Reducing Oil Use Through Energy Efficiency: Opportunities Beyond Cars and Light Trucks

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ABSTRACT

Discussion of strategies to reduce U.S. oil dependence has centered, appropriately, on improving the fuel efficiency of cars and light trucks. Other opportunities exist to save oil through energy efficiency, however, and these are examined in the following report. We present the breakdown of petroleum use in the U.S. by sector and discuss technologies and practices available to improve the efficiency of the major oil-consuming subsectors. These include freight trucks, industrial equipment and processes, and residential and commercial buildings. After estimating the potential to reduce petroleum consumption cost-effectively through a range of measures, we discuss barriers to efficiency in each sector and policies to overcome those barriers. We then define three efficiency policy scenarios, Modest, Moderate and Aggressive, to take advantage of the opportunities identified, and estimate the total oil savings that would follow from the implementation of each scenario. While achieving ambitious oil savings targets will certainly require major progress on car and light truck fuel economy, this report demonstrates the substantial contribution offered by energy efficiency improvements to other vehicles and in the industrial and building sectors.

ACKNOWLEDGEMENTS

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INTRODUCTION

Context for the Analysis

Since 1997, the United States has imported over half the oil it uses (Davis and Diegel 2004). Imports are projected to reach two-thirds of its total usage by 2020 (EIA 2005a). Surging prices for petroleum products, the slowing of the discovery of new oil reserves, and growing attention to global warming have led to a higher level of concern today about oil use than has been evident in the United States for decades.

This situation has led to multiple attempts in Congress over the past three years to set targets and timelines for the United States to reduce its oil consumption. A proposal to save one million barrels per day of oil by 2015, for example, passed overwhelmingly in the Senate in 2003, but did not emerge from the subsequent House-Senate conference. The latest of these efforts are two bipartisan bills, S. 2025 and H.R. 4409, introduced in 2005. The Senate bill calls for savings of 2.5 million barrels per day by 2016 and 7 million barrels per day in 2026 (relative to projected oil consumption), while the House bill would require savings of 2.5 million barrels per day by 2015 and 5 million barrels per day by 2025.

Cars and light trucks are by far the largest user of petroleum products, consuming 9.3 million barrels per day, or 47% percent of the total. And there is plenty of room to make these vehicles more efficient, as we discuss briefly below. At the same time, opportunities exist to make the other half of U.S. oil use more efficient, and these opportunities beyond cars and light trucks are the focus of this report. What follows, then, is not a comprehensive review of the potential to reduce oil use in the United States, but rather a quantitative look at some of the less frequently discussed efficiency opportunities and how they could contribute to reaching oil savings targets over the next fifteen years.

Overview of Oil Use in the United States

Twenty million barrels of petroleum products are supplied daily in the United States, of which 56% percent is imported (EIA 2005a).[1] These petroleum products are used as fuels, in products such as waxes and asphalts, and as intermediates for the production of other products such as plastics, chemicals, and pharmaceuticals. Two-thirds of this oil is supplied to the transportation sector and one-quarter to industry. Residential and commercial uses are a distant third at 6% (see Figure 1).

Oil use is expected to reach 26.3 million barrels per day (MBD) by 2020, of which 65% will be imported. The breakdown by sector will shift slightly further towards transportation over that period of time, because transportation is the fastest-growing end-use for oil.

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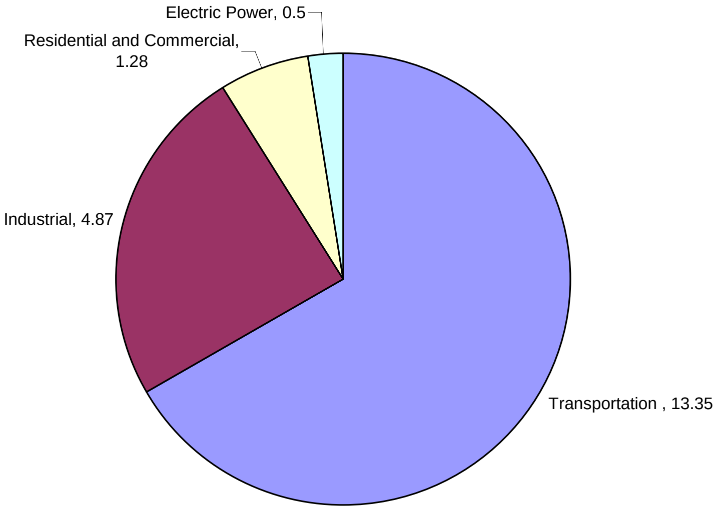
[1] The *Annual Energy Outlook* (EIA 2005a) is the source of any data not otherwise attributed in this overview. The *Annual Energy Outlook*, along with several other publications cited in this report, is a product of the Energy Information Administration (EIA), the branch of the U.S. Department of Energy (DOE) responsible for energy statistics. EIA compiles the most comprehensive data on current and projected oil use. The *Annual Energy Outlook* was chosen as the primary source because it maintains a petroleum balance for the U.S. economy, avoiding to as great an extent as possible double counting.

Figure 1. Refined Petroleum Products Supplied in the United States, 2003 (Million Barrels per Day)



Source: EIA 2005a

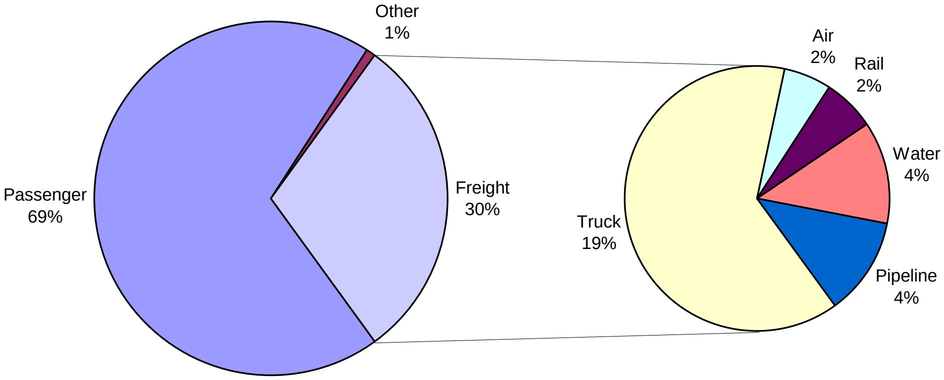
Transportation

The transportation sector is 97% oil-dependent (notable exceptions being pipelines and passenger rail). Of the oil consumed in the sector, 69% goes to passenger movement and commercial uses, 30% to freight movement, and the remainder to recreational uses (Figure 2). These figures exclude "non-road" transportation, primarily construction, mining, and agricultural uses, which are included in the discussion of the industrial sector, below.

Cars and light trucks in the United States are fueled almost entirely by gasoline; diesel vehicles currently account for less than 2% of fuel use among these vehicles, even when heavy pickup trucks are included (Davis and Diegel 2004). Fuel economy for these light-duty vehicles is subject to regulation under Corporate Average Fuel Economy (CAFE) standards. The standards have remained almost unchanged for two decades, and average fuel economy has been on a slight downward trend since the late 1980s. EIA projects that growth in vehicle miles traveled will average 2.0% per year and that car and light truck oil use will grow at 1.9% per year over the next two decades.

The second largest oil user is freight trucks. While trucks move less than half of all freight ton-miles, they are the preferred mode for short-to-medium distance, time-sensitive goods, and they move the bulk of all freight value. Trucking is an energy-intensive mode and accounts for 63% of freight energy use, consuming 2.4 MBD of oil in 2002 (Davis and Diegel 2004). In addition, trucks' oil use is projected to grow at 2.1% per year. Hence trucks are an important place to look for energy savings in the transportation sector, and they are the focus of the transportation element of this report.

Figure 2. United States Transportation Energy Use by Mode in 2002



Source: Data from Davis 2004

Air transport of both people and goods accounts for 8% of transportation oil use. Growth recently has slowed from its earlier rapid pace and is projected to average 2% per year over the next twenty years.

Industry

The use of petroleum products in the industrial sector is more diverse than in any other sector. In 2003, the industrial sector was supplied with 9.31 Quads[2] of petroleum, about 4.87 MBD of oil. The majority (about 78%) goes to non-fuel uses, with the remainder consumed as fuels. By 2020, this is projected to grow to over 11 Quads.

The industrial sector is made up of four sub-sectors: agriculture (including farming, ranching, forestry, and fisheries), construction, mining, and manufacturing (see Figure 3). In the agriculture sub-sector, almost all the petroleum products are used as fuels. This sub-sector uses distillate (primarily diesel) for off-highway vehicles and equipment (e.g., tractors and combines), propane for heating drying operations, and gasoline primarily for stationary engines to generate electricity or pump water (Brown and Elliott 2005).

The construction sub-sector uses 71% of its petroleum products for non-fuel uses (primarily road tar and paving asphalt). The remainder is used primarily for off-highway construction equipment (e.g., grading, earth moving, and excavation equipment) and onsite power generation. In the mining sub-sector, the vast majority of the petroleum used is distillate (i.e., diesel fuel) with only about 11% having non-fuel uses (again, mostly tars and asphalts).

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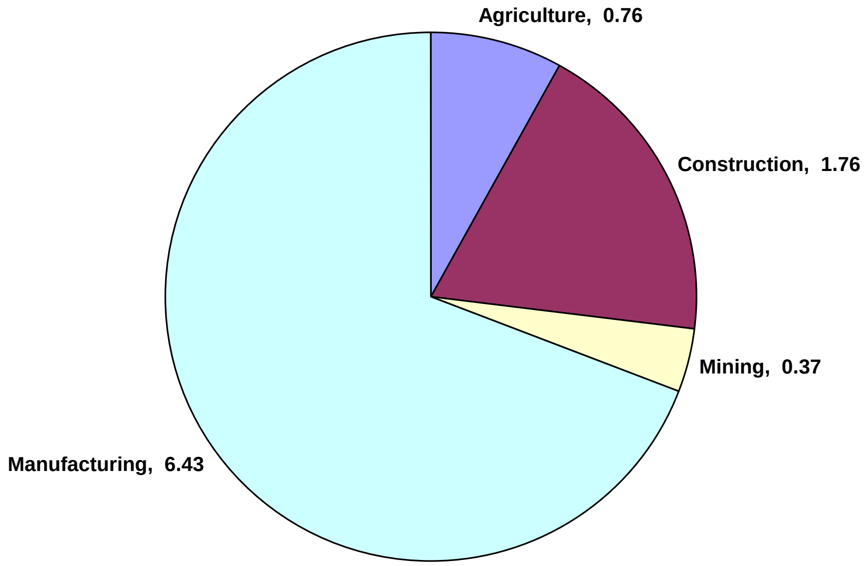
[2] One Quad is 10^{15} Btus (British thermal units). The average heat content of petroleum products is approximately 5.345 million Btus per barrel (EIA 2005a), so a Quad is the energy equivalent of roughly a half-million (0.513 million) barrels per day over one year.

Figure 3. Petroleum Products Supplied to the Industrial Sector in 2003 (Million Barrels of Oil per Day)



Source: EIA 2005a

Manufacturing accounts for the largest share of the industrial petroleum products use at about 6.43 MBD of oil in 2003, or 69 percent, of the petroleum products used in the industrial sector. The vast majority (about 94%) of petroleum products in manufacturing go to non-fuel uses. Of these, about half are used as intermediate feed stocks, principally in the petrochemical industry to make other products such as plastics, fibers, consumer chemicals, and pharmaceuticals. Of these feedstocks, 98% is used in the form of liquefied petroleum gas (LPG) or natural gas liquids (NGL).[3,4] The U.S. organic chemical industry has been based on LPG/NGL feedstocks, in contrast to the majority of the industry in the rest of the world, which has been primarily based on naphtha, another petroleum product. The remainder of feedstock use is primarily naphtha.

Only 6% of manufacturing petroleum is used as a fuel for the production of heat and power, accounting for only about 2% of all energy used as a fuel in manufacturing. Of the petroleum used as a fuel, most (72%) is used as boiler fuel for either conventional boilers or combined heat and power systems (CHP, also known as cogeneration), or in process heating or process drive applications (see Figure 4). The balance of manufacturing petroleum use is for machine drive, HVAC, onsite transportation, or other uses not reported (EIA 2005b).

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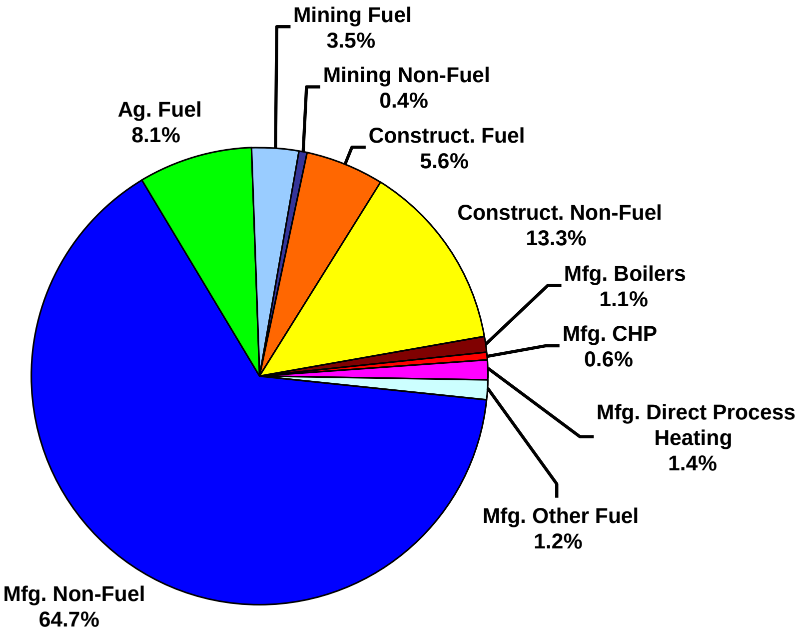
[3] LPG and NGL are essentially the same product. LPG is derived from petroleum but is similar to natural gas in its applications. NGL is those hydrocarbons in natural gas that are separated from the gas through the processes of absorption, condensation, adsorption, or other methods in gas processing plants. Generally such liquids consist of propane and heavier hydrocarbons and are commonly referred to as condensate, natural gasoline, or liquefied petroleum gases (EIA 1997).

[4] These totals also do not include crude oil inputs to petroleum refining that were converted to other energy products (e.g., crude oil converted to residual and distillate fuel oils, and gasoline) and sold to other consumers in the U.S. economy (EIA 2005b). (With total crude averaging about 15 million barrels per day in 2002, this represents about 32 quads of crude—or on the order of an additional five times the total reported petroleum used by U.S industry [EIA 2005a].)

Figure 4. Total Petroleum[5] by Use in Industry in 2002



Source: ACEEE from EIA 2005a, 2005b

Over the next twenty years, industrial oil consumption is projected to increase at about one percent per year, with both LPG/NGL and residual fuel increasing somewhat more rapidly (EIA 2005a) than other fuels.

Residential and Commercial

EIA estimates that, in 2002, the residential sector used 1.54 quads of petroleum products and the commercial sector used 0.74 quads. Thus, petroleum use in the residential and commercial sectors represents 6.4% of oil use and a little over 2% of total energy use in the United States.

Fuel oil is used in the residential and commercial sectors primarily to heat homes, apartment buildings, and older commercial buildings, and secondarily to heat water. Most of this oil use is concentrated in the Northeast, including New England and the Mid-Atlantic region (i.e., New York, New Jersey, and Pennsylvania). In addition, LPG is used throughout the country, primarily in rural regions not reached by natural gas lines. It is widely used for space heating, water heating, and cooking. Finally, a small amount of oil is used to produce kerosene, which is used in kerosene space heaters. Interestingly, in spite of common perceptions that oil use in buildings is declining, EIA projects that oil use in the residential and commercial sectors will increase modestly over the 2002–2020 period, from 1.26 MBD in 2002 to 1.41 MBD in 2020. This modest increase applies to both the residential and commercial sectors.[6]

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[5] Total petroleum is the sum of residual fuel oil, distillate and diesel, and LPG and NGL.

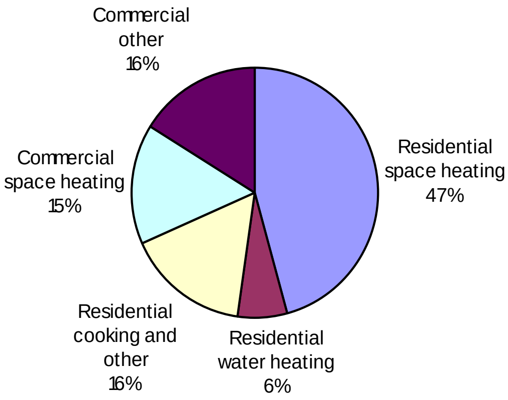
[6] Key data sources are AEO, the *Residential Energy Consumption Survey 2001* (RECS—EIA 2004), and the *Commercial Building Energy Consumption Survey 1999* (CBECS—EIA 2002).

The residential sector used about 0.92 quads of fuel oil (59% of sector oil use), 0.57 quads of LPG (37%), and 0.06 quads of kerosene (4%) in 2002. EIA projects that by 2020 fuel oil will decline to 53% of total residential sector oil use, and LPG and kerosene will increase modestly to 41% and 6%, respectively, of total sector oil use.

The commercial sector used 0.74 quads of oil in 2002. This is broken down as 78% fuel oil, 14% LPG, and 8% kerosene and gasoline. EIA projects that by 2020, fuel oil use will grow to 82% of sector oil use while LPG and kerosene/gasoline will decline to 11% and 7%, respectively. In both 2002 and 2020, it's estimated that more than 85% of fuel oil use will be distillate fuel (the same as used in the residential sector), while just over 10% is residual fuel (a heavier fuel used in power plants and some industrial boilers).

A breakdown of residential and commercial sector petroleum use by end-use is provided in Figure 5.

Figure 5. Projected Petroleum Use in Buildings by End-Use, 2020



Source: Data in Table 5

Power Generation

Petroleum use in the power generation sector has largely been eliminated in recent years, accounting for only 2.5% of total petroleum refined goods supplied in this country in 2003 (EIA 2005a). This is a substantial reduction from earlier years. For example, in 1975, petroleum power generation accounted for 9% of U.S. petroleum use (EIA 2005e). The importance of petroleum in power generation has also diminished, falling from over 15% of total generation in 1975 to about 3% in 2003 (EIA 2005f). Of the petroleum now used for power generation, about 29% is in the form of distillate and 71% as residual fuel oils. Increasingly, petroleum is used as a backup fuel for gas-fired power plants, or in remote areas where delivery infrastructures for other fuels are unavailable.

POTENTIAL OIL SAVINGS THROUGH EFFICIENCY

Having broken out U.S. petroleum consumption by sector, we now consider some of the opportunities to reduce that consumption through efficiency improvements.

Transportation

Cars and Light Trucks

To keep the oil savings opportunities discussed throughout this report in perspective, we discuss briefly the large potential to save oil by improving the fuel economy of cars and light trucks. This report focuses on oil savings opportunities *other* than these, and here we simply point to some relevant findings of recent years:

- ACEEE: DeCicco, An, and Ross (2001) showed in detail the feasibility of achieving an average fuel economy of over 40 miles per gallon in 10–15 years in a cost-effective manner and using conventional vehicle technologies (i.e., no hybrids or advanced diesels).
- National Academy of Sciences: In a widely referenced report, an NAS fuel economy panel concluded that, using "packages of existing and emerging technologies that could be introduced over the next ten to fifteen years," fuel economy could be increased substantially in a cost-efficient manner (NRC 2002). Combining the panel's estimates for the various vehicle classes and allowing time to phase in the technologies to product plans, the gains the Academy found achievable in its optimistic (low technology cost) scenario translates roughly to 32 miles per gallon by 2015.

These analyses assumed no penetration of "advanced technology" vehicles such as hybrids and are in this regard conservative.

Heavy-Duty Trucks

Heavy-duty trucks fall into eight classes by weight. Classes 3–6 (10,001–26,000 lbs.) include delivery vans, walk-ins, and beverage trucks. Classes 7 & 8 (26,001 lbs. and over) are largely tractor-trailers, but also include a variety of other types, such as refuse and cement trucks. Trucks in these two heaviest classes, which are almost diesel-fueled, dominate freight truck energy use, accounting for 81% of the total.

The energy consumption of heavy trucks can be improved both through technological improvements and through advances in systems and logistics; this report considers the potential of vehicle technologies only.

Long-Haul Trucks, Classes 7 and 8

Among heavy-duty trucks, Class 7 and 8 long-haul trucks use by far the most fuel, because they are numerous, heavy (over 26,000 lbs. GVW), and travel many miles annually. To estimate potential efficiency gains, we considered improvements in aerodynamics, engines, transmission, and auxiliary systems along the lines of what is set out in DOE's 21st Century Truck Roadmap (DOE 2000). Using the cost and fuel economy gains for individual technologies from an Argonne National Laboratory report (Vyas et al. 2002), we determined which technologies pay for themselves over the life of a van-type, long-distance tractor-trailer, assuming fuel prices of $2.05 and a 5% discount rate for fuel savings.[7] We also considered wide-based (or "super-single") tires, which reduce the number of tires on a truck and thereby lower rolling resistance. The technologies, and the fuel economy improvements and costs attributed to them, are shown in Table 1. These technologies in combination can reduce fuel consumption by 39%. Other trailer types, such as tankers, may not benefit to the same extent from the aerodynamic improvements listed.

Table 1. Technologies to Raise Fuel Economy of Tractor-Trailers

	technology type	**% mpg gain**	**year of introduction**	**hardware cost**	**gallons saved (total)**	**$ per gallon saved (discounted)**
wide-base tires	rolling resistance	3%	2008	$0	3,669	$0.00
thermal management	engine	10%	2010	$2,000	11,117	$0.24
friction reduction	engine	2%	2005	$500	2,180	$0.30
increased peak cylinder pressure	engine	4%	2006	$1,000	4,192	$0.31
more efficient combustion	engine	6%	2007	$1,500	5,932	$0.33
fuel-cell auxiliaries*	auxiliaries	6%	2012	$1,500	5,596	$0.35
vehicle mass	weight	8%	2005	$2,000	6,507	$0.40
electrical auxiliaries	auxiliaries	2%	2005	$500	1,282	$0.51
cab top deflector	aerodynamics	2%	2005	$750	1,701	$0.59
trailer edge curvature	aerodynamics	1%	2005	$500	1,092	$0.61
pneumatic blowing I**	rolling resistance	1%	2015	$500	996	$0.67
pneumatic blowing II	aerodynamics	5%	2010	$2,500	3,951	$0.84
gap closing	aerodynamics	3%	2005	$1,500	1,927	$1.04

* Fuel cell auxiliaries would replace electrical (or mechanical) auxiliaries.
** "Pneumatic blowing," as discussed in Vyas et al. 2002, refers to technologies under development to reduce drag and rolling resistance by blowing streams of air under a vehicle. Such techniques are already employed on airplanes.

There is also considerable opportunity to save fuel through reduced idling. Long-haul trucks typically idle several hours per day to produce heating, cooling, and power for drivers when their vehicles are stationary. There are several anti-idling technologies available today, but they are not yet widely used in the United States. Here we use the auxiliary power unit (APU) to represent emerging anti-idling technologies for purposes of estimating the oil savings potential of reduced idling. An average truck idles 1,830 hours annually, burning one gallon of fuel per hour. An APU could reduce this fuel consumption by about 80%, saving 1,500 gallons annually (Stodolsky et al. 2000).[8]

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[7] For a more detailed account of a similar analysis, see Langer 2004.

[8] There is a hybrid idling technology developed by Chrysler now marketed by Idling Solutions that eliminates all fuel use. The payback for these technologies is less than 6 months (Neff 2005).

Technologies listed above for tractor-trailers are assumed to apply equally to long-distance, straight trucks over 26,000 lbs. GVW, with the exception of idling reduction[9] and aerodynamic improvements. As for the non-van-type trailers above, we assume for simplicity in the analysis below that these vehicles do not benefit from the aerodynamic improvements listed, although subsets of these vehicles could in fact take advantage of such equipment.

Short-Haul Trucks, Class 3–8

For short-haul trucks, the technologies considered for tractor-trailers are not generally cost-effective, in part because annual miles traveled are typically much lower. Also, some technologies (e.g., aerodynamic improvements) give a much smaller benefit for trucks traveling at low speeds. Hybrid technologies, by contrast, are far more viable for short-haul than for long-haul trucks, because hybrids give the greatest benefit in stop-and-go driving, which dominates short-distance travel.

The percent increase in fuel economy due to hybridization depends on the duty-cycle and is still somewhat speculative, given that few heavy-duty hybrid trucks are currently on the road. To assess cost-effectiveness, we assumed a 50% gain in fuel economy from hybridization, consistent with the requirements imposed by Federal Express in its pilot project for delivery trucks, and well below the fuel economies estimated for hydraulic hybrid prototypes produced in U.S. Environmental Protection Agency-sponsored research. A 50% increase is also in the mid-range of fuel economy projections for hybrids in Vyas et al. 2002 and well below those in An et al. 2000. We also used the incremental costs of $6,000 to $10,000 cited in Vyas et al. 2002. Assuming average mileage figures for short-haul trucks in each size class, these hybrid vehicles would recover incremental purchase costs through fuel savings over the life of the vehicle. From the perspective of a purchaser demanding a 3-year payback and discounting at 8%, however, only hybrids in the heaviest classes are cost-effective under the stated assumptions.[10] Tax credits in the Energy Policy Act of 2005, described below, expand the range of classes for which hybrids would meet these cost requirements.

Class 2b

Trucks falling between 8,500 and 10,000 gross vehicle weight, are not regarded as heavy-duty trucks, but we include them here because they are not subject to the fuel economy standards applied to cars and light trucks (below 8,500 pounds). Designated Class 2b trucks, these are predominantly “work” pickup trucks (typically ¾-ton), though an increasing percentage of Class 2b consists of large SUVs and luxury pickups. Class 2b trucks are generally quite similar to their counterparts below 8,500 lbs., and their efficiency can be improved through the same technologies that apply to the lighter vehicles. A fuel economy improvement of 50%-66% in this class is consistent with the discussion above of opportunities to raise the fuel economy of cars and light trucks.

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[9] There is a need to reduce idling for straight trucks as well, but it is less clear that their use patterns would lend themselves to the anti-idling devices evaluated here.

[10] The cost-effectiveness criteria here are more stringent than in the discussion of long-haul trucks, because the policies we recommend below are market-based, so the proposed vehicle efficiency improvements must be cost-effective from the purchaser’s perspective.

Other Transportation Sub-Sectors

Airplanes, as the next largest consumer of fuel in the transportation sector after trucks, also offer substantial savings potential. A report from the Pew Center on Global Climate Change estimates that fuel efficiency could be improved in the near term by 20 percent and by up to 50 percent in the longer term (Greene and Schafer 2003). The report notes that the greatest opportunities lie, as for heavy trucks, in advances in engine technologies and aerodynamics, although there is room for improvement in operational factors as well, including modernization of the air traffic control system to provide for more direct flight patterns (Neff 2005).

Increased locomotive, ship, and pipeline efficiencies could also contribute modestly to oil use reductions in the transportation sector. We do not estimate those savings here, but it should be noted that international shipping is projected to grow dramatically in the coming decades, and fuel savings opportunities from more efficient container ships should be investigated (Neff 2005). System efficiencies throughout the freight sector could also reduce consumption substantially. To gain a sense of savings potential from the expansion of the intermodal system, for example, ACEEE used the findings of a recent report from the American Association of State Highway and Transportation Officials (AASHTO 2002) to estimate potential savings of 0.2 MBD by 2020 (ACEEE 2004).

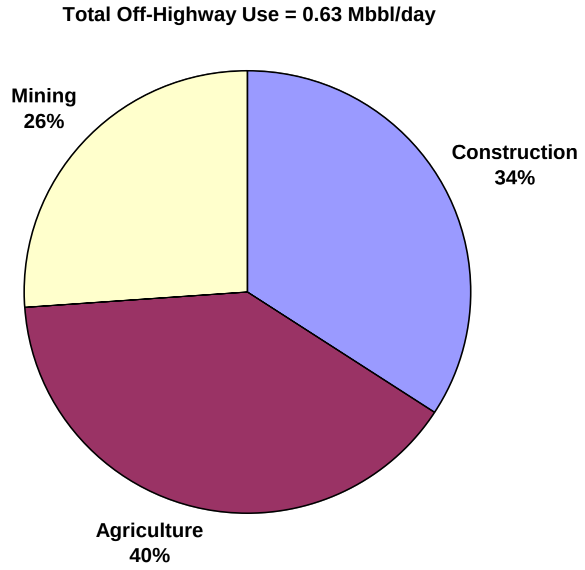
Industry

The potential for reducing use of petroleum is more complex than in other sectors because of the diverse nature of the sector, and the uses of petroleum for both power and heat, and for non-fuel applications. With the majority of use in the industrial sector for non-fuel applications, the opportunities for non-fuel savings may be at least as important as the savings from heat and power applications. Non-fuel savings opportunities will be application specific. Because of the diversity of applications, it is not practical in this report to comprehensively cover every application. Rather we will attempt to provide some characteristic examples of application categories. As a result the projected savings will be extremely conservative.

For purposes of this analysis we will group petroleum use into four broad categories:

1. *Manufacturing heat and power applications:* This category covers the majority of the fuel used in the manufacturing sector. Our analysis will focus on the two largest applications, indirect use as a boiler fuel and direct use for process heating. For purposes of this analysis, we will not consider on-site transportation, power generation, and direct space heating.
2. *Manufacturing feedstocks:* This category covers the non-fuel uses of petroleum, principally NGLs and naphtha, of which about half is used in the production of plastics (Lovins et al. 2004).
3. *Construction asphalt and road-oils*: This category focuses on the non-fuel construction use of petroleum products for road paving and other construction applications.
4. *Off-highway vehicle use:* This category covers vehicle fuel use, principally diesel, in the agricultural, mining, and construction sub-sectors (see Figure 6).

Figure 6. Breakdown of Projected Non-Highway Vehicle Petroleum Use in 2020



Source: EIA 2005a

Our analysis of the potential to reduce petroleum use will focus on these four broad categories by looking at the primary fuel uses and the opportunities to improve the efficiency of fuel use, implement recycling, or substitute alternative feedstocks to displace virgin petroleum use.

Manufacturing Use Reduction from Petroleum for Heat and Power

Estimates for the manufacturing use reduction of petroleum for power and heat were developed using data from the *Manufacturing Energy Consumption Survey 2002* (MECS—EIA 2005b) and the *Annual Energy Outlook 2004* (EIA 2004b). The MECS provided the base year end-use breakdowns. It is assumed that the relative proportion of petroleum use by end-use (boiler, direct-use, and non-process) will remain constant during the study period.

Estimates of technically achievable savings for industrial boiler use (see Table 2) were obtained from previous ACEEE research on policies to promote efficiency improvements and accelerated capital stock turnover of industrial boilers (ACEEE 2003). This research showed that petroleum consumption by industrial boilers could be reduced by 19%. The reduction of total direct process petroleum use (primarily heating) was based on similar research on reducing natural gas consumption for this end-use (Elliott et al. 2003). In that study, we found that direct natural gas process heating could be reduced by 15% by 2020. We have not made estimates of the savings for non-process petroleum fuel use in manufacturing.

Table 2. Estimated Petroleum Use and Cost-Effective Savings for Heat and Power in Manufacturing by End-Use

		End-Use		Savings		
Fuel	2020 (MBD)	Indirect Uses—Boiler Fuel	Direct Uses—Total Process	Indirect Uses—Boiler Fuel	Direct Uses—Total Process	Total Cost-Effective Savings (MBD)
Fraction		49%	35%	19%	15%	
Liquefied Petroleum Gas	0.023	0.011	0.008	0.002	0.001	0.003
Residual Fuel	0.197	0.096	0.069	0.018	0.010	0.029
Total	0.219	0.108	0.077	0.020	0.012	0.032

Manufacturing Petroleum Savings for Non-Fuel Use

As noted earlier, petroleum is used as a feedstock in the production of a range of products. A wide range of options exists to reduce use of petroleum for this application. A significant amount of attention is currently focused on seeking alternative feedstocks to displace these conventional petroleum-derived feedstocks. Among the sources under consideration are gasification of coal or biomass (often referred to as "polygeneration" because the technologies also produce significant quantities of electric power and steam) (see Eastman 2005) and production of chemical feedstocks from biomass, either from fermentation or enzymatic conversion (Miller 2001). These opportunities, which could potentially eliminate the use of petroleum feedstocks in the longer term, will not be considered here because of the scope of this study, which only considers efficiency and not substitution with alternative resources (e.g., coal or biomass).

However, keeping within the efficiency scope of this analysis, significant opportunities do exist to reduce the use of virgin petroleum feedstocks through recycling of existing products. The focus here is on recycling to displace feedstocks, though there also may be some potential to use recycled plastics, particularly mixed plastics, as a fuel to displaced industrial fuels. Shifting to recycled feedstocks can also offer significant process energy savings as well (see Elliot 1993), though they will not be quantified here. For illustrative purposes we will consider the recycling of plastics, which represents the largest use of petroleum feedstocks (~48%). Lovins et al. (2004) reported that in 2001, the United States recycled only 5.5% of discarded plastics, in contrast to Germany, which recycled 57%. As they note, this recycling is driven by statutory product use regulations. Some manufacturing fuel cost savings and displaced solid waste disposal costs will result from the increased recycling, but these will at least in part be offset by additional costs associated with collection and transportation of the recycled feedstock (Elliott 1993). As a result, the economic viability of recycling is unclear, unlike the other measures proposed in this report. However, if we assume that the United States increased its plastic recycling from the current level to the German level of 57%, we could reduce total use of manufacturing feedstocks by 12% in 2020 (Lovins et al. 2004).

Petroleum Savings in Agriculture, Construction, and Mining

As noted above, the primary non-manufacturing petroleum use is for asphalt and road oils, principally in the construction sub-sector, with some additional use in the mining industry. The remainder of non-manufacturing petroleum use is largely for off-highway motor fuels, predominately diesel fuel, in agriculture, mining, and construction.

The largest savings opportunities outside of manufacturing are in asphalt and road oils, which are used mostly in paving operations. As in manufacturing, the efficiency opportunities come from recycling to reduce the requirements for virgin materials. Lovins et al. (2004) identified recycled asphalt paving and the addition of crumb rubber as the most promising opportunities. Both of these techniques are well-proven in the marketplace, though underutilized. By recycling existing pavement combined with the addition of crumb rubber from recycled tires, the amount of new petroleum products can be dramatically reduced. In addition, the rubberized asphalt paving (RAP) has been shown to offer significant performance enhancements. Because of the more elastic nature of the material, the thickness required for a road surface is reduced, requiring less materials, and the surface itself lasts longer reducing the frequency of repaving. These advantages combine to reduce energy used in the paving materials as well as the fuel required for paving, while reducing the cost of maintaining a road surface. In addition, there are some opportunities for additional energy savings because of reduced disruptions in traffic as a result of less frequent repaving in congested urban areas as well as the avoided construction fuel use. This paving material also offers significant non-energy benefits, including significantly reduced road noise and improved traction. While the impact on vehicle rolling resistance requires additional study, research suggests that the smooth surface would be no worse than conventional pavements and may offer an improvement (Neff 2005; RPA 2005; Lovins et al. 2004; Elliott 1994). If the shift were made to these techniques, virgin asphalt for paving could be reduced by 60%, which would represent a petroleum use savings of 51% in all paving applications.

Savings opportunities exist for fuel uses of petroleum as well. Two principal sources of potential savings are improving efficiency of off-highway equipment and altering usage practices of this equipment, particularly in the agricultural sector. Off-highway equipment duty-cycles differ greatly from the duty-cycles of highway vehicles; most applications require low-speed, high-torque operation. As a result, the technological efficiency improvements are different from on-highway transportation. For off-highway vehicles, improvements in diesel engine design through advanced combustion technologies offer opportunities. Hydraulic hybrid technologies could also increase efficiency in the drive-train for certain applications. Because of the range of applications and the aggregate nature of this analysis, we will not attempt to provide precise estimates of the saving, but research indicates that technical efficiency improvements in the 10–30% range are possible with existing technologies (Stephens 2005; Lumkes 2005).

In addition, there are equal or greater opportunities to reduce fuel use in the agricultural sub-sector by reducing the number of tillage operations or improving their effectiveness. Among these opportunities are:

- Introduction of multi-operation equipment allowing the completion of several operations (for example, chisel, disk and planter) in a single pass through a field
- Global positioning system tractor navigation allowing for less overlap in passes through the field, reducing the total number of trips while also making the work more precise
- Reducing the number of cultivation passes through a field, which can reduce weed germination

While the actual results will vary widely by crop, field, local climate, and many other factors, some farmers have been able to reduce field trips by as much as half. When appropriately applied, these techniques can also reduce fertilizer and herbicide usage—another non-fuel petroleum-based input to the agricultural sub-sector that is also a major cost in crop operations. Similar results have also been achieved with changed grazing practices.

Applying all these efficient technologies and practices, we assume that fuel use in these sub-sectors could be economically reduced by 15% by 2020. We assume that a third of this economic potential would come from equipment upgrades and two-thirds from changes in practices. In fact, the real potential could be far greater.

Industrial Petroleum Savings Summary

If we consider only the primary opportunities in the four major use categories proposed at the beginning of this section, an economic potential exists in the industrial sector to reduce its use of petroleum products by 0.94 MBD in 2020, representing an 18% reduction in overall sector use (see Table 3).

Table 3. Summary of Economic Potential for Petroleum Use Reductions in the Industrial Sector by Primary Use Category in 2020

Use Category	2020 Use (MBD)	Cost-Effective Potential (MBD)	
Manufacturing heat and power	0.22	0.032	15%
Manufacturing feed-stock	3.83	0.460	12%
Construction asphalt and road-oils	0.70	0.356	51%
Off-road motor fuels	0.63	0.094	15%
Total industrial	5.38	0.942	18%

Residential and Commercial

Using data from RECS as well as discussions with oil-use experts at the New England Fuel Institute and the Vermont Energy Investment Corp., we broke residential energy use down into end-uses (space heating, water heating, cooking, etc.), building types (single-family and multifamily), and system types (warm-air, hot-water, and steam distribution). For the commercial sector, we used data in the *Annual Energy Outlook 2005* (EIA 2005a) to make a similar breakdown of petroleum use by end-use and fuel. The results are summarized in Table 4.

The breakdowns shown in Table 4 are needed to estimate the size of oil savings opportunities, because efficiency measures vary by end-use, building type, and system type. Based on these allocations, we selected eleven building and system types for further analysis. These were:

- Single-family homes
  - Space heating
    1. Fuel oil with warm air distribution
    2. Fuel oil with hot-water distribution
    3. Fuel oil with steam distribution
    4. LPG with warm air distribution
  - Water heating
    5. Fuel oil
    6. LPG
- Multifamily homes
  - Space heating
    7. Fuel oil with hot water distribution
    8. Fuel oil with steam distribution
  - Water heating
    9. Fuel oil
- Commercial buildings
  - Space heating
    10. Fuel oil with hot water distribution
  - Water heating
    11. Fuel oil

Table 4. Petroleum Use in Residential and Commercial Buildings

	Projected Use in 2020	
	Quads	MBD
Residential		
Fuel oil		
Space heating		
Single-family		
Warm air	0.31	0.15
Hot water	0.28	0.13
Steam	0.03	0.01
Subtotal	0.63	0.30
Multifamily		
Hot water	0.06	0.03
Steam	0.05	0.02
Subtotal	0.10	0.05
Space heat total	0.73	0.34
Water heating		
Single-family	0.08	0.04
Multifamily	0.02	0.01
Subtotal	0.10	0.05
Fuel oil total	0.83	0.39
LPG		
Space heating		
Warm air	0.23	0.18
Room heater	0.08	0.06
Subtotal	0.31	0.24
Water heating	0.05	0.04
Cooking	0.03	0.02
Other	0.26	0.20
LPG total	0.65	0.49
Kerosene		
Space heating	0.09	0.04
	====	====
TOTAL	1.57	0.93
Commercial		
Fuel oil		
Space heating	0.42	0.19
Water heating	0.08	0.04
Other	0.21	0.10
LPG		
Other	0.11	0.08
Kerosene		
Space heating	0.03	0.01
	====	====
TOTAL	0.85	0.43
GRAND TOTAL	2.42	1.35

For each building/system type, we identified a series of efficiency measures that could cost-effectively reduce oil use. For example, for homes using oil furnaces[11] for space heating, the identified measures were additional insulation, infiltration reduction, duct sealing, a replacement oil burner, a full new heating system, a setback thermostat, and new windows. For each measure we estimated average oil savings, the percent of homes that could benefit from the measure, and average installation cost using a variety of sources in the literature and opinions of industry experts. Savings for individual measures were adjusted downward to reflect the fact that savings between many measures overlap. For example, the savings for new windows assume that the heating load is first reduced by all of the other measures. Cost and savings data were then used to estimate the cost of saved energy for each measure, i.e., the average cost of the measure per gallon of oil saved over the measure life.[12] If the cost of saved energy is less than the retail price of oil, then the measure is cost-effective from a lifecycle cost perspective. Oil savings and costs per home were then calculated by multiplying the savings and costs of the measure times the percent of homes that could benefit from the measure. Table 5 illustrates this analysis for oil furnaces (i.e., system type #1 in the list above). The other ten analyses can be found in Table A-1.

Table 5. Analysis of Savings Opportunities for Oil Furnaces

	Annual Base Use	Savings		Buildings Needing	Adjusted Annual Savings	Savings Relative to Base	Cost	Lifetime	Cost of Saved Energy
Measure	(gallons)	(%)	(gallons)	(%)	(gallons)	(%)	($)	(years)	($/gallon)
Oil warm-air space heat	579								
Insulation	579	28%	162.1	40%	64.8	11.2%	2208	30	0.89
Infiltration reduction	514	10%	51.4	75%	38.6	6.7%	350	10	0.88
Duct sealing	476	13%	59.4	50%	29.7	5.1%	500	15	0.81
Replace burner	446	15%	66.9	10%	6.7	1.2%	450	15	0.65
Replace heating system	439	17%	73.2	40%	29.3	5.1%	1500	18	1.75
Setback thermostat	410	7%	28.7	50%	14.3	2.5%	125	15	0.42
New windows	396	11%	41.9	60%	25.2	4.3%	600	30	0.93
Total					208.6	36.0%	2463.2	23	0.88

Note: The total cost and cost of saved energy figures are average costs per home, including allowances for the portion of homes that actually need each measure.

The analysis for oil furnaces is fairly typical and shows an average available savings of 36% (209 gallons of oil per home per year), at an average cost of saved energy of $0.89/gallon (less than half the current retail cost of oil).[13] Savings for other building and system types ranged from 23% (for space heating in the commercial sector) to 43% (for oil water heating in multifamily buildings).

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[11] Oil furnaces distribute warm air throughout the living space using ducts.

[12] Cost of saved energy was calculated by assuming efficiency measures are financed with a loan at 5% real interest rate (i.e., not including inflation) with a term equal to the measure life. The cost of saved energy (in $/gallon) is the annual loan payments divided by the annual gallons of oil saved.

[13] According to EIA (2005c), the average retail price of oil to residential customers during the 2004–2005 heating season was $2.01 per gallon. Prices will presumably be substantially higher in the 2005–2006 season.

BARRIERS TO EFFICIENCY AND POLICIES TO ADDRESS THEM

Transportation

Light-Duty Vehicles

Barriers to efficiency in the light-duty market have been discussed elsewhere in the literature (e.g., NRC 2002). The primary focus of such discussions is consumers' undervaluation of fuel savings associated with efficient vehicles. We do not revisit this topic here except to note that there is considerable overlap with the barriers in the heavy-duty market, discussed below.

The policy historically associated with improving light-duty fuel economy is CAFE standards. Raising these standards has proven politically difficult, and the growing sense of the urgency of reducing oil consumption has raised interest in other policies, notably market incentives for high fuel economy. These include feebates, which consist of a sliding scale of fees and rebates for new vehicle purchases based on fuel economy. A recent Oak Ridge National Laboratory study concluded that fuel economy improvements in the range of 16% to 29% could be achieved through a national feebate. (Greene et al. 2005). Both consumer and manufacturer tax credits for high efficiency, advanced technology vehicles are also widely discussed today; the Energy Policy Act of 2005 contains credits of up to $3,400 for purchasers of light-duty hybrid vehicles, and bills recently introduced in Congress would provide tax credits for manufacturers to "retool" their plants to produce efficient vehicles. Given the strong demand for ever-larger vehicles that drove the U.S. market from the late 1980s until recently, however, tax credits for efficient vehicles cannot guarantee a reduction in fuel consumption absent a policy such as CAFE that governs average fuel economy for all new vehicles. In any case, steps can be taken to strengthen the CAFE program, including the extension of the program to Class 2b vehicles.

Heavy-Duty Vehicles

Fuel costs are an important consideration for the trucking industry, so truck owners are in principle more receptive to vehicle efficiency technologies than automobile owners are. The demand for fuel economy is by no means sufficient to bring all cost-effective efficiency technologies into the market, however.

Barriers

- *Lack of fuel economy information:* The absence of a fuel economy testing and labeling requirement for heavy trucks creates a failure in the current market, in that truck buyers lack the information to choose the most efficient truck. In addition, the variety in tractor-trailer duty-cycles makes trucking companies reluctant to accept claims of efficiency improvements without extended testing of products on their own fleets.

- *High initial cost:* Efficiency technologies typically increase the purchase price of a truck. Many truck purchasers are unable to pay this price increment, even if the technologies have short payback times. For example, APUs can cost up to $7,000, or about three years' worth of fuel savings. Three years is said to be the payback time required by truckers for efficiency technologies (Stodolsky et al. 2000), so some APUs would be marginal in this regard.[14]

- *Driver preferences*: Trucking companies have for some years experienced a severe shortage of qualified drivers and are therefore eager to retain the drivers they have. In some cases, fuel efficiency improvements may conflict with driver preferences with regard to driving practices, aerodynamic treatments, and engine settings.

- *Industry structure*: Truck manufacturing is not a vertically integrated industry for the most part. This makes marketing of efficient components directly to the users more difficult, especially because component manufacturers do not have an avenue for demonstrating their efficiency benefits within complete trucks.

- *Resale market*: Limited value is assigned to efficiency in the used truck market.

- *Manufacturer risk*: The manufacturers' risks in investing in new technology, and the fact that competing manufacturers can often take advantage of the leader's technology, serve as a barrier, particularly in light of fuel price volatility.

Policies

- *Fuel economy standards for tractor-trailers*. There are at present no fuel economy standards for vehicles over 8,500 lbs. in the United States (or elsewhere, for that matter). Tractor-trailers are relatively homogeneous, making this a good class of vehicles for fuel economy standards from the standpoint of feasibility. In particular, because the vast majority of tractor-trailer miles are driven on the highway, the problem of choosing an appropriate test cycle is much simplified.

  Given differences among trailer types, an engine bench test such as the one used for emissions testing has the advantage of simplicity. But aerodynamics and other engine-independent features play an enormous role in heavy truck fuel economy, which such a test cannot capture. Among the efficiency technologies listed in Table 1, engine technologies account for only 40% of all potential savings, so standards based on engine performance alone could be expected to yield less than half of the achievable improvement in fuel economy. Combining individual technology requirements for non-engine components with a bench test could recover some of the remaining efficiency opportunities, but could not be expected to match the results of a vehicle fuel economy standard.

- *Funding for idle reduction technologies:* Partial government subsidies for idle reduction technologies for a limited period of time would result in a decline in cost. The Energy Policy Act of 2005 authorizes $95 million in spending on anti-idling; if appropriated, this would be sufficient to have a major impact. The funds should be applied to develop a

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[14] Less expensive idle reduction technologies with much shorter payback periods may be available in the near future (Neff 2005).

range of technologies, however, and not limited to a single approach such as truck stop electrification that applies to a limited truck population.

- *Extended tax incentives for hybrids:* The Energy Policy Act of 2005 includes tax credits for heavy-duty (as well as light-duty) hybrids. The amount of credit depends on size, fuel economy benefit, and incremental cost (see Table A-2). The credits will offset some of the high purchase costs of these vehicles and bring down the incremental costs by raising production levels. At a fuel price of $2.05 per gallon, the credits together with three years' fuel savings would more than offset incremental costs for Class 6–8 hybrids and would be almost sufficient for Classes 3–5 as well. The credits are only available through 2009, however, which is not sufficient time to allow for new product development. A five-year extension of the credits could greatly enhance the success of the program.

- *Hybrid R&D funding*: Funding for hybrid research and development is also a determinant of the rate at which hybrids enter the market. DOE should renew its commitment to the ambitious fuel economy targets laid out in its "Technology Roadmap for the 21st Century Truck Program" (DOE 2000) and maintain funding levels for development of hybrids and other technologies needed to achieve those targets.

- *Fuel economy standards for Class 2b trucks:* Fuel economy standards, feebates, and incentives to promote hybridization all warrant consideration for Class 2b. This class includes a wide range of vehicle types, but 80% are pickups (Davis and Truett 2002), which together with vans, panel trucks, and sport utility vehicles make up over 96% of the total. These vehicles have under-8500-lb. counterparts and bringing them under CAFE or a feebate scheme would pose no serious technical obstacles.

Airplane Efficiency

The assessment of airplane efficiency potential in the Pew Center analysis (Greene and Schafer 2003) recommended voluntary seat-mile-per-gallon standards, noting the substantial incentive the airline industry has to reduce fuel costs.

Industry

Because the primary opportunities for reducing industrial petroleum consumption apply to non-fuel uses, the policies options are quite different from those in the other economic sectors. Barriers and recommended policies for each of the four categories described previously are discussed below.

Manufacturing Fuel Use

Since nearly three-quarters of manufacturing fuel use of petroleum can be attributed to boilers, CHP, and process heating, and nearly two-thirds of the savings potential can be attributed to savings directly associated with boiler efficiency improvements, it is evident that policy efforts should focus on these technologies.

Barriers: Boilers and CHP

The existing boiler fleet is aging in large part as a result of regulations over the past thirty years that in effect have discouraged replacement of aging boilers. In many cases, the most efficient and cost-effective opportunity is to replace the boiler with a new CHP system. Current environmental regulations have not forced the replacement or upgrading of existing boilers to meet emissions levels required of new boilers. At the same time, utility regulations discourage the installation of distributed generation. As a result, boiler owners are encouraged to extend the life of their existing boilers. Also, boilers are a long-term capital investment, while business plans are increasingly focused on the near term, and many companies are unwilling to make high capital cost investments.

CHP systems are affected by barriers to boiler replacement and additionally face two sets of unique barriers due to their production of both heat and power.

- *Utility practices*: To be practical, most CHP systems need to be connected to the incumbent electric utility. Utilities are in general not motivated to encourage this, because they experience limited benefits and stand to lose revenue. These barriers range from costly interconnection studies to unfavorable tariffs (Elliott et al. 2003).

- *Environmental regulations*: Many environmental regulations at the federal and state level do not fairly provide credit to the heat generated by the system when the emissions rate for the CHP facility is calculated. This fact disadvantages the CHP system because it is not credited for the avoided emission from the displaced boiler (Elliott and Spurr 1998).

Policies: Boilers and CHP

What is needed is a policy to encourage the replacement of existing industrial and institutional boilers, either with new boilers or with new CHP systems. In the current market, it is usually attractive to consider CHP for any boiler that requires replacement. Among the possible strategies are financial incentives and special regulatory treatment.

1. *Financial incentives:* Incentives could come in the form of accelerated depreciation, tax credits, grants, or low-interest loans. Tax credits have been the most widely used, but have a mixed record for the industrial sector (see Elliott 2001). The nonprofit sector can benefit from tax credits only indirectly, through an alternative financing mechanism, such as a synthetic lease. Depreciation appears to have some advantages over tax credits, but faces opposition from tax regulators. Grants and loans are perhaps the most broadly attractive to all sectors.

2. *Regulatory adjustment:* The U.S. Environmental Protection Agency *(*EPA) could allow existing boilers to be replaced with a new unit without requiring re-permitting if the following conditions are met:

    - the new system has thermal capacity no greater than that of the system that it is replacing

- the new system has an efficiency of 78% or greater
- the emissions rate on an output basis is no greater than that of current "best available control technology" for stationary boilers
- the boiler is not used primarily to generate wholesale electricity
- local authorities do not request an exemption from the administrator of the Environmental Protection Agency from this waiver because of pressing local air quality needs

This special provision could apply to any new boiler that replaces a currently operating boiler and is put in service within five years of adoption of this regulation. This short timeframe encourages timely boiler replacements. In addition, a new CHP system should be allowed to replace an existing boiler if its total electric power production from the CHP system is less than the total electric consumption of the existing facility.

3. *Output-based standards:* More generally, a shift to output-based air quality emission standards would more fairly credit the efficiency benefits of the combined power and heat production. Output-based regulations would also encourage a shift to more efficient conventional boilers as well.

A more comprehensive assessment is needed of what steps are likely to motivate replacement of existing boilers in different segments of the market. Also, for CHP, the adoption of national interconnection and tariff standards would address the significant barrier to entry that currently exists (Elliott, Shipley, and Brown 2003).

Barriers: Process Heating

The major barrier to upgrades to process heating equipment is the capital investment required in mature industries. This cost hurdle is complicated by fuel price uncertainties that discourage investments that have paybacks of more than a few months, because of the longer-term uncertainty of the viability of many manufacturing plants in a higher-fuel cost environment. In addition, current tax and investment practices discourage major new capital investments.

Furthermore, direct process heating is an integral part of the manufacturing process. Most manufacturers are hesitant to modify processes because of the risk of unintended impacts on the products. Thus, unless all possible impacts are well understood, there will be a natural resistance to change. What is needed is better understanding of how these improved technologies can be integrated into the overall process.

Policies: Process Heating

To address these two barriers, two separate responses are needed. First, manufacturers need revised tax policies that encourage investments in new, more efficient production assets. This change could be accomplished by more favorable depreciation schedules for investments in production assets or through additional investment tax credits (ASE 1997). It is important to note, however, that the impact of additional tax credits may be limited due to proliferation of tax credits in recent years. With the combined effects of the alternative minimum tax and maximum business credit reduction, many firms currently have more tax credits available to them than they can use in any given tax year.[15]

To address the technology application uncertainty, the expansion of industry-government collaborative research appears the best strategy. Over the years, the Industries of the Future initiative administered by DOE's Industrial Technologies Program has proven very effective in this area. Typically, the results of this research have been deployed in manufacturing plants in three to five years, in contrast to the 10–20 years more typical of fundamental research (Kavanagh 2005). Unfortunately, funding for this program has been cut dramatically over the past five years, so perhaps the best policy would be to restore, if not expand, funding for this initiative.

Manufacturing Non-Fuel Use

Barriers

While continued technology development in both plastic formulations for recyclability and use of recycled feedstock will be beneficial, the primary opportunity is to increase the recycling rate for plastics. It is critical that the materials be source-separated by plastic type to be effective, because mixed plastics have limited applicability as a feedstock. Currently, limited infrastructure exists for collecting plastics for recycling. Expanding point of sale collection (much as drink bottle deposits) would be the most effective way to ensure a high level of separation. However, manufacturer and retailers resist this because of the additional costs associated with running this non-core task (Elliott 1993).

Policies

The plastics recycling rate in Europe is much higher than in the U.S., in large part because of mandatory product lifecycle regulations in place there (Lovins et al. 2004). Similar provisions or so-called “bottle bills” would be effective strategies. These regulations require the distribution channel to handle the collection of their used products, frequently with a refund to the consumer of a deposit charge or other incentive. In Europe these regulations have been effective both in increasing recycling rates and in improving the purity of the recycled feedstock (Elliott 1994). Canada is considering a similar policy (AHAM 2005).

Non-Manufacturing Non-Fuel Use

Barriers

The major barrier to the use of rubberized asphalt appears to be a resistance on the part of the paving industry and the state highway departments to adopt this new practice. The industry would need to invest in new equipment to deploy the technology and may also have a concern that the extended pavement life might adversely affect future revenue prospects.

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[15] For more information on alternative minimum tax and maximum business credit reduction, see Elliott 2001.

Several states such as Arizona and California have adopted RAP while others continue to resist the switch (Elliott 1994; Lovins et al 2004; Neff 2005).

Policies

Attempts have been made at the Federal level to mandate expanded use of rubberized asphalt (e.g., attempts to include it in ISTEA 1991—see Elliott 1994). Perhaps what is needed is a federal mandate, combined with transitional assistance to the paving industry to encourage investment in the new technology.

Non-Manufacturing Fuel Use

Barriers

Less attention has been paid to this area in the literature than has been focused on other areas, so one need is to better articulate the nature and magnitude of the savings potential. Indeed, because there is no standard or testing for the efficiency of off-highway vehicles, as there is for light-duty vehicles, there is not even a known baseline from which to begin.

Policies

Because of the diversity of non-manufacturing fuel uses, it is challenging to identify broad policies that would achieve reductions. As noted in the discussion, the opportunities are as much about practices as about technologies. The policies we recommend to address these barriers are focused on research and education. Funding for research could help to quantify the technical opportunities for vehicle efficiency improvements and to develop strategies to communicate the results to equipment purchasers. Because many of the technologies offer significant non-energy savings benefits, these need to be quantified and communicated as well.

With respect to practice, as noted these opportunities are largely in the agricultural sector. The land-grant university/extension/experiment station system in the United States is uniquely positioned to assist farmers and ranchers in realizing these savings. Unfortunately, this system is currently facing the budget-cutting axe. What is needed is additional, not reduced, funding that specifically targets agricultural practice opportunities.

In addition, because the technical performance of off-highway vehicles is different from the on-highway applications, an assessment is needed of advanced engine and drive technologies specific to these applications.

Residential and Commercial

Barriers

Clearly large, cost-effective savings are available, but many market barriers impede adoption of these barriers. Among the major barriers are the following:

- *Lack of awareness:* Many homeowners and commercial building managers underestimate the amount of energy they use in their homes and buildings and the associated environmental impacts of this energy use. Often, they are not even aware that different models can consume significantly different amounts of energy and that buying more efficient products and making building improvements can lead to energy and oil bill savings. Even fewer home and building owners are aware that many weatherization improvements can improve resident comfort due to fewer drafts or warmer nearby surfaces. When the purchaser is aware of variations in energy efficiency, often he or she is too busy to research the cost-effectiveness of a decision, or information on high-efficiency products or services is not readily available. Many of these products or services are purchased once in a decade; maintaining awareness to facilitate an occasional decision is difficult for most consumers.

- *Third-party decision-makers ("split incentive"):* Many times the decision-maker (e.g., home builder or landlord) is responsible for purchasing equipment but someone else (e.g., tenant or home buyer) is responsible for paying the energy bills. In these instances, the purchaser tends to buy the least expensive equipment because he or she receives none of the benefits from improved equipment efficiency. This problem is particularly pronounced in rental buildings such as multifamily apartments and commercial buildings.

- *Limited stocking of efficient products:* Equipment distributors generally have limited storage space and therefore only stock equipment that is in high demand. This creates a "Catch-22" situation: users purchase inefficient equipment so distributors only stock inefficient equipment. Purchasing efficient equipment thus may require a special order, which takes more time. Most equipment that fails needs to be replaced immediately. Thus, if efficient equipment is not in stock, even customers who want efficient equipment are often stuck purchasing standard equipment.

- *Extra cost of more efficient equipment:* More efficient equipment generally costs a little more, due to better burners, heat exchangers, etc. But frequently high-efficiency equipment costs a lot more than standard equipment because high efficiency is bundled with extra "bells and whistles" that are unrelated to improved efficiency. A buyer may be faced with a choice between a discounted low-efficiency model and a high-efficiency model with expensive features the buyer doesn't want.

- *Lack of financing:* Purchasing efficient equipment and services costs money. While some homeowners and building owners have the funds available, others do not. Many purchasers can turn to banks for financing such as home equity loans, but not all are eligible or the interest rates may be more than they can afford. This is particularly a problem for low-income homeowners and owners of low-rent apartments that are commonly used by low-income tenants.

Policies

In order to address these barriers, we recommend four major policies as follows:

- *Update equipment efficiency standards:* Minimum efficiency standards are now set on residential furnaces, boilers, and room heaters but these standards have not been changed in more than a decade. It is time to update these standards to levels that minimize lifecycle costs. Efficiency standards remove inefficient equipment from the market, raising the average efficiency of equipment available for purchase but still leaving purchasers with a wide array of choices. This helps address several of the barriers discussed above such as low awareness, limited stocking, and high equipment prices. Depending on the type of equipment, efficiency can be increased by at least 5% and in some cases more than 10%.

- *Update building codes:* When a new home is built, decisions are made about insulation, windows, air infiltration levels, and heating system type that are difficult and expensive to change later. It is much less expensive to design efficiency into a new home than to retrofit improved insulation, windows, etc. later. This is less of a consideration in the commercial sector, as few new buildings use fuel oil for heating. The majority of states have building codes that regulate the basic energy features of a new home, but some do not. More importantly, most current codes fall well short of the optimum level of efficiency and need to be updated. Improved codes address the split incentive problem discussed above by removing the option to build inefficient homes that someone else will have to pay to operate. In the long term, we recommend that codes be updated to levels of performance specified by EPA's ENERGY STAR® Homes program. This level of performance reduces energy use by 15–30% relative to current state codes. In the short run, states that have not recently updated their codes to achieve at least moderate savings should do so. Most states would also benefit from better code enforcement.

- *Public information campaign and technical assistance:* It has been many years since a major national public information campaign was conducted on the benefits of improved home efficiency and steps homeowners and building owners can take to improve their buildings. Training is also needed for contractors on the latest developments in home weatherization such as duct sealing, air infiltration reduction, and use of advanced boiler and hot water controls. In addition, technical assistance should be offered to assist building owners through the upgrade process such as answering questions, providing sample specifications, recommending contractors, helping to evaluate bids, etc. Such information and technical assistance will be particularly important and useful if the next policy option is also implemented.

- *Easy to access, modest cost financing:* In order to address the fact that many building owners lack financing for home improvements, we recommend that easy to use financing programs be established, preferably at reduced interest rates. Programs could be set up by states and offered through local banks and local oil dealers with straightforward application requirements and quick approval times. For example, New York operates the Home Performance with ENERGY STAR program to provide "one-stop shopping" to residential homeowners interested in improving the comfort of their home while reducing operating costs. The program includes training, certification, and marketing assistance for contractors; comprehensive assessments to identify appropriate home retrofits; and financing (up to 5% below prevailing rates, depending on income). These comprehensive services make it easy for homeowners to get a quality job done. As of the end of 2004, the New York program had completed more than 6,000 homes and achieved average savings of about 35% in homes served (Fiske 2005). Similarly, the Commonwealth of Massachusetts ran a program in the late 1980s and early 1990s that provided technical assistance (through local housing and energy agencies) and made 0% interest loans available through local banks to finance eligible energy-saving improvements. Over the 1986–1992 period, the program completed more than 27,000 retrofits. Marketing was done only for the first year and thereafter private contractors promoted the program as part of efforts to market their services. The program only ended when funding ran out (Suozzo, Wang, and Thorne 1997). Other examples of successful programs include programs operated during the 1980s and 1990s by the Bonneville Power Administration (Weather Wise and Hood River Conservation Project), Eugene Water and Energy Board (Comprehensive Weatherization), Ontario Hydro (Espanola Power Savers), and the Tennessee Valley Authority (Home Weatherization). These latter programs generally got 60% or more of eligible homeowners to participate over a multiyear period (Nadel, Pye, and Jordan 1994).

Analogous programs can also be run in the commercial sector. For example, EPA runs the ENERGY STAR Buildings program that encourages building owners to benchmark their buildings relative to data on other buildings in their region, and to upgrade buildings to be in the top quartile for their building type and region. EPA provides some technical assistance and also works with states and local utilities that often provide more in-depth services (see http://www.energystar.gov/index.cfm?c=business.bus_index). In the case of oil use, it will generally be states that will need to take the lead on program designs, since electric and gas utilities generally do not invest in measures to reduce oil and LPG use.

In addition, a fifth policy should be considered if the very highest levels of participation and savings are desired:

- *Retrofit ordinances:* Some communities have established ordinances that require a homeowner to upgrade the efficiency of a home, apartment, or commercial building at the time of building sale. Such ordinances set certain efficiency requirements that must be met, unless a specified cost cap is reached first. Upgrades may be done either by the seller or by the buyer with the cost of the improvements incorporated into the mortgage. Such retrofit ordinances take advantage of the fact that many home improvements are done when a home changes ownership and thus this is a good time to make energy-saving improvements. In addition, given recent steep increases in home prices, substantial cash is available at this time to make improvements. Also, new home buyers can roll the cost of the improvements into their mortgages, resulting in positive cash flow (the value of energy savings are greater than the modest increase in mortgage payments). Examples of such ordinances include those in Wisconsin and several cities in California, Michigan and Vermont (Suozzo, Wang, and Thorne 1997). To help home and building sellers and purchasers with these changes, the technical assistance and financing programs discussed above would be of great assistance.

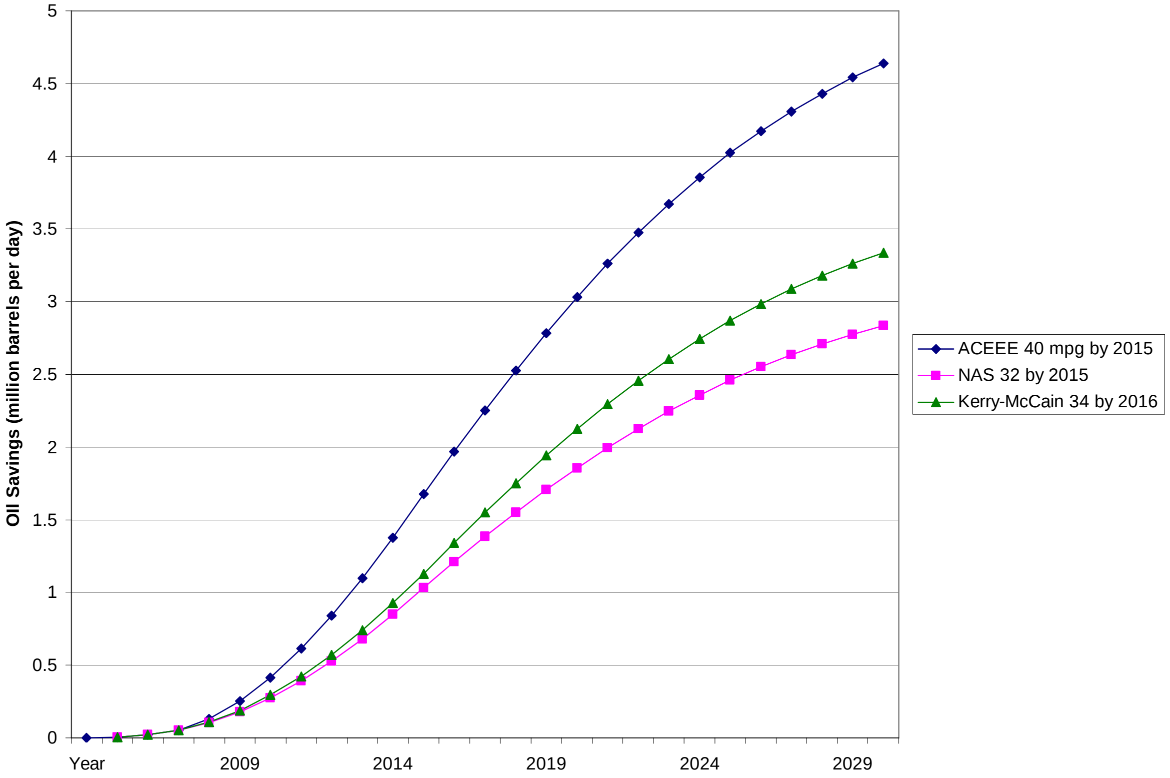
OIL SAVINGS FROM EFFICIENCY POLICY SCENARIOS

For each sector, we consider energy savings associated with three policy packages of increasing stringency, designated Modest, Moderate, and Aggressive scenarios.

Transportation

As explained earlier, cars and light truck savings are included here for reference purposes. We use the findings of the ACEEE and NAS analyses referenced above to define the Modest and Aggressive scenarios for these vehicles, setting fuel economies at 32 and 40 miles per gallon, respectively. For the Moderate scenario, we cite a bill proposed by Senators Kerry and McCain in 2003 that would have required light-duty vehicles to average 34 miles per gallon by 2016. Oil savings from these three scenarios, assuming the increases are phased in linearly over a period consistent with the discussion in the studies, are shown in Figure 7.

Figure 7. Oil Savings through Car and Light Truck Fuel Economy Improvements



Source: ACEEE stock model

For heavy-duty trucks, the three scenarios are as follows:

1. *Modest*: For long-haul trucks, this scenario includes fuel economy standards for engines, together with requirements for aerodynamic treatments and electrical auxiliaries. Cost-effective technologies that could be promoted through engine efficiency standards or component requirements (in particular aerodynamic equipment and electrical auxiliaries)

and will be available by 2008 are phased into the market over 15 years. To promote anti-idling technologies, the government is assumed to pay 50% for 5,000 auxiliary power units per year over three years (at a total cost of $50 million).

For short-haul trucks, the Modest scenario includes tax credits for purchase of hybrids. We assume a 50% fuel economy improvement, as discussed above. Hybrid technologies are phased in over 15 years, and maximum penetration is set at 25%. In all scenarios, savings reflect the percentage of fuel used by short-haul trucks in each weight class.

2. *Moderate*: For long-haul trucks, the Moderate scenario includes the same technologies as the Modest, but adds wide base tires (3% increase). In addition, all technology diffusion is assumed to occur in ten years instead of fifteen. Realizing the Moderate scenario requires a more stringent engine efficiency standard in terms of speed of phase-in and percent increase in efficiency. The policy to promote idling reduction is a 50% government subsidy of 10,000 APUs each year for three years.

   This scenario is the same for hybrids as the Modest scenario, except that maximum penetration rises to 50% for the technology.

3. *Aggressive:* For long-haul trucks, the Aggressive scenario is fuel economy standards for complete vehicles. The technologies used to meet the standards add to the above pneumatic blowing (6%) and mass reduction (7.5%), and electrical auxiliaries are replaced by fuel cell auxiliaries (6%) starting in 2012. These technologies are somewhat more speculative than those in the previous scenarios. The Aggressive scenario also assumes that the entire eligible truck fleet (18% of Class 7&8 trucks—those that travel more than 500 miles from home base) is retrofitted or sold with diesel APUs.

   Some hybrids have been projected to increase fuel economy by far more than 50%, such as EPA’s Class 6 hydraulic hybrid. Therefore, for short-haul trucks, we set the Aggressive scenario fuel economy at 70% improvement over the 2005 average, keeping maximum penetration at 50%.

For Class 2b trucks, all scenarios involve application of fuel economy standards, which could be difficult politically because this class includes many pickup trucks used for work purposes. In the Modest scenario, the standard is set 50% above the current average for this class of vehicles, but excludes pickup trucks. The benefits are small because three-quarters of vehicles in this weight class are pickups (Davis and Diegel 2004). The Moderate scenario also includes fuel economy standards at a 50% increase over current fuel economy for the class, but in this case applied to all trucks in the class. The increase is phased in over the period 2008–2015. The Aggressive scenario for Class 2b is a 66% increase in fuel economy, corresponding to light-duty standard of 40 miles per gallon.

Oil savings associated with the heavy-truck policy packages in 2015 and 2020 are shown in Table 6, along with Class 2b savings.

Table 6. Oil Savings from Heavy-Duty Truck Efficiency in Three Policy Scenarios (million barrels per day)

	2015	2020
Long-haul trucks, Classes 7&8		
Modest	0.12	0.26
Moderate	0.19	0.38
Aggressive	0.27	0.53
Anti-idling		
Modest	0.01	0.03
Moderate	0.05	0.06
Aggressive	0.06	0.06
Short-haul trucks, Classes 3-8		
Modest	0.01	0.02
Moderate	0.02	0.04
Aggressive	0.04	0.07
Class 2b		
Modest	0.02	0.03
Moderate	0.07	0.11
Aggressive	0.09	0.14
TOTAL		
Modest	0.16	0.34
Moderate	0.33	0.60
Aggressive	0.46	0.80

With regard to efficiency gains in aviation, Greene and Schafer (2003) assign fuel savings of 1% of total transportation consumption in 2015 and 2% in 2030 through their proposed voluntary seat-mile-per-gallon standard. Using EIA projections of transportation petroleum consumption (EIA 2005a) and interpolating, we assign savings of 170,000 barrels per day in 2015 and 250,000 barrels per day in 2020 to this policy and designate it as part of the Moderate scenario. We represent Modest and Aggressive scenarios for airplane efficiency by savings 50% less and 50% more, respectively, than the Moderate scenario achieves.

Industry

Assuming the economic savings scenario described above represents the maximum potential, we propose three achievable scenarios consistent with those considered for the other sectors. In the Aggressive scenario we assume that we achieve two-thirds of the economic savings, which is consistent with results we have seen from other economic and potential assessments (see Nadel, Shipley, and Elliott 2004). In the case of construction asphalt and road oil, we assume all of the economic potential suggested by Lovins et al. (2004) as a realistic goal. Because we have not completed a cost-effectiveness assessment for recycled plastics, we will not consider this measure as part of these scenarios.

For the Moderate scenario we assume that we achieve 80% of the manufacturing heat and power and construction asphalt savings of the Aggressive scenario, since these are clearly cost-effective measures, and 75% of the off-road motors fuels, since we are somewhat less sure about the ease with which this potential could be achieved for this end-use. In the Modest scenario, we assume we achieve half of the Aggressive potential.

Table 7. Petroleum Savings for Key Industrial End-Uses (MBD)

	Aggressive		**Moderate**		**Modest**	
Use Category	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
Manufacturing heat and power	0.016	0.021	0.013	0.018	0.008	0.011
Construction asphalt and road-oils	0.267	0.356	0.210	0.280	0.134	0.178
Off-road motor fuels	0.047	0.063	0.035	0.047	0.024	0.031
Total Industrial	0.330	0.440	0.258	0.344	0.165	0.220

In the industrial sector, our estimates of the cost of reductions are substantially less well defined than in the other sectors because of the significantly lower level of research effort that has been applied to these issues in the past. We present estimates of the costs for each scenario in Table 7. The manufacturing heat and power savings come predominately from replacement of the existing boiler stock with new boilers or CHP capacity. We use a cost of $0.0293 per pound of installed steam generation capacity as the basis for the cost (NREL 2003). Lovins et al. (2004) projected that the cost of shifting to rubberized asphalt cement paving is a negative $64 per barrel as a result of the reduced lift thickness required for the more flexible pavement and the longer life due to greater wear resistance. Finally, ACEEE estimates that reductions in off-highway motor fuels can be had for little if any cost for the agricultural sub-sector, because they predominately result from practice changes that require little additional capital investment and may reduce other costs including maintenance and other operating costs. For the other sub-sectors, we would anticipate the costs are modest.

Table 7. Estimated Cumulative Costs of Savings Scenarios by 2020

		Scenario Costs		
End-Use	**Unit Cost ($/bbl/day)**	**Aggressive**	**Moderate (Million $)**	**Modest**
Manufacturing heat and power	5,596	179	119	60
Construction asphalt and road-oils	(64)	(45)	(23)	(11)
Off-road motor fuels	~0	—	—	—
Total Industrial		134	96	48

For purposes of this analysis, we estimate only the direct cost savings resulting from reductions in the use of petroleum products (see Table 8). The 2020 petroleum product prices are based on those by EIA (2005a). As can be seen, the direct savings far out weigh the costs. In addition, we would anticipate non-petroleum and non-energy benefits from these measures. The estimation of these additional benefits is beyond the scope of this analysis.

Table 8. Estimated Direct[a] 2020 Annual Savings from Petroleum Use Reductions

End-Use	Fuel $/bbl	Aggressive	Moderate (Million $)	Modest
Manufacturing heat and power[b]	31	362	242	121
Construction asphalt and road-oils	27	3,568	3,568	1784
Off-road motor fuels	41	1,408	938	469
Total Industrial		5,338	4,748	2,374

Notes: a. We consider only the avoided petroleum consumption expenditure and do not consider any indirect effects such as savings in other inputs such as natural gas or fertilizer.

b. Assumes 4/5 residual and 1/5 LPG

Residential and Commercial

The three policy scenarios considered for residential and commercial building efficiency were as follows:

1. *Modest:* Modest expansion of current efforts including new/upgraded efficiency standards (on residential furnaces, boilers, and room heaters and on commercial boilers), moderate building code improvements, and a modest expansion of public education and energy efficiency promotion efforts.

2. *Moderate*: Same as above but a more significant upgrade to building codes (bringing them up to ENERGY STAR Homes program levels) and addition of a home, apartment building, and commercial building retrofit program (e.g., reduced cost loans plus technical assistance; tax incentives could be an alternative to the interest subsidy).

3. *Aggressive:* Same code and standards provisions as above, but enactment of ordinances requiring implementation of all cost-effective upgrades up to a cost cap (based on retrofit ordinances enacted in a few communities around the United States.). This last level is the maximum feasible level but will be a political challenge.

To analyze savings and costs for these policies and packages, we examined each specific policy, looking at the number of homes and buildings eligible (using EIA data), the number of homes and buildings that are expected to participate (using experience from past programs), and average costs and savings per home and building (using the measure packages discussed above, but also guided by experience of actual programs in the field). The analysis is summarized in Table 9.

Table 9. Residential and Commercial Buildings—Policy Savings and Costs

Policy	Units Eligible (million)	Participation Rate (%)	Base Use (quads)	Average Savings (%)	Savings in 2020 (quads)	Savings in 2020 (MBD)	Savings in 2020 (million $)	Cost/ Home ($)	Costs Thru 2020 Direct Costs (million $)	Costs Thru 2020 Admin Costs (million $)	Payback on Program Costs (years)
Efficiency standards		effective 2010									
Residential oil furnaces & boilers	5.7	46%	0.63	5%	0.014	0.006	200	150	394	2	0.0
Residential LPG furnaces	2.5	56%	0.23	11%	0.014	0.007	209	450	625	2	0.0
Residential LPG room heaters	1.1	77%	0.08	13%	0.008	0.004	114	192	162	2	0.0
Commercial boilers (includes multifamily)	0.6	33%	0.52	6%	0.011	0.005	154	3,700	777	2	0.0
Building codes for new homes	es built 2009-2020										
Energy Star levels (30% savings)	1.7	100%	0.08	30%	0.024	0.011	347	1,500	2,550	9	0.0
Moderate levels (15% savings)	1.7	100%	0.08	15%	0.012	0.006	173	500	850	3	0.0
Single-family home retrofit program	pre-2001 homes										
Education/promotion only	11.6	10%	0.90	10%	0.009	0.004	130	1,167	1,353	75	0.6
Moderate cost program	11.6	38%	0.90	20%	0.068	0.032	976	2,333	10,151	1,269	1.3
Zero interest loans + technical assistance	11.6	65%	0.90	30%	0.176	0.083	2,537	3,500	26,390	6,598	2.6
Retrofit requirements (maximum possible)	11.6	90%	0.90	30%	0.243	0.114	3,513	3,500	36,540	9,135	2.6
Multifamily building retrofit program	re-2001 buildings										
Education/promotion only	2.1	10%	0.12	10%	0.001	0.001	17	533	112	38	2.2
Moderate cost program	2.1	25%	0.12	20%	0.006	0.003	87	1,067	560	70	0.8
Zero interest loans + technical assistance	2.1	40%	0.12	30%	0.014	0.007	208	1,600	1,344	336	1.6
Retrofit requirements (maximum possible)	2.1	90%	0.12	30%	0.032	0.015	468	1,600	3,024	756	1.6
Commercial building retrofit program	re-2001 buildings										
Education/promotion only	0.4	10%	0.36	5%	0.002	0.001	26	1,500	65	38	1.4
Moderate cost program	0.4	25%	0.36	10%	0.009	0.004	130	3,000	326	41	0.3
Zero interest loans + technical assistance	0.4	40%	0.36	15%	0.022	0.010	312	4,500	781	195	0.6
Retrofit requirements (maximum possible)	0.4	90%	0.36	20%	0.065	0.030	937	6,000	2,344	586	0.6
Totals											
Standards, moderate code & education/promotion						0.033	1,023		4,339	161	0.2
Above plus Energy Star codes and moderate retrofits						0.072	2,216		15,545	1,397	0.6
Above plus substantial retrofits						0.133	4,081		33,024	7,146	1.8
Above plus retrofit requirements						0.193	5,942		46,416	10,494	1.8
Maximum possible (100% participation)						0.235	7,231				

As can be seen, savings and costs gradually escalate as we progress from the most modest to the most extensive packages. By 2020, a modest expansion of current efforts could save 0.03 MBD. The second package (primarily extensive retrofit packages) could save 0.13 MBD, while the addition of retrofit ordinances would increase the savings to 0.19 MBD. The maximum possible package would save 0.24 MBD with 100% participation. The packages range in cost from $160 million cumulatively over the 2006–2020 period (expressed in current dollars) for a modest expansion of current efforts to about $7 billion cumulative for the extensive retrofit package (and even more for retrofit ordinances backed by financing and technical assistance). To fund the moderate and substantial retrofit packages, we recommend a small fee on each gallon of oil and LPG that is sold to the residential and commercial sectors. Based on the costs in Table 9, we estimate the following fees would be needed:

> $0.001 per gallon[16] for the modest expansion of current efforts (modest scenario)
> $0.024 per gallon for the above plus substantial retrofits (moderate scenario)
> $0.035 per gallon for the above plus retrofit ordinances (aggressive scenario)

We estimate that these government investments will be paid back in society-wide oil savings in less than two years—a very cost-effective investment.

In the next and final section of this report, we include only the three policy cases and not the maximum possible scenario.

CONCLUSIONS AND RECOMMENDATIONS

Substantial petroleum savings are available in all sectors through efficiency improvements. The opportunities discussed in detail above in the transportation, industry, and buildings sectors would yield, in the Aggressive policy scenario, cost-effective savings of almost one million barrels per day in 2015 and 1.5 million barrels per day in 2020. Savings in the Moderate scenario would achieve three-quarters and two-thirds of those targets, respectively, in 2015 and 2020. Oil savings of this magnitude would yield substantial societal benefits, including reduced pollution, reduced reliance on imported oil, and modest downward pressure on oil prices. The savings are summarized in Table 10.

Table 10. Oil Savings Achievable with Selected Efficiency Measures In Three Policy Scenarios (MBD)

	Modest		**Moderate**		**Aggressive**	
Year	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
Transportation	0.16	0.34	0.33	0.60	0.46	0.80
Industry	0.17	0.22	0.26	0.34	0.33	0.44
Residential and Commercial	0.02	0.03	0.08	0.13	0.13	0.19
Total	0.34	0.59	0.67	1.07	0.91	1.44

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[16] Fees are calculated per gallon of fuel oil. For LPG we recommend multiplying this fee by 0.62 to account for the lower Btu content of a gallon of LPG.

The scenarios reflected in Table 10 take advantage of efficiency opportunities in selected sub-sectors only. Other measures alluded to but not analyzed above could greatly increase these savings. Plastics recycling, for example, an efficiency opportunity we did not evaluate from a cost-effectiveness perspective, could save another 310,000 barrels per day by 2015 and 460,000 by 2020. Increased airplane efficiency as mentioned above would save an estimated 170,000 barrels per day by 2015 and 250,000 in 2020. Most importantly, the scenarios reflected in Table 10 omit cars and light trucks, by far the largest use of petroleum, for which cost-effective savings exist of up to 3 million barrels per day by 2020, even without substantial penetration of hybrids, diesel vehicles, or other alternative technologies (see Figure 7). Savings opportunities from these measures are summarized in Table 11.

Table 11. Savings Achievable Including Additional Efficiency Measures In Three Policy Scenarios (MBD)

	Modest		Moderate		Aggressive	
Year	2015	2020	2015	2020	2015	2020
Total from Above	0.34	0.59	0.67	1.07	0.91	1.44
Plastics Recycling	0.07	0.10	0.13	0.20	0.31	0.46
Airplanes	0.08	0.12	0.17	0.25	0.25	0.37
Subtotal	0.49	0.81	0.98	1.53	1.47	2.27
Light-Duty Vehicles	1.03	1.86	1.13	2.12	1.68	3.03
TOTAL	1.52	2.67	2.11	3.65	3.15	5.30
Total as % of U.S. oil consumption[a]	6%	11%	9%	15%	13%	21%

Notes: [a]As projected by EIA (2005d)

The list of sub-sectors and measures in Table 11 is still not comprehensive, but one would expect that these represent the bulk of the petroleum savings available through efficiency. As the table indicates, a one million barrel per day target for 2015 would be met in the Modest scenario. Savings in the Moderate scenario would approach the target of 2.5 million barrels per day in 2015 and 2016 in pending bills S. 2025 and H.R. 4409, respectively.

While we did not explicitly project savings beyond 2020, reductions from the measures reflected in Table 10 would approach 2 million barrels per day in 2025 in the Aggressive scenario and 1.4 million barrels per day in the Moderate scenario, assuming savings trends continue. Combined with projected 2025 savings from the remaining measures in Table 11, savings would be about 7 million barrels per day for the Aggressive scenario and almost 5 million barrels per day for the Moderate scenario. Thus, the 2026 target in S. 2025 could be met with these measures alone in the Aggressive scenario and the 2025 target in H.R. 4409 with just the Modest scenario.

Nor is efficiency the only tool available to reduce petroleum consumption. There is renewed enthusiasm for increasing production of domestic fuels, particularly biofuels. One recent estimate places the potential oil savings through use of ethanol at 0.28 million barrels per day in 2015, climbing to 3.92 million barrels per day in 2025 due to rapid growth in the production of cellulosic ethanol starting in 2015 (Bordetsky et al. 2005). Considerable growth in biodiesel production is possible as well, but land area and cost constraints may limit total production to a small percent of total fuel use. There is also growing interest in coal-to-liquid fuels, although the widespread use of coal for fuels may raise environmental concerns.

More efficient cars and light trucks will be essential to meeting the ambitious oil reduction targets, but other efficiency opportunities presented above can make a substantial contribution. The existence of these opportunities, as well as the potential for diversification of liquid fuels, allows flexibility in charting a course toward reduced oil dependence.

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APPENDIX TABLES

Table A-1. Savings Analysis by Building and System Type

	Annual Base Use	Savings		Buildings Needing	Adjusted Annual Savings	Savings Relative to Base	Cost	Lifetime	Cost of Saved Energy
	(gallons)	(%)	(gallons)	(%)	(gallons)	(%)	($)	(years)	($/gallon)
Single family									
Oil warm-air space heat	579								
Insulation	579	28%	162.1	40%	64.8	11.2%	2208	30	0.89
Infiltration reduction	514	10%	51.4	75%	38.6	6.7%	350	10	0.88
Duct sealing	476	13%	59.4	50%	29.7	5.1%	500	15	0.81
Replace burner	446	15%	66.9	10%	6.7	1.2%	450	15	0.65
Replace heating system	439	17%	73.2	40%	29.3	5.1%	1500	18	1.75
Setback thermostat	410	7%	28.7	50%	14.3	2.5%	125	15	0.42
New windows	396	11%	41.9	60%	25.2	4.3%	600	30	0.93
Total					208.6	36.0%	2463.2	23	0.88
Oil hot water space heat	579								
Insulation	579	28%	162.1	40%	64.8	11.2%	2208	30	0.89
Infiltration reduction	514	10%	51.4	75%	38.6	6.7%	350	10	0.88
Replace burner	476	15%	71.3	10%	7.1	1.2%	450	15	0.61
Replace heating system	468	17%	78.1	40%	31.2	5.4%	1800	25	1.64
Modulate water temp.	437	11%	48.1	85%	40.9	7.1%	250	15	0.50
Setback thermostat	396	7%	27.7	50%	13.9	2.4%	125	15	0.43
New windows	382	11%	40.5	60%	24.3	4.2%	600	30	0.96
Total					220.9	38.1%	2545.7	25	0.82
Oil steam space heat	579								
Insulation	579	28%	162.1	40%	64.8	11.2%	2208	30	0.89
Infiltration reduction	514	10%	51.4	75%	38.6	6.7%	350	10	0.88
Replace burner	476	15%	71.3	10%	7.1	1.2%	450	15	0.61
Replace heating system	468	17%	80.0	40%	32.0	5.5%	1800	25	1.60
Improved steam vents	436	6%	26.2	50%	13.1	2.3%	450	20	1.38
Setback thermostat	423	7%	29.6	50%	14.8	2.6%	125	15	0.41
New windows	409	11%	43.3	60%	26.0	4.5%	600	30	0.90
Total					196.4	33.9%	2558.2	25	0.92
LPG warm air space heat	594								
Insulation	594	28%	166.3	40%	66.5	11.2%	2208	30	0.86
Infiltration reduction	527	10%	52.7	75%	39.6	6.7%	350	10	0.86
Duct sealing	488	13%	61.0	50%	30.5	5.1%	500	15	0.79
Replace heating system	457	28%	127.1	40%	50.8	8.6%	1150	18	0.77
Setback thermostat	407	7%	28.5	50%	14.2	2.4%	125	15	0.42
New windows	392	11%	41.6	60%	25.0	4.2%	600	30	0.94
Total					226.6	38.1%	2278.2	24	0.73
Oil water heating	233								
Pipe wrap	233	10%	23.3	50%	11.7	5.0%	100	15	0.41
Showerheads/faucets	221	11%	24.3	70%	17.0	7.3%	35	10	0.19
Low water clothes washer	204	18%	36.7	79%	29.0	12.4%	400	14	1.10
Combo SH/WH system	175	35%	60.7	45%	27.3	11.7%	750	25	0.88
Total					85.0	36.5%	728.2	20	0.68
LPG water heating	183								
Pipe wrap	183	10%	18.3	50%	9.2	3.9%	100	15	0.53
Showerheads/faucets	174	11%	19.1	70%	13.4	5.7%	35	10	0.24
Low water clothes washer	160	18%	28.8	79%	22.8	9.8%	400	14	1.40
New water heater	138	5%	6.7	95%	6.3	2.7%	75	13	1.20
Total					51.6	28.2%	461.95	14	0.91

Table A-1 (cont.) Savings Analysis by Building and System Type

	Annual Base Use (gallons)	Savings (%)	Savings (gallons)	Buildings Needing (%)	Adjusted Annual Savings (gallons)	Savings Relative to Base (%)	Cost ($)	Lifetime (years)	Cost of Saved Energy ($/gallon)
Multifamily									
Oil hot water space heat	301								
Infiltration reduction	301	10%	30.1	90%	27.1	9.0%	250	10	1.08
Attic insulation	274	3%	8.2	70%	5.8	1.9%	94	30	0.74
Replace burner	268	15%	40.2	10%	4.0	1.3%	19	15	0.04
Front-end boiler	264	10%	26.4	21%	5.5	1.8%	168	30	0.41
Replace heating system	259	17%	43.1	60%	25.9	8.6%	186	30	0.28
Modulate water temp.	233	11%	25.6	25%	6.4	2.1%	17	15	0.06
New windows	226	11%	24.0	60%	14.4	4.8%	400	30	1.08
Total					89.1	29.6%	684	25	0.54
Oil steam space heat	301								
Infiltration reduction	301	10%	30.1	90%	27.1	9.0%	250	10	1.08
Attic insulation	274	3%	8.2	70%	5.8	1.9%	94	30	0.74
Replace burner	268	15%	40.2	10%	4.0	1.3%	19	15	0.04
Replace heating system	264	17%	45.1	60%	27.1	9.0%	425	30	0.61
Mainline air vents	237	10%	23.7	75%	17.8	5.9%	69	30	0.19
Thermostatic vents	219	6%	13.2	40%	5.3	1.7%	239	20	1.46
New windows	214	11%	22.7	60%	13.6	4.5%	400	30	1.15
					100.6	33.4%	935	25	0.66
Oil water heating	148								
Pipe wrap	148	10%	14.8	50%	7.4	5.0%	100	15	0.65
Showerheads/faucets	141	11%	15.5	70%	10.8	7.3%	35	10	0.29
Low water clothes washer	130	18%	23.3	60%	13.9	9.4%	400	14	1.73
Combo SH/WH system	116	35%	40.2	55%	22.1	14.9%	1125	25	1.99
Pump controller	94	16%	15.0	60%	9.0	6.1%	39	15	0.25
Total					63.3	42.7%	955	21	1.17
Commercial									
All end-uses	2982								
Oil space heating	1764								
Boiler tuneup	1764	5%	88.2	50%	44.1	2.5%	250	5	0.65
Modulate water temp.	1720	11%	189.2	25%	47.3	15.7%	600	15	0.31
Setback controls	1672	7%	117.1	50%	58.5	3.3%	500	10	0.55
Roof insulation	1614	8%	129.1	37%	47.8	2.7%	1600	20	0.99
New windows	1566	11%	166.0	60%	99.6	5.6%	2400	30	0.94
Replace heating system	1466	17%	244.4	60%	146.6	8.3%	5400	30	1.44
					399.8	22.7%	5797	26	1.01
Oil water heating	336								
Pipe insulation	336	10%	33.6	50%	16.8	5.0%	300	15	0.86
Pump controller	319	32%	102.1	60%	61.3	20.4%	1400	15	1.32
New boiler	258	17%	43.0	67%	28.8	9.6%	100	30	0.15
New water heater	258	9%	23.5	33%	7.7	2.6%	261	10	1.44
					114.6	34.1%	1143	15	0.96

Notes:
"Annual base use" adjusts for savings of prior more cost-effective measures in order to avoid double-counting of savings.
"Buildings needing" is the approximate percentage of buildings that have not yet used a measure but for which the measure is technically feasible. There is no time frame associated with this estimate.
"Adjusted annual savings" = Base Use * Savings (%) * Buildings Needing (%).
"Cost" figures are incremental replacement costs for heating systems, water heaters and windows, and retrofit costs for all other measures.
"Cost of Saved Energy" is the average discounted cost of a measure over its lifetime per gallon of oil saved.
Measures with a cost of saved energy less than the retail price of oil will generally be cost-effective to consumers.

Table A-2. Energy Bill Tax Incentives for Heavy-Duty Hybrids

Improvement in city fuel economy	30-40%	40-50%	>50%
% incremental cost covered by tax credit	20%	30%	40%

Vehicle weight	**Maximum incremental cost**
<14,000 lbs. (Class 2b–3)	$7,500
14,000–26,000 lbs. (Class 4–6)	$15,000
>26,000 lbs. (Class 7&8)	$30,000

Source: Energy Policy Act of 2005