Implications for Future Transportation Energy Supply

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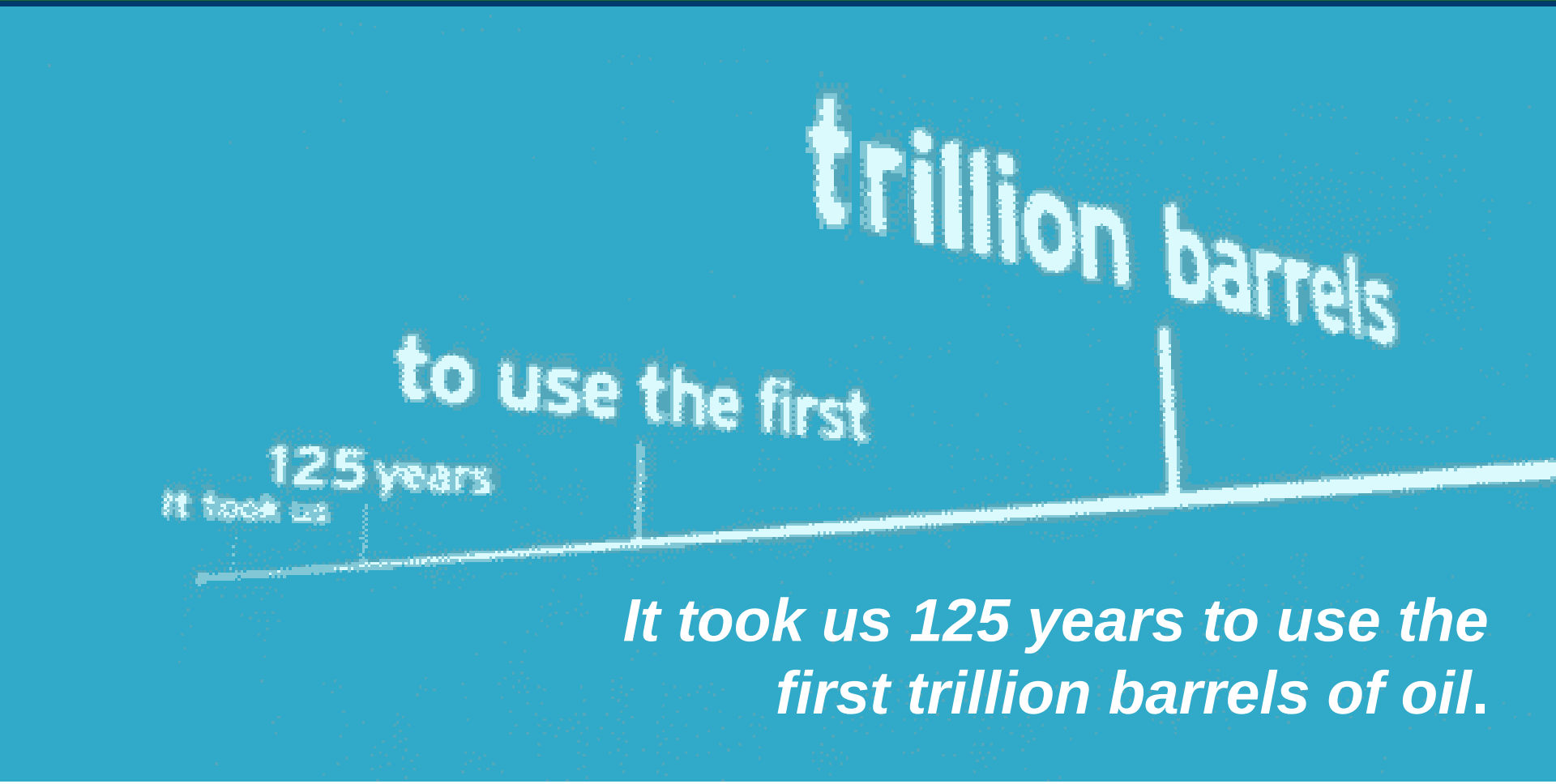
Presented at the
Meeting with ANL Staff
Argonne, IL
August 4, 2005

FCVT Program Mission

To develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum.
--EERE Strategic Plan, October 2002--



It took us 125 years to use the first trillion barrels of oil.

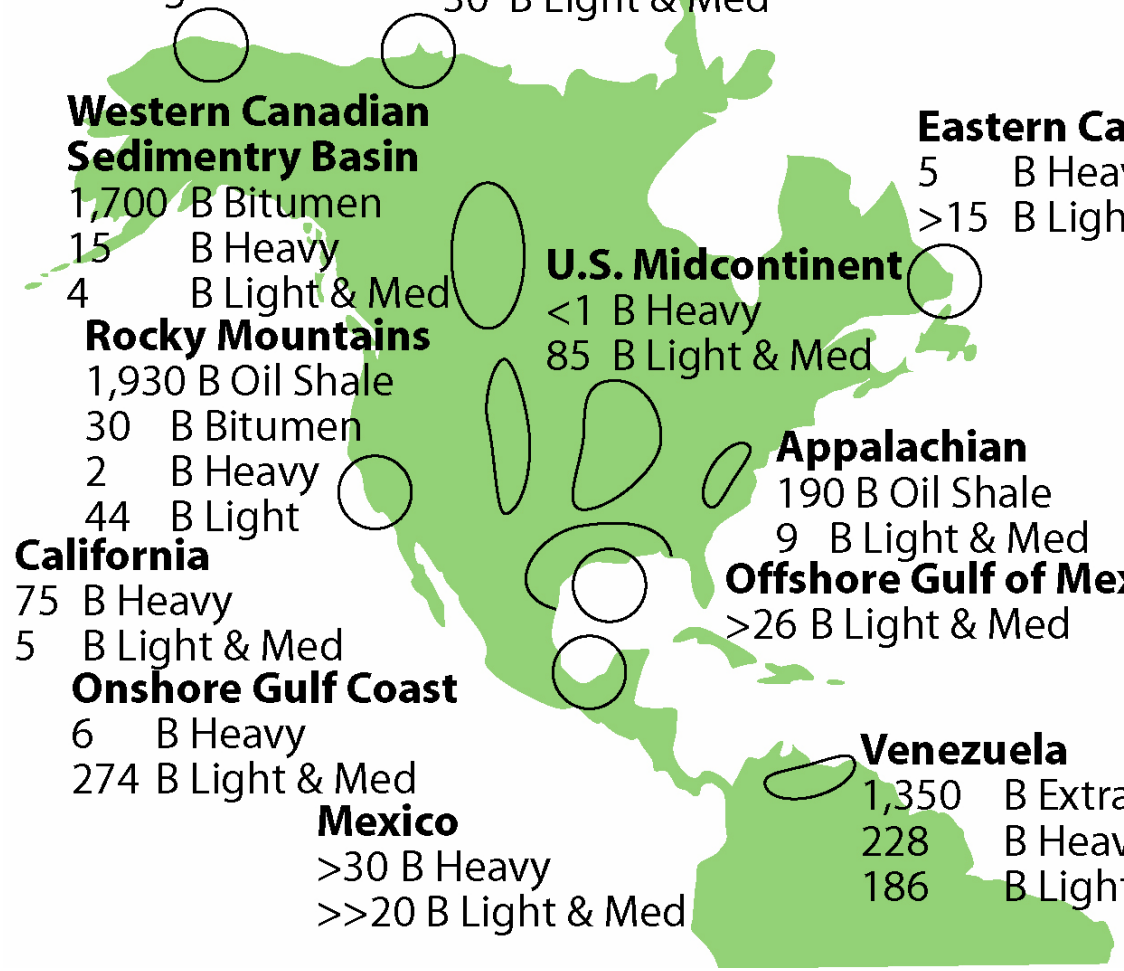
We'll use the next trillion in 30.

Source: www.willyoujoinus.com

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Western Hemisphere Oil Resources

(Billion of Barrels OOIP) Map does not include Ecuador or Columbia Resource



Totals

Canada

80 B Heavy
>49 B Light & Med
1,700 B Bitumen

U.S.A.

<111 B Heavy
>469 B Light & Med
30 B Bitumen
2,120 B Oil Shale

Mexico & Venezuela

>258 B Heavy
>>206 B Light & Med
1,350 B Extra Heavy

Grand Total

449 B Heavy
724 B Light & Med
1,730 B Bitumen
2,120 B Oil Shale
1,350 B Extra Heavy

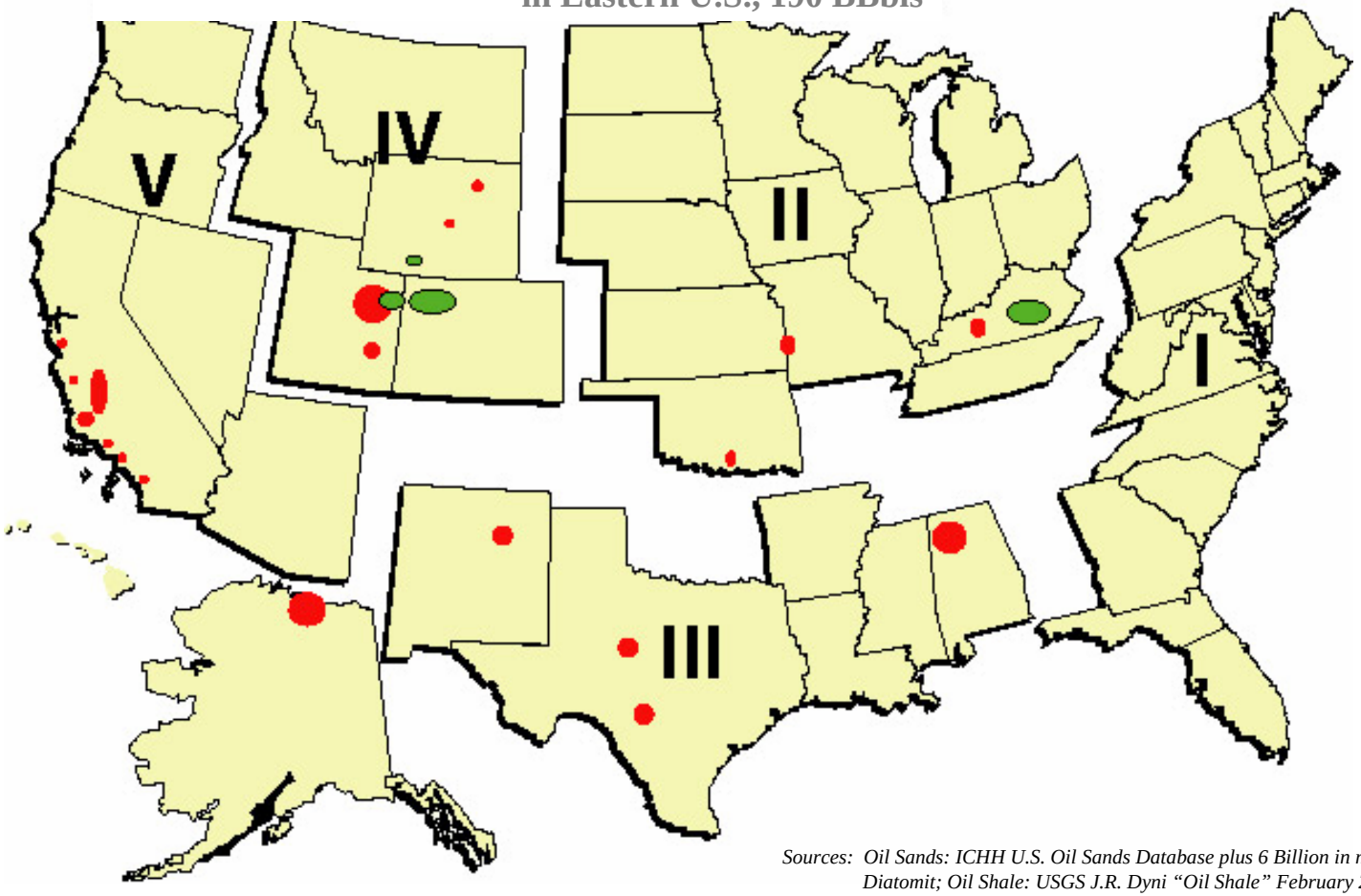
TOTAL ***6,373 B***

Source: ICHH Heavy Oil and Bitumen Database, NPTO Light Oil Database

U.S. Oil Sands and Oil Shale Resource

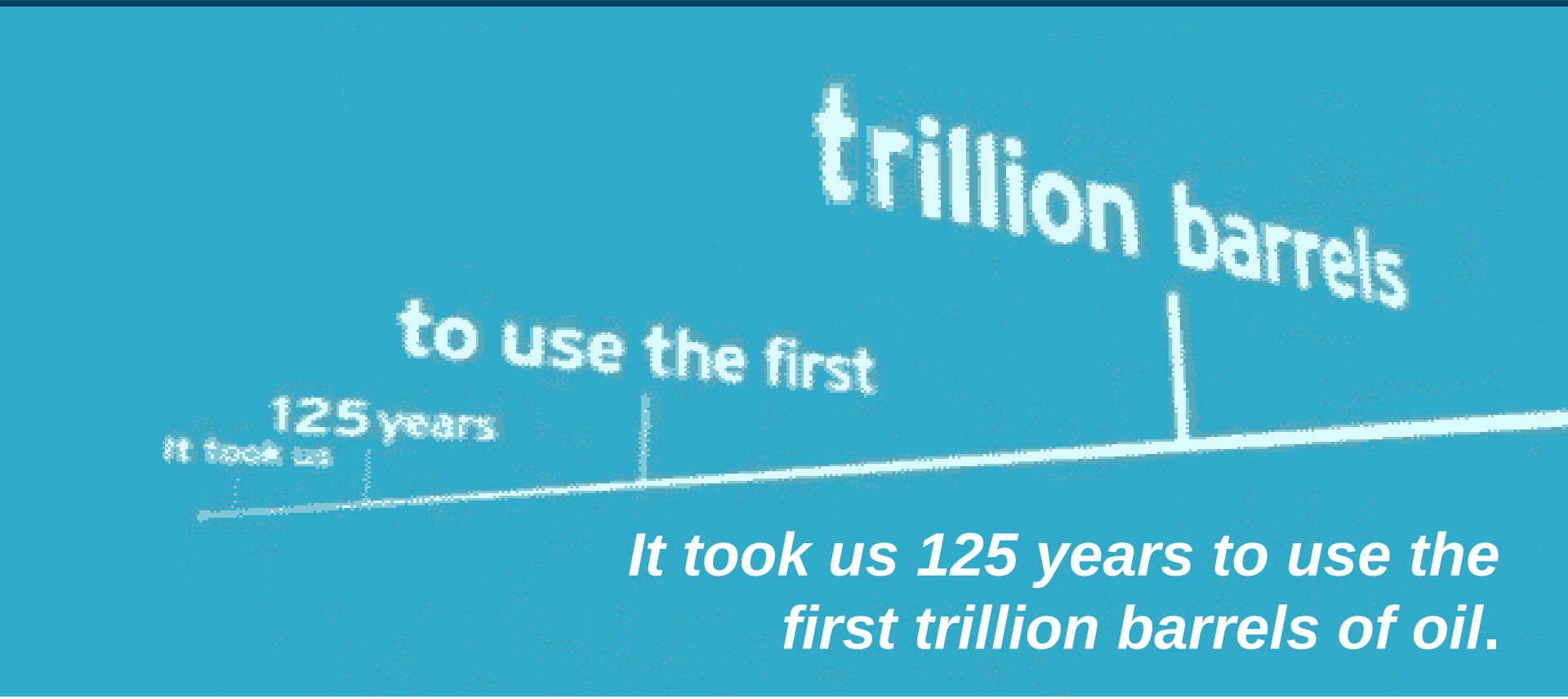
Oil Sands in Lower 48 States, 65 BBbls
In Alaska, 19 BBbls
Oil Shale in Rocky Mountains, 1930 BBbls
in Eastern U.S., 190 BBbls

} 2,204 BBbls



Sources: Oil Sands: ICHH U.S. Oil Sands Database plus 6 Billion in mineable California Diatomit; Oil Shale: USGS J.R. Dyni "Oil Shale" February 2000

Why Should We Care?



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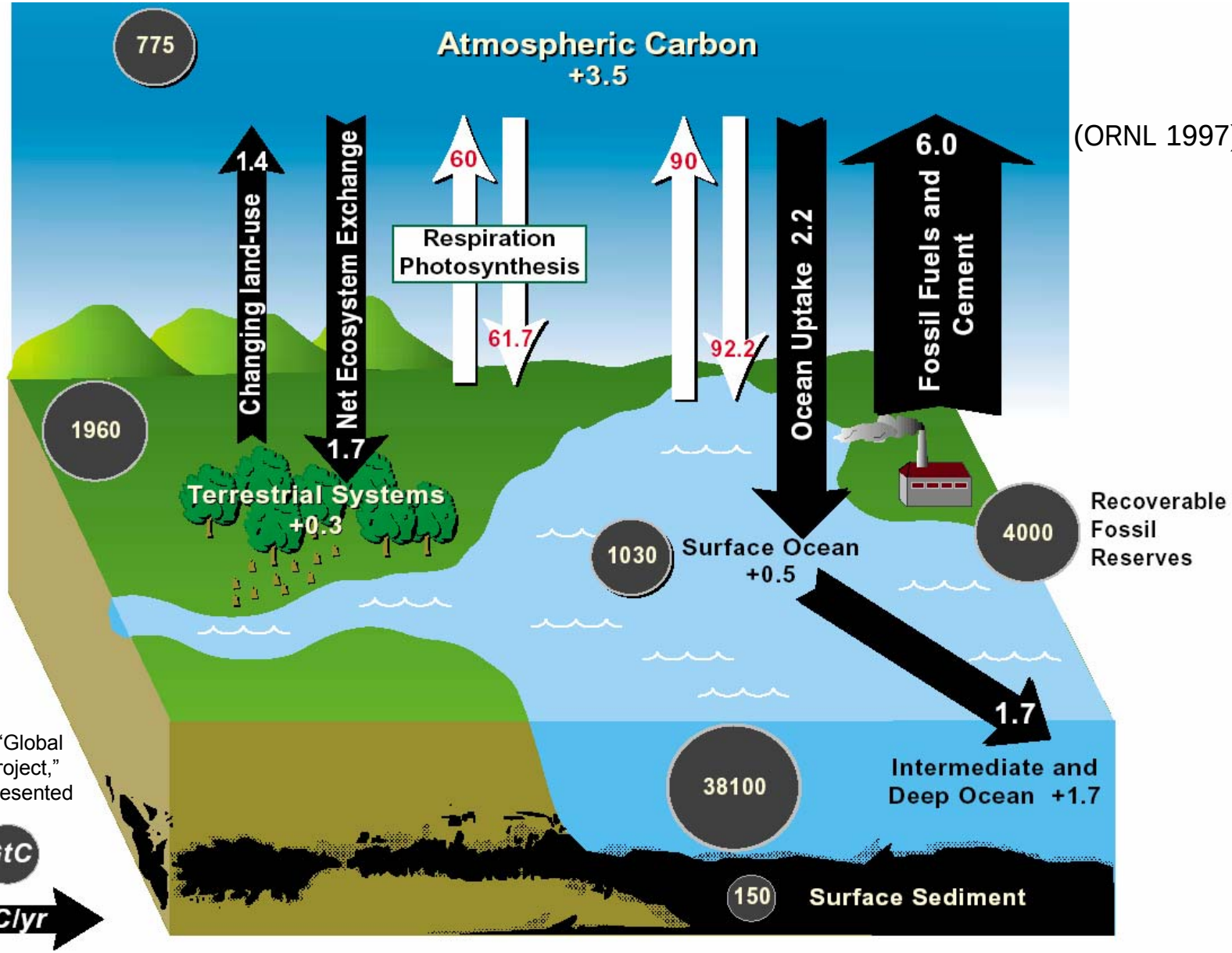
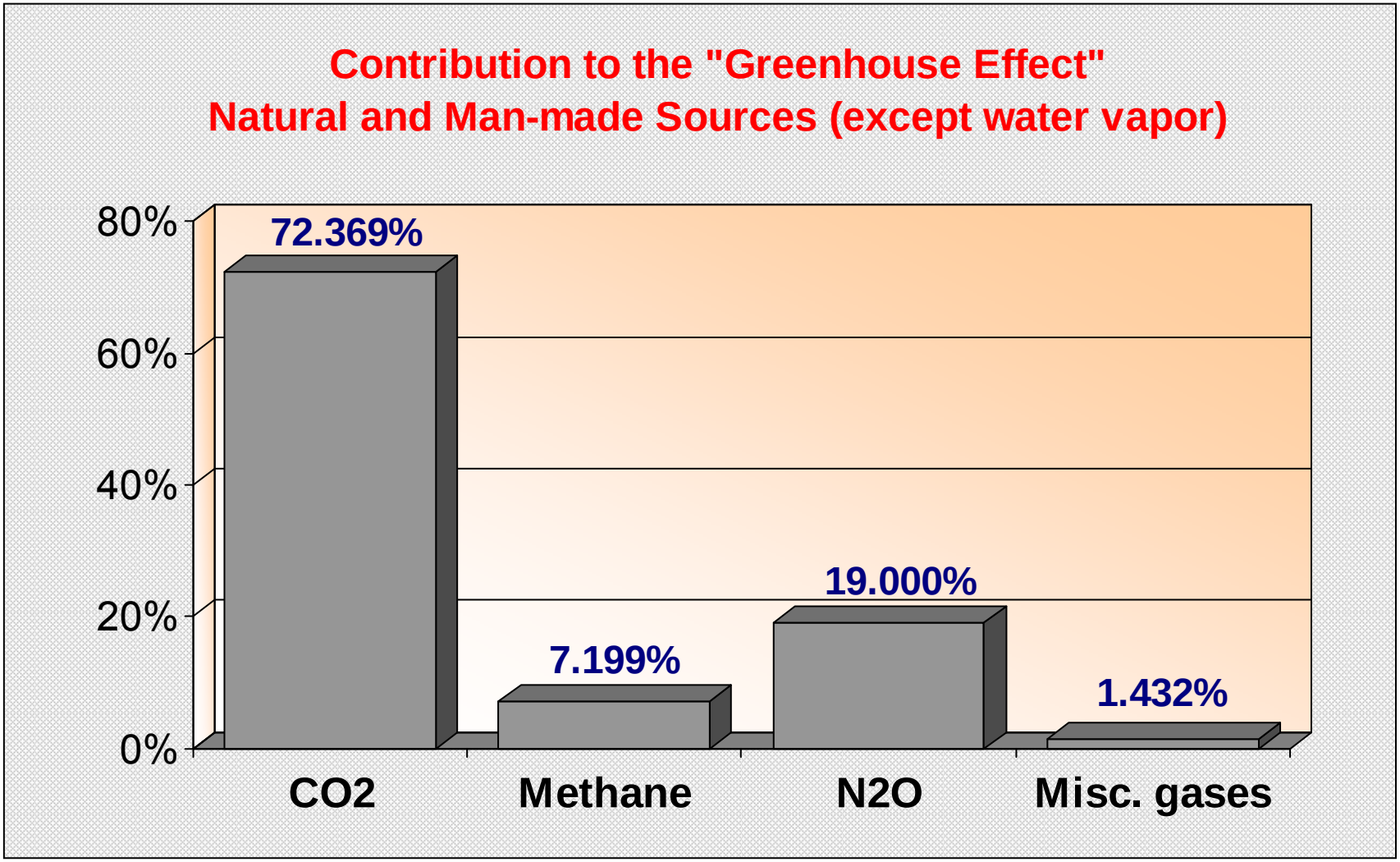
Source: www.willyoujoinus.com;

Cambridge Energy Research Associates
http://www.cera.com.



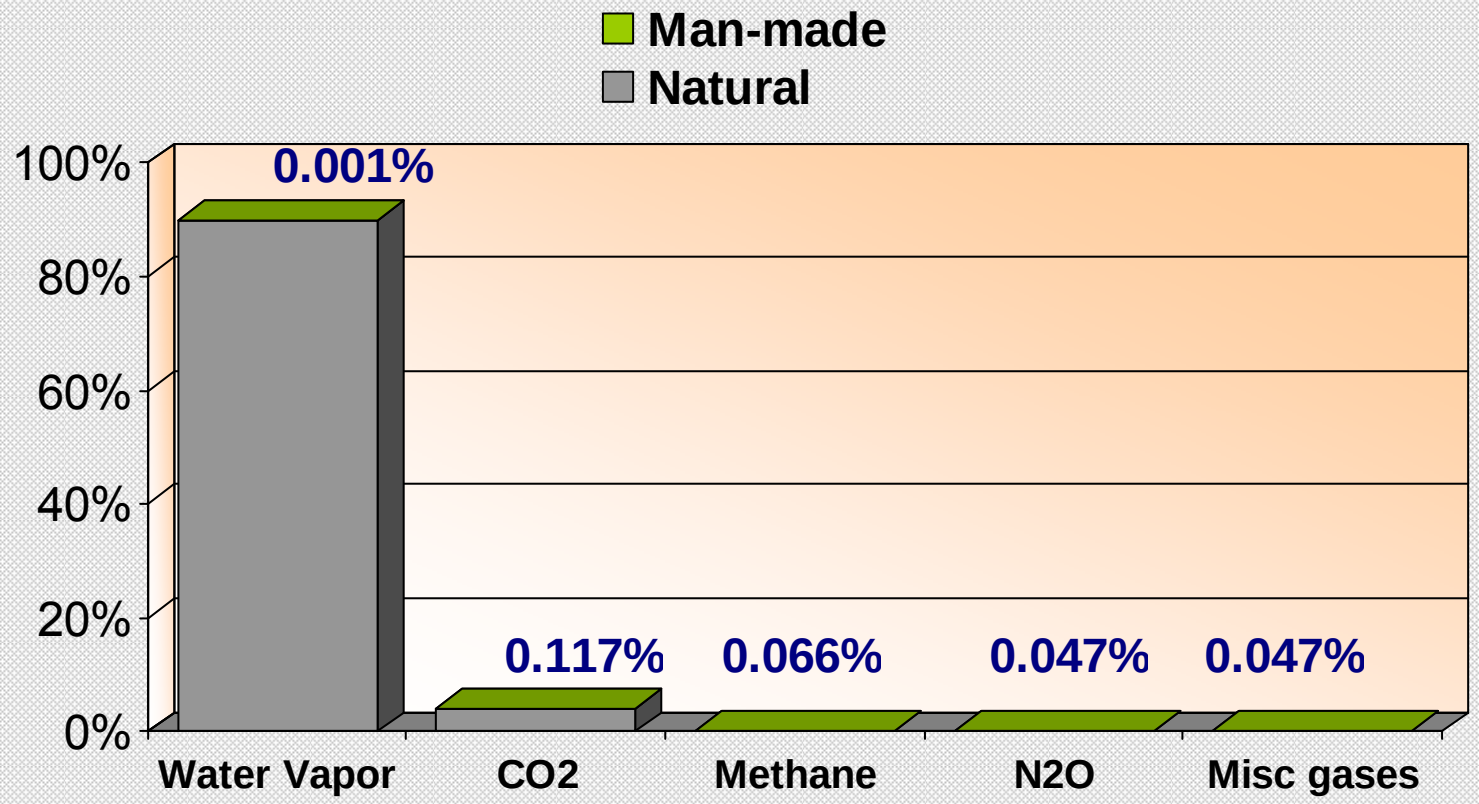
(ORNL 1997)

Source: Edwards, C., "Global Climate and Energy Project," Stanford University, presented at DEER 2003.



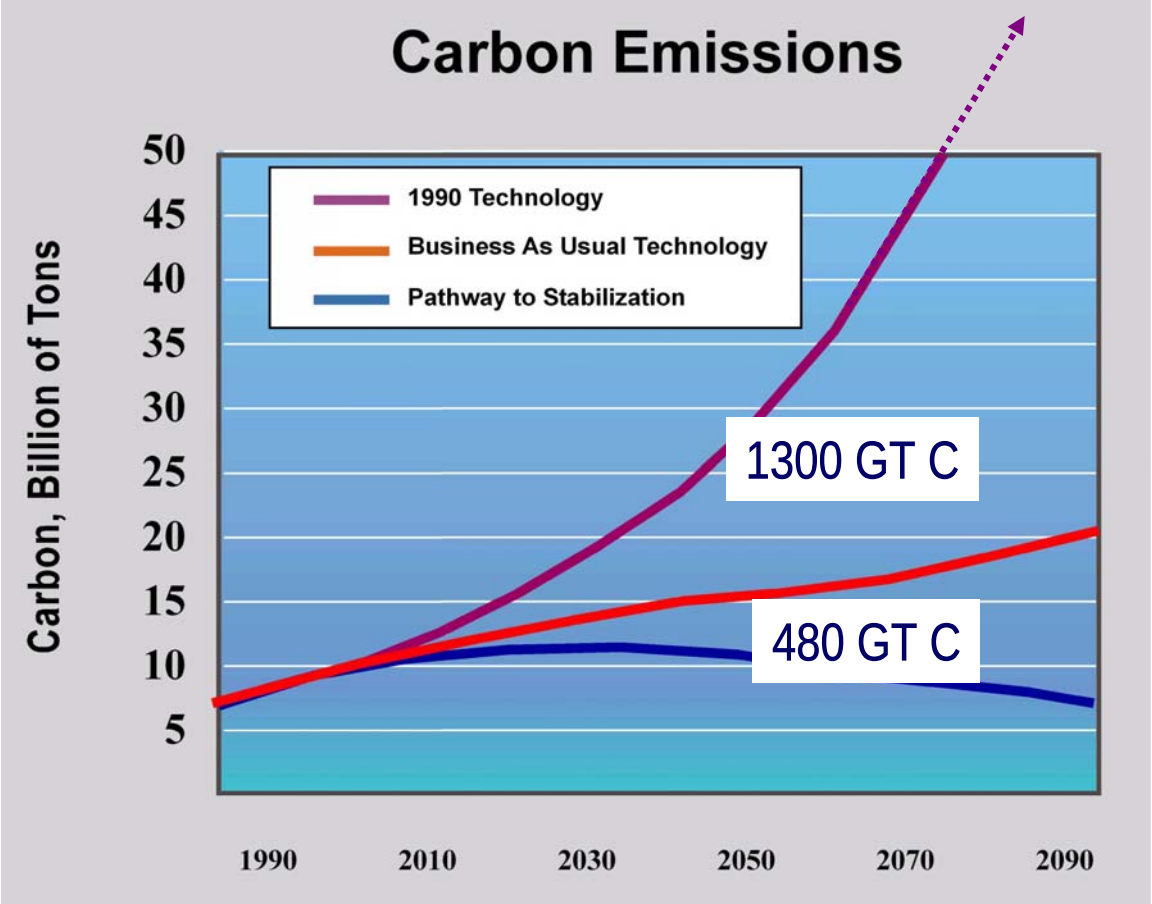
Source: “Global Warming: A Closer Look at the Numbers” (www.clearlight.com/~mhieb/WVFossils/greenhouse_data.html)

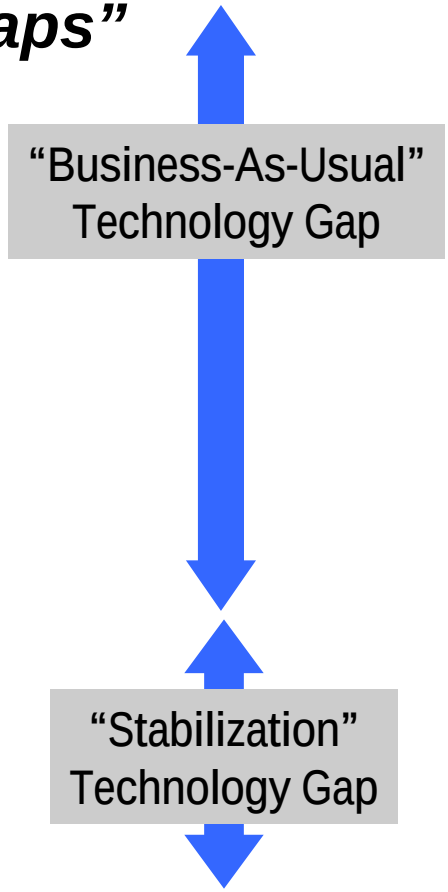
Contribution to the "Greenhouse Effect" (including water vapor)



Source: “Global Warming: A Closer Look at the Numbers” (www.clearlight.com/~mhieb/WVFossils/greenhouse_data.html

Commitment to Stabilization
Requires Closing TWO "Technology Gaps"





Source: Geffen, C., et al., "Climate Change and the Transportation Sector – Challenges and Mitigation Options," Joint Global Change Research Institute, presented at DEER 2003.

What would it take to reduce carbon emissions by a gigaton per year?

Technology	1 Gigaton Carbon / year (1 billion tons C / year)	Major Issues
Coal Plants with Sequestration	700 1GW plants all CO2 sequestered	Economic Viability, Regulatory Approval, Social Acceptance
Geologic Sequestration	3500 Sleipners, at 1 Mt(CO_2)/year[1]	Technical, Social, & Economic Viability
Nuclear	1500 1GW plants	Economic & Social Viability, Proliferation Concerns
Efficiency	2 billion cars at 60 mpg instead of 30 mpg [1]	Point of Diminishing Return is Reached Unless Lifestyle Change
Wind	150 x current[1]	Geographic Limitations, Storage
Solar PV	2000 x current[1]	Geographic Limitations, Storage
Biomass fuels from plantations	200×10^6 ha[1]	Land-Use Changes and Biotech Concerns
Storage in new forest	500×10^6 ha[1]	Land-Use Changes

Roughly seven times the fossil fired capacity built in the USA since 1980

More than three times number of nuclear power plants currently on the planet

Three times the number of cars that currently exist on the planet

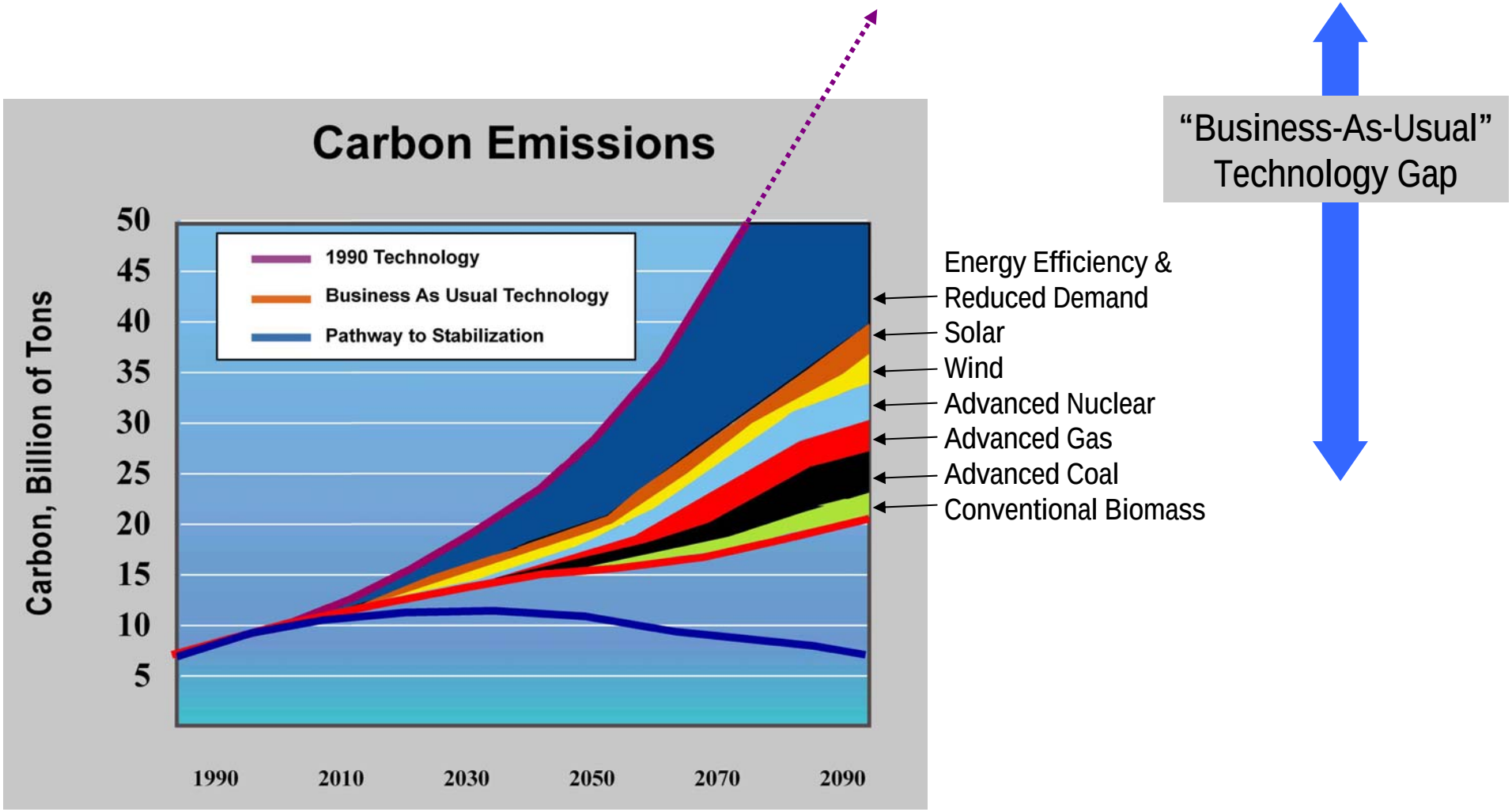
Nearly six times the acreages devoted to corn production in entire USA

Source: Geffen, C., et al., "Climate Change and the Transportation Sector – Challenges and Mitigation Options," Joint Global Change Research Institute, presented at DEER 2003.

[1]Estimates from Princeton University (Socolow 2002)

Business-As-Usual Gap

Extraordinary Improvement is Built in



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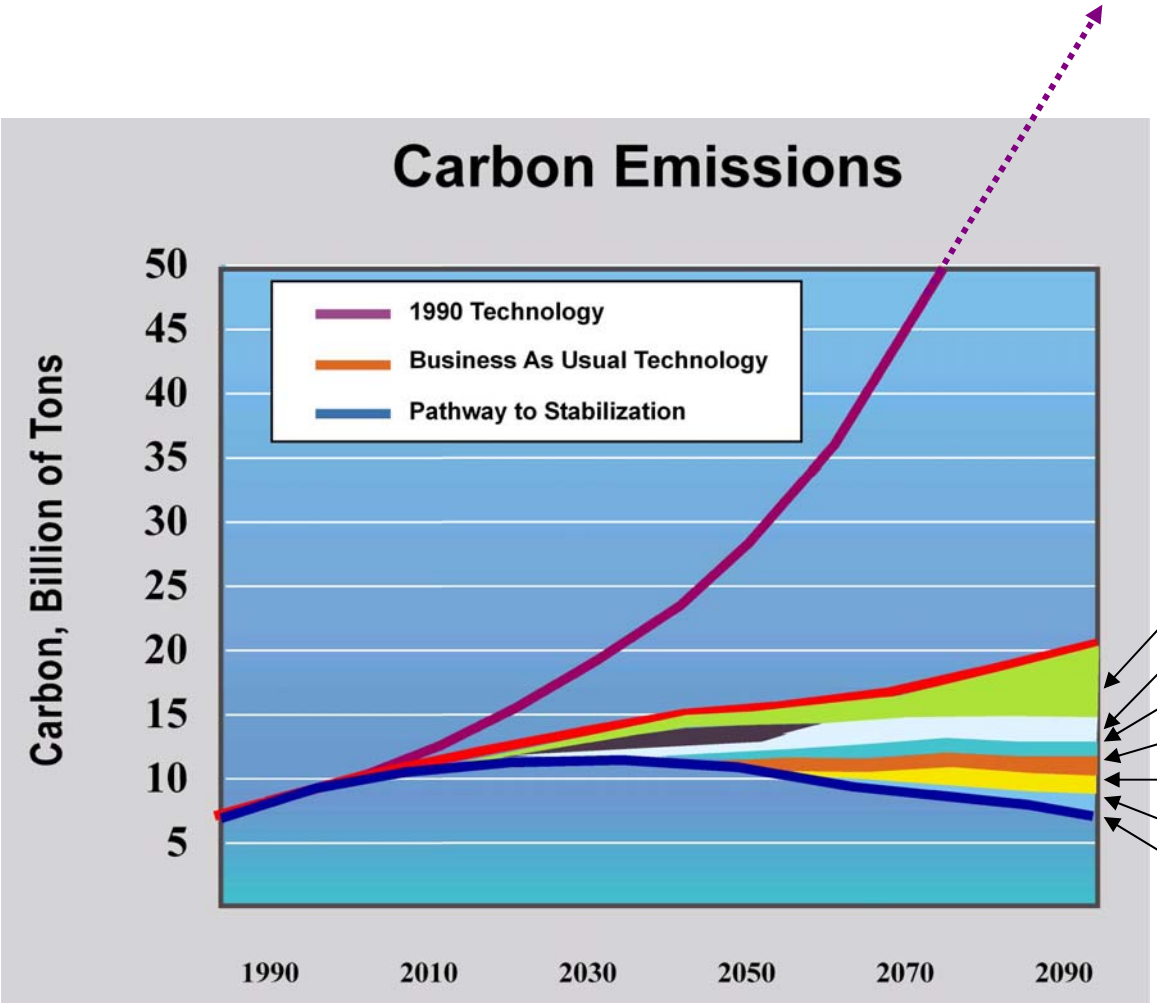
Stabilization Gap



Tremendous Additional Technological Advance Are Required

Advanced Biomass
Soil Sequestration
H2 w/Sequestration
Fossil Power w/Seq.
Addt'l Solar/Wind
Addt'l Nuclear
Addt'l Efficiency & Reduced Demand

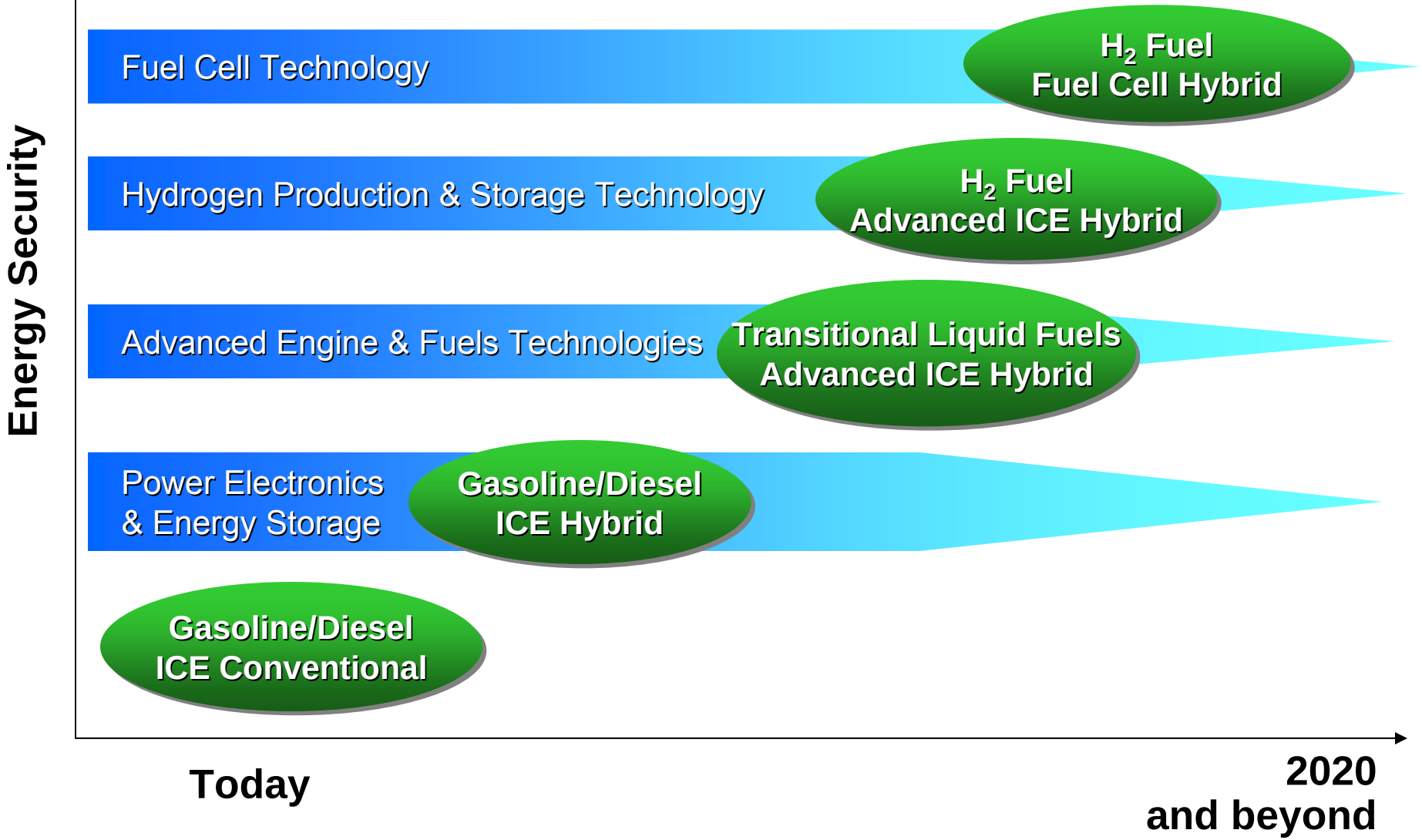
"Stabilization" Technology Gap

Note: Conceptual Market Penetrations

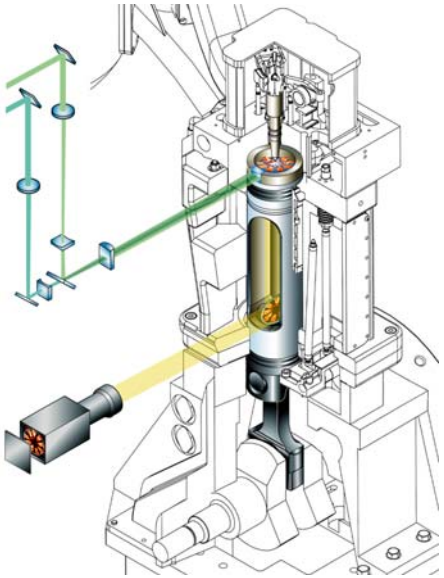
Source: Geffen, C., et al., "Climate Change and the Transportation Sector – Challenges and Mitigation Options," Joint Global Change Research Institute, presented at DEER 2003.

Strategic Approach to Transportation Energy Security

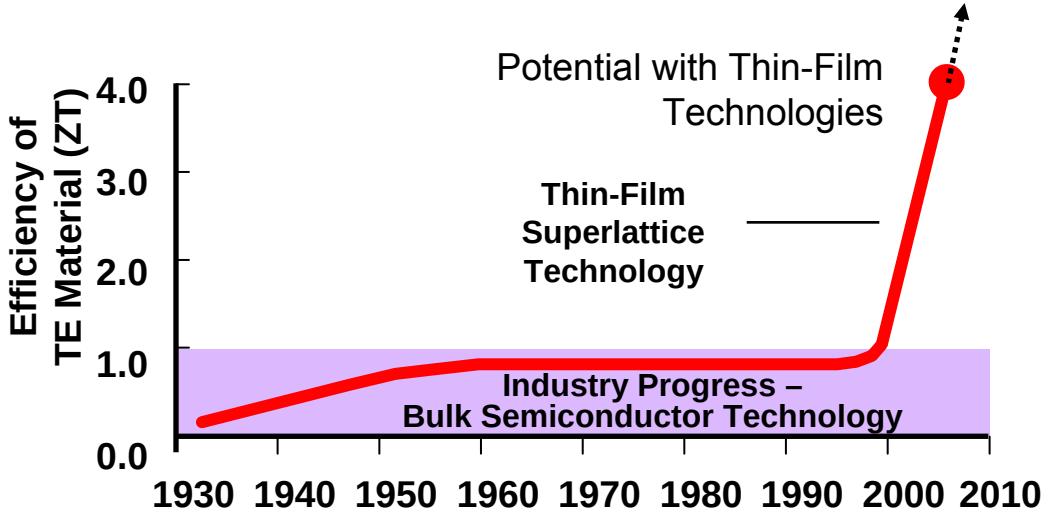
- ***Research Will Make Technology Available***



Emerging Areas



- Advanced Combustion Regimes
- Fuels/Fuel Blends



- Waste Heat Recovery

Vehicle Thermoelectric Technologies

Near Term (3-5 yrs)

- Thermoelectric Generator providing 10% fuel economy gain
- "Beltless" or more electric engine
- Integrated Motor/Alternator/Starter

Mid Term (5-8 yrs)

- 5 Thermoelectric Generators mated diesel engine ΔT's
  - 60% efficient heavy duty truck engine
  - 55% efficient light truck (SUV's, Pick-ups, Mini-vans), auto
- Thermoelectric air conditioner/heater for vehicles
- Aluminum/Magnesium frame & body replacing steel (Process waste heat recovery)

Long Term (8-15 yrs)

- 35% efficient Thermoelectrics with 500°C ΔT
  - Replace Internal Combustion Engine
  - Combustor burns any fuel

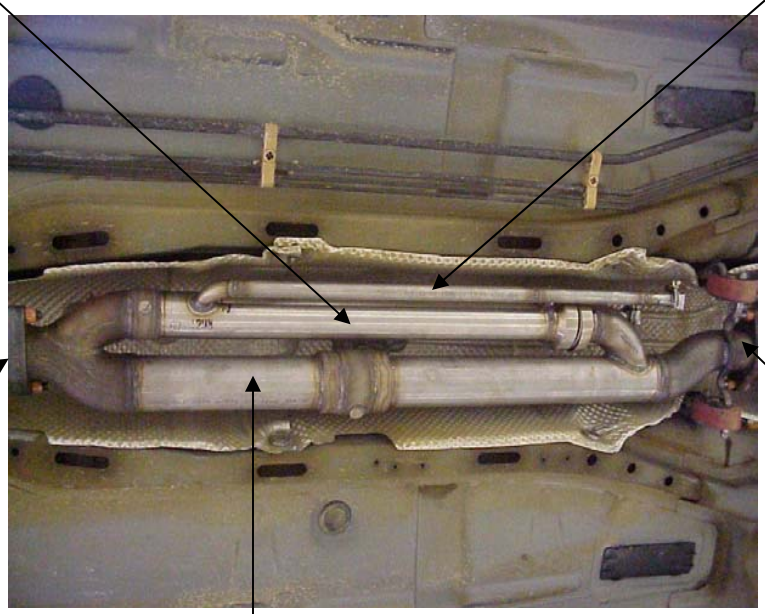
Very Long Term (25 + yrs)

- Radioisotope replaces combustor for vehicle propulsion
  - 30+ years life powertrain
  - Replace vehicle body periodically

Heat Transfer Science Is A Key Enabler For Thermoelectrics

Shell & tube heat exchanger for exhaust gas heat transfer

He/Xe working fluid transports thermal energy to TGM



Catalytic converter

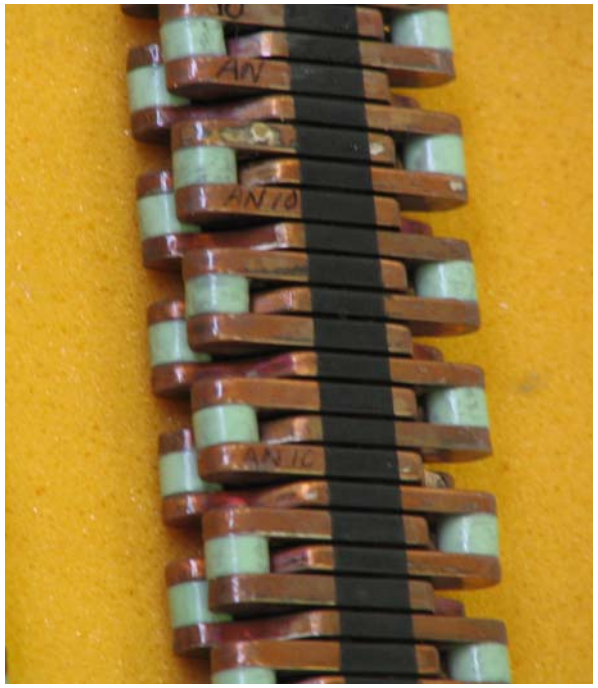
Muffler

Exhaust gas bypass flow

BSST early generation liquid to liquid high density heat exchanger design

- High power density liquid to liquid heat exchanger
- Modeled performance validated through testing

BSST TE Heating and Cooling Devices



Single “stack” device

Multiple pre-production single “stacks” which have been incorporated into a full-scale heating and cooling device

Implications for Future Transportation Energy Supply

Summary

- The world will consume energy over the next 30 years at a faster rate than it has for the previous 125 years.
- Natural and anthropogenic carbon emissions are being and will continue to be generated at a faster rate than the natural sequestration of carbon.
- Thermoelectrics can potentially contribute to reducing transportation energy use and associated carbon emissions via economic capture of waste heat.
- Thermal science is a key enabler for thermoelectrics.
- Argonne National Laboratory has a history of leadership in thermal sciences and heat transfer technology.