Towards Energy Independence in 2025

Prepared with Support from Americans for Energy Independence

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Abstract

Significant inroads towards achieving energy independence can be made by reducing oil use in the light duty transportation sector. By increasing CAFÉ (Corporate Average Fuel Economy) standards, biofuel use, hybrid vehicle market share, and promoting the development of plug-in hybrid vehicles, we find oil imports can be reduced by 20-32% by 2025. Further, under our most aggressive case, 22% (6.3 million barrels per day) of daily oil use is saved from business-as-usual practices by 2025, realistically eliminating imports from the Persian Gulf by 2021. At the same time, carbon emissions can be reduced by 50% from light duty transportation with a cost savings of up to $1.1 trillion (2005 $). Additionally, electricity savings from implementing energy efficiency measures (EE) can provide enough energy to power nearly 42 million plug-in hybrid vehicles by 2025.

Introduction

The US currently consumes 20 million barrels of oil per day and is projected to consume over 28 million barrels per day by 2025 according to recent government projections.[1] We currently import 55% of our daily oil supply, a figure that is forecasted to rise to 70% by 2025.[2] Many of these imports come from politically volatile areas and regimes. In fact, over 49% of these imports come from the Persian Gulf, Africa and Venezuela (Table 1). For this report, we analyzed scenarios for reducing US dependence on foreign oil and found enormous opportunities for achieving energy independence through light duty fleet transportation improvements and energy efficiency (EE) measures in the stationary power sector. We focus on light duty transportation fleet improvements because it is the option with the highest potential for achieving energy independence by 2025. Light duty vehicles account for 93% of the total vehicle fleet (Figure 1) and is the sector with the highest vehicle turnover (15 years compared to 28 years from heavy duty vehicles).[3] Please see Appendix for discussion on natural gas fuel and the hydrogen economy.

Table 1
Summary of Oil Imports

Year	Total Oil Use	Imports	Persian Gulf Imports	African Imports*	Venezuelan Imports	Total Persian Gulf, African & Venezuelan Imports
	mbbl/day	%	%	%	%	%
2005	20.84	55%	22%	14%	13%	49%
2015	24.80	63%	22%	14%	13%	49%
2020	26.41	66%	22%	14%	13%	49%
2025	28.30	70%	22%	14%	13%	49%

Notes:
Assume regional import percentages remain constant from 2005-2025.
* African imports include imports from Nigeria, Angola, Algeria and Gabon.

Sources:
Oil use and import projections from 2005 EIA Annual Energy Outlook, Table 11.
Regional imports from Energy Information Administration, Form EIA-814, "Monthly Imports Report".

Transportation Sector

Transportation demand accounts for over 70% of total oil use (Table 2a), 61% of which is used to power the light duty vehicle fleet (Table 2b). Further, the light duty vehicle fleet, comprised of passenger vehicles, light trucks (under 8,500 lbs), vans and

[1] 2005 Annual Energy Outlook, Table 11, Energy Information Agency.
[2] *Ibid*.
[3] Davis, S., Diegel, S. Transportation Energy Databook: Edition 24. Oak Ridge National Laboratory, ORNL-6973 **2004**.

SUVs account for over 93% of the total fleet (Figure 1). Additionally, light duty vehicles have an average vehicle life of 15 years, as opposed to 28 years for heavy duty vehicles.[4] Therefore, our analysis focuses on reducing oil consumption in the light duty vehicle fleet as these policies will have the most immediate impact in reducing oil dependence by 2025. Once substantial reductions have been made in light duty vehicle fleet oil consumption, attention should focus on reducing oil use in the heavy duty vehicle fleet and industrial energy use sectors (Tables 2a & 2b).

Table 2a
Summary of Oil Usage

Sector	Use mbbl/day	Percentage %
Transportation	14.28	68.5%
Industrial	4.93	23.7%
Residential & Commercial	1.34	6.4%
Electric generators	0.29	1.4%
Total	20.84	100%

Source:
Table 11, 2005 Annual Energy Outlook, Energy Information Agency.

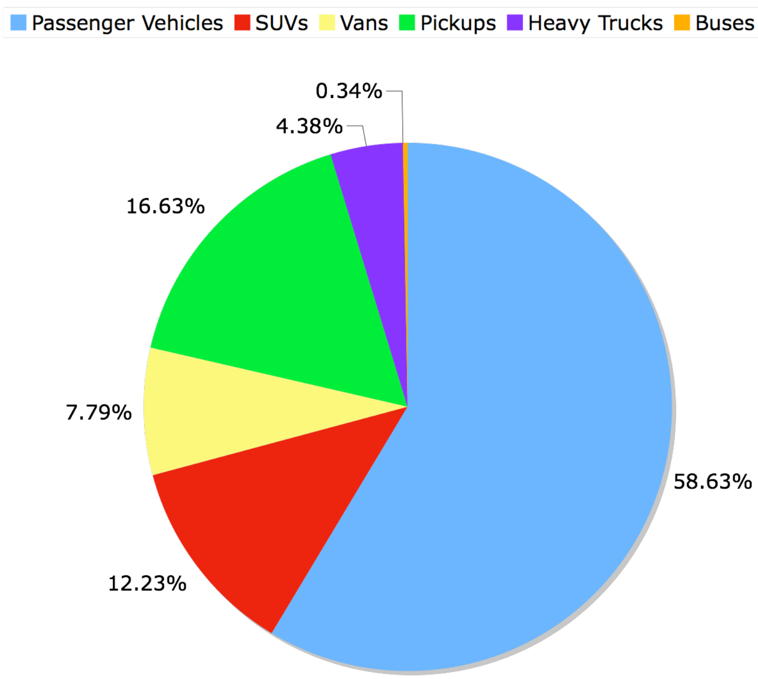
[4] Davis, S., Diegel, S. "Transportation Energy Databook: Edition 24" Oak Ridge National Laboratory, ORNL-6973 (2004).

Table 2b
Summary of Transportation Sector Oil Usage

Sector	Use	Percentage
	mbbl/day	%
Light-Duty Vehicles	8.93	62.5%
Commercial Light Trucks	0.33	2.3%
Bus Transportation	0.12	0.8%
Freight Trucks	2.09	14.7%
Rail, Passenger	0.06	0.4%
Rail, Freight	0.22	1.6%
Shipping, Domestic	0.15	1.0%
Shipping, International	0.31	2.2%
Recreational Boats	0.17	1.2%
Air	1.40	9.8%
Military Use	0.36	2.5%
Other	0.14	1.0%
Total	14.28	100%

Source:
Table 7, 2005 Annual Energy Outlook,
Energy Information Agency.

Figure 1
2003 Vehicle Registrations by Class



Source:
Highway Safety Statistics 2003, Tables mv1 & mv9, Federal Highway Administration.

We analyzed four alternative scenarios of future oil reductions from business-as-usual (BAU) forecasts. Three main technological options are explored:

1. Increasing CAFÉ standards for conventional vehicles,
2. Rising market share of hybrid vehicles
3. Displacing gasoline with biofuels, namely, ethanol

The scenarios reflect varying degrees of policy implementation for making progress towards achieving energy independence and they all result in substantial, yet realizable oil reductions. In fact, emerging developments in vehicle technology may further advance the US' progress towards achieving energy independence.[5]

Scenario Overview

Table 3 summarizes the parameters of each scenario. Our first scenario examined potential reductions from moderate increases in CAFÉ standards, hybrid market share

[5] Plug-in hybrid vehicles advocated by http://www.calcars.org/ and fuel cell technology.

and gasoline displacement. As CAFÉ standards have not been increased in 15 years, we analyzed a scenario of achieving reductions through moderate increases in CAFÉ standards and aggressively promoting both hybrid technology and biofuel use (Scenario 2). Because an aggressive gasoline displacement strategy is heavily dependent on cellulosic ethanol production, which is not yet commercially viable in the US, we examined a scenario of aggressive increases in CAFÉ standards, aggressive growth in hybrid market share and moderate growth in biofuel use (Scenario 3). Finally, we examined an integrated scenario in which energy savings from improved energy efficiency measures in the stationary power (electricity) sector are used to "fuel" plug-in

Table 3
Scenarios Analyzed

Business-As-Usual*	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1.9% annual increase in oil use	Moderate CAFÉ, Moderate Hybrids, Moderate Ethanol	Moderate CAFÉ, Aggressive Hybrids, Aggressive Ethanol	Aggressive CAFÉ, Aggressive Hybrids, Moderate Ethanol	Aggressive CAFÉ, Plug-In Hybrids, Aggressive Ethanol

Note:
Growth rate from Table 7, 2005 Annual Energy Outlook, Energy Information Agency.

hybrid vehicles (Scenario 4).

Scenario Parameters

CAFÉ. Enacted in 1975, the CAFÉ standards regulate the average fuel economy of cars and light trucks. Through a combination of penalties and credits, manufacturers have been encouraged to produce vehicles that meet standards for better mileage. Nevertheless, the average fuel economy peaked in 1987 at 22.1 miles per gallon (mpg) and has worsened to 20.3 mpg today due to loopholes in these regulations. Vehicles with mileage as high as 44 miles per gallon are commercially available today,[6] yet there is very little incentive for manufacturers to produce them unless higher CAFÉ standards are enforced. Under the moderate CAFÉ path, light duty fuel economy increases to 25 mpg in 2010 and increases by 5 mpg every 10 years to reach 30 mpg in 2025 (Figure A1). In the aggressive CAFÉ path, fuel economy reaches 30 mpg in 2010 and increases by 5 mpg every 5 years to reach 40 mpg in 2025.

Hybrids. Hybrid vehicles improve fuel efficiency by combining the combustion engine with an electric drivetrain and battery. Gains are realized by recapturing braking energy, storage of unused idle power, and reductions in the overall weight of the engine

[6] 2006 VW Golf diesel, non-hybrid http://www.fueleconomy.gov/feg/best/bestworstNF.shtml

and vehicle. Hybrid drivetrains alone can increase mileage by 50% under average driving conditions and up to 100% in stop-and-go traffic.[7] According to EIA projections, hybrid vehicles accounted for 1% of new light duty fleet vehicle sales in 2005 (assuming 17 million vehicle sales), an 83% increase over 2004 sales levels (Table 4). In our analysis, we assumed a hybrid market share of 25% by 2025 in our moderate case and a 35% market share under our aggressive case (Figure A2). Additionally, we projected the fuel economy for hybrid vehicles to increase from today's 55 mpg[8] to 75 mpg by 2025.

Table 4
Hybrid Vehicle Market Share Growth

Light Duty Vehicles Sold	2004 Hybrid Vehicles Sold	2005 Hybrid Vehicles Sold	2004 Market Share	2005 Market Share*	Growth Rate
17,000,000	88,272	161,805	0.52%	0.95%	83%

Note:
*EIA projection of hybrid vehicle sales.

Source:
Tables 14 & 20, Alternative Fueled Vehicles Made Available, EIA.

Ethanol. Ethanol accounts for almost all biofuel alternatives in the US market. The 0.296 quadrillion BTUs produced annually from corn as a blend stock for gasoline accounts for approximately 1.4% of the total vehicle fuel used in the US.[9] There is strong potential for rapid market growth in this sector. A recent report by Oak Ridge National Laboratory and the US Department of Agriculture determined that adequate land resources are available in the US to sustainably produce a supply of biomass capable of displacing 30% of petroleum use by the year 2030.[10] Additionally, a recent study by the Energy and Resource Group (ERG) at UC Berkeley cast serious doubt on the long held notion that ethanol production has a negative energy balance – that is, the energy used in the production process exceeds the energy content of ethanol – and concluded ethanol production is less petroleum-intensive than gasoline production.[11] However, a broad transition to ethanol is compelling only when it is also produced from cellulosic or woody, fibrous plant sources. Following the Oak Ridge/USDA report, which is highly contingent on cellulosic ethanol production, we assumed a 30% ethanol market share by 2050 in our moderate case and a 30% market share by 2030 in our aggressive case. Given

[7] Interlaboratory Working Group on Energy-Efficient and Clean Energy Technologies, Department of Energy, *Scenarios for a Clean Energy Future*, 1997.
[8] Based on the combined fuel economy for a 2004 Toyota Prius as reported by the EPA http://www.fueleconomy.gov/feg/findacar.htm.
[9] Calculated using Table 2, 2004 Renewable Energy Trends, EIA and Table 7, 2004 Annual Energy Outlook, EIA.
[10] Oak Ridge National Laboratory, Department of Energy, *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply* **2005**.
[11] Farrell, A, Plevin, R, Turner, B, Jones, A, O'Hare, M, and D.M. Kammen, D.M. Ethanol Can Contribute to Energy and Environmental Goals, *Science* (301) **2006**

these targets, we project a 5.5% market share under our moderate case and a 16% market share under our aggressive case by 2025 (Figure A2).

Plug-Ins & Energy Efficiency (EE). Transportation vehicles based on electric powered batteries were among the first vehicles developed. However, when the combustion engine became competitive in the early 1900s, interest in electric vehicles diminished and all vehicles in the US are now primarily powered by gasoline and some diesel. With hybrid vehicles rapidly gaining market share, there are also advocates who are actively campaigning for plug-in hybrids,[12] which are not only powered by fossil or ethanol fuels but also directly from the electricity grid. Because hybrid engines already rely on batteries for storage of energy, only minor modifications using existing technology are needed to make these vehicles chargeable with electric power. Plug-in vehicles do involve a lifestyle change as owners would have to charge the battery to extract the highest fuel cost savings. However, in light of rising gas prices, we believe this is a tradeoff many vehicle owners will be eager to make. The electricity for the vehicles is obtained through increases in generation capacity and end-use efficiency measures that cut demand in buildings.

Model Results

Our analysis reveals light duty fleet oil use can be reduced from 30-50% by 2025 (Table 6) and total oil use can be reduced from 14-22% (Table 7). At current oil prices of $65/barrel, the scenarios represent a cumulative cost savings of between $650 billion and $1.1 trillion from the 2005 through 2025 period (Table 8).

[12] http://www.calcars.org

Table 5
Scenario Parameters

	CAFÉ	
	Moderate	**Aggressive**
Current fuel economy	20 mpg	20 mpg
fuel economy increase	5 mpg	5 mpg
increment	10 years	5 years
Year of first increase	2010	2010
Fuel economy at first increase	25	30
Fuel economy in 2025	30	40
	Hybrids	
	Moderate	**Aggressive**
Current market share	1%	1%
2025 market share	25%	35%
Current fuel economy	55 mpg	55 mpg
2025 fuel economy	75 mpg	75 mpg
	Ethanol	
	Moderate	**Aggressive**
Current market share	1.4%	1.4%
Year of 30% gasoline displacement	2050	2030

Table 6
Summary of Potential Oil Use Reductions in Light Duty Fleet Transportation

	2015			***2020***			***2025***		
	Oil Use	**Daily Oil Savings from BAU**	**% Reduction from BAU**	**Oil Use**	**Daily Oil Savings from BAU**	**% Reduction from BAU**	**Oil Use**	**Daily Oil Savings from BAU**	**% Reduction from BAU**
Strategy	**million bbl/day**	**million bbl/day**	**%**	**million bbl/day**	**million bbl/day**	**%**	**million bbl/day**	**million bbl/day**	**%**
BAU	10.92	-		11.74	-		12.75	-	
Scenario 1	9.92	1.00	9.2%	9.60	2.14	18.3%	8.86	3.90	30.6%
Scenario 2	9.85	1.06	9.7%	9.39	2.35	20.1%	8.33	4.42	34.7%
Scenario 3	9.33	1.59	14.5%	8.23	3.51	29.9%	6.92	5.83	45.7%
Scenario 4	9.28	1.63	14.9%	8.07	3.67	31.3%	6.48	6.28	49.2%

Table 7
Summary of Potential Total Oil Use Reductions

	2015			2020			2025		
	Oil Use	Daily Oil Savings from BAU	% Reduction from BAU	Oil Use	Daily Oil Savings from BAU	% Reduction from BAU	Oil Use	Daily Oil Savings from BAU	% Reduction from BAU
Strategy	million bbl/day	million bbl/day	%	million bbl/day	million bbl/day	%	million bbl/day	million bbl/day	%
BAU	24.80	-		26.41	-		28.30	-	
Scenario 1	23.80	1.00	4.0%	24.27	2.14	8.1%	24.40	3.90	13.8%
Scenario 2	23.74	1.06	4.3%	24.06	2.35	8.9%	23.88	4.42	15.6%
Scenario 3	23.21	1.59	6.4%	22.90	3.51	13.3%	22.47	5.83	20.6%
Scenario 4	23.17	1.63	6.6%	22.74	3.67	13.9%	22.02	6.28	22.2%

Table 8
Summary of Potential Total Oil Cost Savings

	2005-2015		2005-2020		2005-2025	
	Cumulative Oil Savings	Cumulative Cost Savings	Cumulative Oil Savings	Cumulative Cost Savings	Cumulative Oil Savings	Cumulative Cost Savings
Strategy	billion bbl	$billions (2005)	billion bbl	$billions (2005)	billion bbl	$billions (2005)
Scenario 1	1.27	$82.27	4.23	$275.00	10.10	$656.60
Scenario 2	1.34	$87.42	4.57	$297.01	11.13	$723.46
Scenario 3	2.01	$130.43	6.96	$452.57	16.02	$1,041.07
Scenario 4	2.07	$134.50	7.27	$472.48	17.00	$1,104.91

These oil savings can reduce foreign oil imports by 20-32% by 2025 (Figure 2). Starting from the left side of the graph, the figure shows foreign imports starting at 100% today and the projected need for imports under each scenario through 2025. Furthermore, if all savings are applied to reducing US imports solely from the Persian Gulf region, these imports can be completely eliminated by 2025 under Scenarios 2 through 4, assuming the US continues to obtain 22% of its total imports from the Persian Gulf (Figure 3). In our most aggressive case (Scenario 4), all Persian Gulf imports are eliminated as early as 2021.

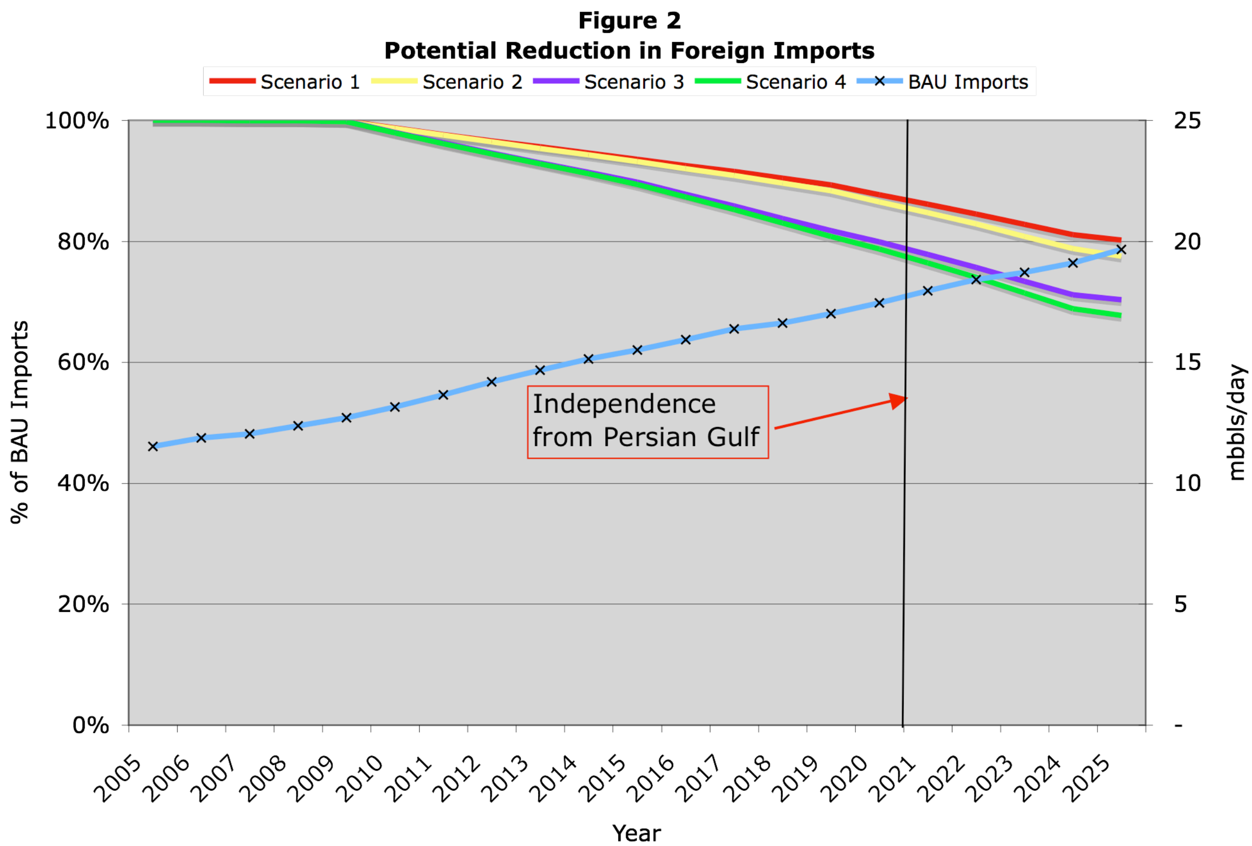
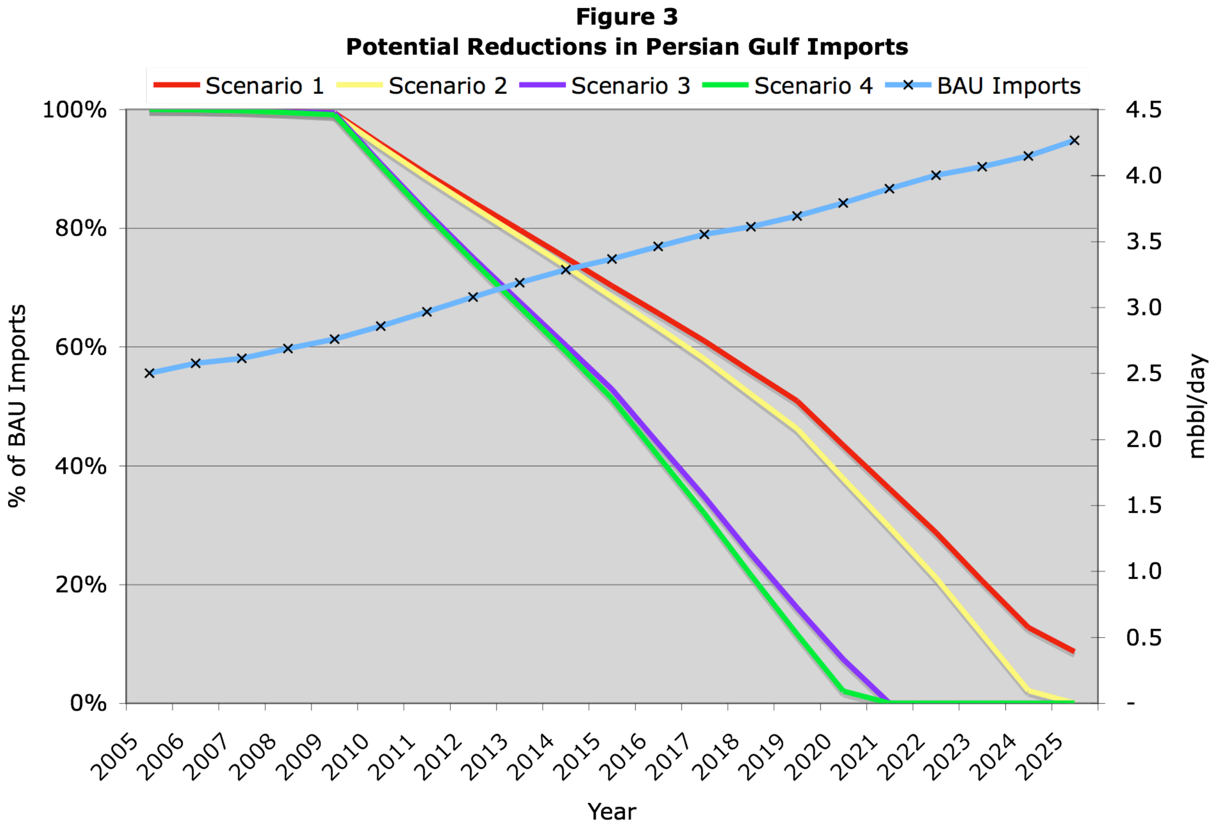


Figure 2
Potential Reduction in Foreign Imports
Scenario 1
Scenario 2
Scenario 3
Scenario 4
BAU Imports
100%
80%
60%
40%
20%
0%
% of BAU Imports
25
20
15
10
5
-
mbbls/day
Independence
from Persian Gulf
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Year



Plug-In Analysis

Plug-in hybrid prototypes based on lithium ion battery enhanced Toyota Priuses have 30 mile ranges solely on electricity and have effective mileages of over 100 mpg.[13] As the average commute for drivers is 35 miles per day, these vehicles would carry enough electric charge to provide nearly all of their fuel.[14] In Scenario 4, we assumed that by 2015, all hybrid vehicles are sold with plug-in technology, effectively bringing their mileage up to at least 150 mpg, which has been reported with current prototypes at *Calcars*. While battery storage technology has improved considerably, the main obstacle for both hybrids and plug-in hybrids is to develop longer lasting and more affordable storage. The amount of electricity needed to power the fleet is estimated by a conversion factor of 500 kWh of electric power for every barrel of petroleum that is displaced. This is based on an average value of 0.33 kWh per mile that is typically achieved by hybrid vehicles today and the general assumption that all vehicles have an average mileage of 36 miles per gallon over the 2005 to 2025 period. Figure 4 shows the amount of power required from the grid. The fuel saved by switching from simple hybrids to plug-ins is used to calculate the electricity needed.

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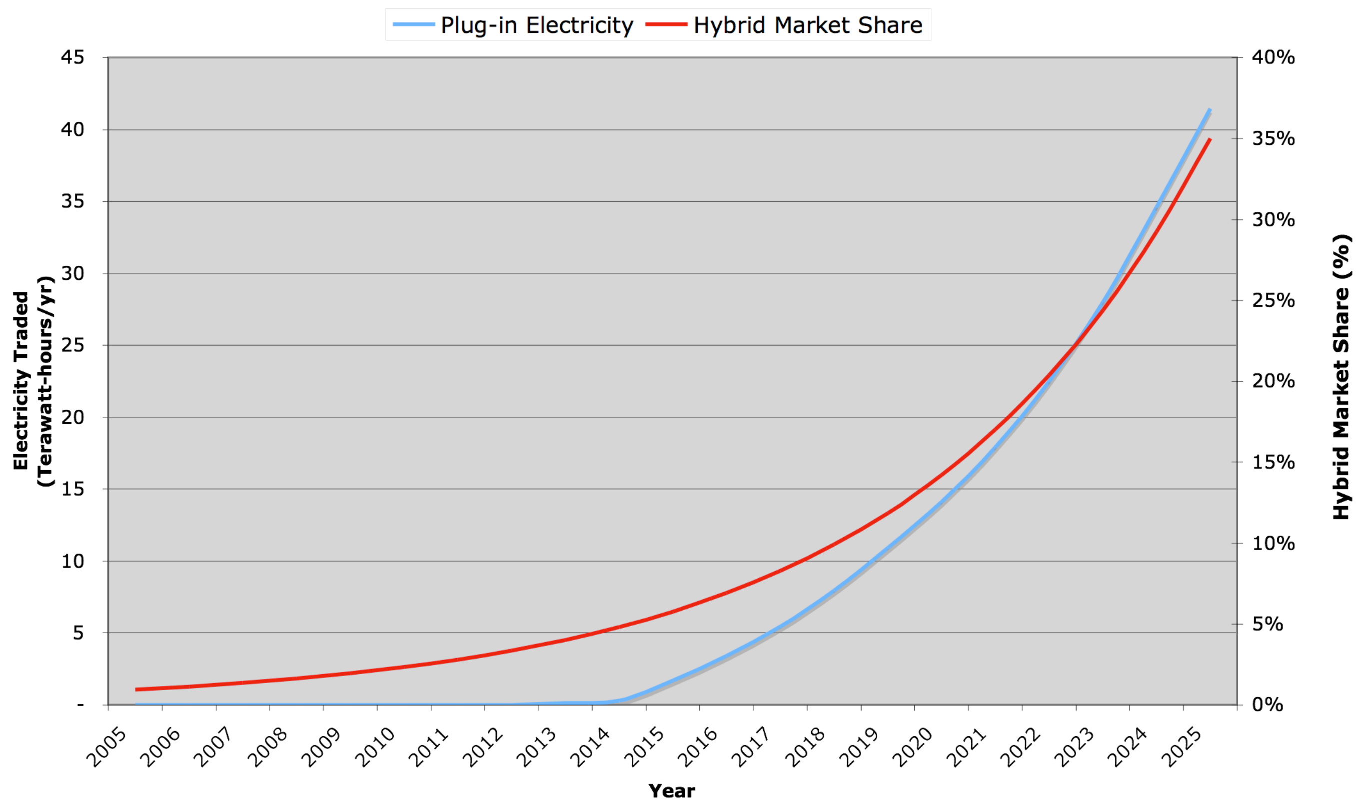
[13] http://www.calcars.org/priusplus.html
[14] 2001 National Highway Transportation Survey, Bureau of Transportation Statistics.

Figure 4
Plug-in Hybrids (Scenario 4)



By 2025, approximately 42 terawatt-hours (TWh) of electricity are needed to power all hybrids, which account for about 42 million units or 10%[15] of the entire light vehicle fleet. An additional 0.23 million barrels of oil would be saved each day by switching from fossil fuels to electricity for these hybrids. There are several options for obtaining this clean energy. Our preliminary analysis[16] shows that the power can be easily traded from efficiency measures in the residential and commercial sectors, which alone will reduce electric demand by nearly 3,000 TWh[17] per year from today's level in twenty years (Figure A4). With such drastic reductions in intensity, not only would 1.5% of efficiency savings be sufficient to provide for the plug-in hybrids, no new electric generation capacity would be needed and there would be enough supply for years to provide for the entire light vehicle fleet as electric powered transport becomes the dominant mode of transportation.

[15] Extrapolated from hybrid share (aggressive scenario) between 2015 and 2025 (see Figure A3).
[16] Ling, F.H. and Kammen, D.M. Aggressive strategies for residential energy and carbon savings by 2025. AMERICAN GEOPHYSICAL UNION CONFERENCE, PUBLIC AFFAIRS DIVISION, DEC 17 **2004.**

[17] Based on 293 TWh per quad of energy and approximately 10 quads in reduction between 2005 and 2025.

In addition, the same power for vehicles could be obtained through the construction of five 1-GW nuclear power plants or from wind sources, which can provide over 40 TWh per year based on current trends of installation.

Costs

The consumer costs for each scenario were estimated through the following standards assumptions: $50 for each additional mile in CAFÉ increase in non-hybrid vehicles, $2500 per hybrid vehicle, and $4500 for each plug-in vehicle.[18] These values represent the improvements associated installing the technology over the BAU scenario. The extra expense needed for plug-in vehicles over regular hybrids come primarily from the additional battery capacity needed for run these vehicles. Table 9 shows the cumulative cost increase associated with each scenario. The costs are calculated by independently determining the costs associated with increasing CAFÉ and with replacing the stand-alone combustion engine with hybrid or plug-in technology. The cost of converting a conventional engine to a flexible fuel engine is estimated to be approximately $100,[19] which is a negligible cost in comparison to raising CAFÉ standards or installing new engines.

Table 9
Cumulative Costs ($ Billions)

Scenario 1	Scenario 2	Scenario 3	Scenario 4
197	219	335	420

In comparison to the values of estimated fuel savings (Table 8), the amount of additional capital costs needed to implement these measures is roughly half of the savings. For the plug-in model (Scenario 4), there are several options for obtaining the electricity needed for powering the electric vehicle fleet. It is estimated that only $4 billion in start-up capital is needed to generate the electricity, assuming that nuclear powered plants are used. This represents less than 1% of all costs and presumably with wind power or efficiency measures, the expenses are even less.

Emission Reductions

In addition to reducing the country's dependence on oil, these strategies help to reduce carbon emissions from transportation sources, which currently account for 33% of total US emissions. The light duty fleet accounts for 26% of total emissions and 79% of transportation emissions (Table 10).

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[18] Graham, R. Comparing the Benefits and Impacts of Hybrid Electric Vehicle Options. EPRI **2001**.
[19] www.setamericafree.com

Table 10
2004 Light Duty Fleet Vehicle Emissions

Total Emissions	Transportation Emissions	% of Total	Light Duty Fleet Emissions*	% of Total	% of Transportation
MMTCE	MMTCE	%	MMTCE	%	%
5,985.85	1,968.48	33%	1,560.72	26%	79%

Sources:
Table 19, Carbon Dioxide Emissions by Sector and Source, 2005 Annual Energy Outlook, EIA.
Table 7, Transportation Sector Key Indicators and Delivered Energy Consumption, 2005 Annual Energy Outlook, EIA.

Note:
Light duty fleet emisisons derived from 2005 projected oil use and assuming there are 11.4 kg of CO2 emitted per gallon of gasoline consumed (GREET Model).

Our analysis reveals that carbon emissions from the light duty fleet can be reduced approximately 30-50% from BAU levels by 2025 (Table 11).

Table 11
Summary of Potential CO_2 Emissions Reductions from the Light Duty Fleet Transportation Sector

	2015		*2020*		*2025*	
	CO2 Emissions	% Reduction from BAU	CO2 Emissions	% Reduction from BAU	CO2 Emissions	% Reduction from BAU
Strategy	MMTCE	%	MMTCE	%	MMTCE	%
BAU	1,908	-	2,052	-	2,229	-
Scenario 1	1,736	8.99	1,686	17.83	1,564	29.83
Scenario 2	1,732	9.24	1,669	18.68	1,515	32.02
Scenario 3	1,632	14.44	1,442	29.70	1,217	45.40
Scenario 4	1,630	14.58	1,429	30.37	1,171	47.48

Glossary/Acronyms

a) Bbl – Barrel, equivalent to 42 gallons.

b) BAU – Business-as-usual

c) BTU – British thermal units

d) CAFÉ – Corporate Average Fuel Economy, the sales weighted average fuel economy a manufacturer's light duty vehicles (vehicles less than 8,500 lbs) must achieve for a given model year. Current standards are 27 miles per gallon (mpg) for passenger vehicles and 20.7 mpg for light duty trucks. The National Highway Safety Administration (NHTSA) sets the CAFÉ standards and the Environmental Protection Agency (EPA) calculates the CAFÉ of each manufacturer. More information is available at: www.nhtsa.dot.gov

e) Cellulosic – ethanol from wood chips of fibrous plant materials

f) EE – energy efficiency

g) Ethanol – combustible fuel, which is obtained from the breakdown of agricultural materials. The energy density per volume is approximately two-thirds that of regular gasoline.

h) Mbbl – million barrels

i) MMTCE – million metric ton carbon equivalent

Appendix

Choice of Light Transportation Fleet

The sectors chosen for this study are based on known life-cycles of the light vehicle transportation fleet, which are considerably shorter than that of trucks, construction vehicles, rail, maritime, and air. Although some of these modes of transportation rely on diesel, there is no comprehensive analysis on the efforts or costs needed to supply these fleets with biodiesel, which remains a valid option. Ethanol cannot be readily used either because of the power requirements for heavy transportation. In fact, with alternative fuel vehicles and hybrids, there is a tradeoff in drivetrain output that would not significantly decrease the driving experience.

Hydrogen Economy

While hydrogen has gained considerable hype as the solution to our energy needs, a closer analysis shows that the technology for an economic and clean hydrogen strategy is still many years off.[20] Hydrogen has some advantages, namely, it can be burned without cleaned or in a fuel cell, does not produce carbon dioxide at point of use, and can be produced from traditional or renewable sources of fuel. The problem with hydrogen arises from the infrastructure needed to transition to a hydrogen based economy and technological breakthroughs in conversion and storage for these vehicles to match the performance and cost of current vehicles in terms of their range, size, and convenience.[21] Preliminary costs show that infrastructure improvements would exceed $5000 per vehicle even with economies of scale and the process to store the equivalent of hydrogen to displace gasoline is about six times the energy contained in the gasoline.

Natural Gas

Similarly, the US is increasing its reliance on natural gas (NG) as a major source of power for electricity. Figure A1 shows that 17% (4 trillion cubic feet) of NG are imported today and under a BAU scenario, the proportion will rise to 24% (7.5 trillion cubic feet) by 2025 in order to fulfill demand for cleaner power for the electricity grid. Although much of the supply will still be met from domestic sources, there will also be nearly a doubling of foreign natural gas supplies. Unless breakthroughs are made in recovering natural gas from untapped sources (e.g. ocean floor), much of the increase in supply will come from the same regions where oil is being produced today.

Non-fossil fuel alternatives to natural gas include nuclear power, renewable sources (wind, solar, biomass, and geothermal). Independence from foreign NG can be accomplished by the aggressive implementation of these sources as well as from efficiency measures that reduce demand for power (Figure A4).

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[20] Lipman, T. What Will Power the Hydrogen Economy? Present and Future Sources of Hydrogen Energy report UCD-ITS-RR-04-10 Natural Resource Defense Council **2004**.
[21] Keith, D.W. and Farrell, A.E. "Rethinking Hydrogen Cars" *Science* **301**, 315, 2003.

Figure A1 shows BAU scenarios for the domestic and foreign supply of crude and natural gas.

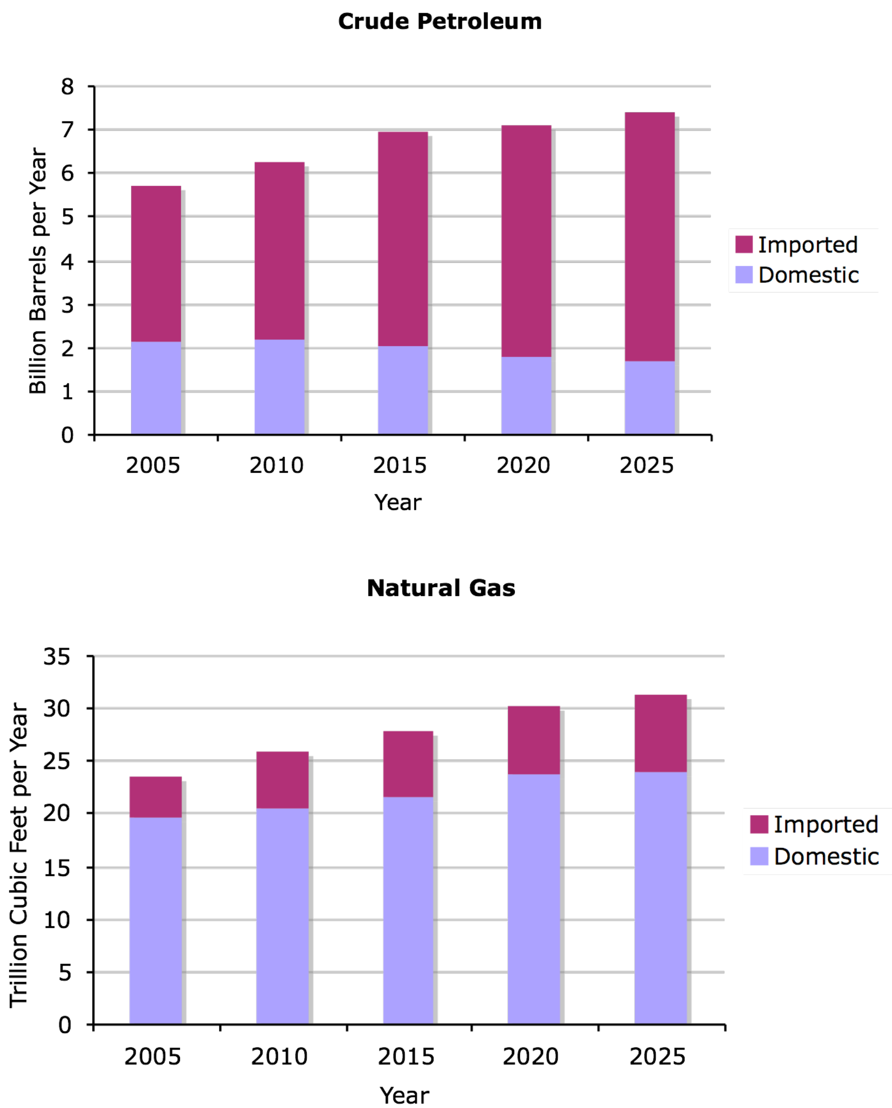


Figure A1. Crude oil and natural gas supplies under business-as-usual scheme.

Figure A1
Projected CAFE Standards

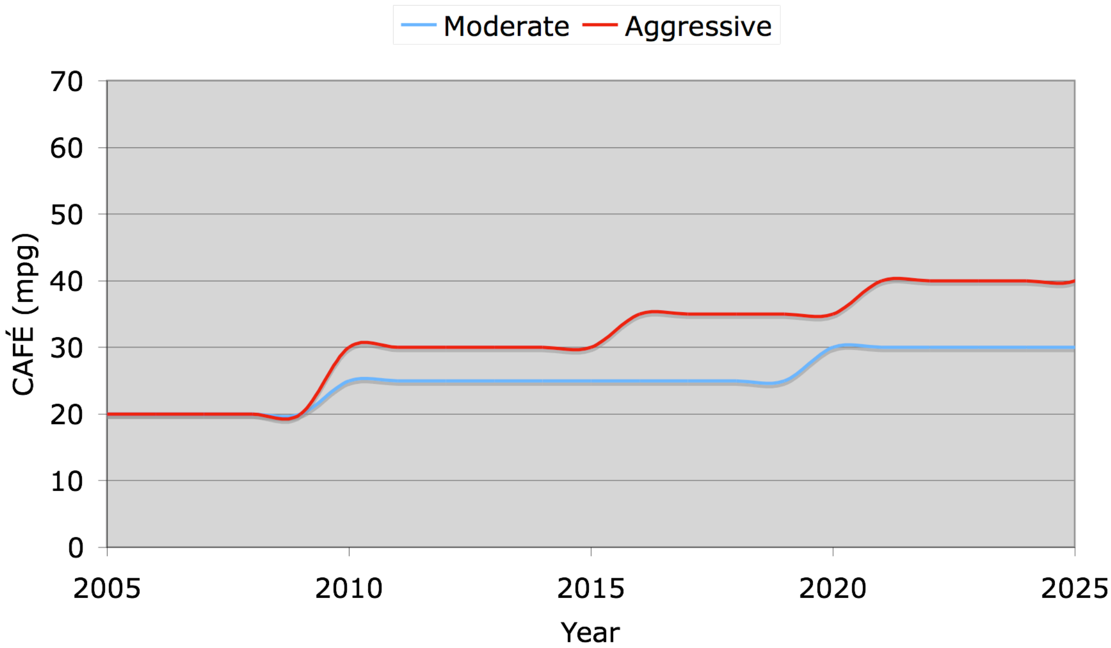


Figure A2
Projected ethanol shares

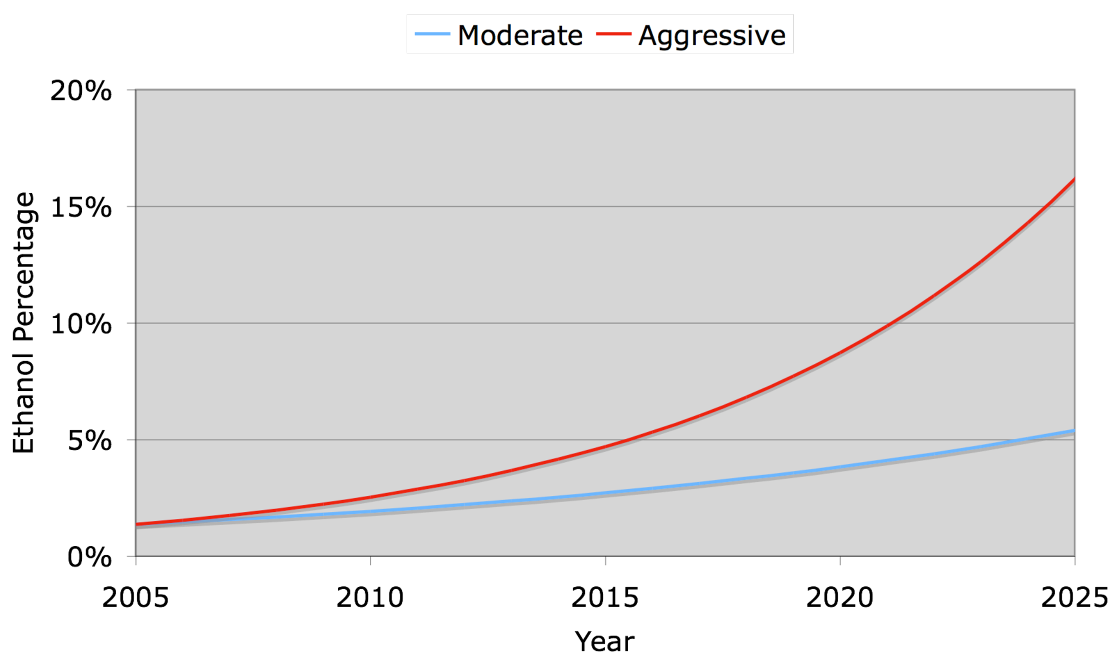


Figure A3
Projected Hybrid Share

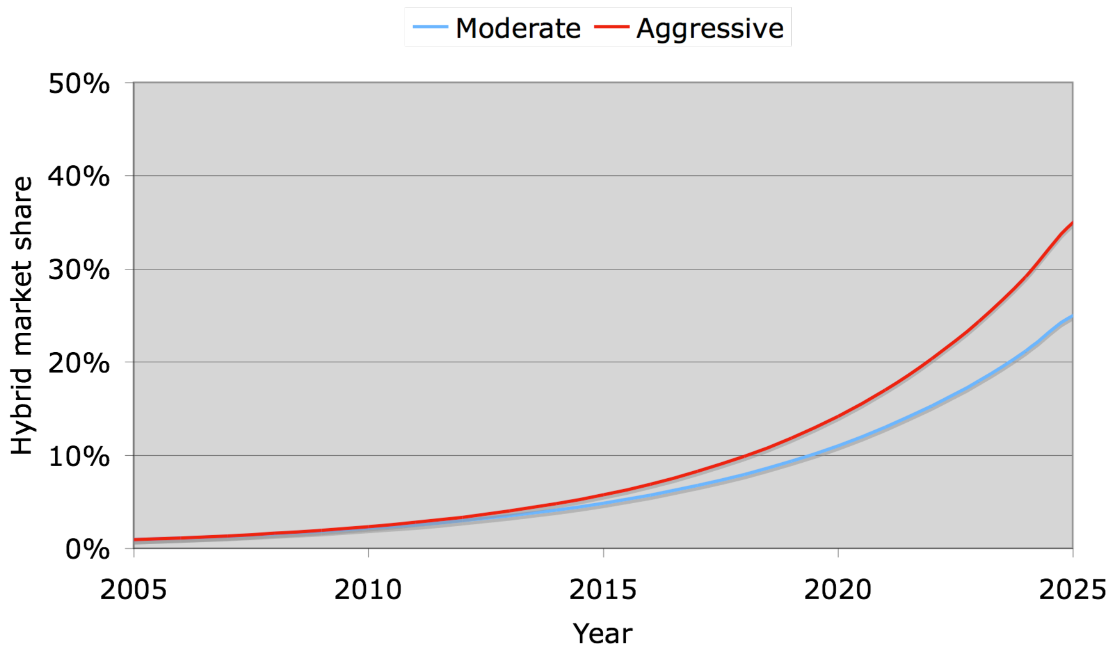
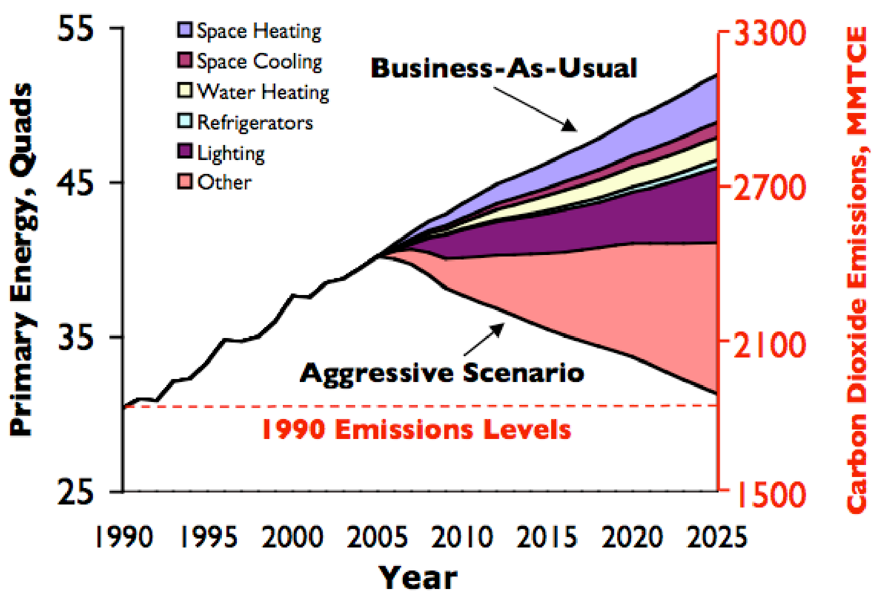


Figure A4
Aggressive Stationary Power Reduction Through Efficiency



Source: Ling, F.H. and Kammen, D.M. Aggressive strategies for residential energy and carbon savings by 2025. AMERICAN GEOPHYSICAL UNION CONFERENCE, PUBLIC AFFAIRS DIVISION, DEC 17

2004. Notes: The wedges for each end-use represent the potential savings through the deployment of best practices that are currently or will likely be available in the future. The “Other” category represents a broad range of electronic devices that include but not limited to major appliances like dishwashers, dryers, vacuums, entertainment (TV, DVD players, stereo), and communication (phone, answering machine, mobile phone chargers).

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