Creating a Renewable Community
A lifestyle vision for future neighborhoods

Terry Penney, Advanced Vehicles Technology Manager

NREL Visitor Center Power Lunch

May 21, 2007

A Reminder –
Transportation and Energy Challenges

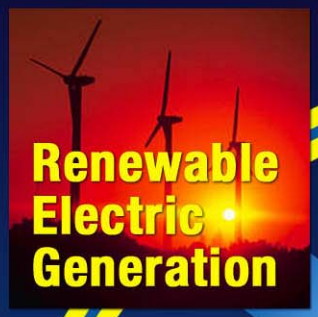
- Increasing demand for a finite resource - petroleum
- Fuel-economy gains from improved technology have been offset by:
  - More people
  - More and bigger cars
  - More vehicle miles traveled

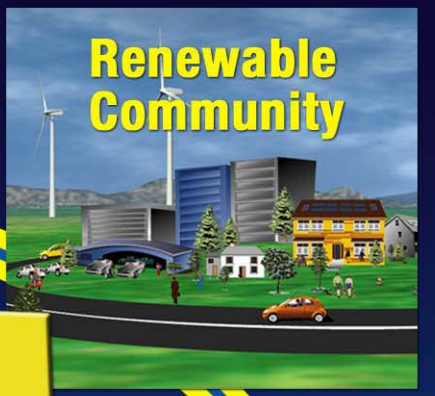
The Civic Hybrid has a new, more advanced version of Honda's patented Integrated Motor Assist system.

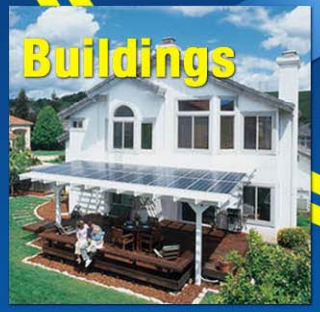
So, what are we doing?

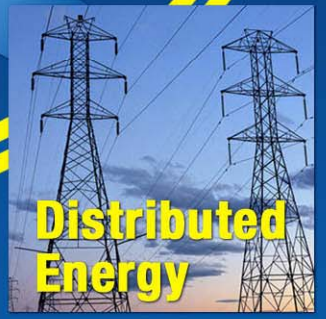
…….Changing the Paradigm

Plug-In Vehicles Are Key Steps to a Renewable Community







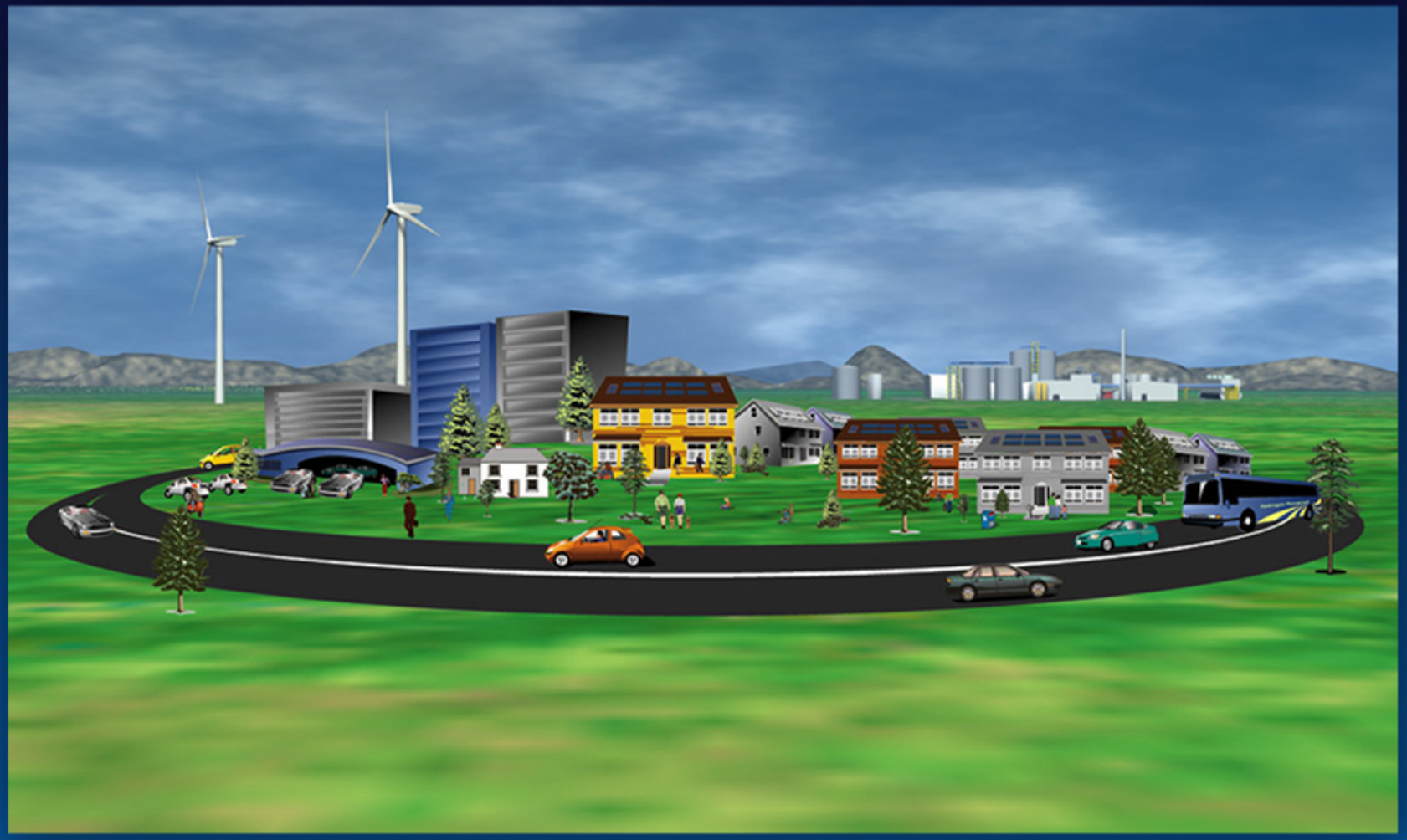


An NREL systems perspective enables the "Renewable Community"

Connecting the Pieces

Vehicles and Fuels + Energy Smart Buildings + Renewables =

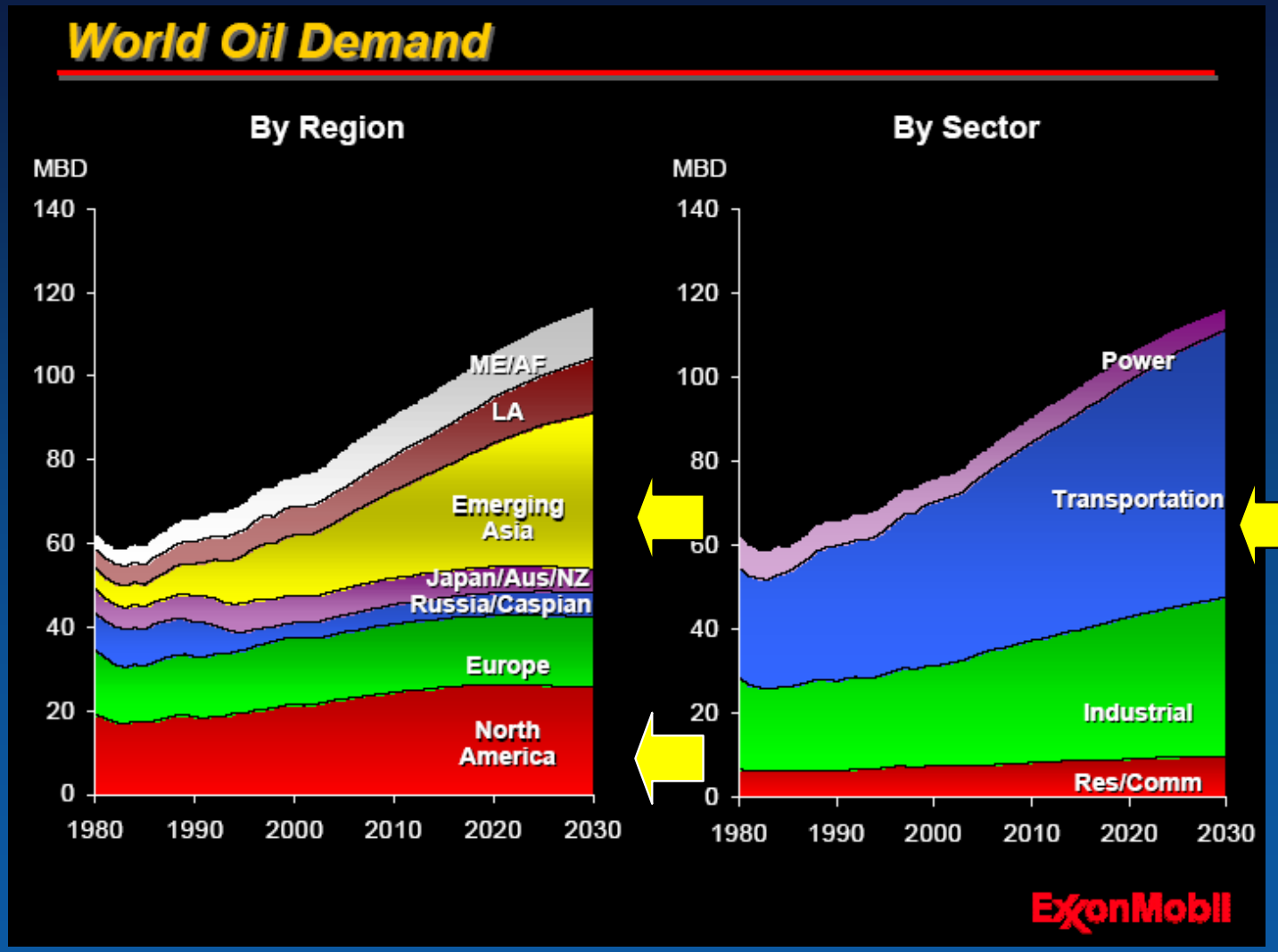
= A Renewable Community



A Pipe dream or possibility? Communities that:

- Require minimal power for their homes and offices
- Draw most of their needed electrical power from local, renewable generation
- “Fuel” their vehicles with that power and renewable fuels

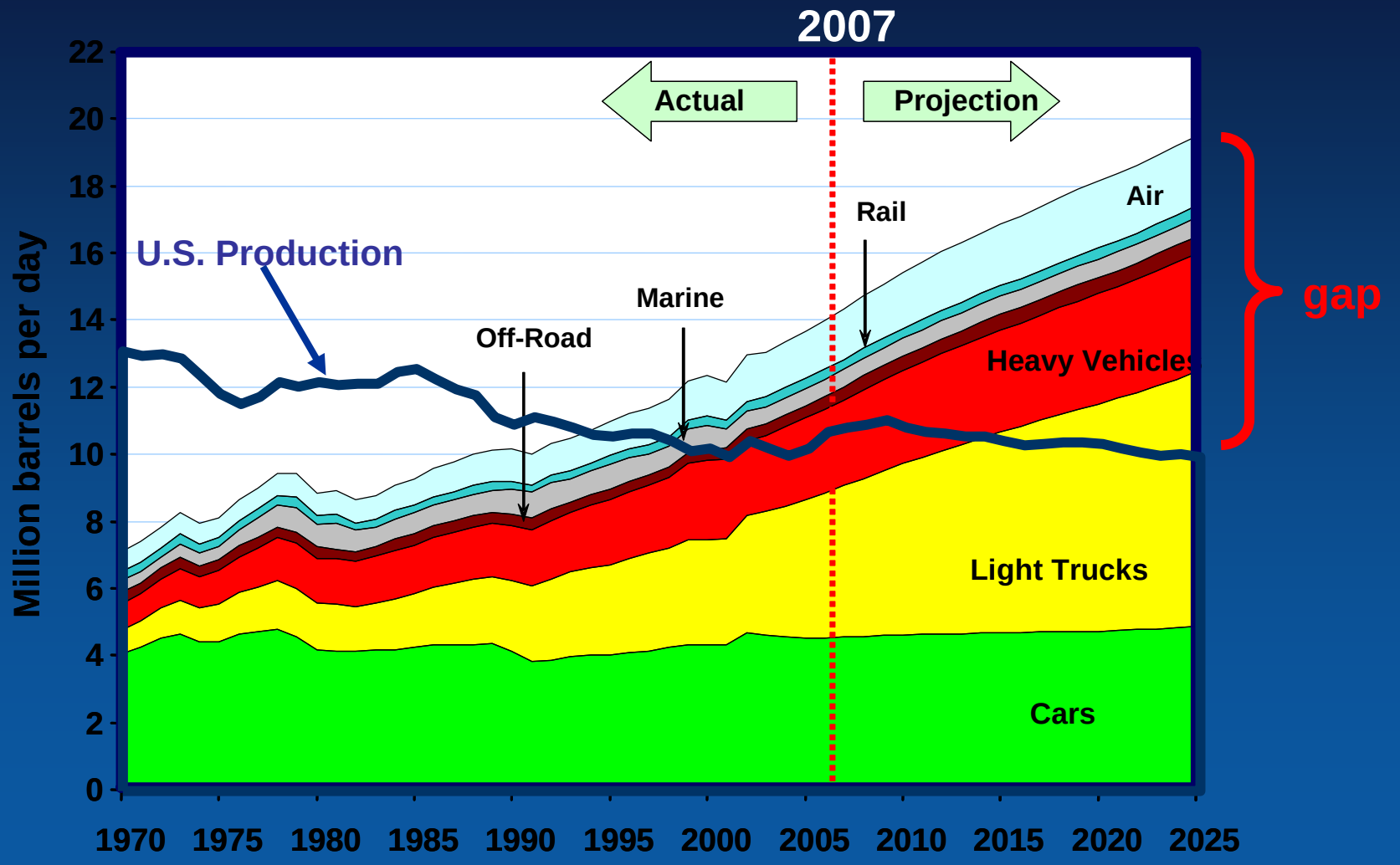
Globally, oil demand is driven by growth in transportation in Asia and America



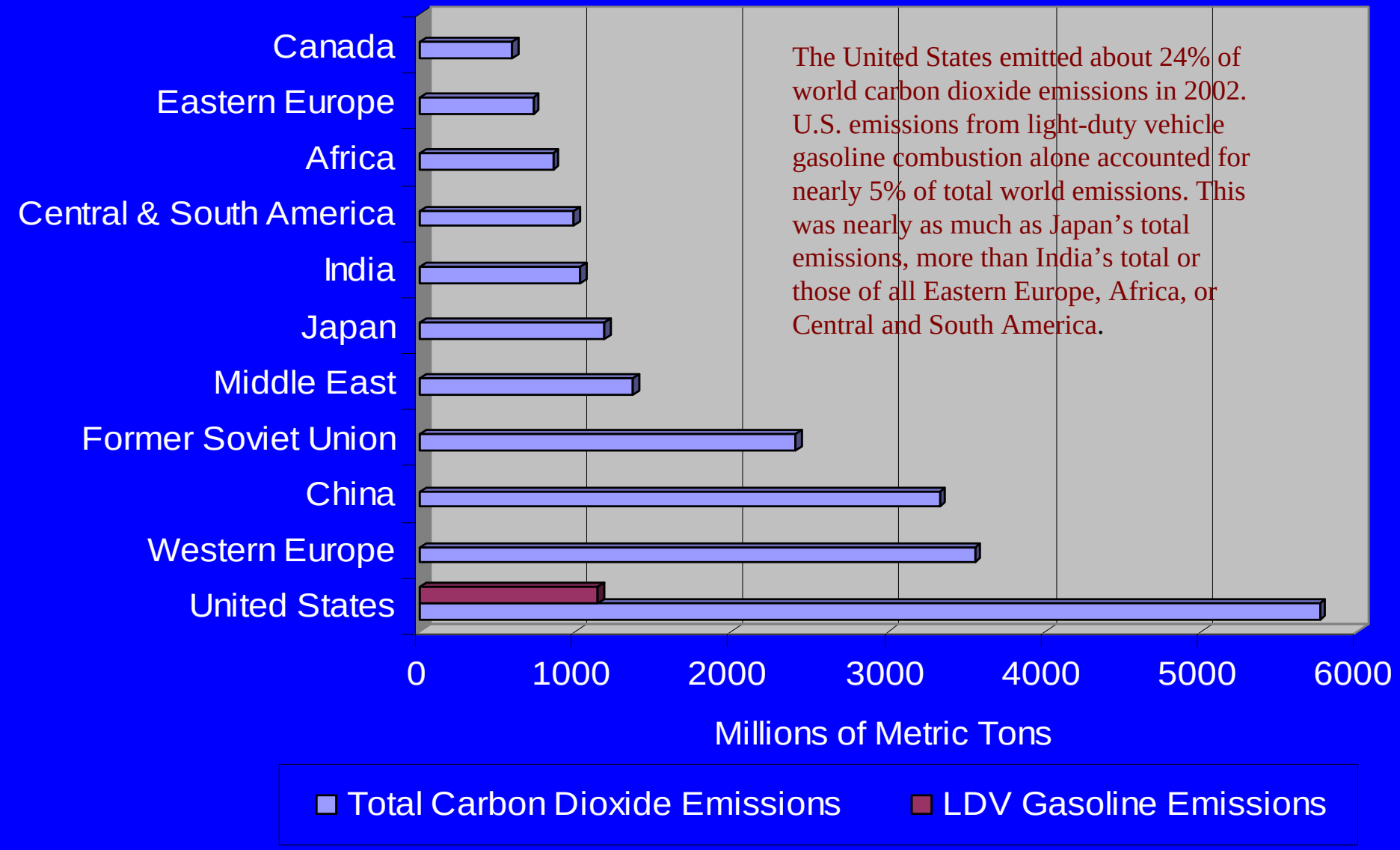
Source: The Outlook for Energy: 2030 View, ExxonMobil

US Demand for Fuels Outstrips Supply

Light-duty vehicles are driving the growth in oil demand



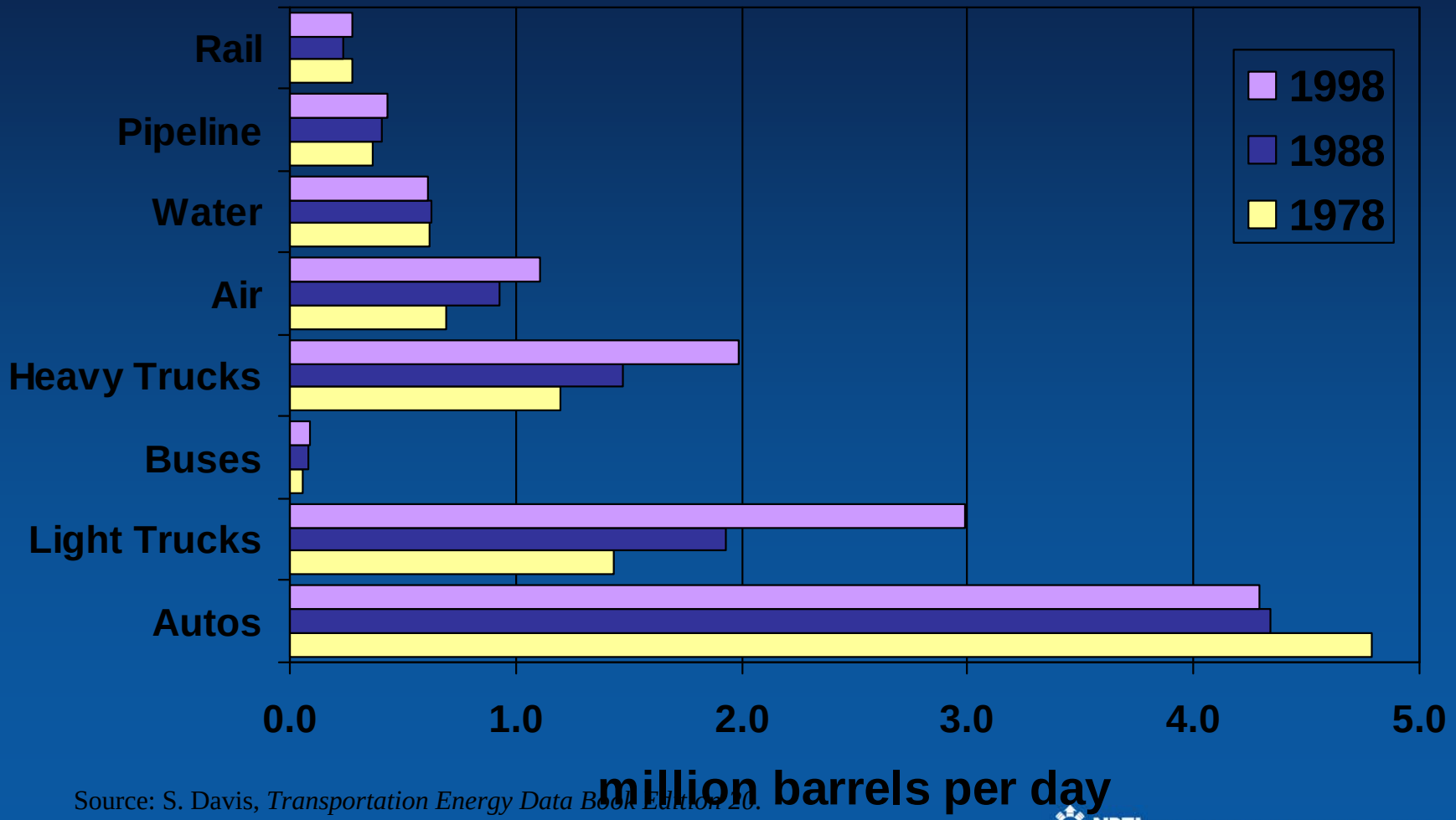
World Carbon Dioxide Emissions 2002



The United States emitted about 24% of world carbon dioxide emissions in 2002. U.S. emissions from light-duty vehicle gasoline combustion alone accounted for nearly 5% of total world emissions. This was nearly as much as Japan's total emissions, more than India's total or those of all Eastern Europe, Africa, or Central and South America.

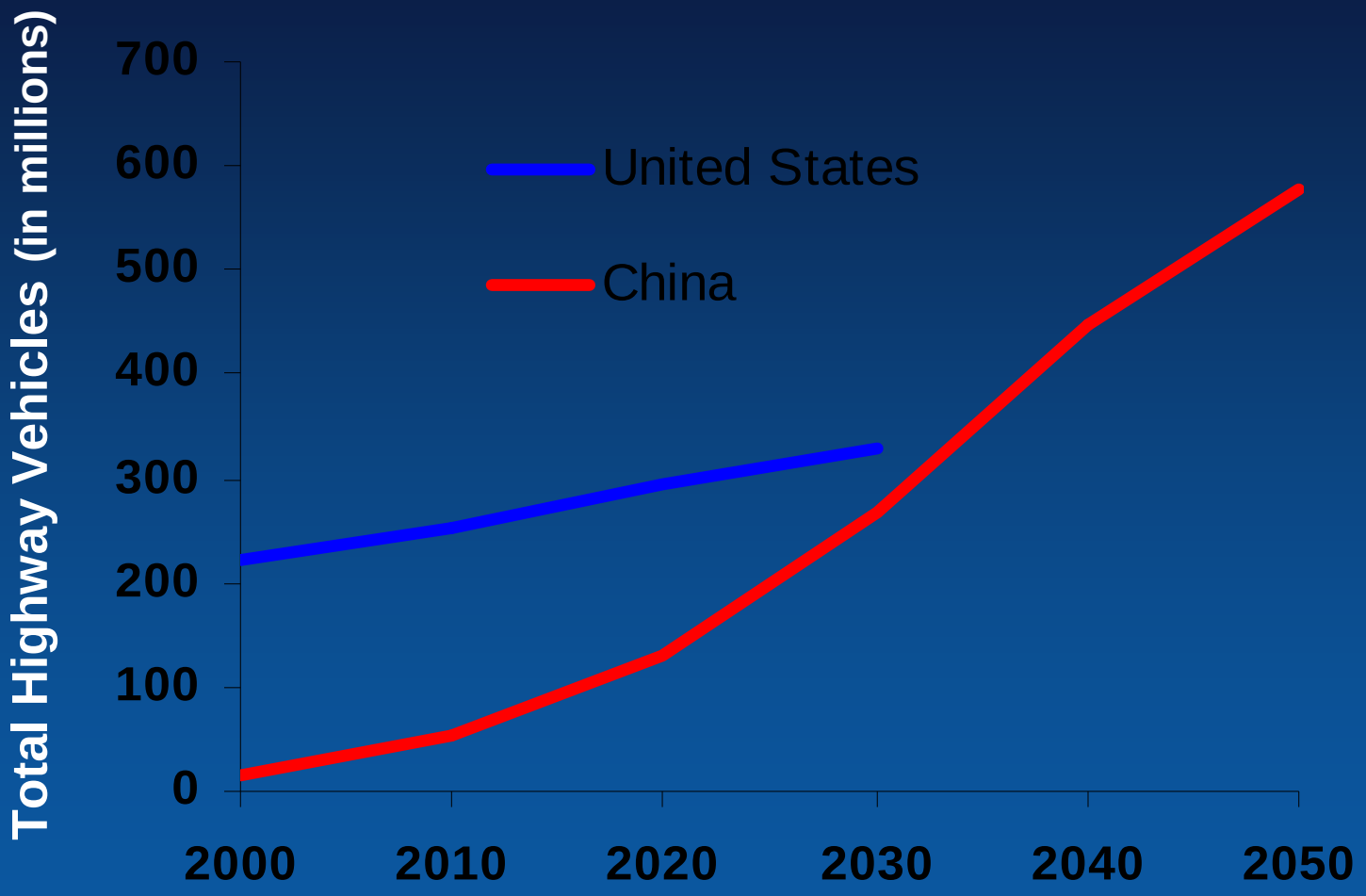
Source: Table 11.1, *Transportation Energy Data Book, 25 Edition,* based on Tables A10 and A11, *International Energy Outlook 2005*. LDV portion based on Tables 11.4 and 11.5

USA Transportation Energy Use



Source: S. Davis, *Transportation Energy Data Book Edition 20.*

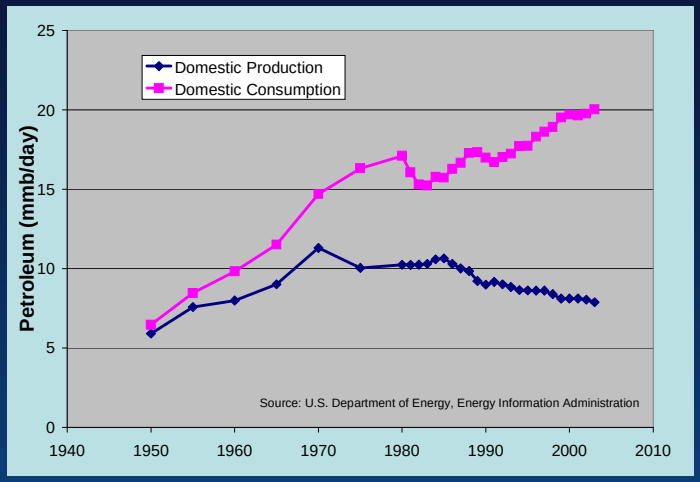
China: Rapid Growth in Vehicle Numbers

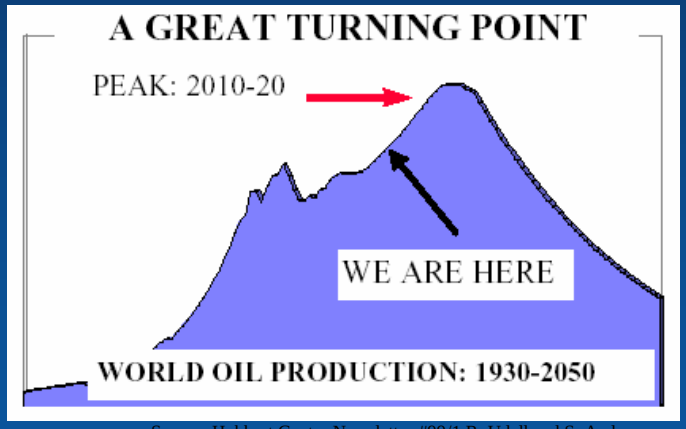


Source: USA Data: EIA, *Annual Energy Outlook 2007*. China Data: Argonne National Laboratory, *"Projection of Chinese Motor Vehicle Growth,"* 2006.

The Perfect Storm

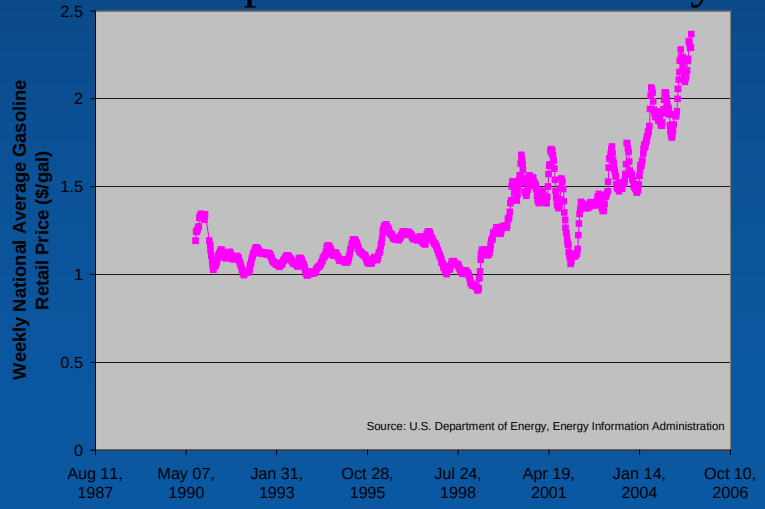
- U.S. Petroleum consumption is steadily growing and domestic production will continue to decline
- World oil production will likely peak within the next 5-15 years
- Recent increase in gasoline price is indicator of growing tension between supply and demand





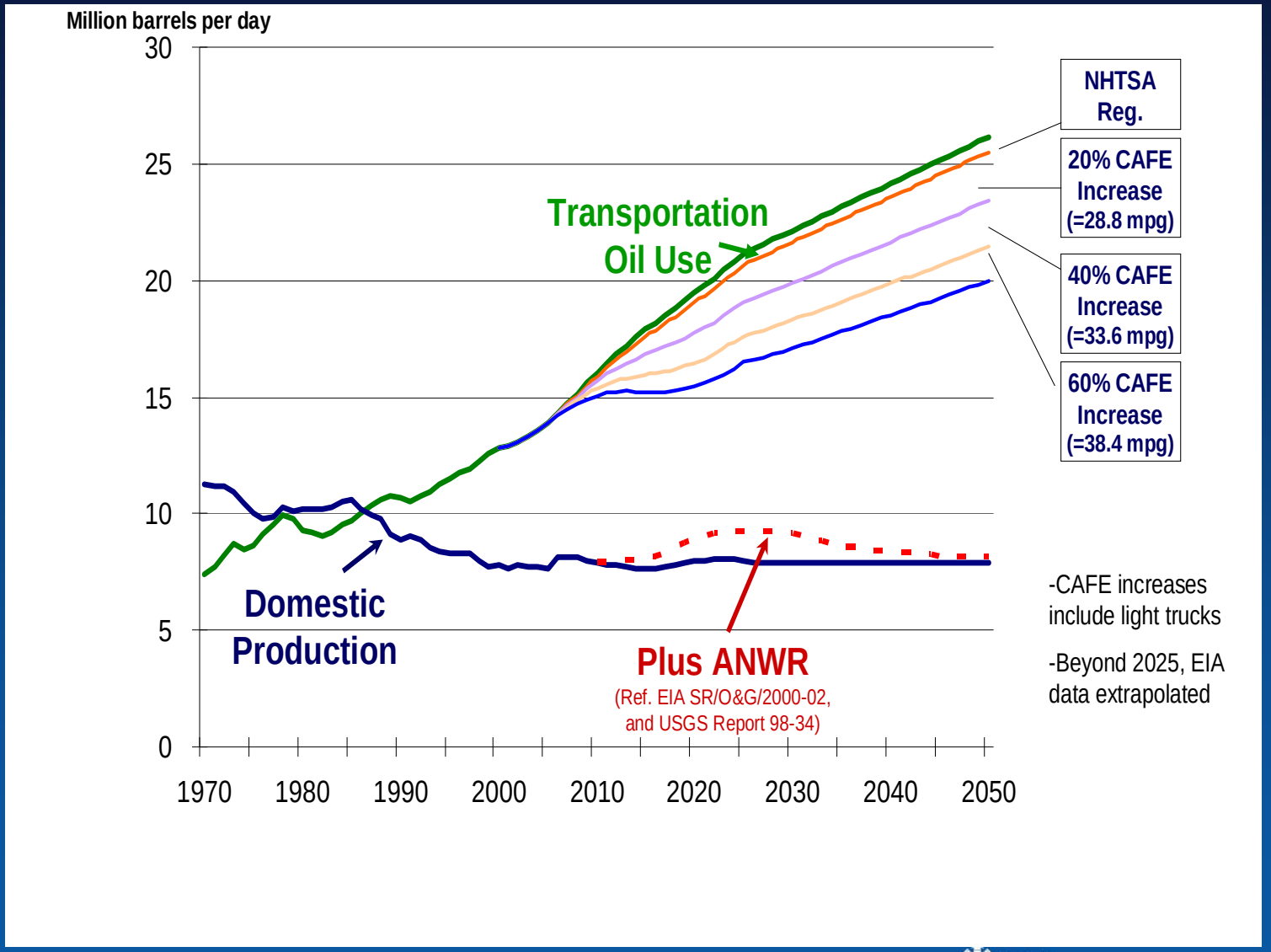
Source: Hubbert Center Newsletter #99/1 R. Udall and S. Andrews

Gasoline price - 75% rise in 5 years!



What's our solutions?

Impact of efficiency on oil use, CAFÉ examples



Fuel Switching and Efficiency Pathways and Opportunities

Biomass Conversion
Efficient conversion and feedstock development

Gasification, Capture, & Sequestration
Validation of sequestration
Integration with gasification processes

Biomass

Coal & Unconv. Hydrocarbons

Nuclear

Renewable

Carbon Fuels

Hydrogen

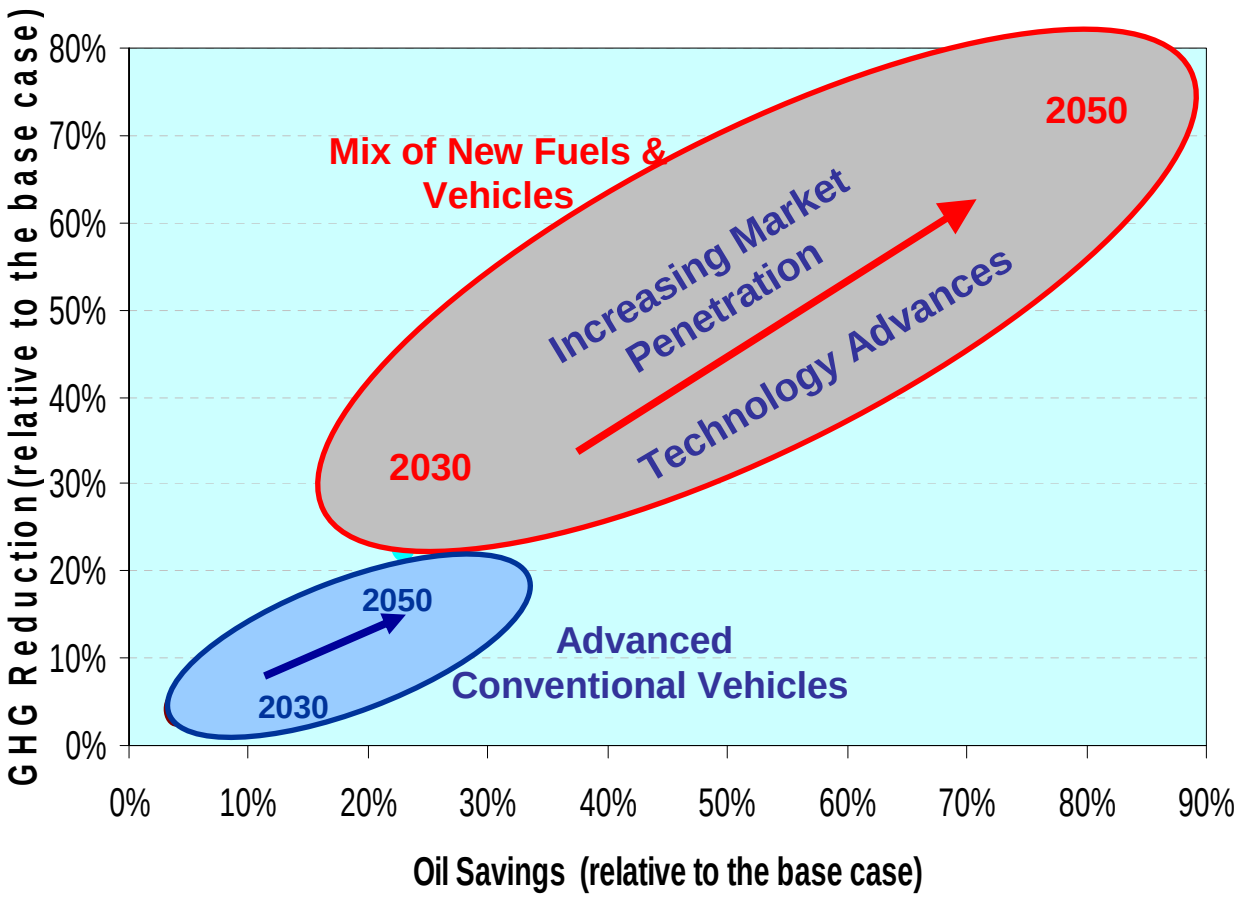
Electricity

Hydrogen RD&D
Cost & energy density of on-board storage & use
Distribution and carbon-free production infrastructure

Energy Storage
High energy and high capacity materials

Vehicle Efficiency
Advanced combustion, lightweight materials, reduced parasitic losses

Significant oil savings and Green House Gas reductions are possible through multiple pathways



Source: Multi-Path Transportation Futures Study, Phase 1: December 21, 2006

- Internal combustion vehicles will continue through 2050
- Incremental advances can yield 27% oil savings
- Benefits of combining technologies exceeds benefits of individual technologies

Advanced Vehicles and Fuels Options

Conventional Vehicles

Hybrid Electric Vehicles

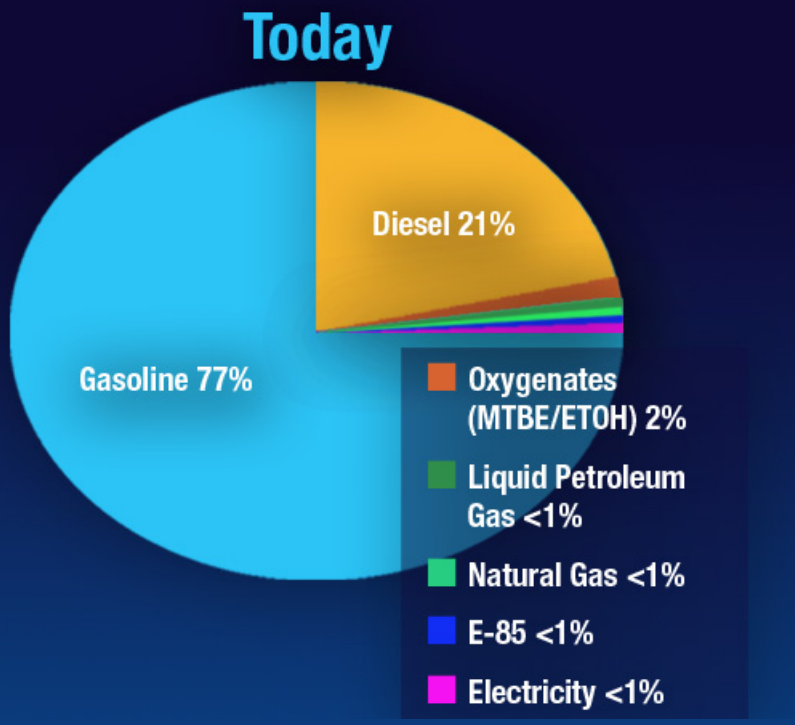
Plug-in Hybrid Vehicles

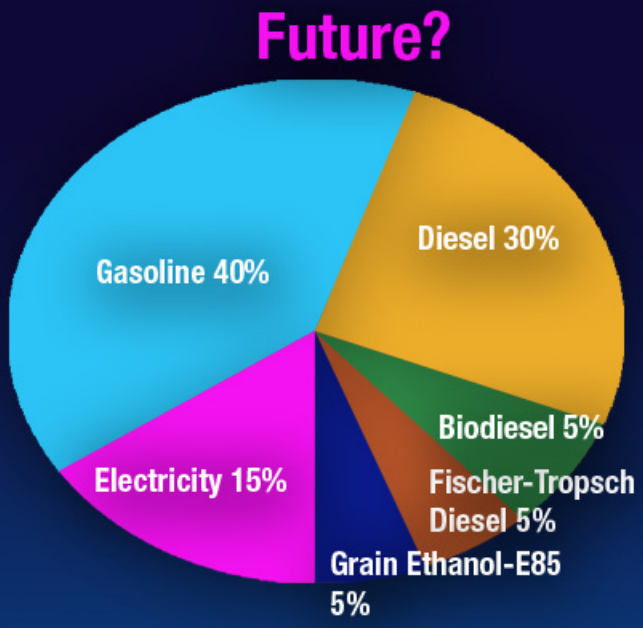
Hydrogen Powered Vehicles (including Fuel Cells)

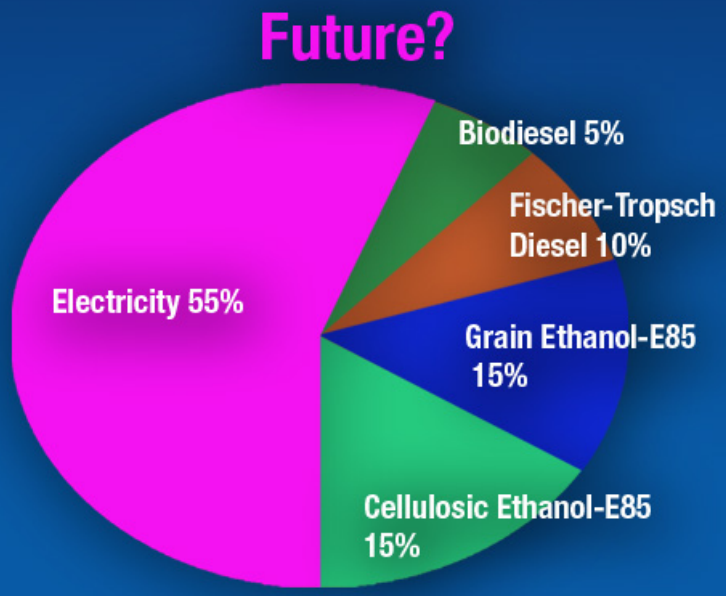
Gasoline, Diesel, Adv. Carbon-based Fuels, Biofuels: Ethanol from Starch, Biodiesel & Cellulosic Ethanol, Electricity, Natural Gas

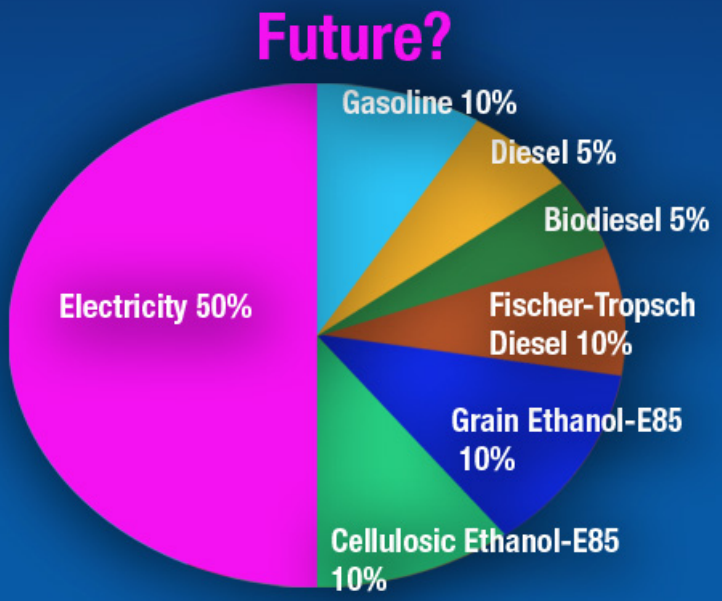
Hydrogen

Renewable Hydrogen


Today
Diesel 21%
Gasoline 77%
Oxygenates (MTBE/ETOH) 2%
Liquid Petroleum Gas <1%
Natural Gas <1%
E-85 <1%
Electricity <1%


Future?
Gasoline 40%
Diesel 30%
Biodiesel 5%
Fischer-Tropsch Diesel 5%
Grain Ethanol-E85 5%
Electricity 15%

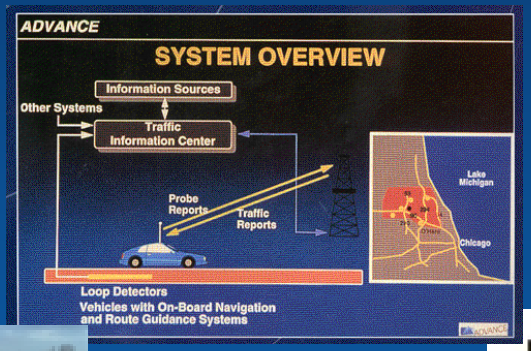

Future?
Biodiesel 5%
Fischer-Tropsch Diesel 10%
Grain Ethanol-E85 15%
Cellulosic Ethanol-E85 15%
Electricity 55%


Future?
Gasoline 10%
Diesel 5%
Biodiesel 5%
Fischer-Tropsch Diesel 10%
Grain Ethanol-E85 10%
Cellulosic Ethanol-E85 10%
Electricity 50%

Transportation Pathways:

What types of vehicle's in a Renewable Community?

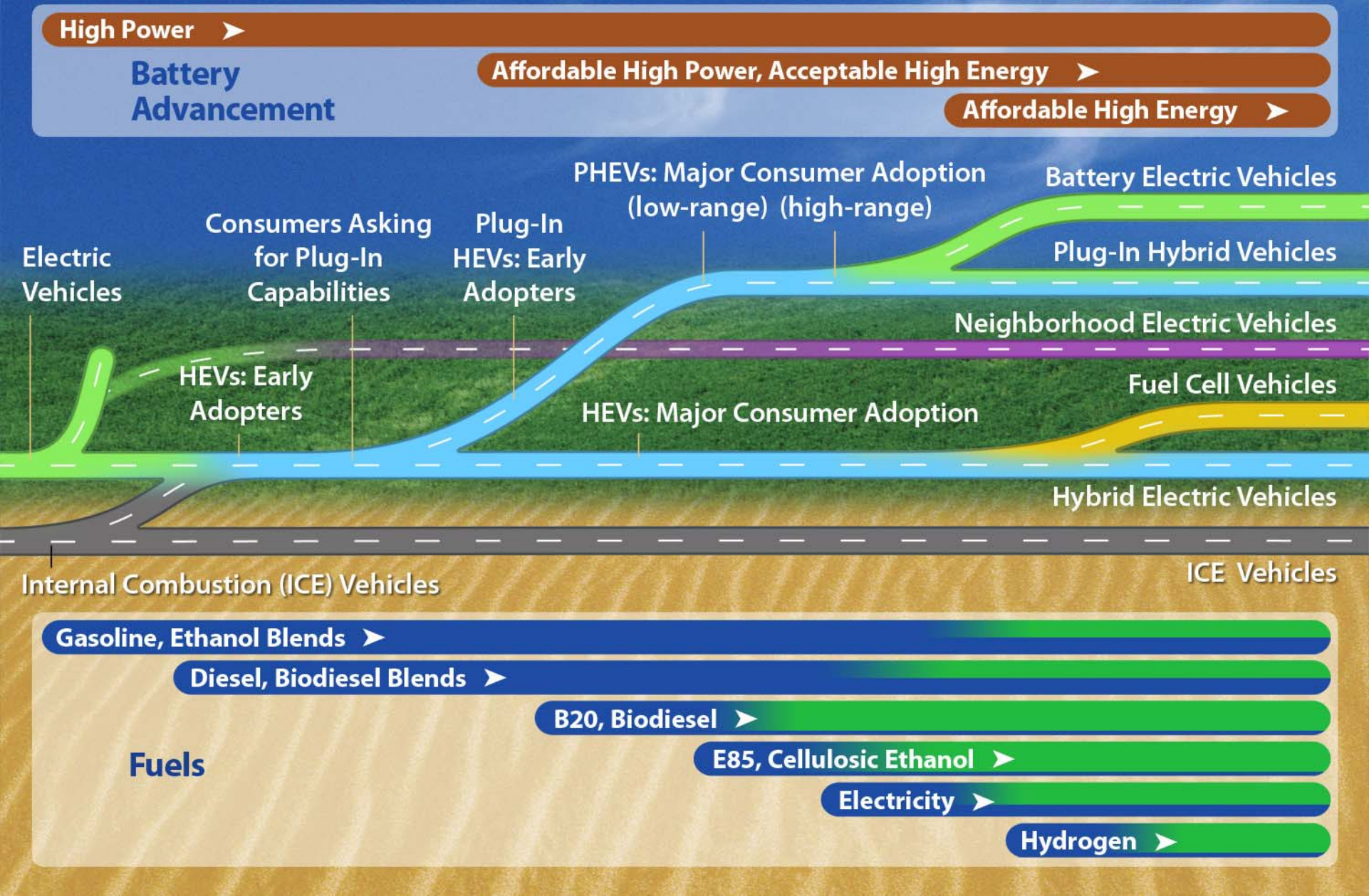
- Electric Vehicles + Bi-directional plug-in
- Hybrid Electric Vehicles + Plug-in
- Fuel Cell Vehicles + Plug-in
- CNG/LNG Vehicles + home refueling
- Clean Diesel / biodiesel
- Car share program
- Others . . .



Vision of Future Transportation

National Renewable Energy Laboratory • Concept - Ahmad Pesaran • Illustration - Dean Armstrong • NREL/GR-540-40698

NREL

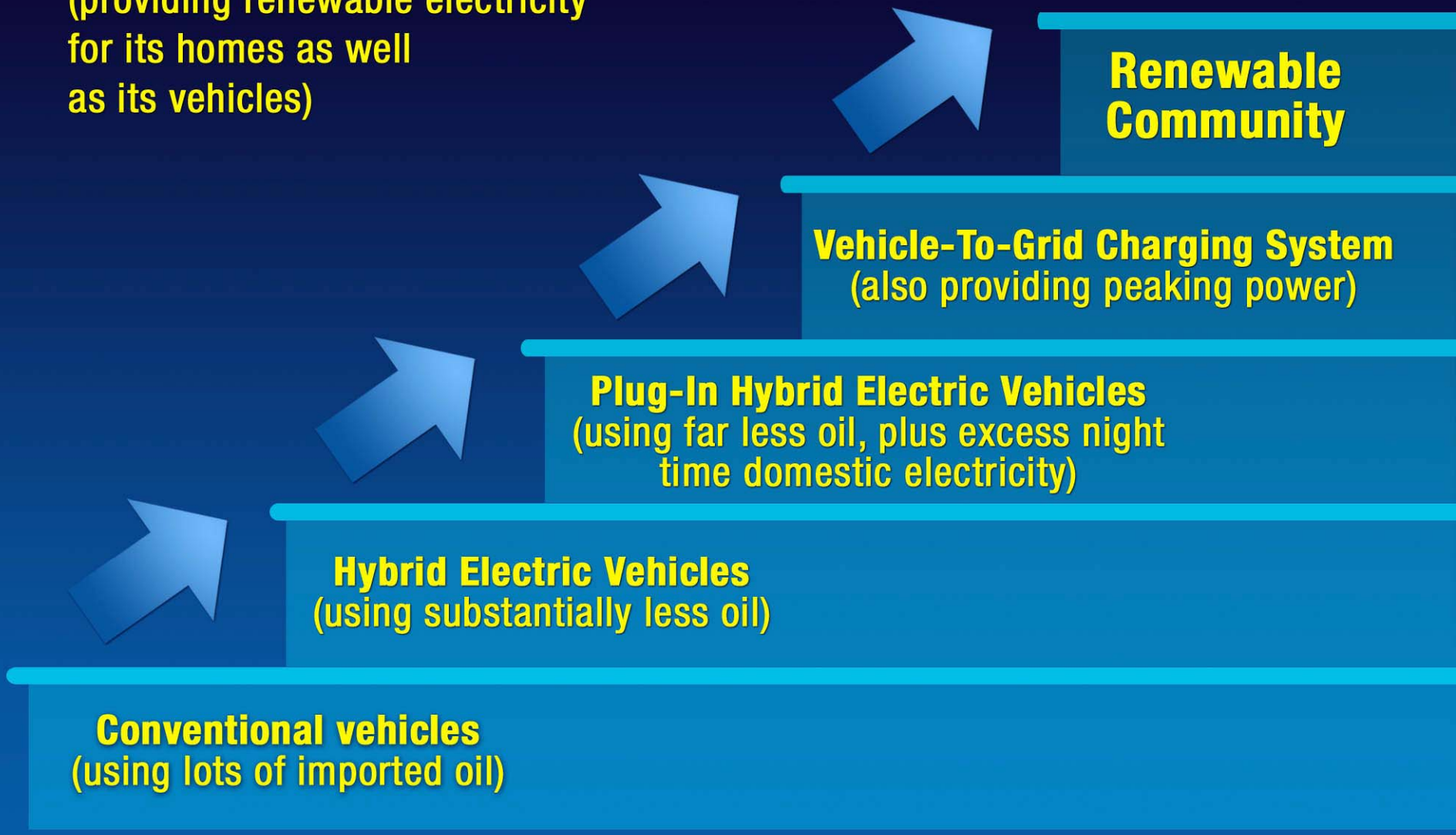


Key Step --- Need to Plug it in

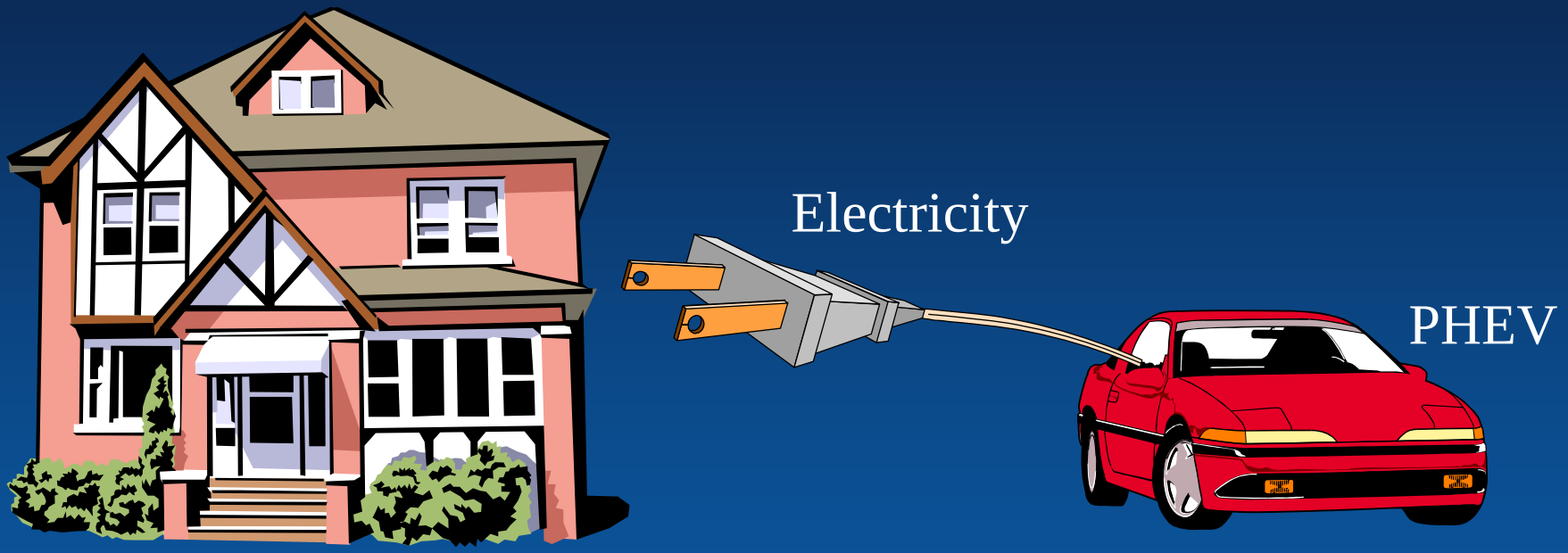
- Very limited options for liquid fuel renewable energy for internal combustion
- We will need to make all the biofuels we can, but that won't be nearly enough
- Electric power operation opens up a wide range of renewable and domestic fossil energy sources

Logical Steps Up to a Renewable Future

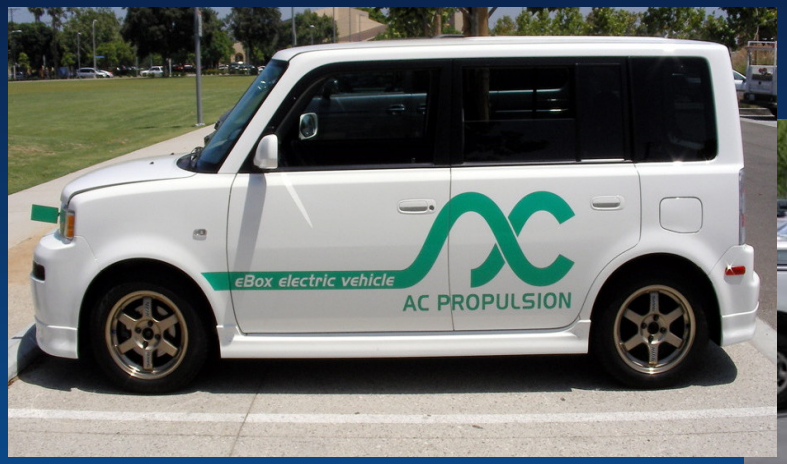
(providing renewable electricity
for its homes as well
as its vehicles)



Home Fueling



Connecting Cars with the Power Grid Creates Value

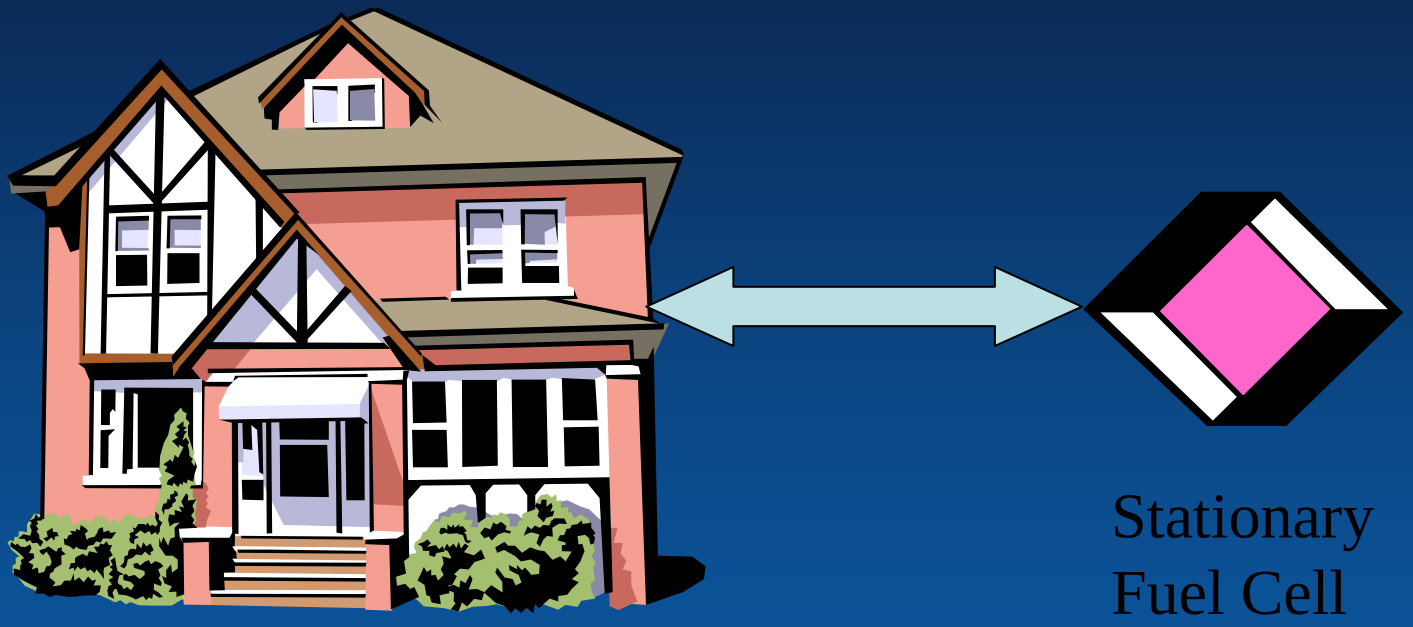


Bi-directional Power Grid Interface

Personal transportation vehicles used only 1 hour/day on average
What to do for the other 23 hours? Put your car to work for you!

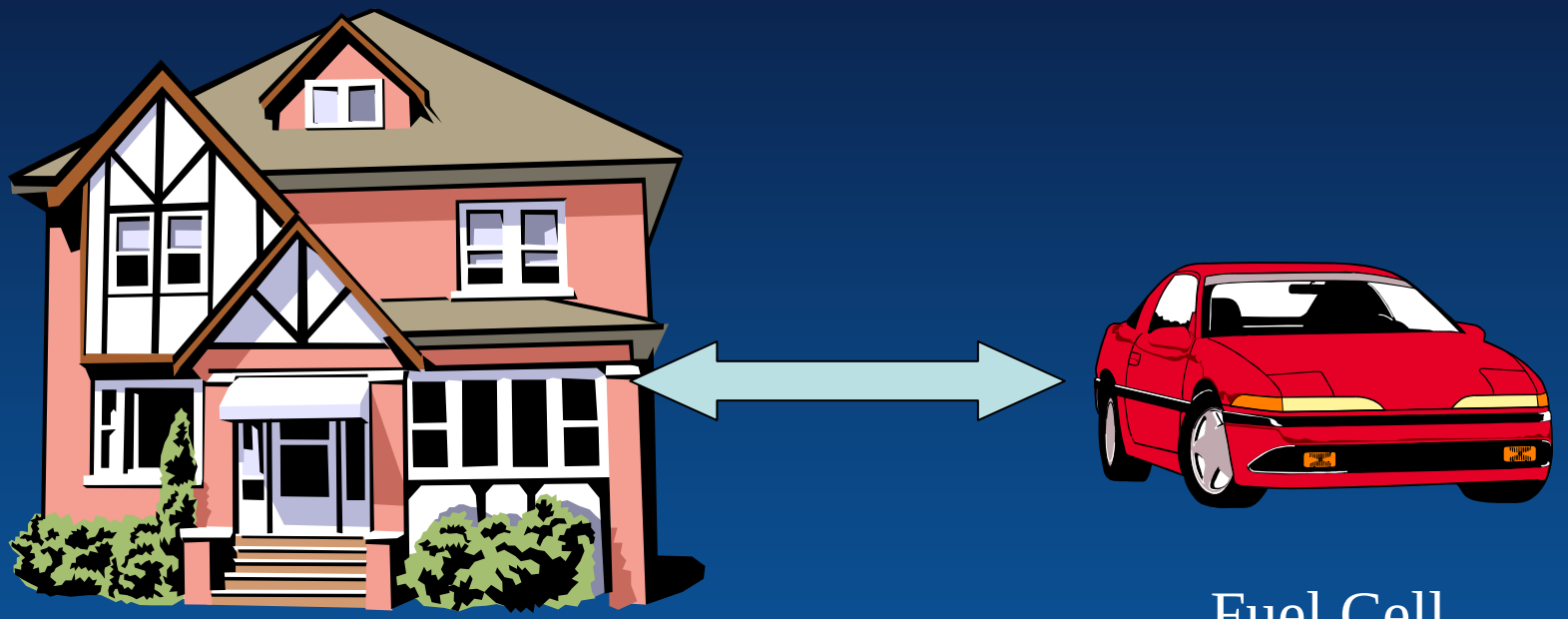
The Car of the Future May Help Power Your Home.
"Electrified transportation will soon be a necessity rather than an option" EPRI

This Scenario Could be Common



Stationary
Fuel Cell

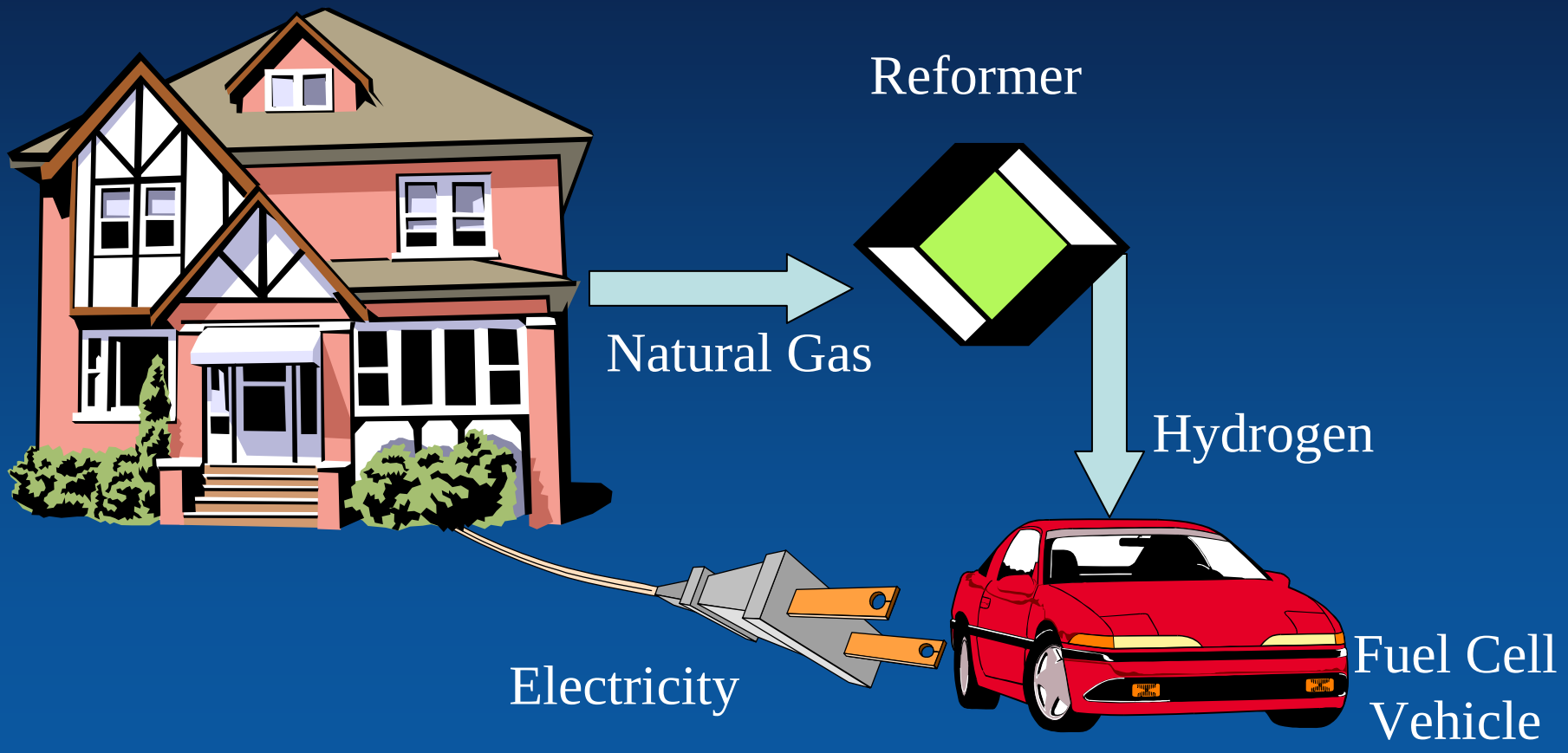
Why not Adopt this Scenario?



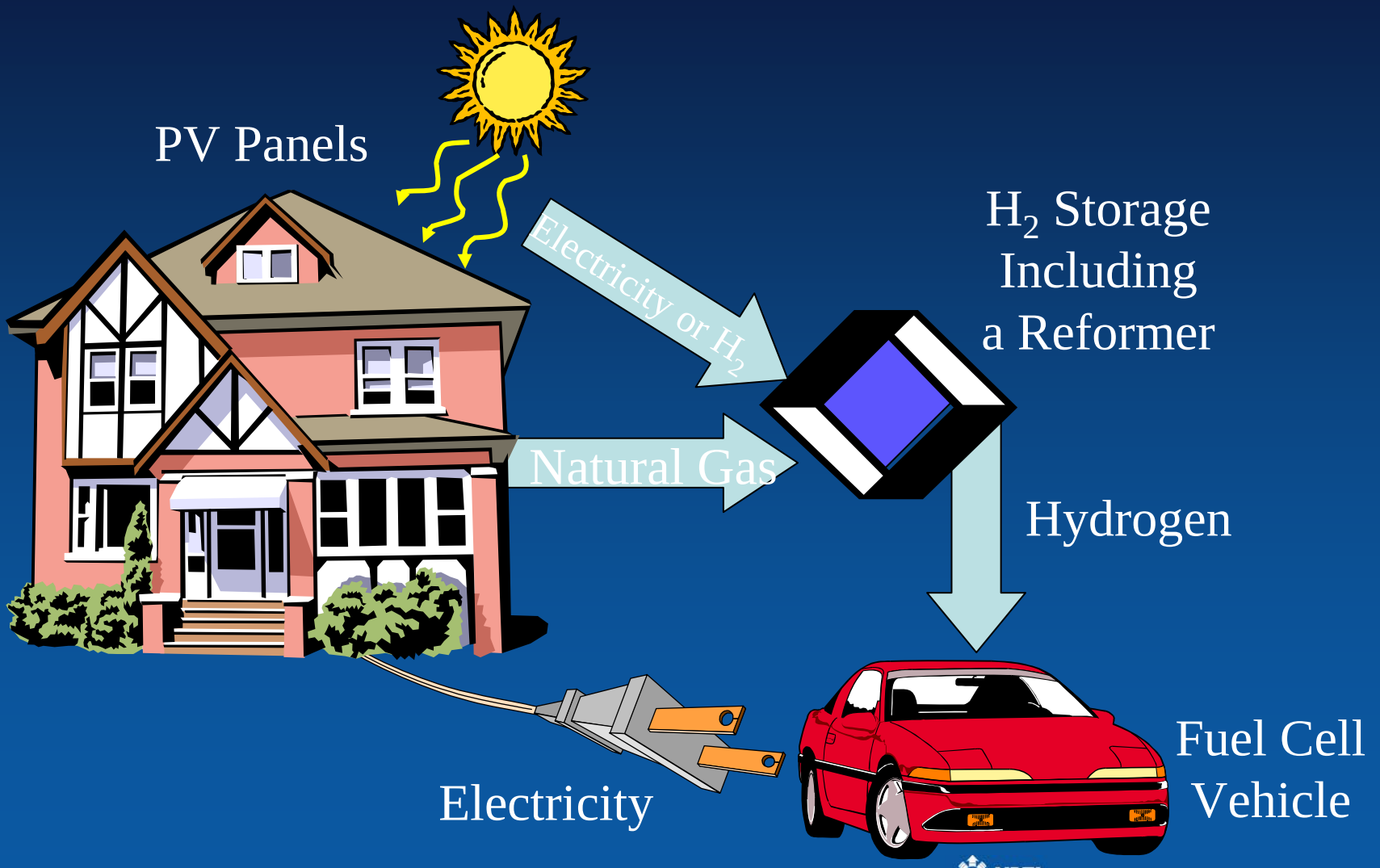
Fuel Cell
in Motion

Example of fuel cell for a vehicle application

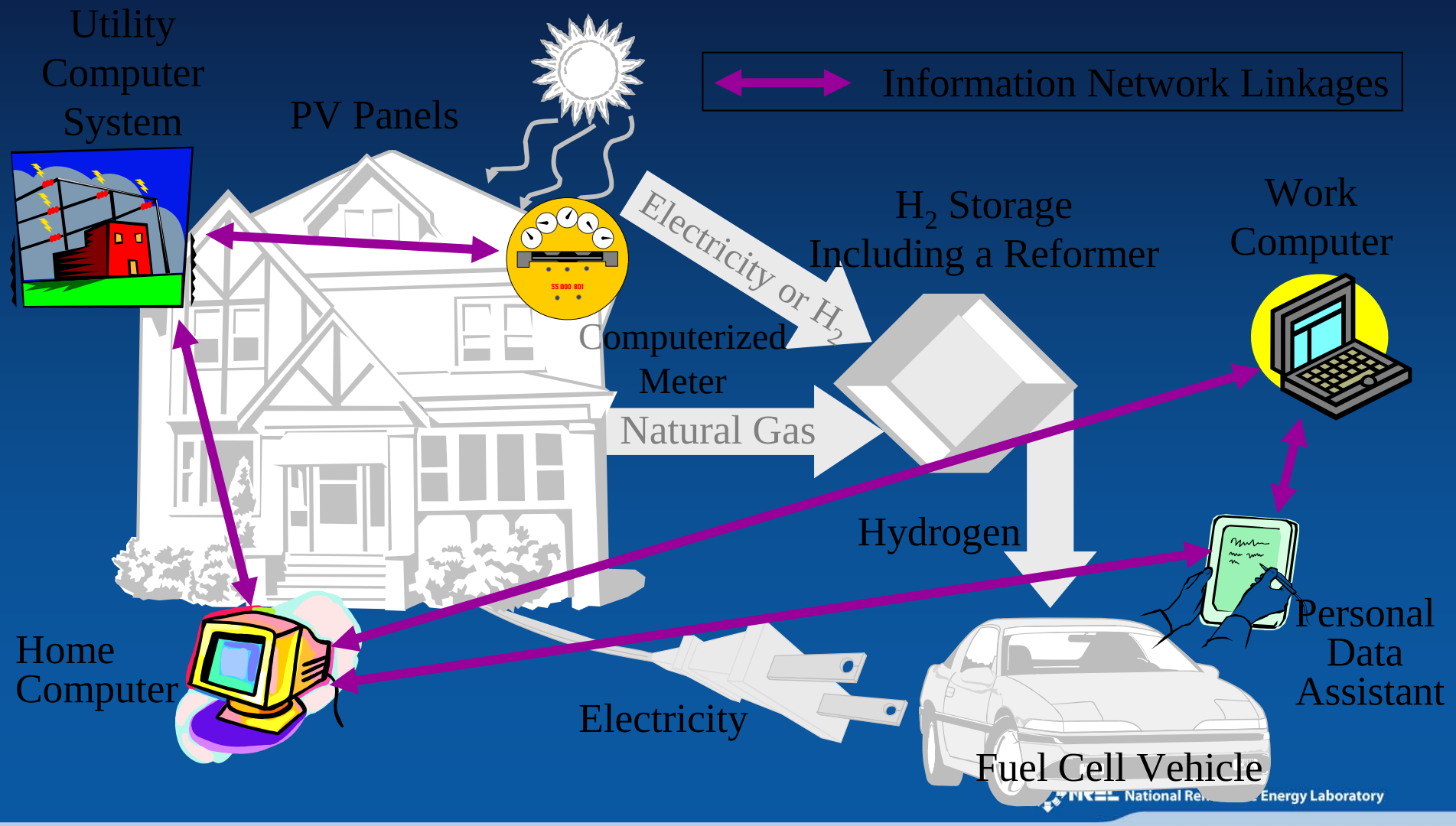
Distributed Power



Ultimate Docking Station



Information Network within the Ultimate Docking Station



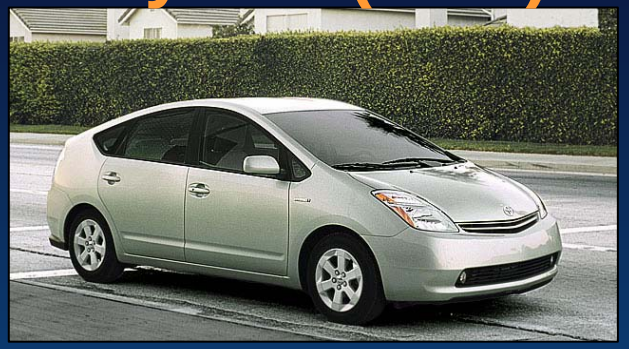
From Hybrids to Plug-in Vehicles

A Plug-in Hybrid Electric Vehicle (PHEV) uses today's hybrid technology, adding a bigger battery and the capability to plug into your garage (or elsewhere) to fuel the battery with electricity.

At 3 cents/mile to fill up an electric vehicle, compared to about 13 cents/mile to fill up a gasoline vehicle today, why not make a shift?

Hybrid Electric compared to Plug-in Hybrid

Hybrid (HEV)

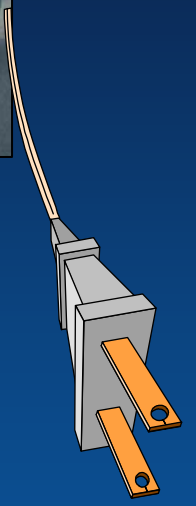


- Smaller battery
- Recharge
  - Regeneration
  - Engine

Increased MPG

All energy still from gas

Plug-In Hybrid (PHEV)

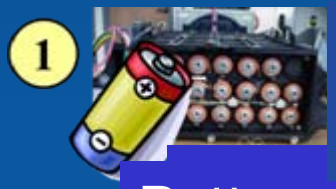


- Larger battery
- Recharge
  - Regeneration
  - Plug

Greatly Increased MPG

Energy from electric grid & gas

Challenges:

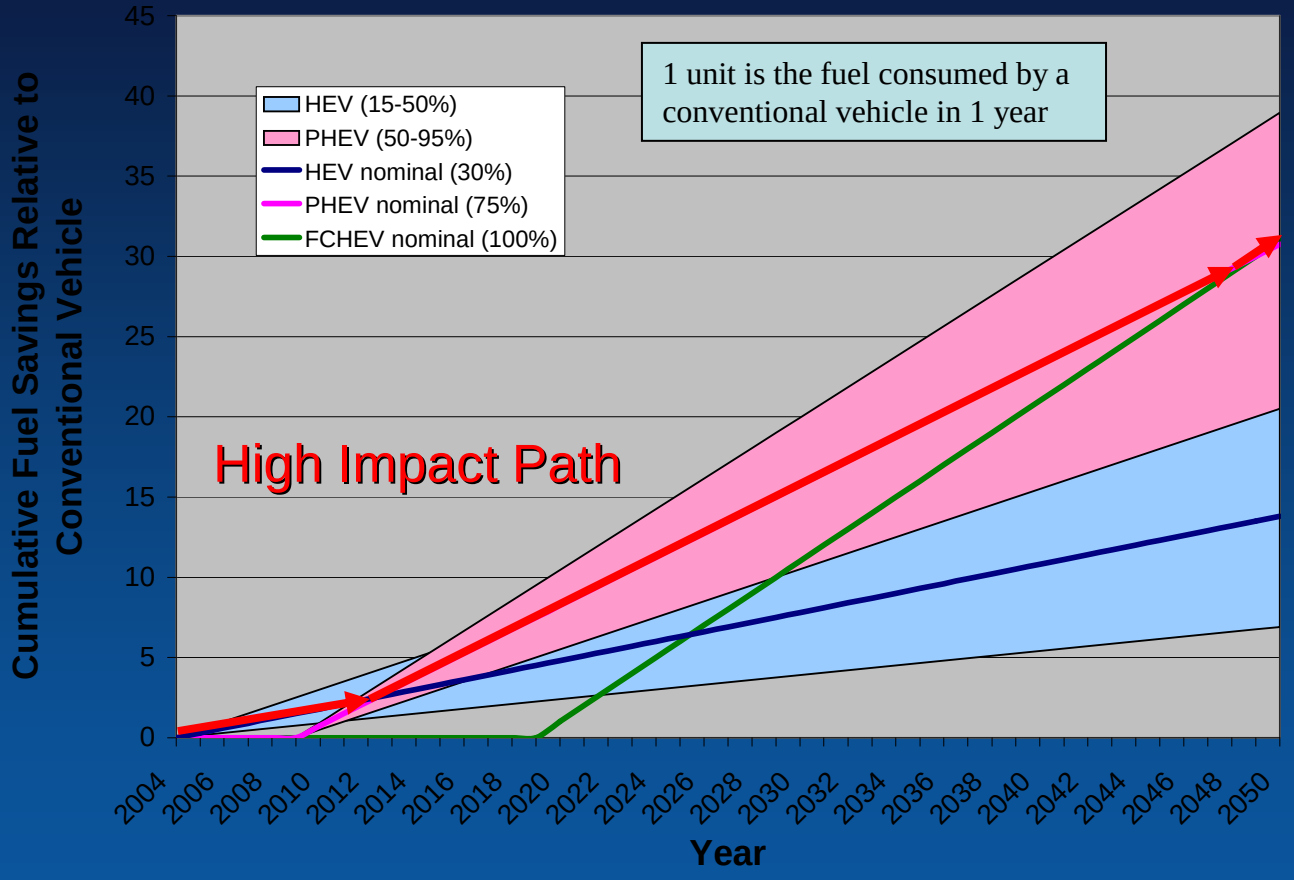


Battery

Motor/Generator

Power Electronics

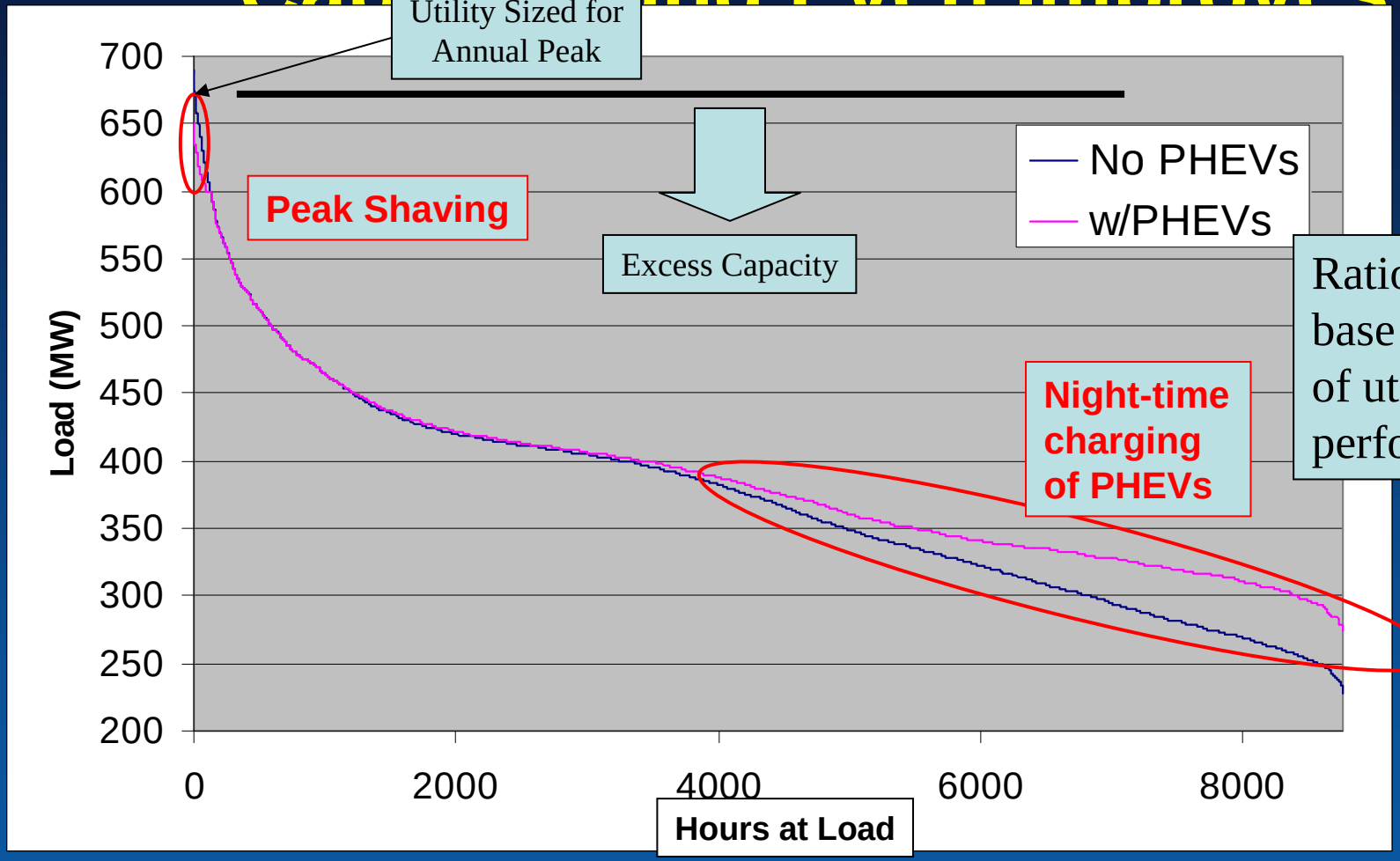
Cumulative Fuel Savings Potential of Technology Options



- Both HEVs and PHEV benefits have a range depending on application and design
- FCHEV assumes hydrogen fuel and gains maximum benefit rate

❖ PHEVs provide the best combination of rate and timing to provide significant fuel consumption reduction benefits while hydrogen fuel cell technology is being developed

Plug-in HEVs Require No New Capacity and Even Improves

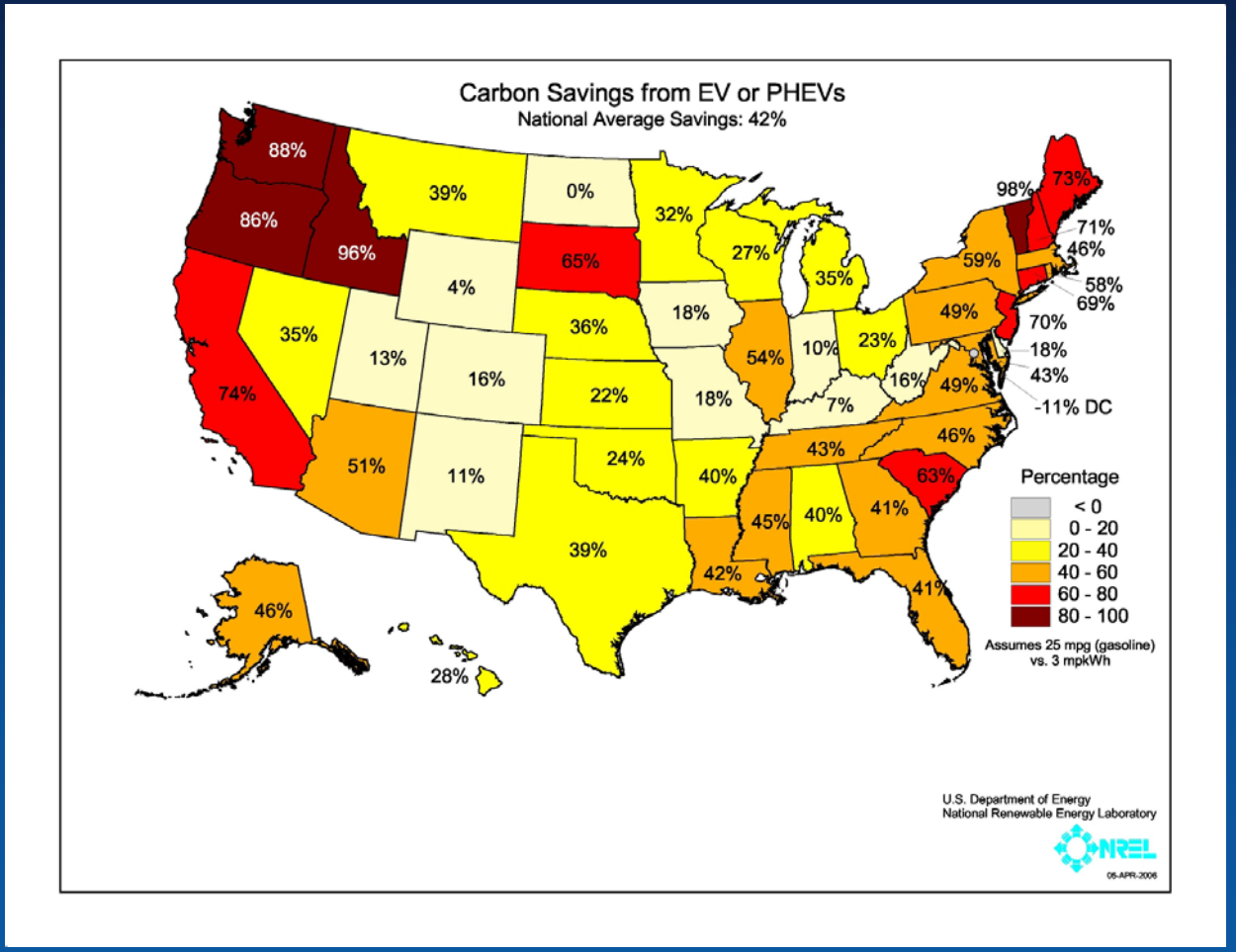


Ratio of peak to base is measure of utility performance

**Assumes utility controlled night-time charging for 50% of the vehicles in this utility district

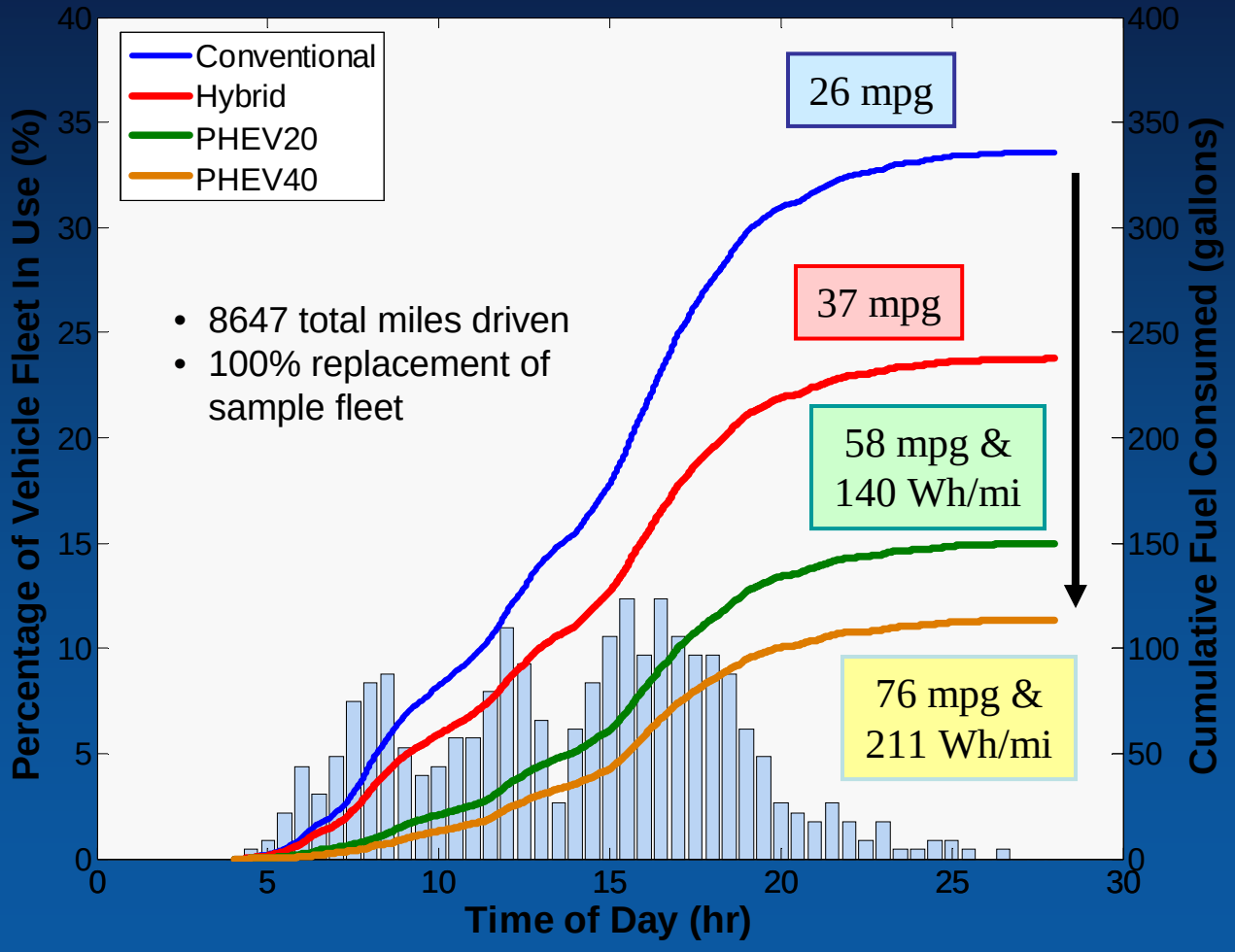
Electricity is lower carbon than gasoline!!

- Large regional variation
- Existing capacity mix
- State-wide average emissions
- Assumes no gasoline miles



Real-World Plug-in HEV In-Use Fuel Consumption

227 vehicles from St. Louis each modeled as a conventional, hybrid and PHEV

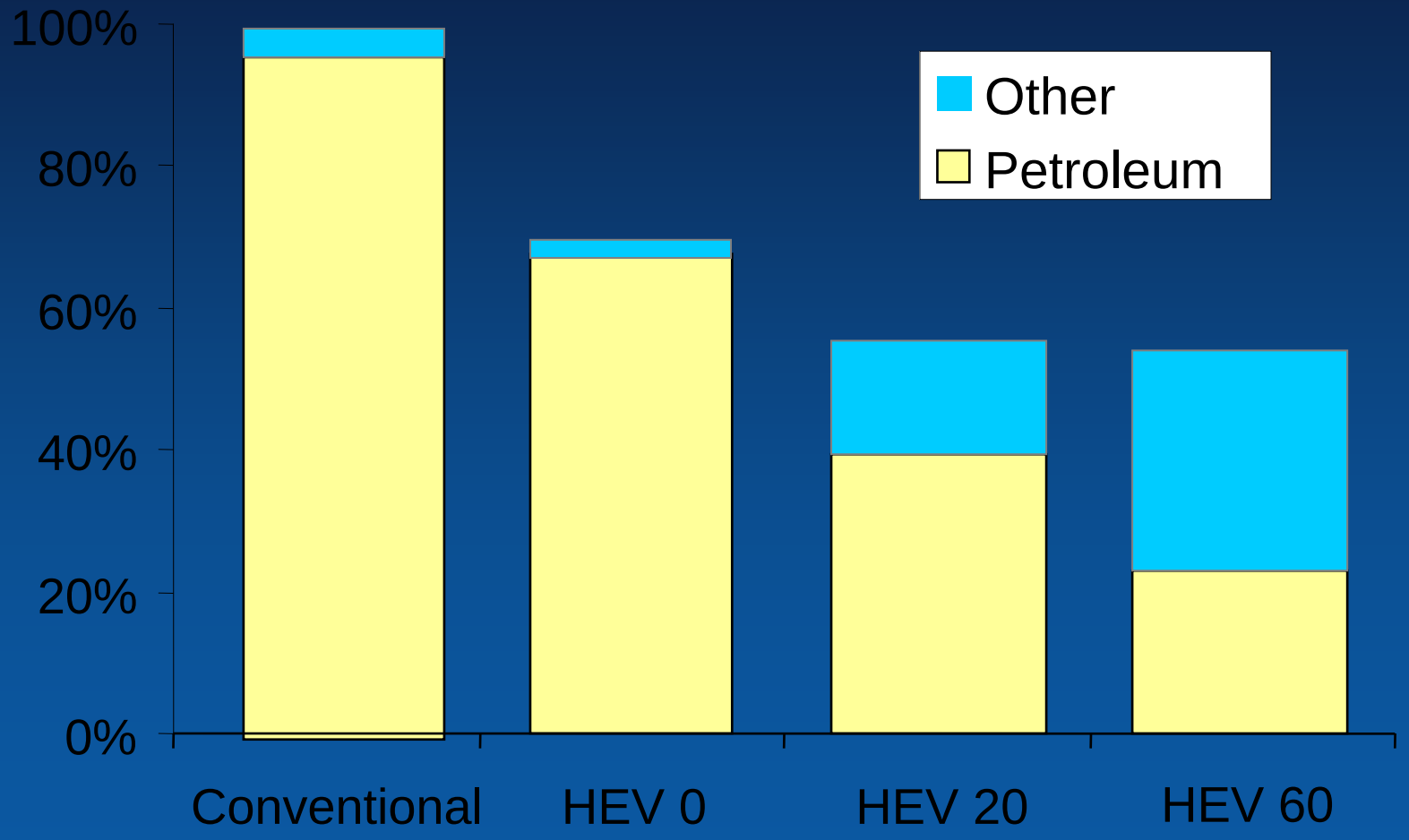


	Average Daily Costs		
	Gas.	Elec.	¢/mi
CV	$3.15	---	8.3
HEV	$2.21	---	5.8
PHEV20	$1.41	$0.48	5.0
PHEV40	$1.08	$0.72	4.7

Assumes $2.15/gal and 9¢/kWh

PHEVs:
~40% reduction in operating costs
~$460 annual savings

HEVs Energy Usage (well to wheels)



Plug-In Hybrid Fuel Economy

Predicted fuel economy and operating costs for midsize sedan[1]

Vehicle Type	Gasoline Fuel Economy	Electricity Use	Annual Energy Use	Annual Energy Cost	Recharge Time[3]
Conventional	27 mpg	---	508 gal.	$1090	---
Hybrid-Electric	36 mpg	---	375 gal.	$810	---
Plug-In Hybrid 20mi range	63 mpg	0.15 kWh/mi	213 gal. and 1960 kWh[2]	$460 + $175	< 4.5 hrs
Plug-In Hybrid 40mi range	95 mpg	0.21 kWh/mi	142 gal. and 2860 kWh[2]	$305 + $255	< 8 hrs

1) Assumes 13,500 miles annually, gasoline price of $2.15 per gallon, electricity price of 9c/kWh
2) Note that average US household consumes 10,700 kWh of electricity each year
3) Using 110V, 20A household outlet

Benefits of a Plug-In

CONSUMER BENEFITS

Lower "fuel" costs

Fewer fill-ups

Home recharging convenience

Fuel flexibility

By plugging it in…

Vehicle-to-grid (V2G) potential

Less CO_2 emissions

Less air pollution

Less petroleum use

Energy diversity

Better utilization of generation capacity

NATIONAL BENEFITS

Plugging-in Vehicles to a Renewable Community

NEV

PHEV

View Videos

View plug-in vehicle animation
View neighborhood animation

Part 2
Defining the Renewable Community

- What is the vision?
- Why do it?
- What would be in it?
- What are the goals?
- How do you get there? What are the pathways?
- Who are the players?
- Where do you put it?
- When do you create it?

Vision

A state-of-the-art, master planned community using advanced technologies and strategies to:

- Maximize sustainability, economic benefits, quality of life
- Minimize environmental impacts
- Integrate currently disconnected systems (e.g., transportation and building energy systems)
- Establish a viable community today while leading the transition to the communities of tomorrow
- Develop technologies and approaches applicable to communities worldwide

The community will have aggressive goals using sound strategic business principles, keeping long-term future goals a focus.

10 Critical Elements of a Renewable Community

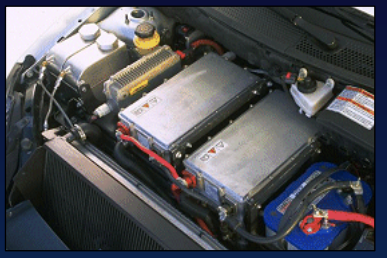
- Community generates its own energy supply
- Design and decisions based on sound business principles
- Cost of living in the community is optimized for consumer over the long-term
- Energy conservation features are core
- Vehicle miles traveled are substantially reduced
- Encourages shared resources to minimize consumption
- Pollution is minimal or non-existent
- Integrate workplace with living place
- Master planned community as an integrated system
- Magnet for economic development
- A community that people will demand to live in!

Your Home in the Renewable Community

What might it look like?

- Near zero energy home
- Local-central wind and rooftop PV power
- Distributed generation/net metering grid connections
- Alternative fuel use
- Plug-in hybrid vehicles

Vehicle Goals in the Renewable Community



Vehicles could…(or should?):

- come with grid power connection standard
- home refueling
- meet peak grid power needs with vehicle-based generation and/or storage.
- provide valued ancillary services to the grid, offsetting operating costs
- provide high-reliability power for businesses and uninterruptible power for homes
- have all the essential elements of a distributed generation system:
  - Generation, storage, fuel
  - Energy conversion, packaging
  - High volume/low cost, mobile

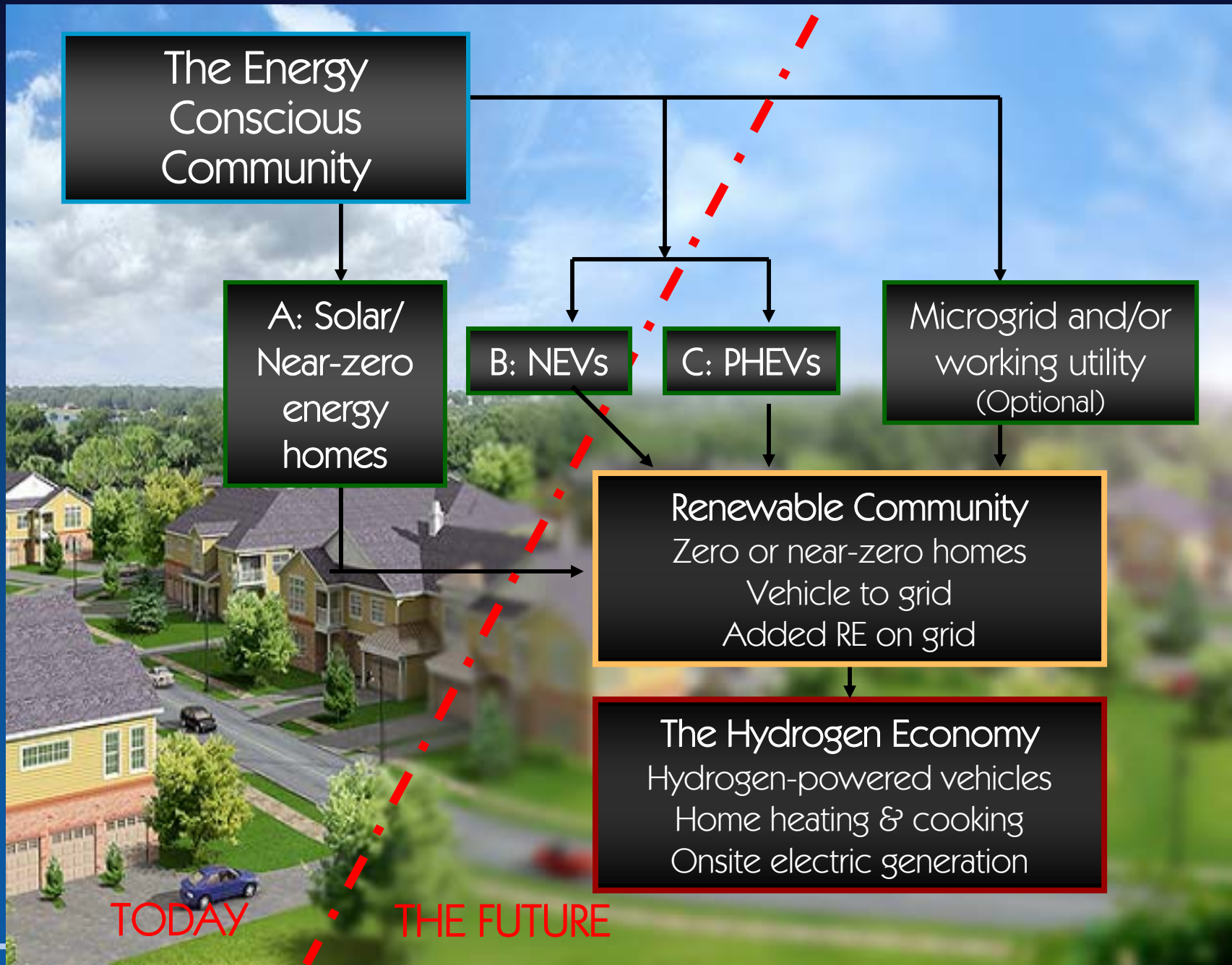
Vehicles Can Be Part of the Home Package

Toyota Dream House PAPI

Plug-in vehicle in a Japanese Home

Net Zero Energy Canadian Home

BECOMING A RENEWABLE ENERGY COMMUNITY



Grid
Internet
Sources of Value

bp solar

Green Grid System

System Operators

Retail Utilities

Home Owners

PUC Government Agencies

Small Commercial Customers

Peak generation
Demand management
Transmission deferral
Grid regulation services

RECs
Distribution deferral

Metering, Data Validation
Marketing Content

Environmental & energy agendas

Green power
Bill reduction
Backup power
Monitoring services
O&M services

BP Trading

bp

Monitoring & Control Partner

BP Solar

bp solar

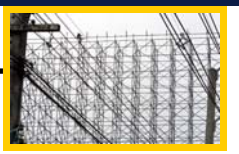
Green Grid System

bp solar

PV Array

Weather Station

Grid



Energy Storage

Main Service Panel

General Loads

Plug-in Hybrid Vehicle

Sub Panel

Critical Loads

Space Heating & Cooling

Inverter

Monitoring Gateway

Wireless Display

Water Heating

Internet

MyPower Node

Normal Mode - Daytime

bp solar

PV Array

Weather Station

Grid

Energy Storage

Main Service Panel

General Loads

Plug-in Hybrid Vehicle

Sub Panel

Critical Loads

Space Heating & Cooling

Inverter

Monitoring Gateway

Wireless Display

Water Heating

Internet Data Uplink

MyPower Node

Sell Mode – Afternoon Peak

bp solar

PV Array

Weather Station

Grid

Energy Storage

Main Service Panel

General Loads

Plug-in Hybrid Vehicle

Sub Panel

Critical Loads

Space Heating & Cooling

Inverter

Monitoring Gateway

Wireless Display

Water Heating

Internet Sell Instruction

MyPower Node

Buy Mode – Night

bp solar

PV Array

Weather Station

Grid

Energy Storage

Main Service Panel

General Loads

Plug-in Hybrid Vehicle

Sub Panel

Critical Loads

Space Heating & Cooling

Inverter

Monitoring Gateway

Wireless Display

Water Heating

Internet Buy Instruction

MyPower Node

Normal Mode – Night

bp solar

PV Array

Weather Station

Grid

Energy Storage

Main Service Panel

General Loads

Plug-in Hybrid Vehicle

Sub Panel

Critical Loads

Space Heating & Cooling

Inverter

Monitoring Gateway

Wireless Display

Water Heating

Internet Data Uplink

MyPower Node

Emergency Mode

bp solar

PV Array

Weather Station

Grid Failure

Energy Storage

Main Service Panel

General Loads

Plug-in Hybrid Vehicle

Sub Panel

Critical Loads

Space Heating & Cooling

Inverter

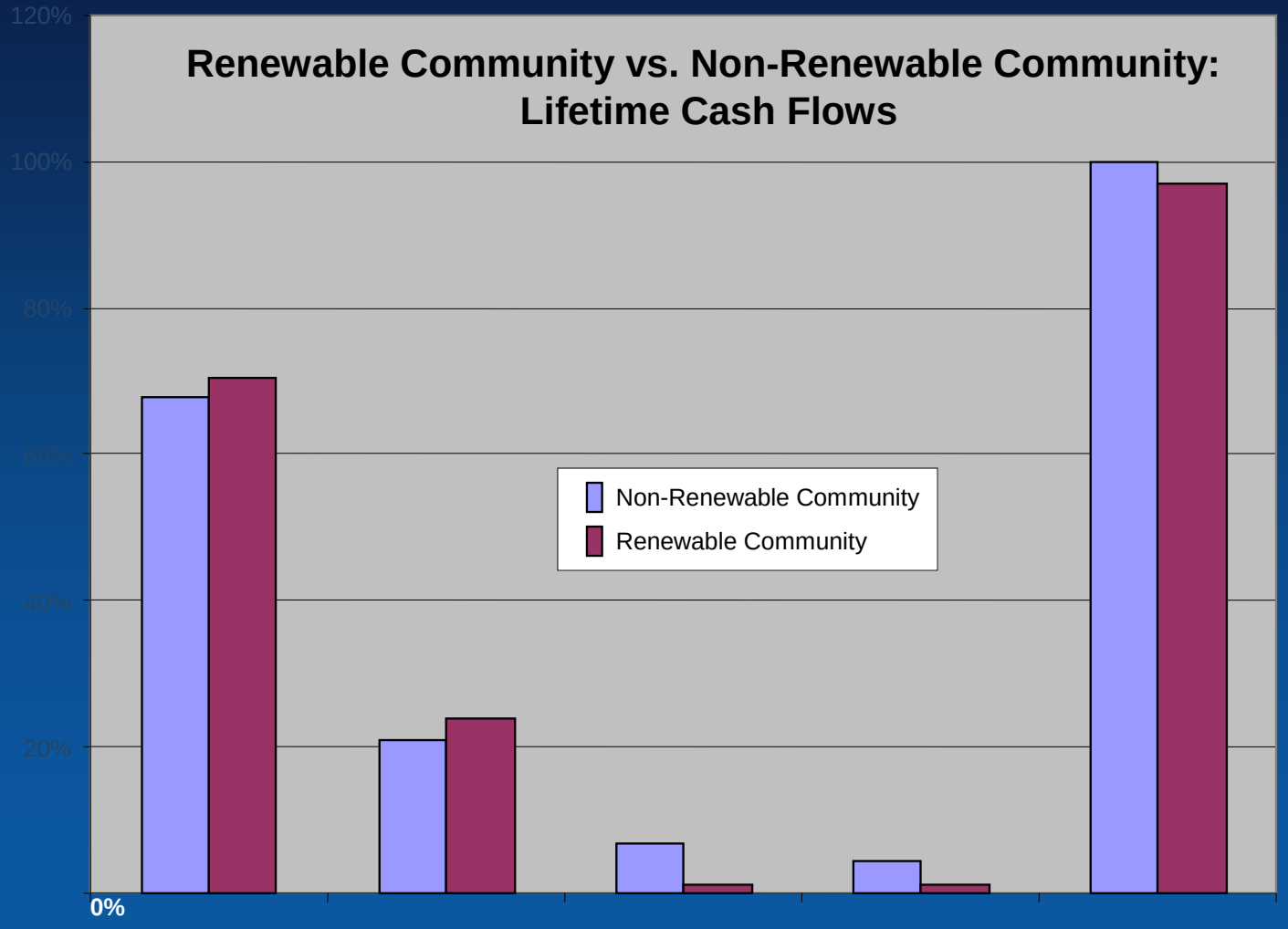
Monitoring Gateway

Wireless Display

Water Heating

Internet Link Failure

From a consumers point of view: A Renewable Community Can Cost Less Than A Non-Renewable Community!



Sarasota County, Florida First Renewable Community Demonstration Project

Plugging in to the Partnership

June 8, 2006

NREL National Renewable Energy Laboratory

Sarasota County
scgov.net | 941.861.5000 | TV19

PARTNERS

1. NREL
2. Sarasota County Government
3. Florida Solar Energy Center
4. Steven Winter & Associates
5. Florida Energy Office, Department of Environmental Protection
6. Florida Power & Light
7. Plug-In Partners Campaign
8. Florida Green Building Coalition
9. Florida Home Builders Ass.
10. Sarasota Home Builders Ass.
11. Sarasota County Economic Development Corporation
12. SCOPE - Sarasota County Openly Plans for Excellence
13. SMR Lakewood Ranch
14. Vision Homes
15. SDC Communities
16. HomeFront, Inc
17. Kimal Lumber Company
18. Eco-$mart, Inc.
19. DaimlerChrysler GEM
20. Hymotion
21. EnergyCS

Renewable Community for Today and Tomorrow

NREL and You Making it Happen?

What did you learn?

- Lets end with a little quiz to show the importance of advancing vehicle technology

How much of U.S. energy use is for transportation?

A. 6%
B. 13%
C. 28%
D. 52%

- *C — 28%, second only to the industrial sector at 32%.*

How much of U.S. petroleum use is for transportation?

A. 13%
B. 28%
C. 52%
D. 67%

- *D — 67%. Cars and light trucks alone account for 38% of U.S. petroleum use—roughly equal to total U.S. oil production. Medium and heavy trucks and buses use about 12%, air travel about 5% and industry about 3%.*

What is the U.S. share of the world's petroleum use?

A. 9%
B. 17%
C. 25%
D. 40%

- *C — 25%, contrasting sharply with U.S. share of less than 5% of world population. Americans use 12.7 million barrels of oil for transportation **each day**. If those barrels were laid end to end, they would span 6,200 miles. The driving distance from Anchorage, Alaska, to Miami, Florida, is less than 5,000 miles*

What is U.S. daily per capita use of petroleum products?

A. 0.2 gallon
B. 1 gallon
C. 3 gallons
D. 8 gallons

- *C — 3 gallons. (per person, not just drivers, and for total petroleum use)*

The second largest user of petroleum after the United States is China. What is China's daily per capita use of petroleum products?

A. 0.2 gallon
B. 1 gallon
C. 3 gallons
D. 8 gallons

- *A — 0.2 gallons. If China's 1.3 billion people were to use petroleum at the same per capita rate as the United States, it would use 91.5 million barrels per day or 111% of the total current world use of 82.6 million barrels per day.* India, with 1.1 billion people uses only about 0.09 gallons per capita per day. Obviously, if the whole world started using petroleum anywhere near as fast as the United States does now, oil supplies would not last long.

How did sales of SUVs and other light trucks change from 1970 to 2004 as a share of light-duty vehicle sales?

A. Increased from 15% to 35%
B. Increased from 15% to 55%
C. Stayed steady at 20%
D. Increased from 20% to 40%

- *B. — Increased from 15% to 55%; small car sales dropped from 40% to 20% during the same period---clearly a major factor in increased gasoline use.*

What is the operating cost to drive an electric-powered vehicle versus a gasoline-powered vehicle?

A. $0.07/mile electric vs. $0.10/mile gasoline
B. $0.10/mile electric vs. $0.07/mile gasoline
C. $0.03/mile electric vs. $0.13/mile gasoline
D. $0.30/mile electric vs. $0.10/mile gasoline

- *C. — $0.03/mile electric vs. $0.13/mile gasoline, based on $2.77/gallon gasoline and $0.08/kilowatt-hour electricity. So why doesn't everyone demand an electric vehicle?*

- *This is operating cost only, not including any difference in vehicle cost for batteries. The most cited reason why electric vehicles did not take off, though, is that they would have limited range. The hybrid-electric vehicle, however, with both an electric motor and a gasoline engine, solves that issue. Adding extra batteries to a hybrid gives you a plug-in hybrid-electric vehicle that could operate on inexpensive electricity most of the time, but use the gasoline engine when additional range is needed.*

How will plug-in hybrid electric vehicles operate?

A. Electrically until battery power is low, then by gasoline
B. By gasoline engine boosted by the electric motor when needed for acceleration
C. Electrically only in urban areas, both electrically and by gasoline elsewhere
D. Any of the above.

- D. — Any of the above.

- A plug-in could be programmed to use its gasoline engine and electric motor in any combination. Most plug-in designs would likely use both the motor and the engine to maximize performance, so net cost would likely be about $0.06–$0.08/mile. They could, however, have manual overrides to allow electric-only use such as in dense urban areas or on short non-freeway drives.

About how much of the energy spent to power an electric vehicle **motor goes to actually propelling the vehicle?**

A. 13%
B. 33%
C. 63%
D. 93%

- B. — 33%.

- Electric motors are actually more than 90% efficient, but electricity is an energy carrier rather than a primary energy source, so, in terms of clean energy, is only as “good” as the way it is made. While some new combined-cycle gas turbine power plants are closer to 50% efficient, electric utility generation typically averages 35–40% efficiency with most of the energy lost as waste heat. So after considering electricity transmission losses and other vehicle losses, only about a third of primary energy makes it to moving an electric vehicle.

About how much of the energy in the fuel goes to actually propelling a gasoline-engine **vehicle?**

A. 13%
B. 33%
C. 63%
D. 93%

- A. — 13%.

- Internal combustion engines are notoriously inefficient, as you can judge from how much waste heat the engine gives off. Diesels are a little better, perhaps __ for a passenger car. This is why electric operation can be less expensive, even though you have to generate the electricity elsewhere and then transfer it to the vehicle. Electricity is also largely domestically generated from a variety of fossil fuels and renewable and other energy sources. Other than ethanol and biodiesel, however, gasoline, diesel, and all other alternatives for internal combustion engines come from scarce petroleum or natural gas.

Plugging-in to Renewable Communities for Today and Tomorrow

It's Time