How Green Will Electricity be When Electric Vehicles Arrive?

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A Few Simple Questions

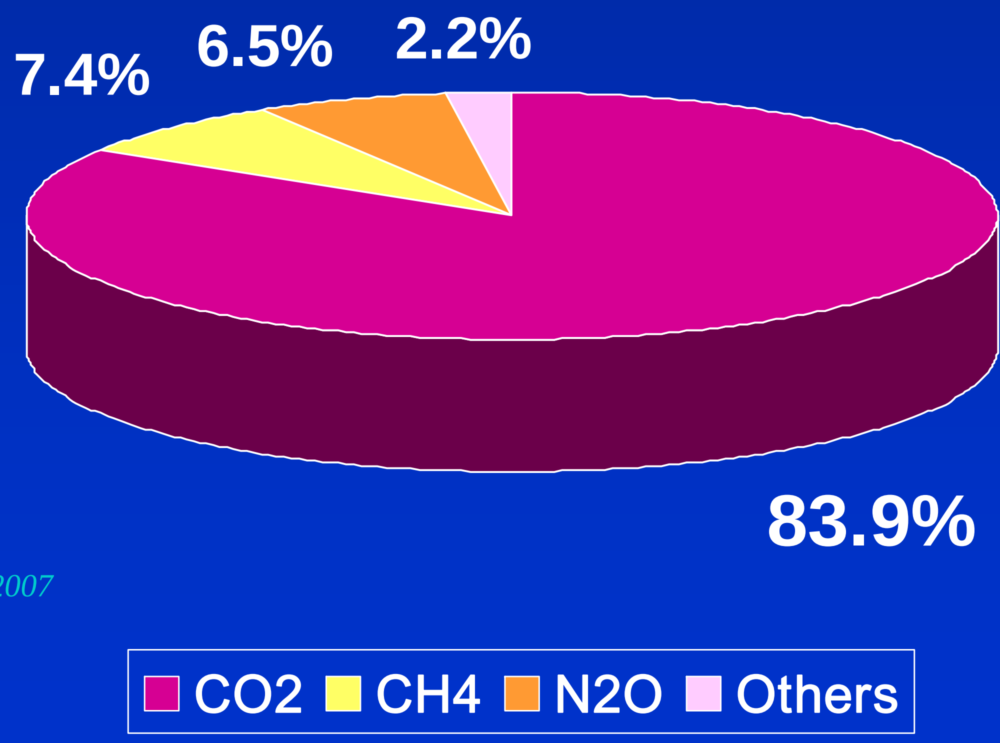
- How "green" is U.S. electricity today in terms of greenhouse gas (GHG) emissions?
- What has been the recent trend in power sector emissions and carbon intensity?
- What is the outlook for low-carbon electricity and plug-in hybrid electric vehicles (PHEVs) ?
- In light of the above, would adoption of PHEVs significantly reduce U.S. GHG emissions?

The Current Situation

CO_2 from Energy Use is the Dominant Greenhouse Gas

U.S. Greenhouse Gas Emissions

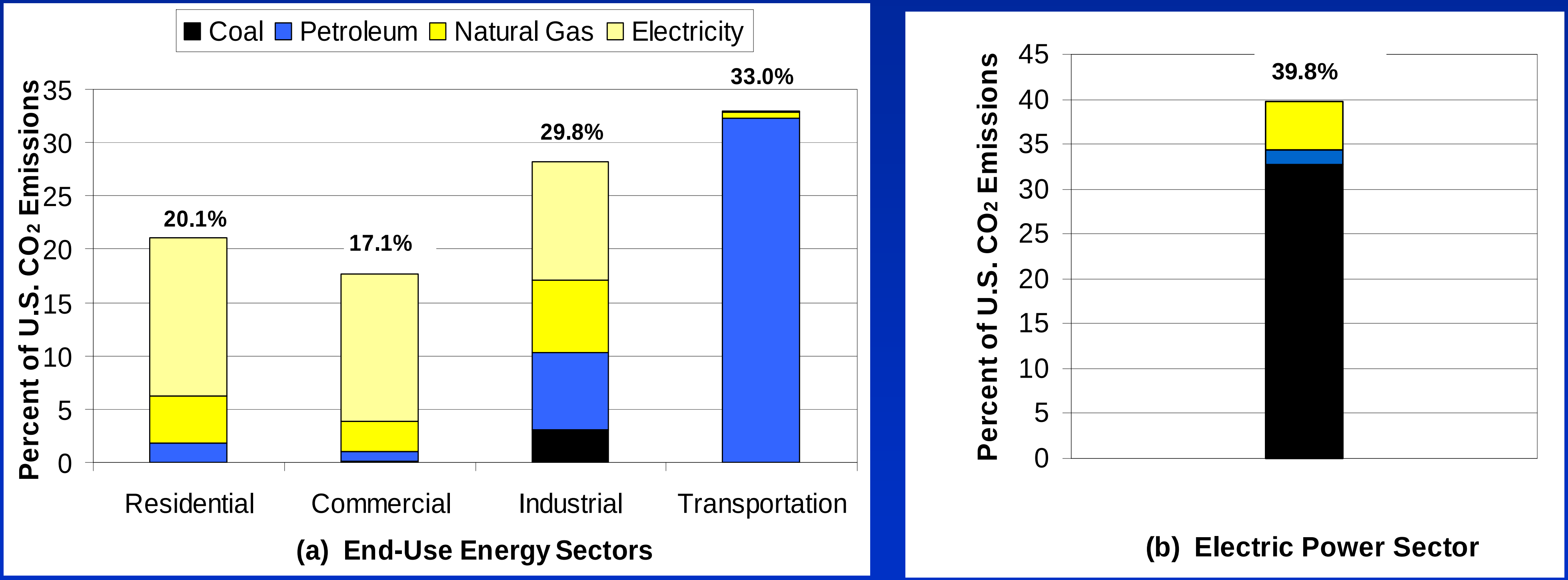
weighted by 100-yr Global Warming Potential (GWP)



Source: USEPA, 2007

Sources of CO_2 Emissions

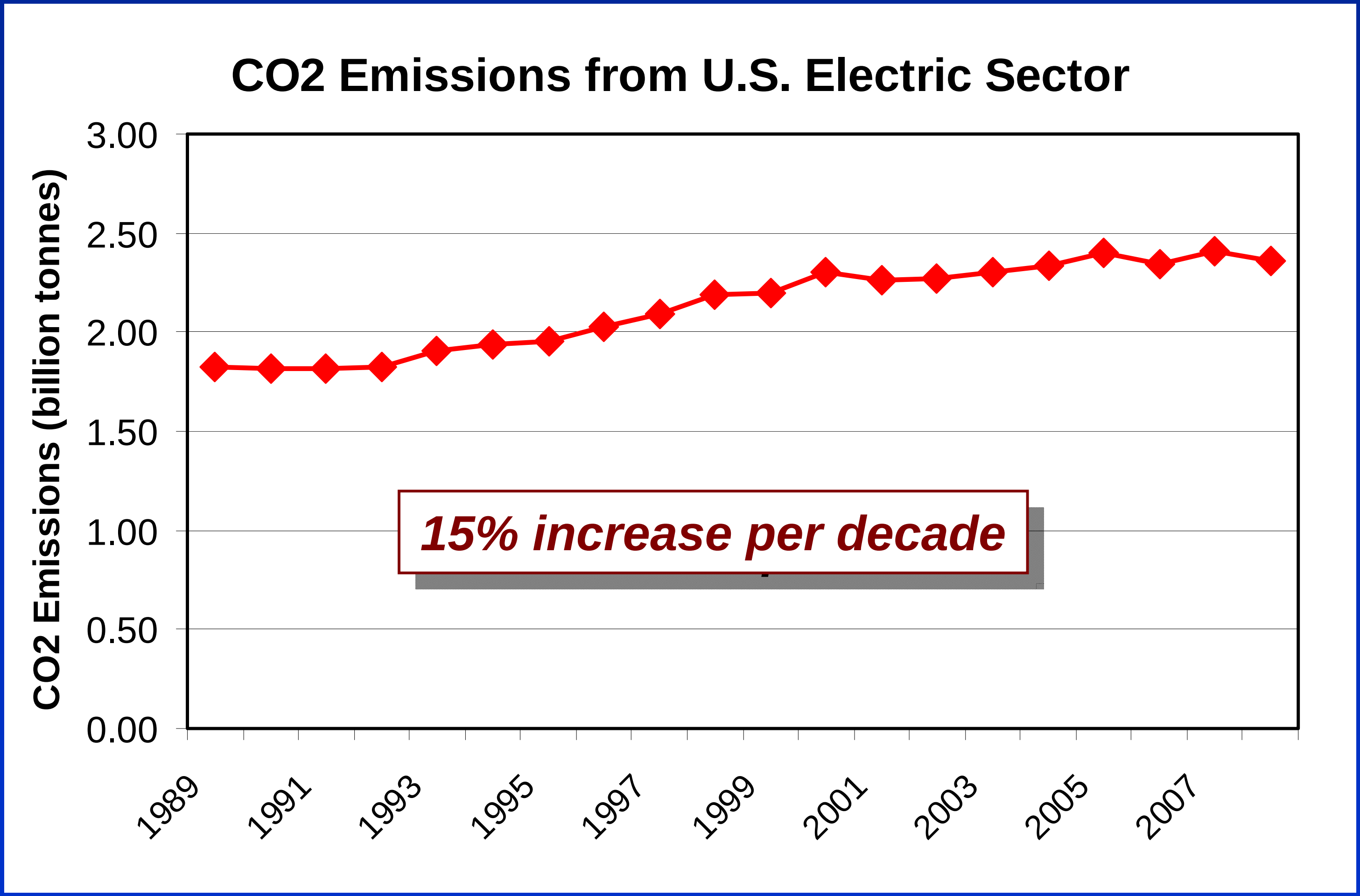
U.S. CO_2 Emissions



Source: Based on USDOE, 2008

- Fossil fuels supply 70% of all U.S. electricity
- Electricity + Transportation emit ~75% of all CO_2

Trend in Power Sector Carbon Dioxide Emissions



Source: Based on data from USDOE, 2010

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Power Plant Carbon Intensity

(CO_2 emissions per net kilowatt-hour)

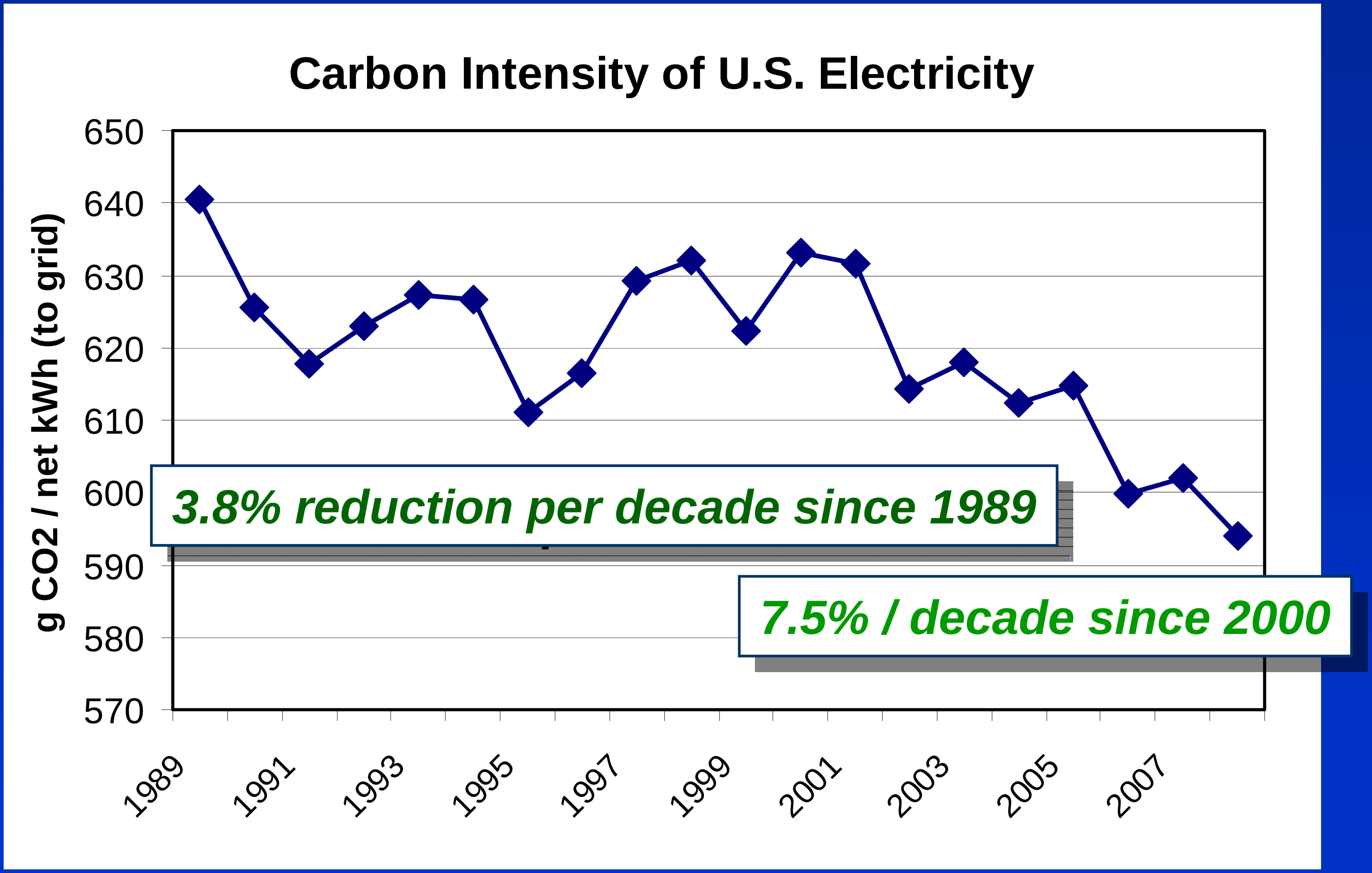
Power Plant Fuel and Type	Direct Emissions (g CO_2/ kWh)
Coal (existing sub-critical)	1000
Coal (new super-critical)	800
Natural Gas (turbines)	800
Natural Gas (comb. cycle)	400
Nuclear	0
Hydro	0
Wind	0

Source: Samaras, 2008; Rubin, 2000

Average emission rate based on U.S. 2008 fuel mix =

0.59 t CO_2 / MWh

Carbon Intensity of Electric Power Sector Has Been Decreasing



Source: Based on data from USDOE, 2010

Upstream Activities Increase Life-Cycle Emissions

Plant Type	Direct GHGs (g CO_2/ kWh)	Upstream GHGs (g CO_2-eq/ kWh)	Total life cycle GHGs (g CO_2-eq/ kWh)
Coal (new)	800	50	850
NGCC (new)	400	75	475
Coal w/ CCS	100	50	150
NGCC w/ CCS	50	75	125
Solar (PV)	0	60	60
Wind	0	15	15
Nuclear	0	10	10
Hydro	0	8	8

Source: Samaras, 2008

Low-Carbon Options

Plant Type	Direct GHGs ($g\ CO_2$/ kWh)	Upstream GHGs ($g\ CO_2$-eq/ kWh)	Total life cycle GHGs ($g\ CO_2$-eq/ kWh)
Coal (new)	800	50	850
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Source: Samaras, 2008

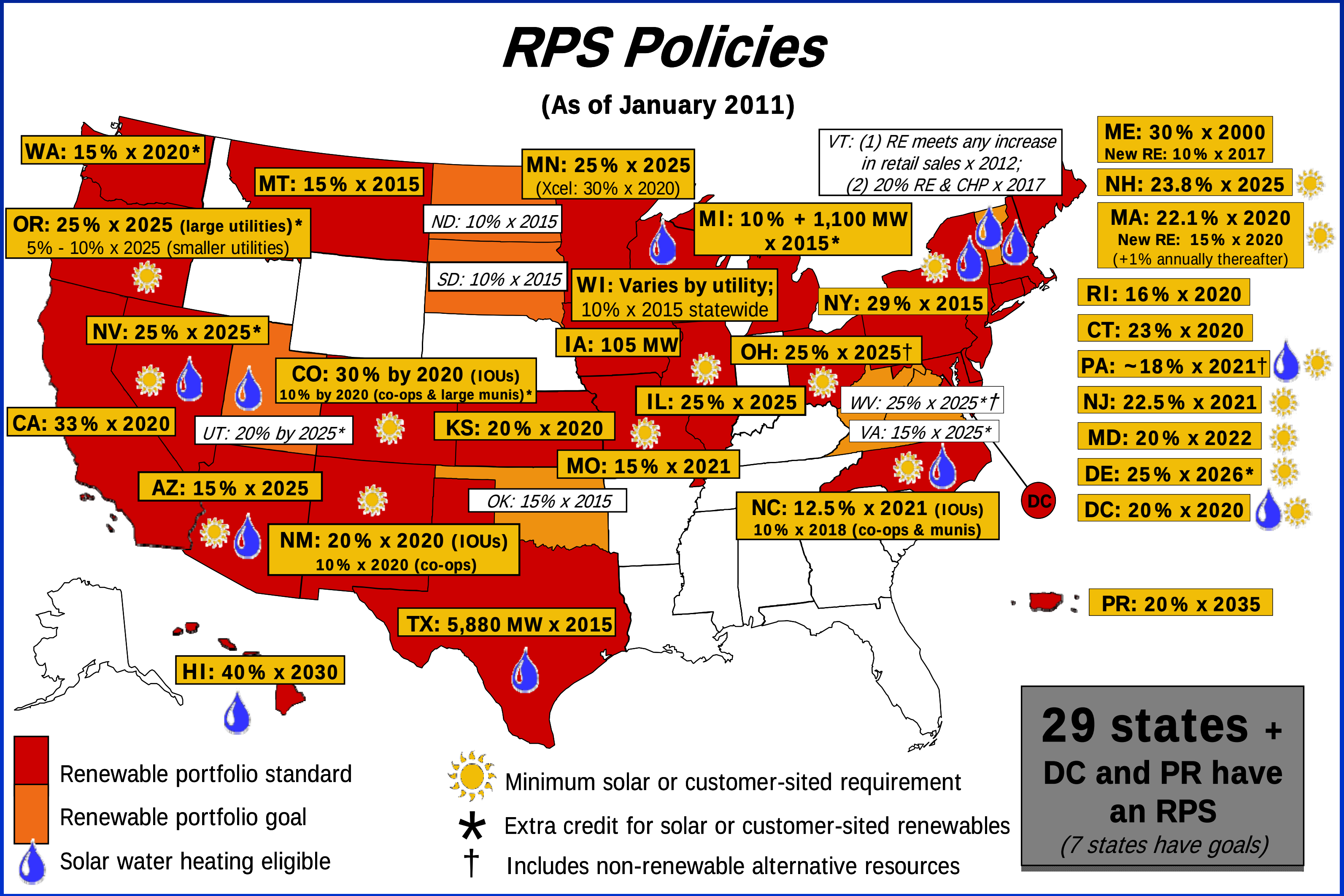
At recent rates of decarbonization, getting to 100 g CO_2 / kWh (direct) would take ~ 100 –200 years!

Future Outlook

Why Decarbonize ?

- Future decarbonization of U.S. electricity supplies will be driven by traditional market forces (e.g., fuel prices and cost of technology), as well as by government policies at the state and federal levels (both “carrots” and “sticks”)
- Major policy drivers currently include:
  - State-level renewable portfolio standards
  - Federal incentives for low-carbon technologies
  - State or regional C-caps and air pollutant limits
  - State & federal regulatory commission actions (can help or impede decarbonization)

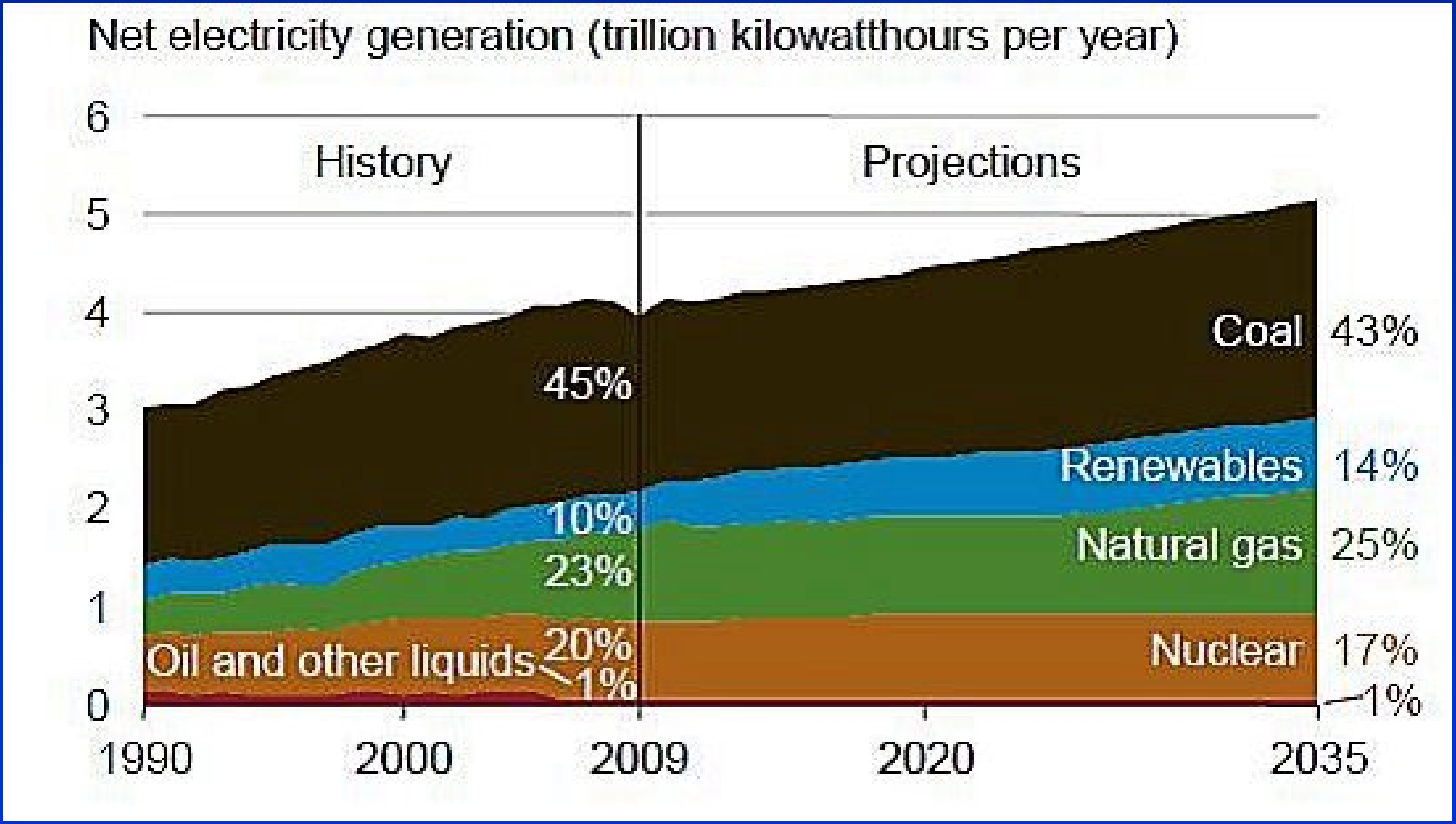
Current State-level Renewable Portfolio Standards



Source: www.dsireusa.org , 2011

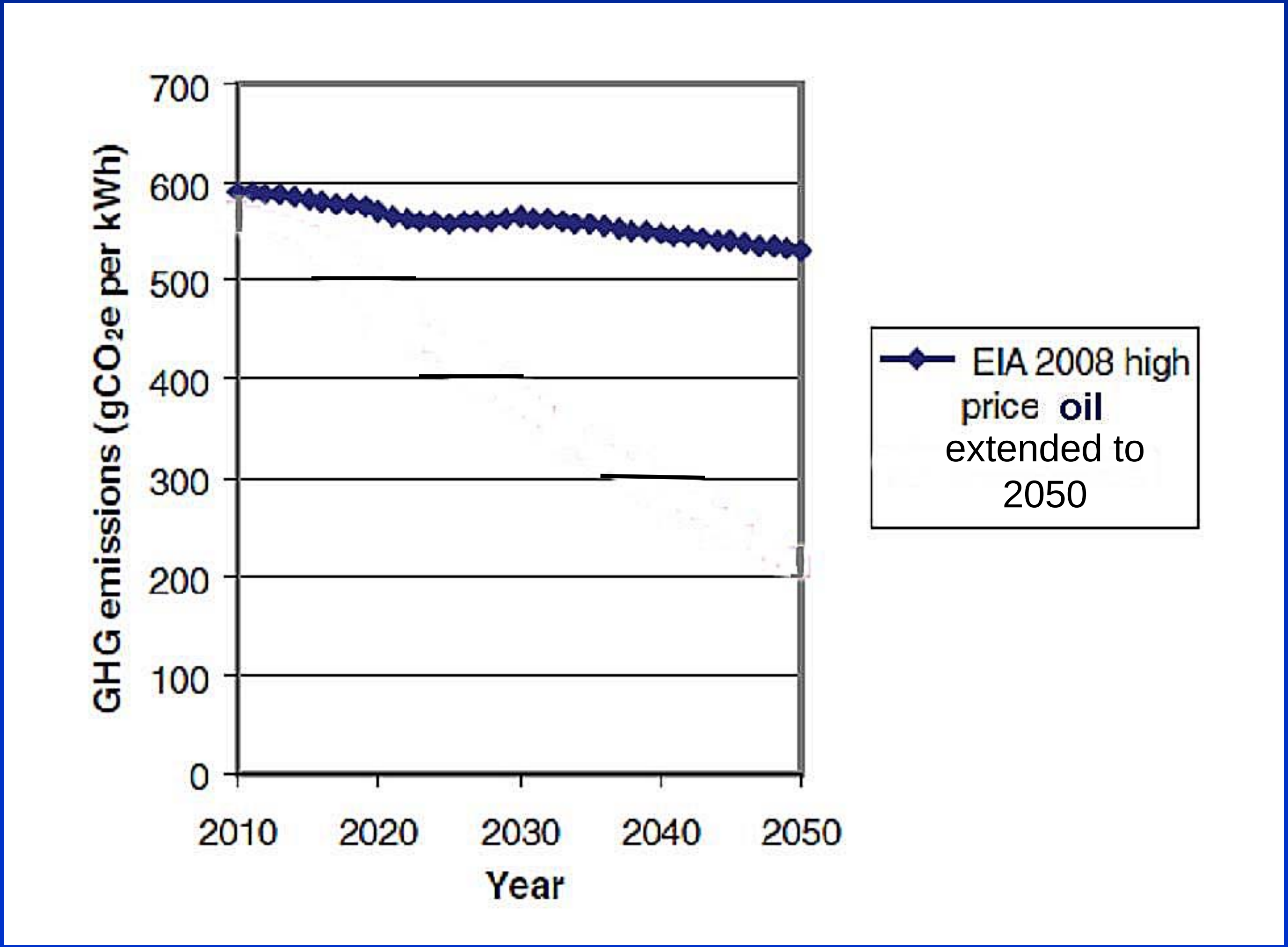
Reference Case:
Current policies only

EIA AEO 2011 Reference Case:
U.S. Electricity Generation, 1990-2035



Source: DOE/EIA , 2011

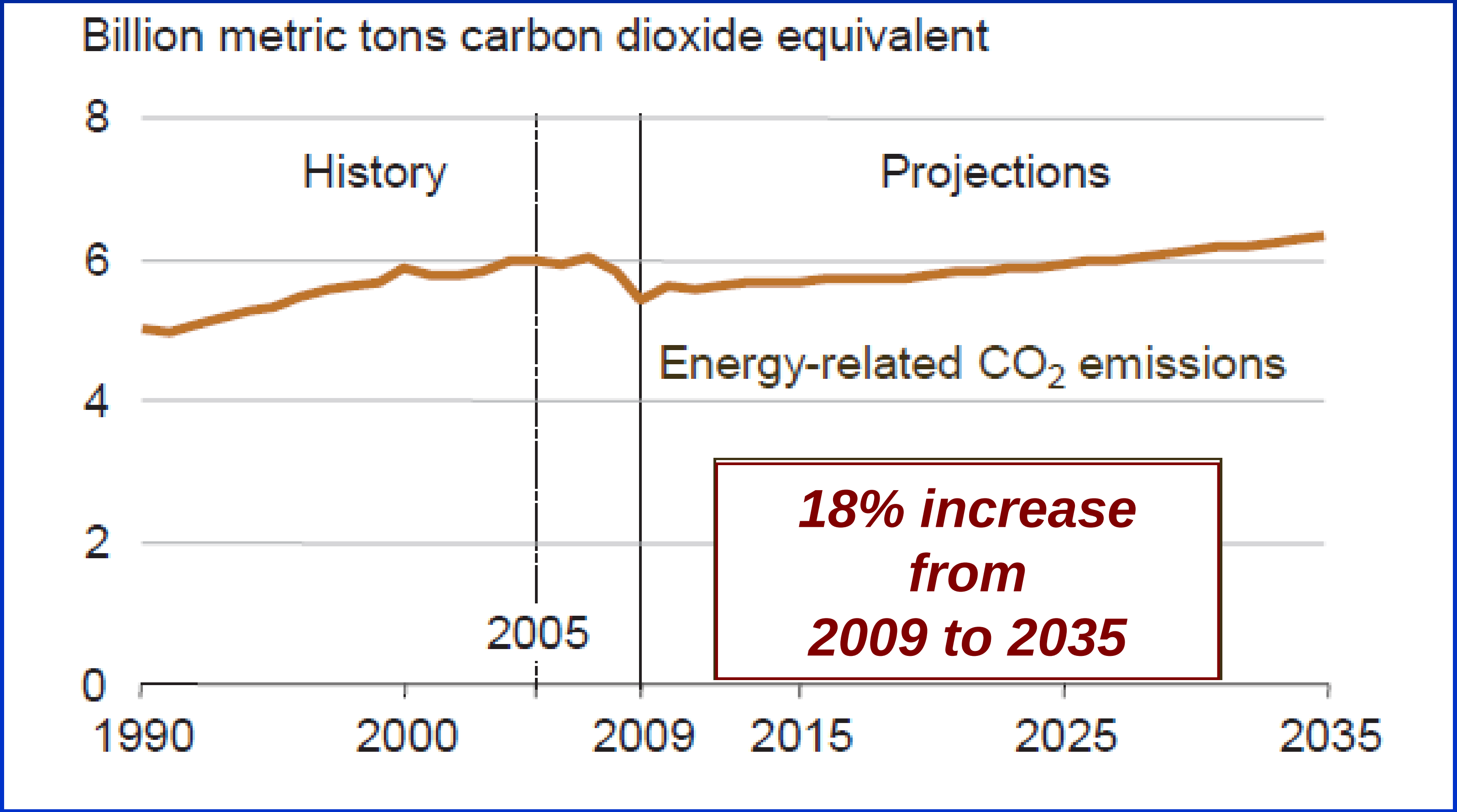
Carbon Intensity of Electric Grid Continues to Fall Gradually



Source: Natl Acad , 2010

Energy-related CO_2 Emissions Continue to Increase

(AEO 2011 Reference Case)



Source: DOE/EIA , 2011

Policy Cases:

PHEVs and Low-Carbon Power

Recent Studies of Interest

- **EPRI /NRDC, 2007.** *Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions*, Report 1015325, Electric Power Research Institute, Palo Alto, CA, July
- **Samaras, 2008.** C. Samaras, *A life cycle approach to technology, infrastructure, and climate policy decision making: Transitioning to plug-in hybrid electric vehicles and low-carbon electricity*. Ph.D. Thesis, Carnegie Mellon University, Pittsburgh, PA.
- **EPRI, 2009.** *The Power to Reduce CO_2 Emissions: The Full Portfolio*, Technical Report 1020389, Electric Power Research Institute, Palo Alto, CA, October.
- **NAS, 2010.** *Transitions to Alternative Transportation Technologies--Plug-in Hybrid Electric Vehicles*, The National Academies Press, Washington, DC.

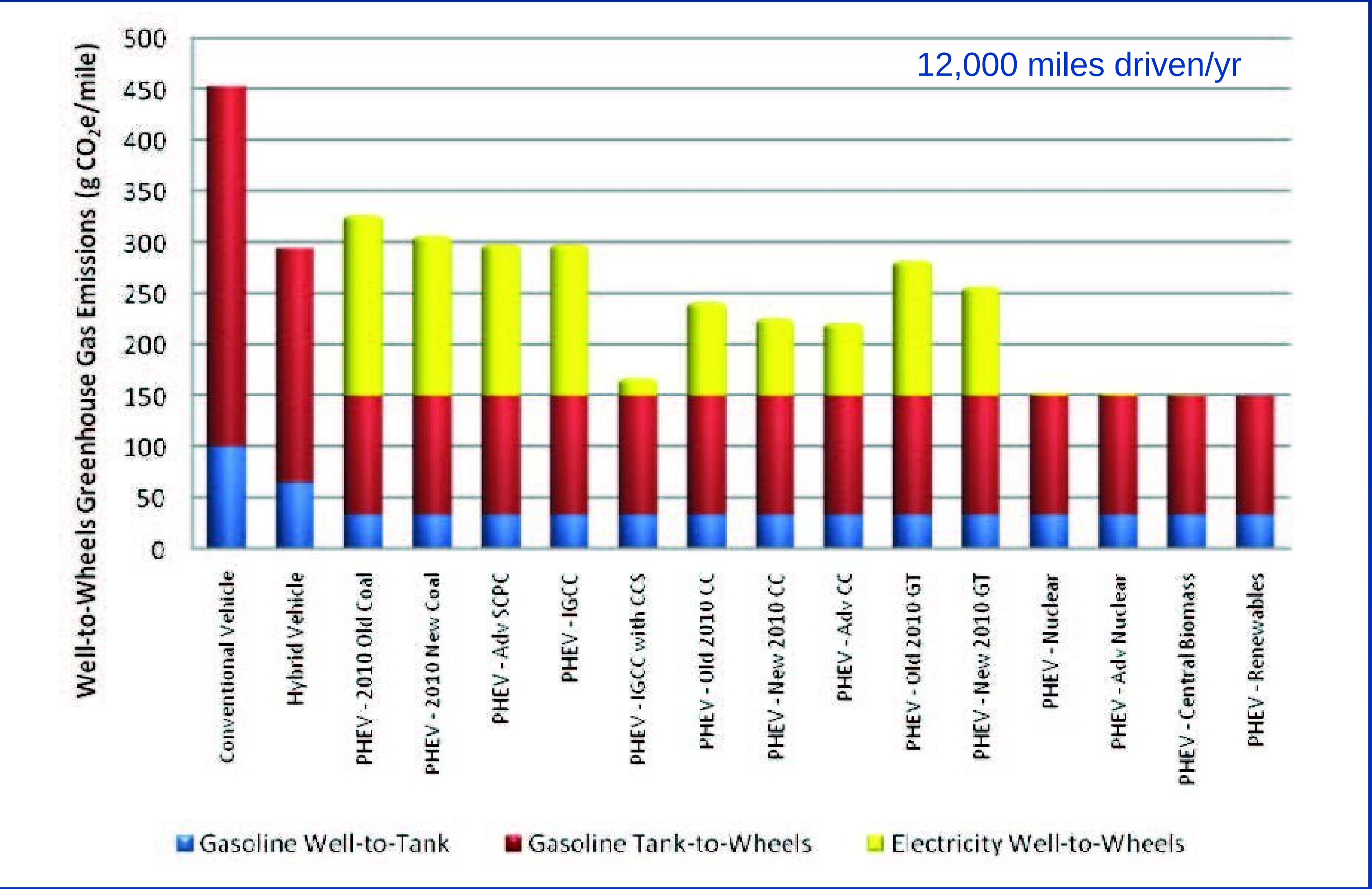
Estimates of PHEV Deployment Vary Widely Across Studies

million PHEVs on the road in given year

Study	2020			2030			2050		
	min	base	max	min	base	max	min	base	max
Samaras, 2008	0.8	**4.1**	8.9	9.2	**37**	76			
EPRI, 2009					**100**				
NAS, 2010		**1.8**	4		**13**	40		**110**	240

EPRI studies

Year 2010 comparison of GHG emissions when PHEV 20 is charged entirely with electricity from specific power plant technologies (EPRI/NRDC)



Source: EPRI /NRDC, 2007

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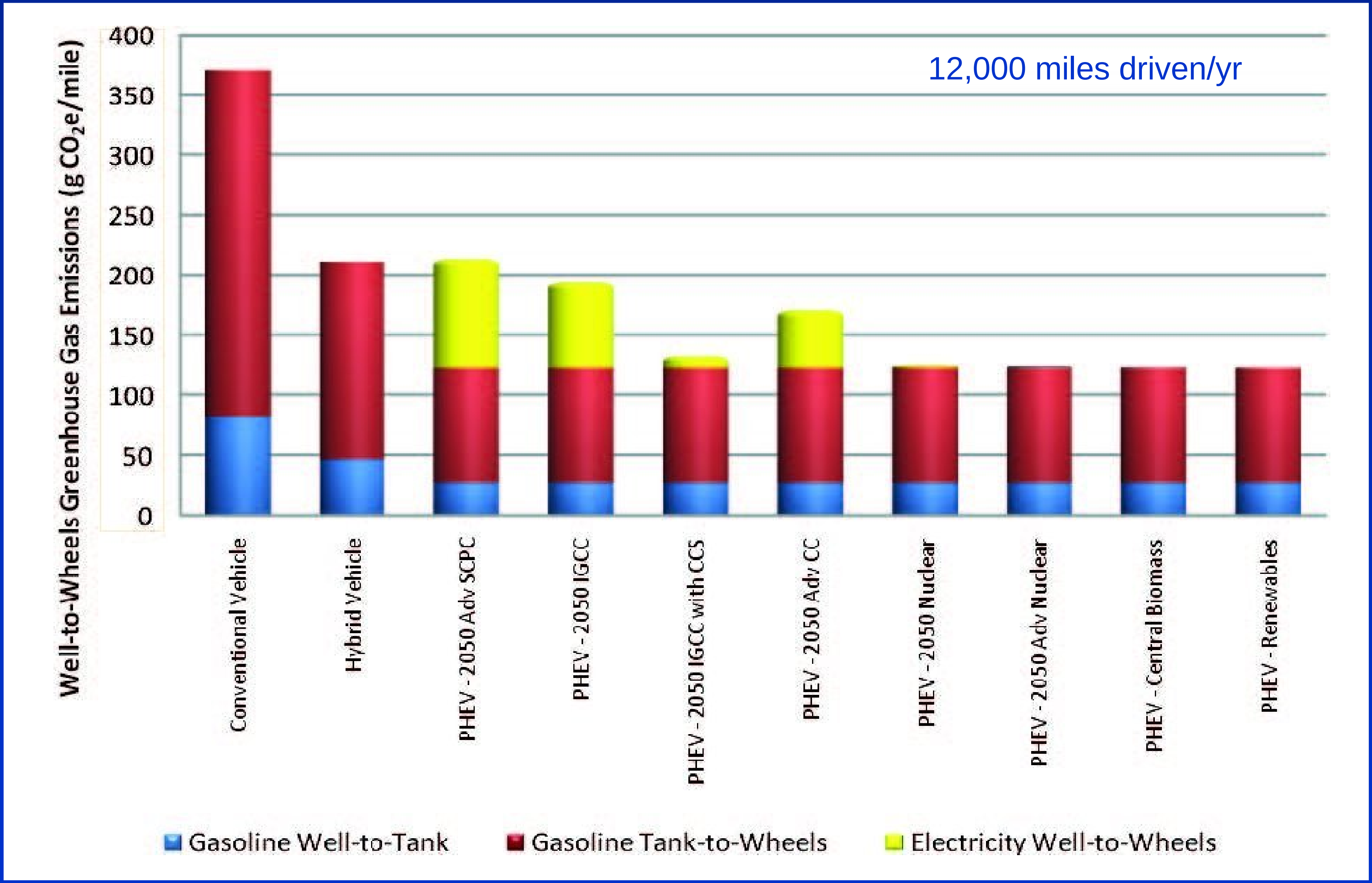
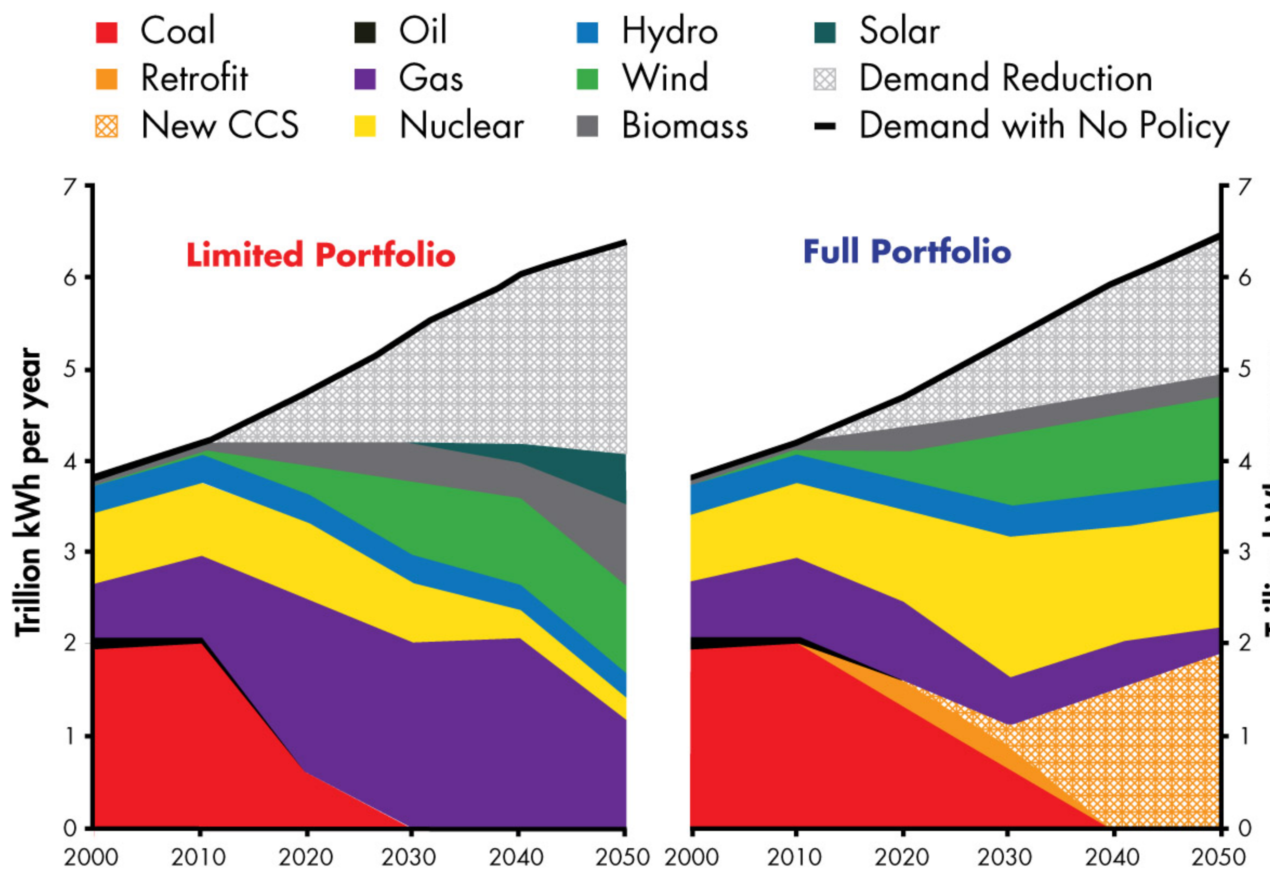
Year 2050 comparison of GHG emissions when PHEV 20 is charged entirely with electricity from specific power plant technologies (EPRI/NRDC)



Source: EPRI /NRDC, 2007

EPRI 2009 MERGE Analysis of Power System Response to CO_2 Limits

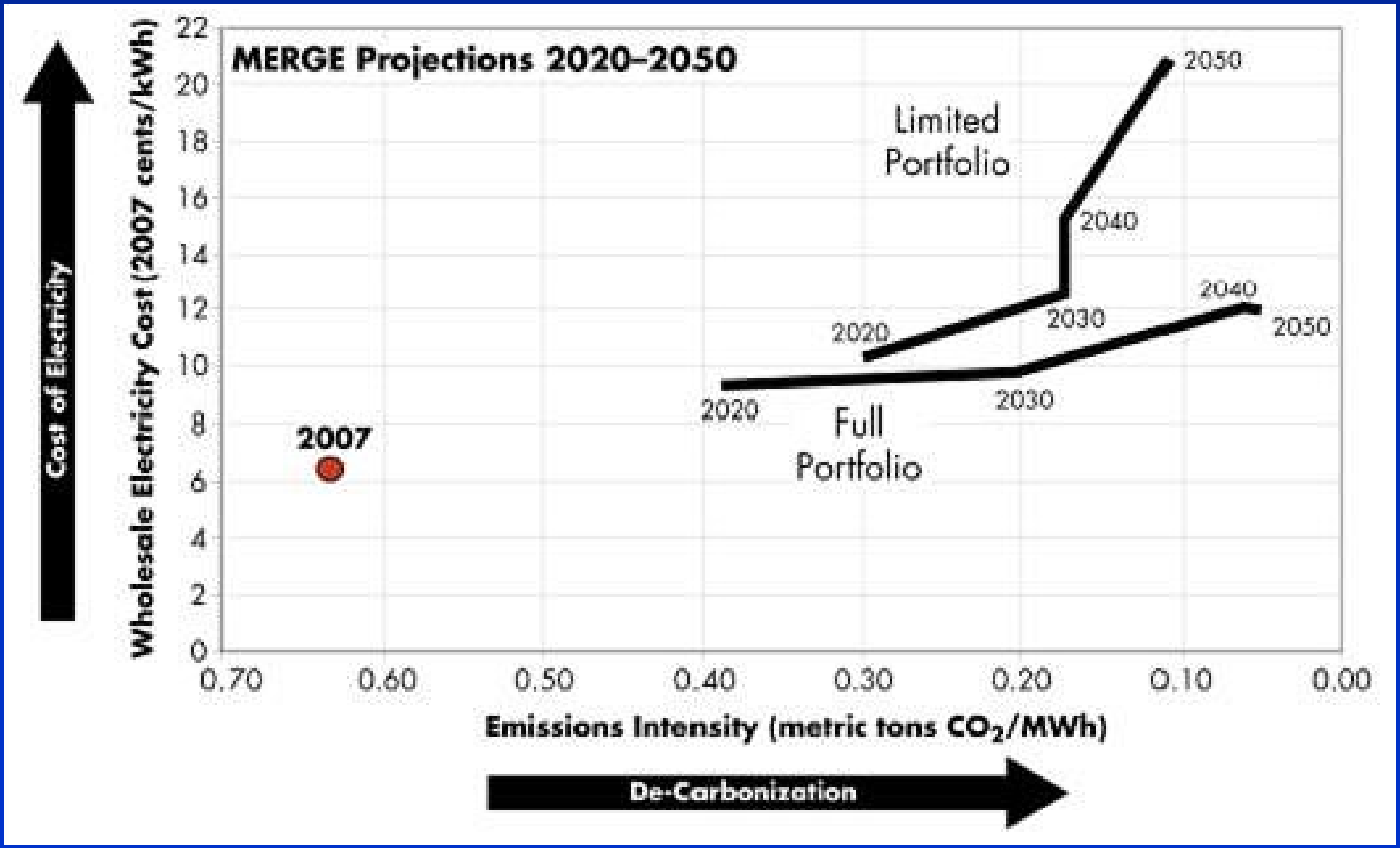
(2050 GHG emissions limit = 83% below 2005 levels)



* Limited portfolio excludes CCS, new nuclear, and PHEVs

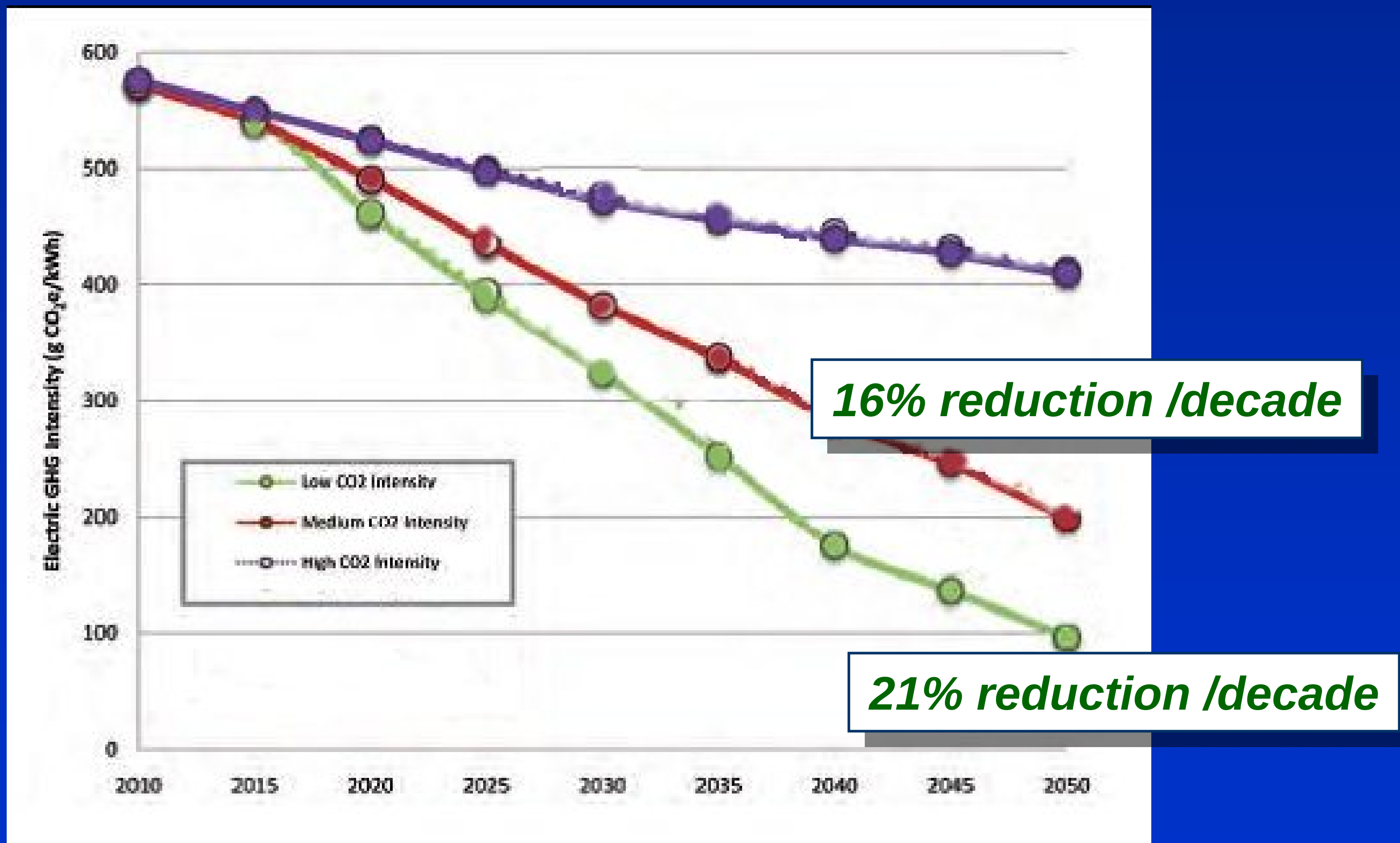
Source: EPRI , 2009

Low-Carbon Power Achievable but Limited Portfolio Raises Power Cost



Source: EPRI , 2009

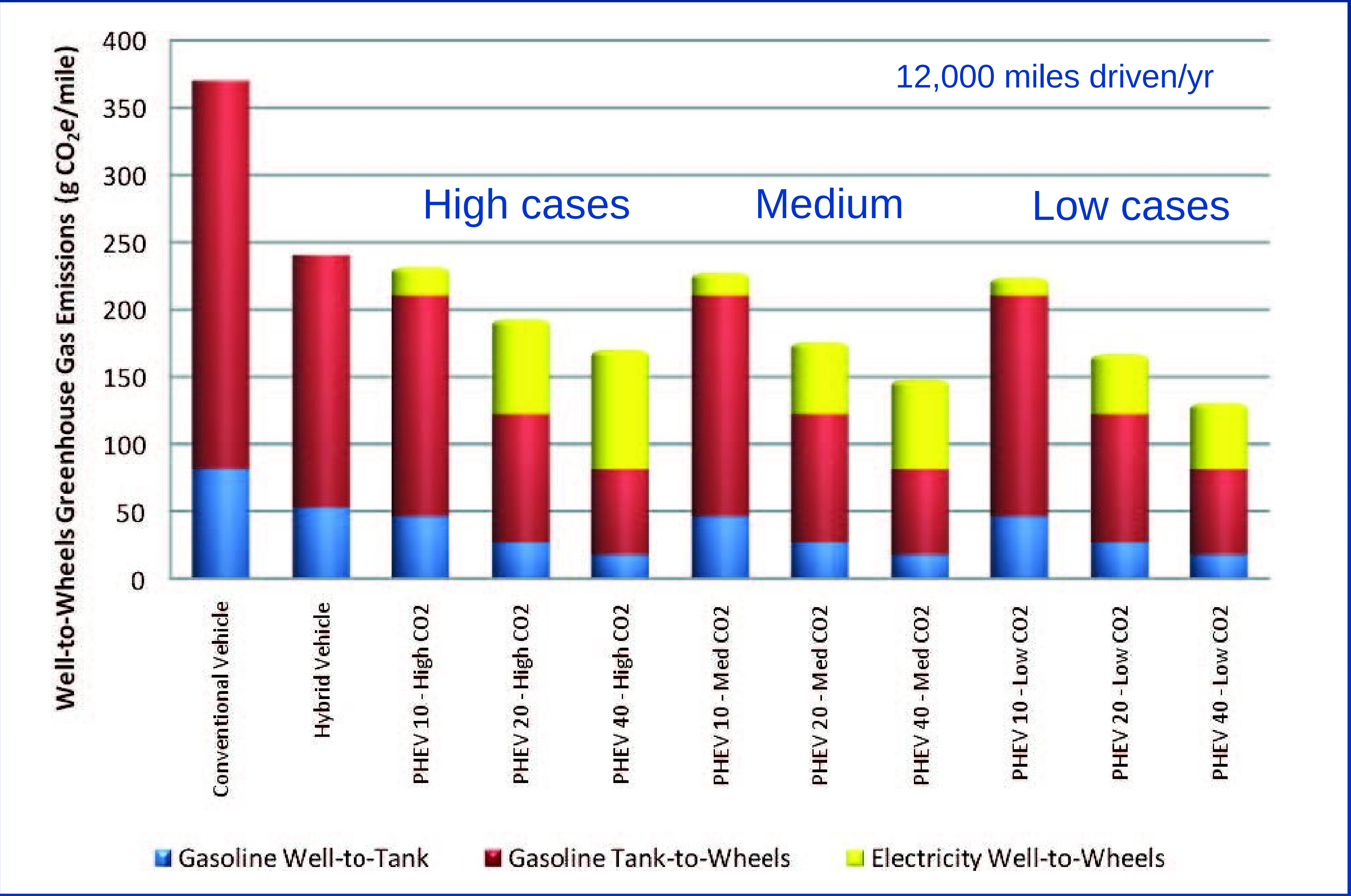
EPRI/NRDC Carbon Intensity Scenarios for the Power Sector



Source: EPRI /NRDC, 2007

Requires much faster decarbonization than business-as-usual

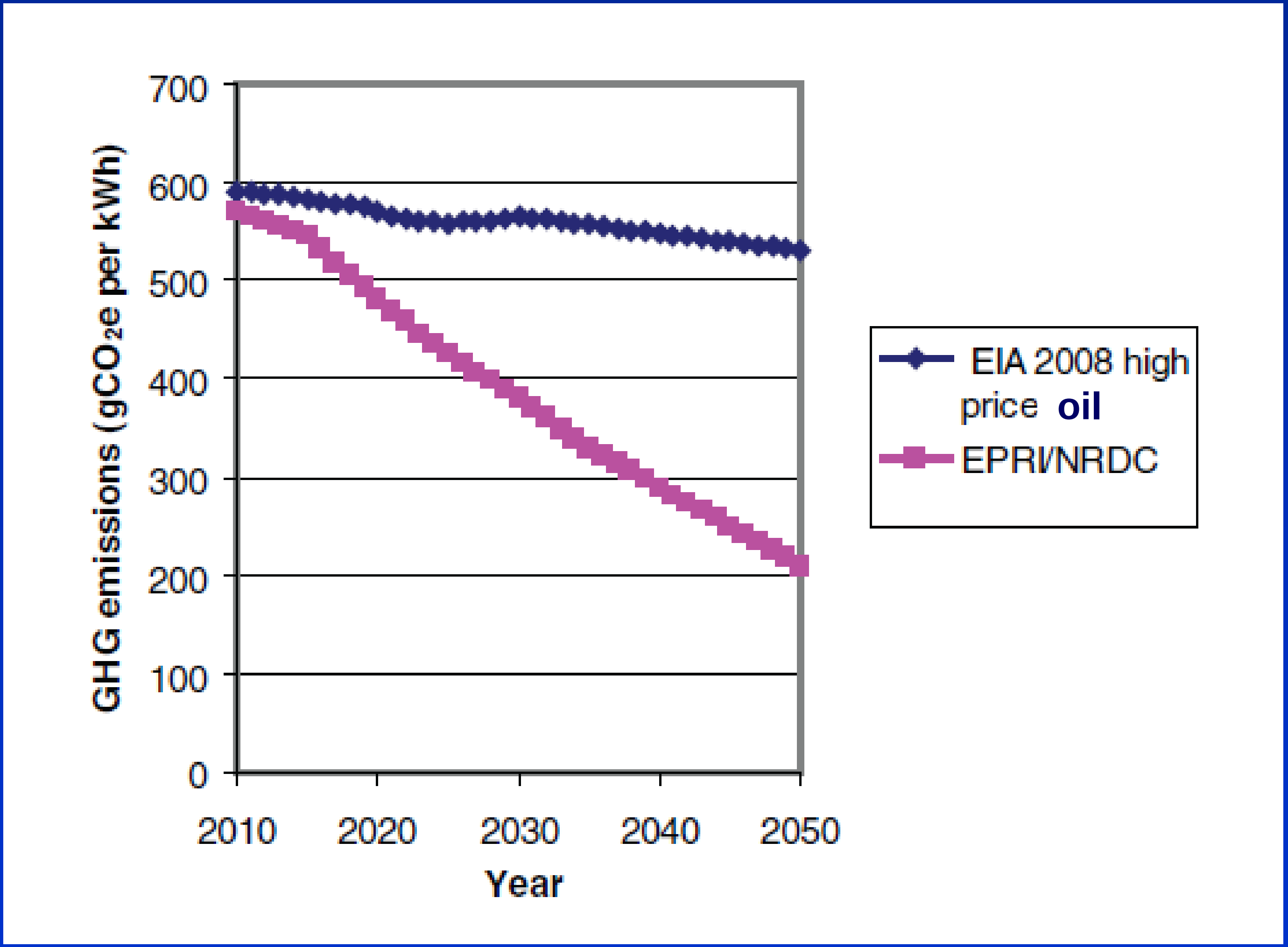
Year 2050 comparison of vehicle GHG emissions for High, Medium, and Low electric sector CO_2 intensity with PHEVs 10, 20, 40 (EPRI/NRDC)



Source: EPRI /NRDC, 2007

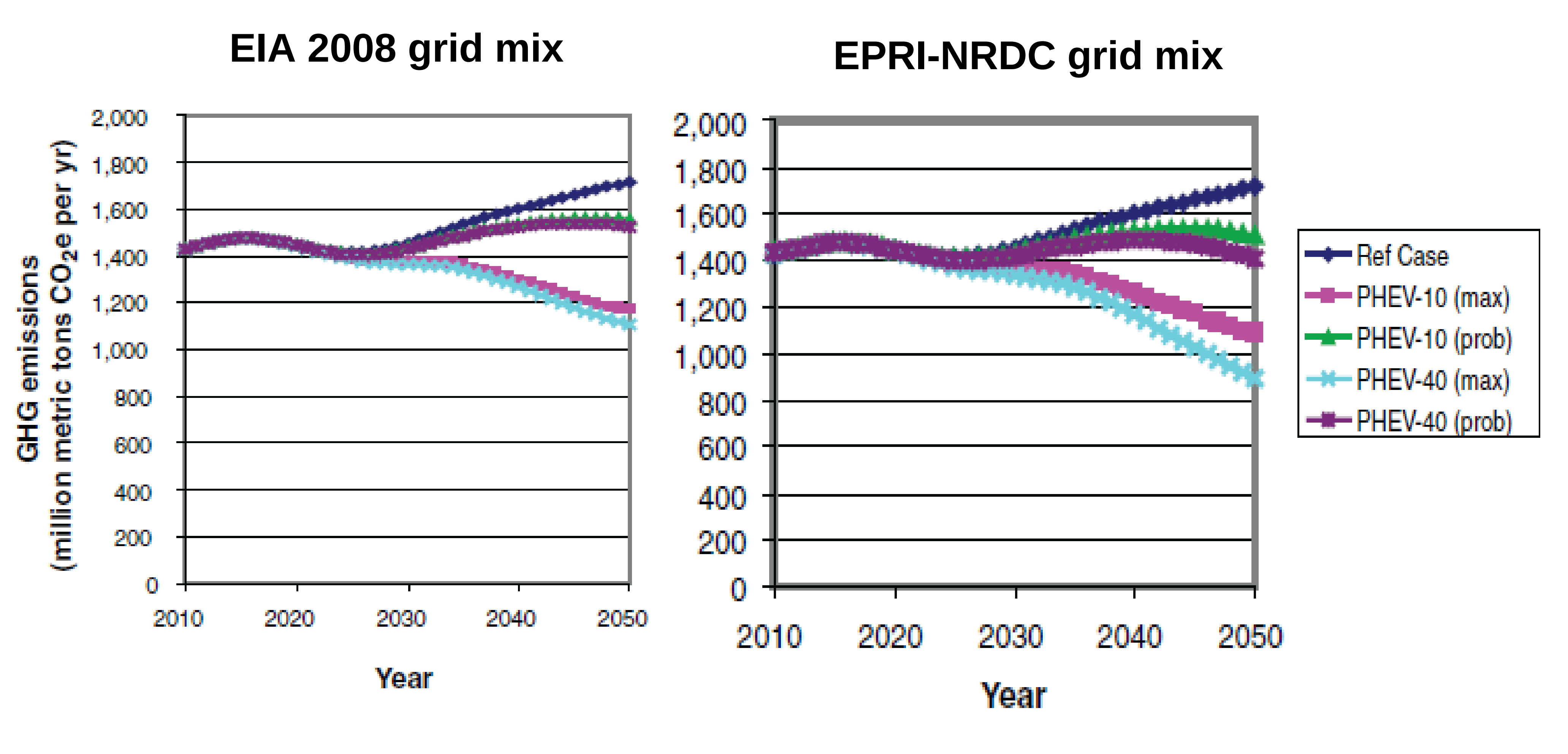
National Academies study

GHG Emission Rates from Future Electric Grid—Two Scenarios



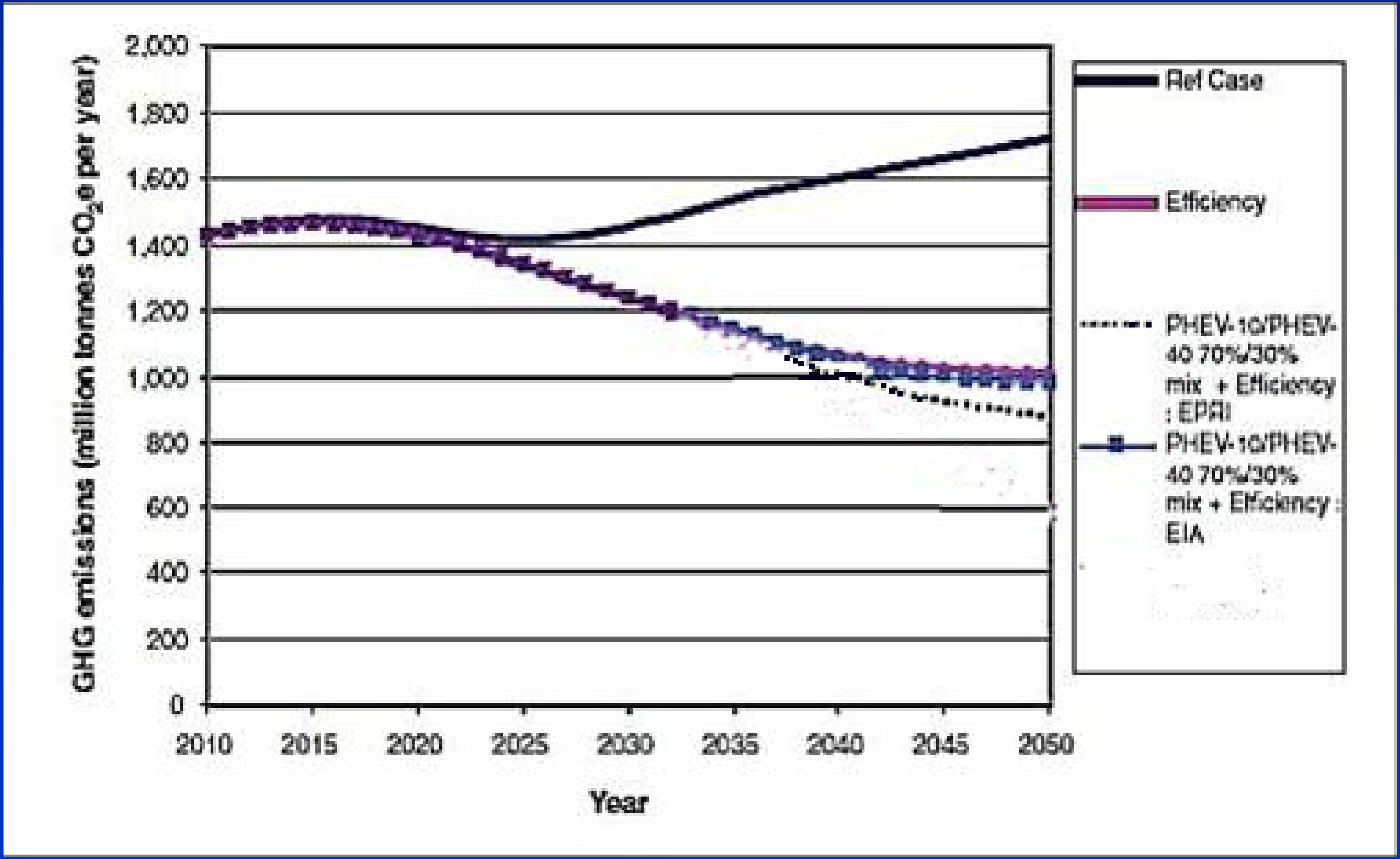
Source: NAS, 2010

GHG Emissions from Light-Duty Fleet for NAS Cases



Source: NAS, 2010

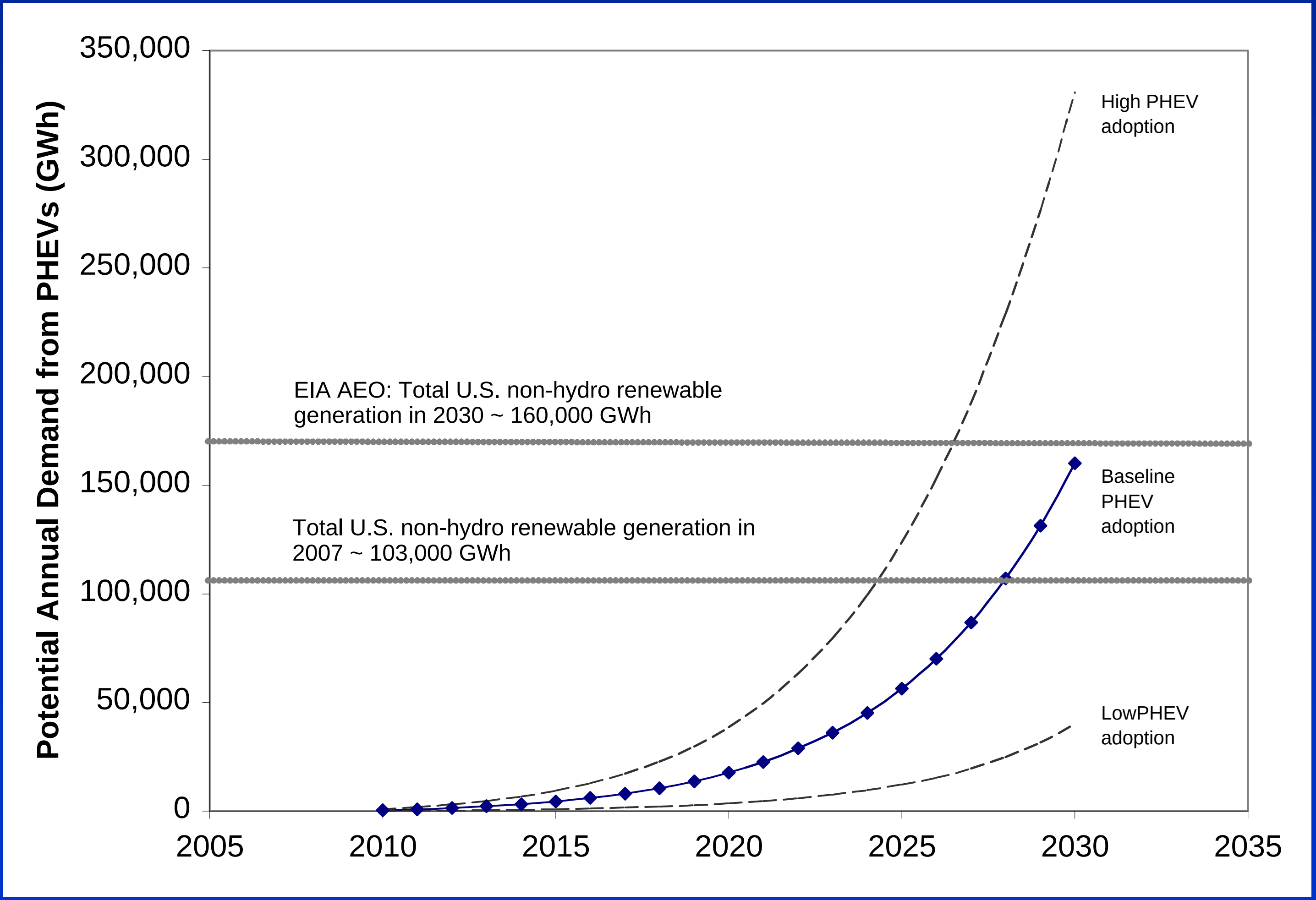
GHG Emissions from PHEVs Compared to Advanced ICE/HEVs



Source: NAS, 2010

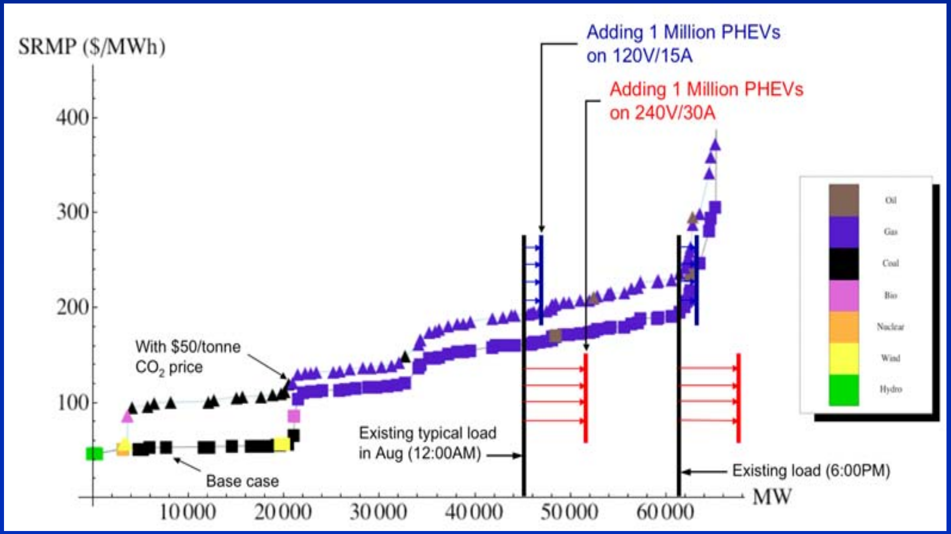
Samaras (CMU) study

Potential Annual Power Demand from PHEV Adoption



Source: Samaras, 2008

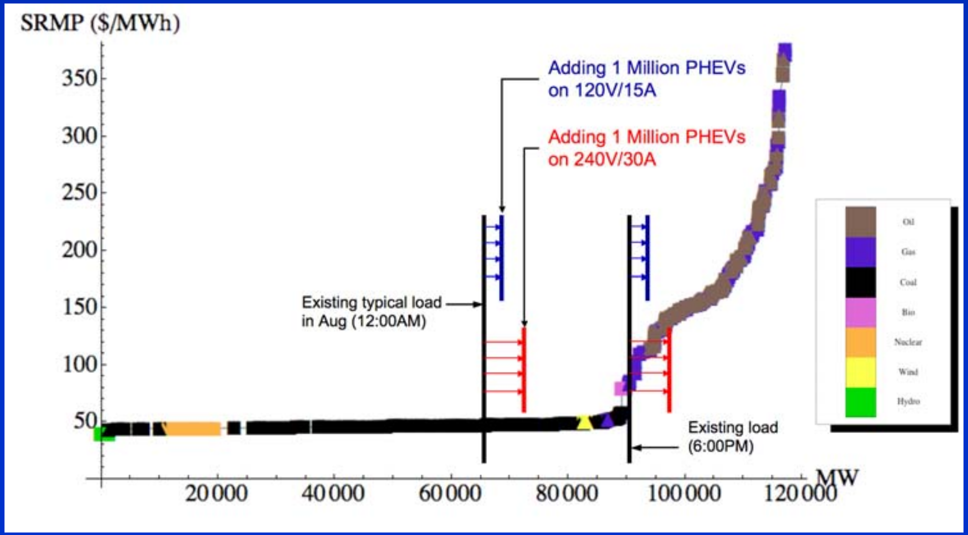
Power Sources for Battery Charging Vary by Region, Season and Time of Day



ERCOT

Source: Samaras, 2008

MISO



Conclusions

- Low-carbon electricity is key to achieving large GHG reductions with PHEVs. New policy drivers will be needed to accelerate the pace of decarbonizing the U.S. grid.
- Even with low-C electricity, GHG reductions compared to conventional hybrid vehicles will be small unless PHEV batteries with extended ranges are commercially viable.
- Achieving large GHG reductions with PHEVs also will require advanced integration and planning of power system capacity and transmission since the marginal fuels used to charge batteries will vary by region, season and time of day.

Thank You

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