The Gap Between Realistic Expectations and Our Transportation GHG Emissions Targets

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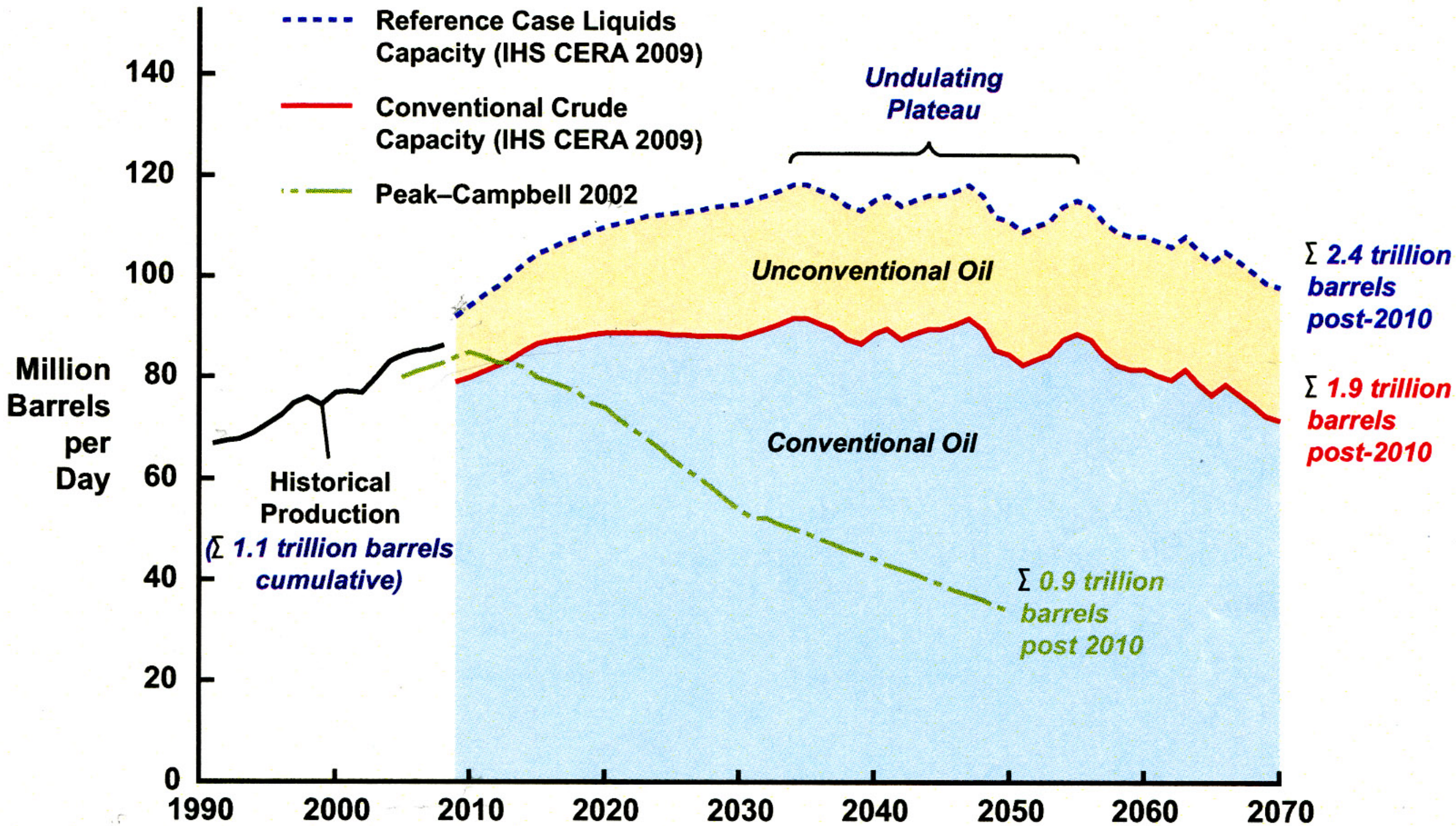
Contexts for Technology-Based Assessments

1. It's "the vehicles that are driven" that have impact: so it is powertrains and fuels in the in-use vehicle fleet that matter.
2. Time scales for assessment are critical: 2020 limited potential for change; 2050 greater potential for change.
3. Regional economic context in the global context will determine growth in regional demand for transporting people and goods. (Many different world regions.)
4. The future availability and price of petroleum is a critical input to assessments of new technology development and deployment.
5. Useful to start with the evolving transportation energy context: cost, availability; "greenness" of petroleum-like fuels and of biofuels, and of electricity, and hydrogen.

Energy Context

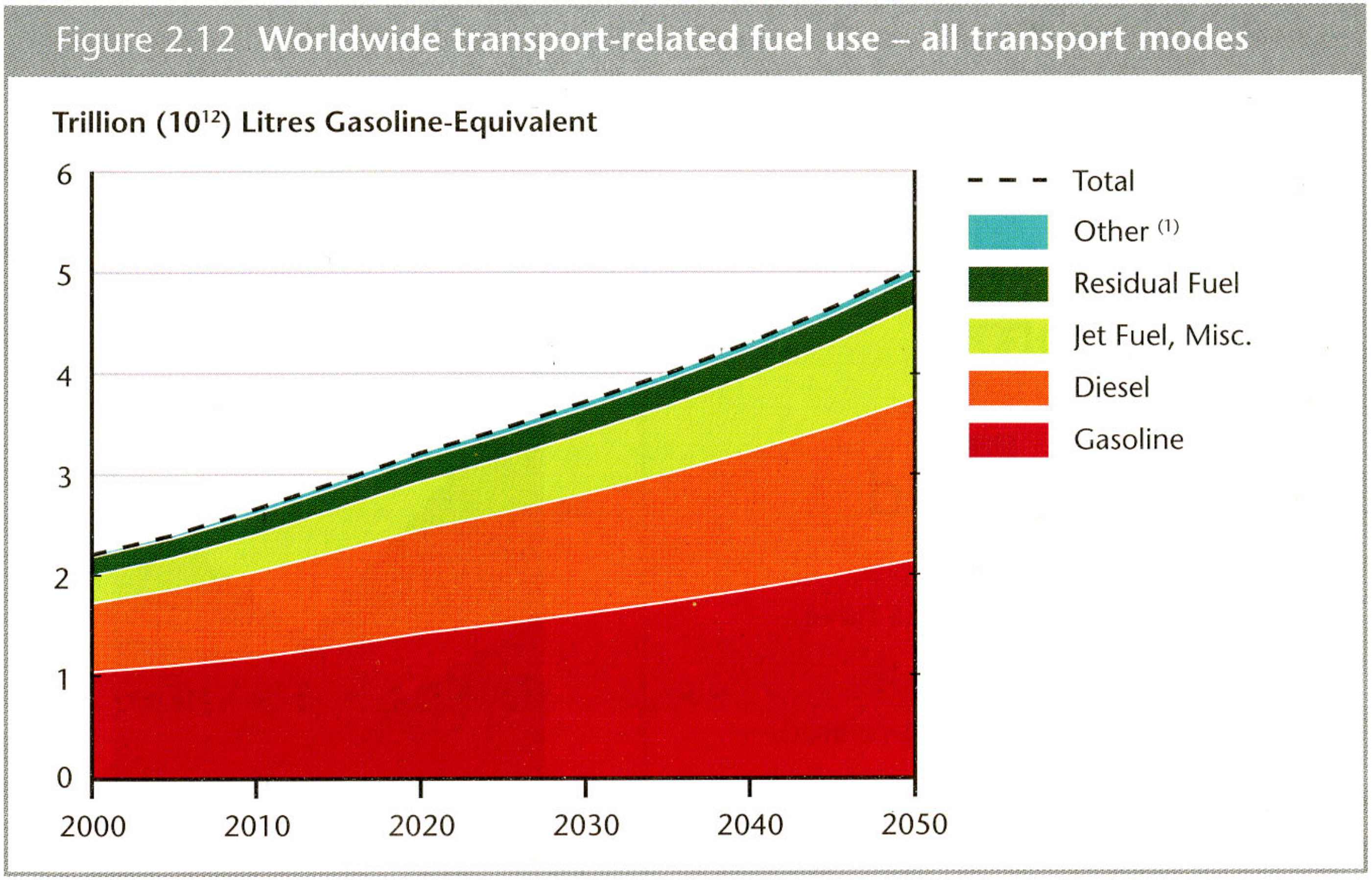
1. Recent CERA projection: petroleum plus tar sands (etc.) plus biofuel **supply** projected to grow at about 1% per year, 2010 to 2035.
2. 2004 WBCSD Sustainable Mobility Project projection: transportation fuel **demand** (largely petroleum-based) grows at about 1.7% per year 2010 to 2035.
3. Plausible that (at least in U.S.) natural gas will be significantly cheaper than petroleum-based fuels.
4. Petroleum consumption, energy use, and GHG emissions are all important (and different) issues: Energy and GHG emissions must be evaluated on a well/source-to-wheels basis.
5. The evolving GHG emissions' impacts of the various fuels/energy sources over time need to be understood.

Future Global Oil Supply



Source: Cambridge Energy Research Associates.
60907-9_2107

Worldwide Transport-Related Fuel Use



(1) CNG\LPG, Ethanol, Biodiesel, and Hydrogen   Source: Sustainable Mobility Project calculations.

Source: Mobility 2030: WBCSD Sustainable Mobility Project Report 2004

Alternative Fuels: Current Status in U.S.

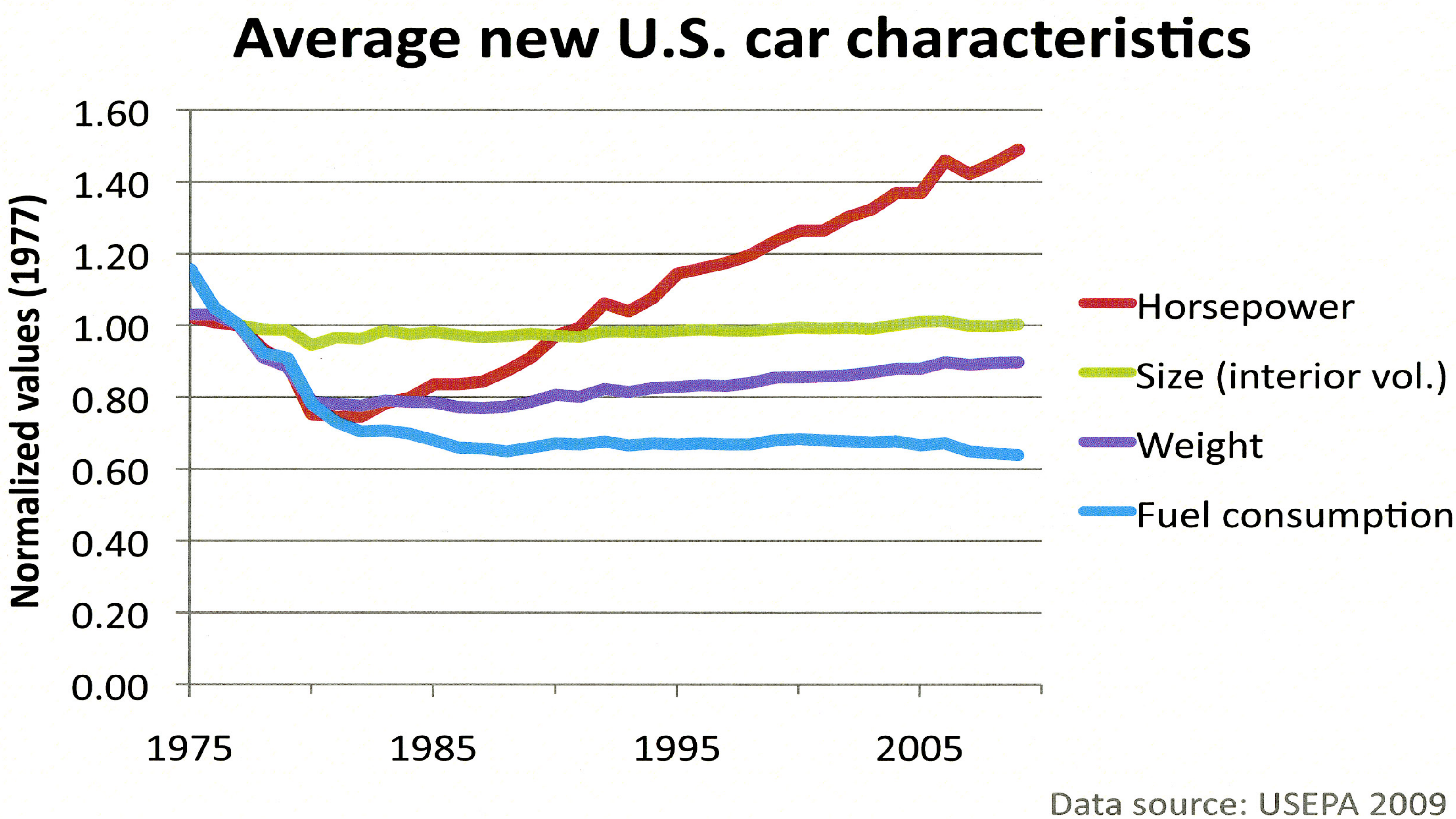
Fuel source	Fuel	Current Status
1. Corn grain, sugar	Ethanol	Limited volume (~10%)
1. Crops, seeds, etc.	Biodiesel	Limited volume (~1%)
3. Biomass (non-food: cellulosic biomass, wood waste, algae)	Ethanol Gasoline/ diesel/butanol	Potential; R & D stage
4.Oil sands/ heavy oil	Gasoline/diesel	Production volumes increasing
5. Oil shale/coal	Gasoline/ diesel, etc.	Potential; development stage; higher GHG
6. Various	Natural gas	Lower cost; use unclear
7. Natural gas/ electricity, etc.	Hydrogen	Major infrastructure issues; uncertain
8. Coal, natural gas, nuclear, renewable	Electricity	Political pressure; market unclear

Balancing Optimism with Realism

We are usually too optimistic because:

1. In this well-established arena, steady improvement in the technologies are likely, but many factors “degrade” performance.
2. Also, because many of the technologies are well established, “breakthroughs” are less likely.
3. Achieving significant penetration of improved or new technologies takes longer than we anticipate.

Trends: History of steadily increasing horsepower/acceleration



Key Steps in Estimating Impacts of Scenarios

1. Predicting fuel consumption and GHG emissions for given propulsion system, vehicle, and fuel.
2. Assessment of fuel consumption/performance/size trade-off.
3. Model for in-use vehicle fleet.
4. Quantitative scenarios for availability of fuel (and energy) streams over the appropriate timeframes.
5. New technology introduction timeframes and deployment rates over time.
6. Life-cycle GHG analysis capability.

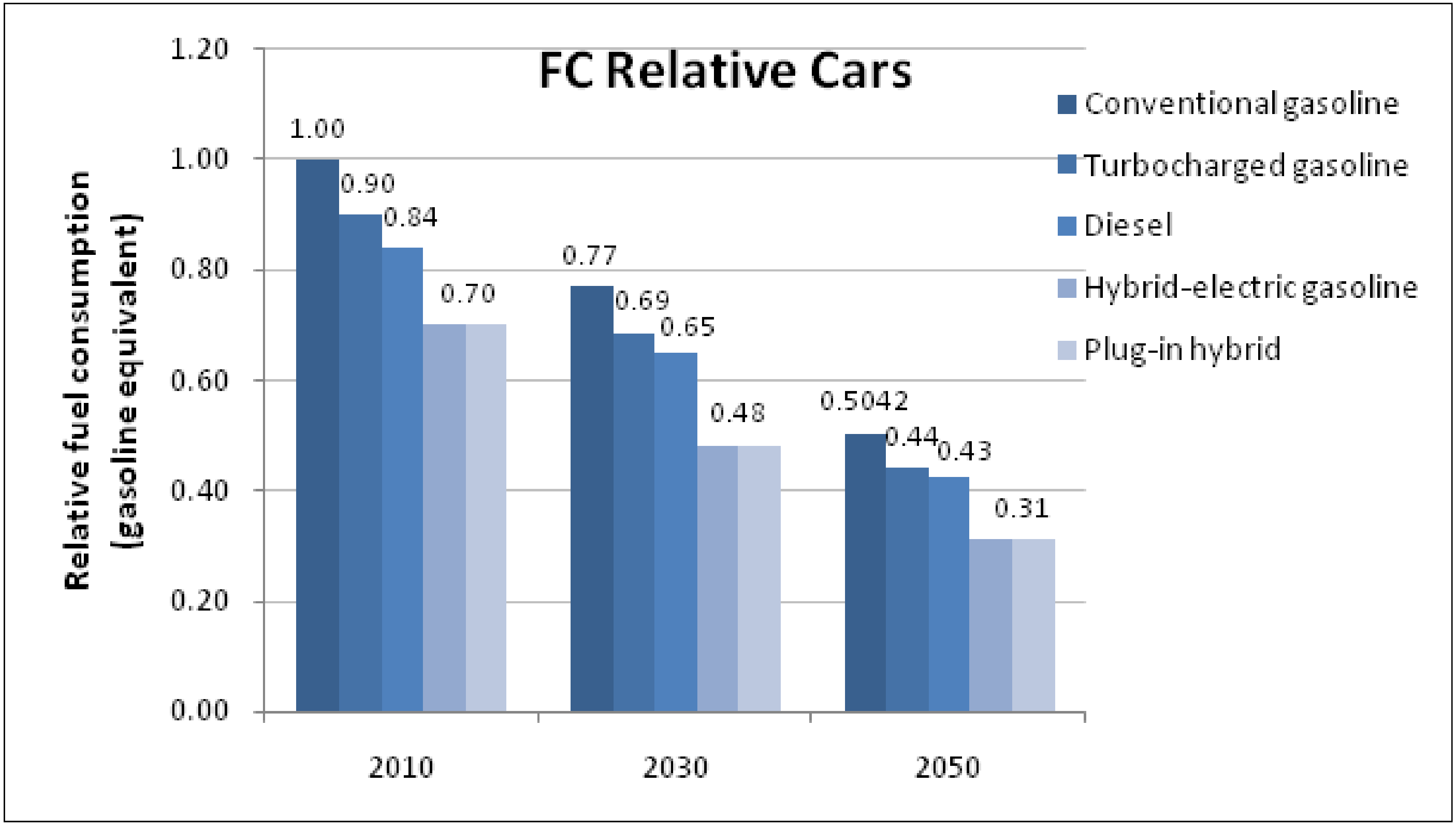
Heywood, J.B., "Assessing the Fuel Consumption and GHG Emissions of Future In-Use Vehicles," PEA-AIT International Conference on Energy and Sustainable Development" (ESD 2010), Chiang Mai, Thailand, June 2-4, 2010.

Important Propulsion System and Transportation Energy Paths Forward

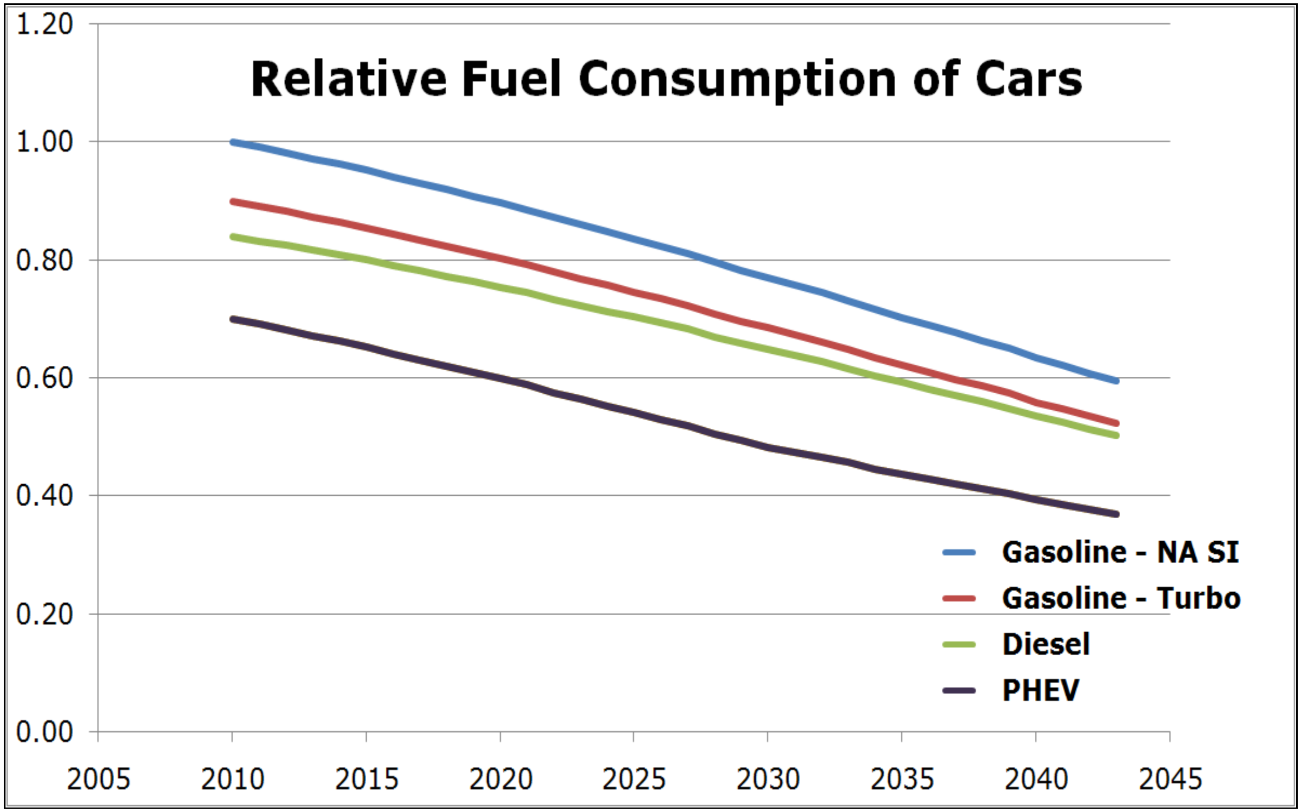
1. Improving mainstream technology
   - More efficient engines (e.g. turbocharged downsized gasoline and diesel engines, charge-sustaining hybrids)
   - More efficient transmissions
   - Vehicle weight, drag, and performance reduction
   - Liquid fuels from biomass

1. Transitioning to new energy sources
   - Electricity (PHEVs, BEVs)
   - Natural gas (spark-ignition engine)
   - Hydrogen (fuel cells)

Relative Fuel Consumption of Future Cars, by Powertrain (at 100% ERFC)



Fuel Consumption Over Time



Relative fuel consumption of cars modal input over time to 2050

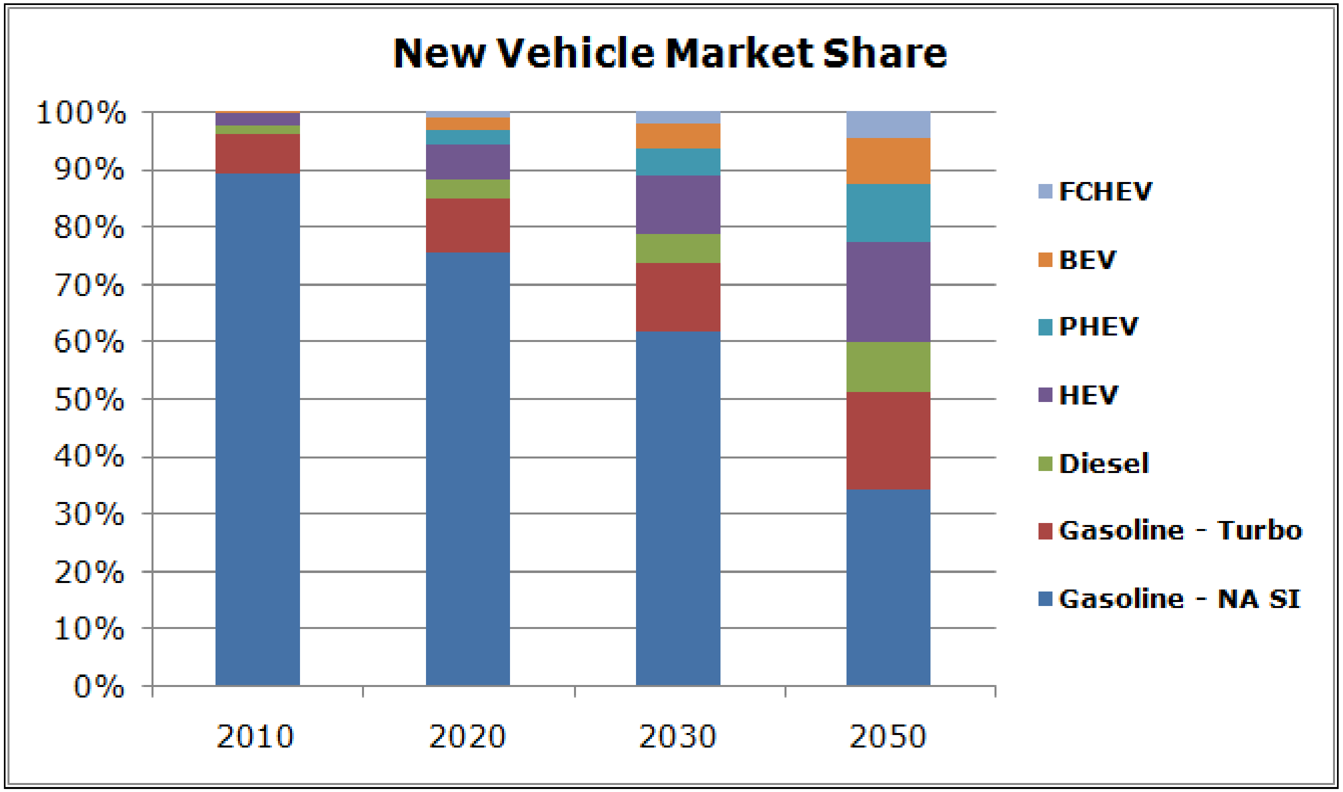
New Technology Deployment Rates

1. Especially difficult question: uncertain and contentious!

2. Need to consider deployment of new technology in several phases: e.g., pilot production; initial market-pulled growth; increasing and substantial growth; asymptotic leveling-off of sales.

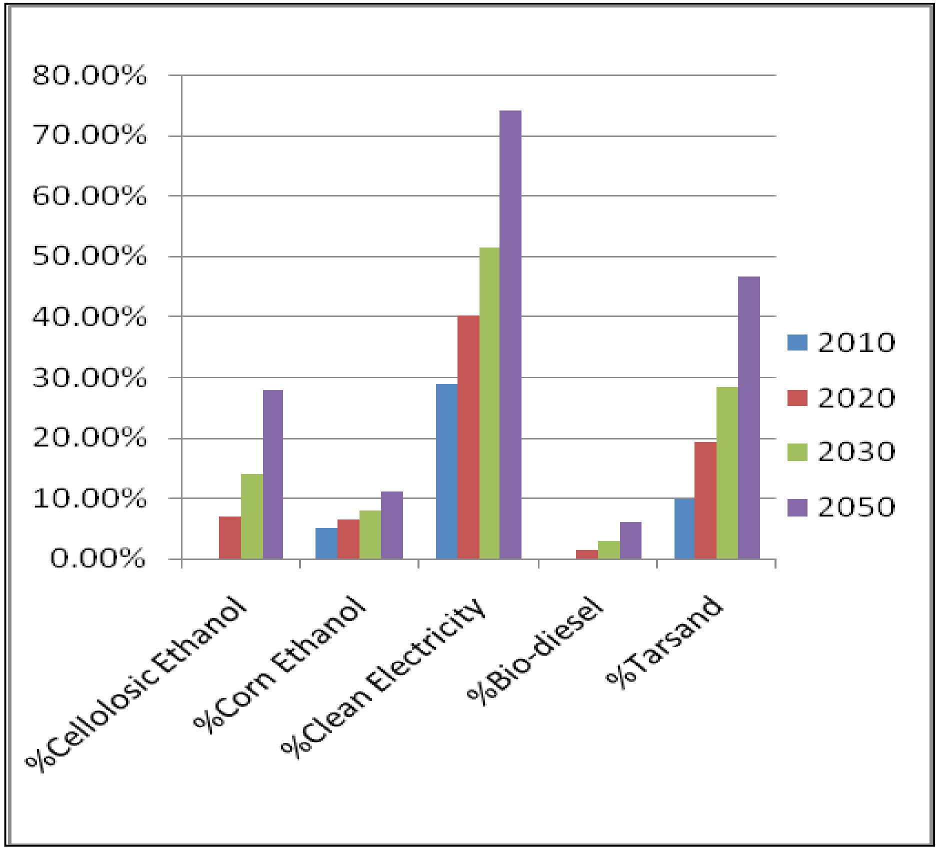
3. Previous major vehicle technology changes took more than ten years to achieve significant volume production (e.g., significantly-increasing-volume phase for diesel in Europe: 1985 10%, 2005 50%: 8 - 10% growth per year).

Technology Market Deployment Over Time



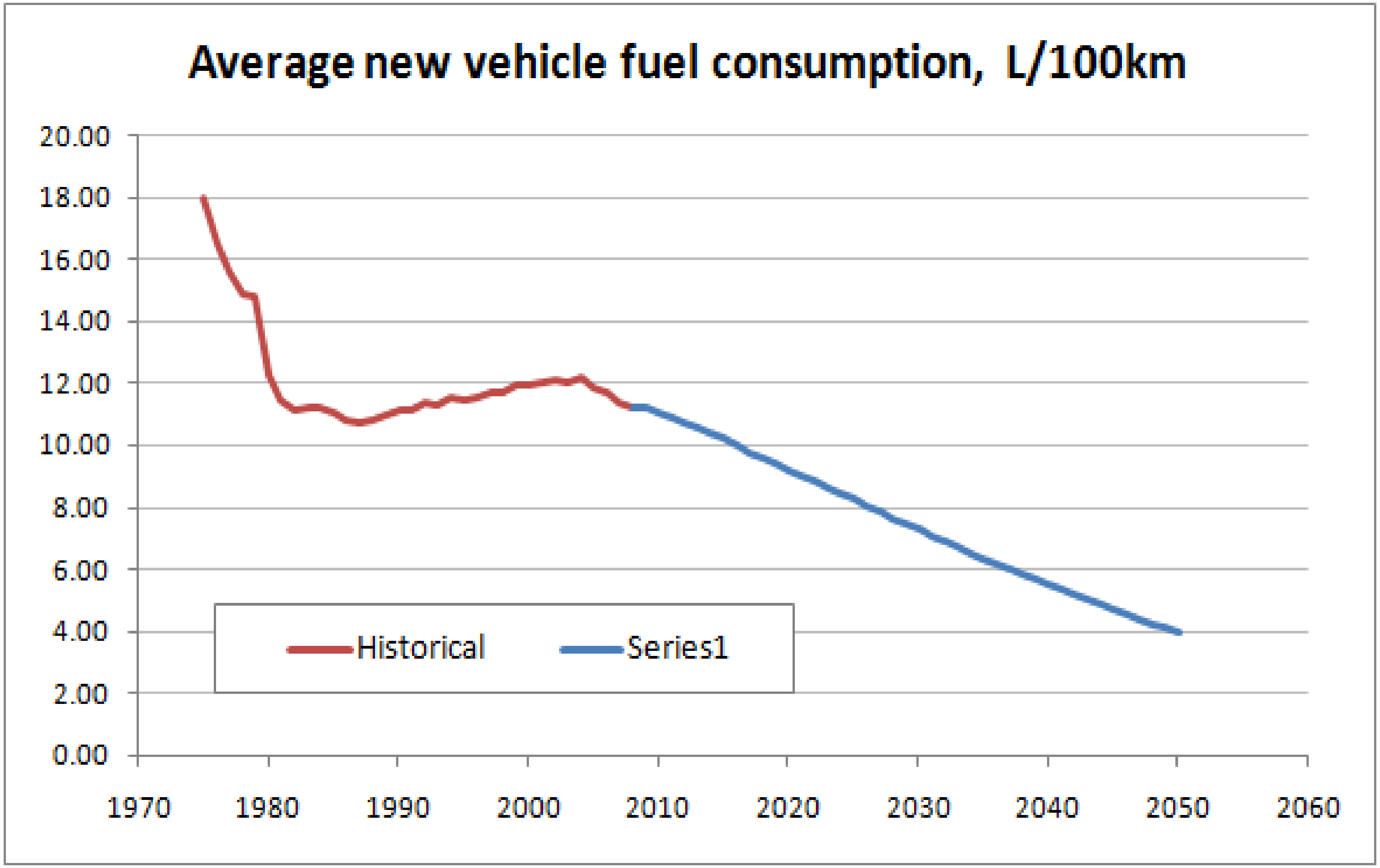
Sales market share modal inputs to 2050

Clean Energy Sources Over Time

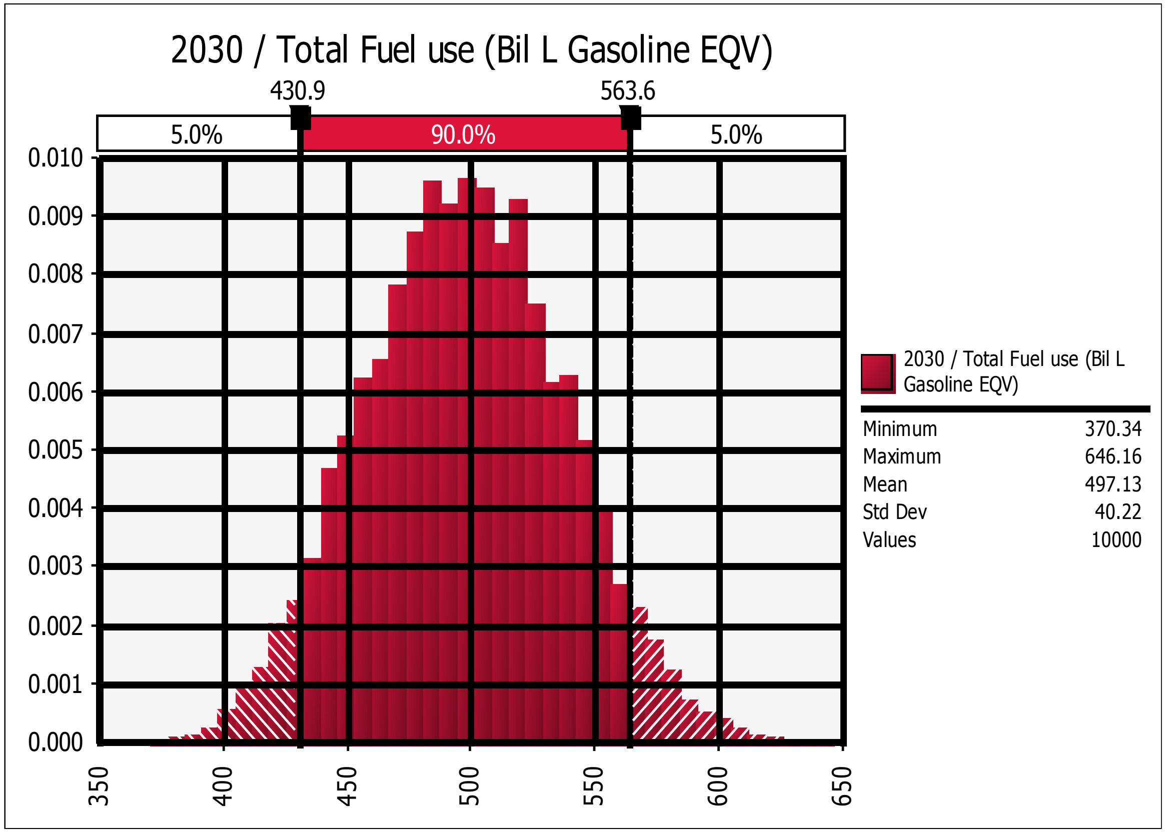


Alternative fuel availability modal inputs to 2050

Average New Vehicle Fuel Consumption Over Time

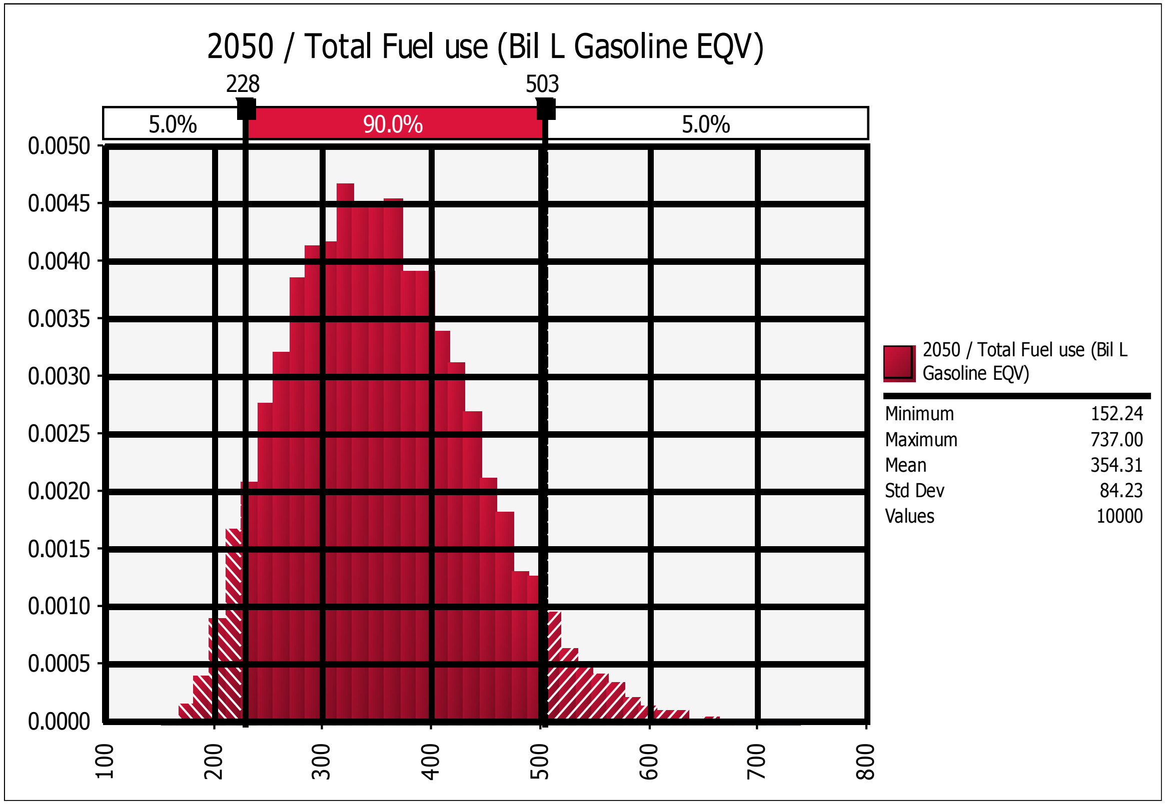


Results: Fleet Fuel use in 2030



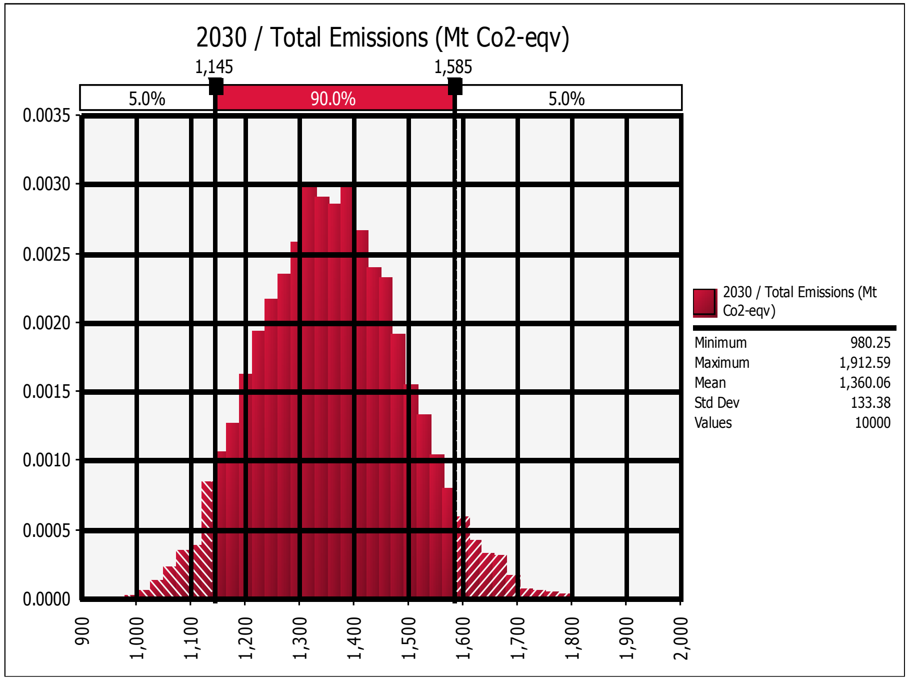
2030 U.S. Fleet fuel use probability distribution
[Bil L gasoline equivalent/year]

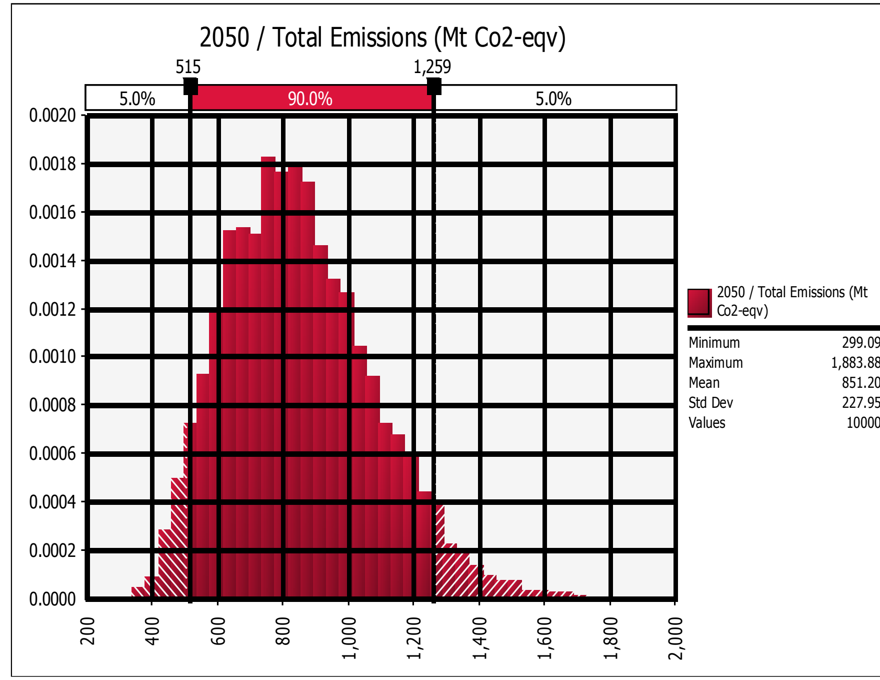
Results: Fleet Fuel use in 2050



2050 U.S. Fleet fuel use probability distribution
[Bil L gasoline equivalent/year]

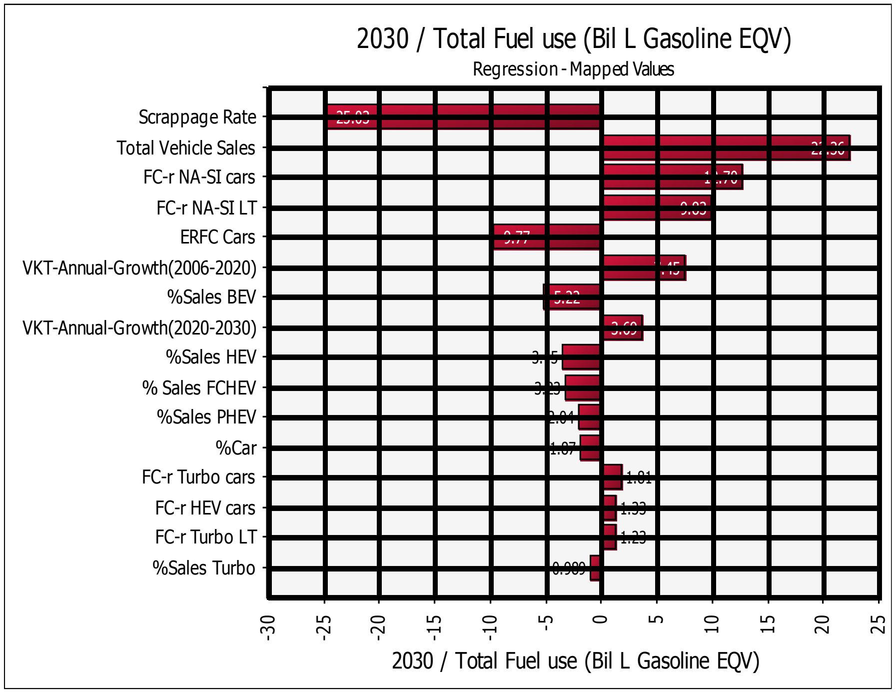
Results: Fleet GHG Emissions in 2030 and 2050

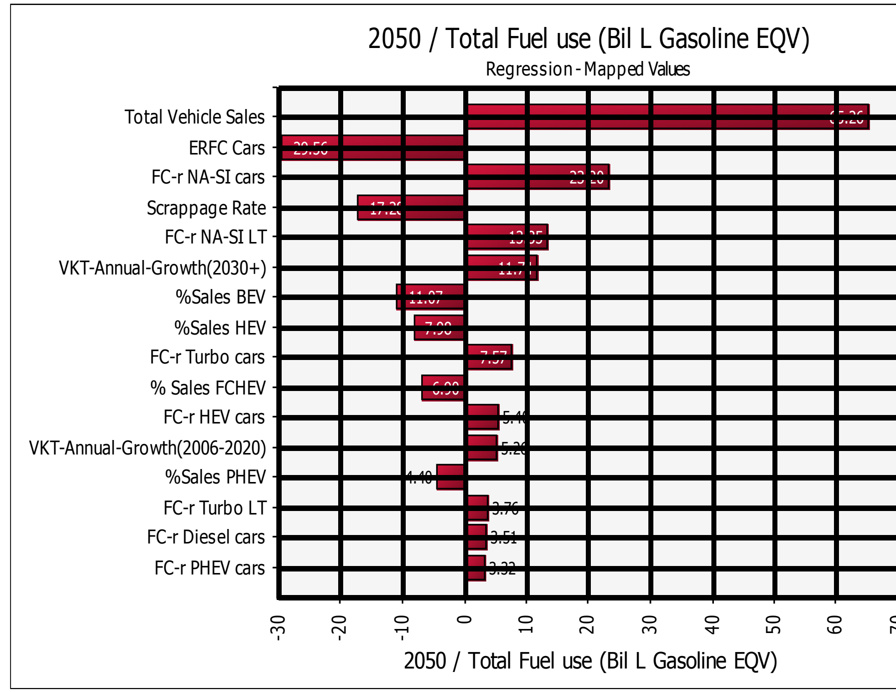




2030 and 2050 U.S. Fleet GHG Emissions probability distribution [Mt CO_2 equivalent/year]

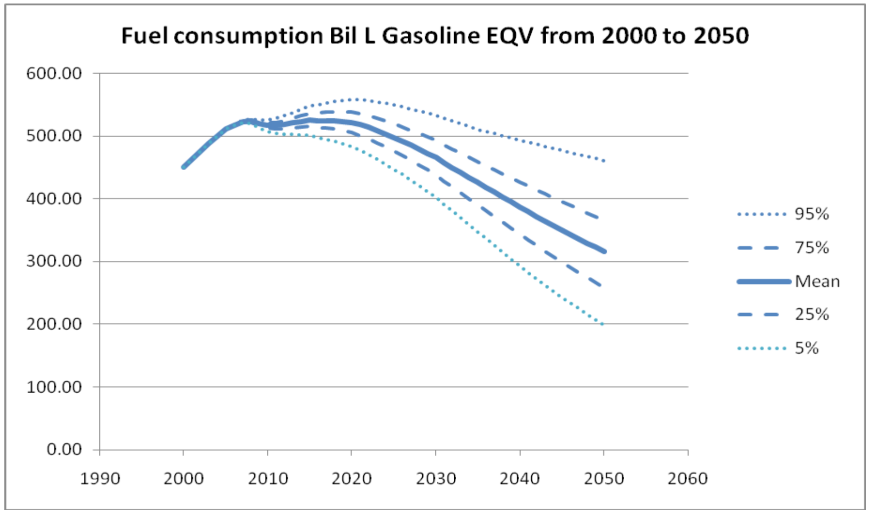
Results: Major Contributing Variables to Fuel use

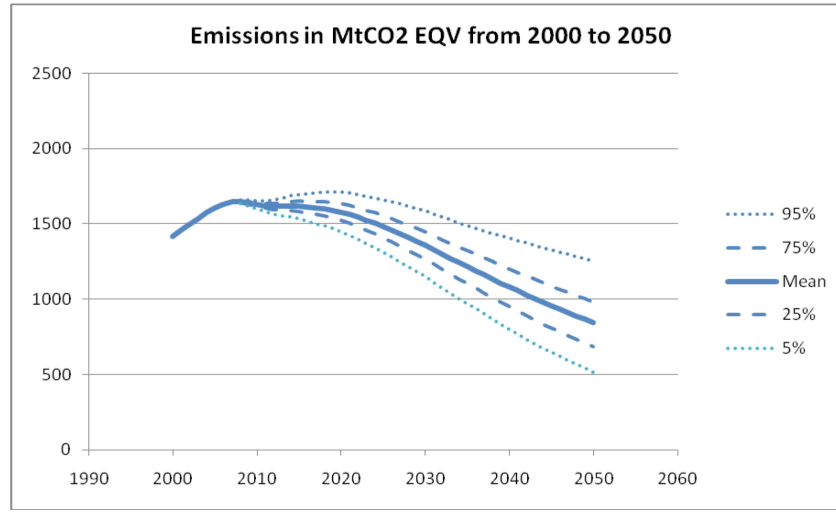




2030 and 2050 U.S. Fleet fuel use ranked major contributing variables [Bil L gasoline equivalent/year]

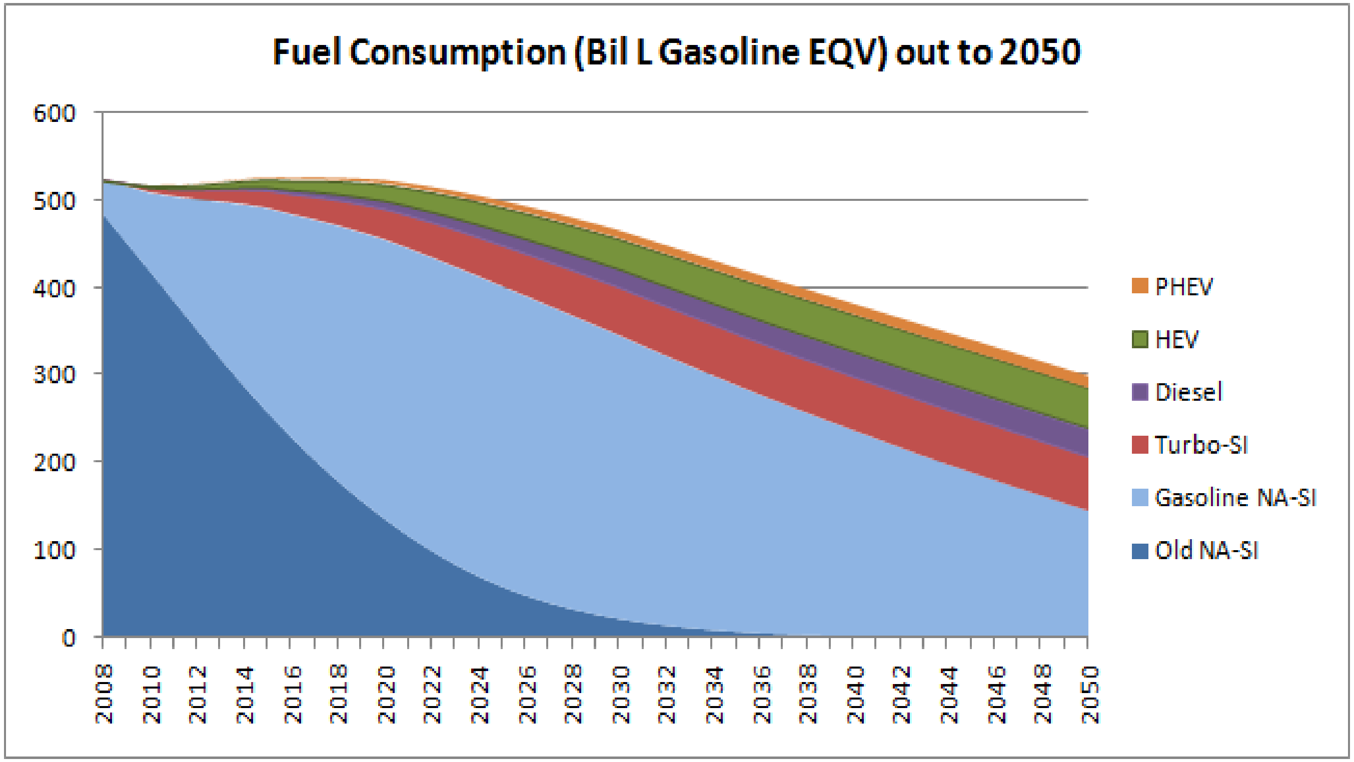
Results: Fleet Fuel use and GHG Emissions out to 2050





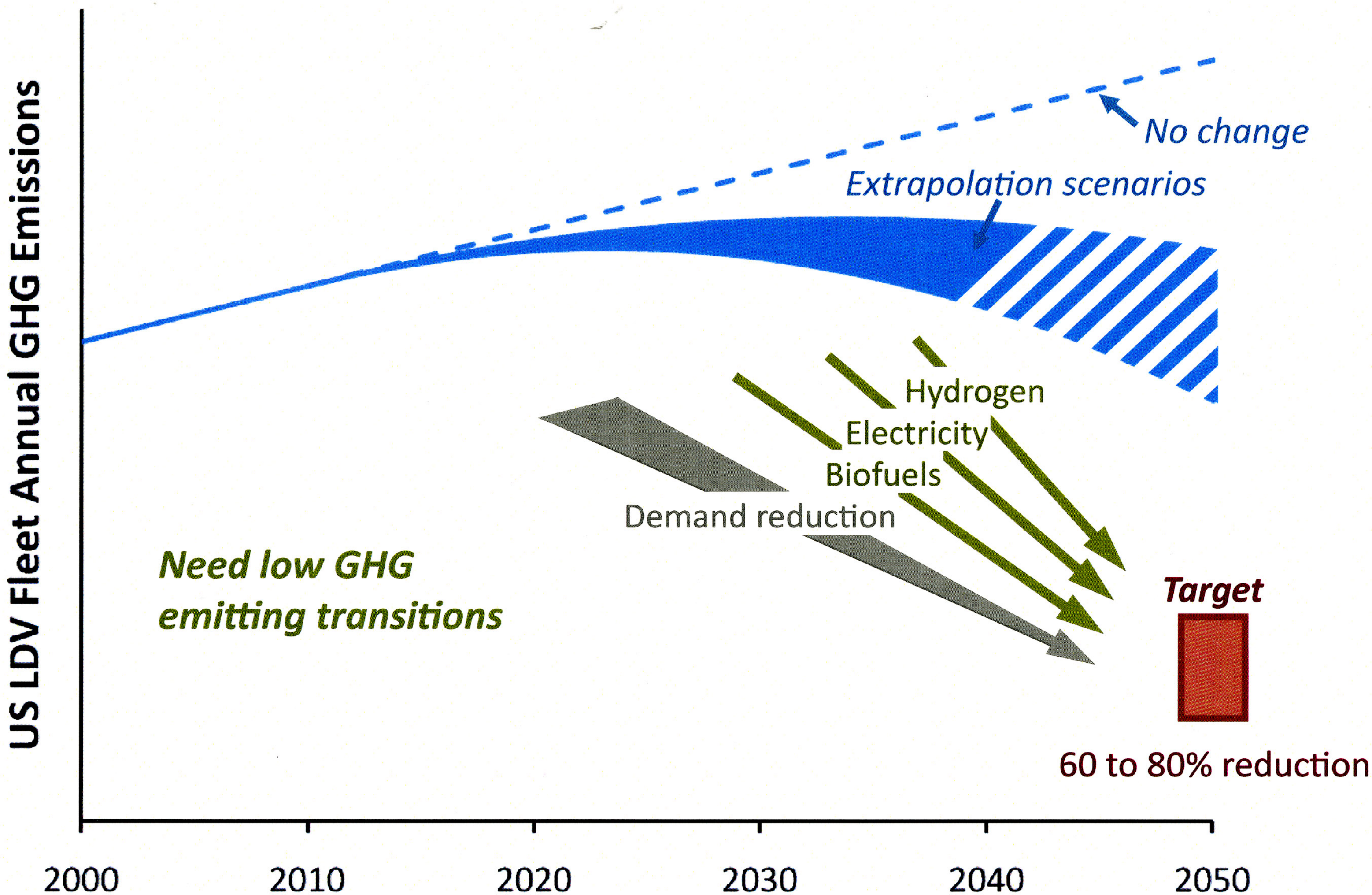
U.S. Fleet Fuel Consumption [Bil L gasoline equivalent/year] and GHG emissions uncertainty profile over time [Mt CO_2 equivalent/year]

Results by Segment: Fleet Fuel Consumption



Fleet Fuel consumption modal output by powertarin share to 2050

Strategic Issues: Reducing US LD Vehicle GHG Emissions



Summary

1. Need for more sophisticated "assessing" of the viable fuel/energy options

2. Performance of the various technology options is relatively well defined (out to about 2030)

3. Technology improvement rates, deployment rates, and cost issues, are especially challenging

4. Uncertainties (of many kinds) make this a "pathways" rather than "end states" problem

5. What are useful approaches for examining plausible reductions by 2050? Develop policies to promote the more promising opportunities

Three Important Energy and GHG Emissions Paths Forward

1. **Improve:** increase the fuel efficiency of mainstream transportation vehicles and develop alternative liquid hydrocarbon fuel sources which can displace petroleum and reduce GHG emissions.

2. **Conserve:** reduce the demand for energy intensive personal and freight transportation services.

3. **Transform:** shift transportation's energy requirements (and propulsion technologies) to alternatives with much lower GHG emissions.

Analysis M-1: Table of Input Assumptions (1)

Parameter	2030 Values						2010 Values
	Min	Mode	Max	Mean	STD	%STD/Mean	
Total light vehicles Sales in 2030	9,387	18,403	23,000	16,930	2,827	17%	11,500
Future Scrappage Rate(2011+)	65%	80%	105%	83%	8%	10%	80%
%Sales Gasoline-Turbo in 2030	6%	12%	18%	12%	2%	20%	7%
%Sales Diesel in 2030	1%	5%	9%	5%	2%	30%	1%
%Sales HEV in 2030	3%	10%	17%	10%	3%	30%	3%
% Sales PHEV in 2030	1%	5%	9%	5%	2%	35%	0%
%Sales BEV in 2030	0%	4%	8%	4%	2%	40%	0%
%Sales FCHEV in 2030	0%	2%	5%	2%	1%	44%	0%
% car (vs. light trucks)	45%	65%	80%	63%	7%	11%	51%
VKT-Annual-Growth(2006-2020)	0.26%	0.50%	0.74%	0.50%	0.10%	20%	0.50%
VKT-Annual-Growth(2020-2030)	0.07%	0.25%	0.43%	0.25%	0.08%	30%	N/A
VKT-Annual-Growth(2030+)	-0.40%	0.00%	0.40%	0.00%	0.16%	N/A	N/A
Emphasis on Reducing Fuel Consumption (ERFC)							
ERFC Cars	40%	80%	100%	73%	12%	17%	50%
ERFC Light Trucks	30%	70%	100%	67%	14%	22%	50%
Electricity Use							
PHEV Elec consumption (Kwh/100km) in 2030	12	24	35	24	5	20%	36
BEV Elec consumption (Kwh/100km) in 2030	12	24	36	24	5	20%	36
FCV Hybrid Electric Energy use (MJ/100km)	30	115	200	115	35	30%	115
Utility Factor	30%	48%	66%	48%	7%	15%	N/A

Analysis M-1: Table of Input Assumptions (2)

Parameter	2030 Values						2010 Values
	Min	Mode	Max	Mean	STD	%STD/Mean	
Emissions							Value in 2010
%blend cellulosic ethanol in 2030	4%	14%	24%	14%	4%	30%	0%
%blend corn ethanol in 2030	2%	8%	14%	8%	2%	30%	5%
%electricity from clean sources in 2030	30%	50%	75%	52%	9%	18%	29%
%bio-diesel	1%	3%	5%	3%	1%	30%	0%
%tarsand in 2030	15%	25%	45%	28%	6%	22%	10%
WTW Coefficients[gco2 eqv/MJ]							
Ethanol WTW in 2030	6	8	14	9	2	18%	10
Corn Ethanol WTW in 2030	60	69	90	73	6	9%	77
Gasoline WTW in 2030	81	92	103	92	5	5%	92
Diesel WTW in 2030	82	94	106	94	5	5%	94
Bio-Diesel WTW in 2030	56	89	122	89	13	15%	89
Electricity WTW in 2030 [gco2/kwh]	376	970	1376	908	205	23%	1078
Hydrogen WTW in 2030	93	123	1376	123	12	10%	137
TarSand WTW in 2030	92	105	118	105	5	5%	109
FC Relative in 2030							
FC-r NA-SI cars in 2030	0.44	0.70	0.96	0.7	0.105	15%	1.00
FC-r Turbo cars in 2030	0.39	0.62	0.85	0.62	0.093	15%	0.90
FC-r Diesel cars in 2030	0.37	0.59	0.81	0.59	0.089	15%	0.84
FC-r HEV cars in 2030	0.21	0.42	0.63	0.42	0.084	20%	0.70
FC-r PHEV cars in 2030	0.21	0.42	0.63	0.42	0.084	20%	0.70
FC-r NA-SI LT in 2030	0.45	0.71	0.98	0.714	0.107	15%	1.00
FC-r Turbo LT in 2030	0.39	0.61	0.83	0.609	0.091	15%	0.83
FC-r Diesel LT in 2030	0.35	0.56	0.76	0.555	0.083	15%	0.74
FC-r HEV LT in 2030	0.22	0.43	0.63	0.426	0.085	20%	0.70
FC-r PHEV LT in 2030	0.22	0.43	0.63	0.426	0.085	20%	0.70

Transportation Demand Reduction Models and Analysis

1. Limited analysis in this area to date: an important area!
2. Recent study "Moving Cooler An Analysis of Transportation Strategies for Reducing GHG Emissions" (Cambridge Systematics, Inc., 2009) illustrates the potential:
   - Near-term strategies (e.g., parking fees/controls, congestion pricing
   - Long-term/maximum results (e.g., transit expansion, active traffic management)
   - Land use transitions (e.g., link smart growth, transit, non-motorized travel) can reduce travel demand
   - How can such studies of changes in demand be connected to technology change impact studies (there are feedbacks)