Global Climate Change and the Unique (?) Challenges Posed by the Transportation Sector

8th Diesel Engine Emissions Reduction Conference

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Outline

- A primer on the “stabilization” of GHG concentrations
- Thoughts on decarbonizing the transportation sector
- Concluding Thoughts

Climate change, what's the ultimate goal?

The United Nations Framework Convention on Climate Change has as its ultimate objective ...

The ultimate objective of this [The Framework] Convention…is…the…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Article 2 (UNFCCC, 1992)

Three Key Elements:

Stabilizing concentrations not emission levels

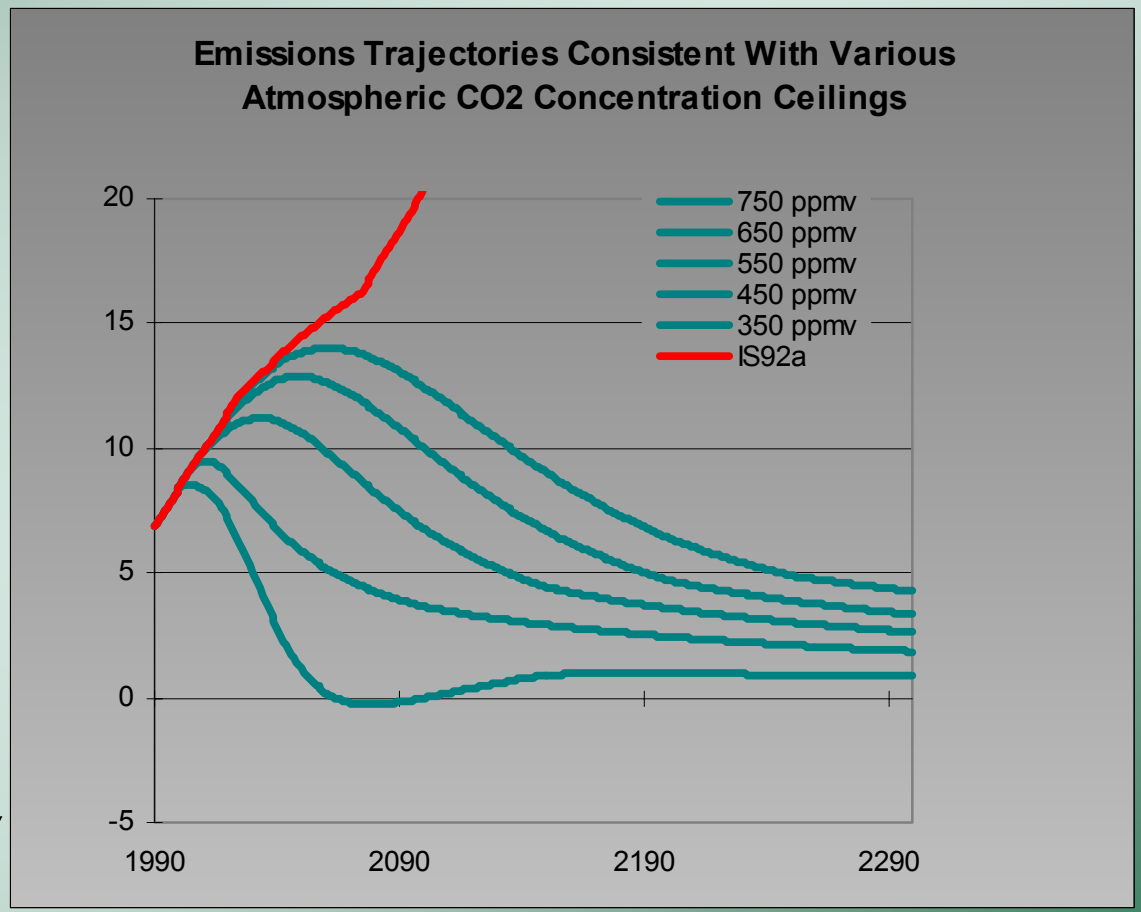
Prevent danger at some unspecified level

Allow economic development to proceed

The Challenge…

Inherent in Stabilizing Concentrations

Stabilization Target	21st Century Global CO2 "Budget"
325 ppmv	0 GtC
450 ppmv	714 GtC
550 ppmv	1043 GtC
650 ppmv	1249 GtC



The Challenge is to manage this "carbon budget" wisely.

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The Challenge …

How to Craft Technology and Policy in Three Different Time Frames

- **Near Term**— *Could be as little as 10 years or up to 30 years*
- **The Middle Term**—*20 to 60 Years*
- **The Long Term**—*50 to 150 Years*

Learn, learn, learn about possible solutions.

AND

Slow global growth in emissions.

The Challenge …

How to Craft Technology and Policy in Three Different Time Frames

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Transformation of global energy system must be well underway.

Infrastructure and technology systems must be deployed on a massive scale

Global emissions must have already peaked.

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The Challenge …

How to Craft Technology and Policy in Three Different Time Frames

- **Near Term**— *Could be as little as 10 years or up to 30 years*
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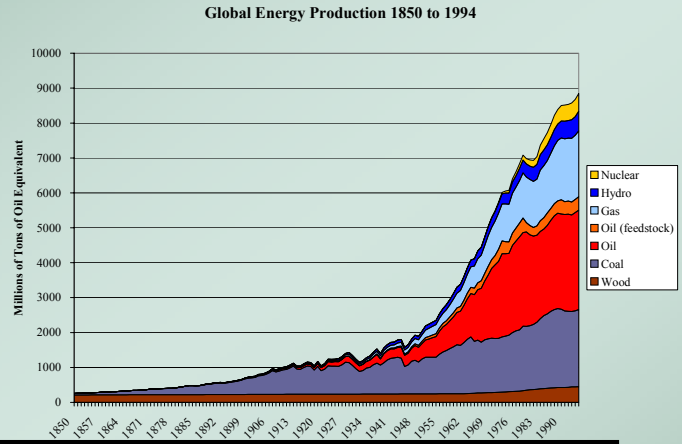
Emissions on path to zero.

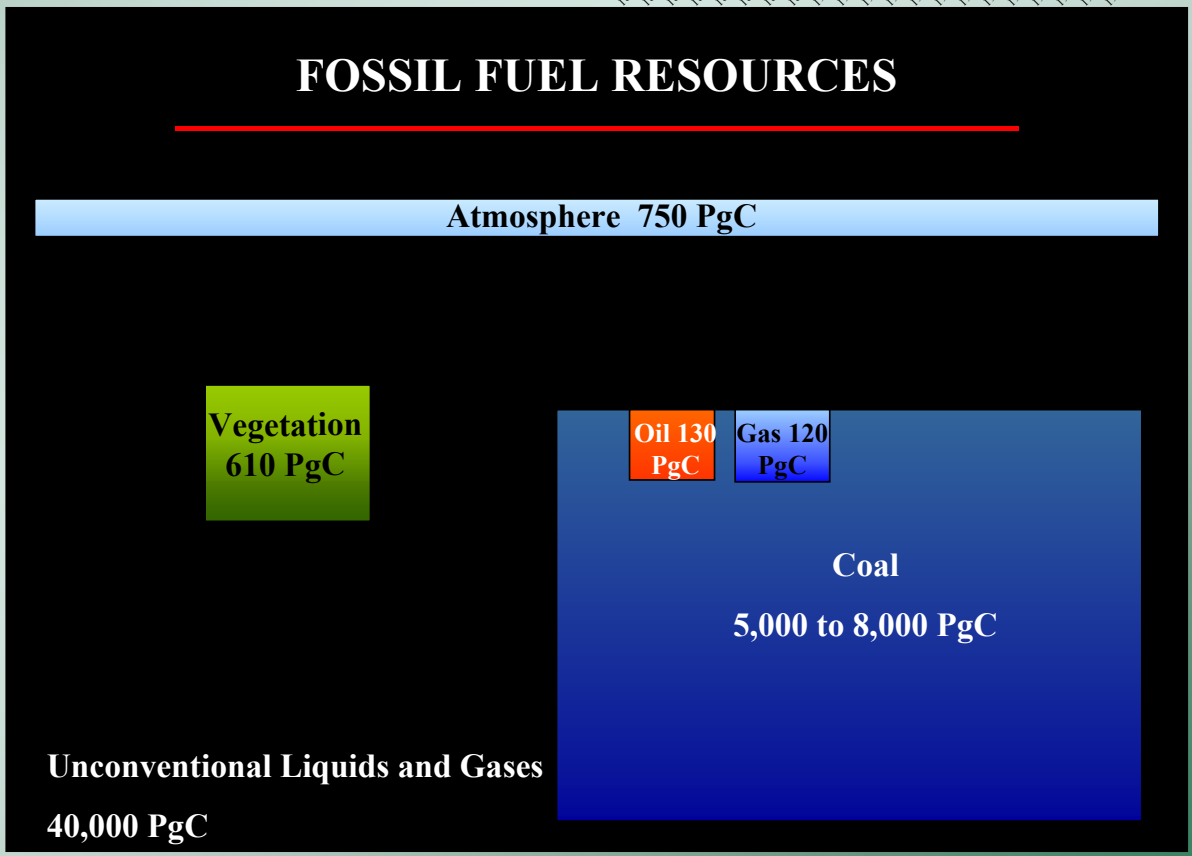
Only four energy end-uses allowed:
- electricity
- hydrogen
- thermal
- carbonaceous fuels with an immediate offset.

The Problem

Stabilization Requires Fundamental Change in The Energy System



Because fossil fuels are abundant and inexpensive, there are plenty of fossil fuels to allow for a doubling or tripling of pre-Industrial CO_2 concentrations.



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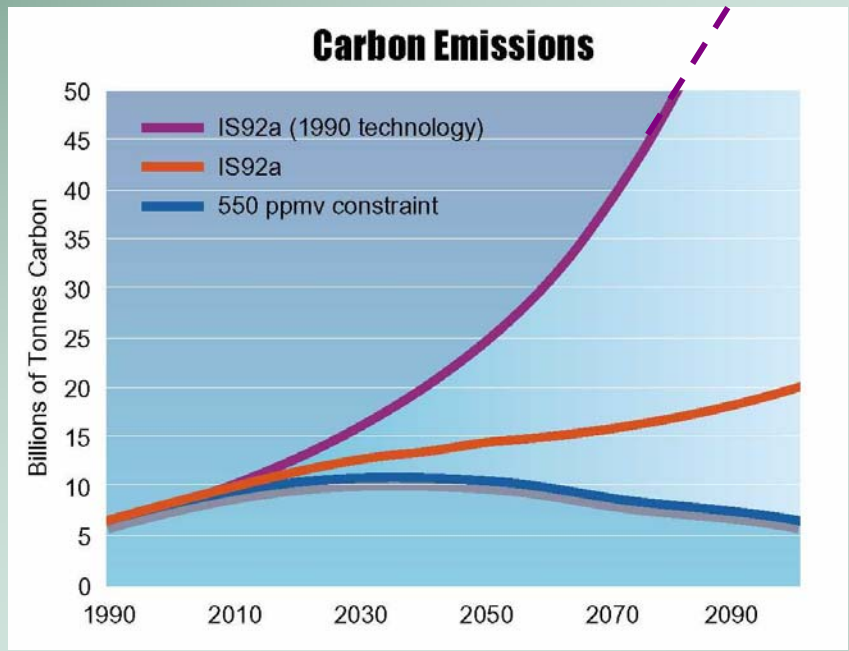
The Problem

Population and economic growth will generate increased demands for energy services.



Where today's technology will take us (~2000 GT over budget)

Solar
Nuclear
Efficient Fossil Electric
Advanced Transportation
End Use Efficiency
Conventional Biomass

Where more advanced versions of current technologies will take us (~500 GT over budget)

Path we need to be on to stabilize carbon at 550ppm
(Carbon Budget = ~1043 Gigatons)

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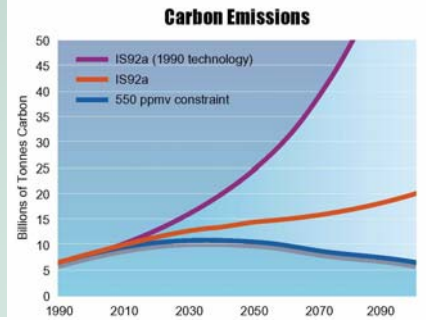
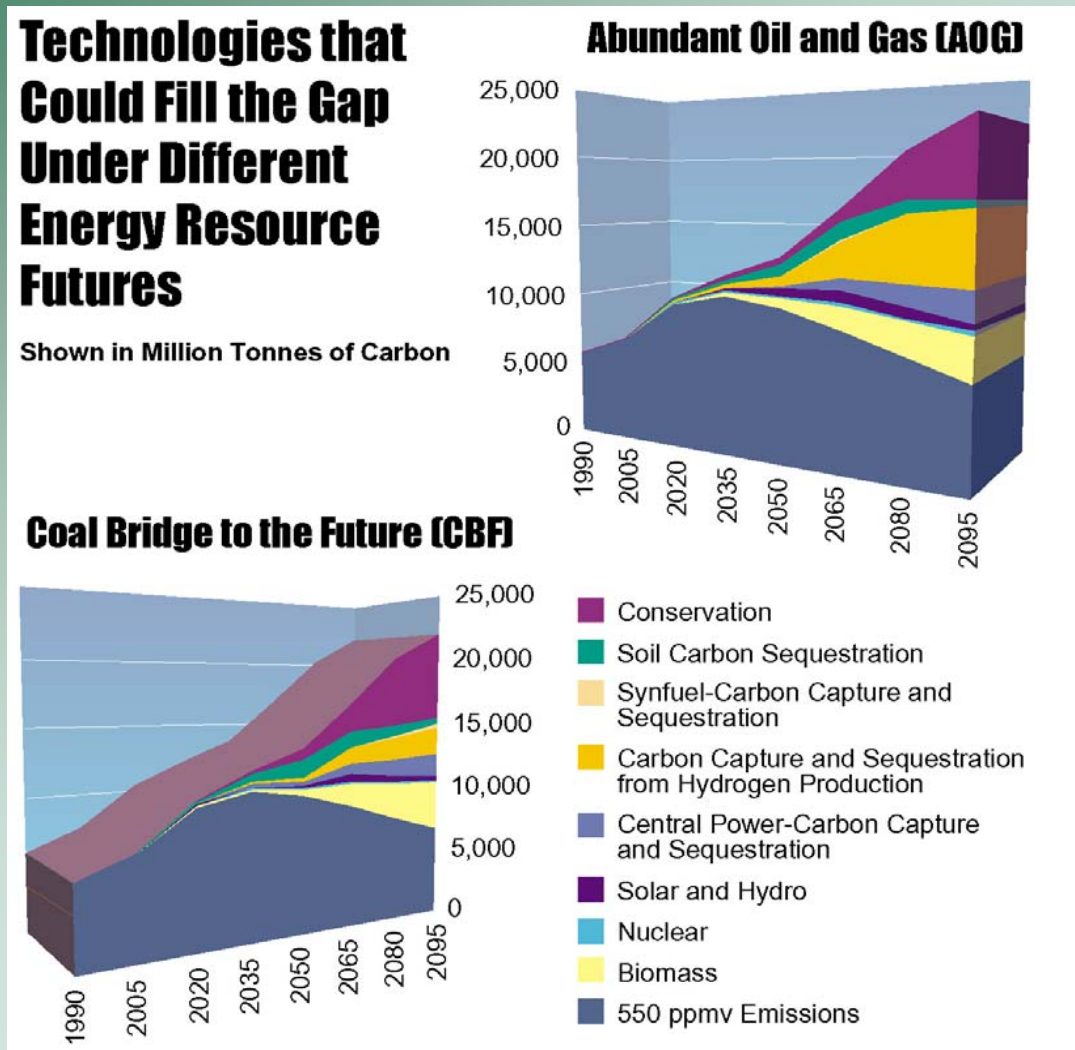
The Solution: Close the Gap (s)

Getting from "business as usual" to stabilization at 550 ppm





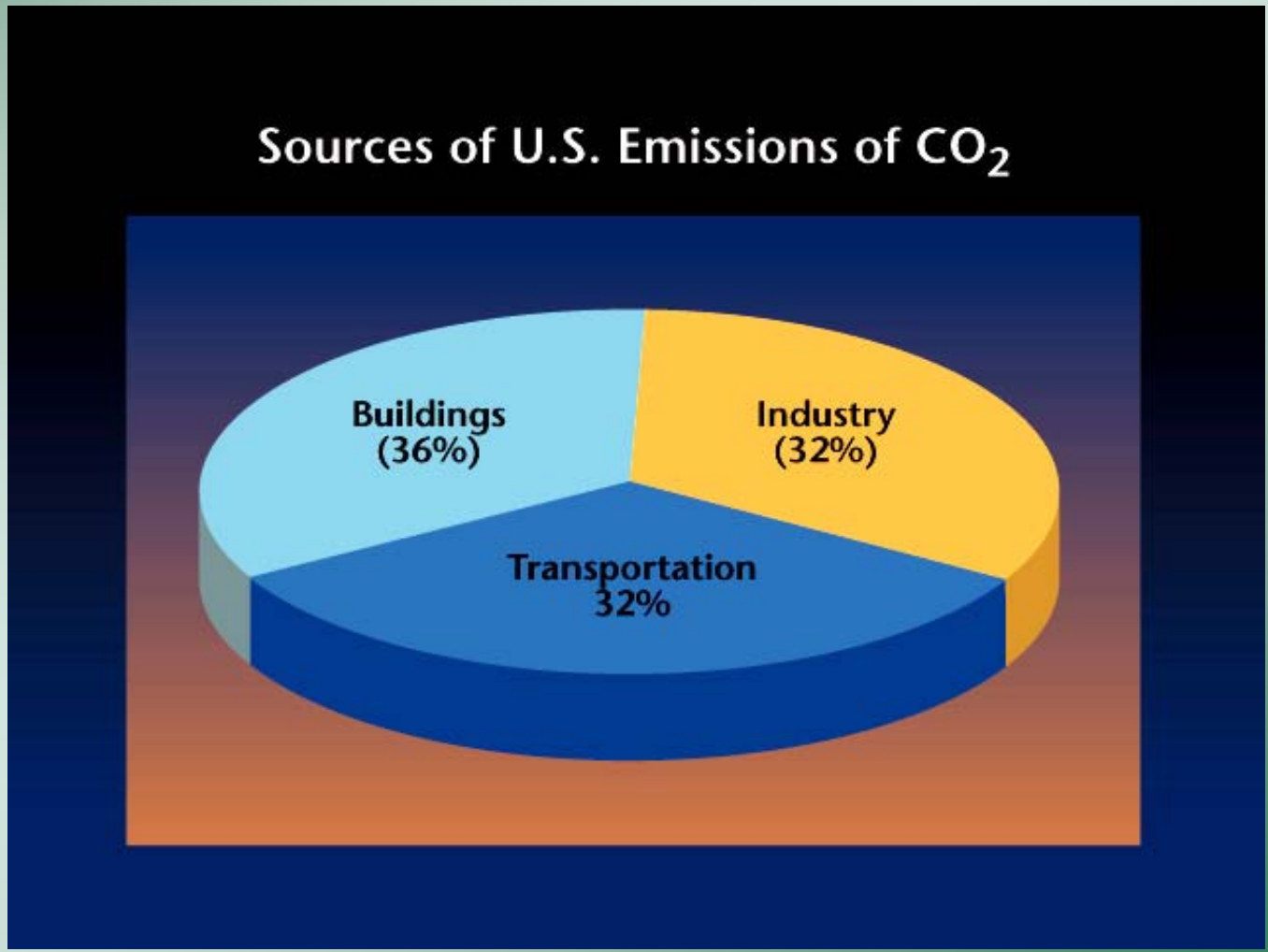
Technologies that could make a big difference in closing the gap are not significant aspects of the current global energy system:

1. **Carbon Capture—*at any point in the energy system***
2. **Geologic Sequestration**
3. **Hydrogen Systems—*production, transportation & distribution***
4. **Energy Storage Systems**
5. **Commercial Biomass Energy**

Key Points from the Climate Primer

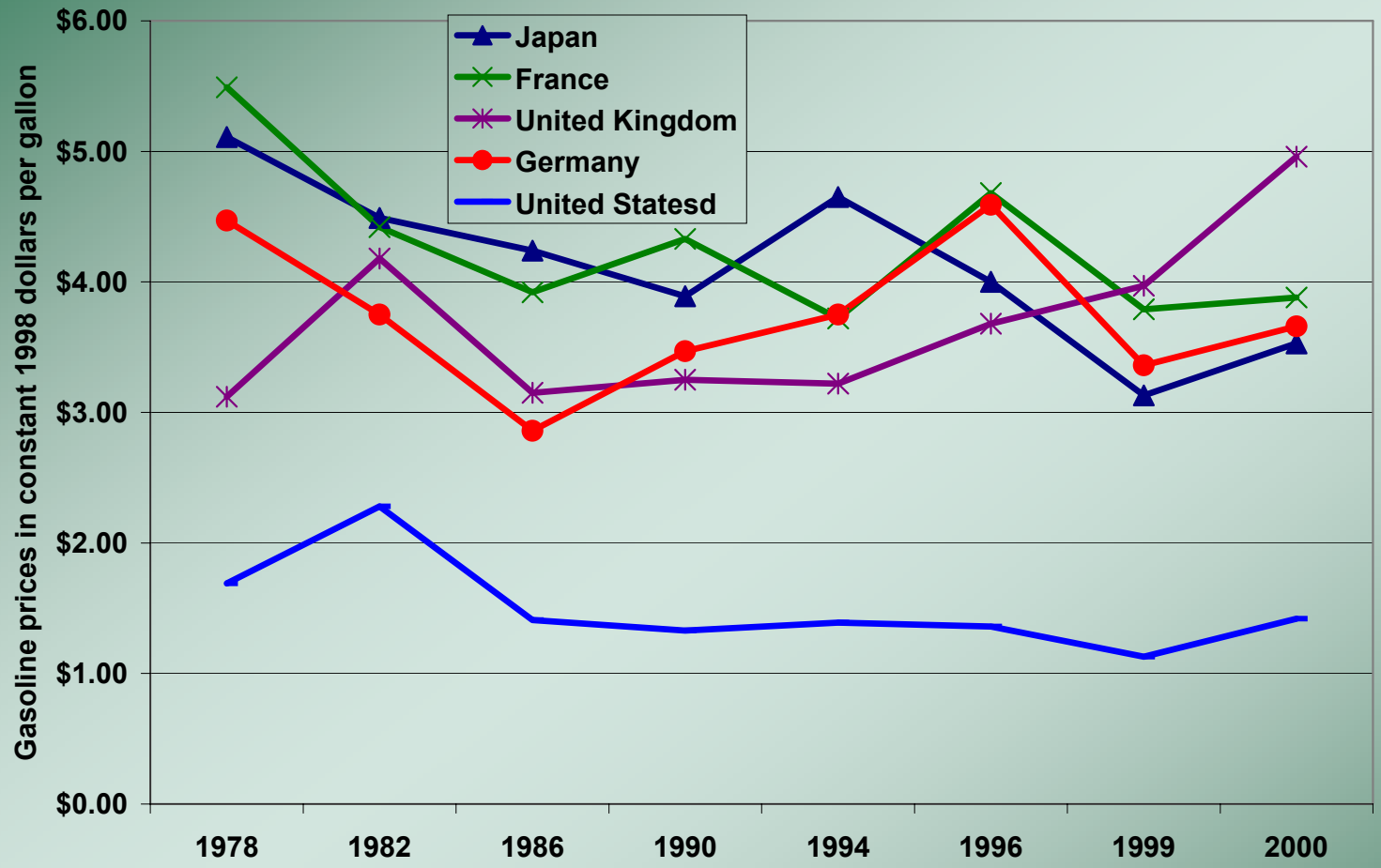
- As far as the atmosphere is concerned, everyone on the planet shares the same carbon budget over the course of this century.
- It is unlikely that we will "run out of fossil fuels" and therefore it is unlikely that the challenged posed by climate change will resolve itself.
- Addressing climate change must be compatible with continued economic growth and prosperity; i.e., we cannot do this "at any cost."
- Advanced technology then is an extremely large part of the solution set (i.e., all of the "easy stuff" is already spoken for in the "business as usual" reference case).

The Transportation Sector
A Large (but often overlooked) Component of CO_2 Emissions



The Transportation Sector

Carbon Taxes Are Likely to Have a Modest Impact on the Transportation Sector's Absolute GHG Emissions



Sustained gasoline price differential of $1.50 to $3.50 per gallon.

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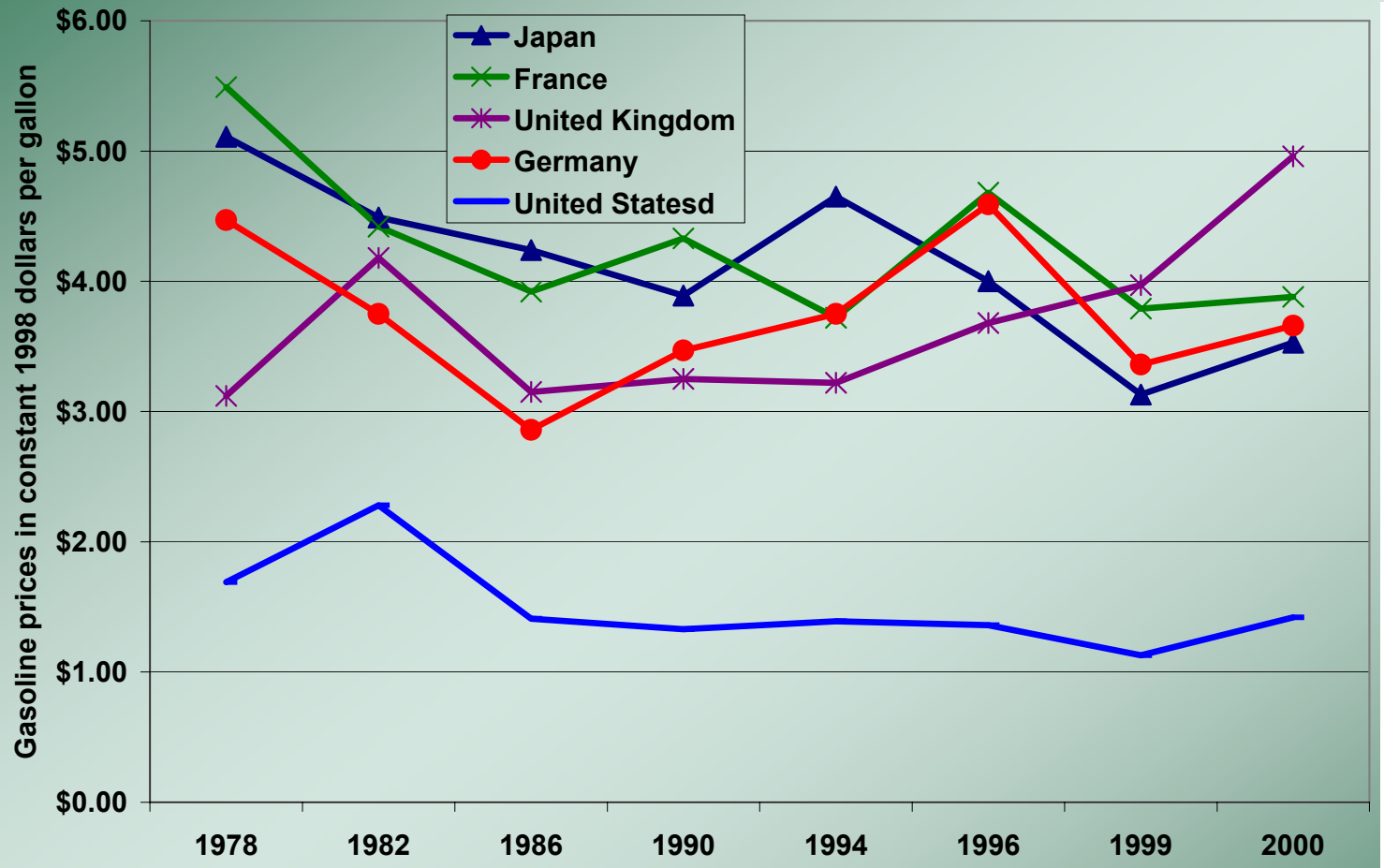

That's the equivalent of a sustained carbon tax differential of $600 to $1400 ton C.

A carbon tax at that level would drive fundamental change in the electric utility sector.

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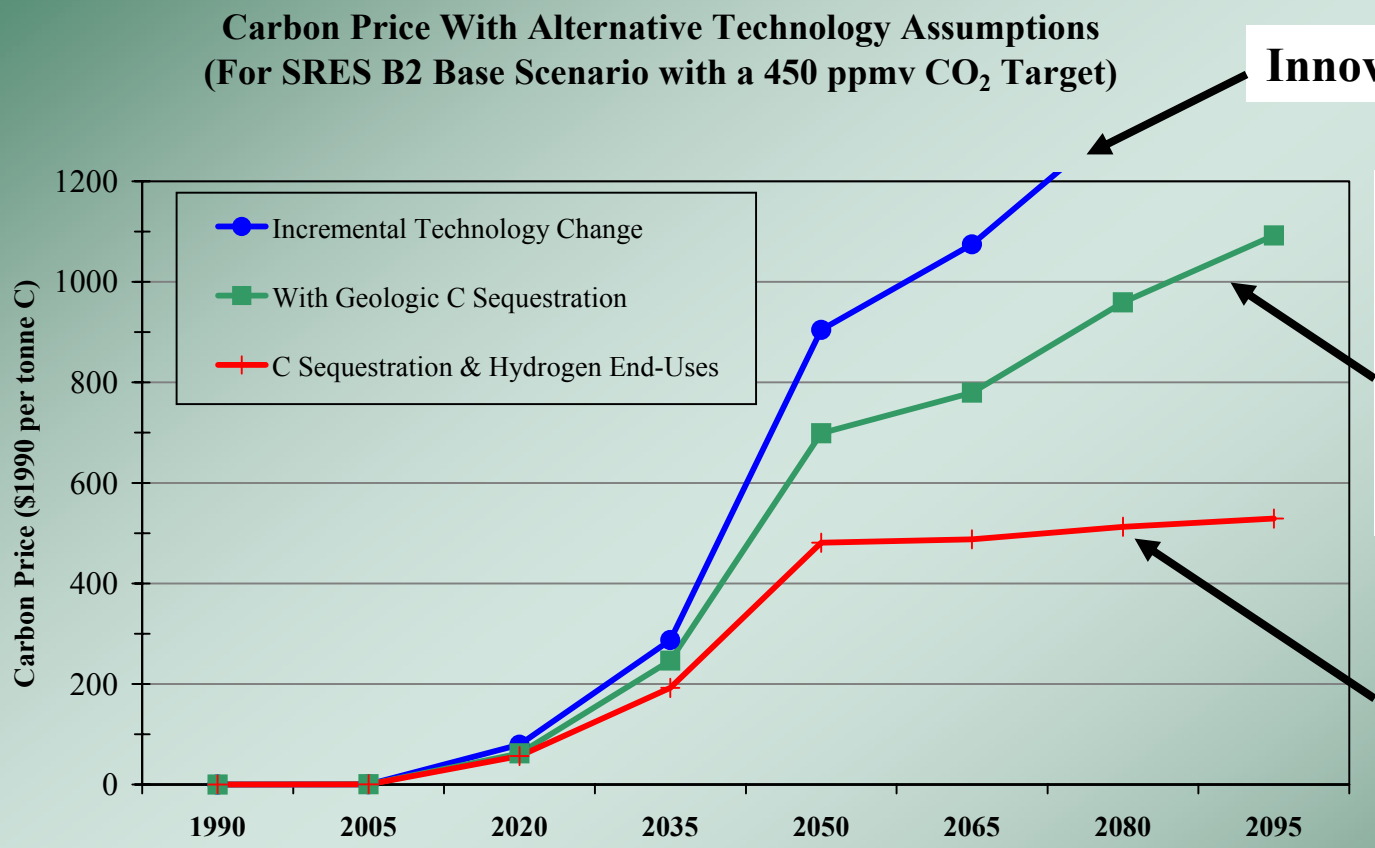
The Transportation Sector

The Ability to Decarbonize the Transportation Sector May Hold the Key to Economically Addressing Climate Change



Innovation as Usual

Tremendous Technological Success in Getting Carbon Out of Electric Power and Industrial Sectors

Carbon Removed from Electric Power and Industrial Sectors and Transportation

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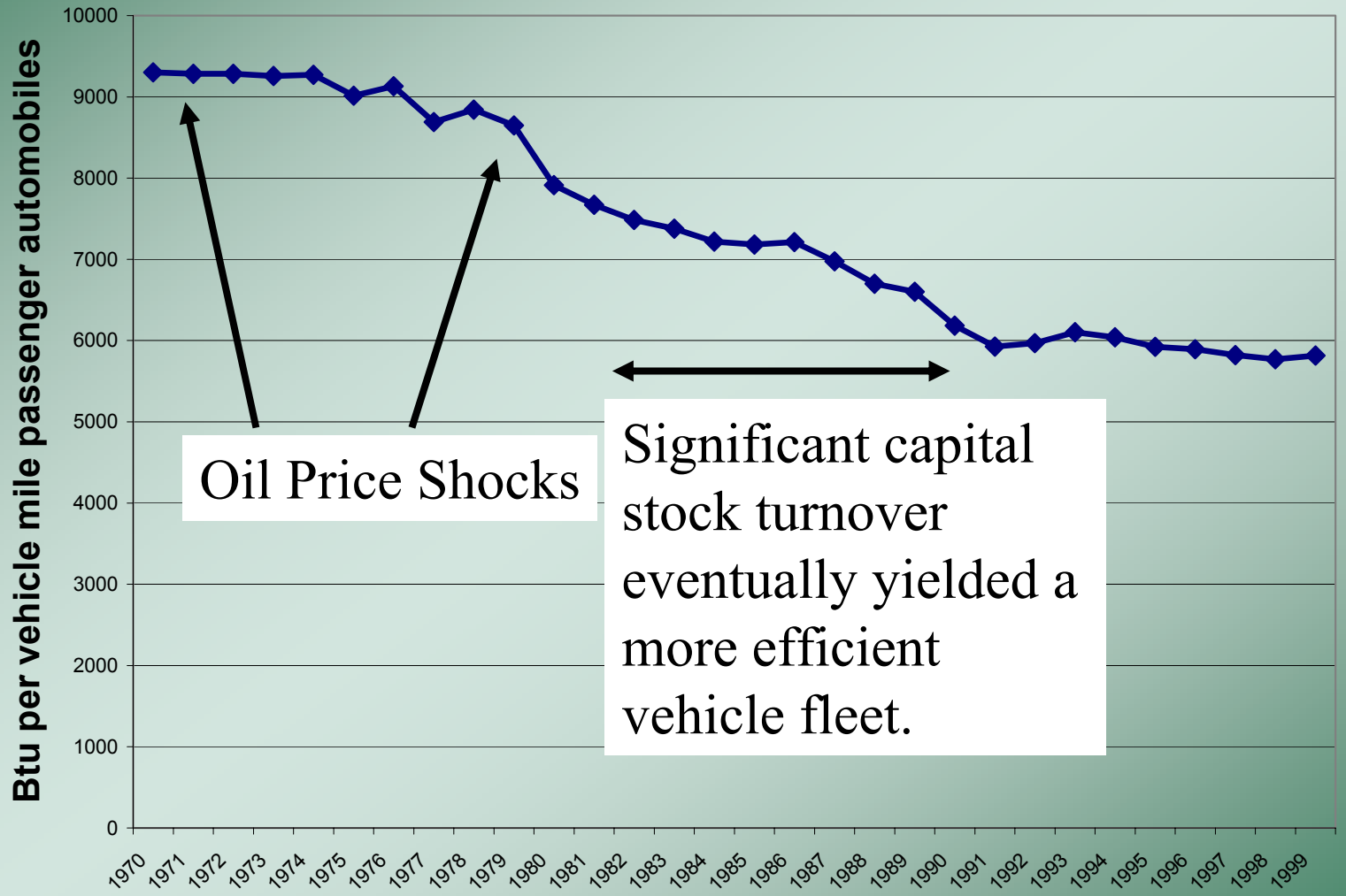
The Transportation Sector

Transportation without emissions, which system(s)?

- Fossil fuels → H_2+Carbon Capture &Sequestration→H_2 pipeline → Local H_2 storage→H_2 fuel cell vehicle.
- Fossil fuels → Natural gas pipeline → Local H_2 production+Carbon Capture &Sequestration → Local H_2 storage→H_2 fuel cell vehicle.
- Commercial biomass → Refinery → Conventional vehicles.
- Wind → H_2 → fuel cell vehicle.
- Fossil fuels → Electricity + Carbon Capture & Sequestration → Electric vehicle.

The Transportation Sector

A Thought Experiment: How Do We Transition to a Zero or Near-Zero Global Transportation Sector?



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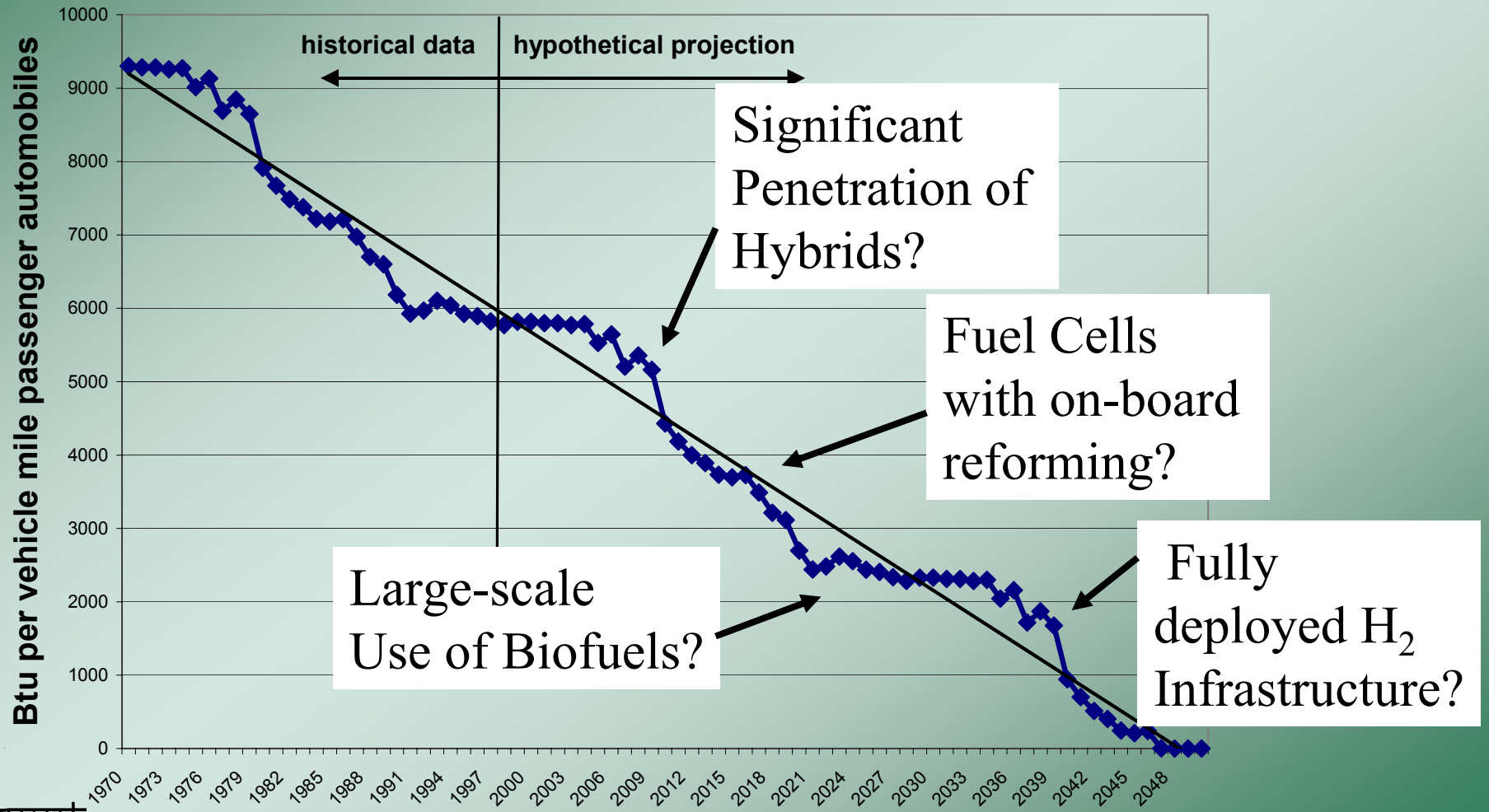

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The Transportation Sector
Key Summary Points

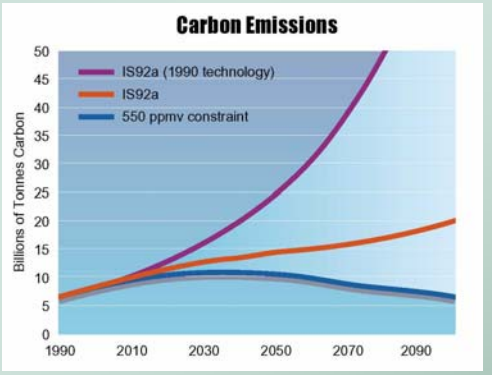
- Other sectors of the economy will likely "go first" in reducing their GHG emissions, but this will not last forever.
- The use of carbon taxes will likely be much more effective in other sectors of the economy in stimulating a move to low carbon or no carbon energy systems.
- Decarbonizing the transportation sector will likely be "technology-led" rather than a "price-led." Technologies need to be ready before they are needed.
- Climate change transportation technology solutions need to be globally deployable.

The Transportation Sector
Key Summary Points

- There are many possible routes to a zero emitting transportation sector, but how many of these can survive simultaneously in the global marketplace?
- Where does the decarbonization of transportation systems take place -- on board the vehicle, at the corner gas station, at the city gate, at a regional refinery, …?
- How do we incentivize "zero emission transportation R&D"? Who gets to decide who the winner is?

"Addressing climate change" is only one of many transportation needs that must be met simultaneously.

A Technology-Based Strategy For Addressing Climate Change Is Desperately Needed



- **Goal is Stabilizing Concentrations**
- **Century-Scale Problem**
- **International Problem: Need Global Solutions**
- **We Need a Comprehensive and Enduring Strategy**
  - *Mitigation*
  - *Technology Development that Supports a Portfolio of Energy Technologies*
  - *Climate Adaptation Research*
  - *Research to Resolve the Remaining Scientific Uncertainty*
- **This paradigm will allow us to reduce the cost of addressing climate change by trillions of dollars and likely facilitates the attainment of other societal goals such as energy security.**