Hydrogen and Climate

Jae Edmonds

Hydrogen Vision Meeting

Park Hyatt Washington, Washington DC, USA
November *15th - 16th, 2001*

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Today's Discussion

- Hydrogen in the Typical Reference Future World
- The Role of Hydrogen in CO_2 Concentration Stabilization
- The Implication of Technology Development for Hydrogen and CO_2 Concentration Stabilization

A Reference Future World

Based on SRES B2

- Population→9.4 billion people in 2100.
- Income per capita disparities shrink between regions, but don't close—average GDP/capita growth = 1.85%/yr.
- Gross World Product increases by an order of magnitude $23T/yr→$200T/yr.
- Technologies improve dramatically.

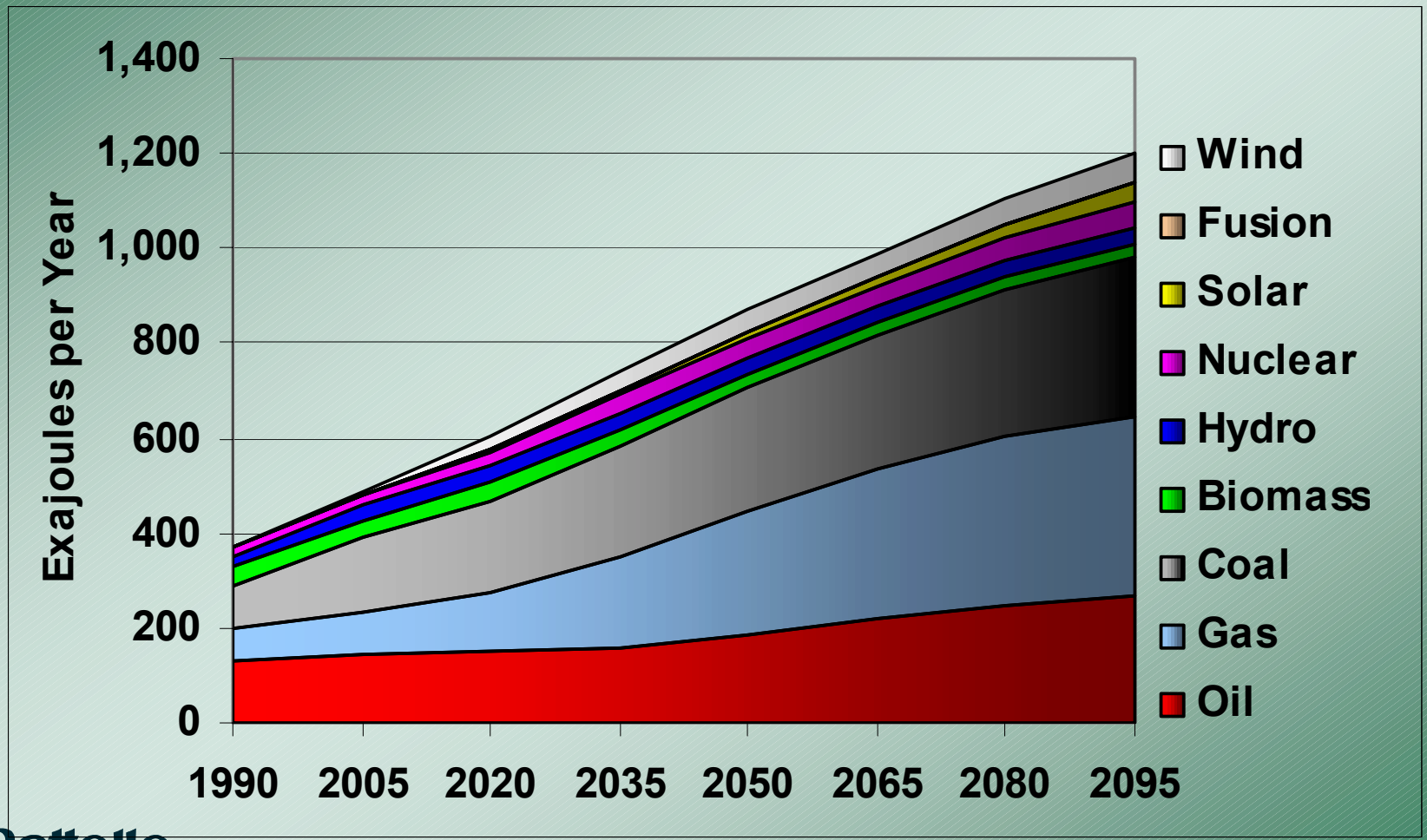
A Reference Future World

Technology Assumptions

Technology	units	year 1990	year 2100	
		Base	AOG	AOG-Enhanced Technology
US Automobiles	mpg	18	60	100
Land-based Solar Electicity	1990 c/kWh	61	5.0	5.0
Nuclear Power	1990 c/kWh	5.8	5.7	5.7
Biomass Energy	1990$/gj	$7.70	$6.30	$4.00
Hydrogen Production (CH_4 feedstock)	1990$/gj	$6.00	$6.00	$4.00
Fuel Cell	mpg (equiv)	43	60	98
Fossil Fuel Power Plant Efficiency (Coal/Gas)	%	33	42/52	60/70
Capture Efficiency	%	90	90	90
Carbon Capture Power Penalty (Coal)	%	25	15	5
Carbon Capture Power Penalty (Gas)	%	13	10	3
Carbon Capture Capital Cost (Coal)	%	88	63	5
Carbon Capture Capital Cost (Gas)	%	89	72	3
Geologic Sequestration (CO_2)	$/tC	37.0	37.0	23.0

The Modeler's Reference Case

The Reference Primary Energy System



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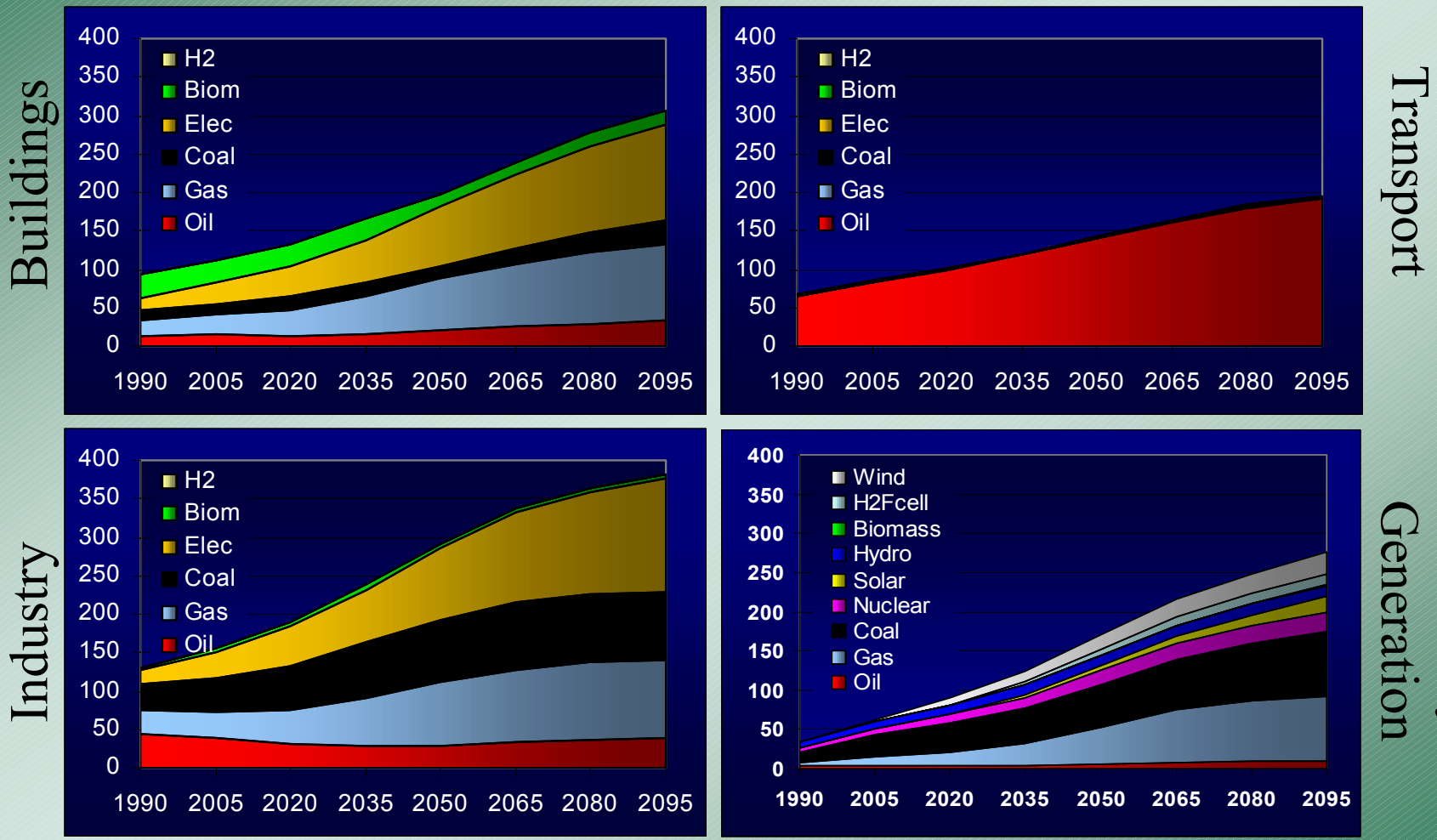
The Modeler's Reference Case

The Reference Energy System (EJ/yr)



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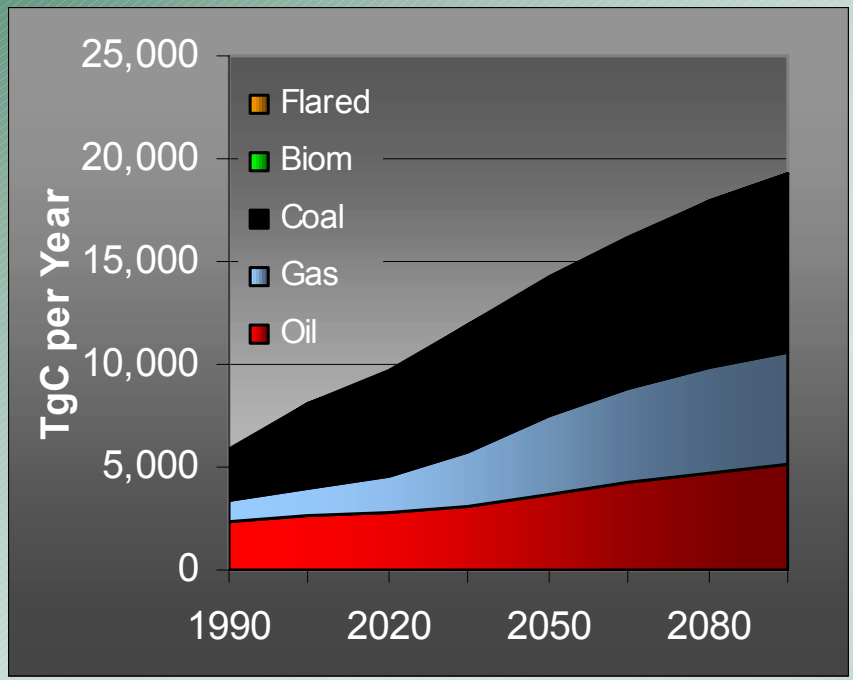
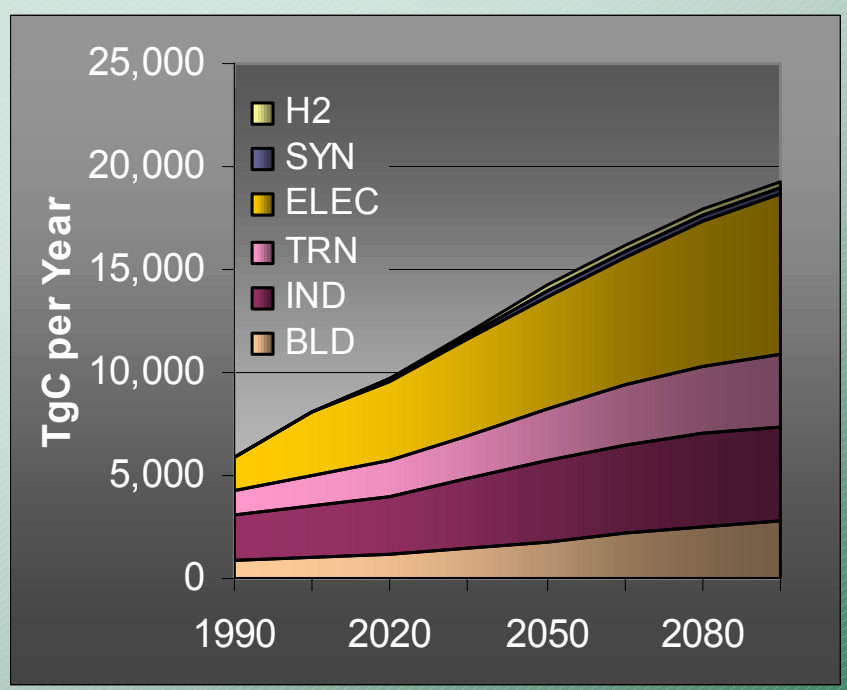
The Modeler's Reference Case

The Reference Energy Emissions





Climate Policy and Energy

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The Framework Convention

- A decade ago the United States and more than 160 other nations created the Framework Convention on Climate Change.

- The FCCC 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)**

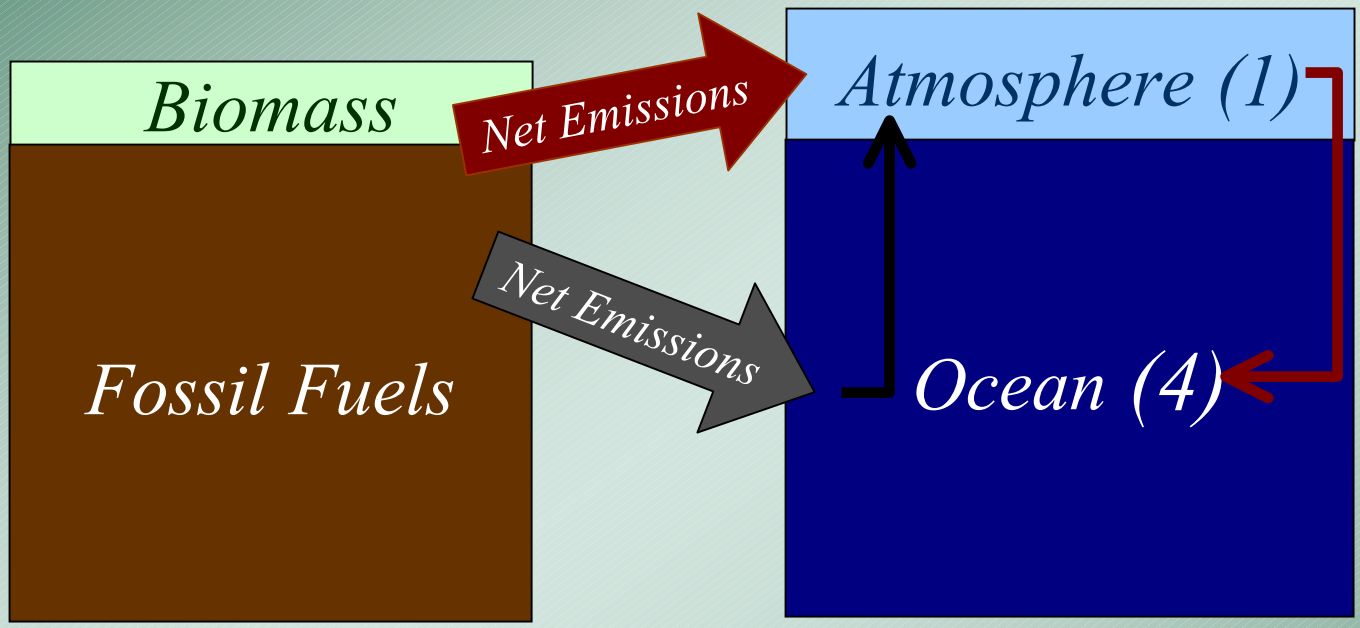
Stabilizing Concentrations …

… has non-trivial implications for energy.

- Any CO_2 concentration is associated with CUMULATIVE NET EMISSIONS from pre-industrial times by everyone, everywhere on the planet.
- Global Net CO_2 Emissions must eventually approach ZERO.

… for any stabilization concentration.

Why Zero?



Long Term Distribution between atmosphere and ocean ~1:4

Stabilizing CO_2 Concentrations

In the long term there are only FOUR different types of END-USE energy carriers:

1. Electricity
2. Hydrogen
3. Hydrocarbons with recapture of the carbon
4. Direct energy services (process heat, steam, mechanical drive, etc.)

REGARDLESS OF THE STABILIZATION CONCENTRATION!

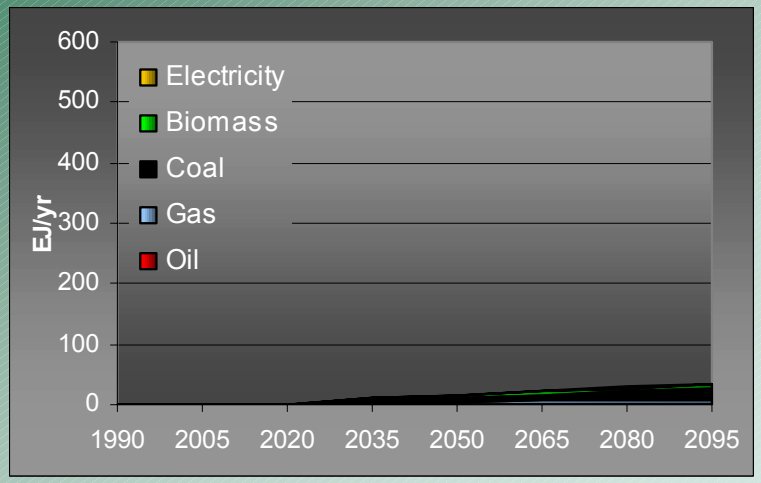
Hydrogen

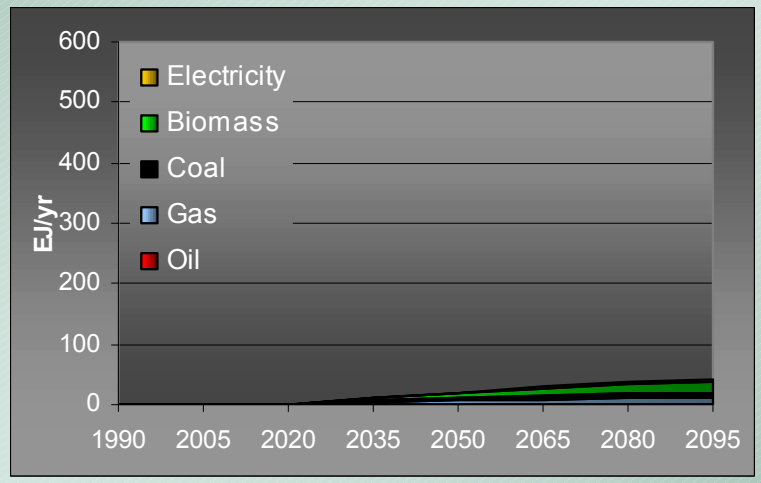
Where would it come from?

- Methane
- Oil
- Coal
- Biomass
- Electrolysis

The Scale & Composition Depend on Technology

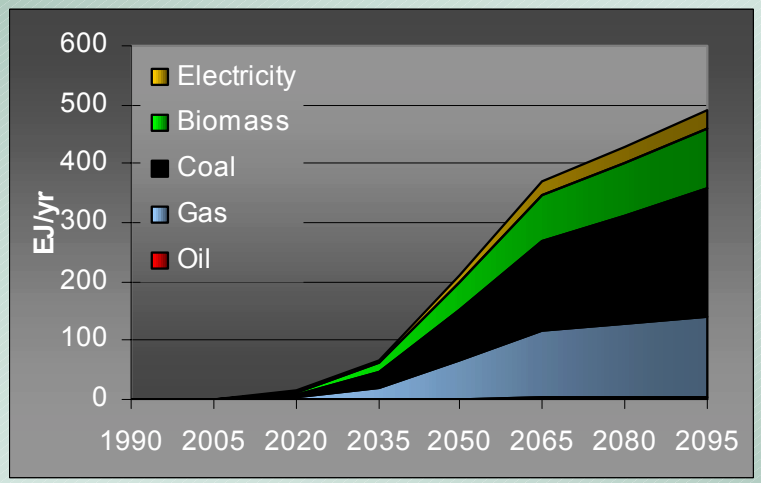
AOG

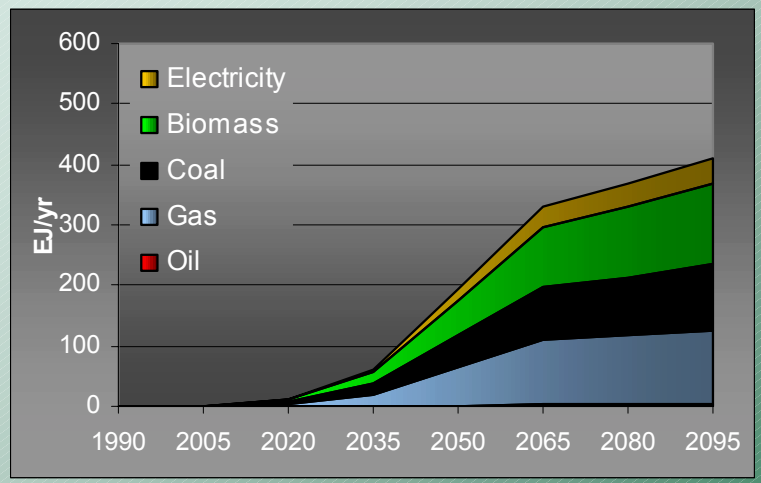




AOG 550

AOG Tech





AOG Tech 550

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Hydrogen With Carbon Capture

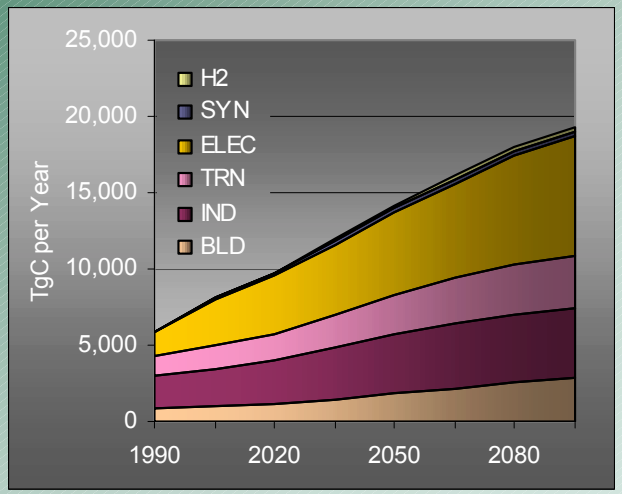
Without Carbon Capture and Sequestration Only Biomass and Electrolysis Have Zero Net Emissions

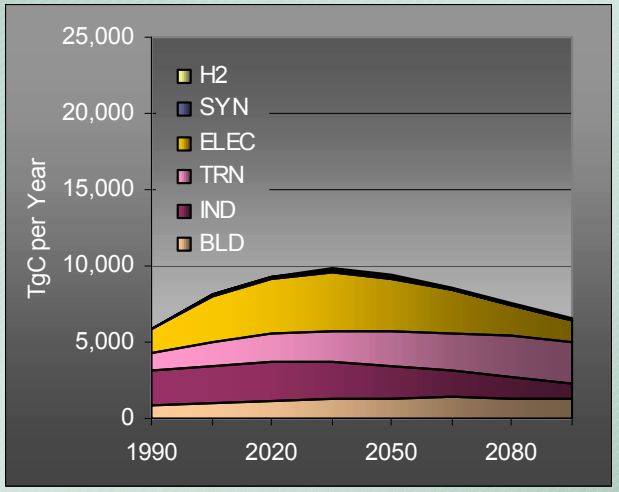
- Methane
- Oil
- Coal
- Biomass
- Electrolysis

With Carbon Capture and Sequestration Fossil Fuel Feed Stocks Have Zero Net Emissions and Biomass Has Negative Emissions

Technology & CO_2 Stabilization

AOG





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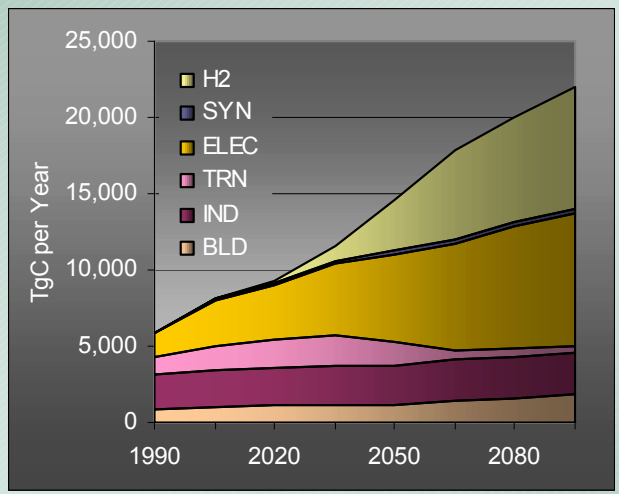

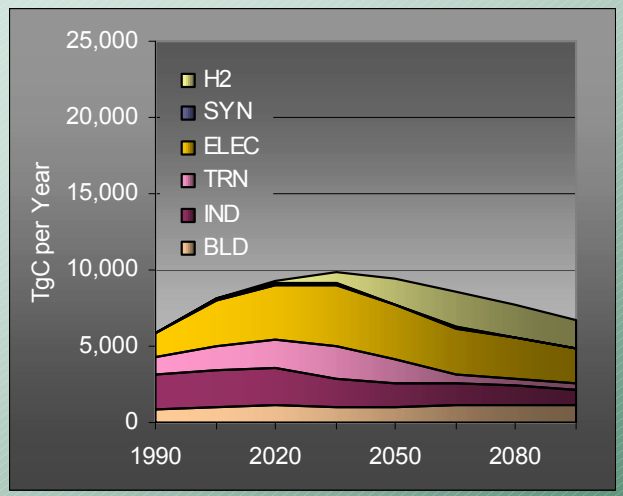

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Hydrogen

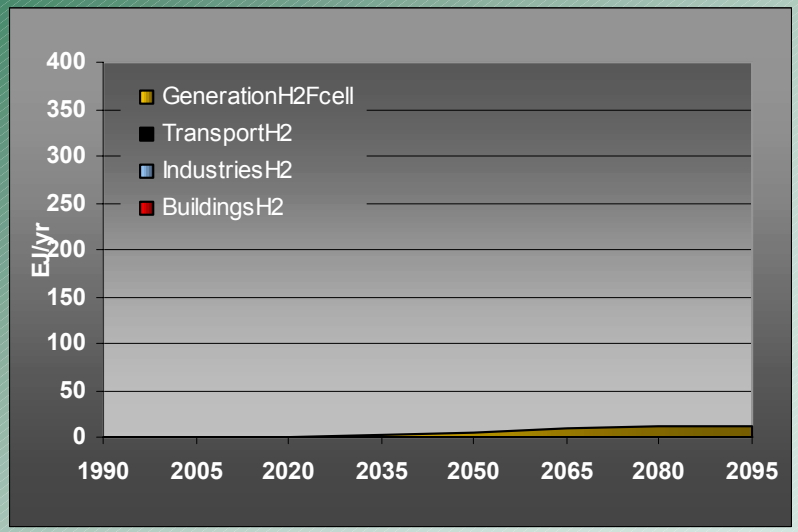
Who Uses The Hydrogen?

- Residential
- Commercial
- Transportation
- Power Generation

H_2 could be used either directly or
With Complementary technologies, e.g. fuel cells.

H_2 Use

AOG



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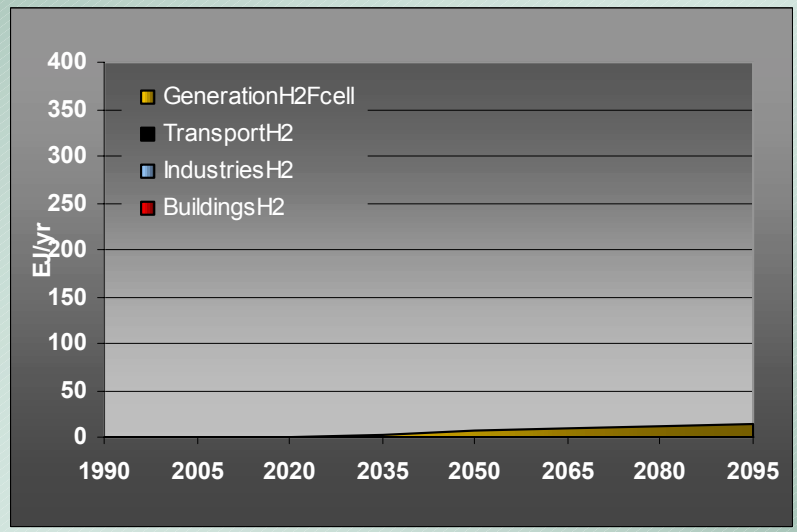

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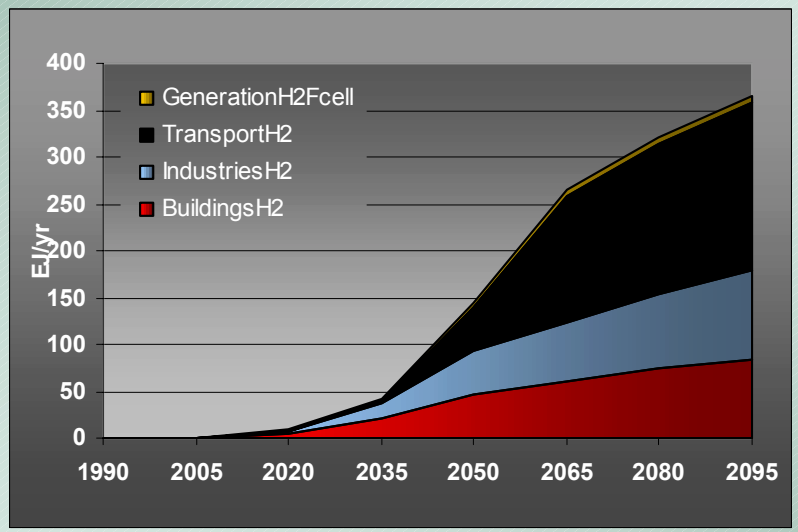

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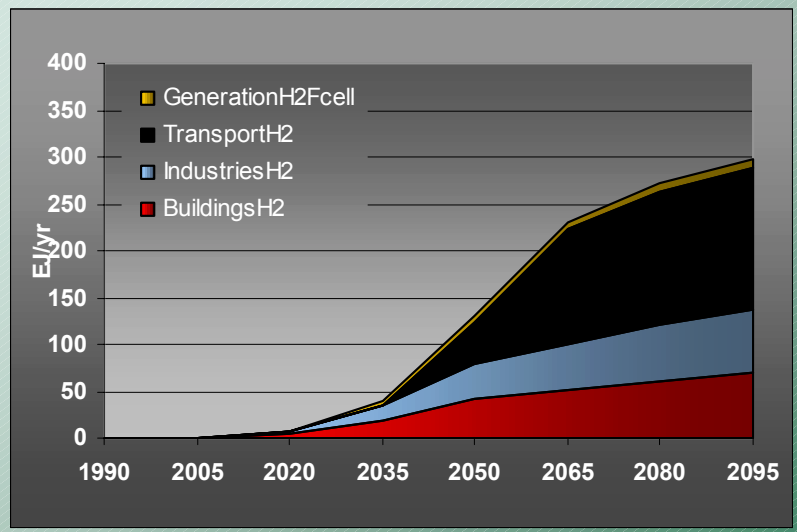

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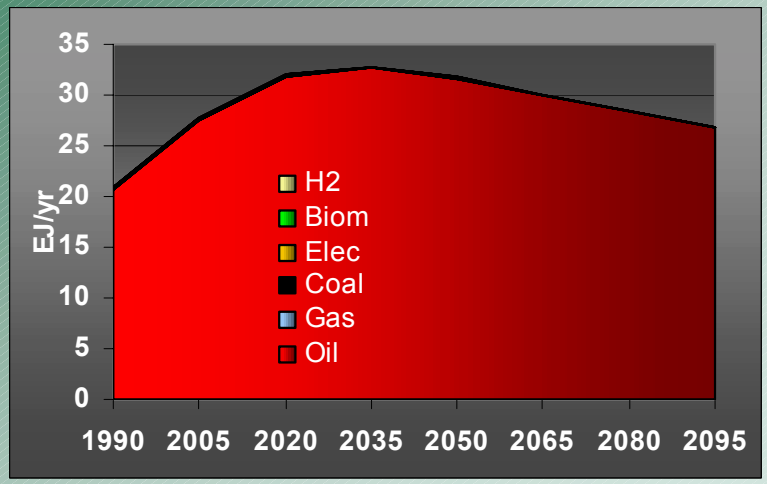
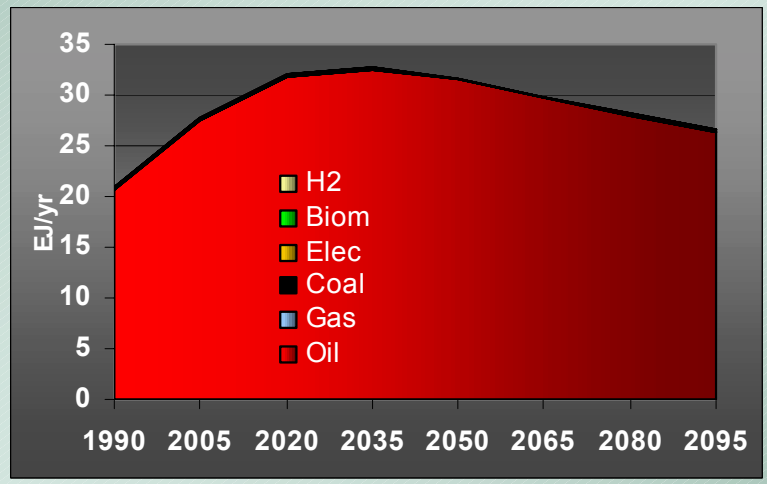
Policy Intervention

The Transportation Sector

Fuel Cells A Critical Path Transport Technology

AOG





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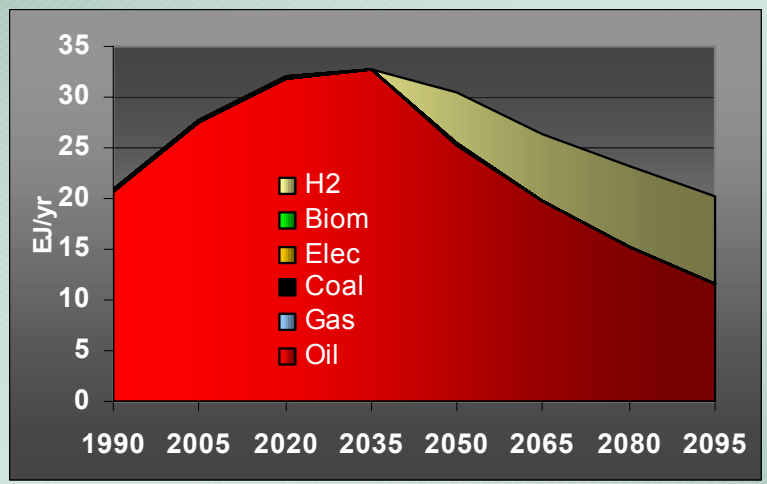

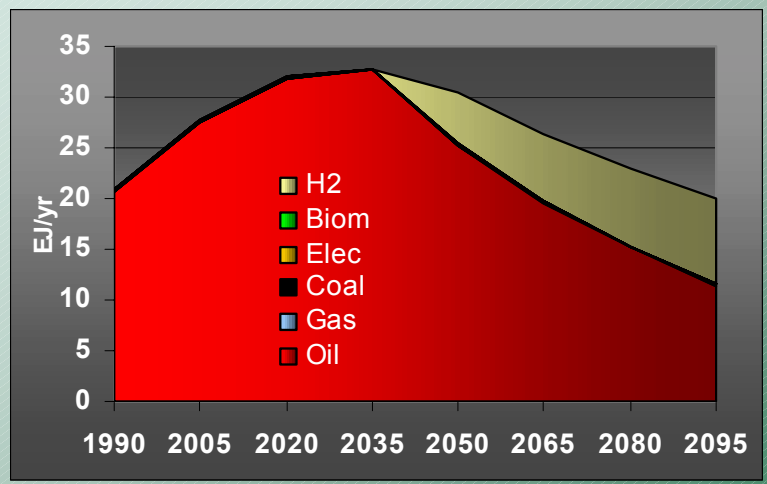

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Why Transport Emissions Are All Technology

- 1990 Total Service Cost = $0.44/mi
- 1990 Fuel Cost = $0.04/mi

- 2100 Total Cost (AOG) = $0.42/mi
- 2100 Fuel Cost (AOG) = $0.01/mi
- 2100 Fuel Cost (550AOG) = $0.02/mi

- 2100 Total Cost (AOG tech) = $0.41/mi
- 2100 Fuel Cost (550 AOG tech) = $0.01/mi

Conclusions

- Most Conventional Long-term Analysis Do Not Adequately Treat H_2
- In the Long Term Stabilizing CO_2 Concentrations Means That There is a Premium on the Successful Development of an H_2 Option
- When Greenhouse Gas Emissions are Constrained, H_2 Technology Penetrates the Market More Effectively With the Concurrent Development of Complementary Technologies, e.g. Fuel Cells and Carbon Capture and Sequestration.