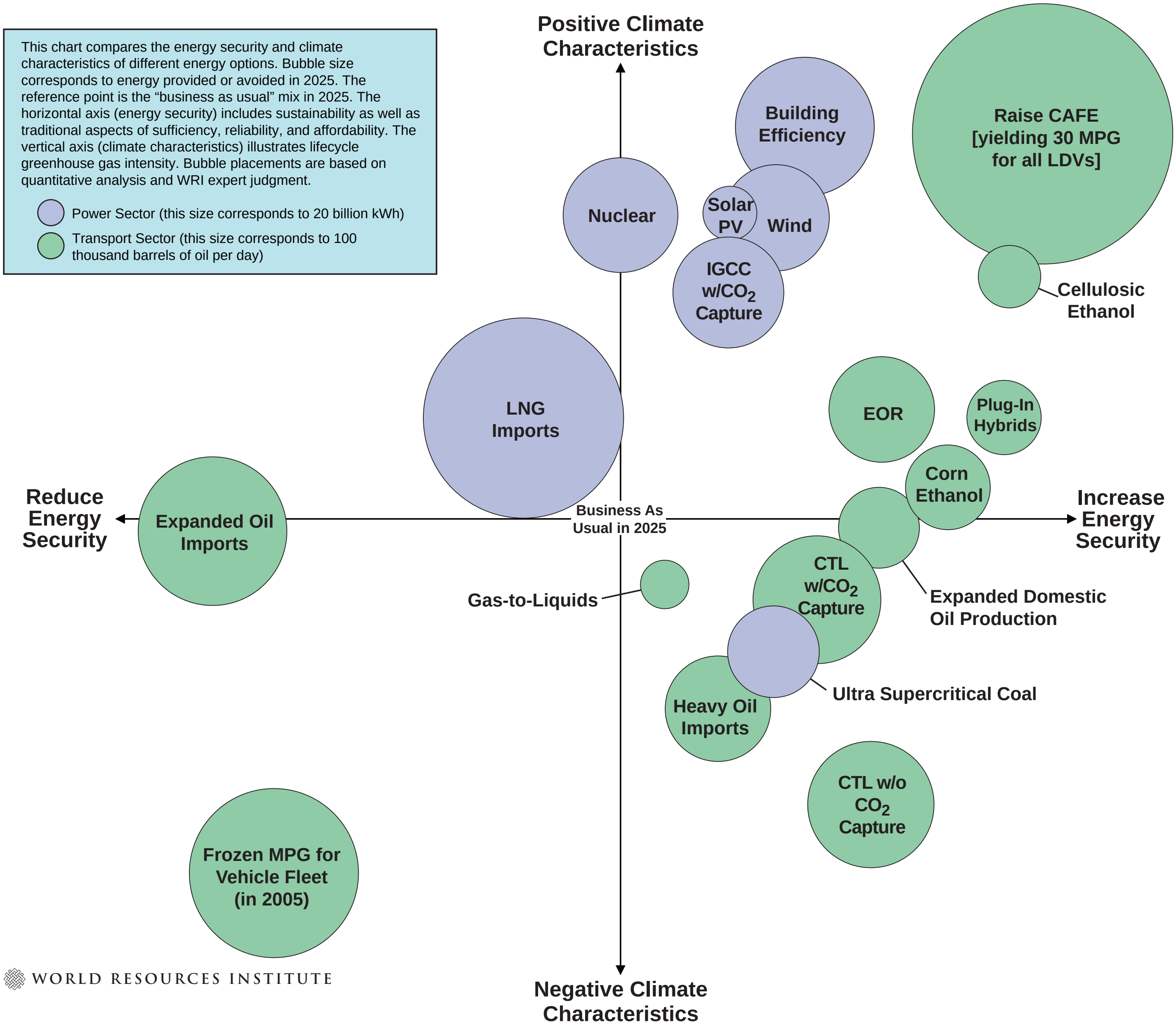
A Snaphot of Selected U.S. Energy Options Today: Climate Change and Energy Security Impacts and Tradeoffs in 2025


This chart compares the energy security and climate characteristics of different energy options. Bubble size corresponds to energy provided or avoided in 2025. The reference point is the “business as usual” mix in 2025. The horizontal axis (energy security) includes sustainability as well as traditional aspects of sufficiency, reliability, and affordability. The vertical axis (climate characteristics) illustrates lifecycle greenhouse gas intensity. Bubble placements are based on quantitative analysis and WRI expert judgment.

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For specific details on the assumptions underlying the options on this chart,
go to http://www.wri.org/usenergyoptions
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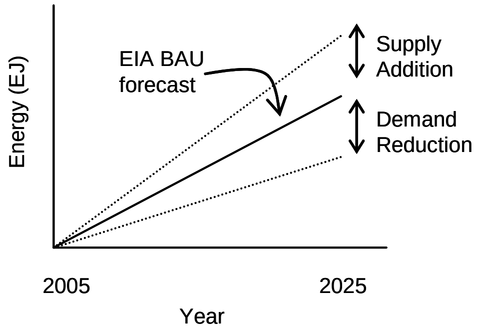
Discussion and Assumptions for U.S. Energy Options

This chart illustrates the climate and security impacts of selected energy options in the United States in 2025. There are cyclical debates in the U.S. about how to meet future energy needs. We are currently in a period of elevated concern due to a combination of high and unstable oil prices, uncertain supply, geopolitical dynamics, and the growing threat of climate change. Sufficient, reliable and affordable energy is considered the basis of any traditional definition of energy security—but sustainability, geopolitical, and social acceptability issues have become increasingly important in recent dialogues. A country's energy system is not secure, after all, if it consumes water supplies unsustainably, fuels political instability internationally, or results in strong local opposition. This chart allows for comparative analysis of different energy options meant to address energy security and climate change challenges.

Explanation of Chart



The size of each bubble represents one view of how much energy the option could deliver (or offset) in 2025 given a modest policy driver. These values are incremental to the amounts forecasted under existing business as usual scenarios (see figure). Sizes are based on a combination of existing forecasts in the literature and our largely qualitative view of how a moderate policy push would impact penetration of different options. Bubble size is measured as the amount of primary coal (power) or oil (transport) that would be offset by implementing each option. We chose coal and oil as the points of comparison for power and transport, respectively, because they are the current most likely options on the margin. Because energy is measured at the same upstream (primary) point of conversion, bubble sizes for each option can be directly compared. This is important given that coal and gas are becoming more substitutable for petroleum. Table 1 lists our assumptions for each option.

The vertical axis illustrates climate characteristics, taking into account lifecycle greenhouse gas emissions for each option. The horizontal axis is a measure of the energy security characteristics of each option. While the vertical position of each bubble is relatively objective, horizontal placements are more subjective and open to discussion. Bubble location is the authors' assessment of the energy security and climate attributes for each option. We do not claim these placements as the only answer.

The chart is divided into four quadrants. Options in the top right quadrant have both positive climate and energy security characteristics. Increasing vehicle corporate average fuel economy (CAFE) standards, for example, directly offsets the need to import petroleum while also reducing CO_2 emissions. Options that fall in the bottom right quadrant have positive energy security but negative climate traits. Using coal-to-liquids (CTL) technology, for example, may allow reduced oil imports, but the additional CO_2 emissions resulting from the conversion of coal to liquid fuel are nearly double those from standard petroleum use (without carbon dioxide capture and sequestration, or CCS).

Options in the top left quadrant have positive climate but negative energy security characteristics. For example, expanding imports of liquefied natural gas (LNG) may expose the country to greater risks of potential imported fuel supply disruption, but this fuel is less carbon-intensive than the forecasted power sector mix in 2025. Finally, options in the bottom left quadrant, such as expanded reliance on imported oil or an effective "freeze" in actual vehicle fleet mileage, have both negative energy security and climate implications.

Increases or decreases in CO_2 from the business as usual (BAU) status quo were estimated for each option and included in Table 1. For the power sector, the BAU is the mix of energy sources forecasted by U.S. DOE EIA[1] to provide this power (coal, nuclear, natural gas, etc.) in 2025. For the transport sector, the BAU is the forecasted mix of energy sources in this sector (mostly petroleum) in 2025.

The chart represents one of many possible energy snapshots of the future and is meant to encourage discussion. It is not an energy forecast and does not include feedback effects.[2] Assumptions used in sizing and locating each bubble are described on the following pages.

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[1] EIA *Annual Energy Outlook 2007.*

[2] It should be noted that scaling up each of these technologies to levels much greater than currently deployed may have environmental and other impacts to land, water, and other resources that have yet to be fully considered. WRI begins to look at some of these issues in a new report, *Scaling Up: Global Technology Deployment to Stabilize Emissions*.

Deployment Assumptions

WRI surveyed a wide range of reports, forecasts, and expert opinions to arrive at estimates of the potential deployment for each option under a moderate policy driver in 2025. Drivers could include broad measures, such as a greenhouse gas cap and trade system, or specific targets like a renewable portfolio standard or tax credits for nuclear power. To compare options against one another, we estimate the primary coal (power sector) or oil (transport sector) in EJ that could be offset by implementing each option. Related studies and forecasts are also provided as additional points of comparison.

Table 1. Assumptions Underlying the Amount of Incremental Energy Provided or Avoided from Each Option

Energy Option	Energy (EJ)	CO_2 (MMT)	WRI Assumptions, Compared to Business as Usual (BAU) in 2025	Other Studies/Forecasts
Electric Power Sector				
Nuclear	1.3	-80	Additional 20 GW of nuclear capacity (5-10 plants).	• EIA reports nuclear capacity of about 100 GW in 2005. • EIA forecasts 9 GW unplanned additions by 2025 in the reference case, 24 GW of new capacity in the high price case, and 27 GW of new capacity in the high growth case. • The U.S. Nuclear Regulatory Commission (NRC) is expecting 22 applications over the next two years, for at least 32 new reactors.
Clean Coal (IGCC) with CCS	1.1	-40	Additional 15 GW of integrated gasification combined-cycle (IGCC) plants with carbon capture & storage (15-60 plants). Assumes 20% energy penalty and 90% capture efficiency.	• EIA forecasts 67 GW of power from IGCC by 2030 in the reference case scenario, assuming no carbon regulation. • NETL reports that over the next 10 years, 159 coal based electricity plants (96 GW) are expected to come into service, 32 of which are proposed to be built using IGCC, roughly 10 GW capacity.
Imported LNG	3.7	-35	Additional 40 BCM (1.4 trillion cubic feet) of imported LNG, fueling 48 GW of additional combined-cycle plants.	• EIA reports net imports at 0.6 trillion cubic feet (tcf) in 2005. • EIA forecasts 4.5 tcf of net LNG imports in the reference case for 2030, 5.7 tcf in the high growth case, and 7.5 tcf in the low price case.
Wind	1.2	-70	Additional 50 GW capacity from wind farms.	• DOE reports wind farm capacity of 11.6 GW in 2006. EIA forecasts a total of 18 GW capacity by 2025 in their reference scenario, although this seems unrealistically low. • In contrast, the American Council on Renewable Energy (ACORE) estimates that wind could provide 248 GW of power capacity in the U.S. by 2025. (Joint Outlook on Renewable Energy)

Energy Option	Energy (EJ)	CO_2 (MMT)	WRI Assumptions, Compared to Business as Usual (BAU) in 2025	Other Studies/Forecasts
Building Efficiency	1.8	-110	Savings of 1.8 QBtu from an additional 5% increase in the efficiency of electricity use and 2% in the efficiency of building natural gas use.	• A study by ACEEE estimates that the median achievable potential across a number of state studies was 24% for electricity, which could be achieved at an average of 1.2% per year. They suggest a total potential of lowering national energy use through energy efficiency by 33% in 2020. • ACEEE also reports that a DOE study estimated that increasing energy efficiency throughout the economy could cut national energy use by about 20% in 2020.
Solar Photovoltaics	0.3	-15	Additional 16 GW capacity from solar photovoltaics, which assumes an annual growth rate of 25% through 2025.	• EIA reports 2005 capacity at roughly 0.21 GW producing 2,700 GWh of electricity. • EIA forecasts 2025 capacity at roughly 1.53 GW producing 3100 GWh of electricity. Annual growth rate for solar PVs is 23% in the electric power sector and 11% in all other sectors (where the most of the current capacity is). • A study by NREL (PV Roadmap) proposes a goal of attaining a 25% annual growth rate for PVs to 2020.
Ultra-Supercritical Coal	0.8	+25	Additional 15 GW of ultra-supercritical pulverized coal (PC) plants achieving 45% efficiency (HHV). (15-30 new plants).	• EIA forecasts 35 GW of new supercritical pulverized coal (PC) plants 2020, and 79 GW by 2030 in the reference scenario. • NETL reports that in the next 10 years, 159 new coal based plants are expected to come online. Of these new plants 14 are expected to use supercritical PC and 4 to use ultra-supercritical PC combustion technology for their operations, with a total capacity of approximately 16 GW.

Energy Option	Energy (EJ)	CO_2 (MMT)	WRI Assumptions, Compared to Business as Usual (BAU) in 2025	Other Studies/Forecasts
Transport Sector				
Raise CAFE (30 MPG LDV fleet average)	6.3	-410	Savings of 3.1 million barrels per day (mb/d) or 48 billion gallons (bgal) from an increase in CAFE or similar measure that results in an average achieved fuel economy of 30 MPG for light duty vehicles (versus about 20 MPG today). Light duty vehicles include passenger cars and light trucks under 8,500 lbs. EIA forecasts that the MPG for LDVs will increase from 19.6 in 2005 to 21.8 in 2025 in the reference scenario. EIA forecasts vehicle miles traveled (VMT) at 3.8 trillion in 2025. If that LDV fleet averages 30 MPG instead of 21.8 MPG, this savings would result.	• CAFE currently is set at 27.5 MPG for new cars, although the average achieved fuel economy for the LDV fleet is roughly 20 MPG (EIA). • The Ten in Ten Fuel Economy Act (S.357) introduced by Senator Feinstein (D-CA) would require new cars and light trucks to get 35 MPG in 2019. The Union of Concerned Scientists estimates that this would save 2.3 mb/d or 35 bgal of gasoline in 2027. • The Fuel Economy Reform Act (S.767) introduced by Senator Obama (D-IL) would push for an increase in CAFE of roughly 4% per year beginning in 2013. The sponsors of a similar bill submitted in 2006 estimated that it will save a cumulative total of 549 bgal by 2028.
Expanded Oil Imports	2.0	+5	Additional 1.0 mb/d (15 bgal) of additional oil imports, roughly an 8% increase in imports.	• EIA reports 22.1 QBtu (23 EJ) of crude oil imports in 2005. They forecast annual imports at 28.6 QBtu (30.2 EJ) in the reference scenario, 33.2 QBtu (35 EJ) in the high economic growth case.
CTL	1.5	+85	Additional 0.75 mb/d (11 bgal) from “coal-to-liquids” (CTL). Assumes 85% more carbon intensive than petroleum.	• EIA assumed 0.9 QBtu for the reference case in 2030, 3.5 QBtu in high price case. This is a difference of about 2.7 EJ, or 20 bgal.
CTL with CCS	1.5	+25	Additional 0.75 mb/d (11 bgal) from “coal-to-liquids” (CTL). Assumes 85% more carbon intensive than petroleum and 70% of process emissions sequestered.	• EIA assumed 0.9 QBtu of traditional CTL (no CCS) for the reference case in 2030, 3.5 QBtu in high price case. This is a difference of about 2.7 EJ, or 20 bgal.
GTL	0.2	+5	Additional 0.1 mb/d (1.5 bgal) from “gas-to-liquids” (GTL). Assumes 25% more carbon intensive than petroleum.	• EIA assumed no production in the reference case in 2030, 0.15 QBtu in high price case, a difference of about 0.16 EJ, or 1.2 bgal.

Energy Option	Energy (EJ)	CO_2 (MMT)	WRI Assumptions, Compared to Business as Usual (BAU) in 2025	Other Studies/Forecasts
Corn Ethanol	0.7	-10	Additional 0.5 mb/d (8 bgal). Assumes better technology and additional land used for corn can expand yield to 20 bgal. Assumes that corn ethanol reduces CO_2 emissions by 15% compared to petroleum, and has a 30% lower energy density.	• EIA reports ethanol consumption in 2005 at about 4 bgal, and forecasts about 12 bgal in 2025. • EPAct 2005 mandates 7.5 bgal of renewable fuels by 2012. • In his 2007 State of the Union Address, President Bush called for 35 bgal of “renewable and alternative fuels” in 2017. • Senators Lugar (R-IN) and Harkin (D-IA) introduced the Biofuels Security Act in May 2006, which would set a renewable fuels standard of 30 bgal per year by 2020 and 60 bgal by 2030. • A study by Alex Farrell *et al* finds that corn ethanol reduces GHG emissions by 13% compared to petroleum (*Science*, January 2006).
Cellulosic Ethanol	0.4	-20	Additional 0.3 mb/d (5 bgal). Assumes lower costs for cellulosic ethanol and higher oil prices. Assumes that cellulosic ethanol reduces CO_2 emissions by 80% compared to petroleum.	• EIA forecasts roughly 5 bgal of cellulosic ethanol produced in 2025 under a scenario of lower capital and operating costs and high energy prices. • The National Commission on Energy Policy estimates that the U.S. could produce 2.2-4.1 mb/d (34 to 63 bgal) of cellulosic ethanol by 2025.
Heavy Oil Imports	1.0	+35	Additional 0.5 mb/d (8 bgal) from heavy oil imports from primarily Canada and Venezuela. Assumes 50% more carbon intensive than traditional petroleum.	• EIA forecasts that the U.S. will increase annual imports of unconventional oil from Canada and Mexico from 1.1 to 3.3 mb/d (17 to 50 bgal) by 2025. • Wood MacKenzie forecast that Canada will increase oil sands production from 1 to 4 mb/d (15 to 60 bgal) by 2020.
CO_2 EOR with CCS	1.0	-25	Additional 0.5 mb/d (8 bgal) from “enhanced oil recovery” production from domestic sources using carbon dioxide as a stimulant.	• DOE reports that about 3 bgal was produced by CO_2 EOR in 2004, and that total potential for all types of EOR in the U.S. is 210 billion barrels. • A DOE/NETL analysis forecasts that CO_2 EOR oil production could quadruple by 2020 with CO_2 incentives.
Expanded Domestic Oil Production	0.6	<5	Additional 0.3 mb/d (5 bgal) production from domestic oil and natural gas sources previously considered “off-limits”.	• EIA forecasts that removing drilling restrictions from the outer continental shelf of the lower 48 states would yield 0.2 mb/d or roughly 3 bgal. • EIA forecasts that if technology advances in the oil industry occur more rapidly than expected, domestic crude oil production could increase 0.3 mb/d in 2030.

Energy Option	Energy (EJ)	CO_2 (MMT)	WRI Assumptions, Compared to Business as Usual (BAU) in 2025	Other Studies/Forecasts
Frozen MPG	2.6	+170	Assumes a policy weakening CAFÉ is adopted, resulting in no increases in vehicle efficiency from 2005 levels (~20 MPG). Additional 1.3 mb/d (20 bgal) of fuel is required.	• EIA forecasts travel by LDVs to increase 45% from 2005 to 2025, and average vehicle efficiency to increase from 19.6 to 21.8 MPG. This bubble assumes that the vehicle-miles traveled and the efficiency remain unchanged from today.
Plug-in Hybrid Electric Vehicles (PHEVs)	0.5	-15	Additional 0.3 mb/d (4 bgal) oil offset by 6 million vehicles. 30,000 PHEVs on the road in 2009, 40% annual growth rate yields about 6 million vehicles in 2025. Assumes that 50% of the needed power requires addition power plant operation (and the remaining 50% would be "free" from off-peak generation that occurs anyway).	• A study by NREL estimates that a high level of market penetration by PHEVs could be obtained with advances in technology, reductions in costs, high oil prices, policies to promote energy security, and carbon constraints. In this high case, they forecast 80 million PHEVs on the road by 2025. PHEVs introduced in 2008 and achieve a 50% market share of the light-duty vehicle stock by 2050. • A study by EPRI assess the potential impacts of 25 million PHEVs in 2025 and 70 million in 2050.

Notes:
- Energy (EJ) values for the power sector options are equivalent to what would have otherwise been consumed by coal power plants to generate an equivalent amount of electricity (1 EJ or exajoule equals 10^18 joules).
- Energy values for the transport options are equivalent to the amount of petroleum that would have been consumed.
- CO_2 (MMT) are the estimated reductions (-) or increases (+) from each policy option in million metric tons of CO_2.
- A gigawatt (GW) is one billion watts of electric generating capacity, roughly equivalent to that of a typical large power plant.
- The U.S. currently consumes roughly 21 million barrels of crude and petroleum products per day (315 bgal), about 65 percent of which is imported.

General assumptions for power sector options:
- Coal consumed in the electric power sector has an energy content of approximately 23 MJ per mt.
- Capacity factors of 85% for nuclear, 75% for coal and natural gas, 30% for wind.
- Efficiency factors in 2025 of 41% for subcritical pulverized coal, 45% for ultra supercritical pulverized coal, and 61% for natural gas combined-cycle plants.
- A 1 GW coal plant emits about 5.6 million metric tons of CO_2 ($MMTCO_2$) per year.
- The electric power sector will emit an average of 530 metric tons of CO_2 per GWh produced in 2025 (EIA).

General assumptions for transport sector options:
- Fuel consumed in the transport sector (primarily motor gasoline and diesel) has an energy content of 5.7 MJ per barrel.
- 12.5 bgal of ethanol is roughly equivalent to 1 EJ.
- One mb/d is equivalent to 15.3 bgal per year.
- The transport sector will emit an average of 65 $MMTCO_2$ per EJ consumed in 2025 (EIA).

Energy Security Assessment

Each option was assessed based on an expanded definition of energy security, which includes elements of sufficiency, reliability, affordability, sustainability, socially acceptance, and geopolitically factors. Most options in the transport sector offset imports of foreign oil, and thus have relatively higher energy security benefits.

Table 2. Energy Security Implications of Each Option

Energy Option	Discussion
Electric Power Sector	
Nuclear	*Positive:* Very low air emissions, especially CO_2; high availability; diversifies fuel supply. *Negative:* expensive; low social acceptability; waste disposal barriers; potential terrorist target, nuclear proliferation.
Clean Coal (IGCC) with CCS	*Positive:* Coal is sufficient, reliable and affordable as currently priced. IGCC largely overcomes criteria pollution concerns. *Negative:* IGCC with CCS is expensive and social acceptability is uncertain; need for new CO_2 transport infrastructure and safety regulations at storage sites, environmental problems associated with mining.
Imported LNG	*Positive:* Relatively clean burning; combined-cycle plants quick to build. Significant new supplies coming on-stream around the globe. *Negative:* increases exposure to global uncertainty; relatively expensive; import terminals and tankers are potential security threats.
Wind	*Positive:* Constant fuel costs; clean; diversifies energy supply; high national social acceptability. *Negative:* power generation not always available (capacity factor of roughly 30%); some local opposition (NIMBY); currently depends on production tax credit.
Building Efficiency	*Positive:* Sufficient, reliable, affordable, sustainable, and socially acceptable. *Negative:* does not offset oil imports; mixed political support.
Solar PV	*Positive:* Constant fuel costs; clean; diversifies energy supply; high national social acceptability. *Negative:* power generation not always available (capacity factor of roughly 20%); currently relies on tax subsidies.
Ultra Supercritical Coal	*Positive:* Coal is sufficient and reliable; ultra-supercritical is relatively efficient, and becoming more commonly used in Europe and Asia; *Negative:* relatively expensive and polluting; somewhat tarnished perception in the U.S. from historical experience.
Transport Sector	
Raise CAFE (30 MPG LDV fleet average)	*Positive:* Offsets oil imports from and wealth transfer to unstable nations; cumulative impacts build throughout fleet turnover; affordable. *Negative:* Mixed political traction.
Expanded Oil Imports	*Positive:* Still relatively affordable compared to alternative fuels. *Negative:* Increases reliance on uncertain global system; wealth transfer to other nations; postpones inevitable transition to a less-petroleum-intensive future.
CTL	*Positive:* Offsets oil imports from unstable nations. Coal is sufficient. *Negative:* expensive; significant climate and sustainability concerns.
CTL with CCS	*Positive:* Offsets oil imports from unstable nations. Coal is sufficient. *Negative:* expensive; significant climate and sustainability concerns; social acceptability of CCS is uncertain; need for new CO_2 transport infrastructure and safety regulations at storage sites.
GTL	*Positive:* Offsets oil imports. *Negative:* increases reliance on natural gas, much of which is from the same regions; relatively energy intensive; energy penalty.

Energy Option	Discussion
Corn Ethanol	*Positive:* Offsets oil imports; diversifies energy supply. *Negative:* Decreased food security, limited land availability, increased fertilizer and water use; energy intensive process.
Cellulosic Ethanol	*Positive:* Offsets oil imports; can be grown in many regions without impacting food production, fertilizer and water use; and auxiliary energy requirements. *Negative:* Not yet commercial.
Heavy Oil Imports	*Positive:* Offsets oil imports from unstable nations if imported from Canada; sufficient, reliable. *Negative:* currently expensive; energy intensive; serious sustainability issues.
CO_2 EOR with Carbon Sequestration	*Positive:* Offsets oil imports; allows otherwise-unlikely domestic oil production; can make good use of otherwise-polluting CO_2. *Negative:* currently limited in application; CO_2 transport infrastructure needed; concern about additionality.
Expanded Domestic Oil Production	*Positive:* Offsets oil imports; reduces wealth transfer. *Negative:* Low social acceptability; remaining resources are limited and relatively expensive to access.
Frozen MPG	*Positive:* May favor domestic carmakers. *Negative:* Increases oil imports and wealth transfer to other nations, increases need to expand domestic oil production, postpones inevitable transition to a less-petroleum-intensive future.
PHEVs	*Positive:* Offsets oil imports; affordable fuel; can be low-carbon alternative if grid has low carbon mix; can capture otherwise lost energy in off-peak generation. *Negative:* Batteries expensive and not yet commercial; can have little climate benefit if grid is largely coal-based.

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Background Information on the
Energy and Technology Choices

For more information, go to www.wri.org/usenergyoptions.

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Background Information for *Climate Change and Energy Security Impacts and Tradeoffs*

Cellulosic Ethanol

Source: Union of Concerned Scientists

Cellulosic ethanol is produced by breaking down complex sugars in plant material into simple sugars using an enzymatic process, and then fermenting the simple sugars to create ethanol. The end-product is identical to grain-based ethanol and can be used as an alternative fuel for transportation. Since cellulose is a primary building block of green plants, a wide variety of grasses and trees can be used as feedstock. Common candidates include fast growing trees and grasses such as switchgrass, corn stover, and grain straw. Cellulosic ethanol is an attractive carbon mitigation and energy security option because resource inputs and local environmental impacts are low compared to grain-based ethanol. There are several demonstration plants around the world, but no commercial plants operate yet.

From a climate perspective, cellulosic ethanol holds great potential to reduce emissions from transportation fuels. The U.S. Department of Energy believes that cellulosic ethanol can reduce lifecycle greenhouse gas emissions by roughly 80 percent compared to traditional gasoline. This is because the portion of the plant that can not be fermented—the lignin fibers—can be burned to generate the heat and power needed during the conversion process, displacing the carbon-intensive coal and natural gas that is used for processing grain ethanol. Grain ethanol's dependence on those fossil fuels results in a modest 10-20 percent reduction in GHG emissions compared to gasoline. Carbon capture could be employed during ethanol production to further reduce GHG emissions.

Cellulosic ethanol holds many of the same energy security benefits as grain ethanol–reducing dependence on foreign oil, diversifying energy supply, and decreasing the environmental impacts associated with the production and use of fossil fuels. However, much less land may be needed for cellulosic ethanol then grain ethanol, as cellulosic crops have the potential to yield about twice the energy per acre. From an energy-balance standpoint, as mentioned above, fewer fossil fuels are required to produce cellulosic ethanol than grain-based ethanol. Further, the diversity of crops that can be used greatly expands the potential to produce cellulosic ethanol across the U.S.

Despite great potential and many advocates, little cellulosic ethanol production capacity exists today. The primary challenges to widespread use of cellulosic ethanol are the high costs and complexity of the enzymatic process, and the high capital costs associated with financing new and untested technologies. While there have been significant advances in enzyme development in recent years, overall costs are still roughly twice that of producing grain ethanol. The Energy Policy Act of 2005 provides a number of incentives for cellulosic ethanol production, and requires the production of 250 million gallons by 2013. Concerns about grain ethanol's impacts on food security, local environmental quality and relatively minor GHG improvements should generate ongoing support for cellulosic ethanol.

Corn Ethanol

Source: U.S. DOE

U.S. investment in corn ethanol has surged over the past few years due to high oil prices and growing concerns over rising petroleum import dependency. Grain ethanol is produced from the distillation of crops such as corn, barley and sugarcane that contain starches or sugars. It is typically blended into gasoline as E10 (10 percent ethanol) to improve octane levels and reduce vehicle pollutants. The world currently produces enough ethanol to displace roughly 2 percent of total gasoline consumption. Brazil is the world's largest exporter of ethanol, and its sugarcane industry supplies 40 percent of their transportation fuel.

While ethanol has been around since the 1800s, it gained popularity in the 1970's during the OPEC oil disruptions. Ethanol has enjoyed renewed popularity as a replacement for both lead and methyl tertiary-butyl ether (MTBE)—less-than-ideal gasoline additives meant to improve combustion. The recent spike in oil prices, and resulting sense of energy insecurity, has created further momentum for ethanol use. Over one-third of the gasoline pumped in the U.S. now contains at least some ethanol, although it offsets only a few percent of the total gasoline used. The other common ethanol blend, E85 (85 percent ethanol), requires special engine modification and can only be used in flexible fuel vehicles (FFV).

Corn ethanol has some lifecycle greenhouse gas benefits compared to regular gasoline. The general consensus among researchers is that corn ethanol provides a lifecycle 10-20 percent reduction in greenhouse gases compared to traditional gasoline, although outlying estimates also exist. The fermentation process requires significant energy input, often in the form of coal or natural gas. Finally, growing the crops that can be converted to ethanol often carries a significant local environmental penalty in terms of water, fertilizer, and pesticide use.

Ethanol production has grown by roughly 30 percent annually in the U.S. recently. Federal subsidies since 1978 have allowed production costs to remain competitive with gasoline, with the current tax credit at 51 cents per gallon. In 2005, 4 billion gallons of ethanol were produced in the U.S. The Energy Policy Act of 2005 requires almost doubling that production to 7.5 billion gallons a year by 2012, and numerous energy legislation proposals in Congress have called for up to 60 billion gallons of "renewable fuels" by 2030.

A major barrier to expansion of grain ethanol in the U.S. is the amount of corn required. Already, 10-20 percent of the nation's corn harvest goes to ethanol production. If more corn is used for ethanol, we will likely see higher prices for commodity crops, higher prices for livestock and other processed goods that rely on commodity crop inputs, fewer commodity crop exports, and more land dedicated to cultivation. Although recent advances have made ethanol production more efficient than in years past, other major cost-reducing breakthroughs are not expected. Another barrier to greater use of grain ethanol is that while there are more than 4 million FFVs on the road, most E-85 stations are in the Midwest, and developing a nationwide infrastructure of service stations will be necessary for large-scale penetration.

Background Information for *Climate Change and Energy Security Impacts and Tradeoffs*

Expanding Domestic Oil and Natural Gas Production

Source: NETL

Domestic U.S. oil production peaked in 1970 and has declined steadily since. Currently, the U.S. is able to meet one-third of its petroleum demand with domestic resources, and imports the remaining two-thirds. Domestic crude oil reserves are estimated at around 22 billion barrels, mostly found in Texas, the Gulf of Mexico, Alaska, and California. For comparison, global reserves are estimated at 1.1 to 1.3 trillion barrels.

U.S. natural gas production is also near its peak, but domestic production continues to meet over 80 percent of demand. The remaining imports come by pipeline from Canada and Mexico, and as liquefied natural gas at 4 major import terminals. While global natural gas reserves are thought to be over 170 trillion cubic meters (TCM), domestic reserves amount to only 5.6 TCM.

Both oil and natural gas contribute to climate change by forming carbon dioxide during combustion. Natural gas emits only about half, and oil about two-thirds, the carbon dioxide per unit of energy as coal. The greenhouse gas profiles of imported oil and gas resources compared to their domestic counterparts are roughly similar. In some cases, imports may result in slightly higher emissions since they are often transported a greater distance. In other cases, however, carbon-intensive infrastructure may be needed to deliver domestic oil and gas to U.S. markets. Oil from the Trans-Alaska pipeline, for example, almost certainly has higher lifecycle greenhouse gas emissions than oil from Canada or even Nigeria.

Other environmental concerns related to oil and natural gas production and transport include: spills, leaks, explosions, and damage to natural habitats. While improved exploration and drilling practices have dramatically reduced local environmental impacts, oil and gas production in pristine areas remains an invasive activity. Refineries that convert crude oil into valuable petroleum products have more concentrated environmental and safety impacts.

Exploiting domestic sources of oil and natural gas helps reduce the amount of oil that the U.S. must import. However, the amount of domestically available oil is limited and the public often opposes drilling in sensitive areas. Furthermore, domestic oil and gas is usually more expensive than imports. When oil and natural gas prices are high, pressure increases to open exploration and drilling in lands previously considered off-limits, such as the Arctic National Wildlife Refuge and many offshore areas. For example, offshore drilling along in the eastern Gulf of Mexico and along the east and west coasts has been prohibited since 1980. Late in 2006, however, Congress voted to open 8.3 million acres to drilling in the Gulf of Mexico that had been previously protected under the ban.

Background Information for *Climate Change and Energy Security Impacts and Tradeoffs*

Liquefied Natural Gas

Source: Wave Dispersion Technologies, Inc

Natural gas accounts for over one-fifth of global energy use. Where pipelines are unfeasible, natural gas can be transported economically by lowering its temperature and increasing pressure until it becomes a condensed liquid. A global market for liquefied natural gas (LNG) has existed since the 1970s. Strong growth in LNG markets is expected to continue as both new producers and consumers emerge, and terminal infrastructure costs continue to decline.

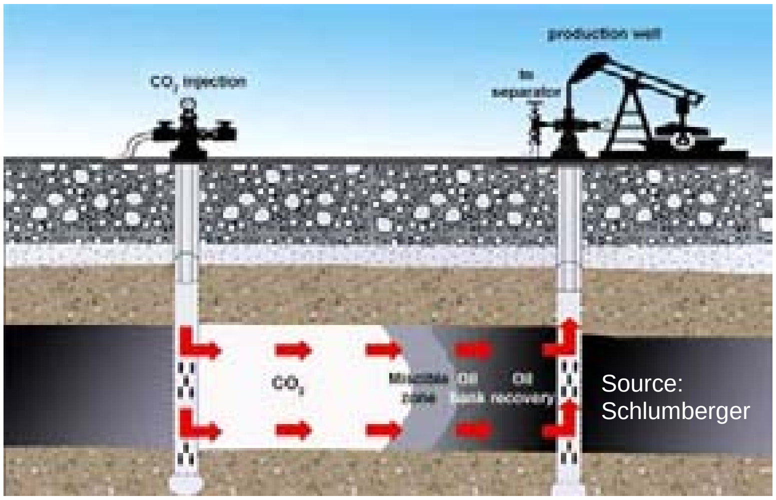
Natural gas offers distinct greenhouse gas benefits compared to coal and oil, although some of that benefit is lost due to the energy penalty of converting the gas to liquid form and vise-versa. A carbon value of perhaps $20 to $40 per ton of CO_2 would provide powerful incentives to switch from coal to natural gas in electricity generation. Natural gas also has significant criteria pollution (oxides of sulfur and nitrogen, particulates, and carbon monoxide, for example) benefits compared to other fossil fuels.

Considerable uncertainty surrounds the future of liquefied natural gas in the United States. Natural gas production in the U.S. peaked in the early 1970s. While prices remained low for much of the 1980s and 1990s, recent price instability reflects supply uncertainty. Key variables surrounding future markets for LNG in the U.S. include:

- Climate change and environmental policies that will impact relative pricing of fuels
- LNG demand in key Asian and European markets
- Investment constraints in building new LNG liquefaction terminals in key gas producing countries such as Qatar, Nigeria, Russia, Iran, Algeria, Trinidad and Tobago, and others
- Public response to the siting and safe operation of LNG import terminals
- Developments of alternative technology, including “clean” coal, renewable, nuclear power, and gas-to-liquid (GTL) fuels

Global LNG trade is now expanding rapidly, and the U.S. appears set for rapid demand growth as well. The U.S. Energy Information Administration forecasts that U.S. LNG imports are projected to increase nearly 8-fold by 2030. While global markets are expected to increase in flexibility, there are very real concerns about energy security and relying on a small group of producers to provide the fuel.

CO_2-Enhanced Oil Recovery



Source: Schlumberger

Only a small percentage of the petroleum in most oil fields can be recovered economically. One option to increase oil recovery is to pump CO_2 into the reservoir to improve the flow of remaining oil through the pore space. After the oil-CO_2 mixture reaches the surface, the CO_2 is separated from the oil and recycled back to the reservoir. A side-effect of enhanced oil recovery is that a portion of the CO_2 that was used to force oil out of the formation is sequestered in the reservoir's pore space. CO_2-EOR is currently used to optimize oil production, but can also be adjusted to boost the amount of carbon dioxide that stays sequestered in the reservoir.

CO_2 has been used in the Permian Basin of Texas for three decades to enhance oil recovery. Most of the CO_2 is supplied from natural sources in Colorado and New Mexico via pipeline, so there are currently few climate benefits in the process. But an experienced industry has developed and is capable of using anthropogenic CO_2 (captured from fossil fuel burning power plants and industrial processes) for the same purpose. A large-scale coal gasification plant in North Dakota is currently capturing its CO_2 and piping it to Weyburn, Canada where it is used for enhanced oil recovery. Other large anthropogenic CO_2-EOR projects are under development.

Currently, CO_2-EOR is used to produce about 250,000 barrels per day of oil in the U.S. that might otherwise not exist. A recent study by Advanced Resources International states that an additional 4 to 47 billion barrels of domestic resources could be economically recovered using CO_2-EOR. The study notes that at least 8 billion tons of CO_2 could be sequestered in the U.S. by using EOR. The carbon abatement cost of CO_2-EOR varies according to field and the price of oil; in some cases in can have negative costs according to Battelle Memorial Institute.

Currently, regulations exist to govern CO_2-EOR activities in order to prevent ground water contamination. However, there are no regulations to govern CO_2-EOR activities operating with the purpose of permanently sequestering CO_2. If and when the U.S. enacts a climate policy that requires CO_2 mitigation, new standards will need to evolve that allow measuring and crediting of CO_2 that is sequestered in oil fields. There are questions of "additionality" that must be addressed: some argue that the net climate impact of sequestering CO_2 in an EOR operation is marginal because of the extra oil that is produced and then combusted. Others argue that the oil would still be produced elsewhere. Other complex regulatory issues such as plant siting, injection criteria, remediation options, and liability concerns must be addressed before CO_2-EOR sequestration is widely deployed as a carbon mitigation technology.

Pulverized Coal Power

A Pulverized Coal Plant in Indiana U.S, Source: Foster Wheeler

Pulverized coal power plants first appeared in the 1920s and serve as the backbone of the power sector in the U.S. They currently supply over half of U.S. electricity. While vastly improved over the past 80 years, pulverized coal remains a relatively simple technology, converting a little more than one-third of the fuel's energy potential into useful electricity.

Pulverized coal power generation starts by crushing coal into a fine powder that is fed into a boiler where it is burned to create heat. The heat produces steam that is used to spin one or more turbines to generate electricity. Subcritical plants make up the bulk of the U.S. pulverized coal system, with efficiencies for new plants usually around 37 percent. Supercritical plants use higher pressure and temperatures to boost efficiency to 40 percent or more. Ultra-supercritical, using still higher pressures, achieves 42-45 percent efficiency. Europe and Asia lead in the deployment of the most advanced pulverized coal systems, although they are gaining renewed attention in North America as well. Carbon dioxide can be captured from the exhaust plume of pulverized coal plants and then sequestered in geological formations, but this process is relatively expensive, especially for retrofit applications.

Pulverized coal power plants have gained renewed interest this decade due to surging natural gas prices. The levelized cost of electricity generated at most pulverized coal plants in the U.S. is currently less than that of natural gas combined-cycle plants. While the capital costs of gas-fired combined-cycle units are only half that of pulverized coal, the fuel costs are much higher and often unstable. Utilities pay special attention to predictability of prices and currently shy away from high and unstable natural gas prices. Moreover, as domestic production of natural gas is limited, further additions to gas-fired power generation would require more imported liquefied natural gas, and exacerbate energy security concerns.

Pulverized coal units have significant environmental concerns. Emissions of oxides of sulfur and nitrogen contribute to acid rain and ozone formation, and are dangerous to human and ecosystem health. Most plants have scrubbers to remove a portion of these gases from the exhaust plume, although power plant efficiency declines as a result. Other emissions include particulates, heavy metals such as mercury and arsenic, and carbon dioxide. Coal is the most carbon intensive fuel and contributes to global warming more intensely than any other source of energy. Given the enormous number of pulverized coal plants being added in China and India each year, we will likely need to find a way to retrofit existing plants to capture CO2 emissions. This is feasible, but will be expensive unless dramatic advances in technology are achieved.

Using domestic coal offers the impression that countries can insulate themselves from global energy insecurities, but the subsequent increase of greenhouse gas emissions can create an altogether different type of security problem.

Background Information for *Climate Change and Energy Security Impacts and Tradeoffs*

Coal-to-Liquids

Source: Sasol CTL plant in South Africa, Cleaner Coal Technology Program. London, UK

Coal-to-liquids (CTL) is a suite of technologies that convert coal to a liquid fuel such as synthetic diesel. Coal is a widely available, abundant, and relatively inexpensive form of energy. However, coal production constraints, infrastructure and externalized costs, and high greenhouse gas emissions may limit CTL's contribution to the U.S. goal of energy security.

CTL technologies were developed in the 1900's spurred by the necessity of domestic fuel production for Germany during WWII and for South Africa during its international isolation in the Apartheid era. Proponents argue that low-cost coal can make CTL products commercially viable when oil prices are high. During the high oil prices of the 1970's numerous additional techniques and processes were developed to more efficiently turn coal into liquid fuel. Currently, only South Africa, with plenty of coal but little oil and gas, uses CTL to meet a share of its transportation fuel needs. More importantly, CTL offers countries like the U.S. and China the perceived opportunity to insulate themselves from unstable international oil markets.

The major drawback of CTL technology, besides high cost, is the increased carbon dioxide emissions and high water requirements. Lifecycle CTL greenhouse gas emissions are nearly double those of conventional oil. Shifting any sizable portion of fuel usage to CTL necessitates a carbon mitigation strategy to ensure that climate objectives are met. Carbon capture and sequestration (CCS) can be used during CTL production, but would only offset a portion of the increased carbon emissions. Final greenhouse gas emissions using CTL with CCS would still be equal to or higher than using standard petroleum, while costs would rise significantly.

Some believe that CTL is economically viable when crude oil prices reach $35 per barrel or more, although this has not been demonstrated in transparent, commercial settings. Capturing a portion of the process-related CTL carbon dioxide and sequestering it underground would further increase costs. China is currently constructing several large CTL facilities and experimenting with a largely untested version of the technology (direct liquefaction). It is now widely acknowledged that China will have difficulty deploying CTL on a massive scale unless the issue of water usage is resolved (each gallon of CTL product requires 10 gallons of process water). In its "high scenario," the Energy Information Administration forecasts that 1 percent of U.S. oil needs will be met with CTL fuels in 2025. If oil prices increase dramatically or major breakthroughs in CTL technologies occur, CTL's potential to contribute could increase significantly.

Gas-to-Liquids

Aerial photo of the GTL plant at Escravos, Nigeria. Photo courtesy of Sasol Chevron

Gas-to-liquid, or GTL conversion, refers to technologies that create diesel fuel from a methane-rich feedstock such as natural gas. While offering certain environmental benefits, GTL production is limited by high investment costs and the uncertainty of natural gas prices.

Diversification of supply is a major tenet of the US energy security strategy. A significant share of natural gas is located outside of the Middle East, making GTL an attractive diversification alternative to oil. However, because 45 percent of the natural gas input is used in the conversion process from gas to liquid, the economics of GTL usually only make sense for inexpensive “stranded gas.” Stranded gas refers to gas that is uneconomic to develop due to transport distances or lack of infrastructure. The bulk of the stranded gas resources are also in politically less stable regions, and therefore use of these resources would do little to assuage U.S. energy security concerns.

Even stranded gas costs may not remain low enough to make GTL economically attractive. As the cost of LNG liquefaction terminals continue to decline and demand increases, the opportunity costs of stranded gas will rise. Currently, stranded gas prices remain low enough to make GTL projects possible. Global natural gas production is expected to peak about 15 years after oil does, so there will likely be a period of greater GTL technology deployment, some of which we are beginning to see now in places like Qatar and Malaysia.

A major environmental benefit of GTL fuel is that it is virtually sulfur-free, and has significantly lower emissions of carbon monoxide, hydrocarbons, nitrogen oxide and particulate matter then conventional petroleum products. However, GTL fuel lifecycle greenhouse gas emissions are approximately 25 percent higher than conventional oil. Carbon capture and sequestration (CCS) could be used during the conversion process to capture enough emissions to make GTL emissions less than those of conventional oil, but costs would further increase.

In general, converting natural gas to liquid petroleum products is becoming more competitive with conventional oil production as the conversion process improves and the benefits of clean synthetic diesel are priced into markets. But competition between liquefying natural gas for the power and industrial sectors, and converting it to a petroleum product for the transport sector will remain a key investment decision. For these reasons, the Energy Information Administration forecasts a relatively minor 0.2 million barrels per day of production increase in its “high scenario” for 2030.

Wind Power

Source: NREL

Humans have used wind as a source of energy for thousands of years. Early windmills ground grain and pumped water. In the late 1800's, inventers designed windmills to produce electricity. However, their use declined during the Great Depression when rural electrification programs extended inexpensive grid electricity to rural areas. Today, wind power is again growing rapidly.

Wind is an abundant source of energy in the U.S. and can contribute to energy security by providing a low-cost, renewable supply. Good wind resources exist in almost every state and are theoretically capable of providing more than the total current electricity consumption of the U.S. Wind is the least expensive renewable energy source today and future technology developments are expected to lower costs further.

Investment in wind power has fluctuated over the past three decades according to changes in fossil fuel prices and government subsidies. When oil prices skyrocketed in the 1970's, investment in developing wind technology increased. Later, when prices fell, investment and development of wind energy slowed. In 2006, the United States total wind power capacity stood at just over 11 gigawatts. While this represent only 0.5 percent of our electricity consumption, the total installed capacity since 1999 has grown 5-fold.

Investment in wind energy is increasing rapidly for a number of reasons. First, federal and state tax credits subsidize wind power production by 1.9 cents per kilowatt-hour. State programs requiring utilities to allow for net metering or to buy back renewable energy production from individuals has also spurred investment. State renewable portfolio standards that require a certain percentage of the electricity to come from renewable resources have also increased investment in wind energy. Demand for wind power has also increased due to public concern over global warming and some utilities allow consumers to choose to purchase renewable energy such as wind by paying a small additional monthly fee. Technology advancements which have lowered the overall cost of wind power and decreased maintenance and increased reliability, has also spurred investment.

The main benefit of wind power is that it does not produce nitrogen and sulfur oxides, particulates, and mercury—the pollutants responsible for acid rain and smog, amongst other environmental harms. It is also a carbon free energy source and therefore can help users meet carbon mitigation goals. Wind power also offers a boost to rural economies, where most wind resources are located. Finally, wind power has predictable fuel costs (zero) over the life of the project, something that many gas-fired combined-cycle operators wish for.

Because wind is not always available, it is not a good baseload power option. However, even without improvements to the power grid to allow transmission from windy regions to large power loads, wind can supply a much larger percentage of our electricity needs than it does today. Countries such as Denmark have shown it is possible to supply one-fifth of their electricity from wind without sacrificing reliability. The American Wind Energy Association estimates that up to 6 percent of the nation's electricity could be supplied by wind power by 2020. The U.S. Department of Energy, however, forecasts that wind will still only provide 1 percent of U.S electricity in 2025.

Background Information for *Climate Change and Energy Security Impacts and Tradeoffs*

Building Efficiency

Source: Natural Resources Defense Council

Residential and commercial buildings consume over one-third of all energy and two-thirds of all electricity consumption in the U.S. Building techniques and materials exist that can dramatically reduce building energy consumption. (See Center for Health and Healing at right with a 61 percent projected energy savings). For example, simply orienting windows to capture the sun's warmth during the winter and the use of appropriate overhangs to keep out the hot summer sun can reduce heating and cooling costs by half or more.

Unfortunately, most buildings do not take advantage of the significant energy savings available. Because buildings have life spans of 50 to 100 years or more, their poor efficiency has a long-lasting effect on energy needs.

While some states such as California have mandated efficiency standards for new buildings, there is no federal program that mandates efficient building practices for the private sector. In contrast, almost all of Europe has minimum building efficiency standards. There are, however, federal regulations which require federal buildings to comply with efficiency standards.

The Leadership in Energy and Environmental Design (LEED) rating system is the most widely used energy efficient building standard. Buildings are awarded points based on areas such as water efficiency, energy efficiency, renewable materials, and indoor environmental air quality.   Buildings which are LEED certified, then, offer more than energy efficiency, they also conserve water and other natural resources and provide a healthy space for occupants.

Building efficiency reduces the pollutants and greenhouse gases emitted into the atmosphere from electricity generation and other fossil fuel use. A study done in 2004[1] found that the costs of constructing energy efficient buildings were the same or only 2 percent more expensive to construct then their "business as usual" counterparts. This marginal increase in cost was recovered by the builders through faster sales and premiums. The owners of the buildings save many times over the increased costs through lower energy bills. Still, construction of energy efficient buildings is hindered by lack of regulations, inexperience of developers, and the fact that developers have to pay the up front cost, while it is the buyers who realize the significant savings. To address this issue, the federal and some state and local governments offer tax credits and other incentives to help offset increased capital costs.

The Energy Information Administration estimates that building energy usage could decline by 20 percent by 2025 if energy efficiency measures are adopted. Out of a toolbox of technologies that can make the U.S. more energy secure and reduce carbon emissions, building efficiency alone has the potential to save owners billions of dollars in energy costs each year.

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[1] Davis Langdon Adamson, "*Costing Green: A Comprehensive Cost Database and Budgeting Methodology*"

Nuclear Energy


Source: US DOE

Nuclear energy is the largest emission-free source of power generation in the U.S. It provides one-fifth of our electricity. There are 103 commercial nuclear reactors currently in operation in the U.S. The last commercial plant was commissioned in the 1970s after which the nuclear industry experienced major setbacks due to financial, regulatory and safety issues. More recent advances in nuclear technology, along with concerns over global warming, have set the stage for a possible revival of nuclear power.

Nuclear power was once famously described as “too cheap to meter”. After a partial meltdown at Three Mile Island in 1979 and complete meltdown and release of radioactive material at Chernobyl in 1986, nuclear power suffered a major setback. New safety measures and designs were enacted. Costs rose considerably, making nuclear power now “too expensive to justify” in most countries. South Korea, Japan, and a handful of other countries continued to construct nuclear power plants, but at a much slower pace.

Today, proponents of nuclear power believe that technological risks have been largely addressed. And while it can be argued that the actual risks of nuclear power are far lower than the perceived risks, and that coal-fired power plants have killed a far greater number of people than nuclear energy, most communities do not want nuclear plants nearby. No country has solved the issue of long-term waste disposal, and new fears have emerged in the post-9/11 world that nuclear plants will become targets for terrorists.

Besides public opposition, the revival of nuclear power depends on its cost competitiveness with other energy options. The levelized cost of nuclear power today is difficult to estimate since few plants are being built, but a recent study by MIT put it at 6.7 cents per kilowatt-hour, considerably higher then pulverized coal or natural gas plants. Still, nuclear power offers powerful carbon benefits and could become competitive with other options with a carbon value of $30 to $50 per ton of CO_2 avoided.

Improved nuclear power technology is under development with U.S. government funding. The Energy Policy Act of 2005 contains incentives to support existing plants and promote R&D for new nuclear plants. But public concerns over plant siting, safe operation and waste disposal are probably the biggest barriers that the nuclear industry faces before this source of carbon free electricity sees a true revival.

IGCC with Carbon Capture and Sequestration

Source: NETL, Wabash River IGCC plant

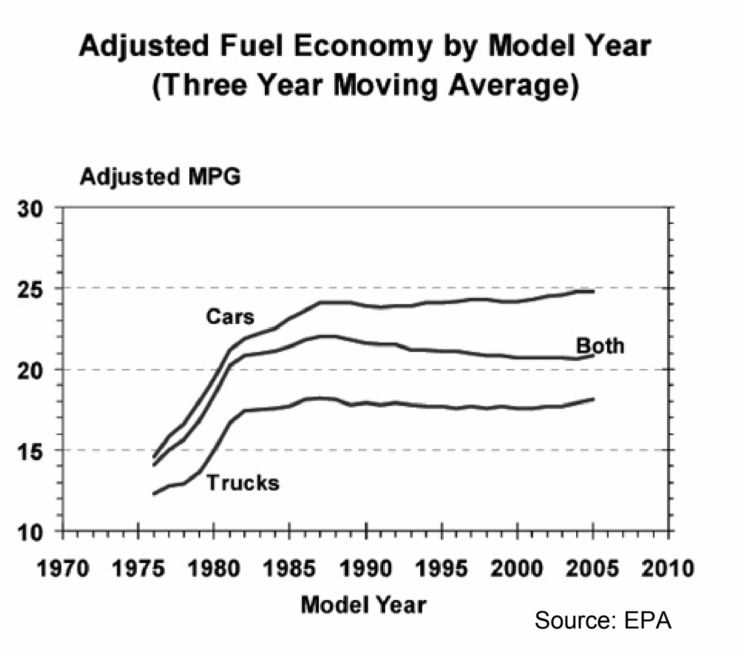
Integrated gasification combined cycle (IGCC) power plants use coal to produce electricity in a fundamentally different process than pulverized coal plants. The process starts by heating coal under pressure to create a methane-rich gas, which, after cleaning, can be used in a combined-cycle unit (gas and steam turbines) for efficient electricity generation. While there are several operational IGCC plants in the U.S., the technology is not yet considered commercial due to its higher costs and questionable reliability. These hurdles, some argue, could be overcome with more field experience. Importantly, IGCC plants offer significant reductions in criteria pollutants and the ability to capture carbon emissions more efficiently than at pulverized coal plants.

Without carbon capture and storage (CCS), IGCC plants are likely to offer, at best, a small reduction in carbon dioxide emissions compared to traditional pulverized coal. With CCS, IGCC plants could capture 85-95 percent of their emissions, which could then be injected into deep underground formations. A recent publication by the Intergovernmental Panel on Climate Change estimates that a carbon dioxide value of $50-75 per ton is required to overcome the added cost of IGCC with carbon capture. This corresponds to an increase in electricity prices of approximately 2-3 cents per kilowatt-hour. To test the technical and economic viability of combining IGCC with CCS, at least two initiatives, FutureGen and Zerogen, are underway, respectively, in the U.S and Australia. Slated for completion in 2012, these initiatives offer major learning opportunities.

U.S. utilities currently face difficult investment choices. Knowing that carbon constraints are no longer a question of “if” but of “when”, most forward-looking utilities seek to mitigate carbon liability risks in their investments decisions. Some would like to build IGCC plants now because of their environmental benefits and ability to capture carbon more easily, either immediately or at a later stage. But in most cases, a back-up gasifying unit is required for reliable operation of IGCC plants today. This spare gasifier raises capital costs and, combined with other uncertainties, makes investing in IGCC hard to justify in some jurisdictions. Clearly, providing greater certainty on the scale and timing of the looming climate policy would help utilities plan and invest more effectively. Without improved certainty, U.S. electric power security is threatened.

Other challenges besides high cost must be overcome before IGCC with CCS is to deploy more widely. Currently no regulatory framework exists to govern how CCS projects are done. How projects are sited, what monitoring must be done to ensure that carbon dioxide remains in specified reservoirs, how accounting is done to properly credit parties fairly, and how to design a financial responsibility system to deal with long-term liability remain unanswered questions. Ultimately, public acceptability of CCS also remains an issue.

Corporate Average Fuel Economy (CAFE)



Source: EPA

One proven way to improve energy efficiency in the U.S. transportation sector is the Corporate Average Fuel Economy (CAFE) program. The program was established by the Energy Policy and Conservation Act of 1975, and was one of the main forces behind a 35 percent increase in new vehicle (cars and light trucks) fuel economy between 1978 and 1985.[2] Without these improvements, the U.S. would be consuming an additional estimated 2.8 million barrels per day of gasoline, or about 25 percent of current demand.

While the CAFE program is not without controversy, it clearly achieved its goal of saving petroleum even in times of low gasoline prices. Since 1985, however, standards have not increased and there has been a slow, but steady decline in average vehicle efficiency.

The debate over raising CAFE requirements is a classic public policy issue that has been controlled by political interests. Done correctly, the economic costs of producing more efficient vehicles is quite manageable, despite the rhetoric voiced by U.S. manufacturers. In fact, a strong case has been made that Detroit's current financial problems are due to the fact that they were protected for too long through successful lobbying against higher CAFE requirements. There are some safety and consumer choice concerns that accompany an increase in CAFE requirements, but these are relatively minor given the overall national public interest of energy security and climate change.

Envelope-pushing revisions to the standards could again have a meaningful impact on U.S. liquid fuel consumption, although the effect would not be immediate. Replicating the success of the CAFE program from 1975, car mileage would need to increase from 27.5 mpg today to about 42 mpg in 2025. Light truck mileage would rise from 20.7 mpg today to 32 mpg by 2025. These new standards could save the country about 3 million barrels per day and reduce oil consumption by nearly one-quarter. Benefits from this policy action are the most cost-effective step the U.S. could take to improve energy security, stop the financing of radical terrorists, slash greenhouse gas emissions, and help make U.S. vehicle manufacturers more competitive.

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[2] Based on adjusted EPA sales-weighted data, and reduced by EPA to reflect the fact that cars or light trucks typically obtain only 85% of their tested fuel economy on the road. The fuel economy of cars alone increased more, but the shift to light trucks reduced the overall impact.

Plug-In Hybrid Electric Vehicles

Source: www.delta-q.com

A plug-in hybrid electric vehicle (PHEV) can operate on electric power for short trips without needing the liquid-fuel combustion engine. It thus offsets the need for liquid fuel by relying partially on the electricity grid. While liquid-fuel savings can be significant, the climate benefits of PHEVs depend on the local grid characteristics (coal/gas/nuclear/ renewables mix), when charging occurs, and the driving/recharging profile. As of 2007, no commercially-produced PHEVs were available to the general public.

Plug-in hybrids differ from traditional hybrids by having additional battery capacity and the ability to be recharged from an external electrical outlet. Depending on the size of the battery pack and other factors that typically affect fuel efficiency, PHEVs have an electric-only range of anywhere from 10 to 60 miles. The internal combustion engine is not needed for moderate speeds within this range, but is available for longer trips or if additional power is needed. Battery types include nickel-metal hydride (NiMH), currently used in all conventional hybrids, and lithium-ion (Li-ion). Li-ion batteries are smaller and lighter than NiMH, though they cost more and are not as safe or durable. When operating on liquid-fuels, PHEVs carry a weight penalty due to the relatively large batteries they carry.

The fuel and climate benefits of PHEVs are largely dependent on the amount of time the vehicle is using electricity instead of liquid fuel, which is further dependent on the electric-only range of the vehicle, trip duration, and recharging method. Climate benefits are additionally determined by the fuels used to produce the electricity, and whether excess capacity in the grid can be used. Due to this wide range of factors, estimates of the potential for plug-in hybrids to reduce CO_2 emissions compared to standard petroleum vehicles range from 10 to 60 percent. If users do not charge their cars during off-peak times, the climate benefits of PHEVs are reduced.

Operating costs in the electric-only mode are estimated to be roughly equivalent to around $1 per gallon of gasoline, much lower than liquid fuel vehicles. However, PHEVs have higher upfront costs (largely for the battery) of roughly $7,000-10,000 compared to traditional vehicles. Additional R&D is needed to develop long-lasting, efficient batteries.

PHEVs offer significant energy security benefits, as they offset oil consumption with mostly domestic sources of energy whenever battery power is used. Additionally, PHEVs can reduce air emissions in urban areas as they do not emit pollutants during the electric-only mode. Conversely, they can lead to increased mercury, sulfur, and other pollutants from coal-fired plants supplying additional electricity.

PHEVs are still an emerging technology today, primarily due to their high upfront costs and limited electric-only range. With advances in technology that increase this range and reduce battery costs, plug-in hybrid vehicles are likely to become more common.

Background Information for *Climate Change and Energy Security Impacts and Tradeoffs*

Heavy Oil and Tar Sands

Source: David Dodge, The Pembina Institute

Unconventional oil—which includes tar sands, heavy oil, bitumen, or shale oil—refers to any type of crude-like resource that does not flow easily and is hence difficult to produce. Remarkable quantities of heavy oil and tar sands are concentrated in Canada and Venezuela. The *Oil and Gas Journal* reclassified 174 billion barrels of Canadian oil sands to "established reserves" in 2002, catapulting the country to second behind Saudi Arabia in terms of total petroleum reserves. Venezuela's "extra heavy oil" could follow a similar reclassification soon, potentially adding another 235 billion barrels to its reserves, and making it the world's largest reserve holder. These two countries will likely play an important role in supplementing the eventual decline in conventional oil output. There are profound technical, economic, and environmental challenges to overcome, however, before these oil resources can play a more significant role in the global energy supply.

Canadian tar sands are currently produced by surface mining and *in situ* extraction, in roughly equal amounts. The former method, relying on massive earth-moving equipment and processing facilities, has limited future capacity since 80 percent of the oil sand resources lie deep underground and are not accessible to open pit mining. The latter method currently relies on energy-intensive steam injection and large volumes of natural gas. However, conventional natural gas production may have peaked in Canada, leaving policymakers scrambling to figure out how future needs will be met. Nuclear power plants could substitute for natural gas to produce the steam needed, but the oil sands still require natural gas during the refining process to upgrade the petroleum product to a marketable commodity. New technologies are under development to make the deeper-lying resources economically and physically accessible. The International Energy Agency expects that Canadian oil sands output will rise from 1 million barrels per day (mb/d) now to 5 mb/d in 2030.

Venezuela has equally massive reserves of heavy oil in the Orinoco Belt. Approximately one-quarter of Venezuelan's current crude output of 4 million barrels a day comes from heavy sources. This percentage is expected to rise as conventional resources decline and heavy oil recovery technologies improve. Currently, only a small percentage (5-10%) of original oil in place can be recovered economically. The World Energy Council believes Venezuelan heavy oil output will grow to 5.5 mb/d by 2030.

Greenhouse gas emissions associated with heavy oil production vary depending on location, oil quality (need for upgrading), and extraction method. Lifecycle emissions vary from roughly 15 percent above conventional oil use levels to over 50 percent or more. Carbon dioxide capture and sequestration could be applied to offset a portion of the extra greenhouse gas emissions from some heavy oil production, but it would add to costs. The local and regional environmental impacts of heavy oil and tar sands production can include: significant water consumption, massive earth moving and ecosystem disturbance, increased criteria and other air pollution, and release of heavy metals and toxic materials. New technologies have the potential to lower these environmental impacts, although they will likely remain substantially higher than conventional crude production.

Oil Imports

Source: Saudi Aramco

Petroleum has a wide variety of uses, from fuel for cars to wax for candles. The majority, however, is converted to motor gasoline and diesel fuel for use in cars, trucks, planes, ships, rail, and other forms of transportation. The U.S. currently accounts for one-quarter of the world's oil use, despite holding less than 2% of total global reserves. This discrepancy causes us to import the majority of our oil. In 2005, the U.S. imported over 13 million barrels per day (mb/d) of crude oil and petroleum products, roughly two-thirds of our oil needs. Almost 60% of this oil came from just five countries: Canada (2.2 mb/d), Mexico (1.7 mb/d), Saudi Arabia (1.5 mb/d), Venezuela (1.5 mb/d), and Nigeria (1.2 mb/d). According to *The Oil & Gas Journal*, over half of total global reserves are located in the Middle East.

The Arab oil embargo of 1973 led by the Organization of Petroleum Exporting Countries (OPEC) caused a major energy crisis in the U.S., triggering fuel shortages, long lines at the pump, and greatly inflated prices. Combined with other factors, these events led to an economy-wide recession, high unemployment, and widespread inflation. Reducing dependence on foreign nations for our energy supply quickly became a national priority. The enactment of fuel efficiency standards for cars and trucks (CAFE), establishment of the strategic petroleum reserve, a 55 mile-per hour federal speed limit, and expansion of daylight savings time all originated out of concerns to limit our dependence on foreign oil. New sources of energy were sought by expanding domestic exploration and production, and pursuing alternative fuels. Demand side management and end-use efficiency policies received enormous attention at the federal and state level. Energy security became an integral component to foreign policy, particularly in dealing with the Middle East. While powerfully effective during the initial years, support for these policies melted away as energy prices declined during the 1980s and 1990s. Today, we import more than twice as much oil as we did in the mid-1970s, and roughly 40% of our oil imports originate in OPEC countries.

Oil use has a number of environmental concerns. When fuels derived from oil are combusted, air pollutants such as CO, NO_x, and NMVOCs as well as CO_2 are emitted to the atmosphere. Cars and trucks now have sophisticated pollution control equipment such as catalytic converts to reduce emissions of local air pollutants. However, no cost-effective equipment can trap and reduce CO_2 emissions from vehicle tailpipes. Emissions from the transport sector, primarily from petroleum fuels, account for roughly one-third of all greenhouse gas emissions in the United States.

High oil prices, the possibility of peak oil, and our reliance on unstable nations are again inciting calls for the U.S. to move towards 'energy independence.' Today, there are a flurry of bills in Congress promoting energy security through initiatives promoting domestic oil production, alternatives such as coal-to-liquids, biofuels such as ethanol and biodiesel, and increased energy efficiency through CAFE or similar measures. However, our growing energy needs, the relative affordability of oil compared to alternatives, and a lack of access to remaining petroleum resources will likely cause the U.S. to continue relying on oil imports substantially in the near term.

Solar Photovoltaics

Source: NREL

Solar photovoltaics (PV) convert solar energy directly into electricity using a semiconducting material. Conventional crystalline silicon-based solar PV cells comprise the majority of this market today, though recent shortages of silicon have increased investments in alternative types of PVs such as thin film cells. Thin film technology is cheaper than silicon-based PV, but is currently less efficient.

Solar cells can be used in small products such as calculators and watches, or grouped into solar panels, which in turn can be assembled into arrays to meet greater energy needs (see figure). Larger applications include remote stand-alone systems, grid-connected systems for buildings, and large-scale power plants. The modular flexibility, ease of installation, low maintenance, and minimal environmental impacts make PVs attractive long-term prospects for mass production and application in many parts of the world. Solar PVs produce energy without emitting air pollution or greenhouse gases; thus, they are an important option to meet rising electricity demand in a carbon-constrained world. There are some environmental and human health concerns associated with chemicals, such as cadmium and arsenic, used in the manufacturing process. However, these hazards can be minimized with proper handling and safety precautions.

According to the Solar Energy Industries Association (SEIA), global PV market growth has averaged 25 percent annually over the last 10 years, with worldwide growth rates for the last 5 years well over 35 percent. Despite this rapid growth, PVs still account for a small percentage of global electricity generation. Deployed PV systems around the globe totaled approximately 5,000 megawatts of capacity in 2005. One of the primary reasons for limited diffusion of PVs is high costs, particularly for grid-connected systems. Capital costs have declined significantly since the 1970s from $30-35 per watt to $4-5 per watt today. Nevertheless, PVs are not yet competitive with grid connected systems. The intermittent nature of this power is an additional hurdle; off-grid systems require back-up power or battery storage, increasing overall costs.

The main challenge facing the solar industry today is to improve the efficiency of PV systems while making costs comparable to other electricity generating technologies. Solar PVs are gradually becoming popular, particularly for small off-grid applications. Japan and Germany are leading the way with robust national incentive policies, despite inferior sunlight availability. In the United States incentives are being provided by states to buy down the costs of PV installation. California’s Million Solar Roofs Program, with a goal to create 3,000 megawatts of new solar installations by 2017, is a significant step in promoting the abundant resource. With technological innovation, coherent policies and further cost reductions, solar photovoltaics will play an increasingly important role in meeting our energy needs.