

# Meeting our Transportation Challenges: What Does The Future Hold?



Terry Penney, Laboratory Program Manager  
Advanced Vehicles and Fuel Technologies  
National Renewable Energy Laboratory

# Three Major Messages

- **The big picture** – There are more than 230M vehicles in the US – whatever changes occurring now in either advanced vehicles or alternative fuels, will take decades to change the fleet
- **Profound energy impacts coming** - The impacts of existing or new energy sources, carbon, smart grid, smart growth and economic prosperity in the world will have a profound impact and will come sooner than expected
- **Plan and act now for the long term** – tools, information and best practice examples are available everywhere – **be a leader!**



# **Growth Projection: Build 200 billion sq. feet for 70 million more people by 2030 Creating ten megapolitans**





# Traffic Congestion, Delhi





# The “Vending Machine” solution to mass car parking lots

*(German engineering at the extreme)*



# The Environment (Near-term)

- Now to 3 yrs (2012)
  - PHEVs from several vendors in the market
  - EVs from a few vendors available
  - Smart Grid reaches 30% of consumers
  - Substantial vehicle purchase incentives
  - Election year
  - Economy on up turn for last 18 months
  - Surge in consumer home energy monitoring equipment
  - Growing consumer perception of energy issues
  - Gasoline at \$4/gal



# The Environment (Mid-term)

- 3-6 yrs (2012-2015)
  - Economic recovery plateaus (no more stimulus)
  - PHEVs less than 5% of sales even with incentives
  - EV introductions from several vendors
  - Charging infrastructure installed along major highways and in city centers
  - All gen1 HEV batteries retired (available for second use?)
  - Original PHEV conversion and OEM batteries degraded
  - Carbon Tax/Trade system in place
  - Smart Grid mature
  - 20% national RPS in place
  - Xcel reaches 20% renewable goal
  - Consumer in home energy monitoring equipment becomes common place
  - Social Networking on Energy use?
  - Gasoline at \$5-6/gal in 2015
  - Massive growth in other countries influencing US

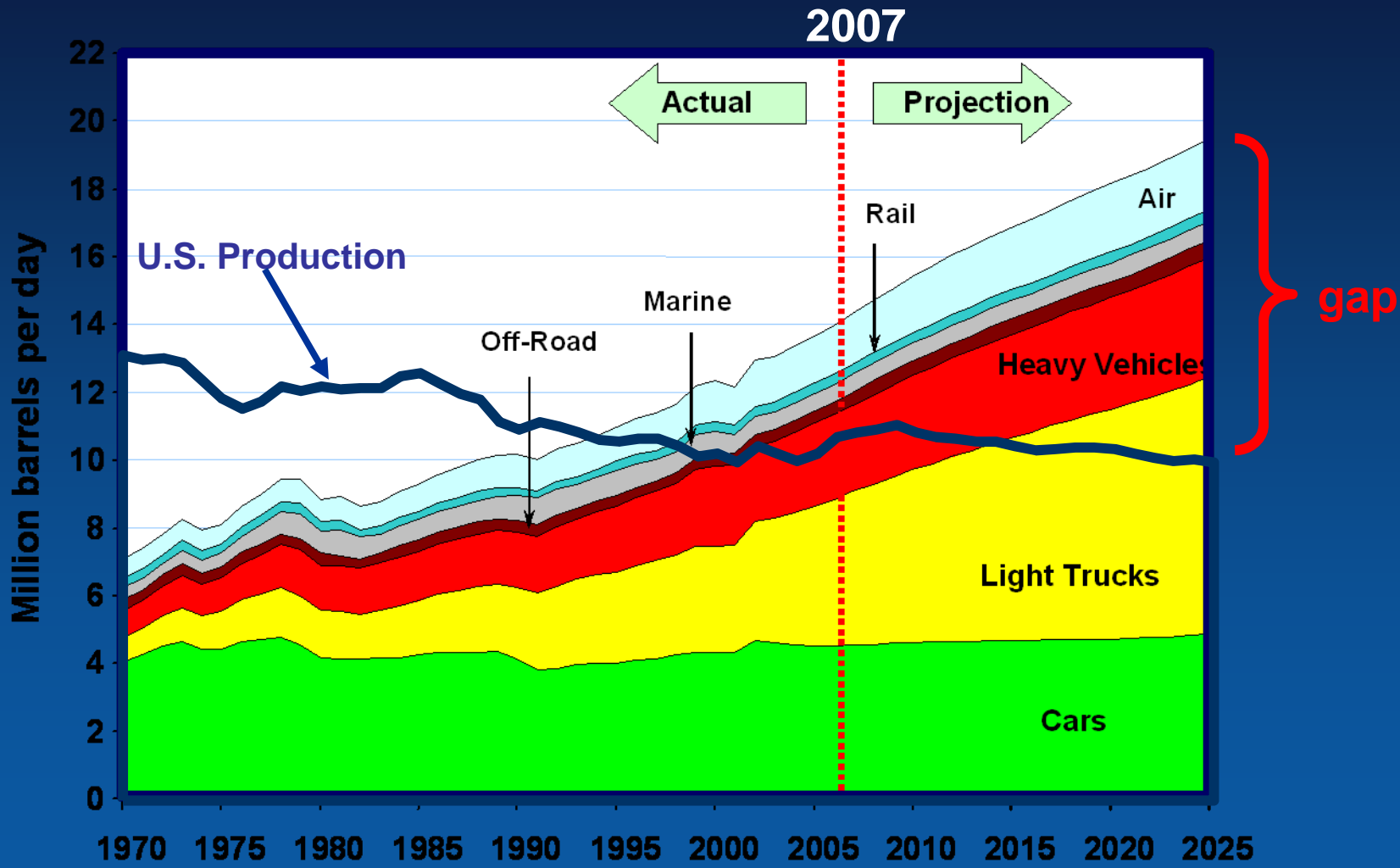
# The Environment (Long-term)

- 2030 - 20 years
  - Full turn over of vehicle fleet from baseline year
  - 40% fleet market share of plug-ins?
  - EVs at 10% fleet sales
  - Petroleum 60% of transportation
  - PEV batteries used for 5 years in grid support functions
  - Mass transit affects need for vehicles
  - World energy demand constrained
  - *Wants*
    - Robust personal mobility system
  - *Needs*
    - Fast charging locations with distribution upgrades
    - Communications infrastructure to support alternative distributed workplaces
- 2050 - 40 years
  - 75% of fleet miles are electrified
  - Petroleum consumption 10% of transportation
  - Renewables serve 30-50% of load regionally
  - 1.5-3C global mean temp rise - climate change impacts dramatic
  - Several types of energy storage incorporated into grid
  - *Wants*
  - *Needs*
    - Advanced personal mobility system to overcome congestion and consumption challenges



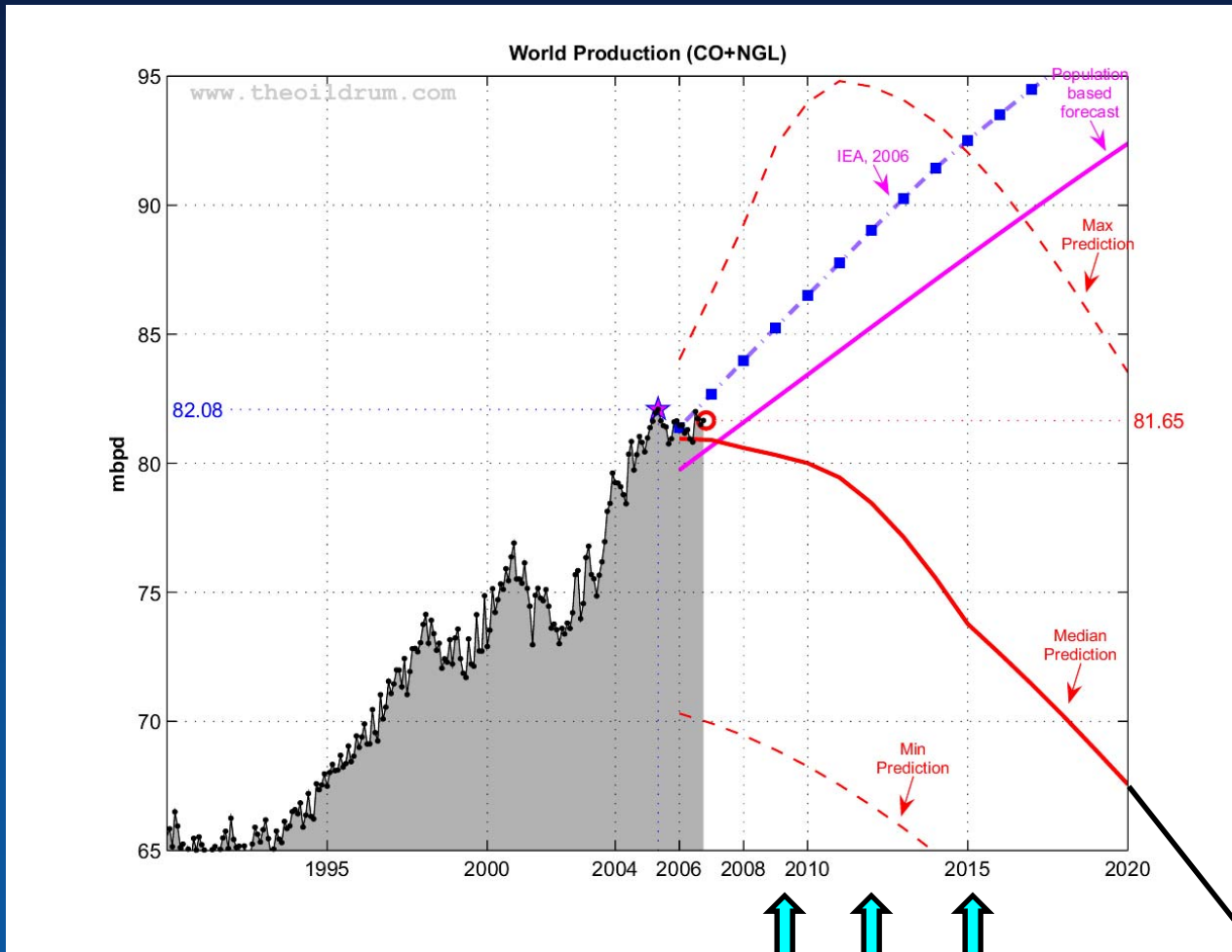
# U.S. Demand for Fuels Outstrips Supply

Light-duty vehicles are driving the growth in oil demand

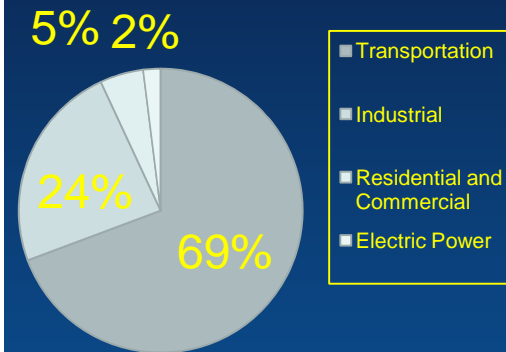


# The Environment and Oil

Jan 2007



Percent of Petroleum Consumption - US 2007



Now 3 Yrs 6 Yrs

20 Yrs

40 Yrs

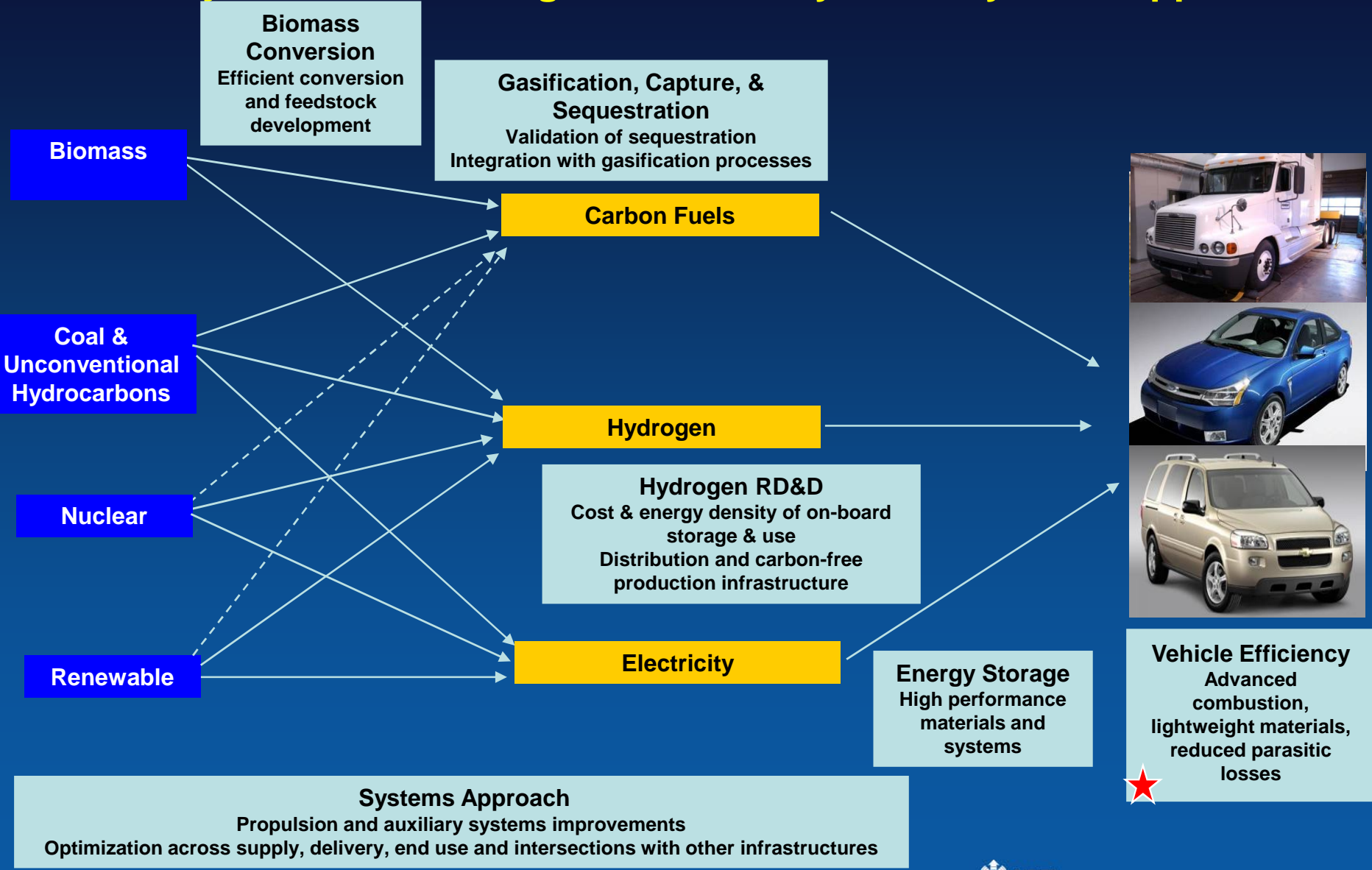
52mbpd?

22mbpd?



# The "Big" Picture.....

## Summary of Fuel Switching and Efficiency Pathways and Opportunities



# Vision of Future Transportation

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

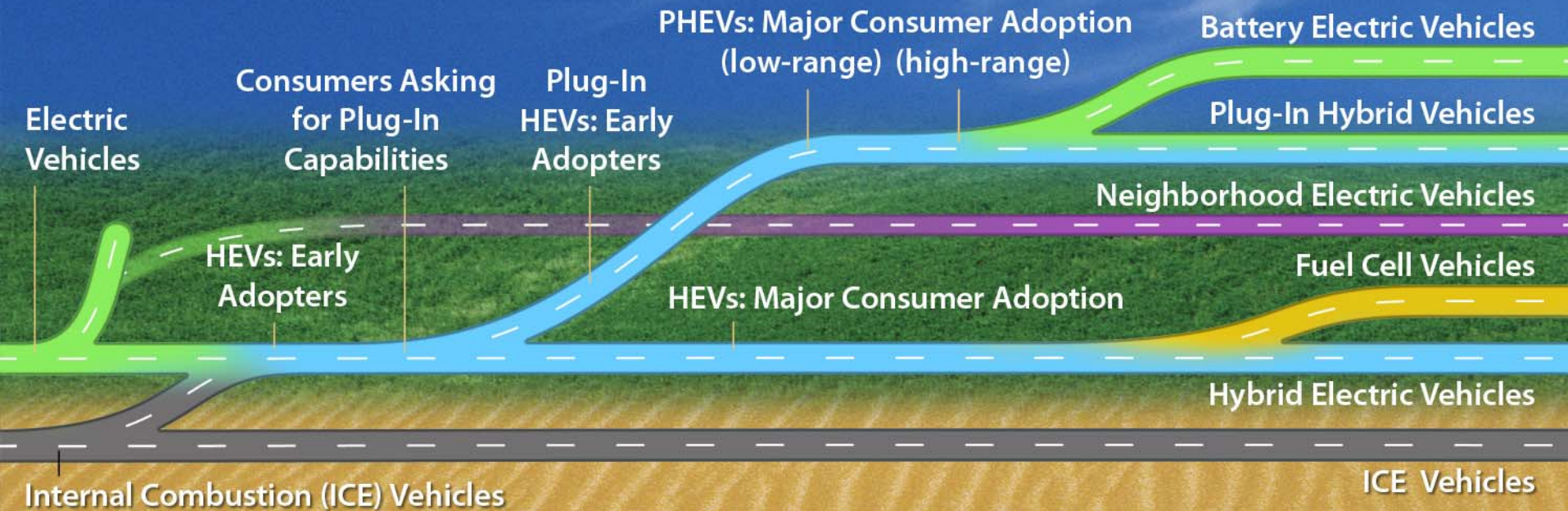


High Power ➤

Battery  
Advancement

Affordable High Power, Acceptable High Energy ➤

Affordable High Energy ➤



Gasoline, Ethanol Blends ➤

Diesel, Biodiesel Blends ➤

B20, Biodiesel ➤

E85, Cellulosic Ethanol ➤

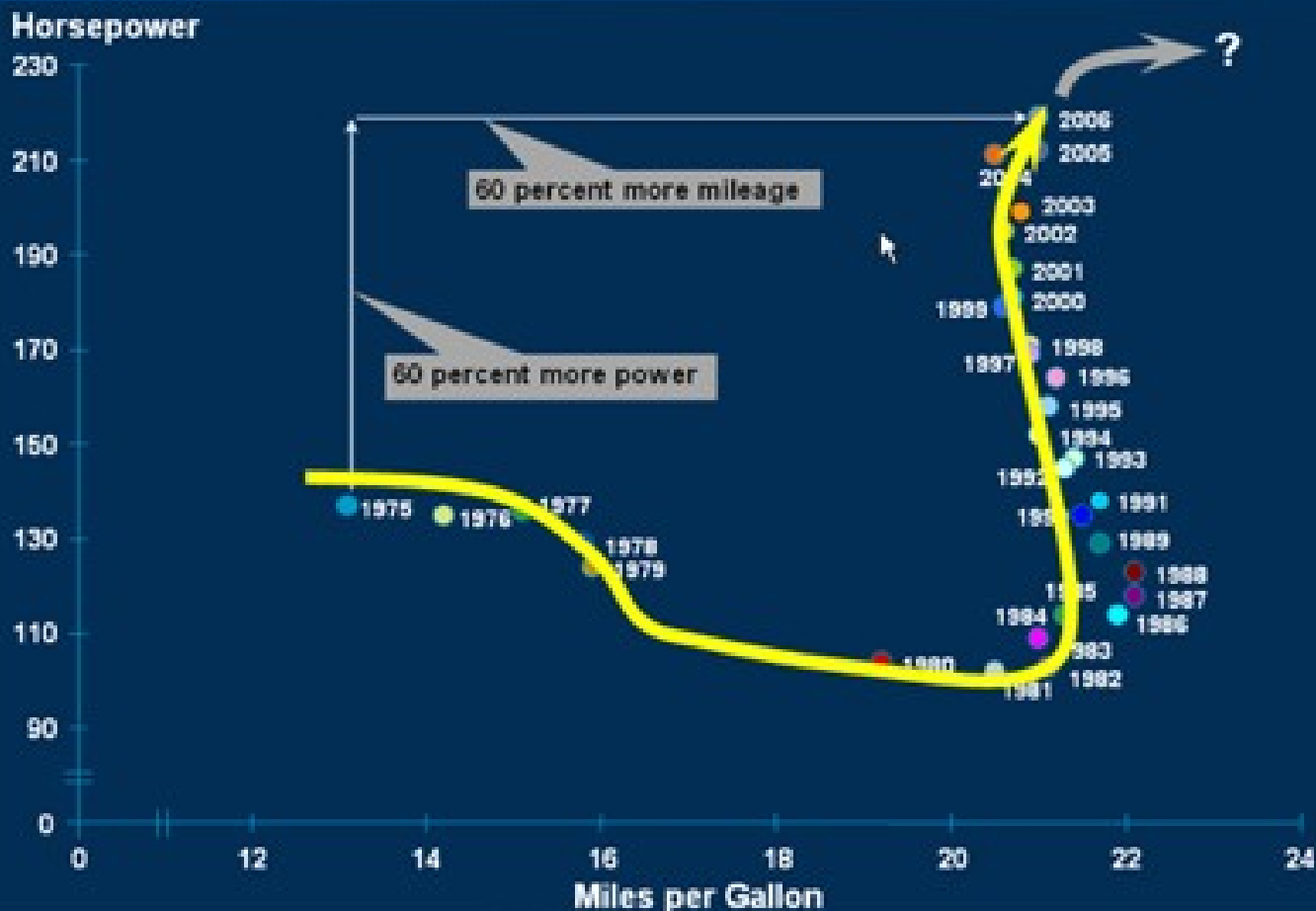
Electricity ➤

Hydrogen ➤

Fuels

*Innovation for Our Energy Future*

# On-Road Fuel Economy for New Light-Duty Vehicles 1975-2006 Model Years Sales-Weighted Horsepower and MPG

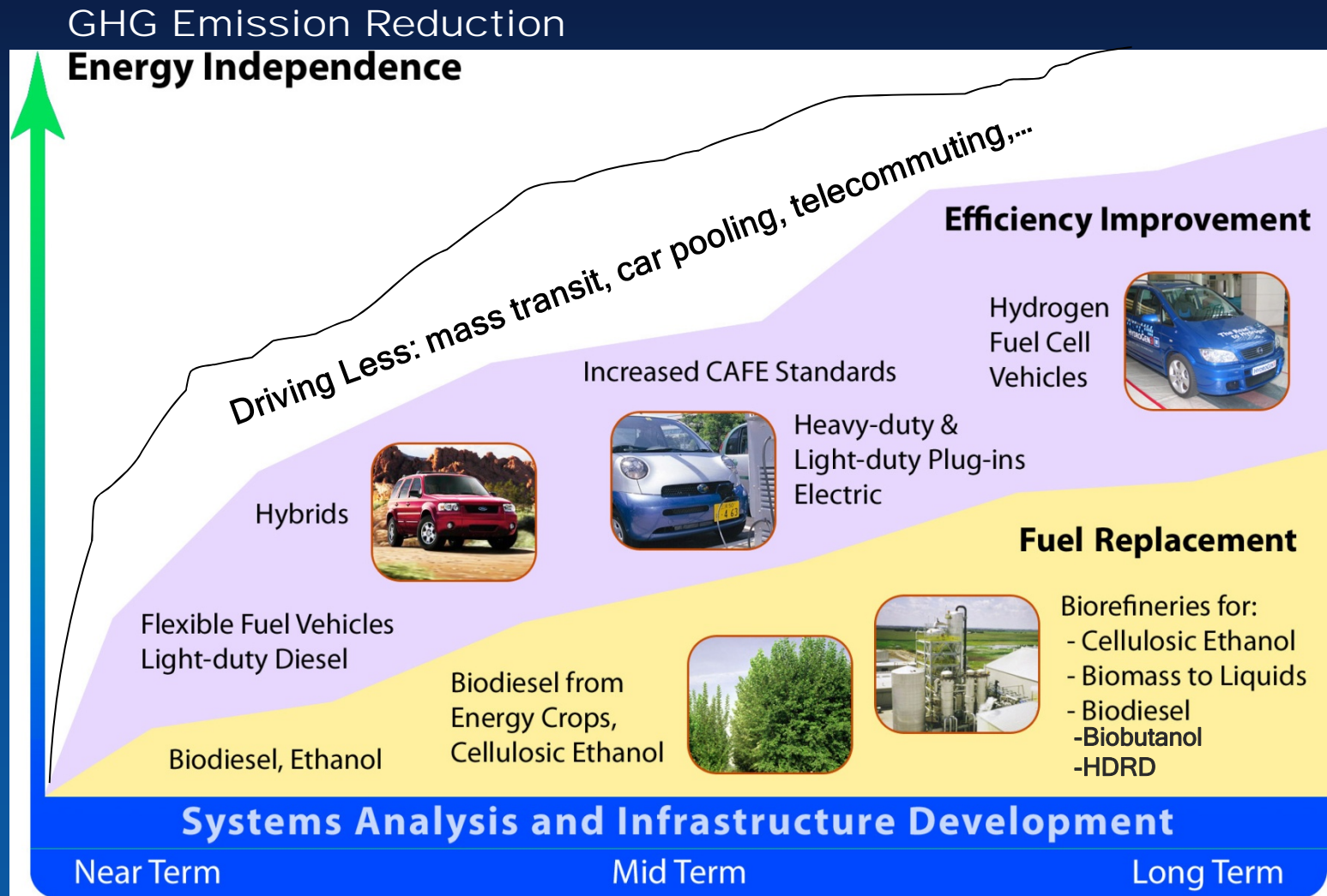




# Increased “Cow Power” too!

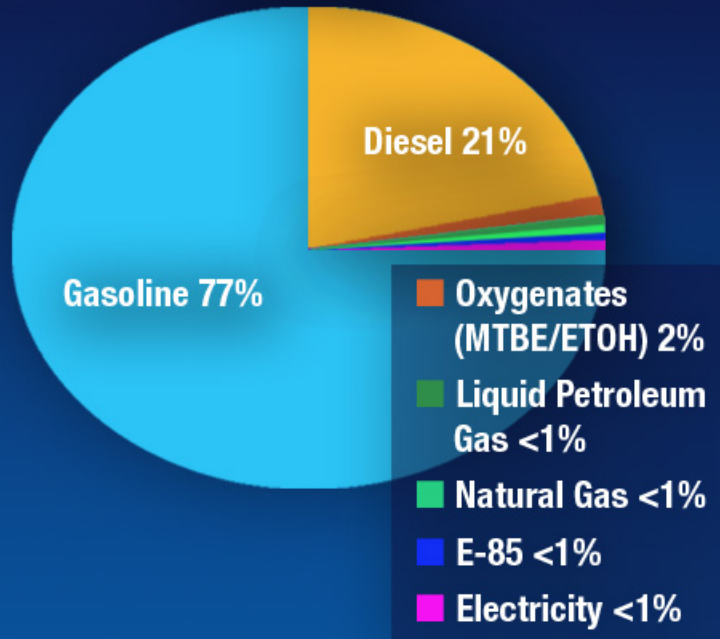


# Biofuels are not “the only” answer

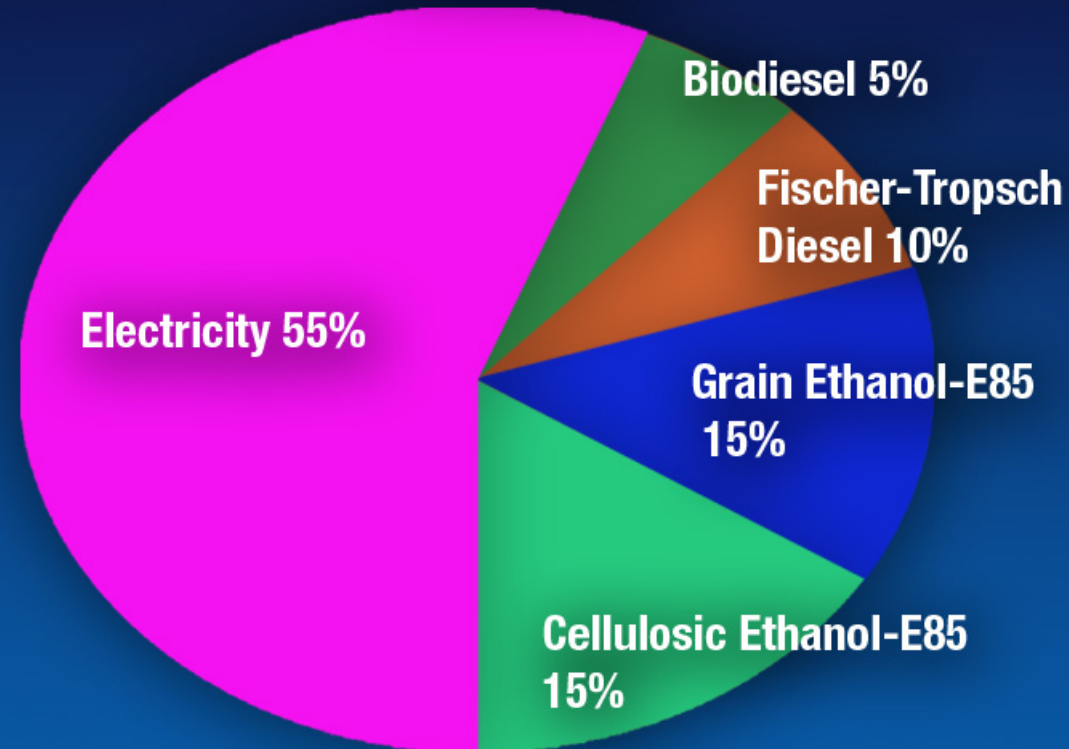


# Maybe the Future Can Look More Like This

## Today



## Future?





# Auto's in Daily use around the world... and “sneak” preview of some “advanced” designs!

- How long do cars last?
- Do all cars go to the junk yard?
- Creative uses for cars?
- “Pimp my ride” concepts

# Considering Emissions?



*AllFastCars.com*





Let's  
move  
across  
country!



# Public School Bus – 10 seater!



# Advanced Vehicles and Fuels Options

Conventional Vehicles



Hybrid Electric Vehicles



Plug-in Hybrid Vehicles



Hydrogen Vehicles—ICE or Fuel Cell



Corn Ethanol, Cellulosic Ethanol  
Biodiesel, Fischer-Tropsch Diesel  
Natural Gas other Petrochemicals

Electricity from Grid  
Distributed Renewable Electricity

Hydrogen from Natural Gas  
Renewable Hydrogen



# The Latest "Buzz" - PHEVs

## Renewable Fuels for Plug-in Hybrid Electric Vehicles

Communication

Solar

Wind

Utility Interface

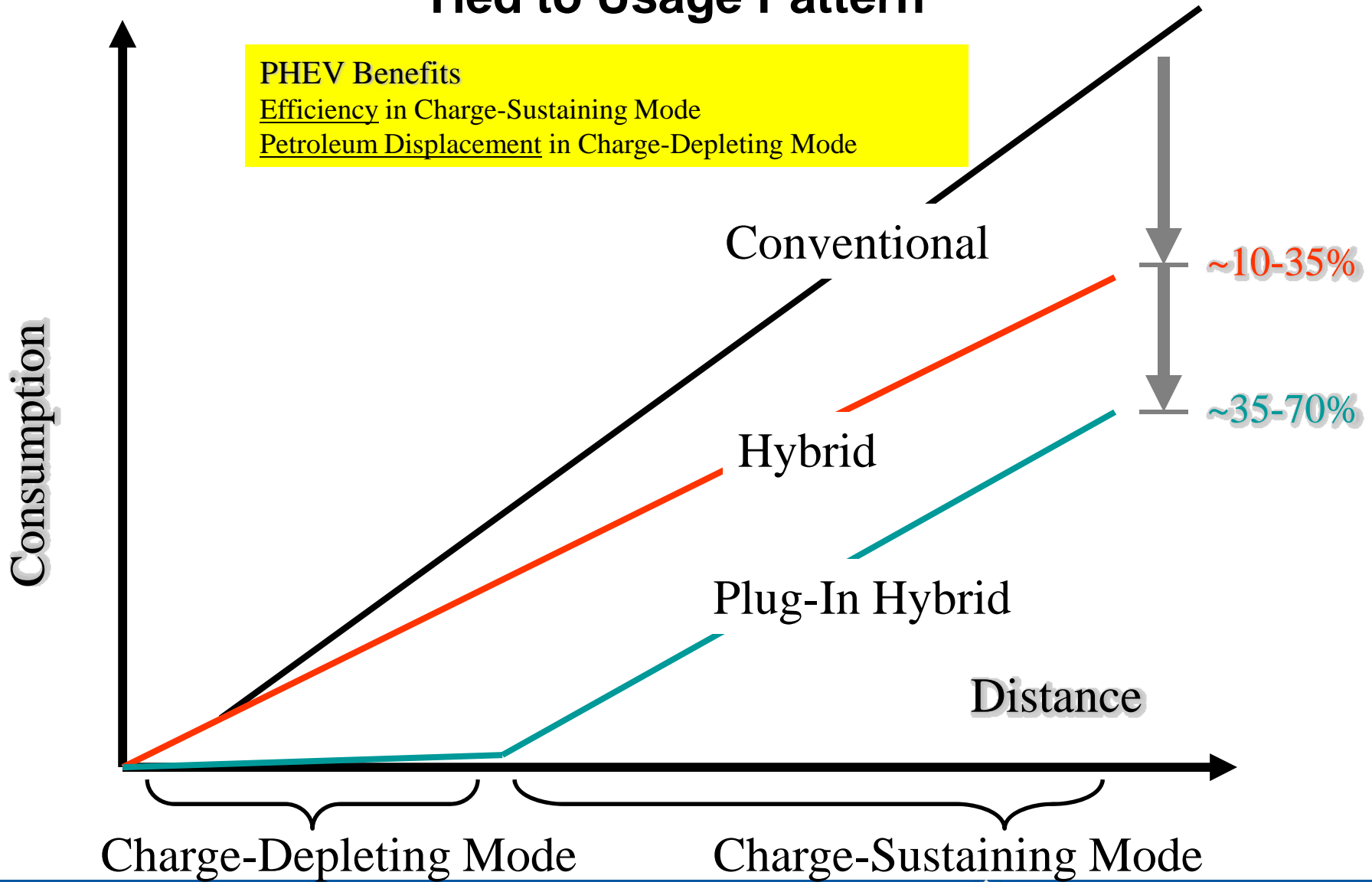
Energy Storage

Biofuels

Plug-in Hybrid Electric Vehicles

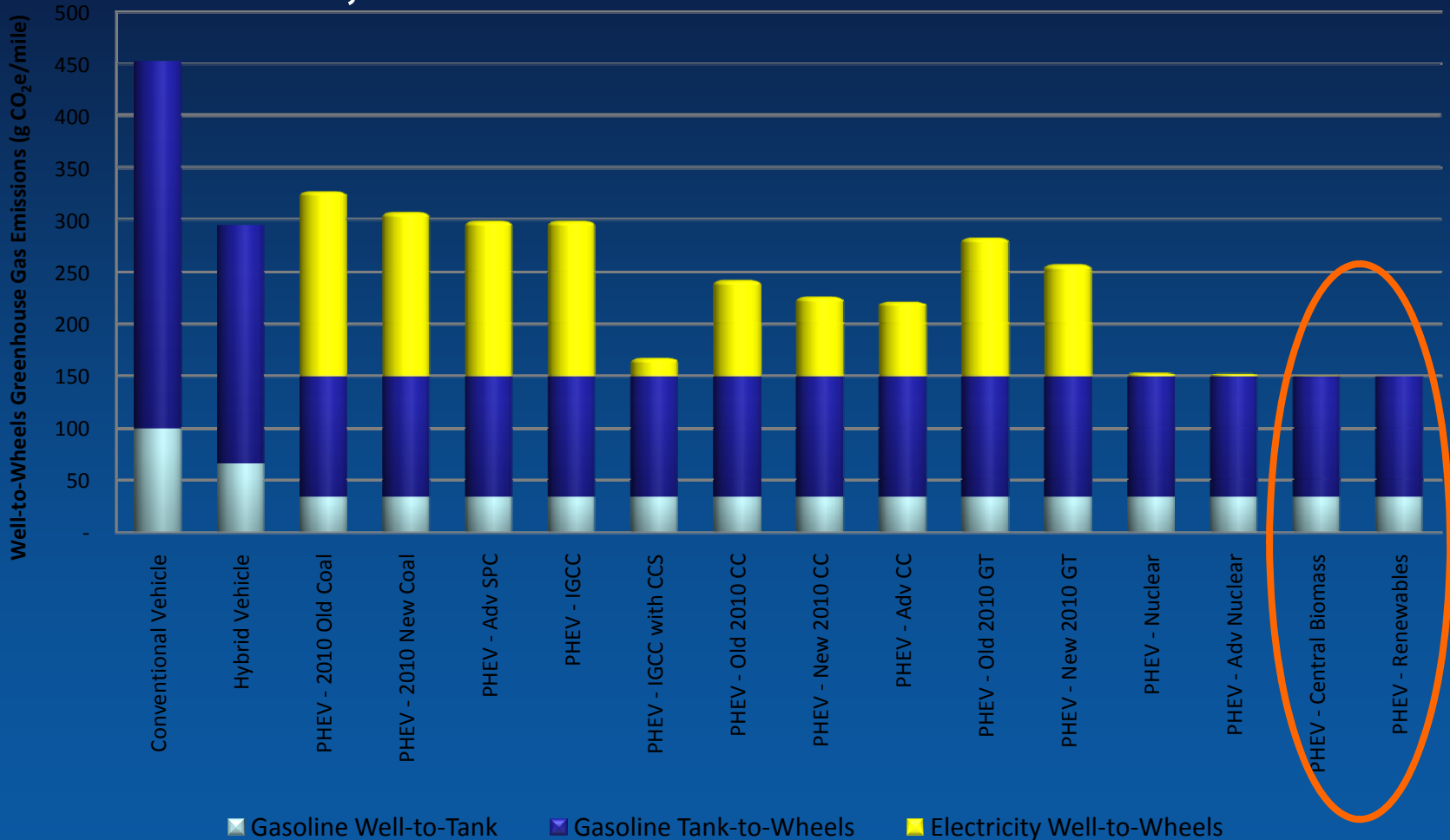


# Consumption Benefits of PHEV Technology Tied to Usage Pattern



# PHEVs with Renewables Provide CO<sub>2</sub> Benefits

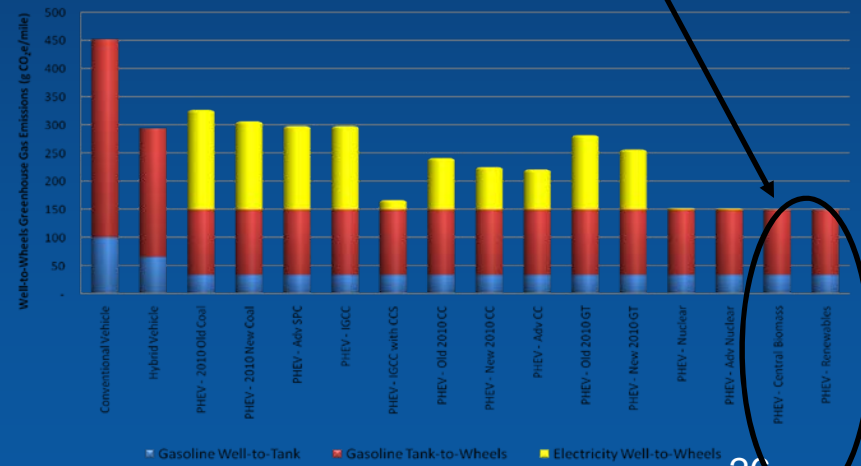
## Power Plant-Specific PHEV Emissions in 2010 PHEV 20 – 12,000 Annual Miles



# Importance of V2G

- Offset the high cost of energy storage systems for PHEVs
- Ability to access a stranded resource and use it to,
  - Reduce cost of electricity
  - Expand renewable generation

- Increase grid flexibility and reliability
- Achieve CO<sub>2</sub> benefits of renewables fuels in transportation

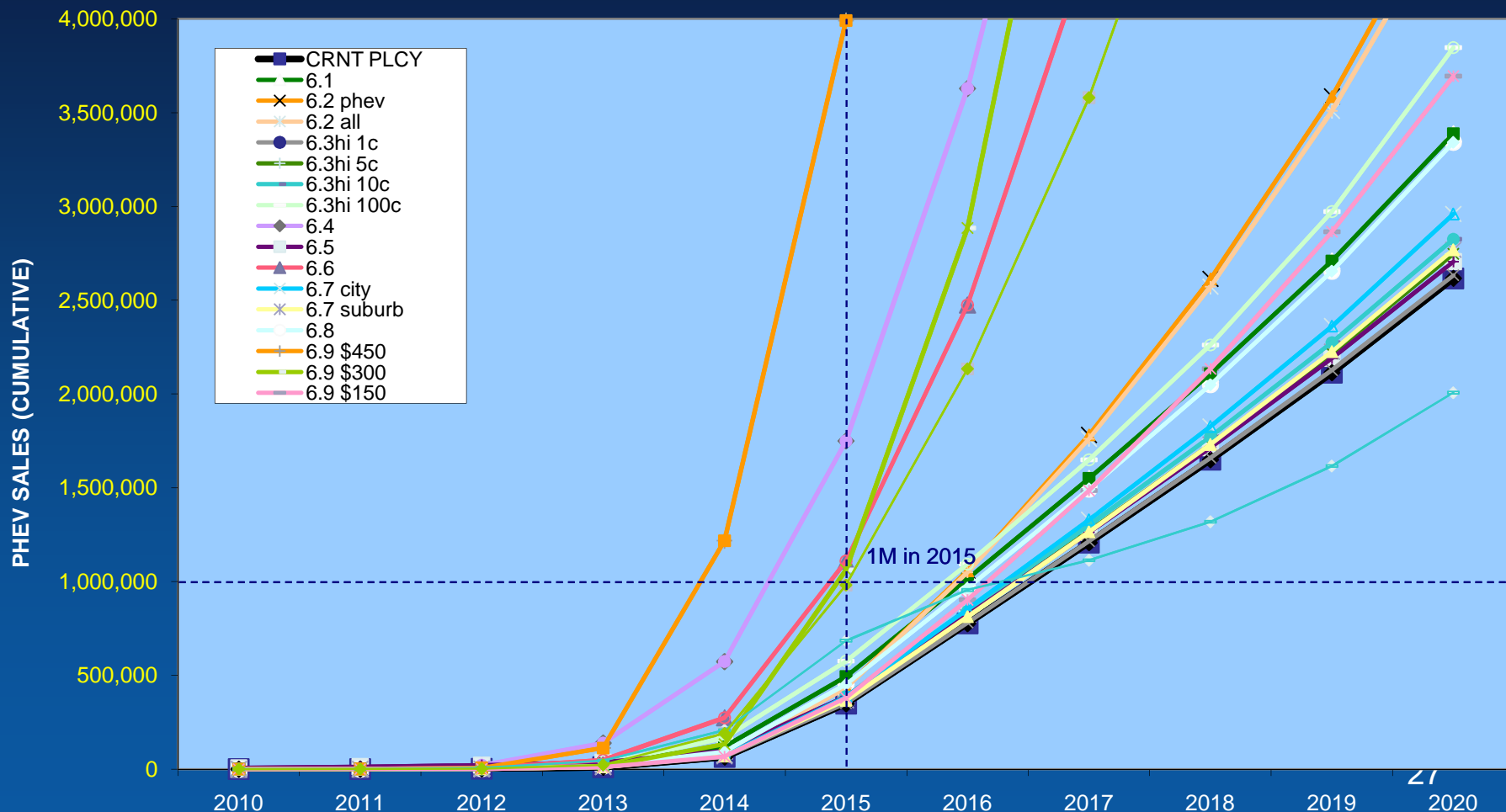


EPRI/NRDC PHEV Impacts Study

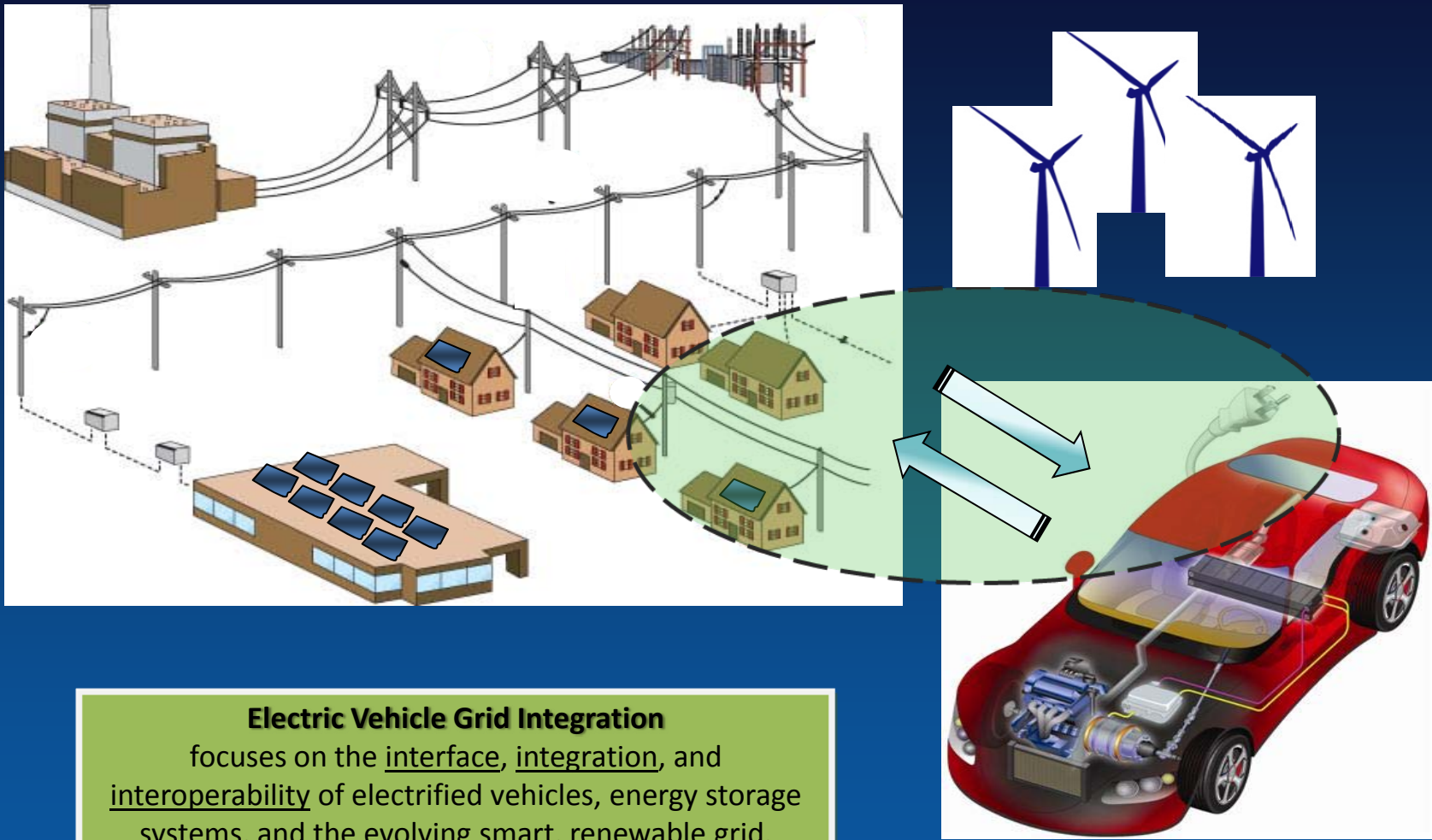


# The ORNL PHEV Choice Model supported the Sentech PHEV Market Introduction Study

## PHEV PROJECTED SALES















**Electric Vehicle Grid Integration**  
focuses on the interface, integration, and interoperability of electrified vehicles, energy storage systems, and the evolving smart, renewable grid.

# Recent PHEV Announcements

## Formula for Success

Battery makers are racing to develop lithium-ion cells to power new generations of plug-in hybrids and electric cars. Their challenge: find the right chemistry for different types of cars that will maximize longevity, power, capacity and safety.

DEVELOPER	CHEMISTRY	EXPECTED VEHICLE	WHEN	
A123	<b>Doped lithium nanophosphate</b>	Chevy Volt electric Saturn Vue plug-in hybrid ▶ Think City electric	2010 2009 2009	
Compact Power (LG Chemical) NEC	<b>Manganese spinel</b>	Chevy Volt electric ▶ Nissan electric	2010 2010	
Panasonic EV Energy Johnson Controls/Saft	<b>Lithium nickel cobalt aluminum oxide (NCA)</b>	Toyota plug-in hybrid <sup>1</sup> Mercedes S400 hybrid ▶ Saturn Vue plug-in hybrid	2010 2009 2009	
Hitachi	<b>Lithium manganese oxide</b>	future GM hybrids ▶	2010	
Commercially available lithium-ion cells	<b>Lithium cobalt oxide and others</b>	Tesla Roadster electric ▶	2008	
Altair Nanotechnologies	<b>Lithium titanate spinel (anode)</b>	Phoenix electric ▶	2008	
Lishen	<b>Lithium iron phosphate</b>	Miles XS500 electric ▶	2009	
EnerDel	<b>Lithium manganese titanate</b>	Think City electric ▶	2009	

<sup>1</sup>According to industry sources.



# Real Soon.....



- With gas at \$2/gallon, that number is down to one-quarter (4¢ vs 8¢) and plug-ins will be here soon
- (Prius left in 2010? , Chevy Volt right in 2010)

# Opel Flextreme concept



**Ford's new "Fusion"  
\$27,270 base price hybrid  
41 mpg city, 36 mpg highway**

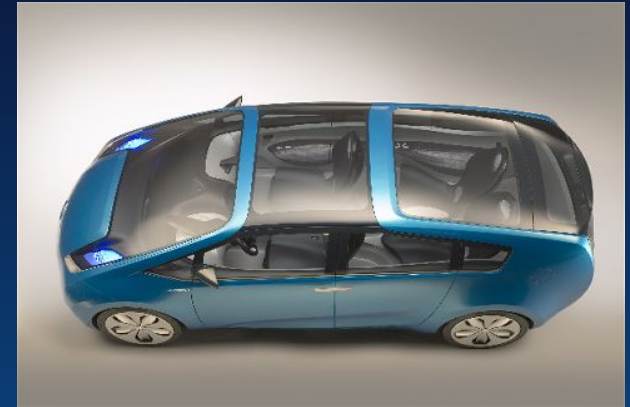


**Not a PHEV but a competitor to Toyota's HEV Camry with "Prius" like mileage**

# Toyota's Concepts



iQ



Solar Powered



PHEV



# Fisker's Sunset PHEV



(~\$90K, high performance, 50 mi EV range)

# BYD's 60 mile PHEV ~\$22,000 (only available in China)



# Tesla Roadster



~\$100K, pure electric 200mi range

# And More to Come: Chrysler beyond NEVs....



Chrysler ecoVoyager



Dodge ZEO



# VW 1-Liter Car (100 Kilometers per Liter--That's 235 mpg) More than 22,000 Sold



Volkswagen 1-liter Car

[www.vortex.com](http://www.vortex.com)

# Mitsubishi EV – “MIEV”



47 kW electric motor, 330V Li battery pack, 80 mi range

# Subaru Stella



- Four Passenger 50 mph, 50-mile range

# Italy's new electric vehicle – B zero





# Fiat's "Phylla"



# REVA-NXG (India)



- Two Passenger 75 mph, 124-mile range

# Some niche lower cost EVs.....

- Xebra (ZAP!) 40 MPH, 25-mile range
- NmG (Myers Motors) 75 MPH, 45-mile range



# And other niche vehicles

- Phoenix SUV/SUT  
95 MPH, 100-mile  
range



- Triac (Green Vehicles)  
80 MPH, 100-mile  
range





# and Neighborhood Electrics....

- GEM e2 (Global Electric Motorcars 25 MPH 35-mile range
- MEGA Tilt Bed (Columbia ParCar) 25 MPH 50-mile range



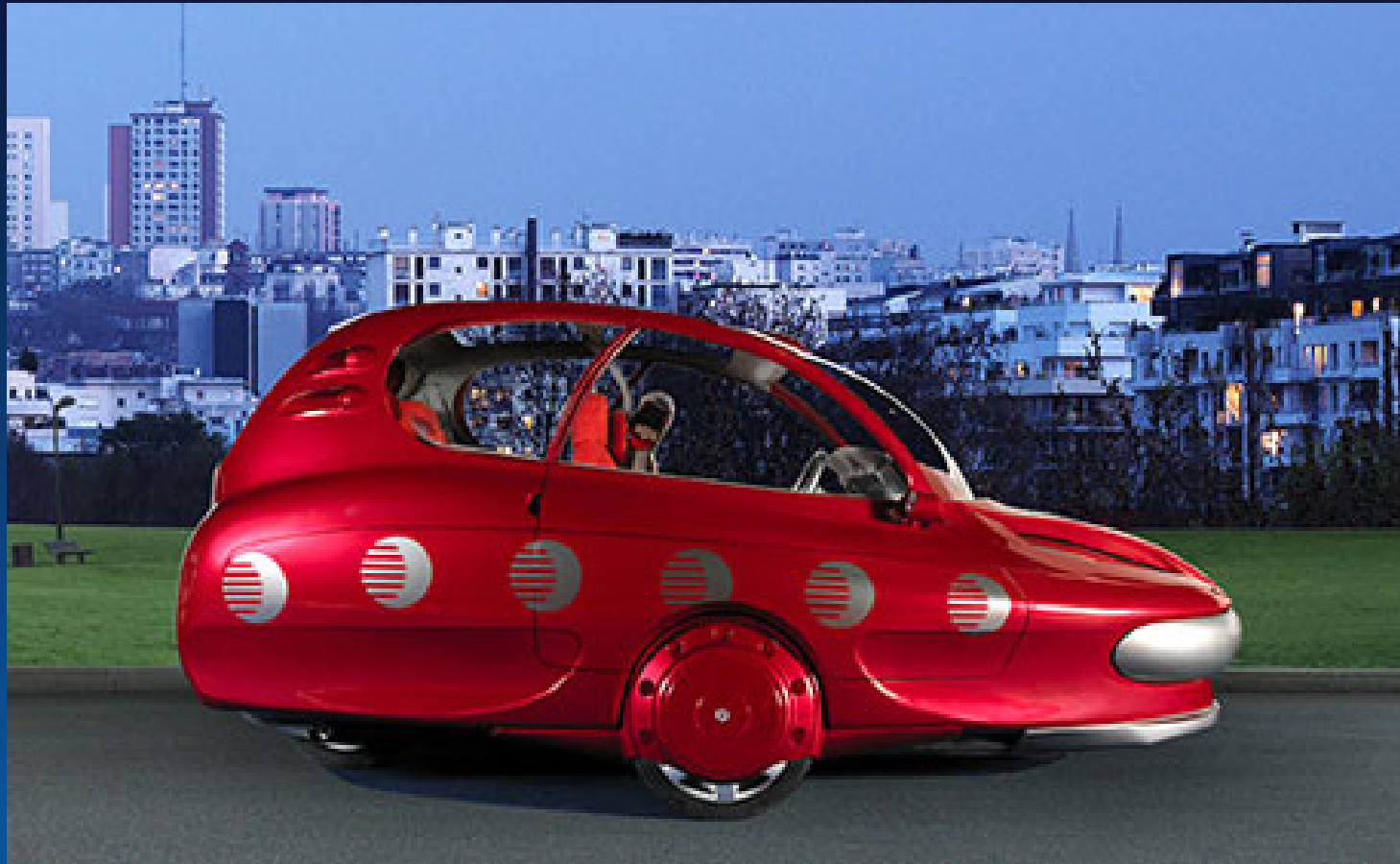
# Honda



# Nissan



# Franco Sbarro “City Car”



18-mile electric range; 46-mpg gasoline drive; 360° rotation



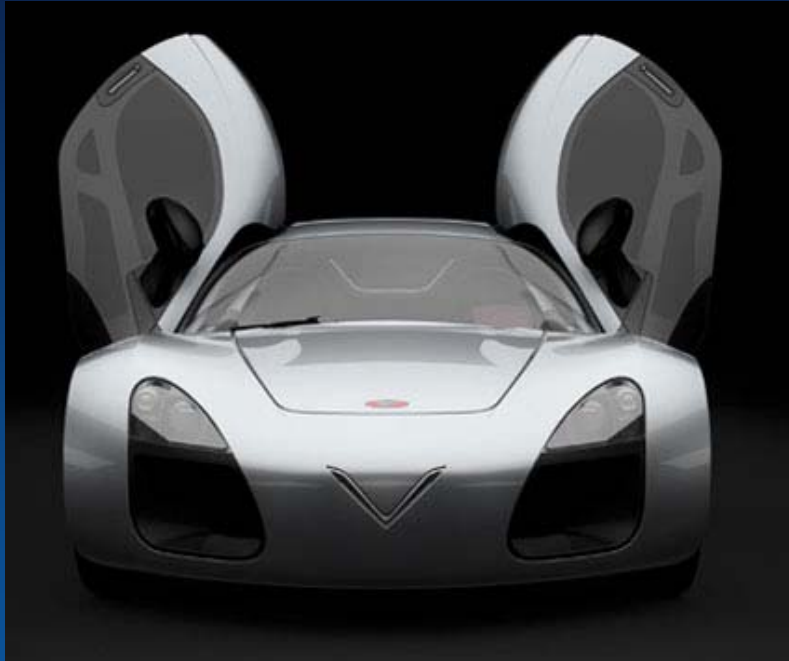
# “Big Box” car



# Venturi's "Astrolab"



# Venturi more serious EVs



Venturi's Fetish

- With 4 drive wheels with active suspension, the Venturi Volage has no equivalent. “Michelin Active Wheel” technology in fact incorporates 2 electric motors per wheel (1 for suspension and 1 for drive)

# Aptera's 3 wheeler





# Personal (one seater) “Big Wheels”



# And Plug-In Technology is Making it to Heavy-Duty Vehicles as Well

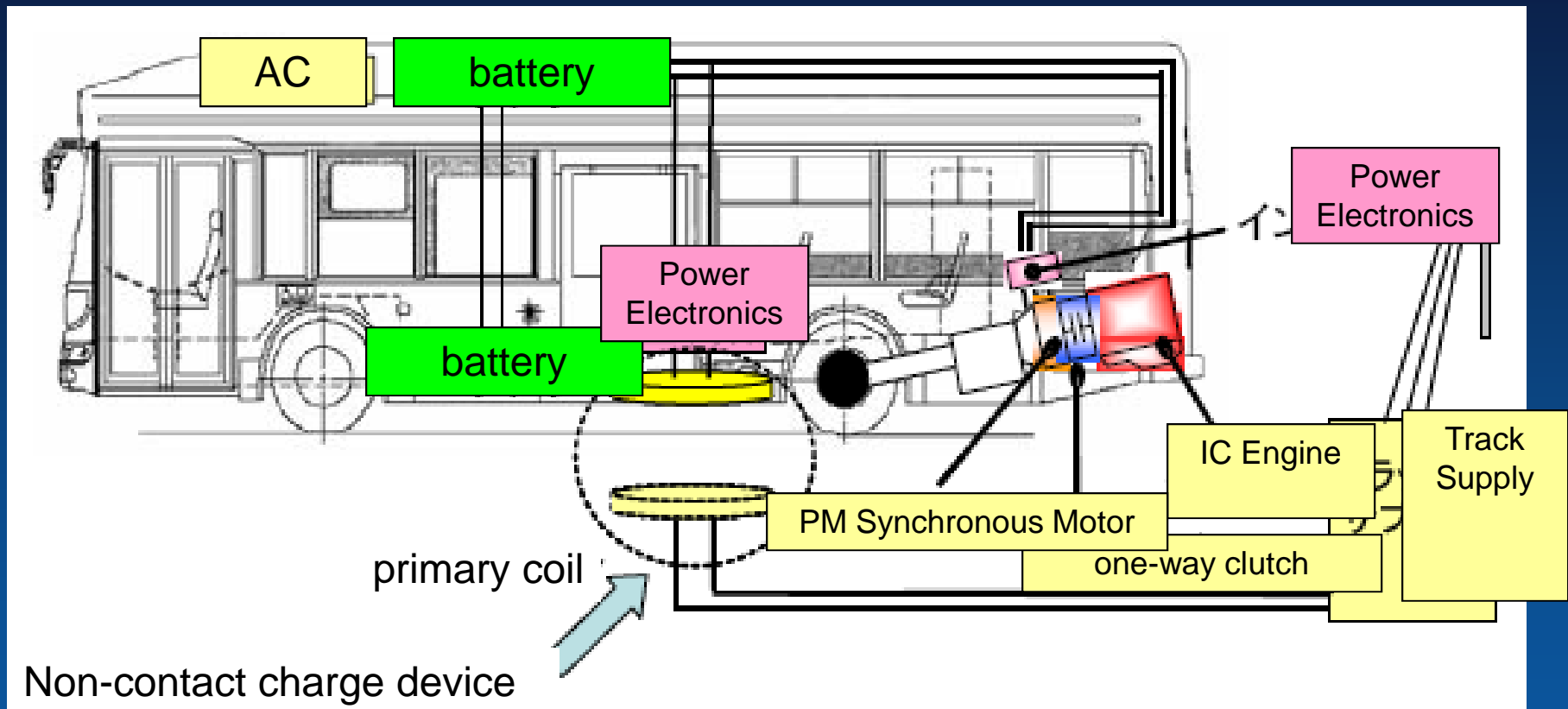
Overhead electrified bus stop



CHINA  
City of Shanghai



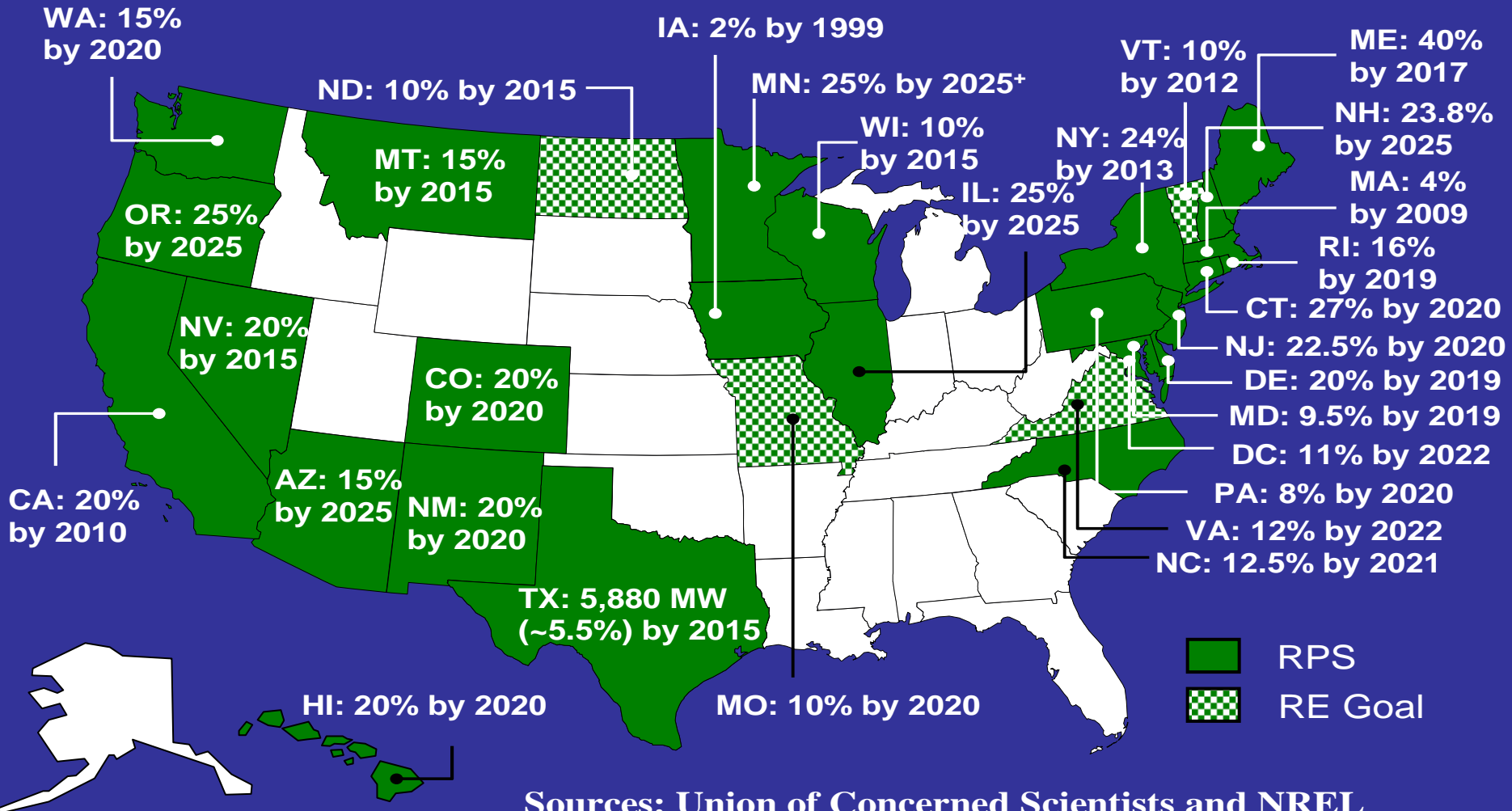
# Or Charged from Below



## Tokyo Haneda Airport, JAPAN

*Hino inductively charged HEV demo for 2007 Tokyo Motor Show*

# State's Renewable Portfolio Standards

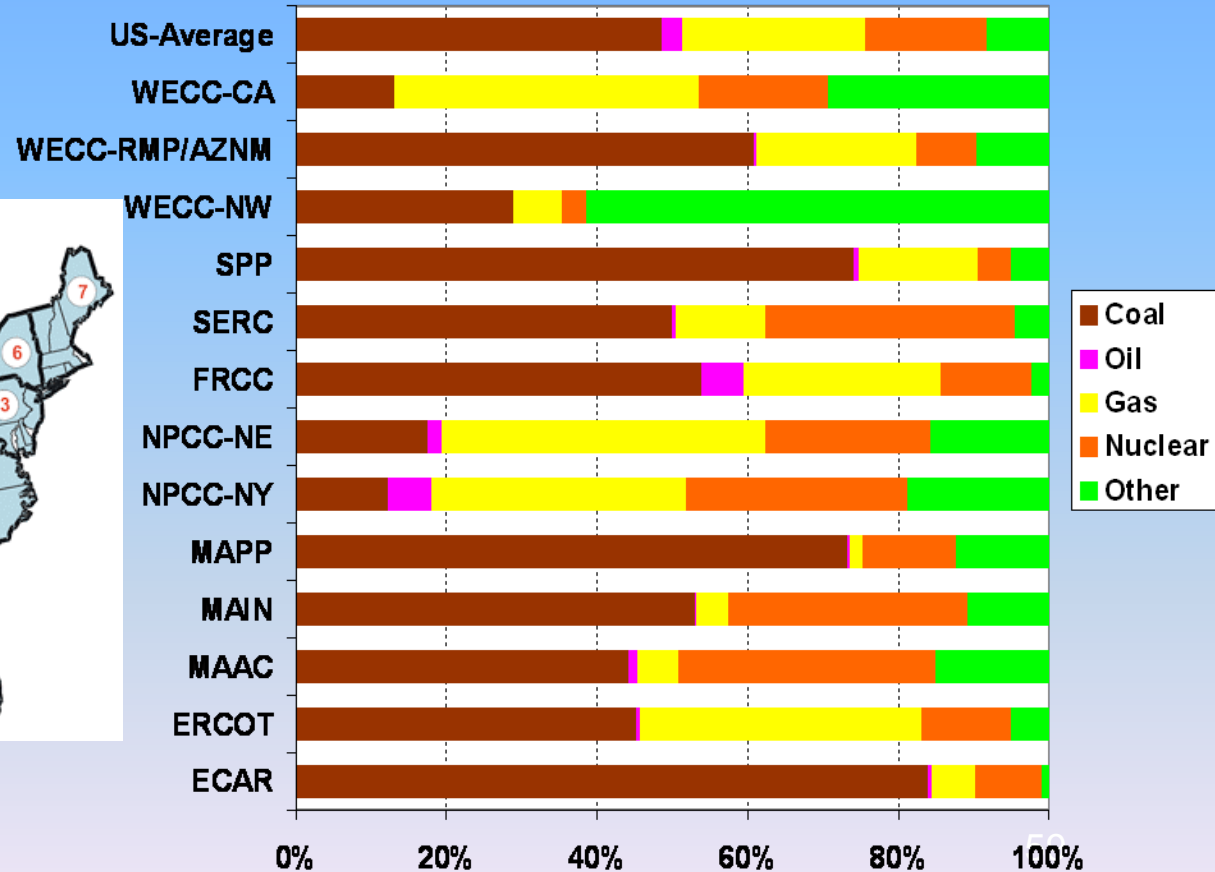
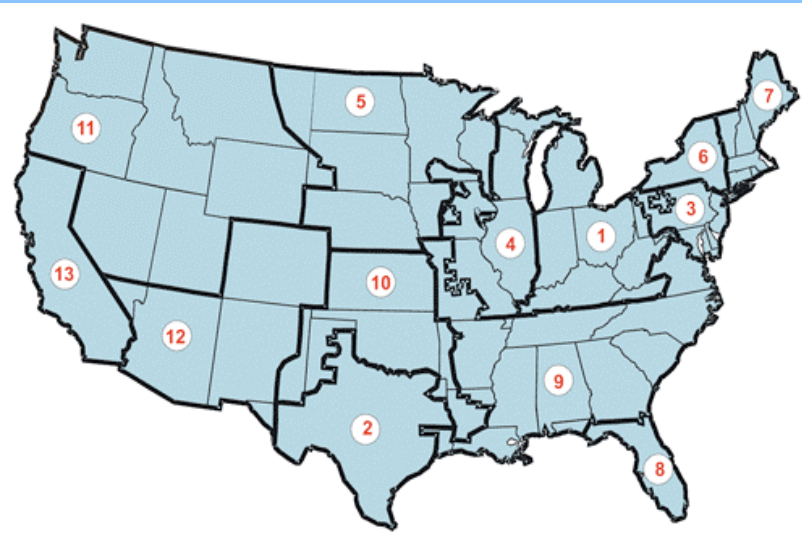


Sources: Union of Concerned Scientists and NREL

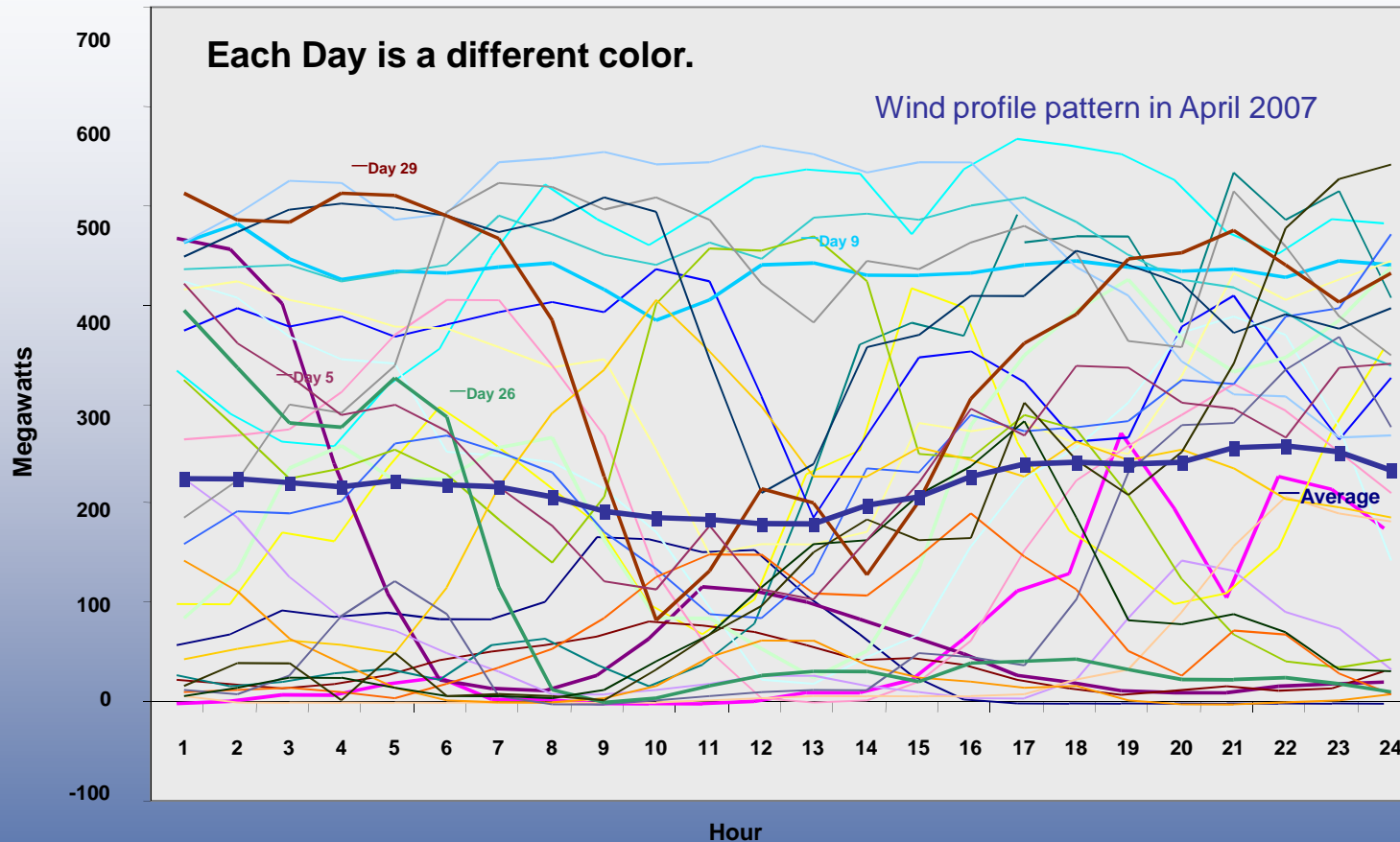


# GREET: What is the Electricity Generation Mix?

Either an average generation mix, such as averages for NERC regions, or some postulated mix (e.g., specified marginal fuel such as 100% renewables) could be used to examine PHEV GHG effects



# Wind Generation Variability Results in Dispatch Challenges

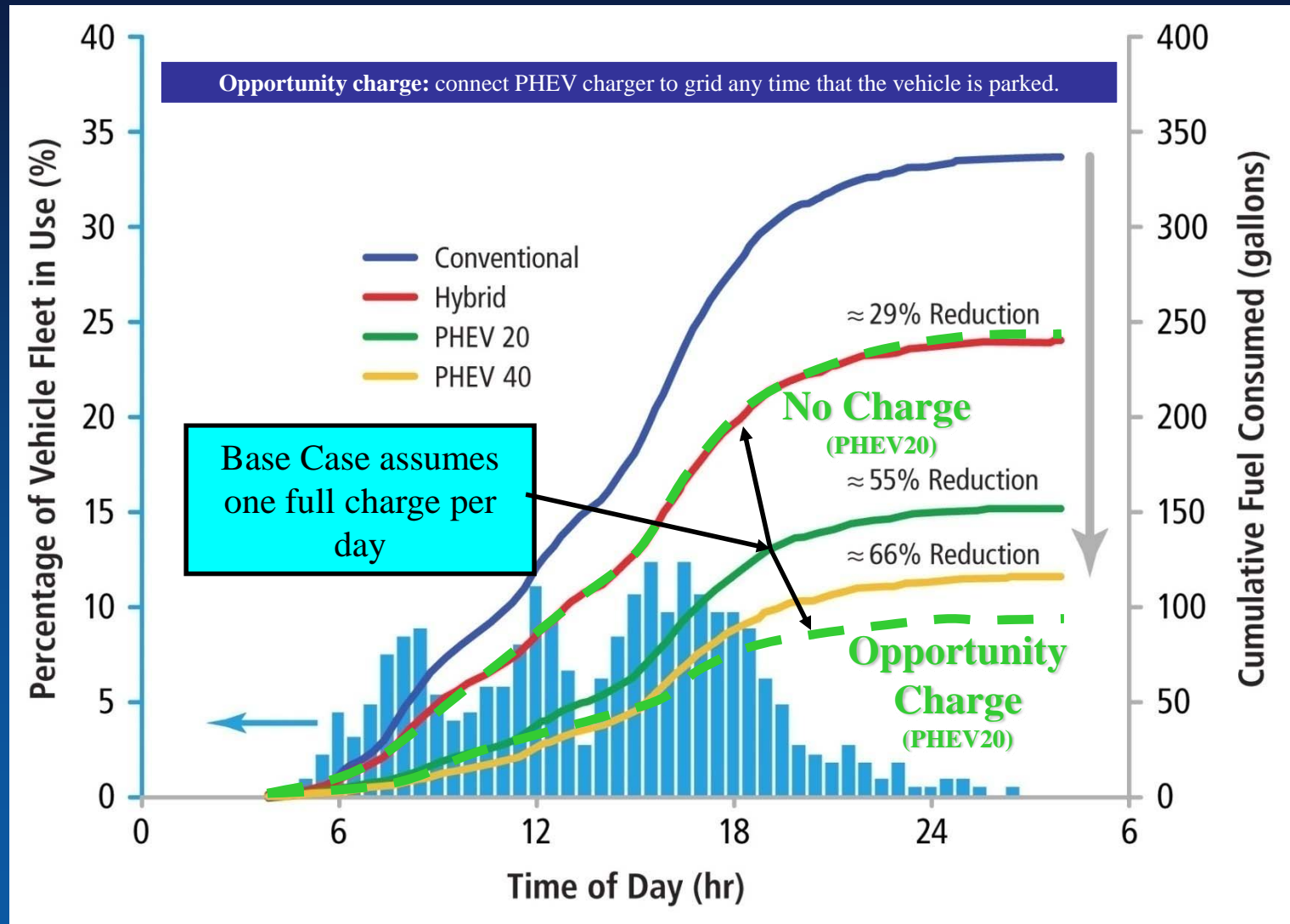


Smart charging has the potential to dispatch the EV load in alignment with the availability of intermittent resources such as wind

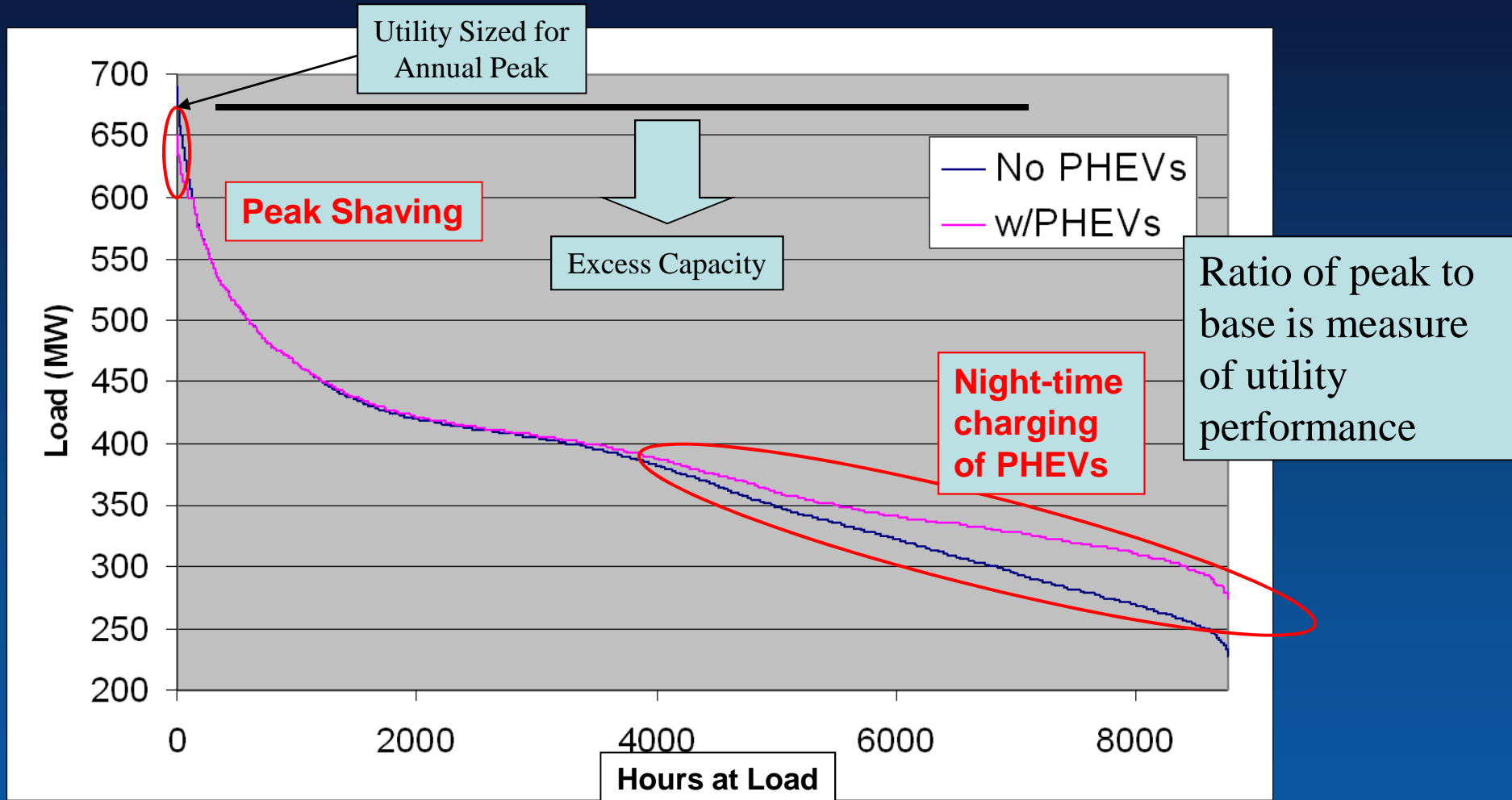
# Venturi Electric – solar, wind



# Recharge Scenario Impacts on PHEV Petroleum Consumption Benefits



# Plug-in HEVs Require No New Capacity and Even Improves Utility Performance

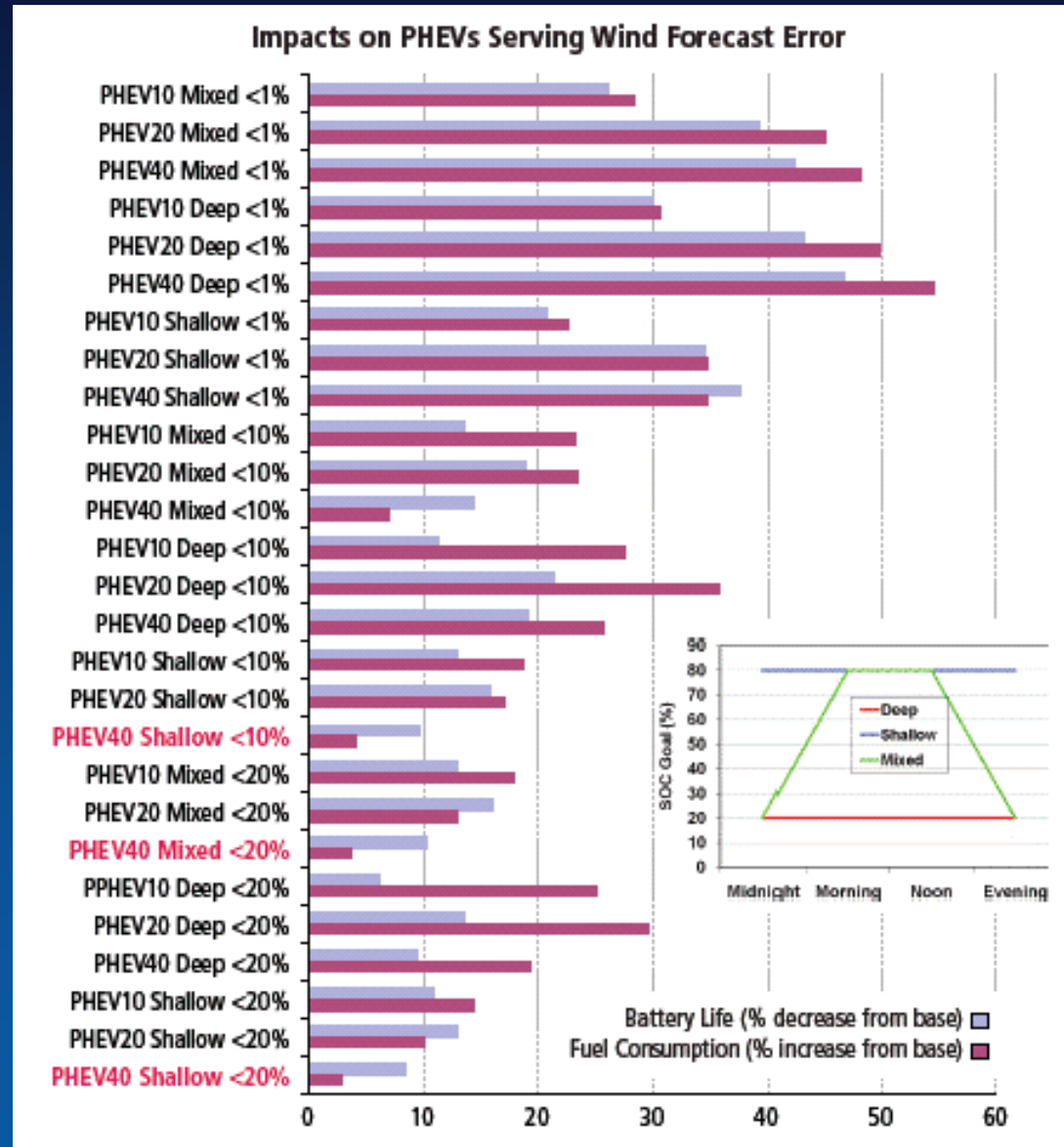


\*\*Assumes utility controlled night-time charging for 50% of the vehicles in this utility district

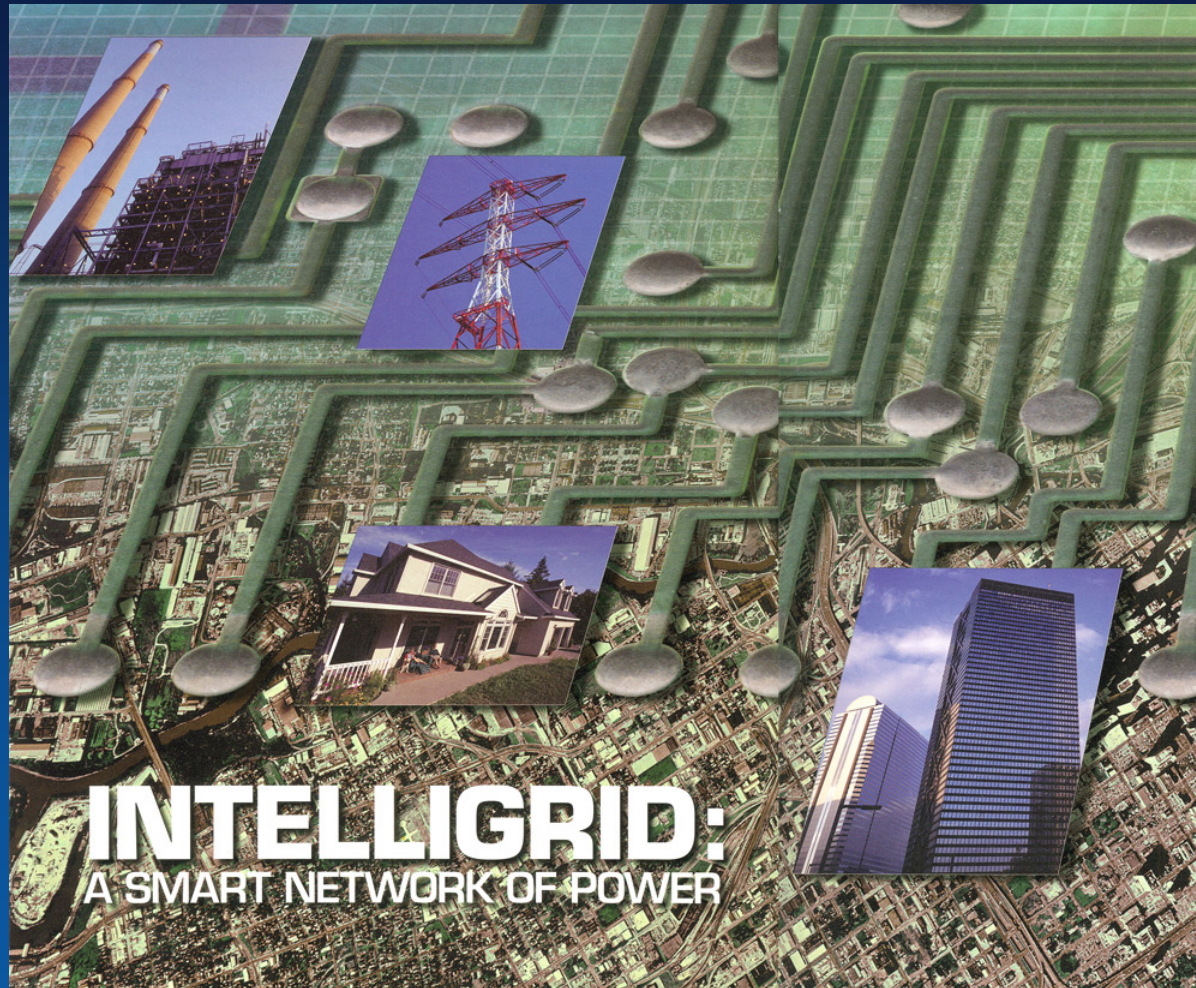


# V2G Systems Analysis with Renewables

- PHEV charge/discharge synchronized with Wind forecast error
- Large battery and market penetration preferred to reduce impact on battery life and fuel consumption

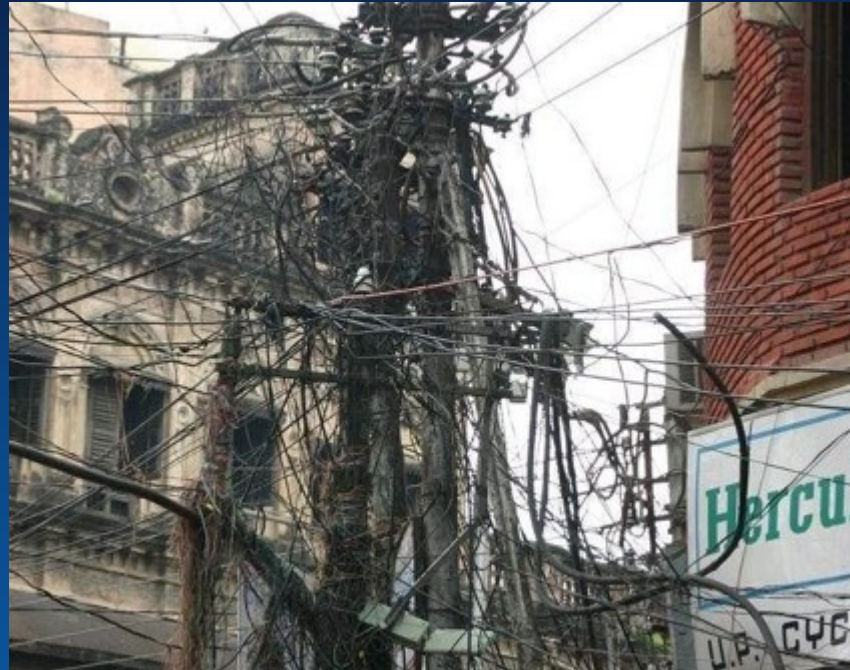


# PHEVs Can Play a Major Role in Such a Smart Grid or Intelligrid of the Future



Source: Electric Power Research Institute. Fall 2005 *EPRI Journal*

# Movement to “smart grid”



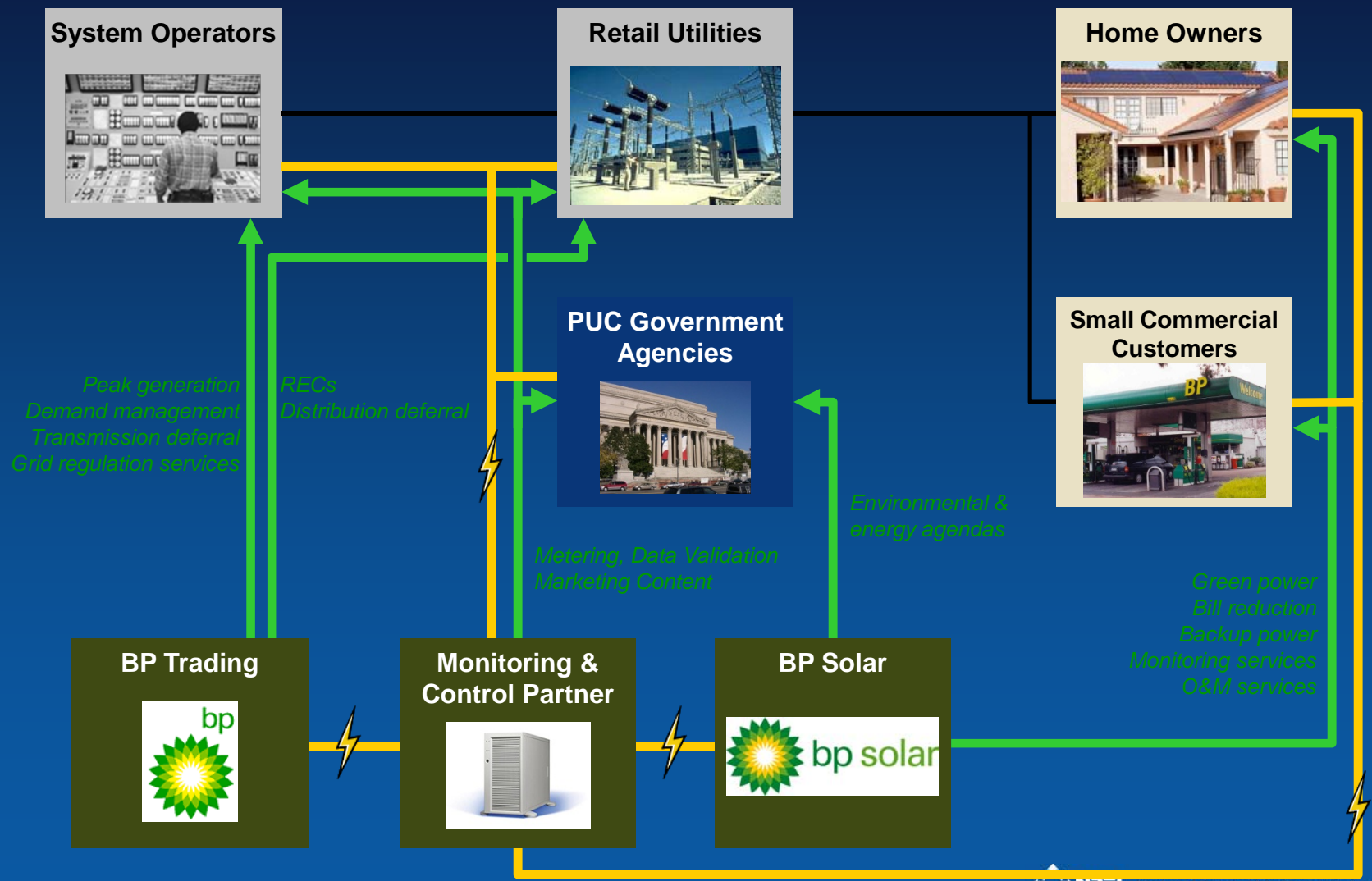
This is obviously not “smart”!



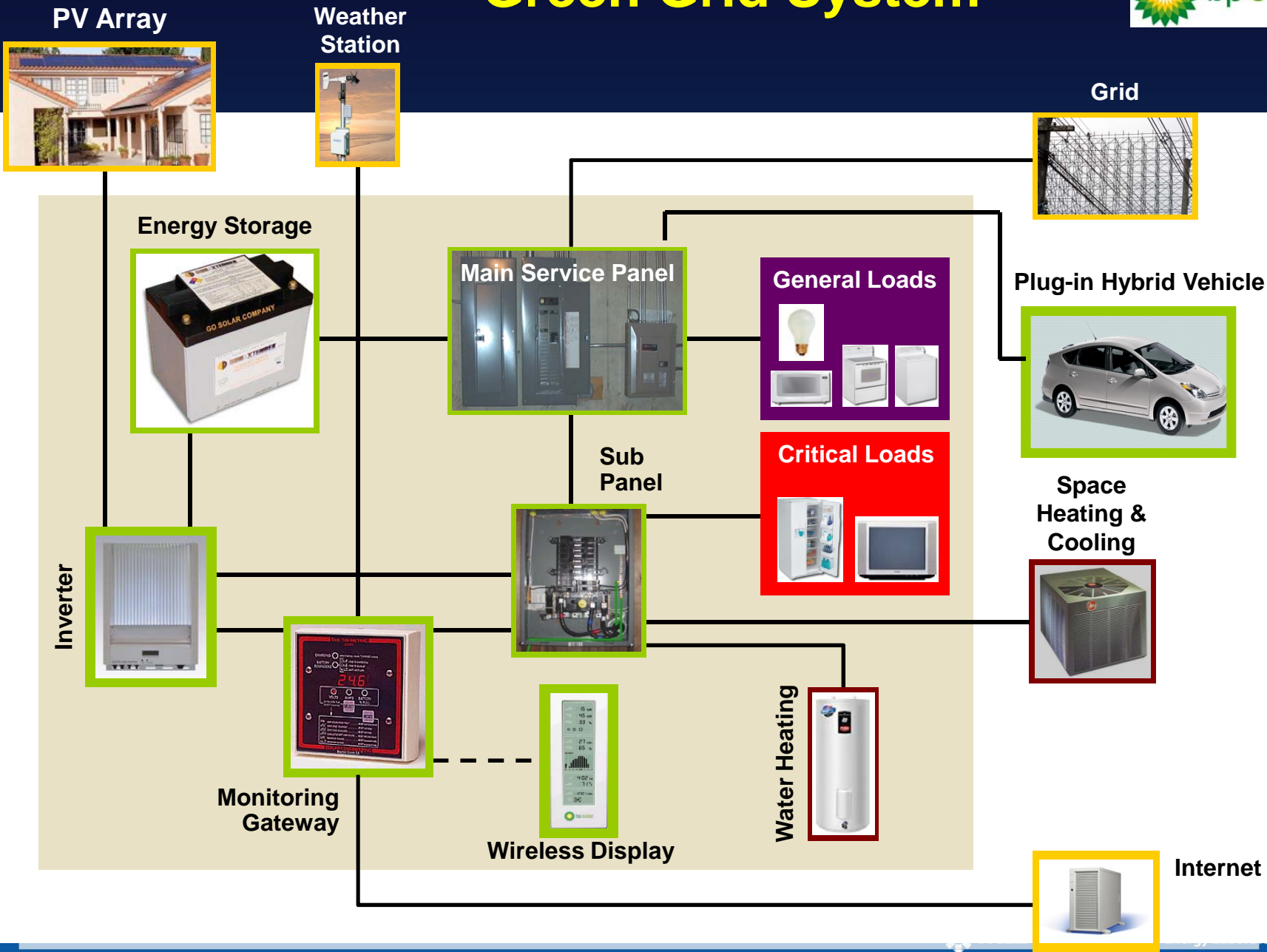
 Grid  
 Internet  
 Sources of Value



# Green Grid System



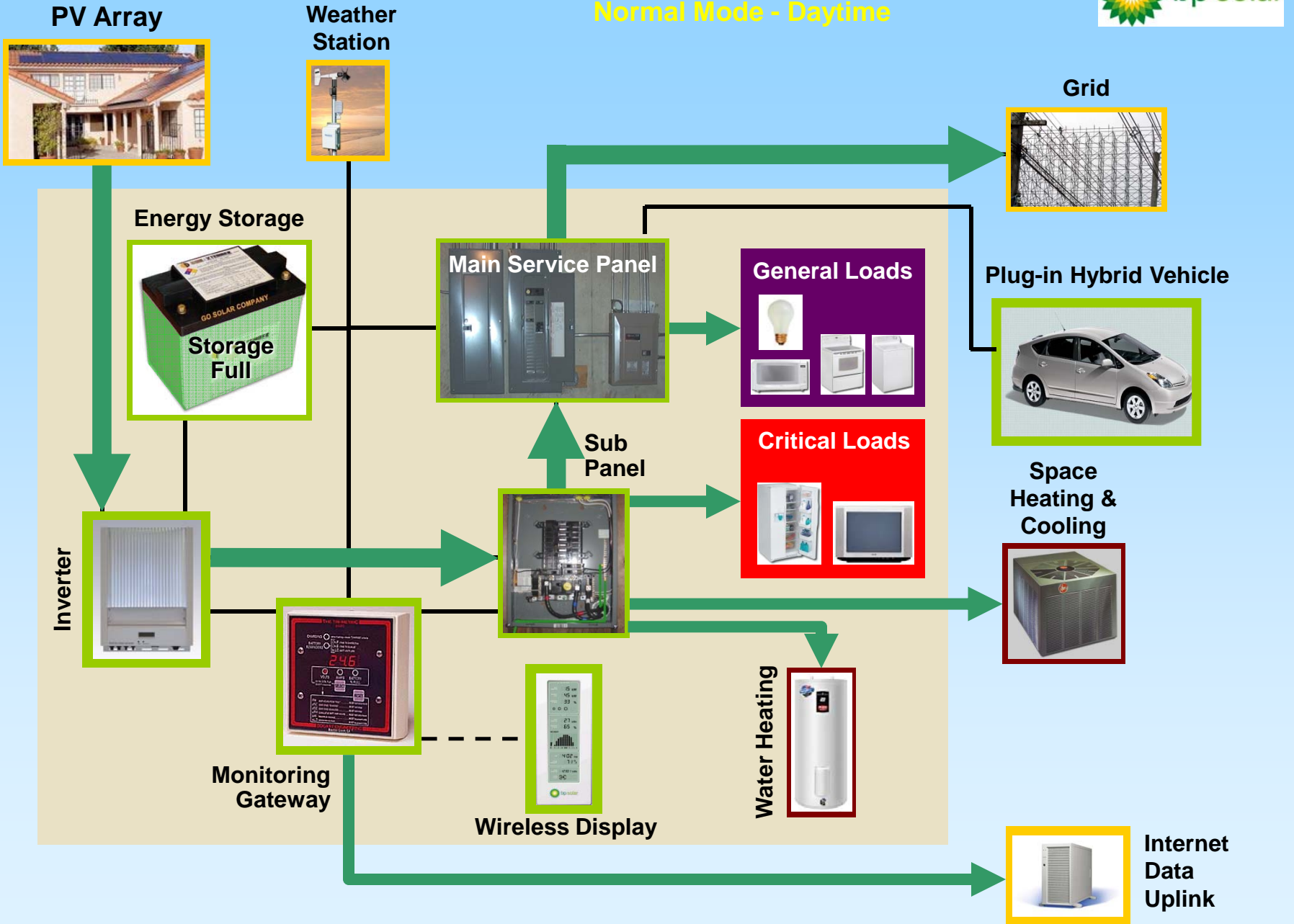
# Green Grid System





# MyPower Node

Normal Mode - Daytime



PV Array



Weather Station



Energy Storage



Main Service Panel



General Loads



Plug-in Hybrid Vehicle



Space Heating & Cooling



Critical Loads



Water Heating



Inverter



Monitoring Gateway



Wireless Display

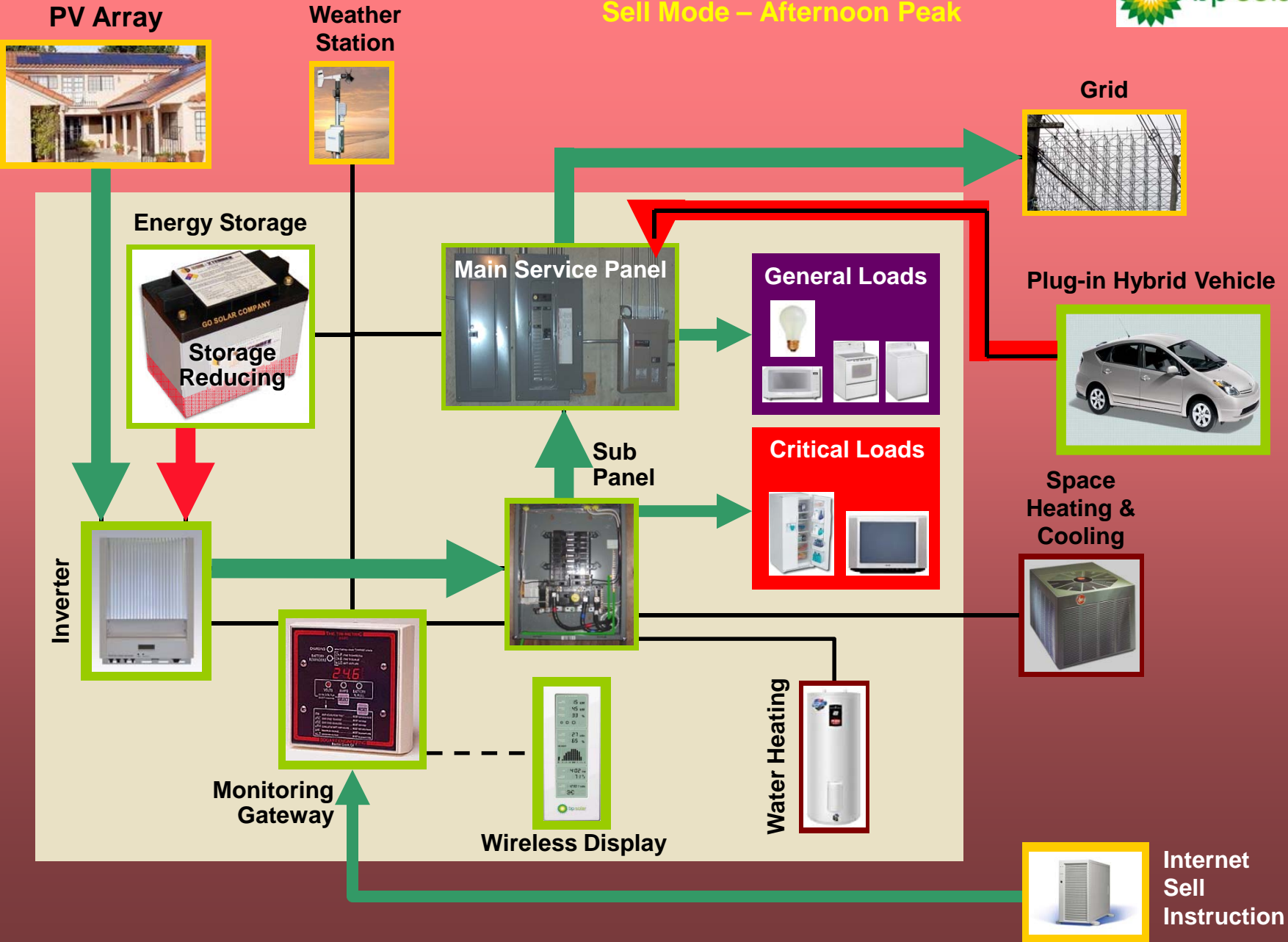


Internet Data Uplink



# MyPower Node

Sell Mode – Afternoon Peak



# MyPower Node

Buy Mode – Night



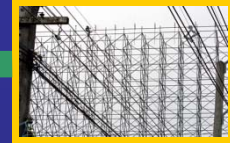
PV Array



Weather Station



Grid



Energy Storage



Main Service Panel



General Loads



Plug-in Hybrid Vehicle



Sub Panel



Critical Loads



Space Heating & Cooling



Inverter



Monitoring Gateway



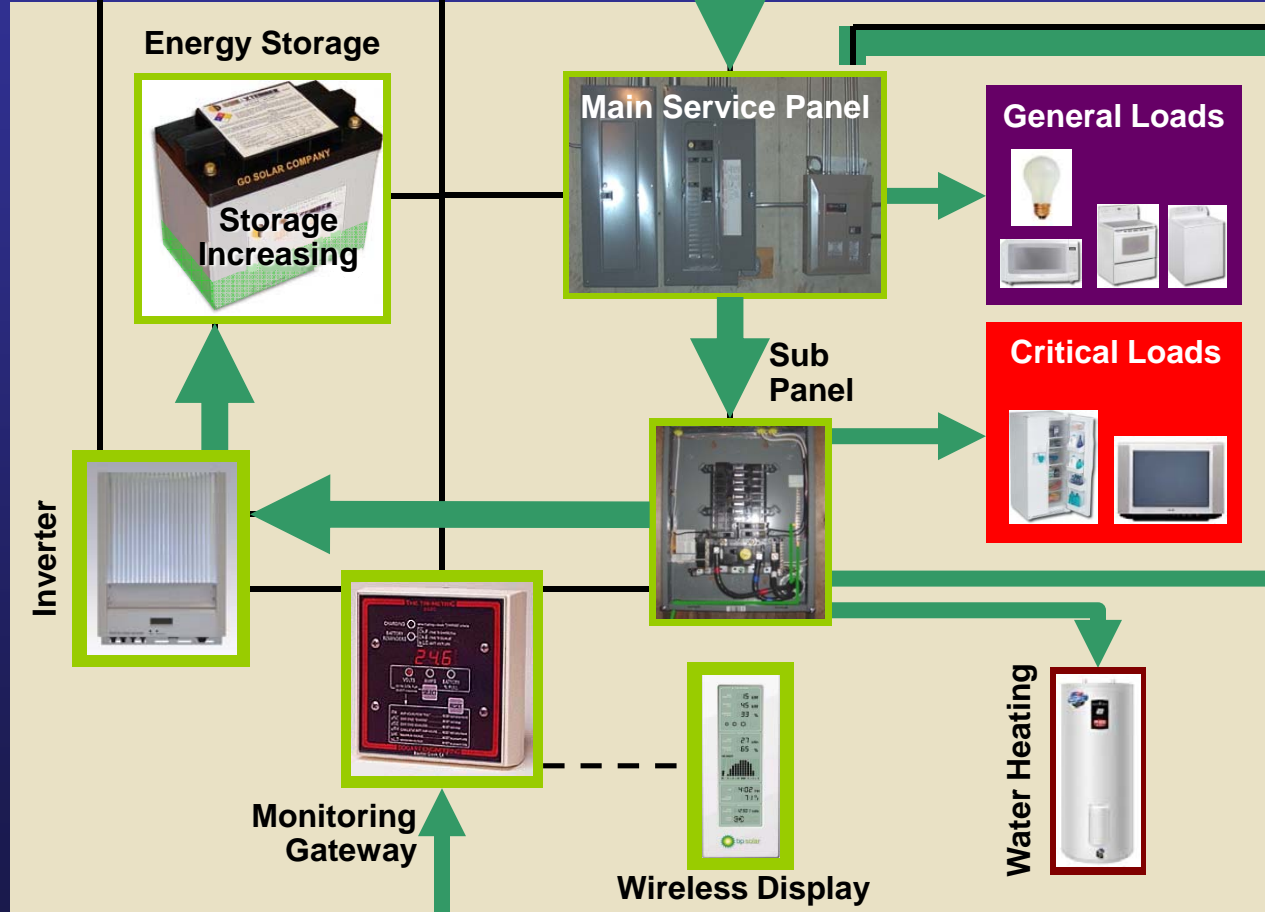
Wireless Display



Water Heating



Internet Buy Instruction



# MyPower Node

Normal Mode – Night



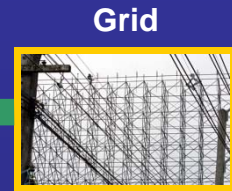
PV Array



Weather Station



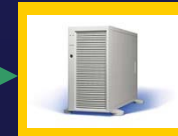
Energy Storage



Grid



Space Heating & Cooling



Internet Data Uplink

Monitoring Gateway

Wireless Display

Water Heating

# MyPower Node

## Emergency Mode



PV Array



Weather Station



Grid Failure



Energy Storage



Main Service Panel



General Loads



Plug-in Hybrid Vehicle



Inverter



Sub Panel



Critical Loads



Space Heating & Cooling



Monitoring Gateway



Wireless Display



Water Heating



Internet Link Failure





# Toyota Dream House

Simple outlet in the garage will suffice, but connection can be more

“Intelligent” house in Aichi Prefecture, Japan, showcases computer technologies that control all the systems in the house, along with a fuel cell, solar panels, and Toyota modular housing systems.



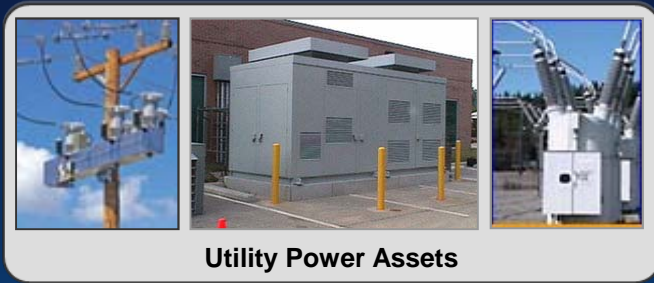
Includes two-way connection to PHEV Toyota Prius to charge vehicle battery pack or conversely provide electricity to the house for up to 36 hours

# “Eliica” Japan’s “8” wheeler



# This GridPoint® PHEV Smart Charging System is Already on the Market

## Utility Operator Control



### GridPoint Support Systems

- Logistics & Installation
- Configuration & Provisioning
- Monitoring & Support

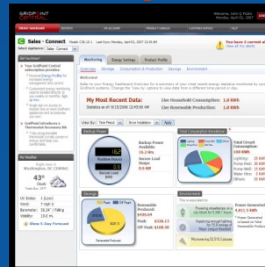
### Utility Systems

- Utility Ops Center
- Operations & Control Center
- Billing & CRM Systems

### Residential Customers

- Load Measurement & Control
- Energy Storage Integration
- Renewables Integration
- PHEV Integration
- Other Distributed Technologies

### Legacy Systems



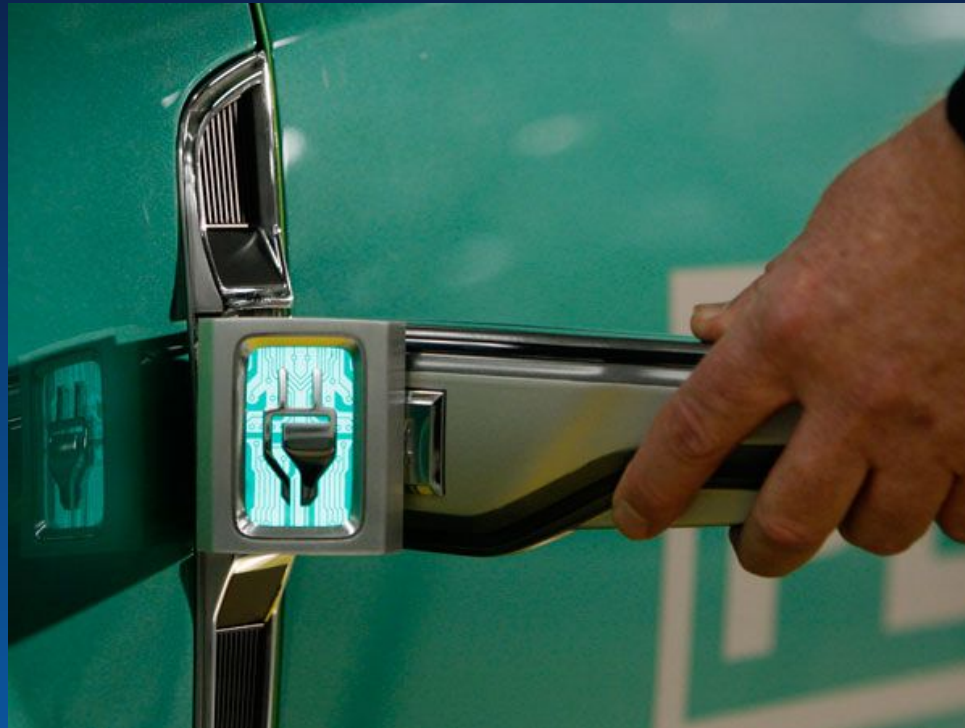
## Consumer Interfaces

- Portland's new concept electric "filling station"





# Panasonic's PHEV music & fuel connector



- Panasonic's idea of creating a cable that uploads music and data to an electric car (or a plug-in hybrid) while it charges.



# And Companies Are Developing Appropriate Equipment

- As this Coulomb electric-car charging station installed in San Jose, California demonstrates



# A “Solar Tree” in Germany Future Charging Station?



What if Denver  
“planted” 5 solar  
trees/year for the next  
25 years?

As a side benefit what  
image would be  
created?

# Ideas, Tools & Best Practices

- Singapore's Mass Rapid Transit system
- Going Carbon Neutral – measure, reduce, offset
- CA Safe routes to schools program
- Genuine Progress Indicator – tool for sustainable development
- Walking in America – Surface Transportation Policy Project 2003
- Ecological “footprint” measurement – energy, housing, food, goods & services, transportation, recycling
- Linking Transit on Demand with Smart development and new urbanism
- Scenarios for Sustainability (S2)

# Climate Protection in Sonoma County

Adopting bold emission reduction target in the United States:  
**25% below 1990 levels by 2015.**  
 (data provided by Climate Protection Campaign)

	1990	2000	2015	2020	2050
SONOMA COUNTY			25% below 1990 levels Sonoma County	1990 levels California's Global Warming Solutions Act	80% below 1990 levels Executive Order S-3-05
Total Net GHG (tons)	2,910,354	3,739,380	2,182,765	2,910,354	582,070
Population	388,222	458,614	542,000	546,151	761,177
GHG/Person	7.5	8.2	4	5.3	0.8

# Victoria Transport Policy Institute

<http://www.vtpi.org/tdm/tdm52.htm>

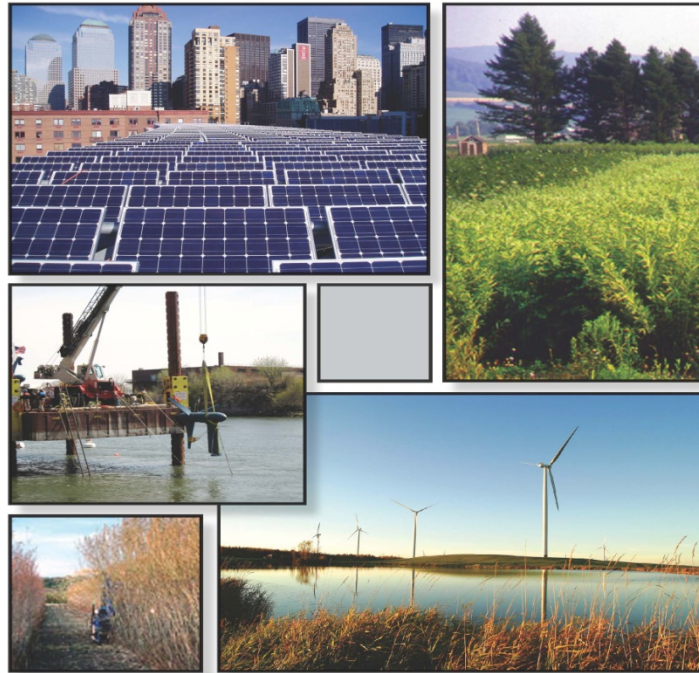
**Win-Win Transportation Solutions Cost-Effective, Market-Based  
Strategies To Encourage Efficient Transport**

***For example:***

- Parking Cash Out
- Location Efficient Development
- Distance-Based Vehicle
- Transportation Choice
- Pedestrian and Cycling Conditions
- Rideshare Services
- Public Transit
- Telework
- Access Management
- Smart Growth; New Urbanism



# New York's Renewable Energy and Enhanced Energy Independence Plan

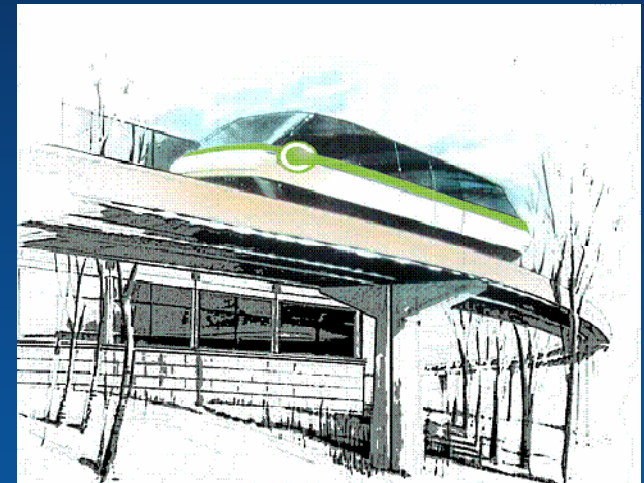


## **CLEAN, SECURE ENERGY AND ECONOMIC GROWTH: A COMMITMENT TO RENEWABLE ENERGY AND ENHANCED ENERGY INDEPENDENCE**

THE FIRST REPORT OF THE RENEWABLE ENERGY TASK FORCE  
TO LIEUTENANT GOVERNOR DAVID A. PATERSON  
FEBRUARY 2008

# Other option for Mass Transit—Pod Cars

Personal rapid transit or PRTs that take you on flexible guiderail routes in the comfort of a personal “car”



Images all of commercial prototypes or plans from newsletter on upcoming “Podcar City” conference in Ithaca, New York, next week—September 14-16

And “detachable PRTs”—transit networks that carry you along main corridors in your “own car,” but you drive that car from home to the main corridor and from the main corridor to your final destination

Ms.wmv

Video Link  
Above





# BECOMING A RENEWABLE ENERGY COMMUNITY

STEP  
1

**The Energy  
Conscious  
Community**

STEP  
2

**A: Solar/  
Near-zero  
energy  
homes**

**B:  
NEVs**

**C:  
PHEVs**

**Microgrid and/or  
working utility  
(Optional)**

STEP  
3

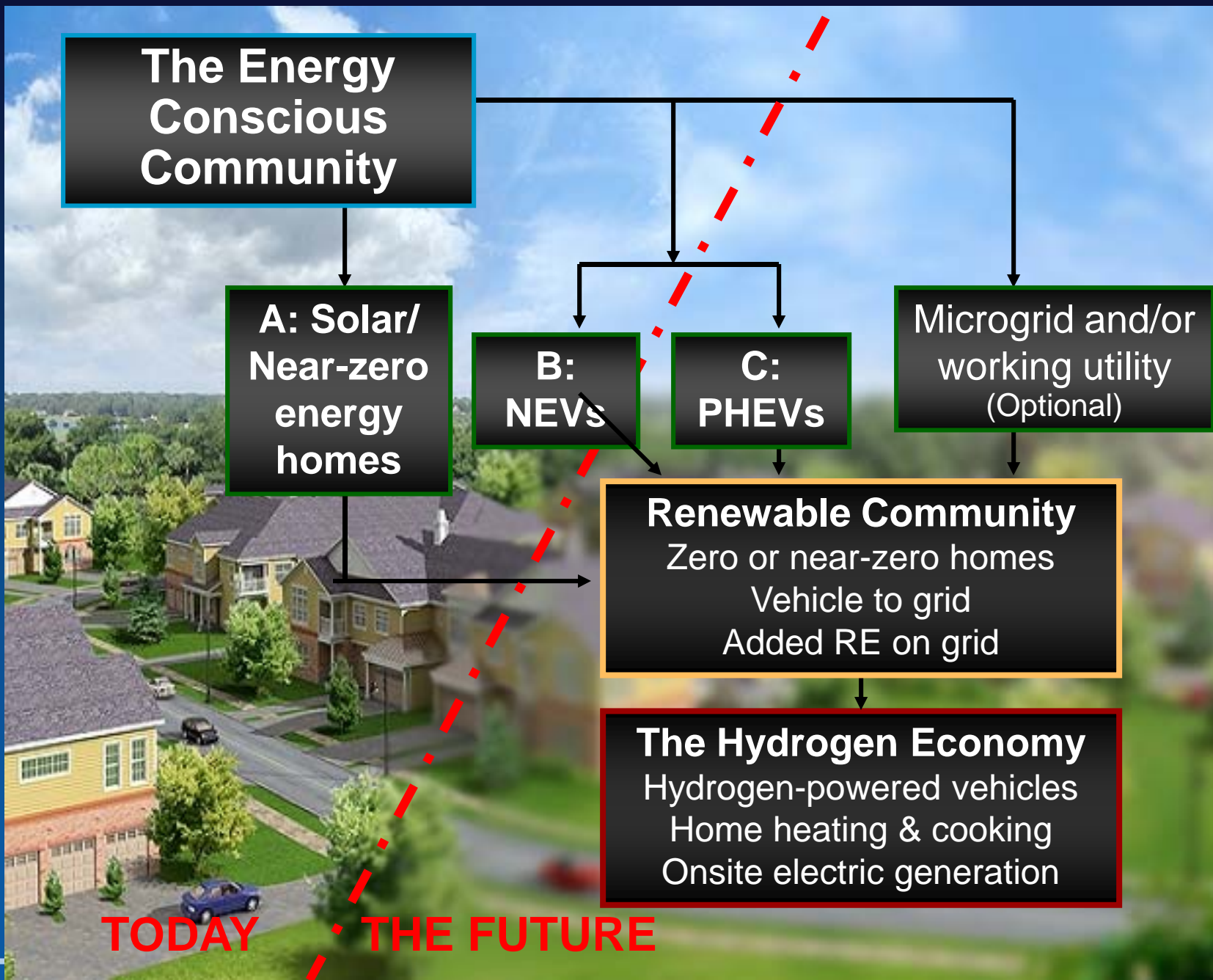
**Renewable Community**  
Zero or near-zero homes  
Vehicle to grid  
Added RE on grid

STEP  
4

**The Hydrogen Economy**  
Hydrogen-powered vehicles  
Home heating & cooking  
Onsite electric generation

**TODAY**

**THE FUTURE**



# Putting it All Together



Vehicles and Fuels + Energy Smart Buildings + Renewables =

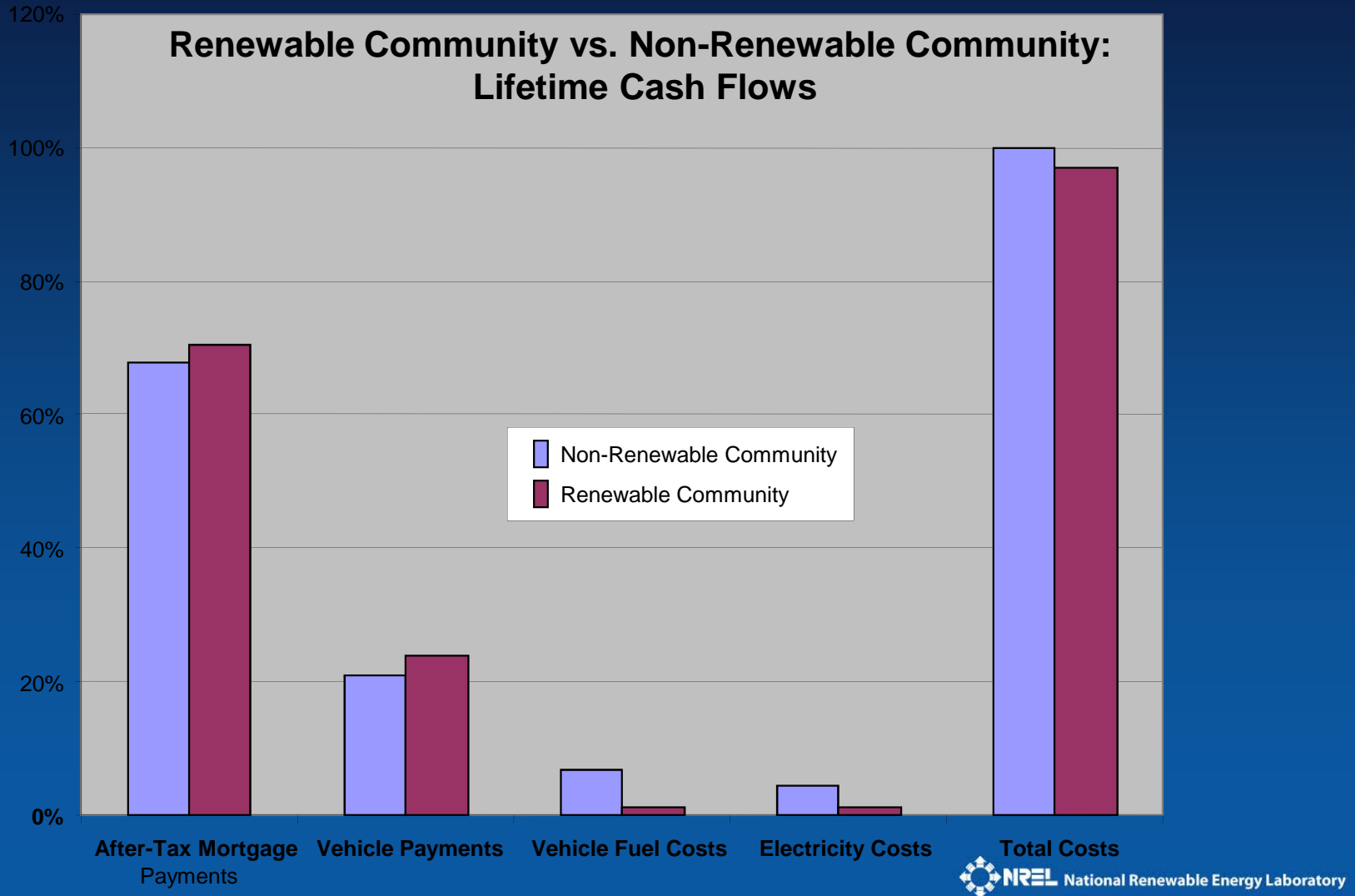
And, of course, as Nancy set the stage and Tim explained the possibilities for buildings, we can put vehicles, buildings, and sound community and transportation planning all together to create the vision for what this conference is all about.....



# Renewable Community Vision



# *A Renewable Community Can Cost Less Than A Non-Renewable Community!*



# Key points.....

- Data and best practices of what to do are everywhere.....
- **Set aggressive goals** over short, medium and long term time frames - do a “portfolio” analysis to see where you stack up with others – pick the “right” metrics
- **Measure progress over time** – balance “carrots and sticks” – what gets measured, gets done!
- Take the **larger sustainable system view** – balancing energy security, energy independence, water management, economic growth, etc – but encourage action at the local level
- **Private-public partnerships** are critical – bring in all stakeholders early in the planning stages