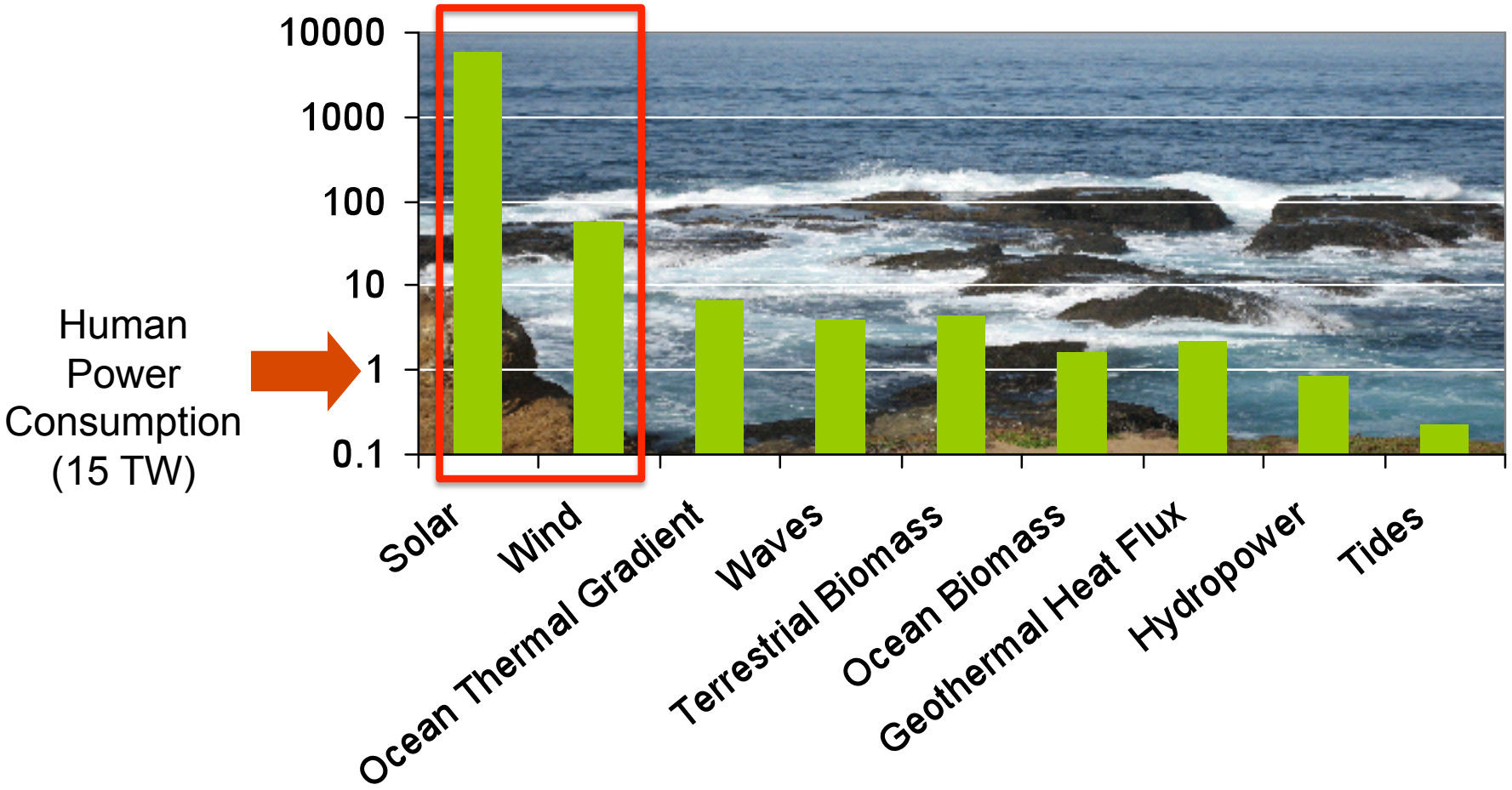
Near zero by the end of the century

This Can Only Be Achieved with a Major Overhaul of Our Energy System



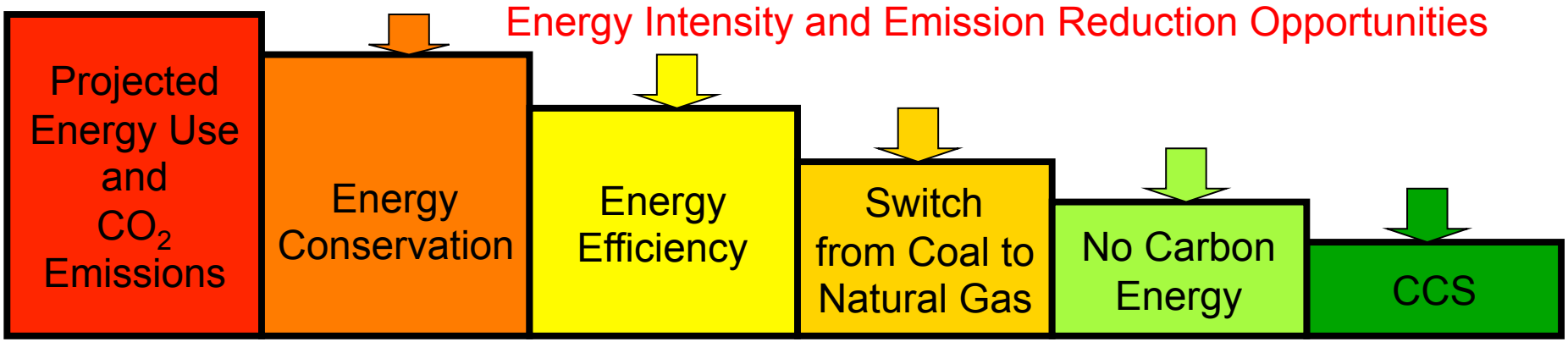
EIA, 2012.

Renewable Energy Resources are Large



What Can We Do?

- Energy conservation
- Energy efficiency improvements
- Switching to fuel with lower emissions
- No and low-carbon energy sources
  - Renewable energy (particularly solar and wind energy)
  - Nuclear energy
  - Geothermal energy
- Carbon dioxide capture and sequestration (CCS)



Major Short Term Opportunities

1. Energy Efficiency and Demand-Side Management
   - Reduce energy use in buildings – zero net energy
   - Transportation – high mpg cars (e.g. hybrids)
2. Wind Energy
   - Larger turbines produce low cost electricity
   - Growing at 20-30%/year
3. Solar Photovoltaics (PV)
   - Dramatic cost reductions in PV manufacturing
   - Growing at 40-70%/year
4. Shale Gas
   - Large new reserves
   - Application in power generation and transportation

What's Coming Next?

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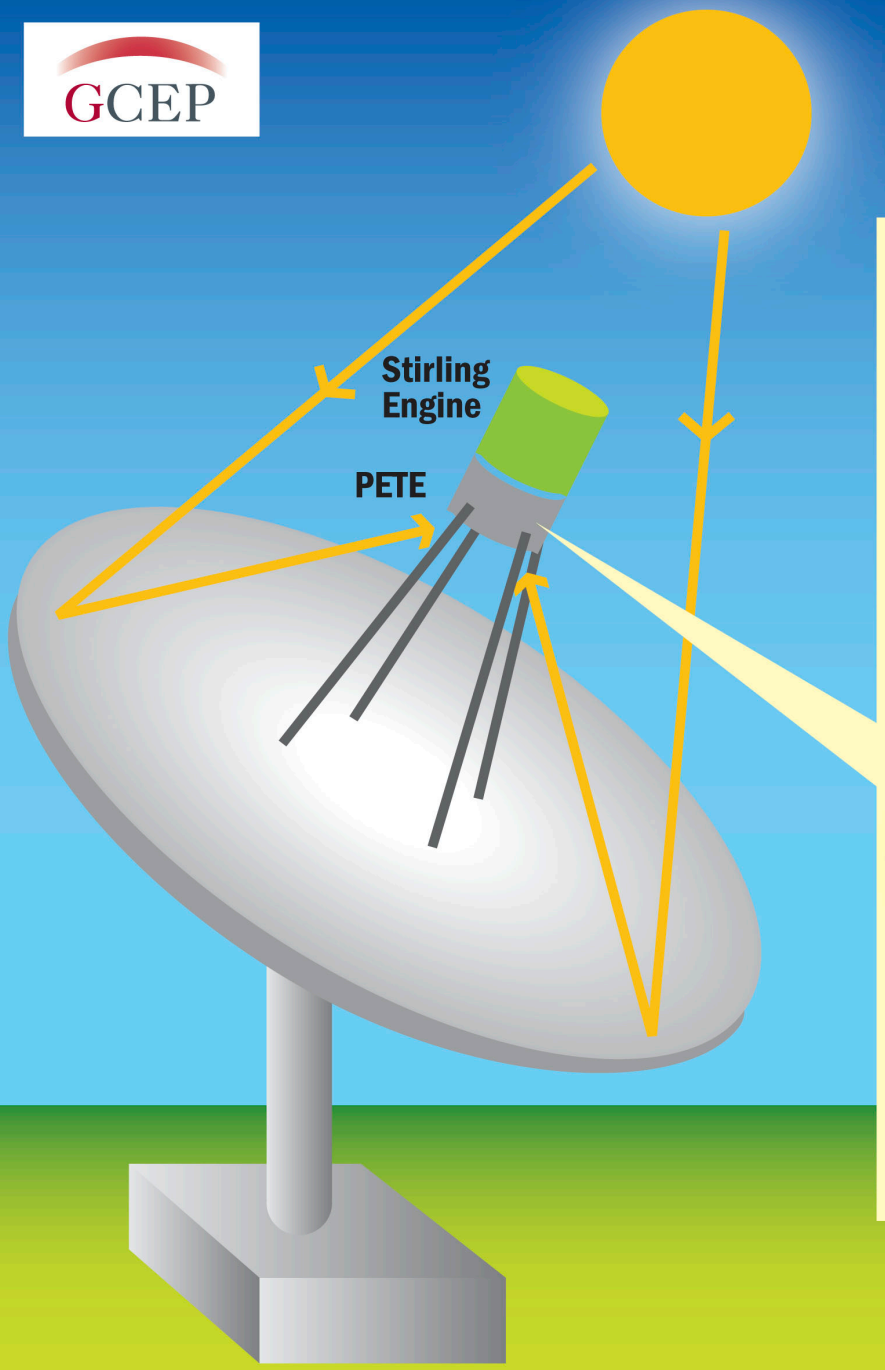
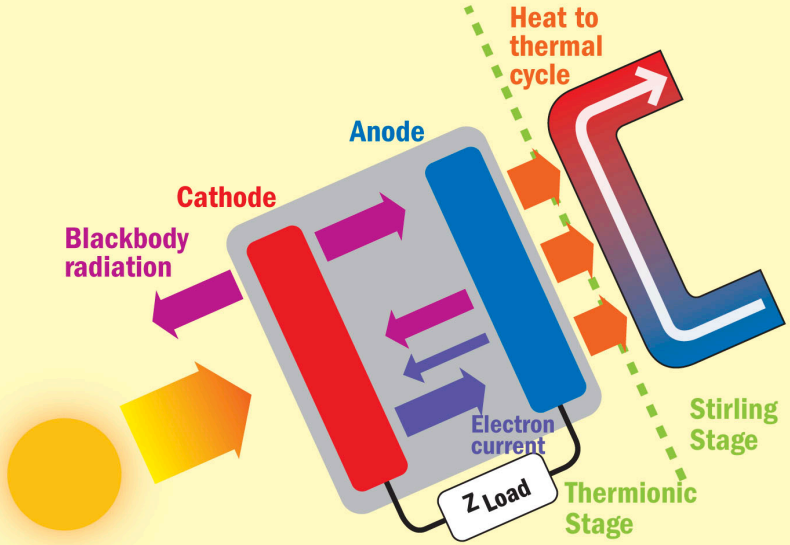
GCEP RESEARCH FOR ADVANCED SOLAR ENERGY CONVERSION



PHOTON ENHANCED THERMIONIC EMISSION (PETE) FOR SOLAR CONCENTRATOR SYSTEMS

Nick Melosh and ZX Shen, Stanford University

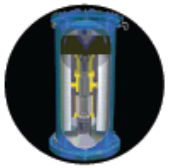


- Approach combines quantum and thermal mechanisms into a single physical process.
- Waste heat from PETE device is used to power a secondary thermal engine.
- Theoretical combined conversion efficiencies for solar electricity generation are above 50%.

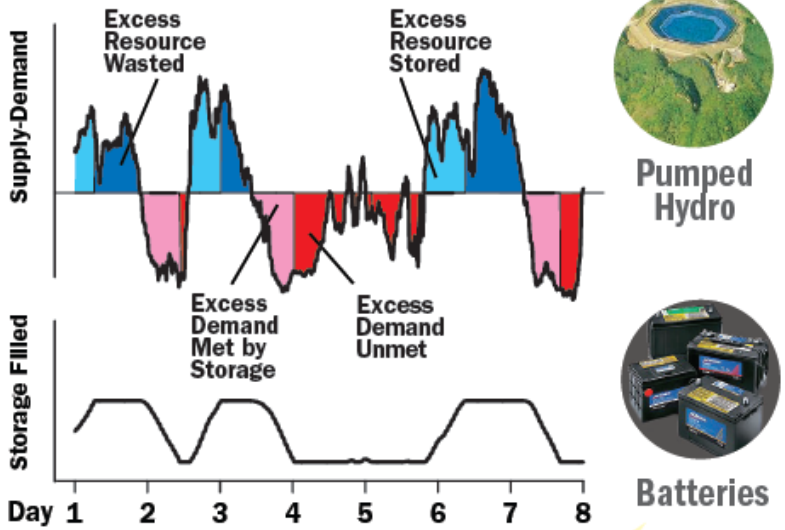
GCEP RESEARCH IN ADVANCED GRID STORAGE

Energy Storage

CAES



Flywheel



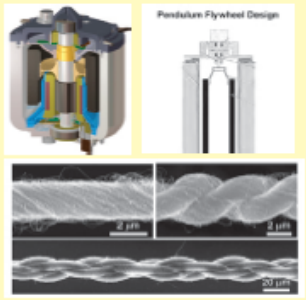
Pumped Hydro

Batteries

Low-Cost Flywheel Storage

Robert Hebner, Richard Thompson, Ray Baughman, *et al.*, UT-Austin and UT-Dallas

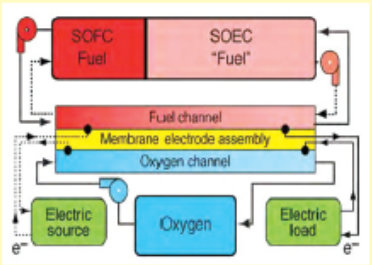
- Application of novel flywheel designs
  - Based on pendulums and hubless rings
  - Composed of nanotubes and nanofibers spun into yarns
- Could lead to deployable ultra-low loss, efficient, multi-day energy storage technology

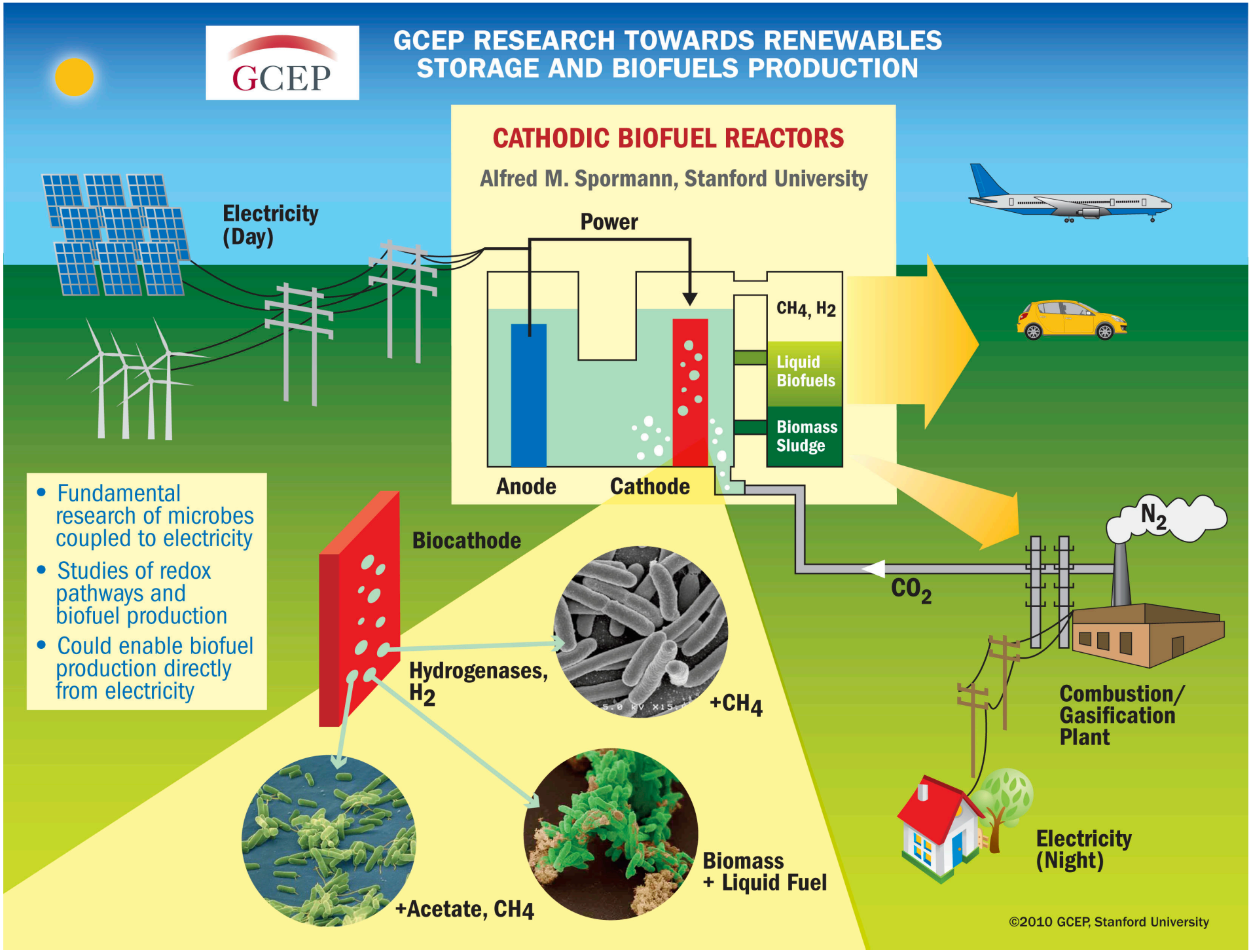


A Novel Solid Oxide Flow Battery

Scott Barnett, Robert Kee, and Robert Braun, Northwestern U and Colorado School of Mines

- Development of a device that bridges solid oxide fuel cells and flow batteries.
  - Operates reversibly using gaseous fluids in tanks.
- Could be used to store large amounts of energy due to their high roundtrip efficiency and minimal leakage.

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GCEP RESEARCH TOWARDS RENEWABLES STORAGE AND BIOFUELS PRODUCTION
CATHODIC BIOFUEL REACTORS
Alfred M. Spormann, Stanford University
Electricity (Day)
Power
CH4, H2
Liquid Biofuels
Biomass Sludge
Anode
Cathode
• Fundamental research of microbes coupled to electricity
• Studies of redox pathways and biofuel production
• Could enable biofuel production directly from electricity
Biocathode
Hydrogenases, H2
+CH4
+Acetate, CH4
Biomass + Liquid Fuel
CO2
N2
Combustion/ Gasification Plant
Electricity (Night)
©2010 GCEP, Stanford University

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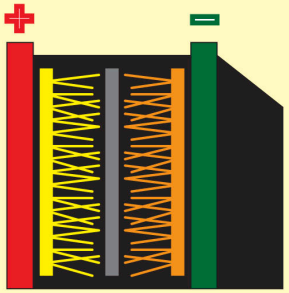
GCEP RESEARCH FOR ADVANCED ELECTRIC TRANSPORTATION

ADVANCED BATTERY STORAGE

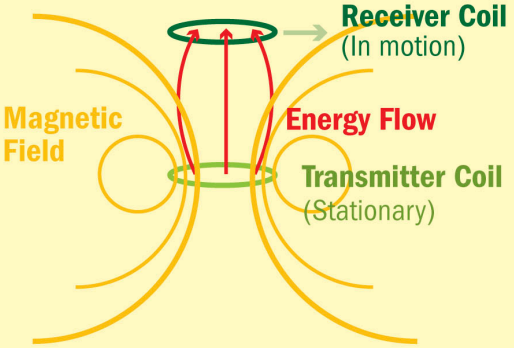
Yi Cui *et al.*, Stanford University



- Development of core-shell nanowire-based Li-ion batteries
- Potential for order of magnitude improvements in:
  - Weight of battery
  - Number of charging cycles

WIRELESS ELECTRIC POWER TRANSFER TO MOVING VEHICLES

Shanhui Fan, Stanford University



- Modeling studies of wireless electric power transfer to moving vehicles via resonant coupling of non-radiating magnetic fields
- Possibility for on-road charging of electric vehicles allowing:
  - Unlimited range
  - Autonomous control

Power Control Station

Electric Car

Battery

Receiver Coil

Electric Motor

Transmitter Coil

Power Line

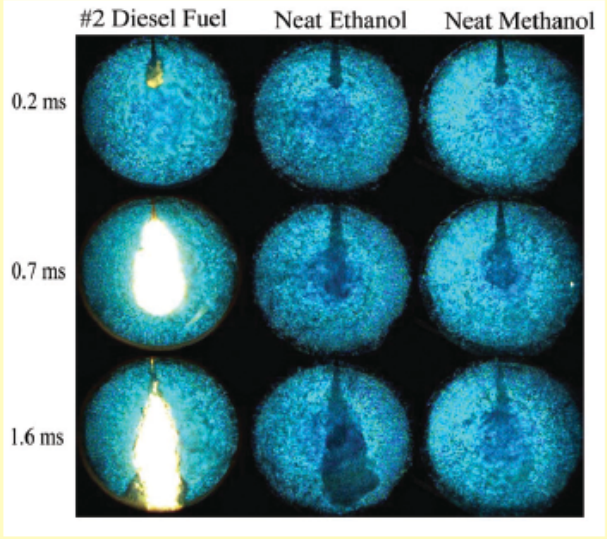
GCEP RESEARCH IN ADVANCED COMBUSTION

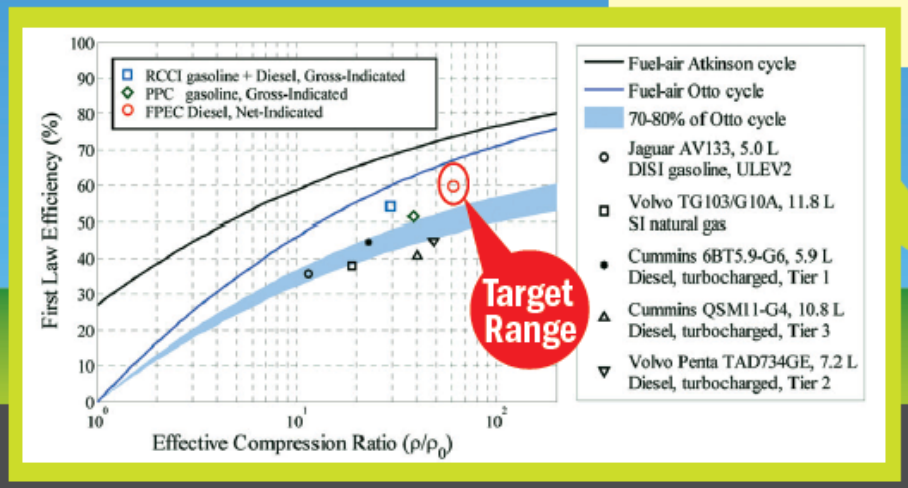
Sootless Diesel: High-Load, High-Efficiency, Clean Combustion

Chris Edwards, Stanford University

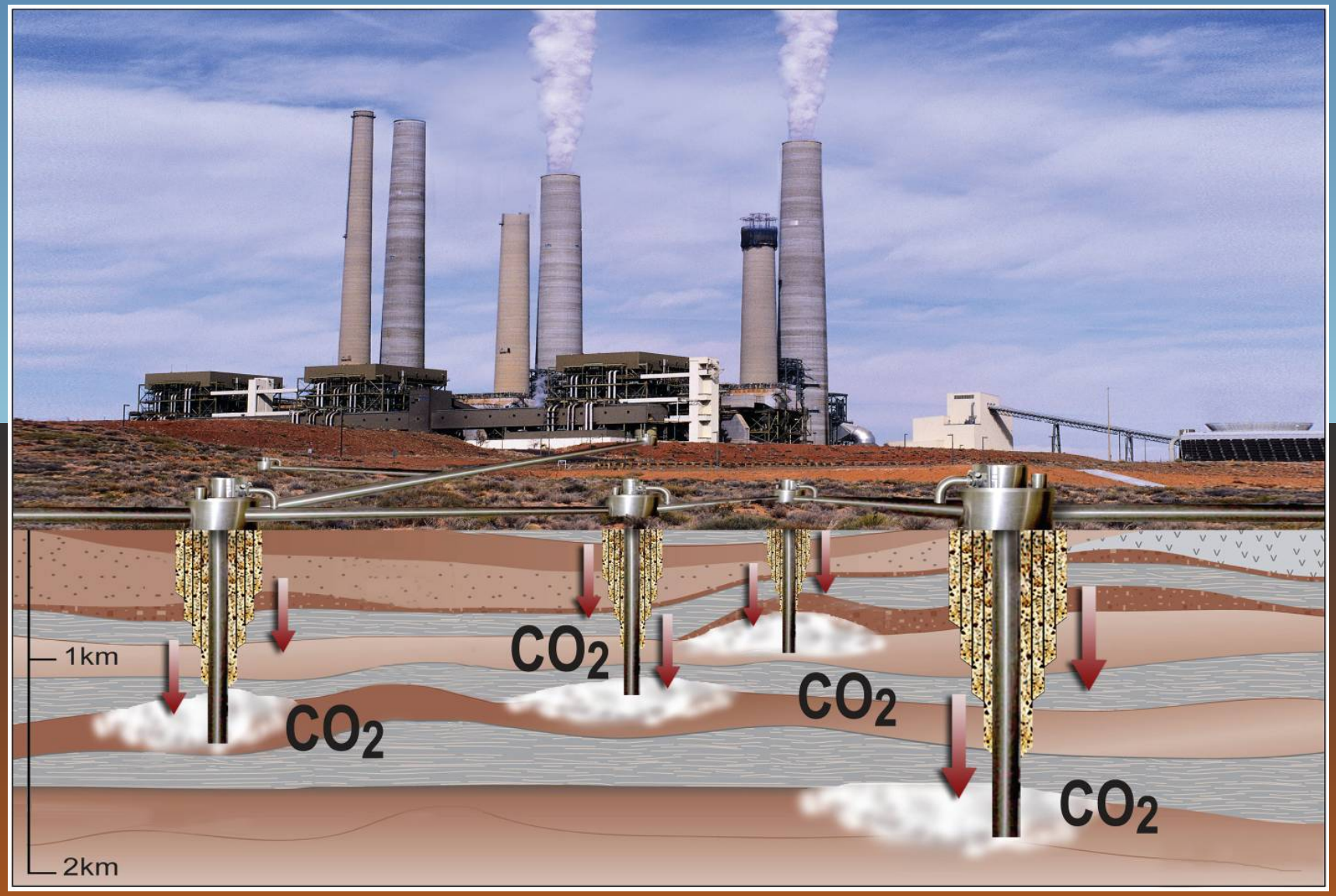
- Less CO_2
- No Soot

- Operate engines at high temperatures and high compression ratios such that:
  - Fuel composition in the plume is transformed to CO, H_2 and short-chain hydrocarbons.
  - Combustion is near-stoichiometric
- Could lead to combustion processes using a variety of transportation fuels with:
  - No soot production
  - High efficiency
  - High energy density





CO_2 Capture and Sequestration Stops Emissions from Power Generation and Industrial Sources



Changing our Energy System is Hard: But, There's Lot's We Can Do

- Concerted action is needed on a number of fronts
  - Energy Conservation
  - Energy Efficiency improvements
  - Fuel switching
  - Low carbon electricity
  - Carbon capture and sequestration
- Let's get started…
- And keep it up… for a long time