



**Center for Energy, Environment, and Transportation Innovation**

Technology Briefing  
Electrifying Transportation  
Washington D.C.  
May 19, 2006

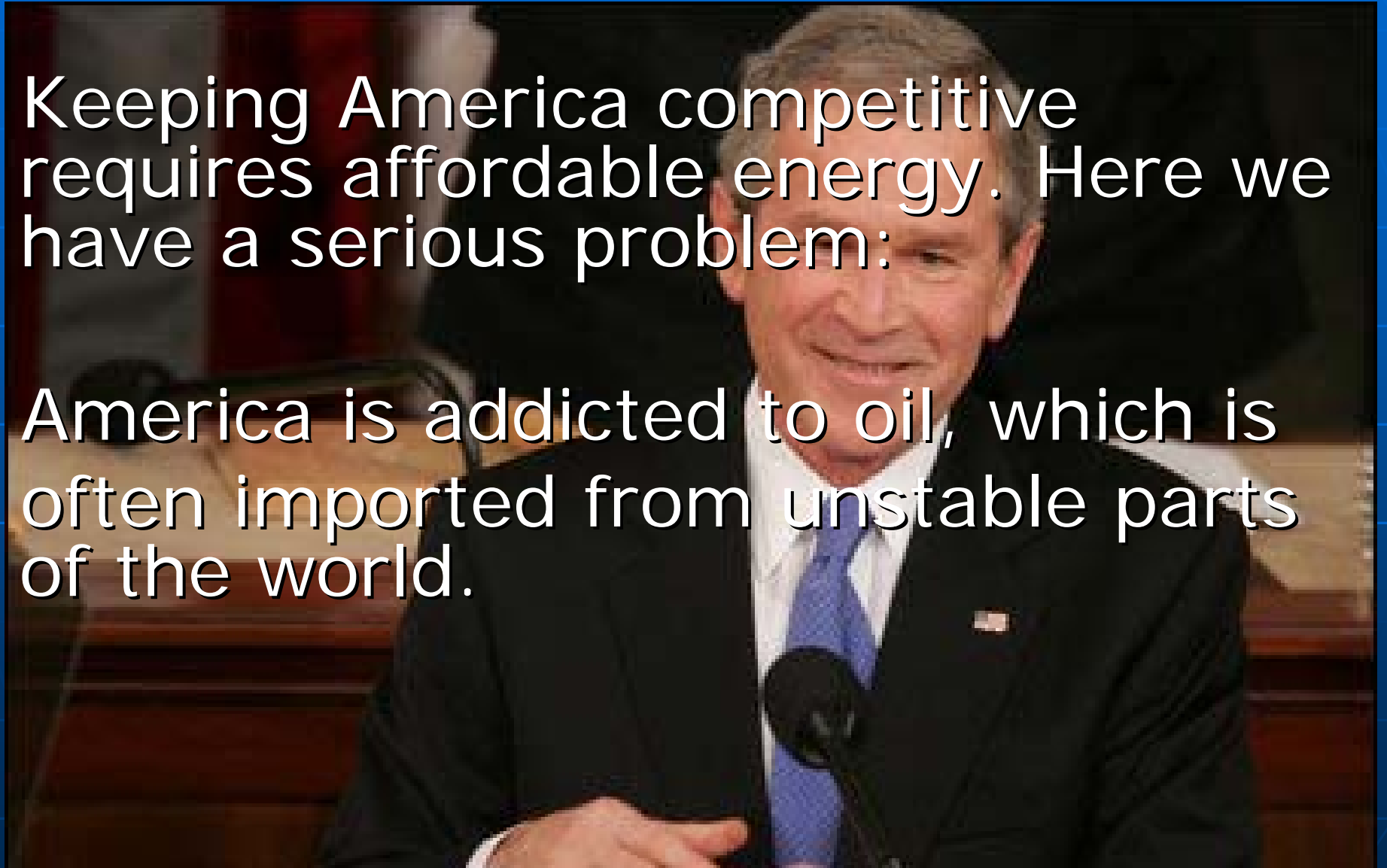


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## 2006 State of the Union Speech

Keeping America competitive requires affordable energy. Here we have a serious problem:

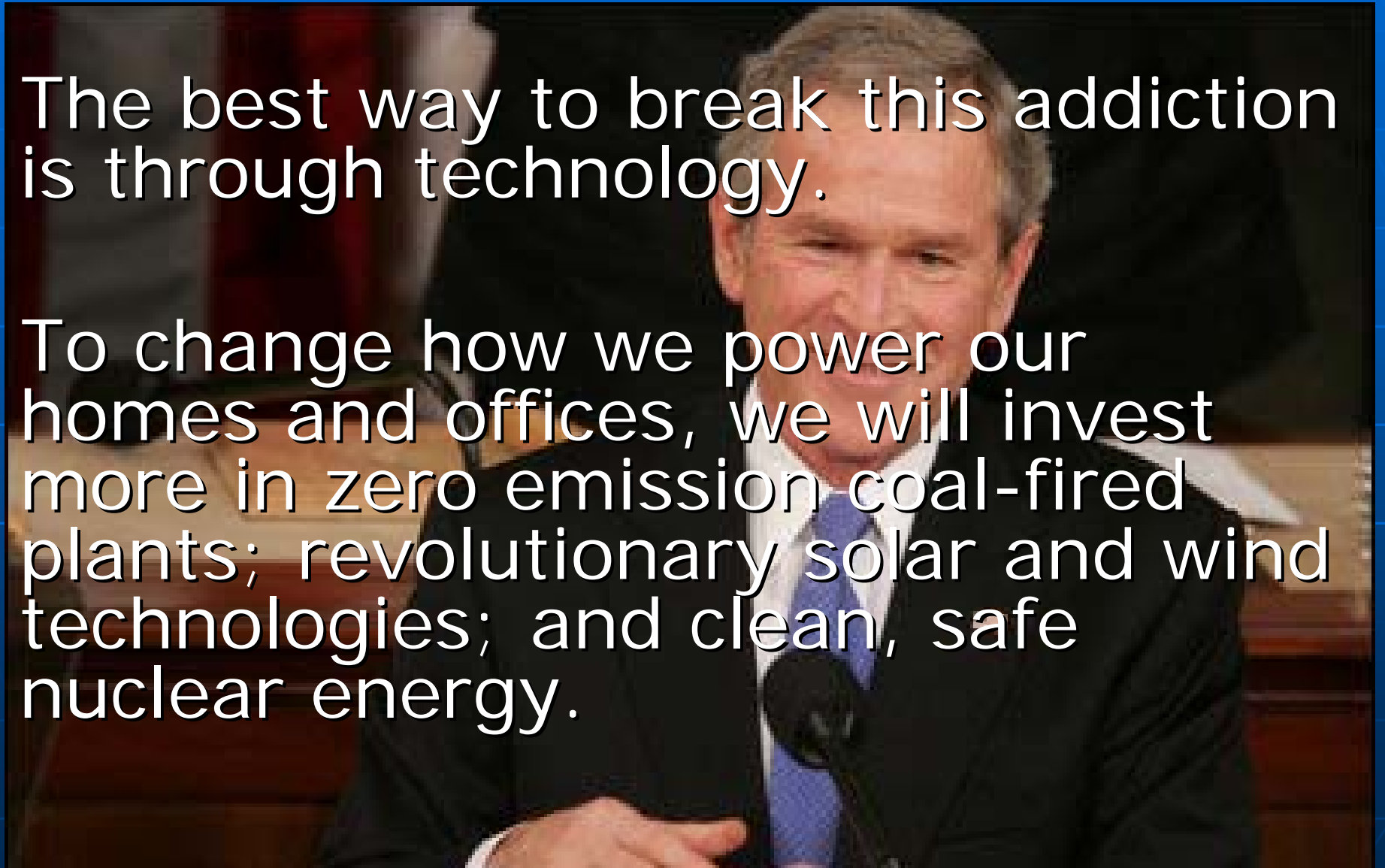
America is addicted to oil, which is often imported from unstable parts of the world.



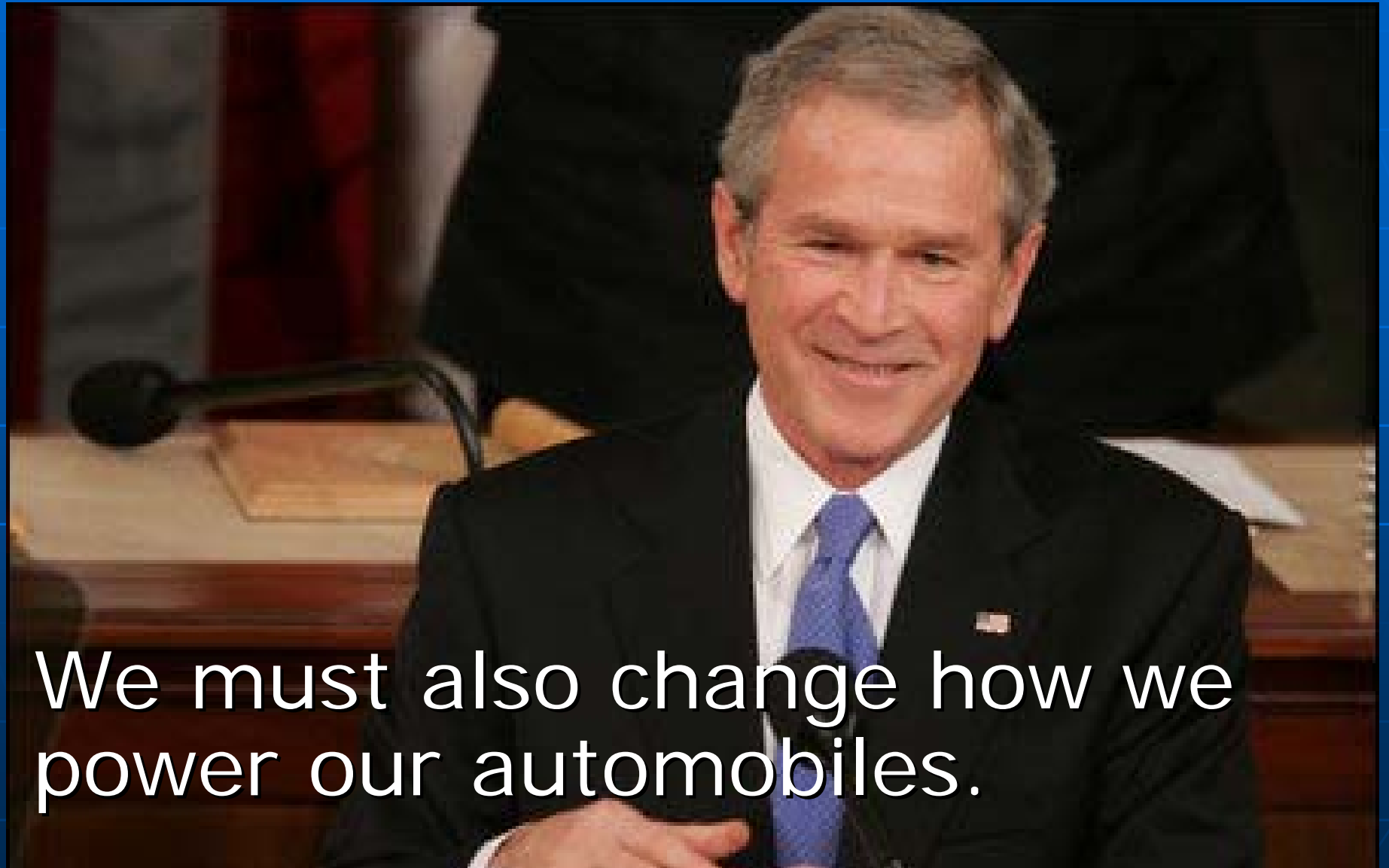
## 2006 State of the Union Speech

The best way to break this addiction is through technology.

To change how we power our homes and offices, we will invest more in zero emission coal-fired plants; revolutionary solar and wind technologies; and clean, safe nuclear energy.



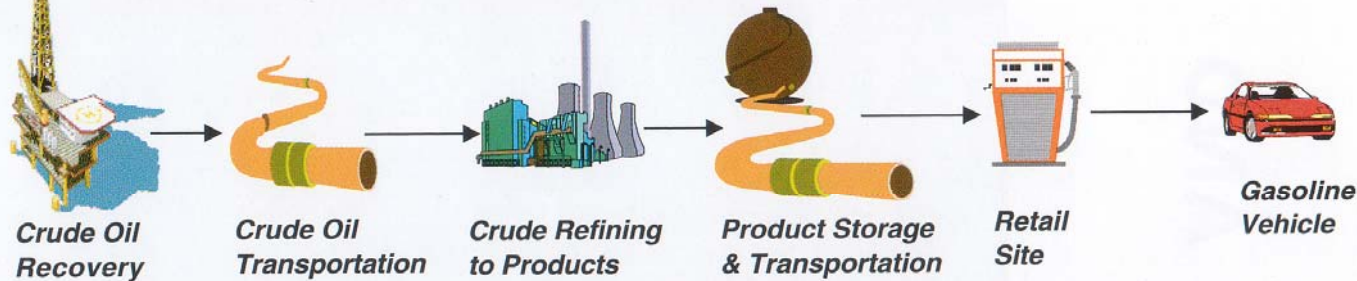
# 2006 State of the Union Speech



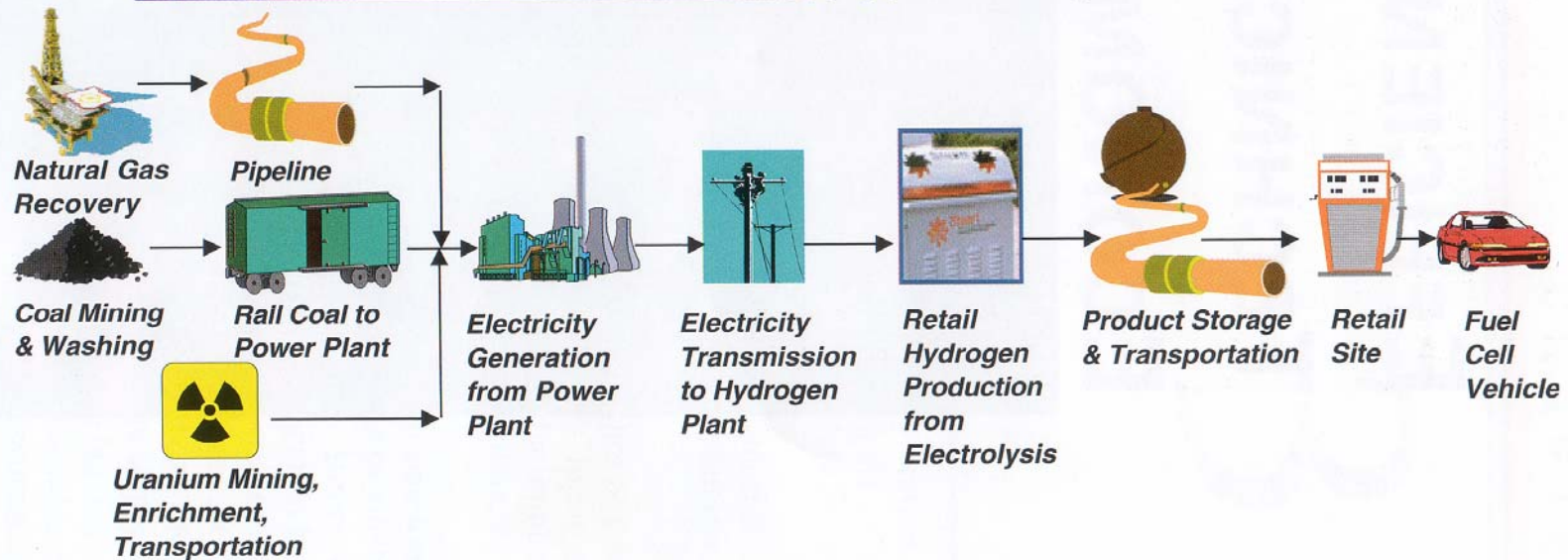
We must also change how we power our automobiles.

# From Oil to Hydrogen

## Gasoline Internal Combustion Engine (Present)



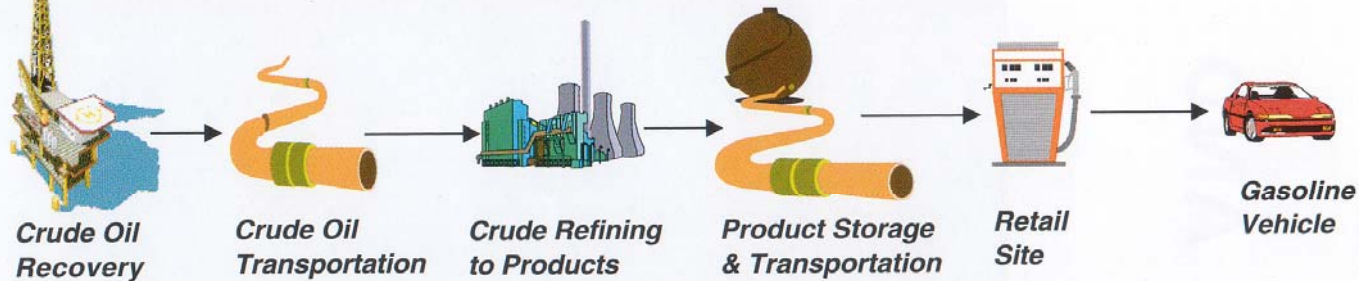
## Hydrogen Fuel Cell from Electricity (Hypothetical)



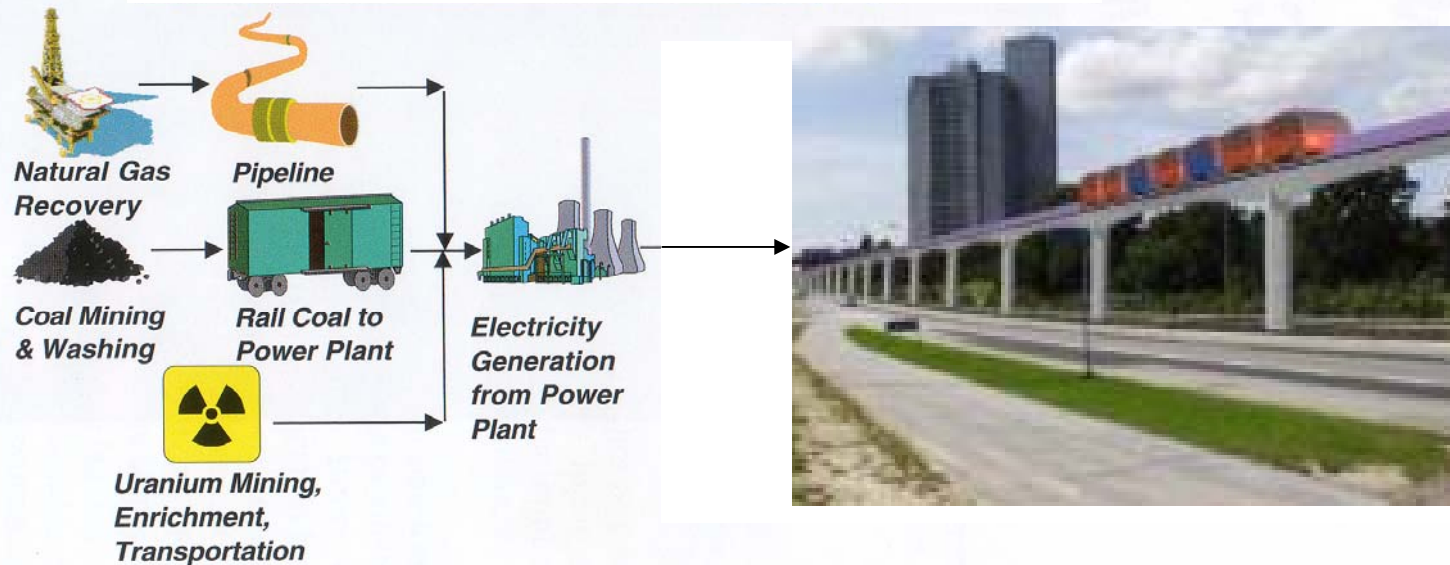
Source: Bradley and Fulmer, *Energy The Master Resource*, 2004

# From Oil to Electricity

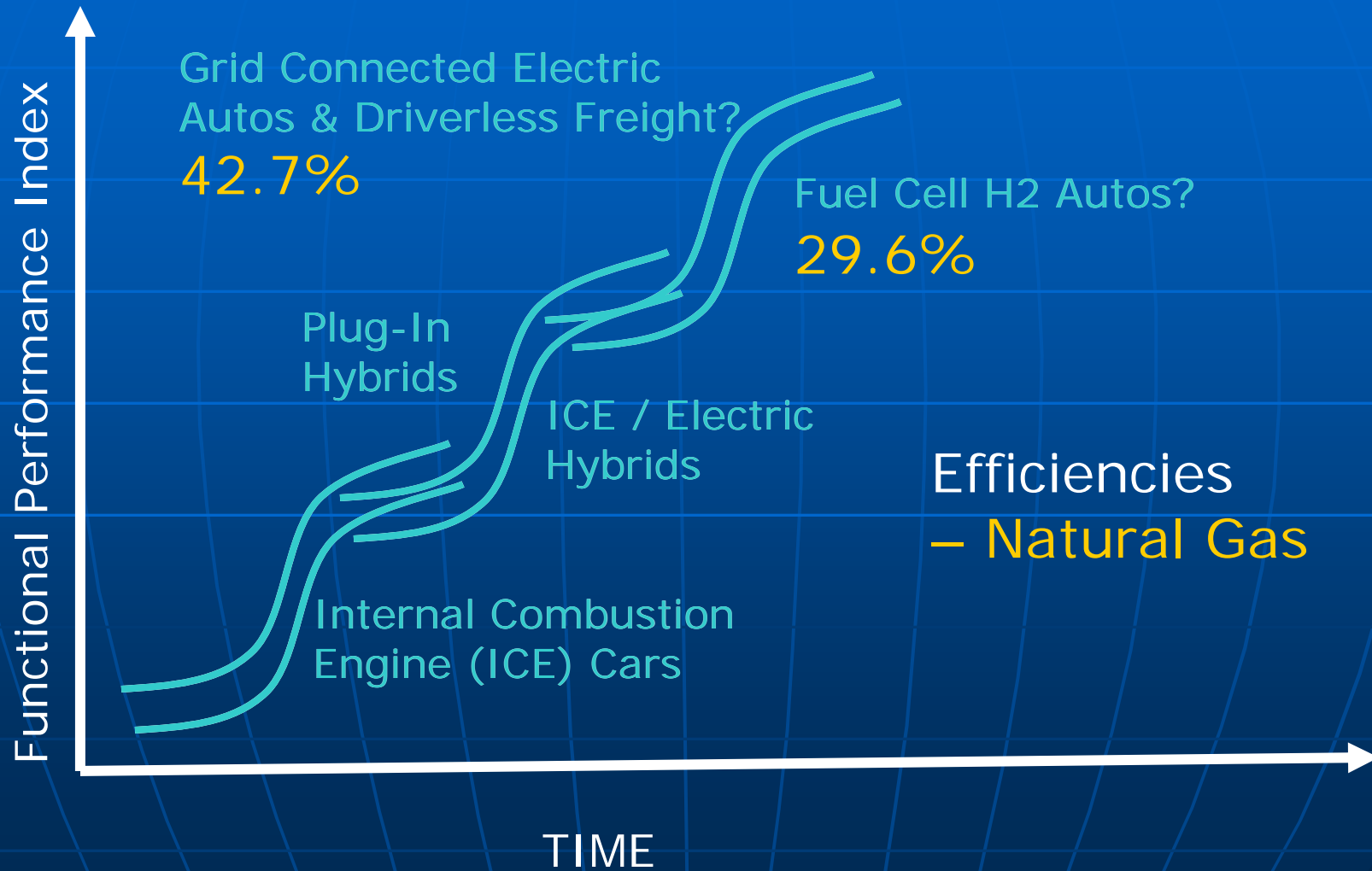
## Gasoline Internal Combustion Engine (Present)



## Electrified Guideways (Hypothetical)



# Evolution of Future Architectures



# Changing the Consumer Experience



Photos of GM HyWire Concept Car

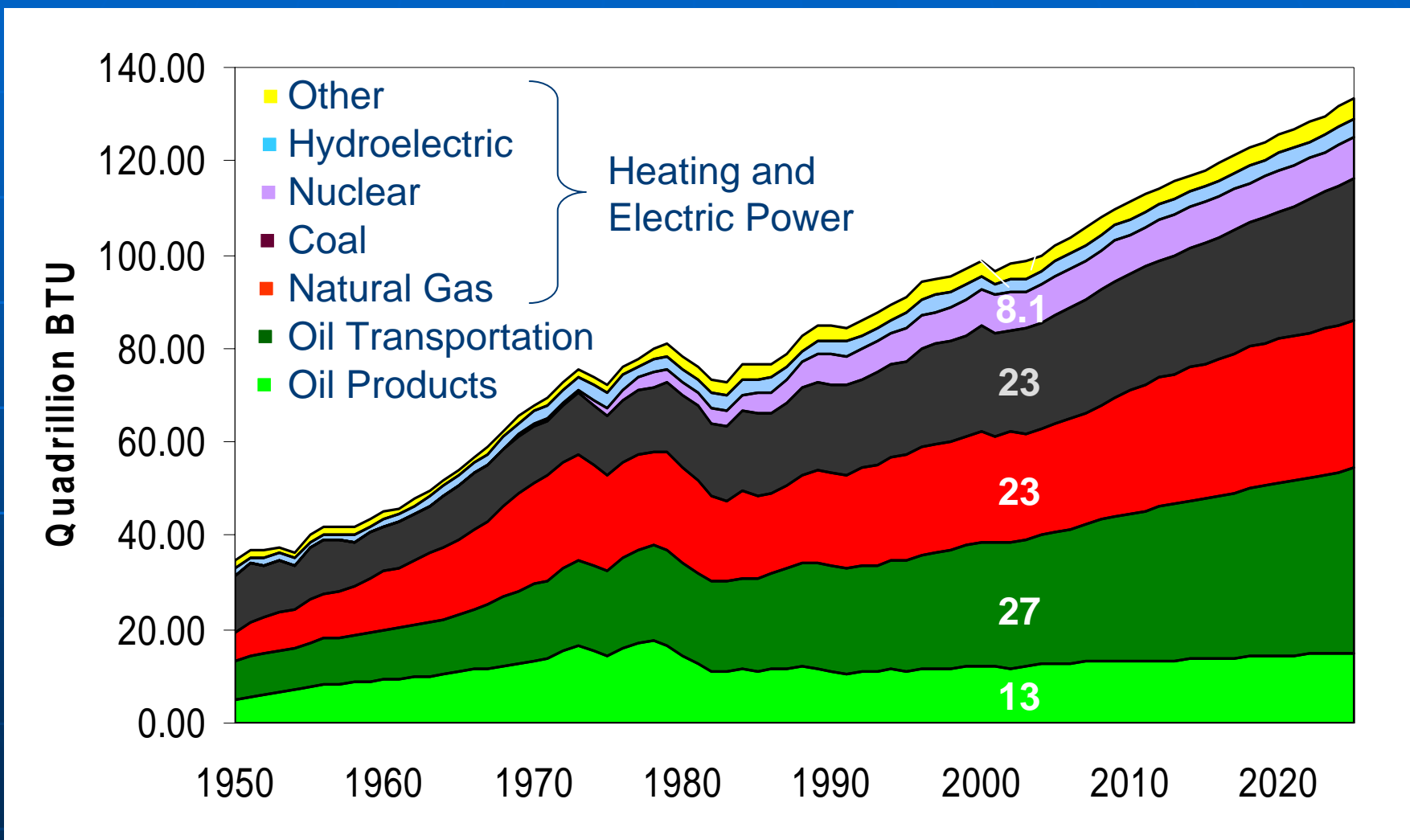
# Dual-Mode Vehicles



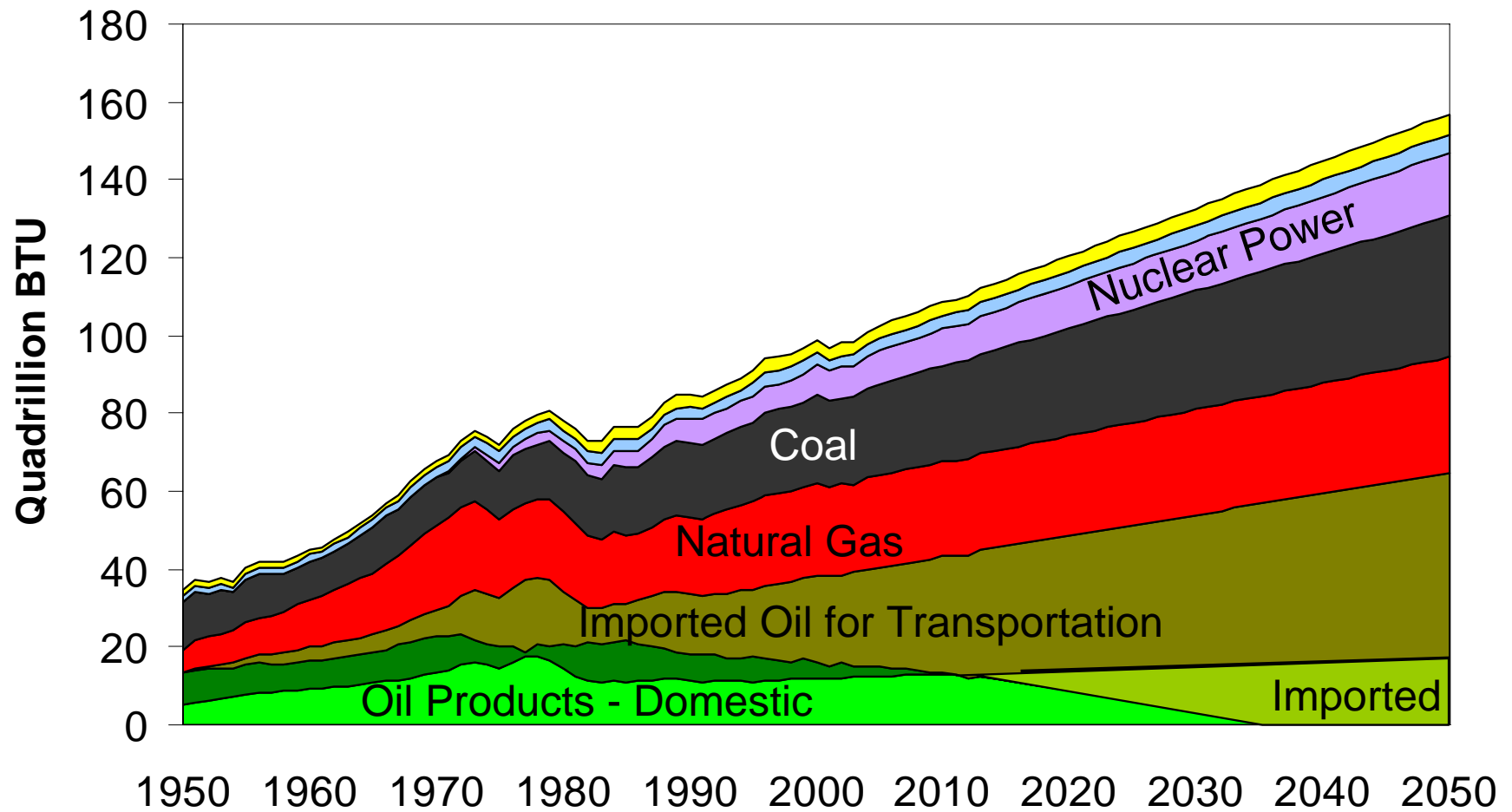
environmentally friendly, point to point travel at high speed -  
**private mass transit**

Sources: Ruf International

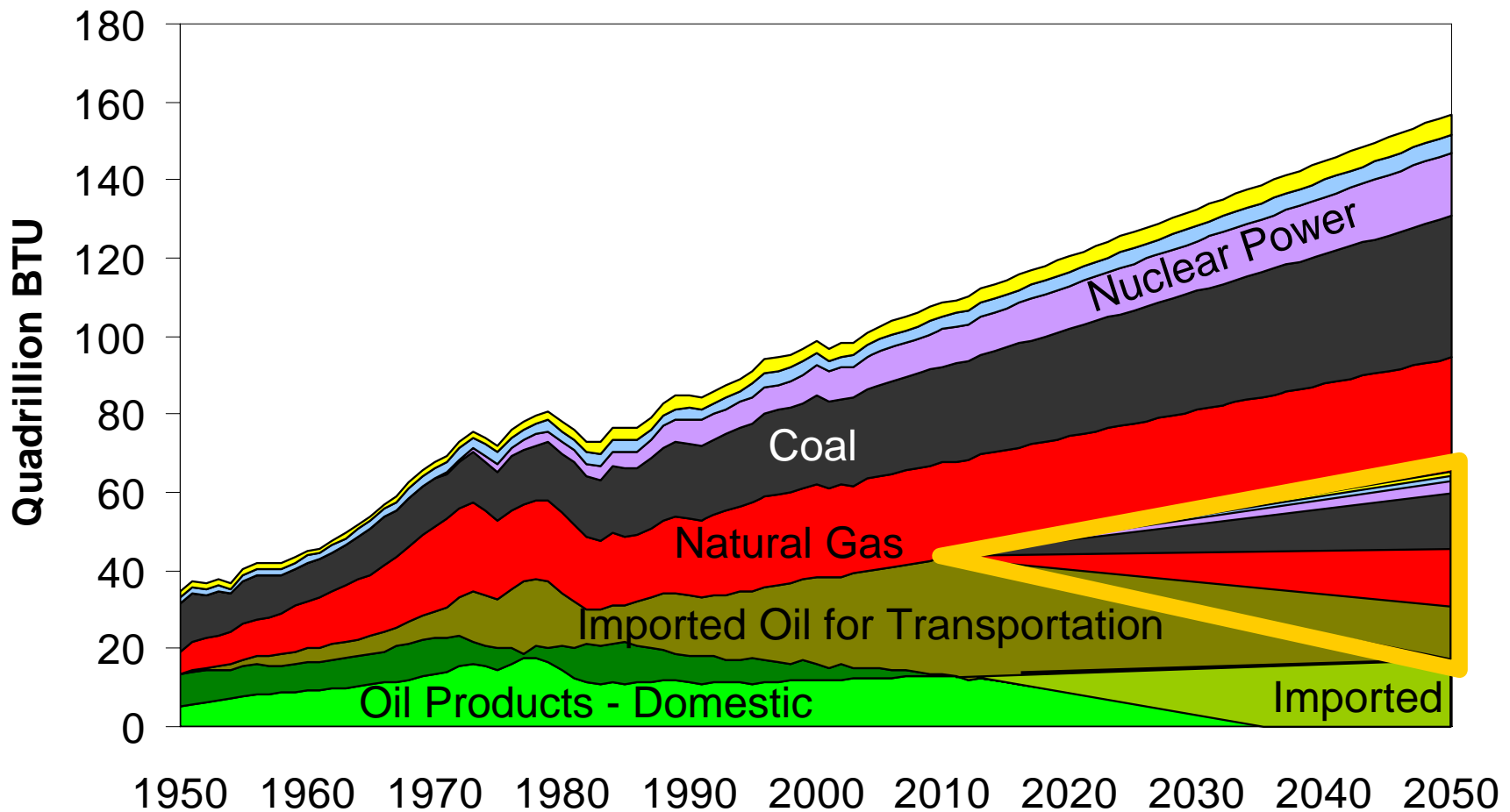
# US Energy Consumption



# US Dependence on Imported Oil

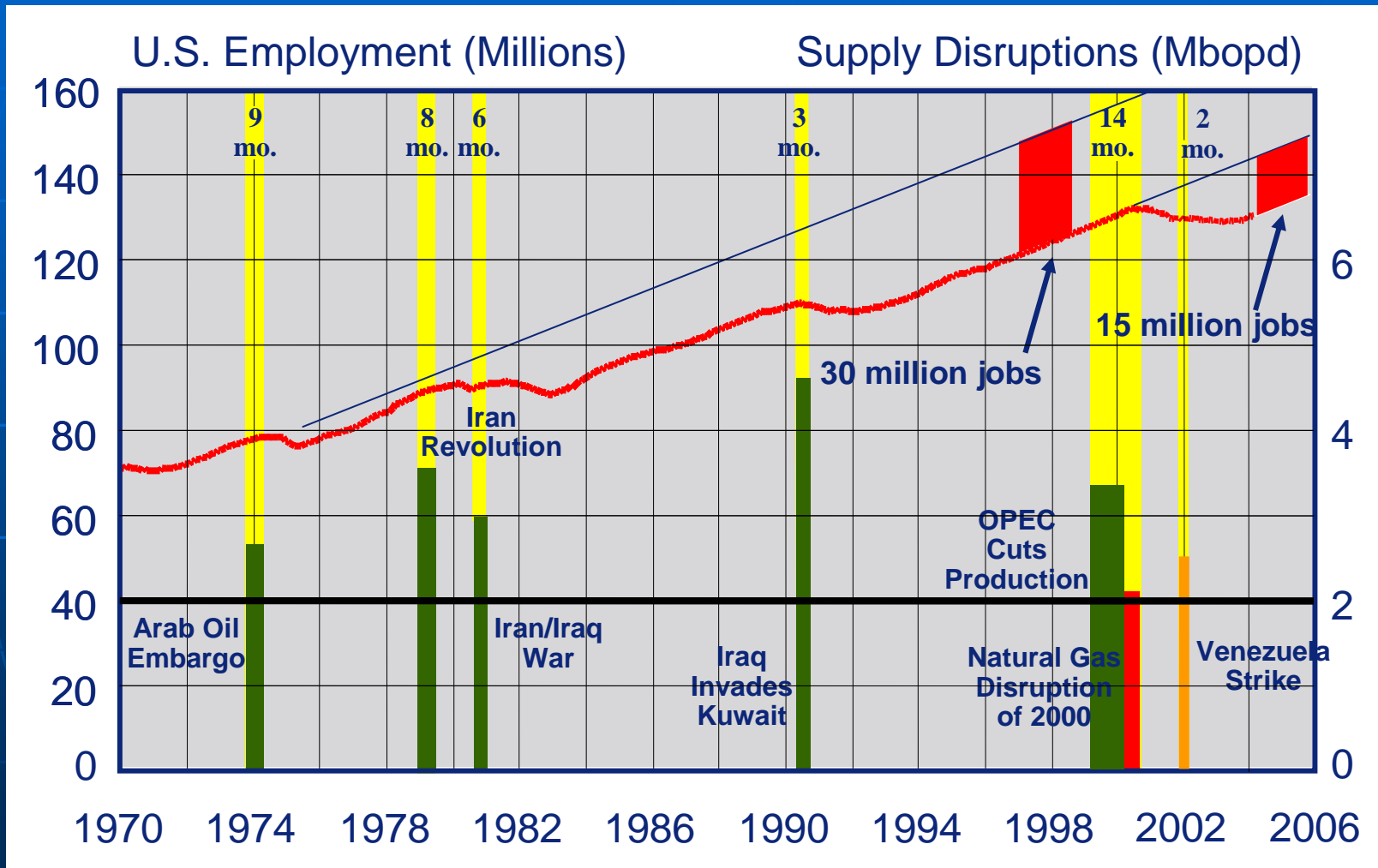


# Future - Electric Transportation



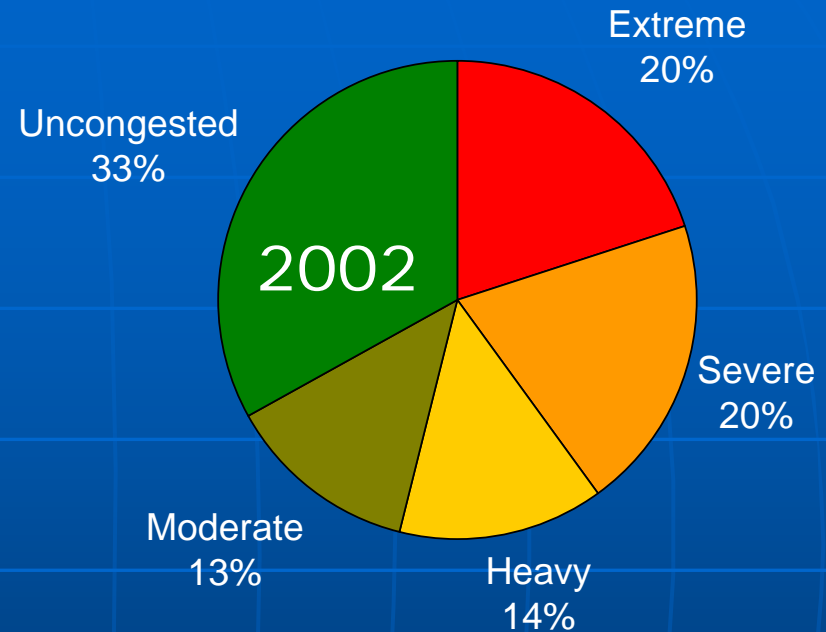
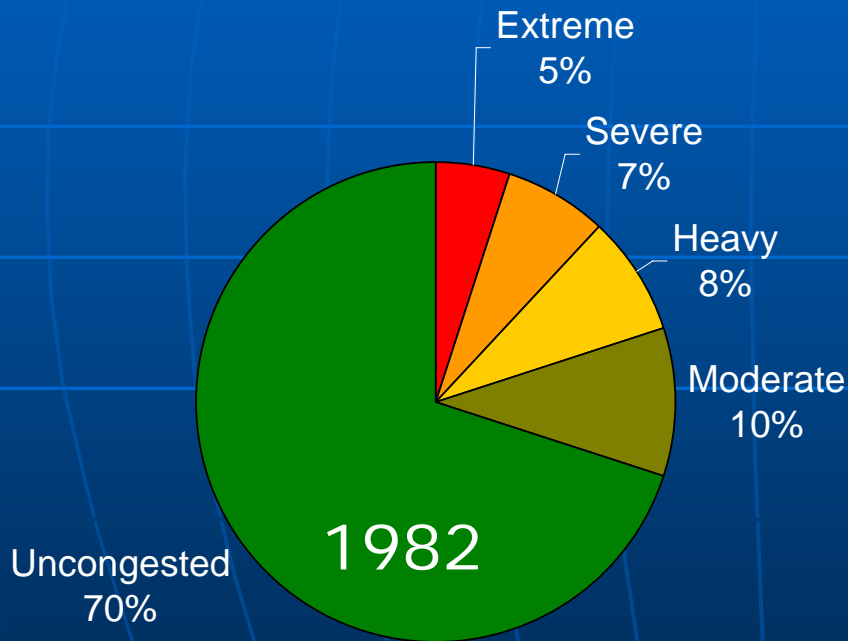
**Annual Waste - \$189 billion**

# U.S. Employment and Major Petroleum Supply Disruptions in OPEC Era



**Annual Waste - \$33 billion**

# Impact of Congestion



1	LA	93
2	SF	73
3	DC	67
4	DFW	61
5	ATL	60
6	HOU	58

**Annual Waste - \$64 billion**

Source: TTI 2004 Urban Mobility Study

# Transportation Safety Issues

- 41,000+ US highway deaths annually
- 3.2 million people injured in 2002 vehicle crashes
- 4.2 million crashes causing property damage only



**Annual Waste - \$230 billion**

Source: US DOT, National Highway Traffic Safety Administration, Traffic Safety Facts 2001

# Emissions from Combustion Engine Exhaust of Roadway Vehicles

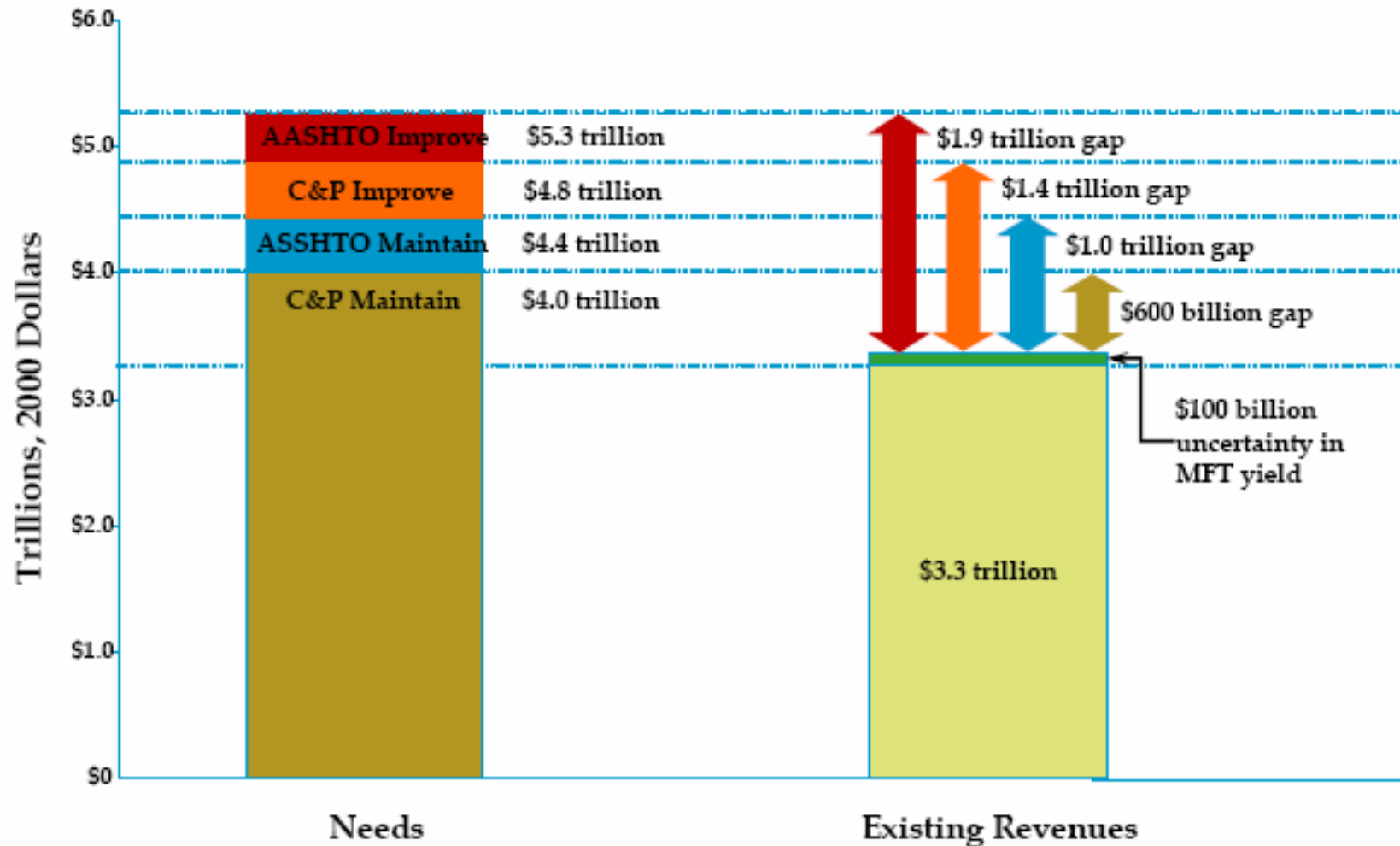
- 66% of all Carbon Monoxide
- 38% of all Nitrogen Oxides
- 26% of all Volatile Organic Compounds
- 30% of all Carbon Dioxide

**Annual Waste - \$17 billion**

# Annual Waste of Current Architecture

Energy Security	<b>\$33 billion</b>
Energy Monopoly	<b>\$189 billion</b>
Congestion	<b>\$64 billion</b>
Safety	<b>\$230 billion</b>
Emissions	<b>\$17 billion</b>
Total	<b>\$533 billion</b>

# Current Path is not Sustainable



Source: Cambridge Systematics based on FHWA and AASHTO data

# Critical Infrastructure Protection



TIME Magazine, Oct. 3, 2005

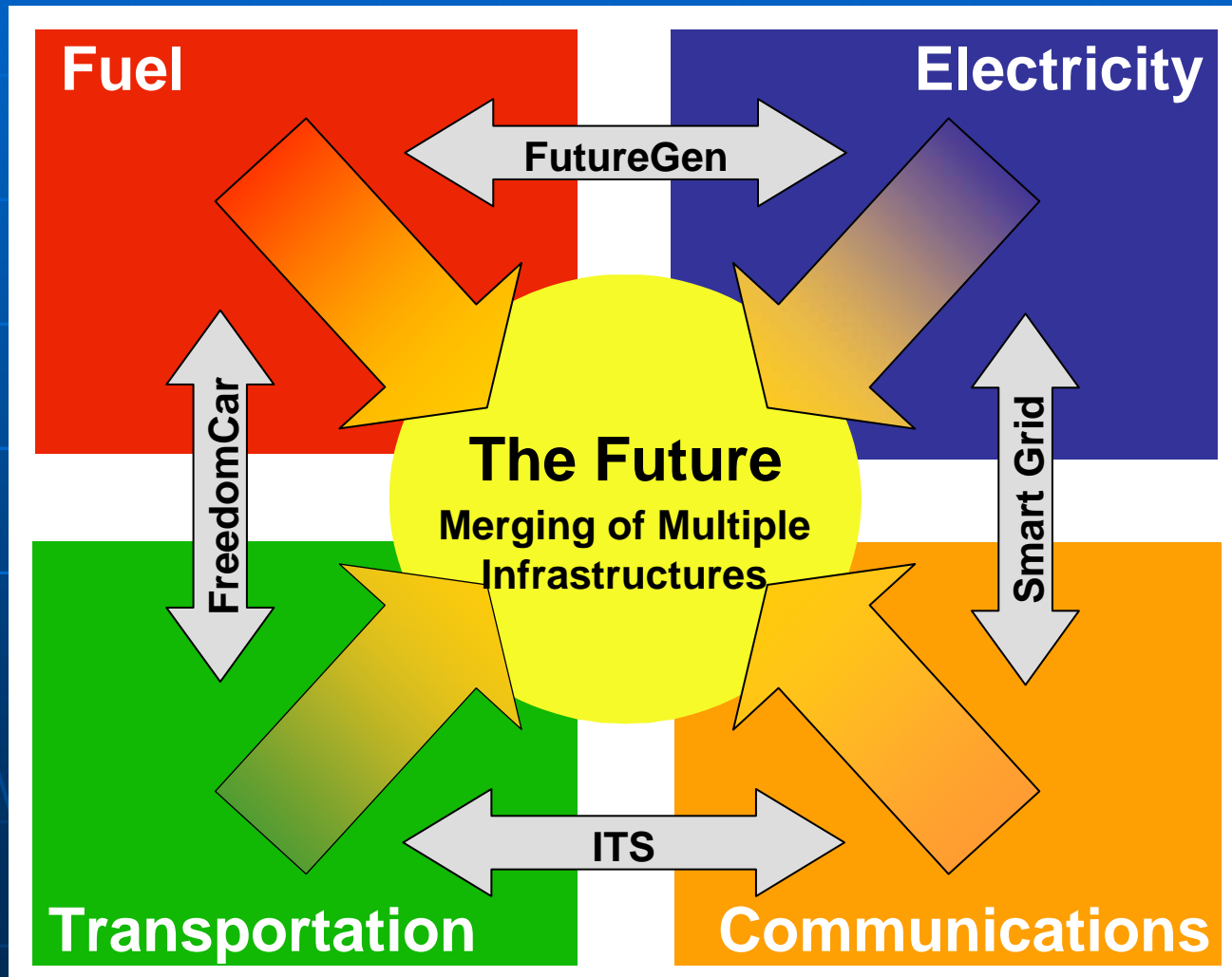
# Simultaneous Objectives

- Better Energy Security
- Reduced Traffic Congestion
- Cleaner Environment
- Safer Operations
- Protected Critical Infrastructure

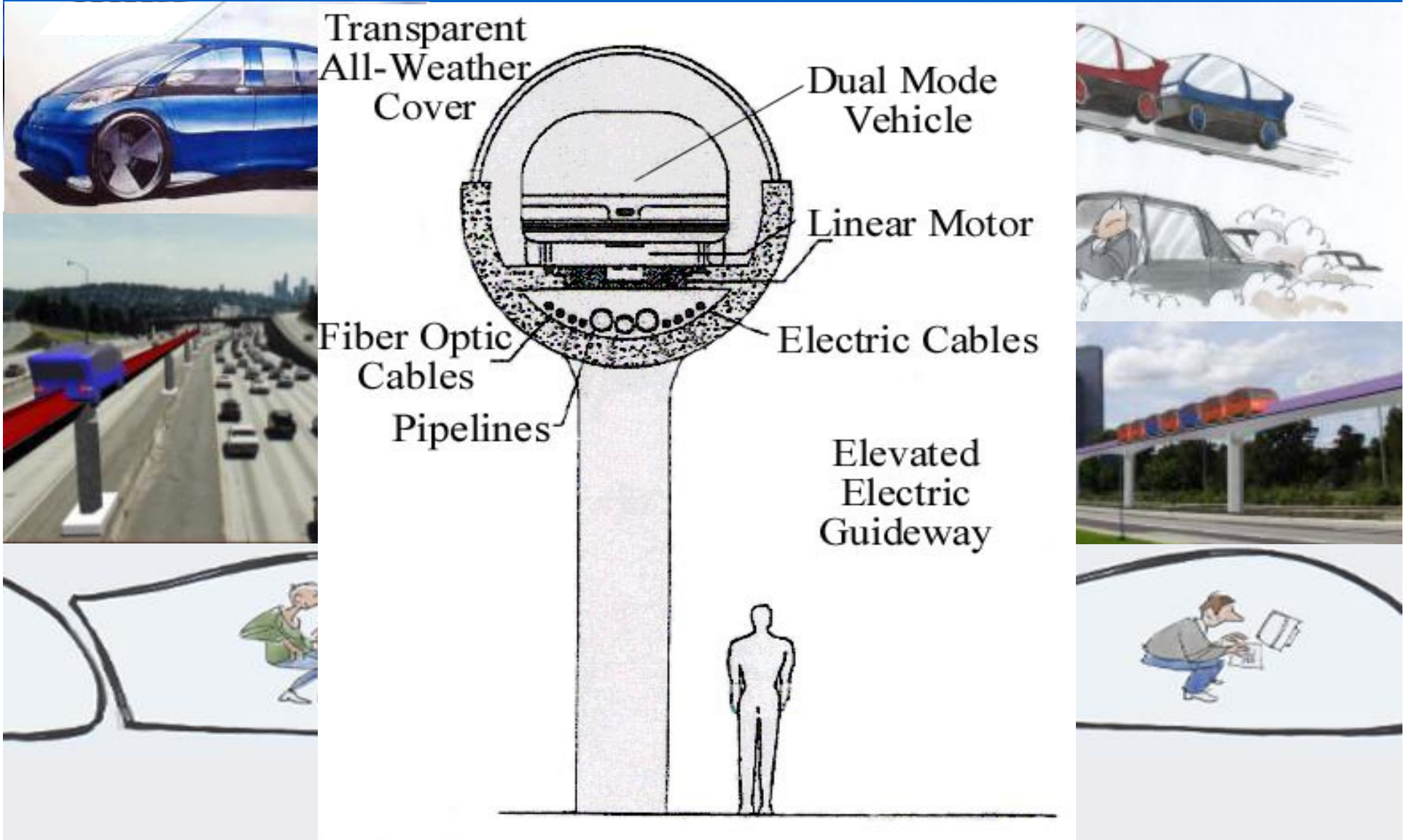
# Simultaneous Objectives

- Better Energy Security
  - Reduced Traffic Congestion
  - Cleaner Environment
  - Safer Operations
  - Protected Critical Infrastructure
- 
- Continued Economic Growth
  - Personal Mobility & Freedom
  - Long Term Sustainability

# New System Architecture



# Dual-Mode Vehicles



Sources: Ruf International and 2020 Engineering

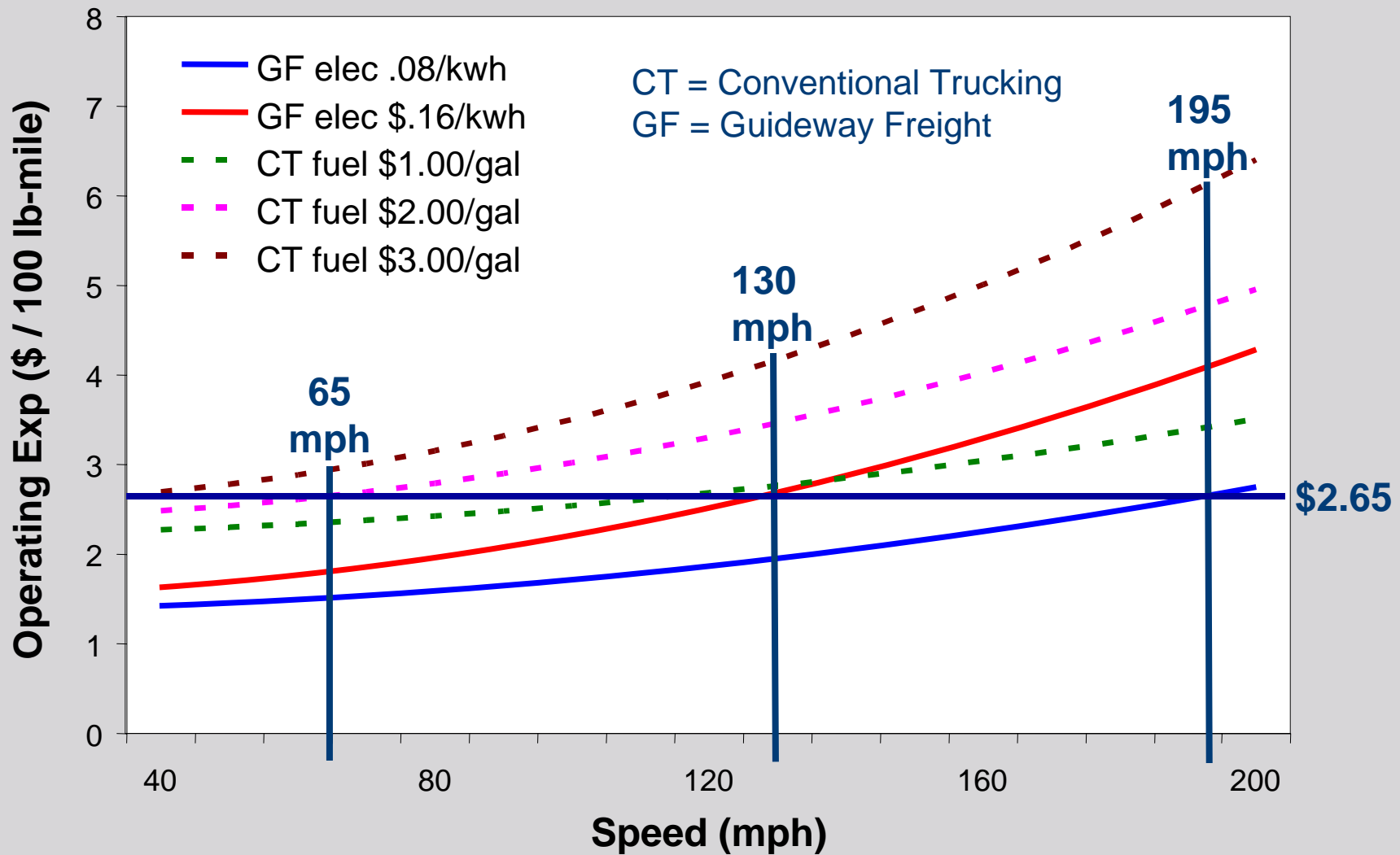
# Electric Guideway Features

- Reduced headway between vehicles (computer control)
- Higher speeds (60mph urban, 130 mph rural)
- Higher throughput capacity
  - 1 urban guideway = 8 conventional hwy lanes
  - 1 rural guideway = 24 conventional hwy lanes
- Reduced travel times
- Travel time reliability
- Faster turnover of "highway warehouse inventory" (reduced working capital – better economic efficiency)

# Driverless Freight



# Faster Freight Deliveries for the Same Operating Cost per 100 lb-Mile



# A Vision to Enable



# What was the impact of the Interstate Highway System?

- \$349 billion investment starting in 1956
- 40 years to implement
- \$6 benefit for every dollar invested
- 25% of national productivity gains over last 40 years
- Saved lives of 187,000 people
- Avoided injuries to nearly 12 million people
- Improved international competitiveness
- Enhanced international security
- Provided freedom of mobility



# Cost of Guideway Infrastructure

- Parallel 46,508 miles of Interstate
- \$40 million/mile urban (14,460 miles)
- \$15 million/mile rural (32,048 miles)
- **Total Cost = \$1.059 trillion**
- Add 9870 miles urban expressways @ \$40 million/mile = +\$394.8 billion
- **Total w/urban expwys = \$1.454 trillion**

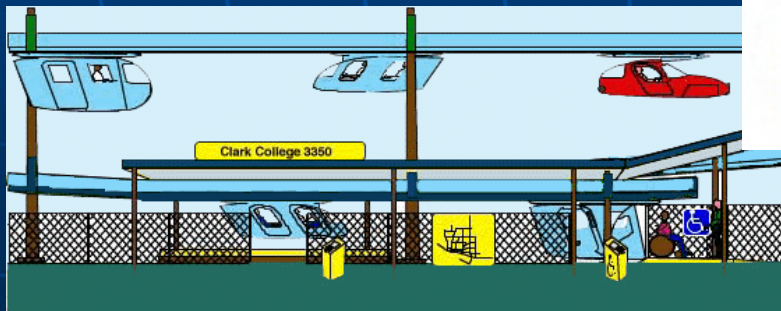
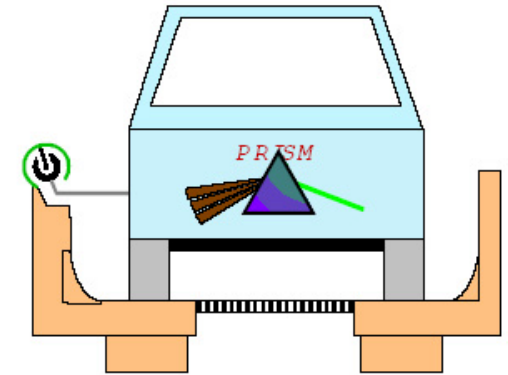
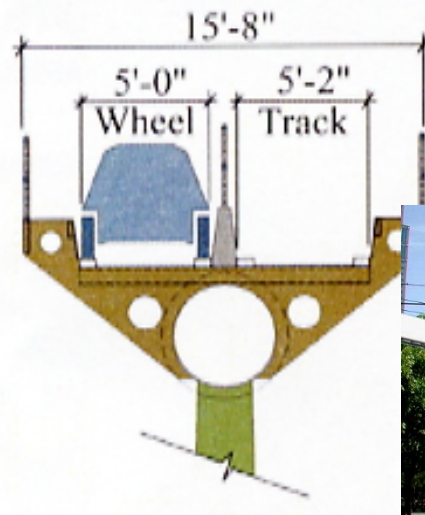
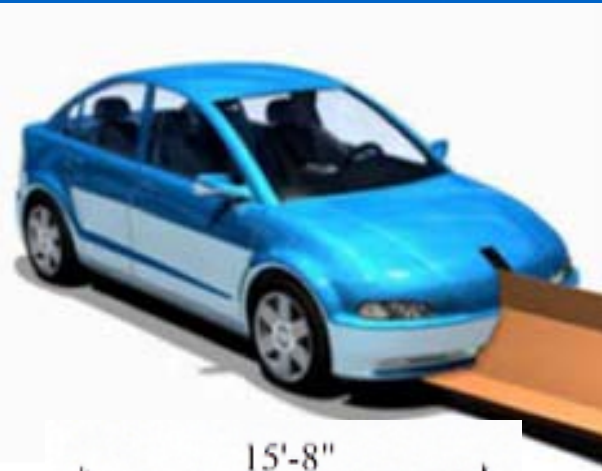
# Cost of Guideway Infrastructure

- Over 30 years ~ \$48.5 billion/yr
- \$89.57 net increase in annual household transportation expense
- For doubled speed, no congestion, no high speed accidents, no stress long distance travel in personal vehicle on demand

# US Impact of Guideways

	<u>Impact</u>	<u>Available</u>
■ Diversify fuel	<b>\$55.3</b>	<b>\$189 billion</b>
■ Reduce accidents	<b>\$37.9</b>	<b>\$230 billion</b>
■ Eliminate congestion	<b>\$18.7</b>	<b>\$64 billion</b>
■ Eliminate vehicle emissions	<b>\$5.0</b>	<b>\$17 billion</b>
■ Boost national productivity	<b>\$75.0</b>	<b>\$75 billion</b>
■ Other benefits - new technology exports, global sustainability, & economic growth	<b>?</b>	<b>?</b>
<b>Total Annual Value</b>	<b>&gt;\$192</b>	<b>&gt;\$534 billion</b>
<b>30 Yr Cum Value</b>	<b>&gt;\$5.76</b>	<b>&gt;\$16 trillion</b>

# Dual Mode Entrepreneurs Abound



# Solutions Impacts

Solution	Impact on			
	Fuel	Congestion	Emissions	Safety
Hybrid vehicles	less oil	↔	cleaner	↔
Natural Gas vehicles	replace oil	↔	cleaner	↔
Biomass vehicles	replace oil	↔	CO <sub>2</sub> balance	↔
Hydrogen fuel cell vehicles	replace oil	↔	H <sub>2</sub> O only	↔
Dual mode freight	replace oil	minimize	zero*	↑
Dual mode vehicles	replace oil	minimize, and increase travel speed	zero*	↑

\* from vehicle

# Next Steps

- Funding should be made available to study stationary electric grid powered transportation as an alternative architecture for the future
- A Sematech-equivalent public-private partnership model for collaborative development of the new architecture should be established
- Competition to develop dominant design in new electrified architecture
- Development of national standards



**CEETI Mission:** to ensure open collaboration in the development of a 21st century transportation system that improves energy security, safety, emissions, personal mobility, and productivity.

**CEETI Vision:** to become the recognized center-of-gravity for the electrified transportation architecture; an innovative research and development center dedicated to accelerating the use of electrified transportation in the United States and around the globe.



**Center for Energy, Environment, and Transportation Innovation**

**Thank You – Any Questions?**



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# Efficiency of Electric vs Hydrogen with Natural Gas as Primary Fuel

## Hydrogen Carrier

## Electric Carrier

Distribute Natural Gas	.98	.56	ICCGT Electric Generation
Reform Natural Gas to make Hydrogen	.80	.91	Electric Transmission
Compress Hydrogen	.80	.98	Transfer Power to moving Vehicle
Convert Hydrogen to Electricity in Fuel Cell	.60	.90	Consume Electricity in Motor
Consume Electricity in Motor	.90	.95	Magnetic Drag
Drive Train Efficiency	.92		
Energy Loss to heat in tires	.95		
	<b>29.6% Eff.</b>	<b>42.7% Eff.</b>	
	Useful Work moving People/Goods		