5.12 Resource Consumption External Costs

This chapter describes external costs of transport resource (particularly petroleum) production, processing and distribution, and therefore the social benefits of resource conservation. A special section discusses the implications of these external costs on transport fuel policy and pricing.

Chapter Index

5.12.2 Definitions

Resource Consumption External Costs refers to various costs not borne directly by users resulting from the production, import and distribution of resources (primarily petroleum), used in construction and operation of transportation facilities and vehicles. Since air pollution and waste disposal external costs are included in other chapters, those impacts are excluded from this chapter's estimates. These external costs include:[1]

- *Economic costs* – macroeconomic impacts from importing resources.
- *Security risks* – military and political costs of maintaining access to resources.
- *Health risks* – injuries and illnesses from resource production and distribution.
- *Environmental damages* – environmental damages from resource extraction, processing and transport, including landscape impacts and oil spills.
- *Depletion of non-renewable resources* – depriving future generations of resources.
- *Financial subsidies* – various financial subsidies to resource production industries.

Various terms are used for evaluating these impacts. *Lifecycle impact analysis* (LIA) refers to total resource costs, including costs incurred during production, distribution, use and disposal.[2] Energy used in production and distribution is sometimes called *embodied energy*. *Material input per unit of service* (MIPS) measures the quantity of materials used to provide a given unit of service, such as person-miles (for personal travel) or ton-miles (for freight travel).[3] For example, when comparing different modes or development policies, comprehensive analysis considers, in addition to direct fuel consumption, vehicle and facility embodied energy, and impacts on per capita travel demands.

5.12.3 Discussion

Estimates of external resource costs can be used to determine the benefits of resource conservation and to estimate the optimal tax that should be applied to products such as petroleum. In an ideal market, all damage costs are fully internalized. For example, petroleum production health and environmental damages (habitat loss, oil spills, accident injuries, etc.) can be internalized if injured parties can sue the firms responsible, so costs are ultimately incorporated into retail prices. However, many damages difficult to fully compensate, as discussed in Chapter 4. For example, ecological degradation can result from many dispersed sources making fault difficult to assign; ecological damages are often difficult to monetize; ecological systems often lack legal status for compensation; and little compensation may be paid for the death of a worker who has no dependents. As a result, total environmental and health costs, and society's willingness to prevent such damages, is often much greater than compensation, resulting in large external costs.

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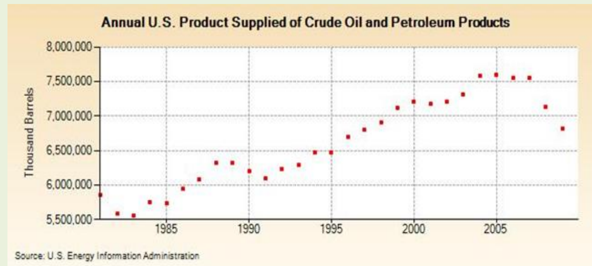
[1] EC (2005), *ExternE: Externalities of Energy - Methodology 2005 Update*, European Commission (www.externe.info); at www.externe.info/brussels/methup05a.pdf.

[2] *Institute for Lifecycle Environmental Assessment* (http://iere.org/ILEA/index2.html) and *Transportation Lifecycle Assessment* (www.transportationlca.org)

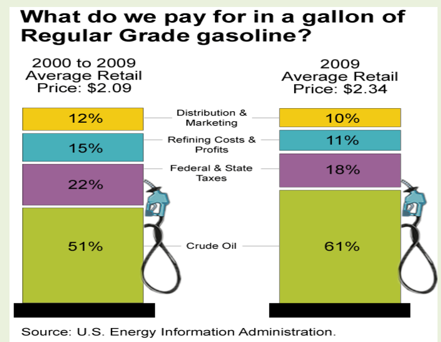
[3] *MIPS (Material Input Per Service Unit) Method*, Dictionary of Sustainable Management; at www.sustainabilitydictionary.com/m/mips_material_input_per_service_unit_method.php.

Petroleum Consumption and User Costs
The following information helps put petroleum external costs into perspective.

- The U.S. consumes 6.6 to 7.8 billion barrels of crude oil annually. At $75 per barrel this totals approximately $500 to $600 billion.[4] About 70% of this consumption is for transport, representing $350 to $420 billion in annual crude oil purchases.[5]



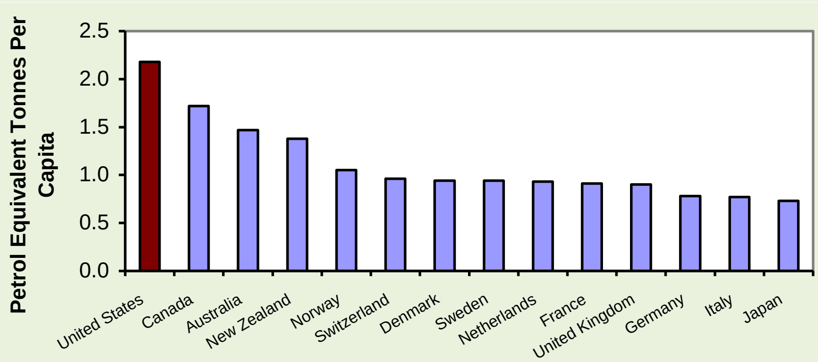
- Of U.S. vehicle fuel retail prices, crude oil represents 51-61%, taxes 18-22%, refining 11-15%, and distribution 10-12%.[6] Users spend approximately $700 and $1,000 billion annually on transportation fuels, averaging $2,333 to $3,333 per capita (including direct consumer expenditures and fuel used in the production of goods and services).



- The Energy Information Administration's *Energy Outlook* predicts that oil prices are likely increase, reaching $100 per barrel about 2015 and $140 per barrel in 2035, and in response the U.S. will significantly increase production of off-shore oil, biofuels, oil shales and coal liquefaction.[7]

- In 2009 the U.S. had a $381 billion trade deficit, of which $253 billion (66%) was from petroleum imports and $160 billion (42%) was from vehicle and vehicle part imports.[8]

- North Americans consume about twice as much transport fuel per capita as residents of most other wealthy countries.[9]



4 www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mttupus1&f=a
5 http://cta.ornl.gov/data/download28.shtml.
6 www.eia.gov/energyexplained/index.cfm?page=gasoline_factors_affecting_prices.
7 www.eia.gov/oiaf/aeo/index.html.
8 http://useconomy.about.com/od/tradepolicy/p/Trade_Deficit.htm.
9 *OECD in Figures*, www.oecd.org/document/62/0,3343,en_2649_34489_2345918_1_1_1_1,00.html.

External Cost Categories

External resource cost categories are described below.

Economic Costs

Dependency on imported resources such as petroleum imposes macroeconomic costs (it reduces employment and productivity) by transferring wealth from consumers to producers, and making an economy vulnerable to supply disruptions and price shocks (sudden price increases). This risk is indicated by the fact that the last three major oil price shocks were followed by recessions.

For much of the last century the U.S. imported significant amounts of petroleum. A major Federal study estimated that oil dependence cost the U.S. economy $150-$250 billion in 2005 when petroleum prices were $35-$45 per barrel.[10] At the start of this century, new drilling methods (hydrolic fracturing or "fracking") and horizontal drilling significantly increased domestic petroleum production, resulting in the U.S. being approximately petroleum self-sufficient in 2020.

Because North America consumes a major share of world petroleum production, high U.S. demand increases international oil prices, called a *pecuniary cost of oil use*.[11] This imposes financial costs on oil consumers and increases the wealth transfer from oil consumers to producers, exacerbating other economic costs. These are primarily economic transfers: costs to oil consumers but benefits to producers, but neutral from a global perspective, and benefits to petroleum producers and related industries.

National Security Risks

Dependency on imported resources imposes military, political and economic costs associated with protecting access to foreign petroleum supplies. For example, Persian Gulf military expenditures currently average about $500 billion annually,[12] plus indirect and long-term costs, such as lost productivity and future disability costs from military casualties.[13] These costs average at least $140 per imported barrel, about $3.33 per gallon ($500 billion costs divided by 3.5 billion barrels of petroleum imports, divided by 42 gallons per barrel) or about 16¢ per vehicle-mile.

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[10] David Greene and Sanjana Ahmad (2005), *The Costs of Oil Dependence: A 2005 Update*, USDOE (www.doe.gov); at http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM2005_45.pdf.

[11] Mark Delucchi (2005), *The Social-Cost Calculator (SCC): Documentation of Methods and Data, and Case Study of Sacramento*, UCD-ITS-RR-05-37, Institute of Transportation Studies (www.its.ucdavis.edu); at www.its.ucdavis.edu/publications/2005/UCD-ITS-RR-05-18.pdf.

[12] Roger J.Stern (2010), "United States Cost of Military Force Projection in the Persian Gulf,1976–2007," *Energy Policy*, Vol. 38, pp. 2816–2825.

[13] David L. Greene (2010), "Measuring Energy Security: Can The United States Achieve Oil Independence? *Energy Policy*, Vol. 38, Issue 4, April, Pages 1614-1621.

Environmental Damages

Resource exploration, extraction, processing and distribution cause environmental damages, including habitat disruption, from exploration and drilling activity, shorelines spoiled by refineries; plus air, noise and water pollution, groundwater contamination, spills, and sometimes earthquakes. Although newer policies and practices are intended to reduce and mitigate these impacts, there are significant residual damages, and many impacts are likely to increase as depletion of relatively accessible oil fields requires development of deep ocean wells and alternative fuels such as tar sands and oil shales.

Hydrolic fracturing ("fracking") combines chemicals (often dangerous ones) with large amounts of water and sand at high pressures to fracture material surrounding oil and gas, enabling them to be extracted. This process causes air, water and soil pollution, habitat disruption, and increased earthquake activity.[14] Because the resulting oil wells have short production lives, they tend o have high environmental costs per barrel produced. Production of alternative fuels such as oil sands and liquefied coal, is generally considered more environmentally damaging than conventional oil production, causing landscape damage, consuming large amounts of fresh water, and producing more climate change emissions per unit of fuel.[15]

As an example, the 2010 Deep Water Horizon oil spill cleanup and compensation costs are predicted to total $20-40 billion.[16] Assuming one such catastrophic spill occurs each decade, this averages $2-4 billion a year, or approximately 5% of total annual crude oil expenditures. However, this only includes direct, legally recognized damages from major spills; it excludes "normal" damages caused by petroleum production and processing (oil wells, refineries and transport facilities) and by smaller spills, and uncompensated ecological costs such as existence and aesthetic losses from destruction of wildlife and landscapes.

As discussed in Chapters 4 of this report, compensation costs are often much smaller than society's total willingness to pay to prevent damages, since generous compensation may encourage some people to take additional risks. This suggests that total petroleum production, processing and distribution environmental costs are many times larger than cleanup and compensation costs, perhaps $10 to $30 billion annually in the U.S., which averages $1.60 to $4.80 per barrel, or 3.8¢ to 11.4¢ per gallon of petroleum products consumed, or 0.2¢ to 0.6¢ per vehicle-mile.

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[14] Marc Lallanilla (2018), *Facts About Fracking*, Live Science (www.livescience.com); at www.livescience.com/34464-what-is-fracking.html.

[15] CAPP (2008), *Environmental Challenges And Progress In Canada's Oil Sands*, Canadian Assocation of Petroleum Producers (www.capp.ca); at www.capp.ca/getdoc.aspx?DocID=135721.

[16] Andrew Ross Sorkin (2010), "Imagining the Worst in BP's Future," *New York Times*, 8 June 2010; at http://dealbook.blogs.nytimes.com/2010/06/08/sorkin-imagining-the-worst-in-bps-future.

Human Health Risks

Resource exploration, extraction, processing and distribution cause various health risks to people, including processing and distribution accident injuries, and pollution-related illnesses. In 2006 petroleum production workers had 20.8 fatalities per 100,000 workers, which is much higher than typical service industry jobs but lower than other heavy industries such as truck drivers (27.5 deaths), coal mining (49.5 deaths), loggers (87.4).[17]

Financial and Economic Subsidies

Resource industries benefit from various financial subsidies and tax exemptions.[18] Their magnitude depends on how they are measured.[19] Such subsidies can include accelerated depreciation of energy-related capital assets, underaccrual for oil and gas well reclamation, low royalties for extracting resources from public lands, public funding of industry research and development programs, and subsidized water infrastructure for oil industries.[20] These are estimated to total tens of billions of dollars annually in the U.S.[21] hundreds of billions of dollars annually worldwide.[22]

Depletion of Non-Renewable Resources

Consumption of non-renewable resources such as petroleum reduces the supply that will be available for future generations.[23] Some economists argue that people have a moral obligation to conserve resources for the sake of intergenerational equity.[24]

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[17] BLS (2007), *Fatal Occupational Injuries, Employment, And Rates Of Fatal Occupational Injuries, 2006*, Bureau of Labor Statistics (www.bls.gov): at www.bls.gov/iif/oshwc/cfoi/CFOI_Rates_2006.pdf.

[18] GSI (2010), *Measuring Subsidies To Fossil-Fuel Producers*, Global Subsidies Initiative (www.globalsubsidies.org); at www.globalsubsidies.org/en/research/gsi-policy-brief-a-how-guide-measuring-subsidies-fossil-fuel-producers; *Subsidy Watch* (www.globalsubsidies.org/en/subsidy-watch).

[19] Kenneth McKenzie and Jack Mintz (2011), *Myths and Facts of Fossil Fuel Subsidies: A Critique of Existing Studies*, Report 11-14, School of Public Policy (http://papers.ssrn.com); at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1940535.

[20] David Coady, et al. (2010), *Petroleum Product Subsidies: Costly, Inequitable, and Rising*, International Monetary Fund (www.imf.org); at www.imf.org/external/pubs/ft/spn/2010/spn1005.pdf.

[21] ELI (2009), *Estimating U.S. Government Subsidies to Energy Sources: 2002-2008*, Environmental Law Institute (www.eli.org); at www.elistore.org/Data/products/d19_07.pdf.

[22] IEA (2010), *Analysis Of The Scope Of Energy Subsidies And Suggestions For The G-20 Initiative*, IEA, OPEC, OECD, World Bank Joint Report; at www.oecd.org/dataoecd/55/5/45575666.pdf.

[23] WB (1995), *Defining and Measuring Sustainability*, World Bank (www.worldbank.org).

[24] J. Gowdy and S. O'Hara (1995), *Economic Theory for Environmentalists*, St. Lucie (www.crcpress.com).

Alternative Fuel External Costs

Alternatives to petroleum also impose external costs, as summarized in the table below.[25] The *Alternative Fuels Data Center* (www.eere.energy.gov/afdc) and the *Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation* (GREET) Model indicate lifecycle energy use of various fuels.[26]

Table 5.12.3-1 **Alternative Transport Fuels Compared With Petroleum[27]**

Fuel Type	Costs Reduced	Costs Increased
Biodiesel (vegetable oils, primarily from soybeans and animal fats)	Renewable; biodegradable; domestically produced; improved lubricity in engine; reduced air pollutant emissions	May congeal at low temperatures; may damage engine components; may slightly decrease fuel economy; non-renewable fuels are used in production; limited availability; may increase nitrous oxide emissions.
Ethanol (primarily corn, also grains or agricultural waste)	Renewable; domestically produced; may reduce harmful air pollutants.	Non-renewable fossil fuels are used in its production; slightly decreases fuel economy.
Natural gas	Reduced air pollutant emissions	Non-renewable fossil fuel source; driving range is generally reduced; limited availability; extra tank is often required which reduces cargo space
Propane	Reduced air pollutant emissions	Non-renewable fossil fuel energy source; limited availability
Electricity	Zero tailpipe emissions; widely available	High vehicle and battery costs; limited range and performance; electricity production mainly from non-renewable sources[28]
Hybrid Electric	Increased fuel economy and reduced pollution; good range and performance	Primarily fueled with non-renewable fossil fuels
Synthetic fuels (tar sands, oil shales, liquefied coal)	Abundant supply exists.	Significant environmental damages from extraction and processing; high carbon emissions (10-20% higher per unit of energy than petroleum); high production costs.

Alternative fuels also impose external costs.

[25] *Alternative Fuels Data Center* (www.afdc.energy.gov/afdc).
[26] ANL (2008), *Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model*, Argonne National Lab; at www.transportation.anl.gov/modeling_simulation/GREET/index.html
[27] Consumer Reports (2006), *Alternative-fuels: How They Compare; Greener Choices* (www.greenerchoices.org/products.cfm?product=alternat&pcat=autos).
[28] Don Anair Amine Mahmassani (2012), *State of CHARGE: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States*, Union of Concerned Scientists (www.ucsusa.org); at www.ucsusa.org/assets/documents/clean_vehicles/electric-car-global-warming-emissions-report.pdf.

Future Trends

Many of these costs are likely to increase as relatively accessible petroleum supplies are depleted, . The point beyond which depletion of existing supply exceeds the development of new supply, is called *Peak Oil*.[29] This has occurred in many countries, including the United States, and is projected to occur worldwide between 2007 and 2015. Petroleum will not suddenly run out but is expected to become more expensive as demand grows and production costs rise. This will result in increased dependence on more difficult to access sources (sometimes called *extreme oil*) such as deep ocean wells, biofuels, tar sands and liquefied coal,[30] which tend to have large economic, social and environmental external costs, as previously described.[31]

Transportation Resource Consumption

Transport activities consume about a quarter of total US energy use and about two-thirds of petroleum, which exceeds total domestic production.[32] Tables 5.12.3-2 through 5.12.3-5, and Figure 5.12.3 compare various modes' energy consumption.

Table 5.12.3-2 **2006 Energy Consumption by Transport Sector**[33]

	Trillion BTUs	Percent Total
Cars and motorcycles	9,305	33.6%
Light trucks (including vans and SUVs)	7,518	27.2%
Heavy trucks	5,188	18.7%
Aviation	2,496	9.0%
Water	1,455	5.3%
Pipeline	842	3.0%
Railroads	670	2.4%
Buses	196	0.7%
Total	*27,670*	*100.0%*

Table 5.12.3-3 **Freight Modes Compared** (per ton-mile)[34]

	Costs	Fuel	Hydrocarbons	CO	NOx
Units	*Cents*	*Gallons*	*Lbs.*	*Lbs.*	*Lbs.*
Barge	0.97	0.002	0.09	0.20	0.53
Rail	2.53	0.005	0.46	0.64	1.83
Truck	5.35	0.017	0.63	1.90	10.17

29 *Association For The Study Of Peak Oil & Gas* (www.peakoil.net).
30 EIA (2010), *Annual Energy Outlook*, Energy Information Administration (www.eia.doe.gov); at www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html.
31 John L. Renne and Billy Fields (2013), "Moving from Disaster to Opportunity," *Transport Beyond Oil: Policy Choices for a Multimodal Future*, Island Press (www.island.org).
32 ORNL (2008), *Transportation Energy Data Book*, Oak Ridge National Laboratories, U.S. Department of Energy (www.ornl.gov), annual report, http://cta.ornl.gov/data/index.shtml.
33 ORNL (2008), Table 2.5.
34 TRB (2002), "Comparison of Inland Waterways and Surface Freight Modes," *TR NEWS 221*, Transportation Research Board (www.trb.org), July-August, p. 17.

Table 5.12.3-4 **Energy Use by Mode** (Passenger-Miles Per Gallon of Gasoline Equivalent)[35]

Mode	Average	Maximum
Bicycle	653	653
Light rail	510	1400
High speed (TGB) train	500	630
Neighborhood electric vehicle	260	870
Commuter train (BART)	244	520
Walking	235	235
Express commuter bus	230	330
City bus (London)	115	330
Airplane	67	85
Hybrid car (Prius)	60	230
Average automobile	20	40
Helicopter	4	20

Table 5.12.3-5 **Energy Use by Mode**[36]

MODE	Pass-mi/Gal**			Btu/pass-mi			CO2 g/pass-mi		
	low	AVG	high	low	AVG	high	low	AVG	high
Motorcoach	225.1	**239.8**	251.2	549	**575**	613	41	**43**	46
Van Pool	60.3	**106.1**	203.8	677	**1,300**	2,289	50	**97**	170
Heavy Rail	55.0	**190.6**	245.5	562	**724**	2,510	99	**127**	442
Commuter Rail	32.1	**90.3**	169.5	814	**1,528**	4,297	143	**183**	320
Intercity Rail (AMTRAK)	73.0	**85.2**	150.3	918	**1,619**	1,892	162	**147**	141
Car Pool - 2 person	36.3	**55.9**	121.1	1,140	**2,470**	3,800	85	**184**	283
Light Rail	6.2	**92.0**	209.6	658	**1,500**	22,212	116	**264**	3,910
Trolley Bus	55.1	**106.6**	125.2	1,103	**1,294**	2,505	194	**228**	441
Domestic Air Travel		**54.8**			**2,519**			**188**	
Car - Avg Trip	25.2	**38.8**	84.1	1,641	**3,555**	5,470	122	**265**	407
Transit Bus	3.6	**70.5**	250.0	552	**1,957**	37,884	40	**136**	2,767
Car - 1 Person	18.2	**27.9**	60.5	2,280	**4,939**	7,600	170	**368**	566
Ferry Boat	2.0	**12.5**	27.1	5,085	**11,003**	70,704	379	**819**	5,264
Demand Response	1.6	**8.6**	59.5	2,317	**15,957**	86,746	167	**1,151**	5,823

**Passenger miles per Diesel Equivalent gallon

This table summarizes low, medium and high fuel consumption and CO_2 emission rates for various passenger transport modes.

[35] Wikipedia (2007), *Fuel Efficiency in Transportation*, Wikipedia (http://en.wikipedia.org); at http://en.wikipedia.org/wiki/Fuel_efficiency_in_transportation.
[36] MJB&A (2014), *Comparison of Energy Use & CO2 Emissions From Different Transportation Modes*, American Motor Coach Association (www.buses.org); at www.buses.org/files/green.pdf.

Table 5.12.3-6 **Energy Use by Mode** (MJ/Passenger km)[37]

Urban				Non-Urban			
Mode	Fuel	Embodied	Total	Mode	Fuel	Embodied	Total
Bicycle	0.3	0.5	0.8	Bus	1.0	0.3	1.3
Private Bus	1.2	0.5	1.7	Rail	1.2	0.7	1.9
Light Rail	1.4	0.7	2.1	International Air	2.2	0.9	3.1
Bus	2.1	0.7	2.8	Domestic Air	3.1	2.7	5.7
Heavy Rail	1.9	0.9	2.8	Regional Air	4.3	5.4	9.7
Car, Petrol	3.0	1.4	4.4	Charter Air	8.7	9.1	17.8
Car, Diesel	3.3	1.4	4.8	Private Air	6.5	12.4	18.9
Car, LPG	3.4	1.4	4.8				
Ferry	4.3	1.2	5.5				

This table summarizes estimated average energy requirements for travel by various modes, including fuel consumption and embodied energy (energy used to produce vehicles).

Fuel consumption rates depend on vehicle operating conditions.[38] Fuel consumption per vehicle-mile tends to increase with vehicle weight, traffic congestion, hills, extreme cold, and very high and low speeds. Fuel consumption per vehicle-mile tends to be minimized between 30 mph and 55 mph and increase significantly above 65 mph.[39] Fuel consumption per passenger-mile also depend on vehicle load factors (passengers per vehicle).

Energy consumption should generally be evaluated using lifecycle analysis which accounts for resources used in vehicle, infrastructure and fuel production.[40] Embodied energy typically represents 25-50% of total energy use. Motor vehicle production uses large amounts of aluminum, steel, lead, and rubber consumption. Most vehicle metals can be recycled, but reprocessing involves substantial energy consumption and pollution. Building, operating and maintaining roadways and parking facilities also adds significantly to a typical vehicle's total resource footprint.[41]

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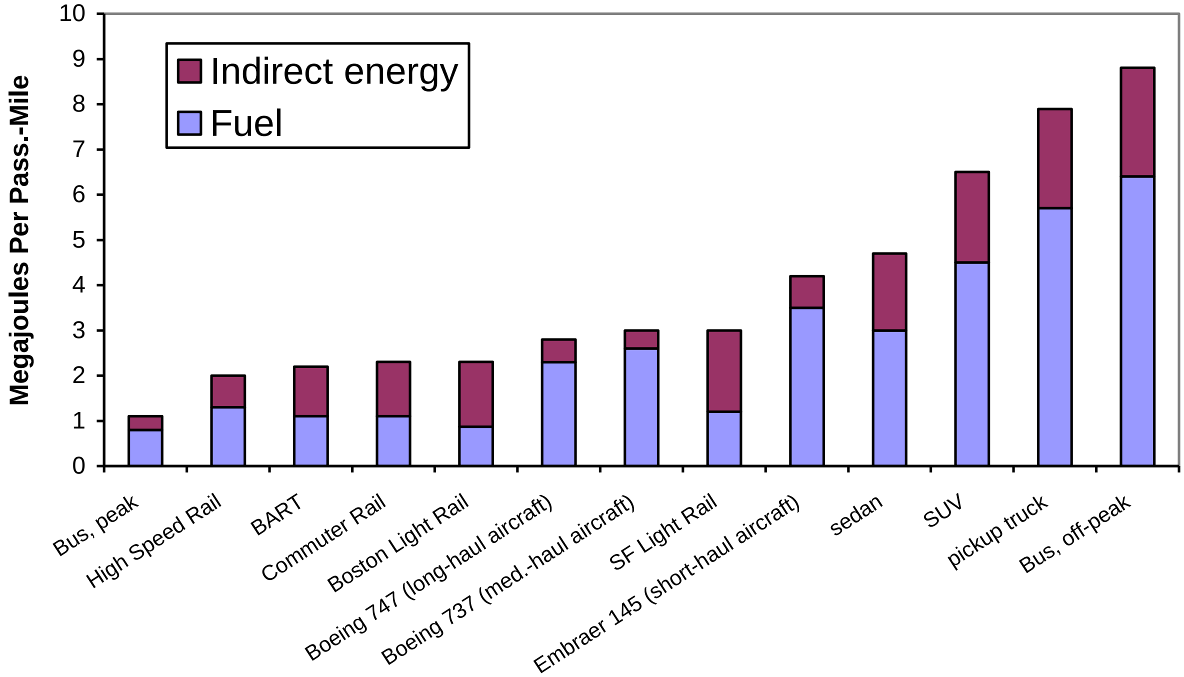
[37] Manfred Lenzen (1999), "Total Requirements of Energy and Greenhouse Gases for Australian Transport," *Transportation Research D*, Vol. 4, No. 4, (www.elsevier.com/locate/trd) July, pp. 265-290.
[38] FHWA (2002), *Highway Economic Requirements System: Technical Report*, Federal Highway Administration, USDOT (www.fhwa.dot.gov/infrastructure/asstmgmt/hersindex.htm); at http://isddc.dot.gov/OLPFiles/FHWA/010945.pdf.
[39] Matthew Barth and Kanok Boriboonsomsin (2009), Traffic Congestion and Greenhouse Gases, *Access*, Fall 2009, University of California Transportation Center (www.uctc.net); at www.uctc.net/access/35/access35_Traffic_Congestion_and_Grenhouse_Gases.shtml.
[40] Mikhail Chester and Arpad Horvath (2008), *Environmental Life-cycle Assessment of Passenger Transportation*, UC Berkeley Center for Future Urban Transport; at www.sustainable-transportation.com.
[41] Luc Gagnon (2006); *Greenhouse Gas Emissions from Transportation Options*, Hydro Quebec (www.hydroquebec.com); at www.hydroquebec.com/sustainable-development/documentation/pdf/options_energetiques/transport_en_2006.pdf.

Figure 5.10.4-1 **Lifecycle Energy Consumption and Emissions**[42]



This figure compares fuel and indirect energy (energy used in vehicle and facility construction and maintenance) for various transport modes.

In a follow up study, Chester, Horvath and Madanat calculate parking facility lifecycle energy consumption, greenhouse gas and air pollution emissions (CO, SO_2, NO_X , VOC, and PM_{10}) based on five parking supply scenarios.[43] Parking energy consumption is estimated to average from 14–18 kJ/Passenger-Km (Scenario 1) to 240–310 kJ/Passenger-Km (Scenario 5) and GHG emissions range from 1.3–1.7 gCO_2e/PKT (Scenario 1) to 19–25 g CO_2e/PKT (Scenario 5). This represents 0.5% to 12% of total estimated transport system lifecycle energy consumption and greenhouse emissions, and 24% to 81% other air pollutants, depending on vehicle type and scenario.

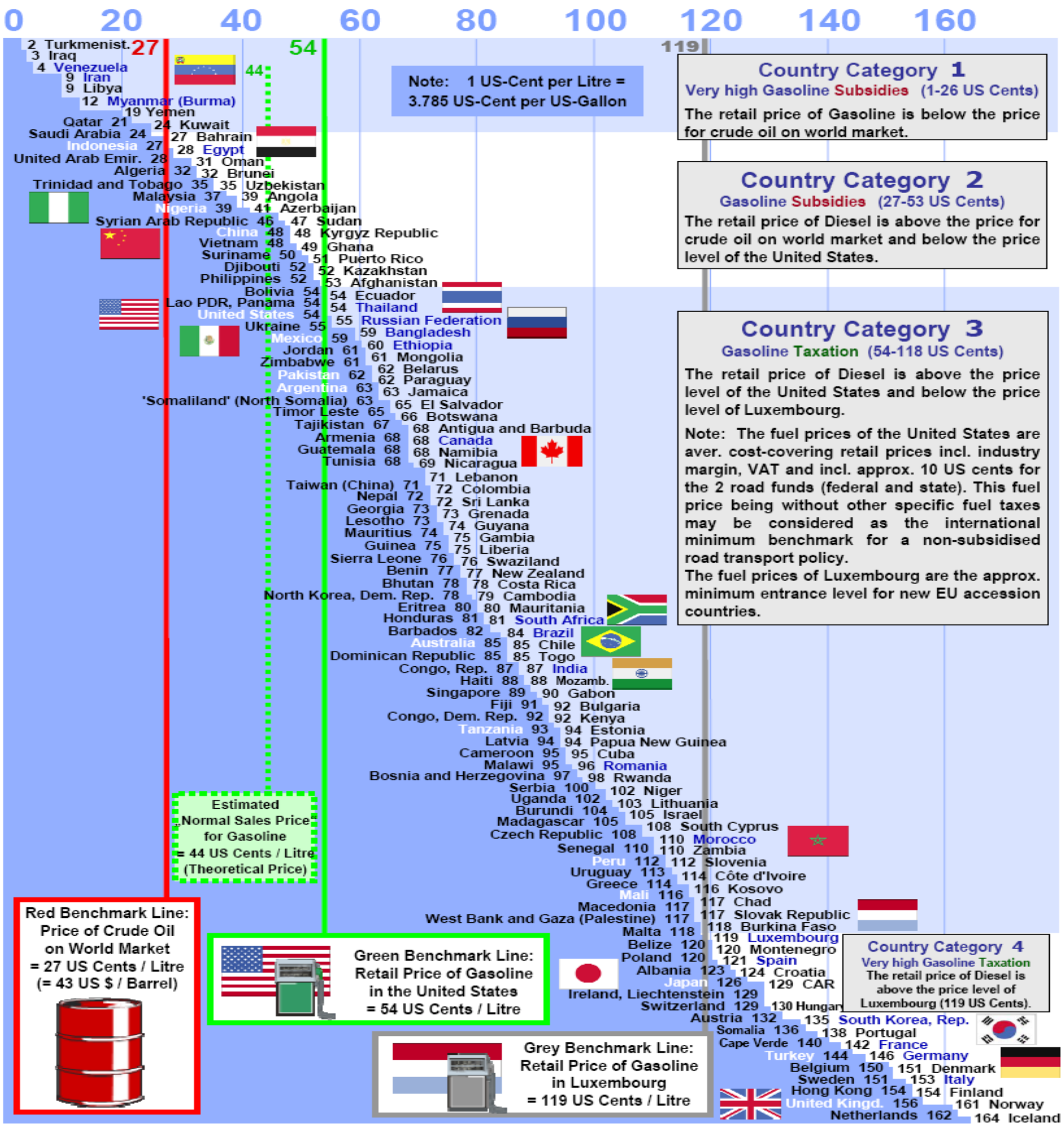
[42] Aurbach (http://pedshed.net/?p=219), based on Mikhail V Chester and Arpad Horvath (2009), “Environmental Assessment Of Passenger Transportation Should Include Infrastructure And Supply Chains,” *Environmental Research Letters*, Vol. 4; at http://iopscience.iop.org/1748-9326/4/2/024008.

[43] Mikhail Chester, Arpad Horvath and Samer Madanat (2010), “Parking Infrastructure: Energy, Emissions, And Automobile Life-Cycle Environmental Accounting,” *Environmental Research Letters*, Vol. 5, No. 3; at http://dx.doi.org/10.1088/1748-9326/5/3/034001.

Fuel Prices and Subsidies

Fuel price data is available from the *International Energy Agency* (www.iea.org), the U.S. *Energy Information Administration* (www.eia.gov) and *International Fuel Prices* (www.internationalfuelprices.com). The GDZ report, *International Fuel Prices 2005*, provides information on gasoline and diesel prices of 172 countries, including time series data, fuel tax rates and revenues. The table below illustrates an example of these data.

Figure 5.10.4-2 **Gasoline Retail Prices in 172 Countries** (2004 US Cents Per Litre)[44]



This figure illustrates gasoline retail prices in 172 countries collected by GTZ.

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44 Gerhard Metschies (2005), *International Fuel Prices 2005, with Comparative Tables for 172 Countries*, German Agency for Technical Cooperation (www.internationalfuelprices.com).

GTZ report authors apply the following principles to calculate fuel subsidies:[45]

1. Fuel taxation should be based on the *users pay* principle, i.e. road users should pay for their road network through fuel taxes or other charges.
2. Transport should contribute to state finances. Fuel should be subject to normal sales taxes (such as VAT) in addition to fuel excise taxes, and possibly additional *sumptuary* taxes to encourage conservation and help fund essential services, such as healthcare, education and security, particularly since it is a relatively easy tax to administer.
3. Prices in transport always have a guiding function. Taxation should thus be designed to avoid undesired price distortions; for example, between different forms of transport such as private transport, local public transport, rail, etc.

Fuel taxation can also encourage fuel efficiency, use of cleaner fuels, and less polluting transport modes. For example, introducing a higher tax rate on high-sulphur fuels can help shift consumption to low-sulphur fuels, and fuel tax revenue can be used to cross-subsidize local public transport. Table 5.12.3-6 summarizes minimal fuel taxes recommended in the GTZ report. It considers fuels subsidized if their prices are below the equivalent of 2004 USD $0.44 per litre, as illustrated in Figure 5.10.4-3.

Table 5.12.3-6 **Minimal Transportation Taxes Recommended by GTZ**

Purpose of tax	Minimum fuel tax
Road tax for highways	USD 0.10 per litre
Transport tax for urban roads and local public transport	USD 0.03 - 0.05 per litre
Energy taxes, eco-taxes, taxes to combat fuel smuggling	Variable, often depending on price level in neighbouring countries
Levy for national fuel stockpile	Variable
Funding measures to improve road safety	Variable; approx. 1.5% of transport spending

This table defines minimal transport tax levels. Tax rates below this level can be considered subsidies of fuel consumption and motor vehicle travel.

International Monetary Fund analysis estimated that 2010 global petroleum product subsidies totaled almost $250 billion, and $740 billion including tax subsidies, 1% of global GDP,[46, 47] Halving these subsidies could reduce projected fiscal deficits by one-sixth in subsidizing countries and reduce greenhouse emissions by 15%. U.S. subsidies are estimated to total tens of billions of dollars annually.[48]

[45] Gerhard P. Metschies, Sascha Thielmann and Armin Wagner (2007), "Removing Fuel Subsidies: Clearing the Road to Sustainable Development," *Subsidy Watch*, Vol. 10 (www.globalsubsidies.org); at www.globalsubsidies.org/en/subsidy-watch/commentary/removing-fuel-subsidies-clearing-road-sustainable-development.

[46] David Coady, et al. (2010), *Petroleum Product Subsidies: Costly, Inequitable, and Rising*, International Monetary Fund (www.imf.org); at www.imf.org/external/pubs/ft/spn/2010/spn1005.pdf.

[47] IEA (2010), *Analysis Of The Scope Of Energy Subsidies And Suggestions For The G-20 Initiative*, IEA, OPEC, OECD, World Bank Joint Report; at www.oecd.org/dataoecd/55/5/45575666.pdf.

[48] ELI (2009), *Estimating U.S. Government Subsidies to Energy Sources: 2002-2008*, Environmental Law Institute (www.eli.org); at www.elistore.org/Data/products/d19_07.pdf.

GTZ recommends using the following steps to achieve optimal fuel prices:

> *Step 1*: Eliminate any subsidies that bring fuel prices below production costs.
>
> *Step 2*: Increase prices to unsubsidised level (the average US pump price less USD 0.10 per litre), then let prices vary in line with changes in world prices.
>
> *Step 3*: Add taxes at least sufficient to finance road maintenance costs, plus any regular value-added tax (VAT), revenues from which contribute to general state budgets.
>
> *Step 4*: If general taxes are not reliable sources for funding road construction and public transport services, raise fuel taxes to finance these in addition to road maintenance.
>
> *Step 5*: Fuel taxes can be raised to generate revenue for other sectors, in addition to financing transport facilities and services, as in European and wealthy Asian countries. Tax rate can also be raised for high polluting fuels, such as high sulphur and leaded fuel.

Economic and Equity Impacts Of Fuel Taxes and Subsidies

People often assume that low fuel prices support economic development (increased employment, business activity, property values and tax revenues), and benefit poor people, which are sometimes considered external benefits that offsets external costs. These assumptions are often used to justify low fuel taxes and subsidies. However, these assumptions are often wrong.

Although low fuel prices and subsidies do stimulate certain economic activities, such as fuel purchases and shipping activity, they tend to be economically harmful overall by transferring wealth from fuel consumers to producers, and by reducing transport system efficiency, leading to increased traffic congestion, accidents, road and parking facility costs, sprawl and pollution emissions compared with what would occur with higher fuel prices.[49, 50, 51] Evidence that low fuel prices and high per capita vehicle travel stimulate economic development tend to confuse cause and effect: vehicle travel tends to increase with wealth, but beyond an optimal level (probably 3,000 to 5,000 annual vehicle-miles per capita, and less in urban areas) marginal economic costs exceed marginal benefits.[52]

Overall, economic productivity tends to increase with *higher* fuel prices, particularly in oil consuming regions (where a significant portion of petroleum is imported), as indicated in Figure 5.10-4.4. This occurs because higher fuel prices encourage people and businesses to use more resource efficient transport options. The result is less wealth transferred to oil producers, leaving more money circulating in the local economy, increasing employment and business activity. It also reduces transportation costs.

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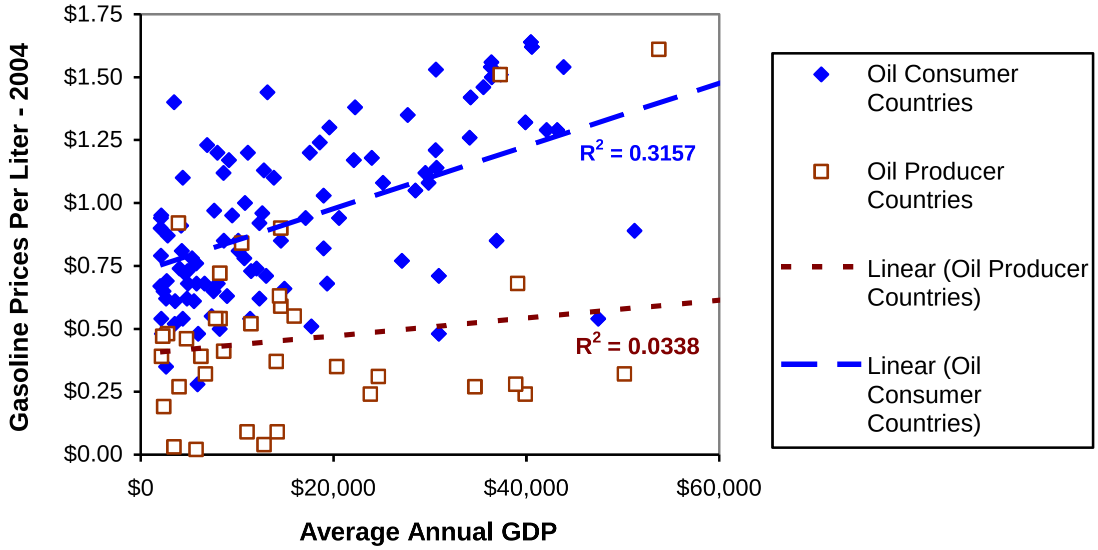
[49] *Global Subsidy Initiative* (www.globalsubsidies.org).

[50] Michael Plante (2011), *The Long-Run Macroeconomic Impacts Of Fuel Subsidies In An Oil-Importing Developing Country*, Federal Reserve Bank Dallas; at http://mpra.ub.uni-muenchen.de/33823.

[51] UNEP (2008), *Reforming Energy Subsidies*, United Nations Environment Programme (www.unep.org); at www.unep.org/pdf/pressreleases/reforming_energy_subsidies.pdf.

[52] Todd Litman (2009), *Evaluating Transportation Economic Development Impacts*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/econ_dev.pdf.

Figure 50.10-4.4 **GDP Versus Fuel Prices**[53]



Economic productivity tends to increase with fuel prices, particularly in oil consuming countries.

Even in oil producing regions, high fuel taxes can support economic development. For example, although Norway is a major petroleum producer it maintains high fuel prices and energy conservation policies, which leaves more oil to export. As a result, Norway has one of the world's highest incomes, a competitive and expanding economy, a positive trade balance and the world's largest legacy fund. Other oil producers, such as Saudi Arabia, Venezuela and Iran, experience relatively less economic development due to low fuel prices that encourage inefficient resource consumption.

Although fuel prices tend to be regressive (the portion of household expenditures devoted to fuel tends to increase with income), overall equity impacts depend on how revenues are used and the quality of transport options available.[54] If fuel taxes substitute for other regressive taxes, or are used to finance services that benefit lower-income households (such as improved public education or transit), and if lower-income people have fuel efficient transport options (lower-income consumers tend to drive less than average and rely on alternative modes), high fuel taxes are not necessarily regressive. This indicates that higher fuel taxes can support economic development and help create more equitable transport systems if implemented gradually and predictably, in conjunction with policies that increase transport system efficiency and diversity, such as improved walking, cycling and public transit service, and more accessible land use development.

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[53] Fuel price (www.internationalfuelprices.com), GDP (http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(PPP)_per_capita), petroleum production (http://en.wikipedia.org/wiki/Petroleum); excluding countries with average annual GDP under $2,000.
[54] Todd Litman (2002), "Evaluating Transportation Equity," *World Transport Policy & Practice* (http://ecoplan.org/wtpp/wt_index.htm), Volume 8, No. 2, Summer, pp. 50-65; at www.vtpi.org/equity.pdf.

5.12.4 Estimates

All values are in U.S. dollars unless otherwise indicated.

Summary Table

Table 5.12.4-1 **Resource Consumption Costs Summary Table – Selected Studies**

Publication	Costs Considered	Cost Value	2007 USD	Per Gallon
Paul N. Leiby (2007)	US non-military	$13.60 per barrel (2004)	$14.96	$0.036
	Cost ranges	$6.70 to $23.25	$7.37 - 25.58	$0.18-0.61
NDCF (2007)	Military	$137.8 billion (2006)	$142 billion/yr	$0.48
	Total	$825.1 billion	$850 billion/yr	$2.89
Greene and Ahmad (2005)	Energy security & wealth transfer	$150-$250 billion in 2005	$160-$275 billion	$0.57-$0.94
Koplow (2004)	Energy subsidies (incl. Non-transportation)	$37 - $64 billion (2003)	$42 – 72 billion/yr	$0.14-$0.24
Stern (2010)	Military costs of oil access	$500 billion/yr (2010)	$500 billion/yr	$1.70
NRC (2001)	Non-GHG	14¢ per gallon*	$0.16	$0.14

*More detailed descriptions of these studies are found below, along with summaries of other studies. 2007 Values have been adjusted for inflation by Consumer Price Index. * The currency year is assumed to be the same as the publication year.** Extrapolated from estimates in study.*

- U.S. oil spill cleanup and damage costs average approximately $16 per gallon ($672 per barrel), from less than $7 per gallon ($300 per barrel) for the 1979 *Ixtoc I* spill in the Gulf of Mexico, up to more than $630 per gallon ($25,000 per barrel) for the 1980 *Exxon Valdez* spill in Alaska.[55] This only reflects costs suitable for compensation; many damages are never compensated because are difficult to attribute (particularly for small spills and spills in international waters) or involve ecological services that lack legal status. According to surveys, the lower-bound estimate of the public's willingness to pay to avoid the *Valdez* spill's wildlife damages was $2.8 billion, about 75% of total cleanup and compensation costs. This suggests that total damage costs, and society's willingness to pay to avoid damages, are significantly (perhaps two to five times) higher than cleanup and compensation expenditures.

- A Rand Corporation study estimated the following external costs associated with petroleum production and use: surface transportation expenditures $91.5 billion; production externalities $1.03 billion; climate change $16.27 billion; national security $23.85 billion; and defense spending $83.25 billion.[56] This totals $13.72 per barrel or 33¢ per gallon for transport expenditures, and $124.40 per barrel or $2.96 per gallong for production and importation external costs, or $3.29 per gallon total.

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55 Mark A.Cohen (2010), *Taxonomy of Oil Spill Costs—What are the Likely Costs of the Deepwater Horizon Spill?*, Resources for the Future (www.rff.org); at www.rff.org/rff/documents/RFF-BCK-Cohen-DHCosts_update.pdf.

56 Keith Crane, Nicholas Burger and Martin Wachs (2011), *The Option of an Oil Tax to Fund Transportation and Infrastructure*, Rand Corporation (www.rand.org); at www.rand.org/content/dam/rand/pubs/occasional_papers/2011/RAND_OP320.pdf.

- An Environmental Law Institute study estimates federal subsidies for fossil fuel and renewable energy production totaled approximately $72 billion for fossil fuels and $29 billion for renewable energy between 2002 and 2008.[57] These include foregone tax revenues due to special tax provisions and under-collection of royalty payments; and direct spending on research and development, and other programs. Fossil fuel subsidies consisted primarily of tax breaks, such as the Foreign Tax Credit ($15.3 billion) and the Credit for Production of Nonconventional Fuels ($14.1 billion). About half of the subsidies for renewables are attributable to corn-based ethanol.

- Greene and Ahmad estimated that oil dependence cost the U.S. economy $150-$250 billion in 2005, and a total of $5 to $13 trillion (constant 2000 dollars) between 1970 and 2005.[58] These costs are relatively evenly divided between transfer of wealth from the United States to oil producing countries, the loss of economic potential due to oil prices elevated above competitive market levels, and disruption costs caused by sudden and large oil price movements. These estimates do not include military, strategic or political costs associated with U.S. and world dependence on oil imports.

- A 2007 federal report estimates U.S. petroleum import external economic costs, excluding military expenditures, total $13.60 per barrel (2004 dollars), with a range of $6.70 to $23.25, or about $54 billion annually for the U.S.[59] This is described as "a measure of the quantifiable per-barrel economic costs that the U.S. could avoid by a small-to-moderate reduction in oil imports."

- The International Energy Agency's, *World Energy Outlook 2008* annual report estimates that energy subsidies (mostly for oil, gas, and coal) totaled $557 billion, as illustrated in the graph below. The IEA estimates that eliminating those subsidies would cut global GHG emissions 10% by 2050.[60]

- Using World Bank data, Davis estimated that global gasoline and diesel subsidies totalled $110 billion in 2012, primarily in petroleum-producing countries that maintain low fuel prices.[61] Under baseline supply and demand elasticities assumptions annual world deadweight losses are estimated to total $44 billion, or $76 to $92 billion including increased external costs.

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57 ELI (2009), *Estimating U.S. Government Subsidies to Energy Sources: 2002-2008*, Environmental Law Institute (www.eli.org); at www.elistore.org/Data/products/d19_07.pdf.

58 David Greene and Sanjana Ahmad (2005), *The Costs of Oil Dependence: A 2005 Update*, Oak Ridge National Lab, US Department of Energy (www.doe.gov); at http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM2005_45.pdf.

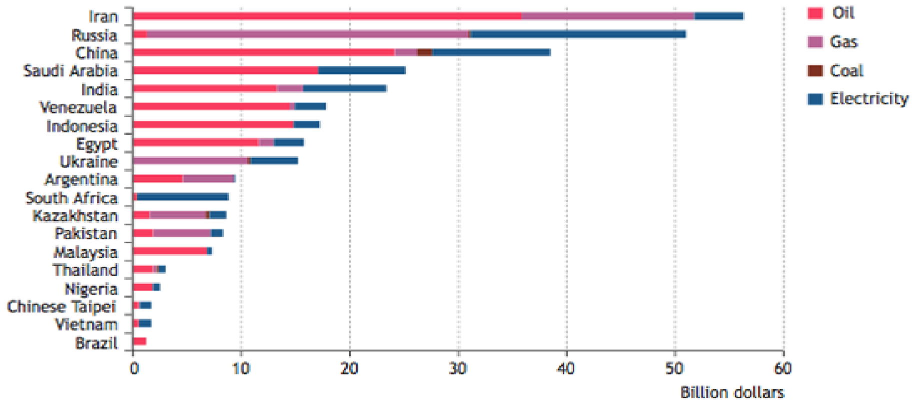
59 Paul N. Leiby (2007), *Estimating the Energy Security Benefits of Reduced U.S. Oil Imports*, Oak Ridge National Laboratory (www.ornl.gov); at www.epa.gov/oms/renewablefuels/ornl-tm-2007-028.pdf.

60 OECD (2010), *Global Warming: Ending Fuel Subsidies Could Cut Greenhouse Gas Emissions 10%, Says OECD*, Organization for Economic Cooperation and Development (www.oecd.org); at www.oecd.org/document/30/0,3343,en_2649_34487_45411294_1_1_1_1,00.html.

61 Lucas Davis (2013), *The Economic Cost of Global Fuel Subsidies*, UC Center for Energy and Environmental Economics (www.uce3.berkeley.edu); at www.uce3.berkeley.edu/WP_069.pdf.

- A Union of Concerned Scientists study compared the lifecycle operating costs and pollution emissions of conventional gasoline and electric-powered automobiles.[62] It concluded that electric vehicles provide environmental benefits only if electrical energy production becomes less carbon intensive, particularly less coal generation.

Figure 5.10.4-3 **Energy Subsidies by Fuel in Non-OECD Countries, 2007**[63]



Many countries subsidize energy consumption.

- Delucchi and Murphy estimate that direct U.S. military costs of the 1991 Gulf War and 2003 Iraq War total approximately a trillion dollars, 60% to 75% of these costs are caused by U.S. desire to maintain oil access, and eliminating U.S. motor vehicle oil consumption could reduce long-run defense spending $6 to $25 billion annually.[64]

- A European Energy Agency study estimates that European energy subsidies totaled EUR 29 billion in 2001, mostly for coal production.[65] These included direct grants; preferential tax treatments, regulations and loans; trade restrictions; infrastructure investments; and uncompensated security and environmental costs.

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[62]Don Anair Amine Mahmassani (2012), *State of CHARGE: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States*, Union of Concerned Scientists (www.ucsusa.org); at www.ucsusa.org/assets/documents/clean_vehicles/electric-car-global-warming-emissions-report.pdf.
[63] IEA (2009), World Energy Outlook 2008, International Energy Agency (www.iea.org); graph from http://arstechnica.com/old/content/2008/11/ieas-annual-report-paints-a-grim-our-energy-future.ars.
[64] Mark Delucchi and James Murphy (2008), *U.S. Military Expenditures To Protect The Use Of Persian-Gulf Oil For Motor Vehicles*, Institute of Transportation Studies (www.its.ucdavis.edu).
[65] EEA (2004), *Energy Subsidies In The European Union*, European Energy Agency (www.eea.europa.eu).

- Koplow estimates that US federal energy sector subsidies totaled $37 to $64 billion, considering approximately 75 programs/tax breaks.[66] Koplow and Dernbach identify the following major energy subsidies:[67]
  - Defending Persian Gulf oil shipping lanes.
  - Subsidized water infrastructure for coal and oil industry use.
  - Federal spending on energy research and development.
  - Accelerated depreciation of energy-related capital assets.
  - Underaccrual for reclamation and remediation at coal mines and oil and gas wells.
  - The ethanol exemption from the excise fuel tax.

- Lenzen compares the energy use of various modes, including both fuel consumption and energy embodied in vehicle production, as summarized in the following table.

Table 5.12.4-3 **Energy Use by Mode** (MJ/Passenger km)[68]

Urban				Non-Urban			
Mode	Fuel	Embodied	Total	Mode	Fuel	Embodied	Total
Bicycle	0.3	0.5	0.8	Bus	1.0	0.3	1.3
Private Bus	1.2	0.5	1.7	Rail	1.2	0.7	1.9
Light Rail	1.4	0.7	2.1	International Air	2.2	0.9	3.1
Bus	2.1	0.7	2.8	Domestic Air	3.1	2.7	5.7
Heavy Rail	1.9	0.9	2.8	Regional Air	4.3	5.4	9.7
Car, Petrol	3.0	1.4	4.4	Charter Air	8.7	9.1	17.8
Car, Diesel	3.3	1.4	4.8	Private Air	6.5	12.4	18.9
Car, LPG	3.4	1.4	4.8				
Ferry	4.3	1.2	5.5				

This table summarizes estimated energy requirements for travel by various modes.

- Metschies provides vehicle fuel price data from 172 countries, identifying direct subsidies in some countries.[69] He recommends a 10¢ per liter minimum vehicle fuel tax to recover basic roadway expenses, and a higher tax may be justified to internalize other costs associated with fuel production and automobile use. He identifies approximately 40 countries where gasoline and fuel retail prices are below international petrol prices, indicating significant subsidy.

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[66] Doug Koplow (2007), *Subsidy Reform and Sustainable Development: Political Economy Aspects*, OECD (www.oecd.org); at www.earthtrack.net/earthtrack/library/SubsidyReformOptions.pdf.
[67] Doug Koplow and John Dernbach (2001), "Federal Fossil Fuel Subsidies and Greenhouse Gas Emissions: A Case Study of Increasing Transparency for Fiscal Policy," *Annual Review of Energy and the Environment*, Vol. 26, (http://arjournals.annualreviews.org/loi/energy) pp. 361-389; at www.mindfully.org/Energy/Fossil-Fuel-Subsidies.htm.
[68] Manfred Lenzen (1999), "Total Requirements of Energy and Greenhouse Gases for Australian Transport," *Transportation Research D*, Vol. 4, No. 4, (www.elsevier.com/locate/trd) July, pp. 265-290.
[69] Gerhard P. Metschies (2005), *Fuel Prices and Taxation: With Comparative Tables for 160 Countries*, GTZ (www.gtz.de/en); at www.internationalfuelprices.com.

- The National Defense Council Foundation estimates that the external costs of US oil imports increased from $305 billion in 2003 to $825 billion in 2006.[70] The following table summarizes their estimate of external or 'hidden' costs of US oil imports.

Table 5.12.4-2 **External Costs of US Oil Imports 2003 and 2006**

	2003	2006
Oil-Related Defense Expenditures	$ 49.1 billion	$137.8 billion
Loss Current Economic Activity Due to Capital Outflow	$36.7 billion	$117.4 billion
Loss of Domestic Investment	$123.2 billion	$394.2 billion
Loss of Government Revenues	$13.4 billion	$42.9 billion
Cost of Periodic Oil Supply Disruptions	$ 82.5 billion	$132.8 billion
Total	*$304.9 billion*	*$825.1 billion*
Job Losses	*828,400*	*2,241,000*

- A National Research Council study estimated the external costs (per gallon and vehicle-mile) from the extraction, distribution, and consumption of various fuels and vehicles for various time periods.[71] It concluded:
  - In 2005, health damages totaled $36 billion for automobiles and $56 billion for all vehicles.
  - Electric vehicles and grid-dependent hybrid vehicles showed somewhat higher damages than many other technologies for both 2005 and 2030 if electricity is generated using fossil fuels, based on current emission control requirements.

- Stern estimates that U.S. Middle East military intervention costs, intended to maintain U.S. access to petroleum resources, average about $500 billion annually.[72] He concludes that these military costs are in addition to comparable magnitude economic costs, implying that U.S. oil dependency costs total about $1 trillion annually.

- Taylor, Matthew and Winfield estimate that Canadian government subsidies for the oil and gas industry totaled CA$1,446 million in 2002, averaging about CA$50 per capita.[73] Their analysis includes federal grants, tax benefits (such as the Resource Allowance and the Accelerated Capital Cost Allowance for oil sands), and government expenditures that directly support oil, gas and oil sands industries.

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[70] NDCF (2007), *Hidden Cost of Oil: An Update*, National Defense Council Foundation (www.ndcf.org); at http://ndcf.dyndns.org/ndcf/energy/NDCF_Hidden_Cost_2006_summary_paper.pdf.

[71] NRC (2009), *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*, National Academy of Sciences Press (www.nap.edu); at www.nap.edu/openbook.php?record_id=12794.

[72] Roger J.Stern (2010), "United States Cost of Military Force Projection in the Persian Gulf, 1976–2007," *Energy Policy*, Vol. 38, pp. 2816–2825; at www.princeton.edu/oeme/articles/US-miiltary-cost-of-Persian-Gulf-force-projection.pdf.

[73] Amy Taylor, Matthew Bramley and Mark Winfield (2005), *Government Spending on Canada's Oil and Gas Industry: Undermining Canada's Kyoto Commitment*, Pembina Institute (www.pembina.org).

- A 2003 UN study concluded that energy subsidies are widespread but vary depending on definitions, analysis methodologies, fuel type and location.[74] It concludes that producer subsidies, usually in the form of direct payments or support for research and development, are most common in OECD countries, while most subsidies in developing and transition countries go to consumers – usually through price controls that hold end-user prices below the full supply costs. Fossil-fuel and nuclear industries receive the majority of such subsidies, although OECD countries are increasing their support for renewable and alternative energy technologies.

5.12.5 Variability

This cost depends on total energy use, including direct fuel consumption and indirect uses such as vehicle production energy. There may be considerable differences depending on the country of consumption, particularly when military expenditures are included or if oil importing and exporting countries are compared.

5.12.6 Equity and Efficiency Issues

These are external costs and therefore horizontally inequitable and inefficient. Lower income households tend to devote a relatively large portion of income to fuel so internalizing these costs through higher taxes or fees may be regressive, although equity impacts ultimately depend on how revenues are used and the alternatives available. Fuel subsidies are an inefficient way to help poor people because most of the benefit goes to the wealthy; according to one study, the highest income quintile captures six times more in subsidies than the bottom. [75]

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[74] UNEP (2003), *Energy Subsidies: Lessons Learning In Assessing Their Impacts And Designing Policy Reforms*, United Nations Environment Programme (www.unep.org); at www.unep.ch/etu/publications/energySubsidies/Energysubreport.pdf

[75] Javier Arze del Granado and David Coady (2010), *The Unequal Benefits Of Fuel Subsidies: A Review Of Evidence For Developing Countries*, International Monetary Fund (www.imf.org); at www.imf.org/external/pubs/cat/longres.cfm?sk=24184.0.

5.12.7 Conclusions

Resource (particularly petroleum) consumption imposes various external costs:

Macroeconomic costs of importing oil, which reduce productivity and employment, particularly when petroleum prices spike. These are primarily economic transfers from oil consumers to producers, and so are not costs from a global perspective. When energy imports are high, these were estimated to cost the U.S. economy $50 to $500 billion annually. *Energy security* costs include military and political costs of maintaining access to oil supplies. These are large but difficult to allocate since such interventions may have multiple justifications. Applying marginal analysis, which only considers the direct savings from reduced fuel consumption, results in a low cost estimate, estimated by Delucchi and Murphy (2008) at $6 to $25 billion annually. However, applying cost recovery analysis, assuming that oil consumers should bear much of these costs, results in estimates of $50 to $500 billion. Delucchi and Murphy's estimate that 60% of Persian Gulf military costs are to maintain access to oil, represents about $300 billion annually.

Energy imports, and resulting macroeconomic and energy security costs declined significantly between 2000 and 2020, due to increased domestic fuel production. Optimistic preductions suggest that this will continue.

Environmental damages include habitat disruption, air, noise and water pollution, groundwater contamination, spills, and earthquakes caused by petroleum production. These costs are probably large but difficult to monetize. Cleanup and compensation costs for major spills total tens of billions of dollars, and there are probably significant additional uncompensated environmental costs, including net losses to people who use environmental resources, damages to ecological functions, so the value of preventing environmental damages is probably much greater than indicated by damage compensation costs. It is likely that these external costs total tens of billions of dollars annually.

Human health risks can result from petroleum production and processing, but these are probably largely internalized through worker compensation.

Various resource production *subsidies and tax exemptions* can be considered external costs. Many were established to support resource industries when commodity prices were low, and continued as prices and profits increased. Various studies estimate these to total tens of billions of dollars annually, depending on assumptions and perspectives.

Some of these costs are likely to increase in the future as declining petroleum production raises oil prices and increases exploitation of higher risk supplies, such as offshore oil, tar sands and liquefied coal. In addition to petroleum costs, alternative fuels and other resources used for transport also impose external costs.

Most external resource cost estimates only consider a portion of these categories and so underestimate total external costs and total resource conservation benefits. Estimates of total annual U.S. external resource costs, including economic and energy security costs, plus billions of dollars in uncompensated environmental damages and subsidies, range from about $50 billion to over $1,000 billion, depending on perspective and assumptions. Fracking has reduced U.S. oil imports and associated macroeconomic and security costs, but has significantly increased environmental damages per unit of petroleum produced.

For this analysis, this cost is conservatively estimated at $120 billion per year, $0.76 per gallon of gasoline, or 3.8¢ per vehicle-mile. Pollution impacts are excluded from this estimate to avoid double counting costs in chapters 5.10 and 5.15. Although this estimate is large, it is modest (about 10%) relative to total transport resource costs.

This cost is somewhat higher under Urban-Peak and lower under Rural conditions to reflect fuel efficiency. The costs of other modes are estimated based on their relative fuel consumption. Electric car resource costs are estimated to be half that of an efficient automobile to reflect lower external costs of this energy source.[76] Rideshare passengers are each estimated to add 2% incremental costs. Electric buses and trolleys are estimated to impose 1/3rd of diesel bus costs. Telework energy costs are estimated at 10% of an average automobile for increased equipment and residential heating energy.

Table 5.12.7-1 Estimate **External Resource Costs (2007 USD per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.046	0.040	0.034	0.038
Compact Car	0.038	0.033	0.028	0.031
Electric Car	0.019	0.016	0.014	0.016
Van/Light Truck	0.060	0.052	0.044	0.050
Rideshare Passenger	0.001	0.001	0.001	0.001
Diesel Bus	0.232	0.200	0.168	0.192
Electric Bus/Trolley	0.077	0.067	0.056	0.064
Motorcycle	0.019	0.016	0.013	0.015
Bicycle	0.000	0.000	0.000	0.000
Walk	0.000	0.000	0.000	0.000
Telework	0.004	0.004	0.004	0.004

Automobile Cost Range

Minimum and maximum values are based on the range of estimates in the literature.

Minimum	Maximum
$0.011	$0.150

[76] At 0.5 kWh/mile electric cars consume the same total energy as a 30 mpg car. External costs of electric power depend on the marginal electrical power source.

5.12.8 Implications for Optimal Fuel Policy And Pricing

This analysis indicates that resource (particularly petroleum) production, processing, importation and distribution impose significant external costs. These justify energy conservation policies, including efficient fuel pricing and other market reforms that result in more efficient resource use, such as those listed below. These reforms can provide a variety of benefits, in addition to energy conservation, including congestion reductions, road and parking facility cost savings, consumer savings, accident reductions, improved mobility for non-drivers, pollution reductions, more efficient land use development, and improved public fitness and health, and so can be justified even if there is uncertainty concerning the magnitude of some external costs.

Smart Transportation Energy Conservation Strategies[77]

- *Planning Reforms* - More comprehensive and neutral planning and investment practices.
- *Transportation Demand Management Programs* - Local and regional programs that support and encourage use of alternative modes.
- *Road Pricing* - Charges users directly for road use, with rates that reflect costs imposed.
- *Parking Pricing* - Charges users directly for parking facility use, often with variable rates.
- *Parking Cash-Out* - Offers commuters financial incentives for using alternative modes.
- *Pay-As-You-Drive Pricing* - Converts fixed vehicle charges into mileage-based fees.
- *Fuel Taxes- Tax Shifting* - Increases fuel taxes and other vehicle taxes.
- *Transit and Rideshare Improvements* - Improves transit and rideshare services.
- *Walking and Cycling Improvements* - Improves walking and cycling conditions.
- *Carsharing* - Vehicle rental services that substitute for private automobile ownership.
- *Smart Growth Policies* - More accessible, multi-modal land use development patterns.
- *Freight Transport Management* - Encourage businesses to use more efficient transport options.

A basic economic principle is that prices (what people pay for a good) should reflect its production costs unless subsidies are specifically justified. At a minimum, prices should reflect marginal costs, for efficiency sake, and in most cases should achieve cost recovery (an appropriate share of non-marginal costs), for equity sake and to reflect long-run costs, plus any general taxes applied to similar goods, for economic neutrality sake (Metschies 2005). These rules have various implications for optimal fuel prices.

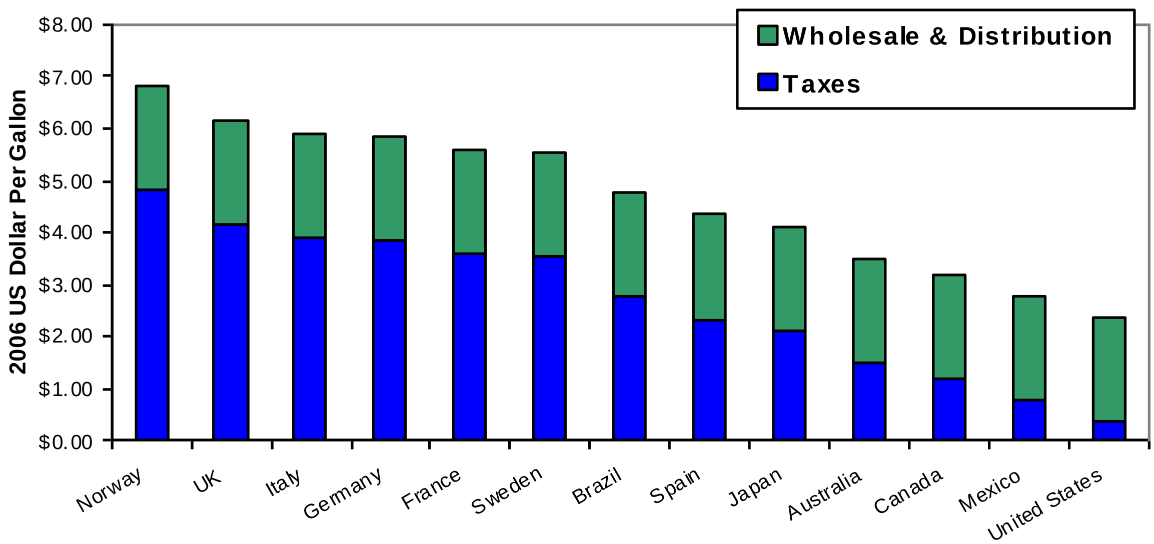
External costs of petroleum consumption are estimated to range from $50 billion to $1,000 billion. About 55% of U.S. oil consumption is used for highway transport, totaling about 175 billion gallons,[78] indicating the optimal fuel tax to internalize these costs is between $0.16¢ and $3.14 per gallon.

[77] Todd Litman (2008), *Smart Transportation Emission Reduction Strategies*, VTPI (www.vtpi.org); at www.vtpi.org/ster.pdf.
[78] ORNL (2009), *Transportation Energy Book*, Oak Ridge National Laboratories, U.S. Department of Energy (www.doe.gov); at http://cta.ornl.gov/data/index.shtml

Special vehicle fuel taxes are often used as a road user fee. U.S. roadway expenditures total about $180 billion,[79] so fuel taxes to recover these costs would average about $1.00 per gallon, and somewhat more to also pay for traffic services such as policing. In many jurisdictions, road user fuel taxes are applied instead of, rather than in addition to, general taxes, but unless there is a specific reason to favor fuel over the consumption of other goods, general sales taxes should be applied.

This suggest that optimal fuel taxes should range between $1.25 (the lower range of estimated external costs, roadway expenditures and general taxes) and $4.50 per gallon (the higher range of estimated external costs, roadway and traffic service expenditures and general taxes), three to eleven times higher than current U.S. fuel taxes, but comparable to tax rates in most other OECD countries, as illustrated below.

***Figure* 5.12.7-1 Vehicle Fuel Retail Prices** (www.internationalfuelprices.com)



North American fuel taxes far lower than those in other developed countries.

Low taxes increase fuel use and vehicle travel.[80] Various studies indicate the elasticity of fuel consumption with respect to fuel price is -0.1 to -0.3 in the short-run and -0.5 to -0.8 in the long-run, so a 10% price increase reduces consumption 1-3% in the short run and 5-8% over the long run.[81] Low fuel taxes help explain why North American per capita fuel consumption is more than twice most other wealthy countries, as Figure 5.12.7-2 indicates.

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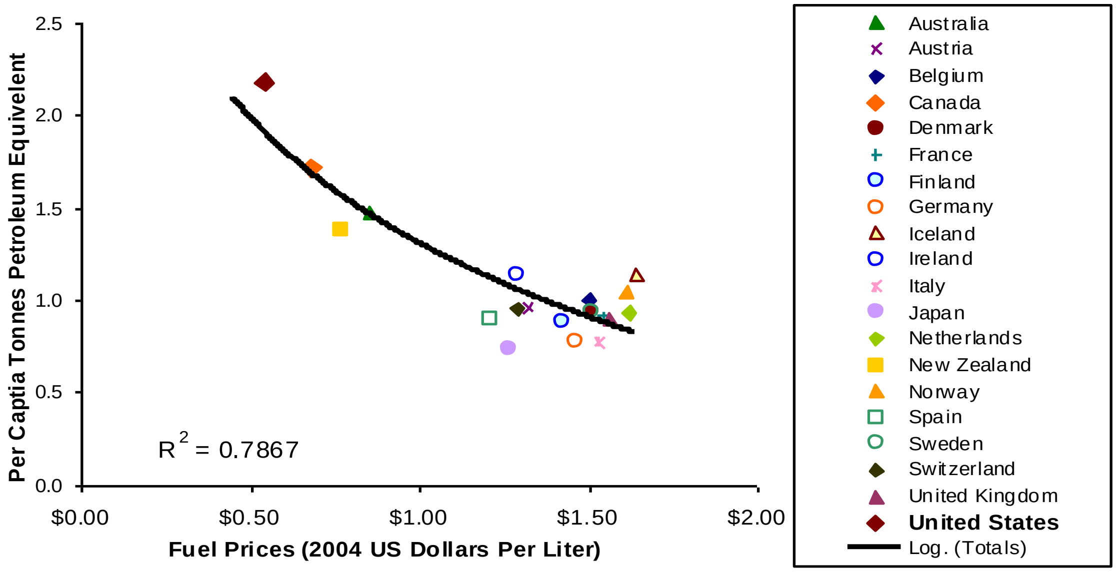
79 FHWA (2008), Table HF-2, *Highway Statistics*, FHWA (www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm).
80 Todd Litman (2008), *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/elasticities.pdf.
81 Stephen Glaister and Dan Graham (2002), "The Demand for Automobile Fuel: A Survey of Elasticities," *Journal of Transport Economics and Policy*, Vol. 36, No. 1, pp. 1-25; at www.ingentaconnect.com/content/lse/jtep/2002/00000036/00000001/art00001.

***Figure* 5.12.7-2 Fuel Price Versus Transport Energy Consumption** (OECD Data)[82]



As fuel prices increase, per capita transportation energy consumption declines.

Fuel underpricing increases total fuel consumption and therefore total fuel costs. For example, with low fuel prices an average consumer may pay $2,000 annually for fuel, but bear $4,000 in indirect and external costs (higher taxes for production subsidies and military expenditures, reduced economic productivity from trade deficit, uncompensated environmental costs, etc.), or $6,000 in total. With higher fuel prices the same consumer might pay $3,000 for fuel but only $1,000 in external costs, $4,000 in total due to a combination of reduced consumption and internalization of indirect costs.

Fuel underpricing may have been justified in the past when petroleum, motor vehicle and roadways systems where first growing and so experienced economies of scale, but these industries are now mature, and fuel consumption and motor vehicle travel impose significant external costs. This suggests that fuel underpricing is no longer justified.

Advocates of underpricing often argue that fuel price increases are regressive, particularly in automobile-dependent areas where even poor people must drive long distances, but this regreassivity ultimately depends on the quality of transport options available and how revenues are used. If fuel taxes are used to reduce equally regressive taxes, finance new services valued by low-income households (such as walking, cycling and transit service improvements, or better education and healthcare services), or are returned as cash rebates, equity impacts can be neutral or progressive overall.[83]

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[82] OECD Data Spradsheet, www.vtpi.org/OECD2006.xls.

[83] VTPI (2010), "Fuel Taxes," *Online TDM Encyclopedia*, VTPI (www.vtpi.org/tdm/tdm17.htm).

5.12.9 Information Resources

Resources below provide information on transport energy supply, demand and consumption.

Energy Consumption Calculators

- *Business Energy Analyzer* (www.energyguide.com). The Business Energy Analyzer is designed to provide a comprehensive analysis of energy use in your business along with customized energy efficiency improvement recommendations.
- *Density Effects Calculator* (www.sflcv.org/density). Indicates how neighborhood density impacts the environment (land, materials, energy and driving).
- *Emissions Calculator* (www.airhead.org/Calculator). This emissions calculator tabulates a user's aggregate monthly emissions of seven air pollutants (in pounds) from electricity and natural gas consumption, airplane trips, and vehicle miles traveled (auto or sport utility vehicle/truck) and compares them with average national emissions.
- *Greenhouse Gas Equivalencies Calculator* (www.epa.gov/cleanenergy/energy-resources/calculator.html). It translates greenhouse gas (GHG) reductions from units that are typically used to report reductions (e.g., metric tons of carbon dioxide equivalent) into terms that are easy to conceptualize.
- *MetroQuest* (www.envisiontools.com). Evaluates the consequences of different long-term planning strategies.
- *Personal* CO_2 *Calculation* (www3.iclei.org/co2/co2calc.htm). This worksheet determines yearly direct personal carbon dioxide emissions. Results include yearly personal carbon dioxide emissions and a per capita comparison chart to other industrialized countries.
- TC (2009), *The Urban Transportation Emissions Calculator* (wwwapps.tc.gc.ca/prog/2/UTEC-CETU/menu.aspx?lang=eng) is a user-friendly, Internet-based tool developed by Transport Canada that estimates greenhouse criteria air emissions from various different vehicle types (e.g., cars, commercial trucks, buses, light rail), fuel technologies (e.g., gasoline, diesel, hybrid, ethanol, biodiesel, etc.), and planning horizons (2006-2031).
- *Tool For Costing Sustainable Community Planning* (www.cmhc-schl.gc.ca/en/inpr/su/sucopl/index.cfm) allows users to estimate costs of community development, particularly those that change with different forms of development (e.g., linear infrastructure), and to compare alternative development scenarios.
- *Travel Matters Emissions Calculators* (www.travelmatters.org). TravelMatters! from the Center for Neighborhood Technology provides a trio of resources - interactive emissions calculators, online emissions maps, and a wealth of educational content that emphasize the relationship between more efficient transit systems and lower greenhouse gas emissions. The site also offers transport emissions by county for all contiguous states.
- The *Zerofootprint Calculator* (www.zerofootprint.net) enables you to measure and understand the impact of your *ecological footprint*, taking into account both direct and indirect resource consumption. *Zerofootprint Cities* is an initiative designed for Mayors of the world's cities to engage their citizens around climate change.

Other Resources

Alternative Fuels Data Center by the U.S. Department of Energy; at www.eere.energy.gov/afdc.

American Petroleum Institute (www.api.org), provides fuel supply, demand and price data.

Roma Malik, Kevin Behan and Gabriella Kalapos (2014), *Why Account for the Full Cost of Energy?*, Clean Air Partnership (www.cleanairpartnership.org); at www.cleanairpartnership.org/files/True%20Cost%20of%20Energy%20Final.pdf.

Javier Arze del Granado and David Coady (2010), *The Unequal Benefits Of Fuel Subsidies: A Review Of Evidence For Developing Countries*, International Monetary Fund (www.imf.org); at www.imf.org/external/pubs/cat/longres.cfm?sk=24184.0.

Experian Catalist (www.catalist.com) provides petroleum price information for various countries.

Mikhail Chester and Arpad Horvath (2008), *Environmental Life-cycle Assessment of Passenger Transportation*, Transportation Lifecycle Assessment (www.transportationlca.org).

Mikhail Chester, Stephanie Pincetl, Zoe Elizabeth, William Eisenstein and Juan Matute (2013), "Infrastructure And Automobile Shifts: Positioning Transit To Reduce Life-Cycle Environmental Impacts For Urban Sustainability Goals," *Environmental Research Letters*, Vol. 8, pp. (2013) (doi:10.1088/1748-9326/8/1/015041); at http://iopscience.iop.org/1748-9326/8/1/015041/pdf/1748-9326_8_1_015041.pdf.

David Coady, et al. (2010), *Petroleum Product Subsidies: Costly, Inequitable, and Rising*, International Monetary Fund (www.imf.org); at www.imf.org/external/pubs/ft/spn/2010/spn1005.pdf.

Keith Crane, Nicholas Burger and Martin Wachs (2011), *The Option of an Oil Tax to Fund Transportation and Infrastructure*, Rand Corporation (www.rand.org); at www.rand.org/content/dam/rand/pubs/occasional_papers/2011/RAND_OP320.pdf.

Lucas Davis (2013), *The Economic Cost of Global Fuel Subsidies*, UC Center for Energy and Environmental Economics (www.uce3.berkeley.edu); at www.uce3.berkeley.edu/WP_069.pdf.

Earth Track (www.earthtrack.net) documents energy subsidies and market distortions.

EC (2005), *ExternE: Externalities of Energy - Methodology 2005 Update*, Directorate-General for Research Sustainable Energy Systems, European Commission (www.externe.info).

EIA (2011), *International Energy Outlook 2011*, U.S. Energy Information Administration (www.eia.gov); at www.eia.gov/forecasts/ieo/pdf/0484(2011).pdf.

EIO-LCA Model (www.eiolca.net) quantifies the economic and environmental impacts of producing goods or services, including total energy consumption and pollution emissions.

ELI (2009), *Estimating U.S. Government Subsidies to Energy Sources: 2002-2008*, Environmental Law Institute (www.eli.org); at www.elistore.org/Data/products/d19_07.pdf.

Jennifer Ellis (2010), *The Effects Of Fossil-Fuel Subsidy Reform: A Review Of Modelling And Empirical Studies*, Global Subsidies Initiative (www.globalsubsidies.org); at www.globalsubsidies.org/files/assets/effects_ffs_0.pdf.

Global Subsidies (www.globalsubsidies.org) is a research institute that investigates energy, road transport, water and agriculture subsidies and economic impacts, and possible reforms.

GSI (2010), *Gaining Traction: The Importance Of Transparency In Accelerating The Reform Of Fossil-Fuel Subsidies*, Global Subsidies Initiative (www.globalsubsidies.org); at www.globalsubsidies.org/files/assets/transparency_ffs.pdf.

GSI (2010), *A How-To Guide: Measuring Subsidies To Fossil-Fuel Producers*, Global Subsidies Initiative (www.globalsubsidies.org); at www.globalsubsidies.org/en/research/gsi-policy-brief-a-how-guide-measuring-subsidies-fossil-fuel-producers.

IEA (annual reports), *World Energy Outlook*, International Energy Agency (www.iea.org/weo/index.asp).

IEA (2010), *Analysis Of The Scope Of Energy Subsidies And Suggestions For The G-20 Initiative*, IEA, OPEC, OECD and World Bank; at www.oecd.org/dataoecd/55/5/45575666.pdf.

IISD (2010), *Mapping The Characteristics Of Producer Subsidies: A Review Of Pilot Country Studies*, International Institute for Sustainable Development (www.iisd.org); at www.iisd.org/publications/pub.aspx?pno=1327. This paper reviews data sources for fossil-fuel subsidies in several countries including China, Germany, Indonesia and United States. The report identifies available data soruces, characterizes the major subsidy types applied to fossil fuels and discusses the current state of knowledge about these categories. Papers in this series:

- Untold Billions: Fossil-Fuel Subsidies, Their Impacts And The Path To Reform: Summary Of Key Findings
- Effects Of Fossil-Fuel Subsidy Reform: A Review Of Modelling And Empirical Studies
- The Politics Of Fossil-Fuel Subsidies
- Strategies For Reforming Fossil-Fuel Subsidies: Practical Lessons From Ghana, France And Senegal
- Gaining Traction: The Importance Of Transparency In Accelerating The Reform Of Fossil-Fuel Subsidies

International Energy Agency (www.iea.org), provides fuel supply, demand and price data.

International Fuel Prices (www.internationalfuelprices.com) provides detailed fuel prices data.

Doug Koplow (2010), *G20 Fossil-Fuel Subsidy Phase Out: A Review Of Current Gaps And Needed Changes To Achieve Success*, EarthTrack (www.earthtrack.net); at www.earthtrack.net/files/uploaded_files/OCI.ET_.G20FF.FINAL_.pdf.

Todd Litman (2007), *Appropriate Response To Rising Fuel Prices*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/fuelprice.pdf.

Todd Litman (2008), *Smart Transportation Emission Reduction Strategies*, VTPI (www.vtpi.org); at www.vtpi.org/ster.pdf.

Todd Litman (2009), "*Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/elasticities.pdf.

Todd Litman (2013), "Full Cost Analysis of Petroleum," *Transportation Beyond Oil: Policy Choices for a Multimodal Future*, (John Renne and Billy Fields, eds), Island Press (www.islandpress.com); at www.vtpi.org/Beyond_Oil_Litman.pdf.

Kenneth McKenzie and Jack Mintz (2011), *Myths and Facts of Fossil Fuel Subsidies: A Critique of Existing Studies*, Report 11-14, School of Public Policy (http://papers.ssrn.com); at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1940535.

Gerhard Metschies (Various Years), *International Fuel Prices* (www.internationalfuelprices.com), German Agency for Technical Cooperation.

MJB&A (2014), *Comparison of Energy Use & CO2 Emissions from Different Transportation Modes*, American Motor Coach Association (www.buses.org); at www.buses.org/files/green.pdf.

Brice G. Nichols, Kara Kockelman (2015), "Urban Form and Life-Cycle Energy Consumption: Case Studies at the City Scale," *Journal of Transportation and Land Use*, Vol. 8, No. 3; at www.jtlu.org/index.php/jtlu/article/view/598.

NRC (2009), *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*, National Research Council (www.nap.edu/catalog/12794.html).

ORNL (annual reports), *Transportation Energy Book*, Oak Ridge National Laboratories, U.S. Department of Energy (www.doe.gov); at http://cta.ornl.gov/data/index.shtml. Provides energy information transport energy production and consumption, and vehicle characteristics.

Michael Plante (2011), *The Long-Run Macroeconomic Impacts Of Fuel Subsidies In An Oil-Importing Developing Country*, U.S. Federal Reserve Bank, Dallas, MPRA Paper No. 33823; at http://mpra.ub.uni-muenchen.de/33823.

Transportation Lifecycle Assessment (www.transportationlca.org) provides information on current research and analysis tools for lifecycle cost analysis for transportation planning, including upstream (energy production), embodied energy (energy used to produce vehicles and facilities), and operating emissions, plus factors such as land use impacts on vehicle travel (e.g., the energy savings from transit-oriented development).

USEPA (annual reports), *Green Vehicle Guide* (www.epa.gov/autoemissions) reports vehicle emission and fuel consumption rates for specific model years.

VTPI (2008), "Energy and Emission Reductions," *Online TDM Encyclopedia*, VTPI (www.vtpi.org); at www.vtpi.org/tdm/tdm59.htm