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ENERGY SECURITY AND CLIMATE CHANGE
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# Weighing U.S. Energy Options: The WRI Bubble Chart

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**Summary**

Concerns about energy security in the United States are not new. The current environment of high prices and uncertain supply is different from earlier crises, however, due to the widespread recognition that climate change needs urgent attention and that conventional global oil production may soon peak. There is also concern in the United States that some post-9/11 oil revenues are fueling global instability. U.S. policymakers have responded by promoting a variety of measures to address at least one of the challenges of energy security and climate change. These challenges are linked, however, and there are often unintended consequences when one is addressed without fully considering impacts on the other. WRI has produced the **"bubble chart"** on page 3 to help inform the debate over the choices at hand. A complete description of the issues discussed in this policy brief is available at www.wri.org/usenergyoptions.

Energy security is, yet again, a key political issue in the United States. Unlike earlier energy crises, the current period of high prices and supply uncertainty is not the direct result of a major supply disruption. Instead, strong global oil demand coupled with shrinking upstream investment opportunities and limited refining capacity have contributed to relatively high crude and refined product prices. And unlike earlier times when oil and gas alternatives were prominent on the U.S. legislative agenda, policymakers today face the looming impacts of climate change and "peak oil" production. Indeed, it now seems certain that climate change and energy security are two of the greatest challenges the global community faces in the 21st century.

Energy policies designed to address one of these challenges alone can have unintended and often negative consequences on the other. Converting coal into a liquid for transportation fuel, for example, can help offset the need to import petroleum. But this option introduces serious climate and environmental sustainability challenges. Alternatively, shifting from coal to natural gas in the power sector to reduce GHG emissions would likely elevate energy insecurity because of the expanded reliance on limited gas producers and a more vulnerable supply infrastructure. Finally, promoting corn-based ethanol offers little climate benefit while introducing new food security and environmental sustainability challenges. The current investment frenzy in corn ethanol production illustrates that political decision-makers can focus too much on local issues at the expense of the national or international public good, as well as more sensible energy choices.

We would benefit by reconsidering what energy security means to us today. The traditional definition of sufficiency, reliability, and affordability now seems incomplete. Environmental sustainability, geopolitical factors, and social acceptability are clearly elements that need to be added to our energy security calculus. 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.

U.S. policymakers are currently considering options to address our energy security and climate change crises. To help inform the political debate, the World Resources Institute has produced a graphical tool to assess energy options in the context of climate change and energy security.

### Assessing U.S. Energy Options

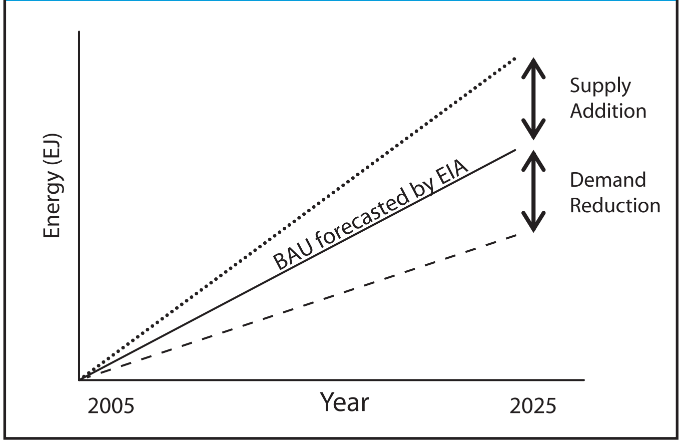
The snapshot on the following page illustrates the climate and security impacts of selected energy options in the United States. The vertical axis illustrates climate characteristics, taking into account lifecycle greenhouse gas emissions for each option. The horizontal axis is an expanded measure of energy security that each option could provide. This definition begins to include environmental sustainability (water use, soil impacts, local air pollution, etc.), geopolitics, and local acceptability. While the vertical position of each bubble is relatively objective given the assumed business as usual (BAU) centerpoint, horizontal placements are more subjective. We do not claim these placements as the only answer.

The size of each bubble represents one view of how much "incremental" energy the option could deliver (or offset) in 2025 given a modest policy driver. These drivers could include general policies such as a cap and trade carbon constraint, or a targeted measure like a renewable portfolio standard or a nuclear tax credit. The energy values are in addition to the amounts forecasted under typical BAU scenarios (see figure at right). 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. While we do not base market penetration directly on levelized cost analysis or other quantitative economic indicators, we have tried to capture the "economic feasibility" of each option given a modest policy push. A unique combination of factors including technology, economic, social, and political elements will influence how quickly any option can penetrate the market.

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.

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).

**WRI Bubble Chart Sizing: Incremental Energy Deployed or Avoided**

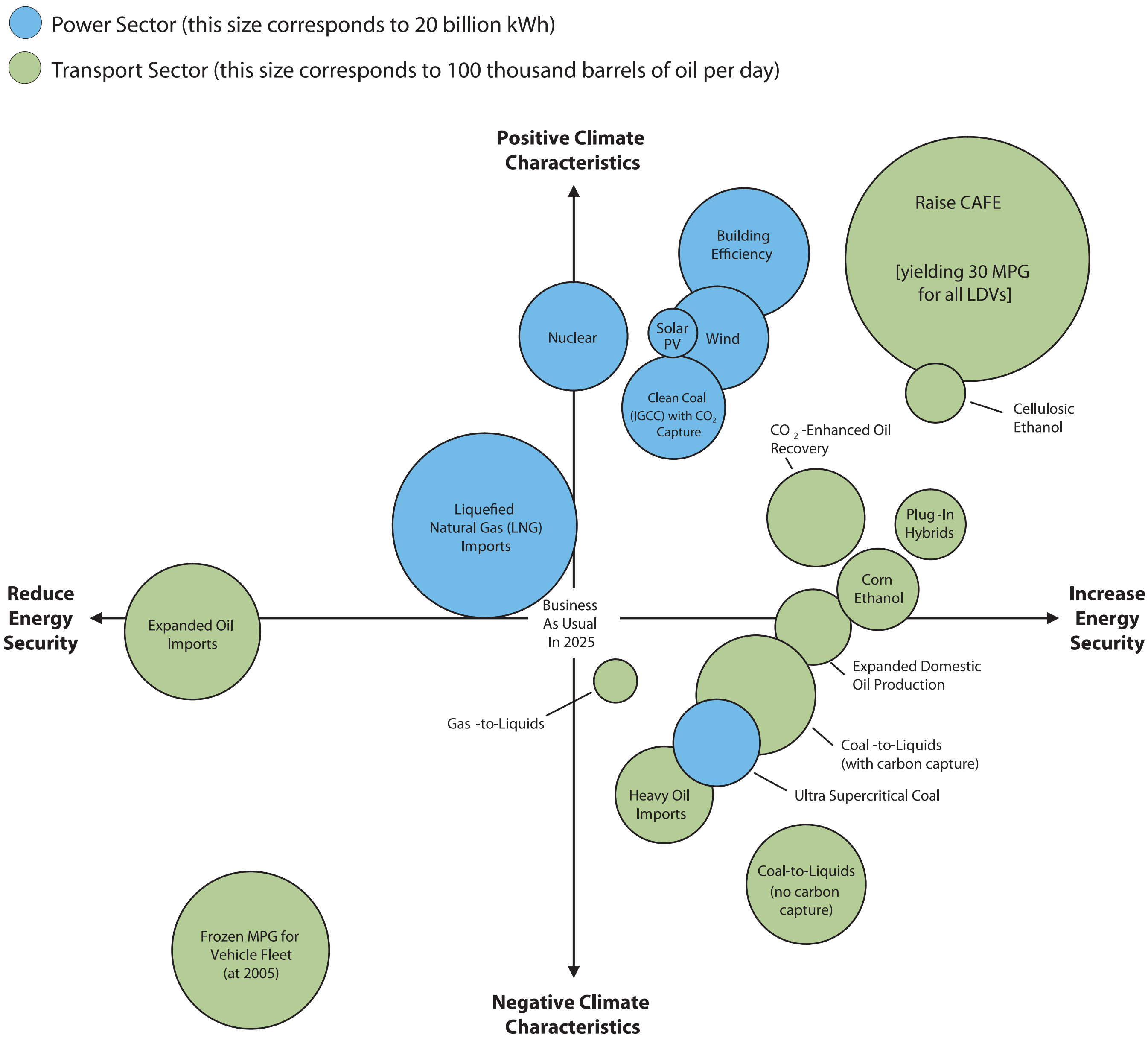



Options in the top left quadrant have positive climate but negative energy security characteristics. For example, expanding imports of liquefied natural gas (LNG) may expose the country to greater risks of potential imported fuel supply disruption, but this fuel is less carbon-intensive than the forecasted 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.

Changes in $CO_2$ emissions from the BAU were estimated for each option and included in Table 1, along with estimates of energy provided or offset. For the power sector, the BAU is the mix of energy sources forecasted (by DOE's Energy Information Administration) 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.[1] We also use EIA forecasts of technology performance and penetration, although in some cases these are very conservative.[2]

## A Snapshot of Selected U.S. Energy Options Today: Climate 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 incremental energy provided or avoided in 2025. The reference point is the "business as usual" mix in 2025. The horizontal axis includes sustainability as well as traditional aspects of sufficiency, reliability, and affordability. The vertical axis illustrates lifecycle greenhouse gas intensity. Bubble placements are based on quantitative analysis and WRI expert judgment.




For specific details on the assumptions underlying the options on this chart, go to www.wri.org/usenergyoptions.

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**TABLE 1 Incremental Energy Provided and $CO_2$ Impact Compared to BAU in 2025**

| Energy Option | Energy (EJ) | $CO_2$ (MMT) |
|---|---|---|
| ***Electric Power Sector*** | | |
| Nuclear | 1.3 | -80 |
| Clean Coal (IGCC) with CCS | 1.1 | -40 |
| Imported LNG | 3.7 | -35 |
| Wind | 1.2 | -70 |
| Building Efficiency | 1.8 | -110 |
| Solar Photovoltaics | 0.3 | -15 |
| Ultra-Supercritical Coal | 0.8 | +25 |
| ***Transport Sector*** | | |
| Raise CAFE | 6.3 | -410 |
| Expanded Oil Imports | 2.0 | +5 |
| Coal-to-Liquids (CTL) | 1.5 | +85 |
| CTL with CCS | 1.5 | +25 |
| Gas-to-Liquids (GTL) | 0.2 | +5 |
| Corn Ethanol | 0.7 | -10 |
| Cellulosic Ethanol | 0.4 | -20 |
| Heavy Oil Imports | 1.0 | +35 |
| $CO_2$ EOR with CCS | 1.0 | -25 |
| Expanded Domestic Oil Production | 0.6 | <5 |
| Frozen MPG | 2.6 | +170 |
| Plug-in Hybrid Electric Vehicles | 0.5 | -15 |

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.[3] Assumptions used in sizing and locating each bubble are described on the following pages.

## Potential Deployment and Energy Security Implications

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. To compare options against one another, we estimate the primary coal (power sector) or oil (transport sector) that could be offset by implementing each option. Table 2 lists our assumptions for each technology or policy.

The energy security implications of pursuing each of these options was then assessed, based on an expanded definition of energy security, which includes elements of sufficiency, reliability, affordability, sustainability, social acceptance, and geopolitical factors. Most options in the transport sector offset imports of oil, increasingly from an unstable Middle East, and thus have relatively higher energy security benefits. A description of the energy security implications for each option is provided at http://www.wri.org/usenergyoptions.

## Key Implications

This chart and accompanying list of assumptions allow for comparison of a wide range of energy choices, penetration potential, and impacts on greenhouse gas emissions and energy security. While many conclusions can be drawn from this analysis, three are particularly significant.

- **Increasing fuel efficiency standards has the potential to make the largest cost-effective contribution to future energy needs.** Like other efficiency options, this measure has a unique combination of positive security and climate traits.
- **Coal-to-liquids can lower our dependence on imported oil in the timeframe considered here, but pursuing this option would have significant negative impacts on global warming and water supply.** Even if most of the $CO_2$ associated with the conversion of coal to liquid fuel is captured and stored, climate impacts are still negative compared to traditional petroleum.
- **Ethanol from corn can deliver significant new energy supply and increase energy security, but the climate benefits are marginal.** The long-term impacts of using large quantities of corn for ethanol fuel are also a major concern. Heavy energy inputs are required to produce and process corn. Food production is offset, and soils are often used unsustainably. Cellulosic ethanol, on the other hand, is likely to face tougher cost challenges through 2025, but has a greater potential to simultaneously address climate and energy security concerns.

There are many options under consideration to address U.S. energy security and climate change challenges. Any real solution must acknowledge the linked nature of the two. While there are few perfect solutions, tradeoffs are often fairly clear, and political willpower may be the biggest hurdle in a complicated legislative environment.

**TABLE 2 Deployment Assumptions for Each Option**

| Energy Option | WRI Assumptions, Compared to Business as Usual (BAU) in 2025 |
|---|---|
| ***Electric Power Sector*** | |
| Nuclear | Additional 20 gigawatts (GW) of nuclear capacity, or roughly 5-10 plants. |
| Clean Coal (IGCC) with CCS | 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. |
| Imported LNG | Additional 40 BCM (1.4 trillion cubic feet) of imported LNG, fueling 48 GW of additional combined-cycle plants. |
| Wind | Additional 50 GW capacity from wind farms. |
| Building Efficiency | Savings of 1.8 EJ from an additional 5% increase in the efficiency of building electricity use and 2% in the efficiency of building natural gas use compared to the baseline. |
| Solar Photovoltaics | Additional 16 GW capacity from solar photovoltaics, which assumes an annual growth rate of 25% through 2025. |
| Ultra-Supercritical Coal | Additional 15 GW of ultra-supercritical pulverized coal (PC) plants achieving 45% efficiency (HHV), or roughly 15-30 new plants. |
| ***Transport Sector*** | |
| Raise CAFE (30 MPG LDV fleet avg.) | 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). |
| Expanded Oil Imports | Additional 1.0 mb/d (15 bgal) of additional oil imports, roughly an 8% increase in imports. |
| Coal-to-liquids (CTL) | Additional 0.75 mb/d (11 bgal) from “coal-to-liquids” (CTL). Assumes 85% more carbon intensive than petroleum. |
| CTL with CCS | 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. |
| GTL | Additional 0.1 mb/d (1.5 bgal) from “gas-to-liquids” (GTL). Assumes 25% more carbon intensive than petroleum. |
| Corn Ethanol | 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. |
| Cellulosic Ethanol | 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. |
| Heavy Oil Imports | Additional 0.5 mb/d (8 bgal) from heavy oil imports from primarily Canada and Venezuela. Assumes 50% more carbon intensive than traditional petroleum. |
| $CO_2$ EOR with CCS | Additional 0.5 mb/d (8 bgal) from “enhanced oil recovery” production from domestic sources using carbon dioxide as a stimulant. |
| Expanded Domestic Oil Production | Additional 0.3 mb/d (5 bgal) production from domestic oil and natural gas sources previously considered “off-limits”. |
| Frozen MPG | Assumes a policy weakening CAFE 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. |
| Plug-in Hybrid Electric Vehicles | 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 additional power plant operation. |

## About the Authors

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## Notes

1. EIA *Annual Energy Outlook 2007*.
2. The EIA forecasts less than 18 gigawatts (GW) of installed wind capacity in 2025 compared to today's 12 GW, for example, and a corporate average fuel economy (CAFE) requirement only slightly higher than today's.
3. 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*.

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