Energy Security FACTS

Details and Documentation

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ATTRIBUTED QUOTATION IS ENCOURAGED. PUBLISHED 18 APRIL 2003 WITH SUPPORT FROM THE OVERBROOK FOUNDATION, THE J.M. KAPLAN FUND, AND THE COMPTON FOUNDATION

SECOND EDITION, UPDATED 2 JUNE 2003

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Unless otherwise endnoted, all data cited or underlying the author's calculations come from the U.S. Energy Information Administration's (EIA's) Annual Energy Review 2001 *— the latest edition, published 11/02 and available at www.eia.doe.gov/emeu/aer/contents.html. These data are all for 2000 because many newer EIA data are preliminary or not yet available, 2000 was typical, and most changes during 2000–03 are immaterially small.[1] Money is in constant year-2000 US$ using the GDP Implicit Price Deflator. Percentage totals may not add up exactly due to rounding errors, stock changes, and statistical discrepancies. Using EIA's convention, oil includes LPGs — liquefied petroleum gases such as propane and butane — that are coproducts of oil and gas.*

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Please note: the supplemental fact sheet "U.S. Energy Security Facts (for a typical year, 2000)" is available in downloadable PDF format at www.rmi.org/sitepages/pid533.php or by contacting Rocky Mountain Institute at 970.927.3851.

Energy Security Facts: Details and Documentation

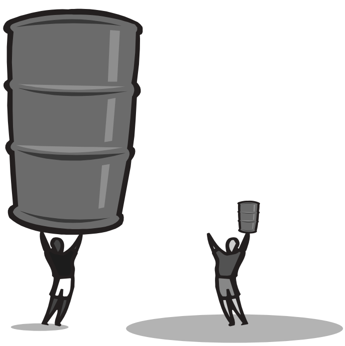
Energy insecurity takes many forms and complex causal routes, chiefly these ten:

1. **Oil imports from unstable countries/regions** (Persian Gulf; currently Venezuela, Nigeria)
2. **Concentration of cheap oil resources**, causing instability in and tension between nations
3. **Being whipsawed by volatile world oil prices** that also set or influence U.S. energy prices
4. **Energy choices and market structures** that expose customers to extreme price swings
5. **Similar or greater import dependence** for U.S. trading partners, allies, and other countries
6. **Other countries using U.S. oil payments to buy destabilizing weapons or fund terrorism**
7. **Relying on U.S. and foreign energy infrastructure** that's easy to disrupt and hard to mend[2]
8. **Indirect but major security threats**, such as climate change and the spread of nuclear weapons, created or exacerbated by the use or promotion of particular energy sources
9. **Energy usage patterns and policies** that perpetuate energy inefficiency, scarcity, inequity, poverty, and unpayable debts in developing countries, thus breeding envy and hatred
10. **Constraining and distorting international relations**, compromising U.S. moral authority and making it look as though whatever we do in the world is motivated by oil

Here we amplify only #1 and #7, but the same solutions can simultaneously address all ten.[3]

Background: U.S. oil sources

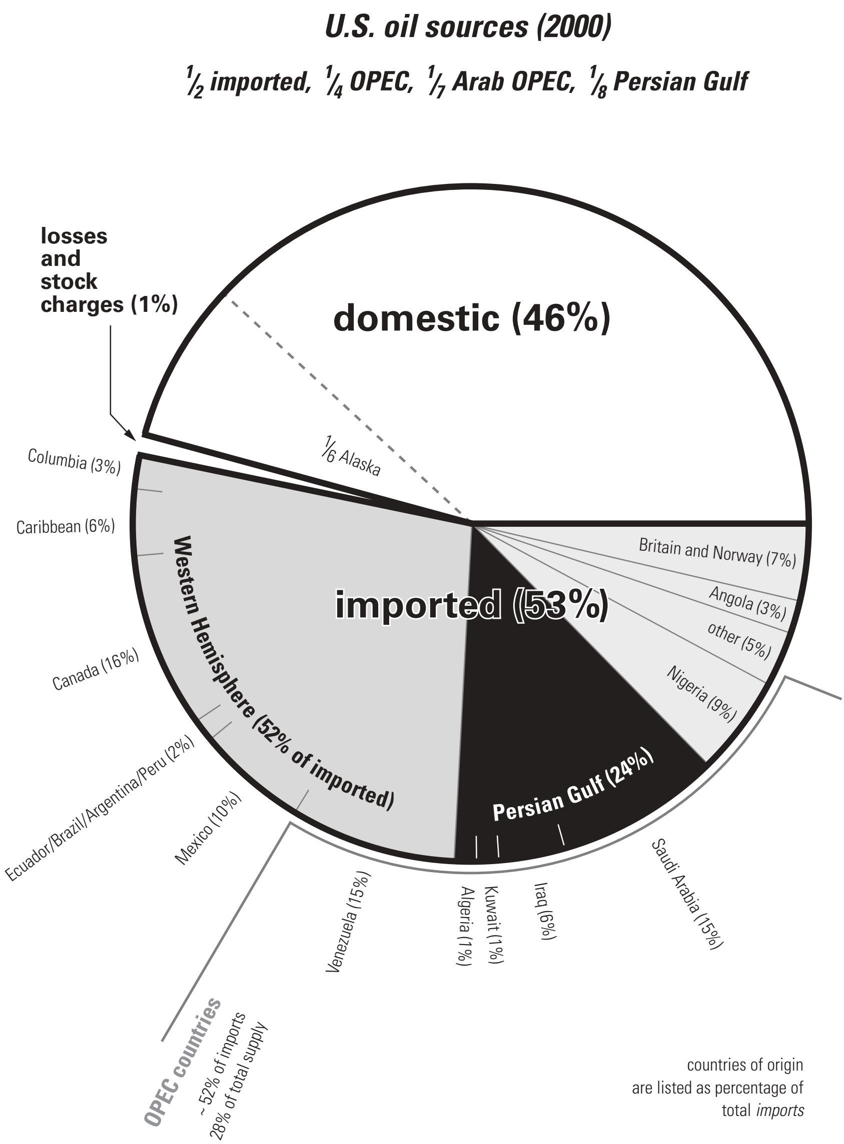
- Of all primary energy consumed in the United States, 39% is oil, 24% natural gas, 23% coal, 8% nuclear, and 7% renewables.[4]
- The United States has less than 5% of the world's population but produces 21% of Gross World Product[5] using 25% of world primary energy consumption. It also uses 26% of world oil, produces 9%, but owns only 2–3%.[6] Two-thirds of the world's proven crude-oil reserves are in the Middle East.
- Of U.S. oil supply, 46% comes from domestic sources (one-sixth of it Alaskan) and 53% from net imports, which are 24% of global oil trade and 89% of U.S. net energy imports.



- Of net oil imports (*i.e.*, imports minus exports), 52% comes from the Western Hemisphere (16% Canada, 15% Venezuela, 10% Mexico, 6% Caribbean, 3% Colombia, 2% Ecuador/Brazil/Argentina/Peru), 24% from the Persian Gulf, 9% from Nigeria, 7% from Britain and Norway, 3% from Angola, and 5% from elsewhere.[7]
- Half of net oil imports and 28% of oil consumption comes from the eleven countries of the supply cartel OPEC[8]— a 31% lower share of net imports than OPEC's peak share in 1977. Of the net OPEC imports, 52% comes from Arab countries: Saudi Arabia (15% of net oil imports), Iraq (6%), Kuwait (2%), Algeria (2%), UAE (0.1%), and Qatar (0.1%).

- Thus in round numbers, of U.S. oil use, one-half is imported, one-fourth is from OPEC, one-seventh is from Arab OPEC countries, and one-eighth is from Persian Gulf countries.[9]
- OPEC's market power as a cartel, able to sell oil for more than its free-market price, is estimated to have cost the U.S. economy about $4–14 trillion (1998 present value) in the past 30 years, roughly the same as total payments on the National Debt during that time.[10]
- Of the 15% of net imports or 63% of Gulf net imports coming from Saudi Arabia, two-thirds relies on one processing plant and two terminals that could be lastingly disrupted.[11]
- Net oil imports cost the U.S. $109 billion in 2000 — 29% of the then-record trade deficit — and $2 trillion during 1975–2000 (an undiscounted 2000-$ total, not present-valued).
- Retail oil products cost Americans more than one-quarter-trillion dollars per year.
- Americans spent about as much in 2000 on transportation fuel ($285 billion[12]) as on national defense ($294 billion in FY2000[13]). This demand for light refined products, especially gasoline, propels imports.
- U.S. taxpayers subsidized oil supply in 1995 (the most recent year studied) by about $16–35 billion more than oil excise taxes recovered for the Treasury.[14]

Background: U.S. oil sources (continued)



Background: U.S. oil uses

Energy Security
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- U.S. oil is used 6% in buildings (two-thirds residential), 8% for industrial fuel, 17% for industrial feedstocks such as asphalt and petrochemicals, and 68% for transportation, which uses 27% of U.S. energy but 68% of U.S. oil.
- U.S. transportation is 97% fueled by oil (the other 3% is almost all pipelines powered by electricity or natural-gas engines). Highway vehicles use 81% of transportation energy. Only 2.5% of their fuel comes from non-oil-based oxygenates (MTBE mainly made from natural gas and ethanol mainly made from corn), 0.2% from all other alternative fuels.[14]
- Only 2.5% of highway vehicles' fuel comes from non-oil-based oxygenates (MTBE mainly made from natural gas and ethanol mainly made from corn), 0.2% from all other alternative fuels.[15] "Dual-fueled" cars that can (but rarely do) use alternative fuels also earn automakers credits for making more-efficient cars than they actually do, thus increasing oil imports.[16]
- Of total petroleum product supplied, 43% is motor gasoline, 19% distillate fuel (two-thirds of it to run diesel engines in vehicles), and 9% jet fuel.
- The oil used in transportation goes 62.9% to light vehicles (36.5% cars plus 26.4% light trucks such as vans, pickups, and SUVs), 5.3% to medium and 14.2% to heavy trucks, 0.6% to buses, 8.7% to aircraft, 5.7% to ships and boats, 2.1% to rail freight, 0.5% to public transit,[17] and 0.04% to passenger rail.[18] Thus the 15.7 quadrillion BTUs of fuel used in 2000 by light vehicles equals 70% of the 22.4 quadrillion BTUs of net oil imports, or 2.9 times net imports from the Persian Gulf.
- U.S. light vehicles use about as much as oil as is produced by Saudi Arabia, by far the world's largest oil exporter — or by Iraq, Iran, and Kuwait put together.

Background: U.S. oil uses (continued)

- Only 3% of all U.S. oil is used to make electricity. Five-sixths of that usage is tarry residual oil or coal-like petroleum coke — both otherwise almost useless byproducts of refining. Only 0.4% of U.S. oil is distilled products made into electricity. Thus new sources of electricity are irrelevant to oil — unless they're cheap enough (which new nuclear plants would not be) to make hydrogen that could displace oil as a vehicular fuel.
- The latest federal government forecast[19] projects 2001–25 increases of 105% in GDP, 43% in energy use, 47% in oil use, 77% in net oil imports, 21% in world real oil price (to $26/bbl), and 43% in CO_2 emissions. Domestic oil output would fall by 9%, which would be nearer 30% without a respite from new Alaskan oil from outside the Arctic National Wildlife Refuge. These forecasts assume that new light vehicles will improve by only 2 mpg and their fleet by only 0.1 mpg during 2000–25, and each vehicle is driven 38% more miles. The high-efficiency forecast variant assumes 4.6- and 2.1-mpg gains, respectively, but with more driving, so projected gasoline use is only 7% lower.
- Of the Department of Energy's forecast increase in oil demand by highway vehicles during 2000–02, 66% is for light trucks, 25% heavy trucks, and only 9% cars.[20]
- In model year 2002, the average fuel economy for cars and light trucks hit a 22-year low (20.4 mpg, the worst since 19.2 mpg in 1980). Yet if their performance and weight had stayed constant since 1981 (instead of increasing 93 percent in horsepower, 29 percent in acceleration, and 24 percent in weight), their fuel economy would have improved 33 percent — enough to displace Persian Gulf imports 2.5 times over.[21]

- Oil accounts for the largest share (42%) of U.S. emissions of CO_2, more than for coal (37%) or natural gas (21%). Light vehicles emit one-fifth of all U.S. CO_2 — more than the total emissions from any country except the U.S., China, and Russia, or about the same as total emissions from Japan.[22] The U.S. emits more CO_2 from burning oil than any other country by far — more than Western Europe and Africa combined, or 2.7 times as much as China and India combined.[23]

- The 1996 peacetime readiness cost of forces whose primary mission is intervention in the Persian Gulf has been estimated at $6–64 billion/year, with a mean of $34b/y and the two most authoritative budget-based estimates at $59b/y (Brookings) and $64b/y (Cato).[24] If that intervention were related solely to oil and not to other interests, an oil-security-related cost of (say) $60b/y would be equivalent to $66/bbl, equal to 2.5 times the 2000 landed price of Saudi crude or (if added to gasoline price with no markup) $1.58/gallon. Paying oil-related military costs through taxes, not at the pump, is thus a big distortion.

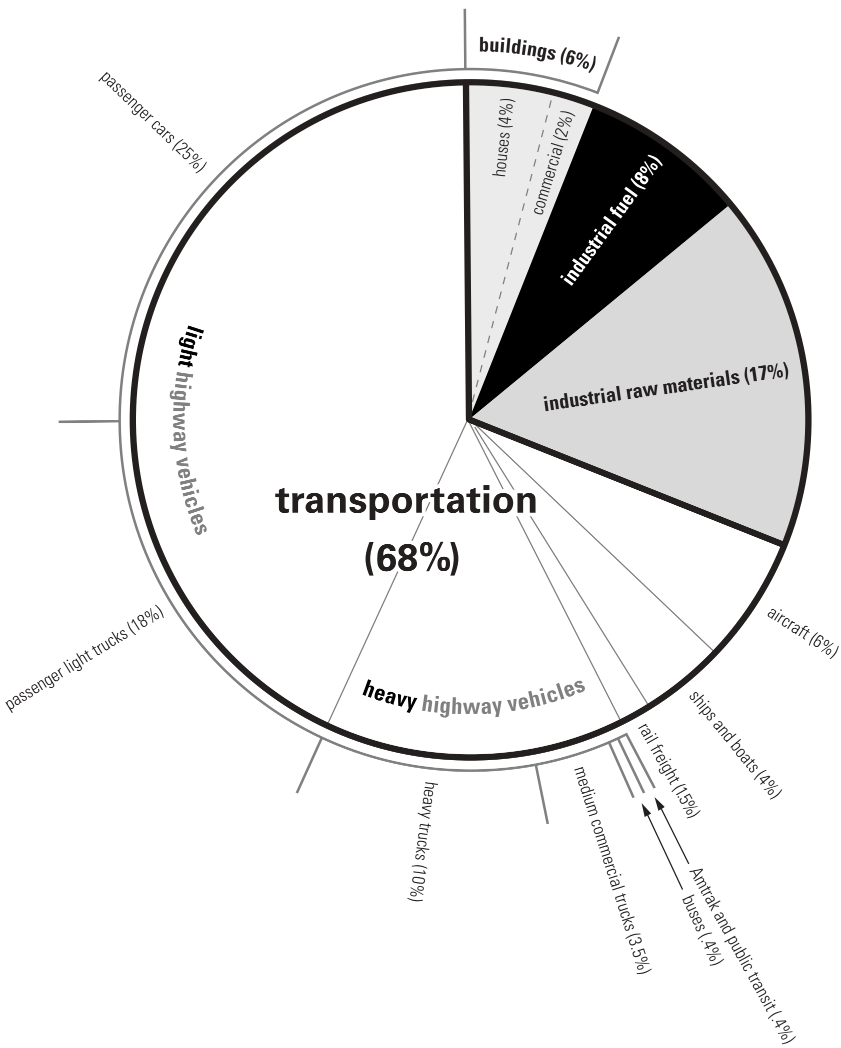
- Even in peacetime, the Pentagon is the world's largest light-oil-products buyer — "nearly 100 million barrels of petroleum products each year… enough fuel to drive 1,000 cars around the world 4,620 times…."[25] DoD is also the nation's largest energy user — 80% of federal government energy use or 0.8% of national energy use — much of it wasted by inefficient land, sea, and air platforms that also compromise military effectiveness.[26]

- Warfighting consumes a great deal of additional fuel. The Department of Energy estimated in 1987 that fighting a war in the Persian Gulf may increase DoD's oil use by about as much as is imported from Kuwait or Iraq.[27] Initial Air Force reports indicate that combat and support aircraft in the Iraq War loaded at least 417 million pounds of jet fuel in 30 days — enough to keep a Boeing 737-300 aloft for 11.9 years.[28]

Background: U.S. oil uses (continued)

U.S. oil uses (2000)

68% transportation, of which 83% is highway vehicles and 63% is* light *highway vehicles (cars, pickups, vans, and SUVs)



U.S. energy efficiency: achievements

- The U.S. in 2000 used 39% less primary energy per dollar of inflation-adjusted GDP than in 1975. "Energy productivity" — GDP per unit of energy used — thus rose by 64%, due mainly to smarter technologies, modestly (but more since 1996) to shifts in composition of the economy, and only slightly to behavioral change. These savings brought U.S. energy use in 2002 to 3%, or 0.6% if adjusted to actual GDP, above the then-controversial "soft energy path" graph published by the author in *Foreign Affairs* in autumn 1976.

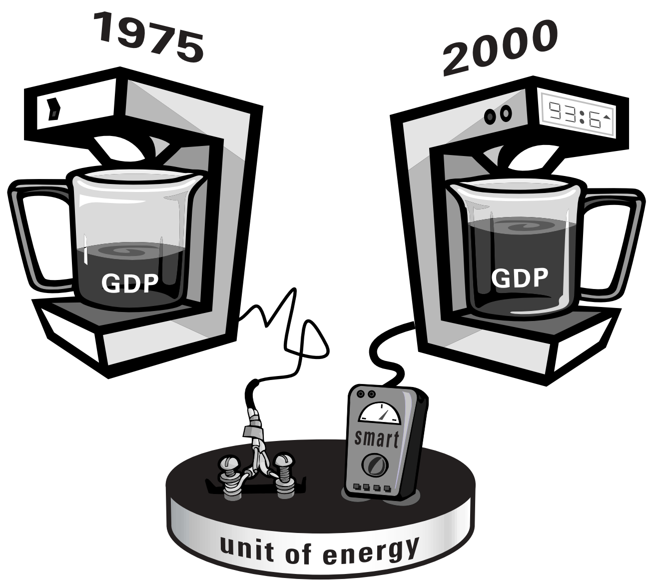
- If the U.S. had used as much energy per dollar of GDP as it used in 1975, its energy bills in 1999, the most recent year for which expenditure data are available, would have been $365 billion higher than they were (in 2000 $), equivalent to a tax of 3.85% of GDP.

- Without the increased energy productivity achieved since 1975, energy consumption would have grown during 1975–2000 by 253% more than it did.

- The 1975–2000 gain in U.S. energy productivity had by 2000 effectively become a new national energy source equivalent to 1.65 times total oil use, 2.8 times net oil imports, 4.2 times domestic crude oil output, or 11.6 times net imports from the Persian Gulf. (Recall that all these "oil" figures include natural-gas liquids.) The energy productivity gain provided two-fifths of all energy services in 2000, making it the nation's biggest energy "source," and the fastest-growing except biofuels, solar cells, and windpower.

- Rather than further developing this enormous "efficiency resource," current federal energy policy focuses almost entirely on subsidizing and increasing new energy supplies. Yet the domestic oil industry has dwindling reserves,[29] falling output, and rising costs, while the efficiency industry has expanding reserves, rising output, and falling costs.

U.S. energy efficiency: achievements (continued)



"Energy productivity" — GDP per unit of energy used — rose by 64% from 1975 to 2000, due mainly to smarter technologies.

U.S. oil efficiency: achievements

- The U.S. in 2000 used 48% less oil per dollar of inflation-adjusted GDP than in 1975. Putting it the other way around, "oil productivity" — GDP per barrel used — rose by 92.5% (and by 98% through 2002[30]).
- If the U.S. had used as much oil per dollar of GDP as it used in 1975, its oil bills in 1999, the latest year for which expenditure data are available, would have been $88 billion (in 2000 $) higher than they actually were.
- The last time the U.S. paid attention to saving oil, during 1977–85, GDP rose 27%, oil use *fell* 17%, net oil imports fell 50% (by 4.28 million barrels a day — 72% greater than U.S. imports from the Persian Gulf in 2000), and *gross imports from the Persian Gulf fell 87%*.[31] That saving took away from OPEC one-seventh of its market. The entire world oil market shrank by one-tenth. OPEC's market share was slashed from 52% to 30%, while OPEC's output fell by 48%, breaking its pricing power for a decade: the U.S. had more flexibility to buy less oil than OPEC did to sell less oil. The U.S. created one-fourth of that reduction by raising oil productivity 52% in eight years. If we'd achieved such rapid oil savings starting in 2000, then Persian Gulf net imports (at the 2000 rate, which was about 10% higher than in 2002) could have been displaced in 28 months.[32]
- The most important part of the 1977–85 oil savings came from a 7.6-mpg improvement in new domestically-made cars.[33] On average, each new car drove 1% fewer miles on 20% fewer gallons, achieving 96% of that efficiency from smarter design and only 4% from smaller size.[34] In 2000, the light-vehicle fleet averaged 21.9 mpg for cars, 17.4 for light trucks[35] — not much better than the 17.5 and 14.3 achieved in 1985 — while new 2000 light vehicles averaged 28.2 and 20.4 mpg,[36] respectively — values that have been nearly stagnant for a decade. No effort has been made to repeat the stunning success of using technology and policy to improve the fuel economy of the entire light-vehicle fleet by 62% during 1975–84 while making vehicles safer, far cleaner, and no less peppy.

U.S. oil efficiency: further potential

- A 3.25-mpg improvement in the 2000 U.S. light-vehicle fleet would have saved as much oil as was imported net from the Persian Gulf (2.483 million bbl/d).[37]

  During Model Years 1979–85, a 3.25-mpg improvement was achieved, on average, every 32 months.[38]

> ***N.B.:*** The 3.25-mpg figure assumes that saving 1 barrel of gasoline would save the 2.165 barrels of crude oil that the average U.S. refinery used to make that barrel of gasoline in 2000.[39] This ratio could become invalid for very large savings, depending on many factors including savings of other petroleum products — although, for comparison, the ratio actually exceeded 3.0 during the rapid and larger gasoline savings achieved in 1977–85. Assuming barrel-for-barrel equivalence, regardless of the complex realities of refinery yield, could correspondingly decrease crude oil savings. Conversely, the fuel used or lost in delivering refinery gasoline to pumps isn't counted here.

in the 2000 U.S.
light-vehicle fleet

- A 3.25-mpg improvement in the 2000 light-vehicle fleet would cut its gasoline usage by 14%. A 2001 National Academy of Sciences study found that light-vehicle improvements have *already* cut gasoline consumption by 14%, yet that conventional further gains cost-effective to the driver can nearly *double* the current fleet efficiency without harming safety or performance. Typical potential fuel savings range from about one-fifth for small cars to one-third for midsize SUVs or nearly one-half for big pickup trucks. These findings are technically and economically conservative, and don't consider fuel cells or ultralight construction.[40]

- Displacing net oil imports equivalent to those from the Persian Gulf in 2000 would require further oil savings eight percent smaller than the absolute reduction in oil consumption that the U.S. achieved during 1977–85. This could be done by, for example, making 26–27% of the 2000 car fleet as efficient as the popular 5-seat Honda Civic or Toyota Prius hybrid cars, which are rated at 49 and 48 mpg, respectively. (The larger, midsize, same-price 2004 Prius will be rated at about 55 mpg.)

- Giving the owner of a typical 23-mpg 1990 car (the average for Model Year 1990) a $4,900 rebate — four times, or about $3,700 above, a typical trade-in value — for *scrapping* it and replacing it with a new, $21,000, 48-mpg, compact, 5-seat hybrid car (such as more than 100,000 Americans have already bought) would pay for itself just in the $1.25-a-gallon gasoline;[41] any externalities avoided would be free benefits.

- In 1987–88, RMI performed for Royal Dutch/Shell Group Planning an influential analysis of how much oil the U.S. could have saved in 1986 by fully installing, wherever they'd make sense, the best oil-saving techniques available or proven by 1987. The result,[42] including using saved natural gas to displace oil in furnaces and boilers, was equivalent to saving 80% of 1986 oil use at an average cost of $3.6/barrel (2000 $), or about one-fifth of recent peacetime oil prices. Today's efficiency potential is believed to be considerably larger and cheaper, because the technologies have improved by more than the opportunities have been used up. The modern potential is being analyzed in an RMI "off-oil" study to be published later in 2003. The new study will also include two forms of substitution for oil not included in the study for Shell — biofuels and hydrogen. However, just the 1987–88 study's documented oil-saving potential would be about 54 times larger and six times cheaper than the oil that the U.S. Geological Survey considers likely to be recoverable from the Arctic National Wildlife Refuge, or about six times bigger and cheaper than 2000 Persian Gulf imports.[43] RMI believes the U.S. today has an overall energy-efficiency potential, mostly in oil and electricity, exceeding $300 billion per year — nearly as large as the recent peacetime military budget of $11,000 per second.

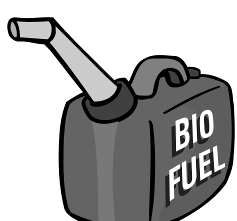
- In the 1980s, at least eight automakers demonstrated compact or subcompact concept cars ranging from 64 to about 121 mpg (Renault 4-seat 121 mpg *Vesta II*, Volvo extra-safe 5-seat 78 mpg *LCP-2000* and Peugeot 4-seat *ECO 2000* at no extra manufacturing cost, and others).[44] Today, 5-seat hybrid-electric family cars (Honda Civic 49 mpg and Toyota Prius 48 mpg) are selling briskly in the U.S., as is a 79-mpg 4-seat VW Lupo in Europe. VW has even demonstrated a small 2-seat diesel-hybrid-electric city car at 238 mpg and up to 74 mph,[45] although the 64-mpg hatchback Honda *Insight* gasoline hybrid now on the U.S. market (and driven by the author) better fits the U.S. 2-seat segment.
- The Big Three automakers have also tested midsize (*Taurus*-class) 72–80-mpg family sedans.[46] Honda and Toyota are test-marketing, at high initial prices, even more efficient fuel-cell cars in the U.S. Six more automakers plan to do likewise over the next two years.

- In 2000, a private startup company spun off from Rocky Mountain Institute (Hypercar, Inc.) designed an uncompromised, cost-competitive, midsize SUV simulated to get the equivalent of 99 mpg with a direct-hydrogen fuel cell, or estimated by the author to get probably 70+ mpg with a gasoline-engine hybrid-electric powertrain.[47] The fuel-cell version of that *Revolution* concept SUV would use 82% less fuel than a similar Ford Explorer, and would use no oil at all. A full global fleet of such efficient vehicles could ultimately displace at least as much oil as OPEC sells.

- If the hydrogen now used by U.S. refineries (much of it to make gasoline) were instead fed into fuel-cell vehicles as efficient as that *Revolution* concept SUV, it would displace one-fourth of all U.S. gasoline — twice as much as comes from Persian Gulf oil.[48]

- The potential cost-effective windpower in the Dakotas could make as much hydrogen as the world now uses — enough, if used in efficient fuel-cell vehicles, to displace all oil now used by U.S. highway vehicles.

- In 1991, the Gulf War cost the U.S. (in 1991 $) $61 billion gross, or $7 billion net of allies' contributions.[49] Investing less than $7 billion (1991 $) in the cheapest available oil savings could have displaced all 1990 or 2000 net imports from the Gulf.[50] In 2002, net imports from the Gulf are 15% larger than in 1990 (2.254 *vs.* gross Mbbl/d *vs.* 1.966), but the efficiency potential is even larger and cheaper. The budget for the warfighting-operations part of the Iraq war through June 2003 exceeds $53 billion ($30 billion deployment + $5 billion/month[51]), although more was at issue than just oil.



Don't trade one security problem for another

- Whether domestic fuels are more secure than imported fuels depends on the relative vulnerabilities of their infra-structure to disruption by accident or malice. For example,[52] over half of the 800-mile Trans-Alaskan Pipeline System (TAPS) is elevated and accessible. This rapidly aging pipeline not only has worsening maintenance and operational problems; it's arguably the most brittle part of the entire U.S. energy infrastructure. Oil from beneath the Arctic National Wildlife Refuge — where leasing was again rejected by the Senate in March 2003 — would prolong dependence on TAPS for decades, and double its oil throughput to more than now reaches U.S. refineries through the Strait of Hormuz. Yet TAPS is even easier to disrupt and harder to mend than that famous Persian Gulf chokepoint. TAPS has already been sabotaged, shot at over 50 times (punctured once), and incompetently bombed twice (penetrated once). In 1999, a disgruntled engineer seeking profits in the oil futures market was luckily caught before blowing up three key sections with 14 sophisticated bombs; he was a bungling amateur compared to al Qa'eda. The original license requirement that the pipeline be able to restart after a three-week interruption at –40° can't be met and was recently changed to an unspecified short interruption at +40°F. A longer hiatus, or in winter, could turn nine million barrels of gooey oil into the world's largest Chap Stick. Such fragile infrastructure hardly seems a suitable centerpiece for what its advocates, soon after 9/11, oddly called the Homeland Energy Security Bill. Real energy security requires, among other things, efficient use and diverse, dispersed, increasingly renewable sources. These also happen to be the best buys and are winning in the marketplace where allowed to compete.[53]

The Trans-Alaskan Pipeline System (TAPS) has already been sabotaged, shot at over 50 times, and incompetently bombed twice. Such attacks threaten to turn nine million barrels of gooey oil into the world's largest Chap Stick!

About Rocky Mountain Institute

Rocky Mountain Institute is a 21-year-old, independent, nonpartisan, nonprofit, entrepreneurial applied research center. Its ~50 staff foster the efficient and restorative use of resources to make the world secure, prosperous, and life sustaining. Its work emphasizes advanced technologies and creative use of market forces, and is integrative, transdisciplinary, and trans-ideological. One of its major current projects is writing a compelling technical, economic, and policy roadmap for getting the United States off oil rapidly, attractively, and profitably — even for oil companies.

About the author

Amory B. Lovins is cofounder and CEO of Rocky Mountain Institute. A consultant physicist, he has advised the energy and other industries for 30 years as well as the U.S. Departments of Energy and Defense. Published in 28 books and hundreds of papers, his work in ~50 countries has been recognized by the "Alternative Nobel," Onassis, Nissan, Shingo, and Mitchell Prizes, a MacArthur Fellowship, the Happold Medal, eight honorary doctorates, and the Heinz, Lindbergh, Hero for the Planet, and World Technology Awards. He advises industries and governments worldwide, including major oil companies, and has briefed 17 heads of state. For the past dozen years, he has also led the development of quintupled-efficiency, uncompromised, same-price automobiles and of a profitable hydrogen transition strategy. Much of his wider work is synthesized in *Natural Capitalism: Creating the Next Industrial Revolution* (www.natcap.org, with Paul Hawken and L.Hunter Lovins). His latest book, *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size* (www.smallisprofitable.org, with RMI colleagues), was named by the *Economist* as one of the best three business and economics books of 2002.

Dr. Lovins's security background includes devising the first logically consistent approach to nuclear nonproliferation (technical papers and two books, 1979–1983); coauthoring for DoD the definitive unclassified study of domestic energy vulnerability and resilience;[2] co-developing a "new security triad" of conflict prevention, conflict resolution, and nonprovocative defense;[54] lecturing at the National Defense University, Naval War College, and Naval Postgraduate School on least-cost security and on how new technologies will transform missions and force structures; leading for ADM Lopez the overhaul of NAVFAC's design process (later in other Services); leading a 2000–01 Office of Naval Research analysis for SECNAV of how to save ~$1 million/y of hotel-load electricity aboard a typical surface combatant (*USS Princeton* CG-59); and serving on a 1991–2001 Defense Science Board panel, chaired by VADM (Ret.) Richard Truly, on *Enhanced Warfighting Capability Through Reduced Fuel Burden*, which identified a multi-billion-dollar-a-year DoD fuel-saving potential that would boost force deployability and effectiveness.[26]

Endnotes

[1] However, 2002 gross oil imports (net not yet available) from the Persian Gulf and OPEC, respectively, were 9% and 12% below 2000 values. This is widely believed to be a temporary result of Iraq jitters and the economic downturn, not a long-term trend.

[2] A.B. & L.H. Lovins, *Brittle Power: Energy Strategy for National Security* (the definitive 1981 Pentagon study), 436 pp., 1,200 refs., Brick House (Andover MA), 1982, out of print but reposted at www.rmi.org/sitepages/pid533.php with other readings, including R.J. Woolsey and A.B. & L.H. Lovins, "Energy Security: It Takes More Than Drilling," *Chr. Sci. Monitor*, 29 March 2002, www.csmonitor.com/2002/0329/p11s02-coop.html.

[3] A.B. & L.H. Lovins, "Mobilizing Energy Solutions" and "Energy Forever," *Am. Prospect* 13(2):18–21 (28 Jan. 2002) and 13(3):30–34 (11Feb. 2002), both annotated at www.rmi.org/sitepages/pid171.php.

[4] The nuclear term, like hydroelectricity (48% of total renewable energy, and lately drought-crimped), is counted at triple the energy content of its electricity, as if an equivalent amount of fossil fuel had been burned to make that electricity in steam plants.

[5] U.S. Central Intelligence Agency, *The World Factbook* — 2002, 2001 estimated data at Purchasing Power Parity, downloaded 30 March 2003, www.cia.gov/cia/publications/factbook/geos/xx.html#Econ.

[6] EIA data show 2%; American Petroleum Institute and British Petroleum data indicate 3%.

[7] EIA, *Petroleum Supply Annual 2001*, Vol. 1, Table 29.

[8] The Organization of Petroleum Exporting Countries, currently comprising Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates (UAE), and Venezuela. Mexico and Norway sometimes imitate them.

[9] These categories are not identical. Iran, a major exporter that currently supplies no oil to the U.S., is a Gulf but not an Arab country. Libya, another non-exporter to the U.S., and Oman are Arab but not Gulf. Gulf states are Saudi Arabia, Iran, Iraq, Kuwait, UAE, Qatar, and Bahrain. Arab OPEC countries are Saudi Arabia, Iraq, Kuwait, Algeria, UAE, and Qatar.

[10] D.L. Greene & N.I. Tishchishyna, "Costs of Oil Dependence: A 2000 Update," ORNL/TM-2000/152, May 2000, Oak Ridge National Laboratory, www.esd.ornl.gov/benefits_conference/oilcost_tq.pdf.

[11] EIA, "Saudi Arabia," www.eia.doe.gov/emeu/cabs/saudi.html.

[12] EIA, *Energy Outlook 2003*, Table A3, converting 2001 to 2000 $, www.eia.doe.gov/oiaf/aeo/download.html.

[13] USDoD, National Defense Budget Estimates for FY2002, www.dod.mil/comptroller/fy2002budget/fy02grbk.pdf, August 2001, Table 1-11.

[14] D. Koplow & A. Martin, *Fueling Global Warming: Federal Subsidies to Oil in the United States*, Industrial Economics, Inc. (Cambridge, MA), 1998, www.greenpeace.org/~climate/oil/fdsuboil.pdf.

[15] U.S. Department of Transportation (DOT), *National Transportation Statistics 2001*, July 2002, www.bts.gov/publications/nts/pdf/entire.pdf.

[16] U.S. Department of Transportation, Department of Energy, & Environmental Protection Agency, *Report to Congress: Effects of the Alternative Motor Fuels Act CAFE Incentives Policy*, March 2002, Table V-4, www.nhtsa.dot.gov/cars/rules/rulings/CAFE/alternativefuels/AMFAReporttoCongress.pdf; see also National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, July 2001, p. ESR-4, www.nap.edu/books/0309076013/html/

[17] DOT, *op. cit.* (ref. 15), Table 4-6.

[18] *Id.* and (corrected for gas-fueled pipeline usage) Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 22* (ORNL-6967), October 2002, www-cta.ornl.gov/cta/data/Index.html, which shows an extra ~4% for mining, construction, etc.

Endnotes (continued)

19 EIA, *Annual Energy Outlook 2003*, January 2003, www.eia.doe.gov/oiaf/aeo/pdf/0383(2003).pdf.

20 U.S. Department of Energy, Office of Transportation Technologies, "Reducing Petroleum Use Is Vital to Our Nation's Long-Term Energy Security," measured from graphic "A Growing Oil Gap," www.ott.doe.gov/fcar_petroleum.shtml.

21 USEPA, *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2003*, EPA420-R-03-006, April 2003, www.epa.gov/otaq/fetrends.htm.

22 EIA, *International Energy Annual 2001*, Carbon Dioxide Emissions, Table H1, www.eia.doe.gov/emeu/iea/tableh1.html.

23 *Id.*, Table H2, www.eia.doe.gov/emeu/iea/tableh2.html.

24 ORNL *Transportation Energy Data Book*, *op. cit. supra.*, 2002, Table 1.8, converting 1996 to 2000 $.

25 Defense Logistics Agency, *Dimensions*, downloaded 30 March 2003, www.dla.mil/dimensions/almanac/desc.htm. This DESC calculation assumes 27.5 mpg and 1:1 gasoline:crude, and erroneously states 115.5 "trillion" [car]-miles; that should be "billion."

26 R. Truly *et al.*, *More Capable Warfighting Through Reduced Fuel Burden*, Defense Science Board report, May 2001, Office of the Under Secretary of Defense for Acquisition and Technology, at www.acq.osd.mil/dsb/fuel.pdf, summarized for lay readers at www.rmi.org/sitepages/art7049.php. Its findings were later supported by RMI's 2001 Office of Nasal Research technical report on Naval hotel-load efficiency under ONR Grant #N00014-01-1-0252, 2001, summarized at www.rmi.org/sitepages/art7057.php.

27 In 1987, the Department of Energy estimated that DoD energy consumption could double or triple in a war (*Energy Security: A Report to the President of the United States*, March 1987, p. 9). Applying these factors to the petroleum fraction (79%) of total FY2001 DoD energy consumption of 0.774 QBTU/y (40% less than FY1987, due largely to force reductions) implies that war could raise DoD's oil use by ~0.3–0.6 Mbbl/d, consistent with the Defense Energy Supply Center's normal provision of 100 Mbbl/y or 0.27 Mbbl/d. For so long as a wartime optempo is sustained, that rise would equate to 12–24% of net imports from the Gulf, or to the 2000 rate of net imports from Kuwait (0.27 Mbbl/d) or Iraq (0.62 Mbbl/d). Actual fuel data from current military operations in Iraq are not yet available, and can't be inferred from the President's 23 March 2003 supplemental budget request, since it includes extra fuel costs through June 2003 both as a $0.4-billion line item (perhaps for higher price, not volume) and as an undisclosed part of a $53+-billion general operational line item: Office of Management and Budget, Est. #4, 108th Congr., 1st Sess., 25 March 2003, p. 3, www.whitehouse.gov/omb/budget/amendments/supplemental_3_25_03.pdf, pp. 1–2 of budget paper.

28 USCENTAF, "Operation IRAQI FREEDOM — By The Numbers," Assessment and Analysis Division, 30 April 2003, p. 8. At a nominal 0.8 density, the implied aircraft fuel flow is only 50,000 bbl/d, but the total with land and sea platforms is much larger. It is also unclear whether the aircraft fuel used was only in-theater, but that is the implication. Fuller assessments of the war's fuel use may not come until late 2003 if then.

29 These showed a 5% uptick during 1998–2000 but were still 30% below their 1997 level.

30 Using EIA, *Monthly Energy Review*, March 2003, www.eia.doe.gov/emeu/mer/pdf/mer.pdf, Tables 1.8 and A3; or 100% using the 0.8-higher final 2002 GDP, 96ch$9.518T, downloaded 30 March 2003 from www.bea.doc.gov/bea/newsrel/gdp402f.htm.

31 Some earlier EIA statistics suggest that net imports may have fallen by 91%, but in recent years, for unknown reasons, EIA statistics have shown net-import statistics from the Gulf as unavailable before 1981.

32 Since oil is fungible in world trade, the displacement is the same size but may not be the same oil molecules.

33 Model Year 1978 (18.7 mpg) *vs.* MY1985 (26.3): ORNL, *op. cit. supra*, Edn. 20 – 2000, ORNL-6959, Table 7.16.

34 P. Patterson, "Periodic Transportation Energy Report 1," DOE CE-15, U.S. Department of Energy, 16 November 1987: "If the 1976 size class shares for autos were applied to the 1987 car class fuel economies, the resulting new car MPG would be 27.7 in 1987 (just 0.4 MPG less than the actual values). Thus, if in 1987 the nation had reverted

back to the 1987 new car size mix, the eleven year gain of 10.9 MPG would have been reduced by only 4 percent." This is not valid for light trucks, whose size shift was dominated by sale of smaller imports to new pickup buyers.

35 EIA, *Monthly Energy Review*, March 2003, Table 1.10.

36 DOT, *op. cit. supra*, Table 4-11, and ORNL, *op. cit. supra*, 2002, Tables 4-23, 7-7, and 7-8. The latter figures are derived from a detailed ORNL stock model and differ slightly from EIA figures (22.0 for the passenger-car and 17.5 for the light-truck fleet).

37 ORNL, *op. cit. supra* (ref. 18), consistent with EIA *Annual Energy Review 2001*, Table 2.9, reports 2000 U.S. driving of 1.602 trillion passenger-car-miles at 22.0 mpg and 0.924 trillion light-truck-miles at 17.5 mpg (Tables 7.1 and 7.2, based on Federal Highway Administration data) — a travel-weighted average of 20.35 mpg. Driving the total 2.526 trillion light-vehicle-miles at 3.25 mpg greater fuel economy for both cars and light trucks would save 17.6 billion gal/y (14% of the 125.7 billion gal/y they actually used), or 1.15 million bbl/d of gasoline, made at 2000 average U.S. refinery yields (0.462 bbl gasoline / bbl crude oil, ORNL Table 1.10) from 2.49 Mbbl/d of crude oil and hence equivalent to net petroleum imports of 2.483 Mbbl/d from the Persian Gulf (which were 97% in the form of crude oil). (In 2001, RMI estimated this required increase as not 3.25 but 2.7 mpg, based on the best preliminary data available at that time.) It is unimportant to correct these calculations for the fraction of the light-vehicle fleet that uses diesel fuel instead of gasoline; the ORNL *TEDB*, Table 2.4, shows that only 0.6% of the fuel used by U.S. cars and 3.8% by light trucks was diesel fuel. Motorcycles' fuel use, sometimes included with that of cars, is also negligible.

38 ORNL, *op. cit. supra*, Edn. 20 – 2000, Table 7.16: 1.22 mpg/y for all new cars, 1.17 for domestic models.

39 EIA, *Petroleum Supply Annual 2000*, Vol. 1, Table 19: 0.462 refinery yield of motor gasoline.

40 The study was published in 2002 at www.nap.edu/books/0309076013/html/. The Academy later amended its findings to reduce some potential savings modestly while increasing some others, but also correctly noted that it "may have underestimated" the near-term (10–15-year) savings available from reducing vehicles' mass and drag: *Wall St. J.*, 17 Jan. 2002, p. A2.

41 Discounting the future value of money at 5%/y real, and properly accounting for the limited life and reduced driving of the old car according to ORNL data, *op. cit. supra*, Tables 6.6–6.10. Society would benefit from avoiding the externalities of obtaining and burning the fuel, including any costs related to the military forces mentioned earlier. If, for illustration, externalities raised the social cost of gasoline to (say) $3/gallon, then a $3,700-over-tradein rebate would save the country nearly $7,000 net.

42 A.B. & L.H. Lovins, "Fool's Gold in Alaska," *For. Aff.* **80**(4):72–85 (July/August 2001), annotated edition posted at www.rmi.org/sitepages/pid171.php, at hypertext for "50 times the average projection" (p. 74).

43 See annotated *For. Aff.* article (ref. 42), hypertext for "range of projections" (p. 79). To the prices shown must be added approximately $1–3/bbl to yield the target return on investment after paying the $2.4 billion lease fees assumed by the Republican Senate leadership in its unsuccessful March 2003 attempt to win drilling approval via the budget process (USGS assumed zero lease fees). This would raise the required sustained price to ~$23–25/bbl — above virtually all industry forecasts — to yield 3.2 billion barrel mean reserves. Below ~$17–20/bbl oil price, no economically recoverable oil would be expected.

44 D.L. Bleviss, *The New Oil Crisis and Fuel Economy: Preparing the Light Transportation Industry for the 1990s*, Quantum Press (Westport CT), 1988.

45 K.-P. Schindler (VW, Wolfsburg), "Advances in Diesel Engine Technologies for European Passenger Vehicles," 8th Diesel Engine Emissions Reduction Conference (DEER), San Diego, 25–29 August 2002, at pp. 32–39.

46 Such as the GM *Precept* (82 mpg gasoline-equivalent), Dodge *ESX-3* (72 mpg), and Ford *Prodigy* (72 mpg) (ORNL, *op. cit. supra*, 2000, p. 9-11, and Bob Purcell, GM, personal communications, 2000).

47 See www.hypercar.com, where previously posted details of the *Revolution* concept SUV should soon be re-posted, and A.B. Lovins, "FreedomCAR, Hypercar®, and Hydrogen," www.rmi.org/sitespages/pid175.php.

Endnotes (continued)

48 For documentation of this and the following point, see RMI's "Twenty Hydrogen Myths," June 2003, www.rmi.org/sitepages/pid171.php.

49 Department of Defense, *Conduct of the Persian Gulf War*, Report to Congress, April 1992, App. P, summarized at http://people.psych.cornell.edu/Horan/gulf/GW_cost/GW_payments.html.

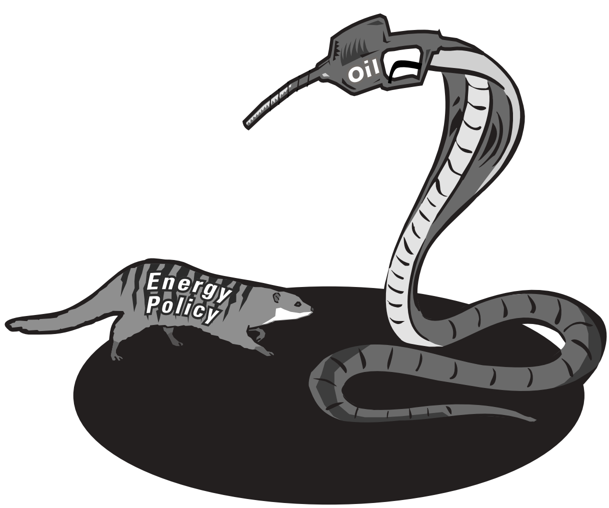
50 See annotated *For. Aff.* Article (ref. 42) at hypertext for "cost the United States" (p. 77).

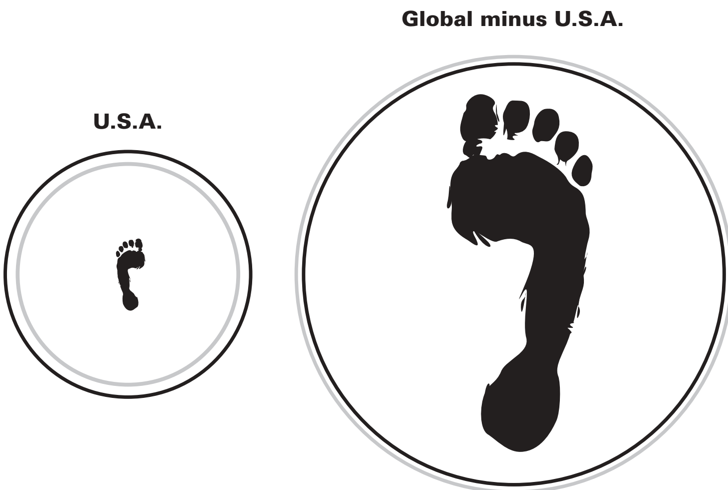
51 Administration brief, 24 March 2003, www.whitehouse.gov/omb/speeches/senior_admin032403.html, p. 4.

52 Details and documentation are in ref. 42, at hypertexts to p. 73.

53 See references 2 and 3, and for general policy context, the bipartisan report of the Expert Group of the National Energy Policy Initiative, www.nepinitiative.org.

54 H. Harvey & M. Shuman, *Security Without War*, Westview (Boulder), 1993, reposted at www.rmi.org/sitepages/pid175.php.





FACT: The United States has 4.6% of the world's population (foot) and produces 21% of Gross World Product (gray circle). But it uses 26% of the world's oil (black circle). See page 2.