The Damage Done, Gas Addiction Edition -- How Detrimental Is Petrol?

Al Bredenberg | Mar 12, 2012 |

In our continuing quest to understand and communicate the environmental effects of energy production and consumption, we have now turned our attention to transportation energy. How do the environmental effects of various transportation fuels -- petroleum, natural gas, biofuels, electricity, hydrogen -- compare? If transportation "goes green," will it really be better for the environment? (For our series on the "Damage Done" by electrical generation, see my summary article, *The Damage Done, Part 10 - Are Renewables Really Better for the Environment Than Fossil Fuels?*, which provides links to the whole series.*)*

(Photo: Barcelona, Spain. Credit: Tomas Fano, CC BY-SA 2.0.)

In my kick-off article on transportation energy last week, *The Damage Done Down the Road - Can Green Energy Reduce Environmental Damage in Transportation?*, I took an overall look at worldwide transportation energy and its environmental impacts. Now let's focus on petroleum specifically.

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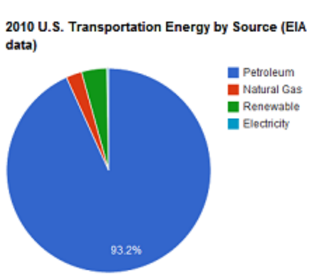

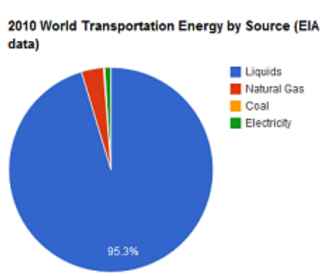

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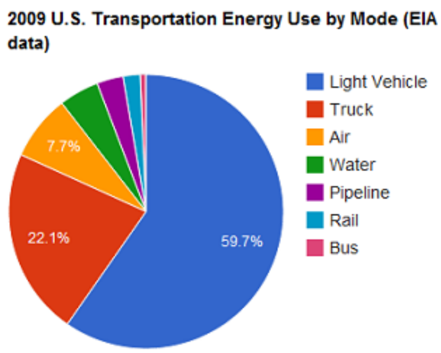
As you can see from the charts above, transportation depends on petroleum, both in the U.S. and globally. While that might change in the future as natural gas, renewables, and electricity become more important, right now most of transportation's environmental impacts are going to be due to burning of petroleum-based fuels such as gasoline and diesel.

The next chart, showing transportation energy use by mode, demonstrates that highway traffic consumes most transportation energy, thus accounting for the most environmental impacts.



The Damage of Driving

In this "Damage Done" series, I've often referred to the idea of "externalities," or the unintended side-effects, positive and negative, of any economic activity (such as driving down the road). In these articles, we are focusing primarily on environmental externalities of energy production and consumption. In the case of transportation, the consumer of a unit of activity -- say, a mile driven -- will pay out certain direct costs, such as $.50 per mile. But the user does not necessarily pay for the environmental external effects of that mile driven -- for example, other people's sickness and premature death from air pollution, or the contribution of that mile driven to human-caused global warming.

"Damage Done" isn't seeking to lay the blame for health problems or climate change at the feet of automobile drivers, but rather trying to find some ways to make apples-to-apples comparisons of the environmental effects of energy sources, both conventional and "green." Research into environmental externalities helps in making that kind of comparison, as it produces measurements of environmental effects that are more-or-less objective. Those kinds of measurements can be applied to any mile driven, whether it's powered by gasoline, natural gas, biofuel, or electricity.

For the first 10 articles in the series, I found a number of studies that allowed for good comparisons among electrical-generation energy sources. For transportation, I find that this kind of study is harder to come by. There is one exception, though: The 2010 report *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*, from the National Academy of Sciences (NAS).

The NAS says that hydrocarbon fuels like gas and diesel "have a complex web of production and transport processes that include resource extraction, transport, refining storage, transfers, and combustion." To understand the environmental externalities of these energy sources, it's necessary to "develop a map of the life cycle of fuel."

(Photo: Petro-Canada oil refinery. Credit: [Mack Male](), [CC BY-SA 2.0]().)

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Despite the complexities, "there are a few components of the fuel life cycle that tend to dominate with respect to overall health and environmental damage associated with the full life cycle of a transportation fuel." Along the way, human populations are affected by the fuel material itself or by "activities and materials associated with a particular phase in the fuel cycle (for example, road development for oil production)," as well as by "generated wastes or byproducts," the report's authors say.

The report identifies five key stages in the hydrocarbon fuel life cycle:

- Fuel feedstock production;
- Storage, transport, and distribution;
- Conversion and processing;
- Storage, transport, and distribution of the finished product; and
- Combustion and use.

Wastewater at production facilities can contain toxic organic and inorganic compounds, and facilities can emit volatile organic compounds (VOCs). Oil spills can cause pollution, either onshore or offshore. The NAS says:

> [Offshore] well blowouts can result in large releases of contaminated water, oil, methane, or other fluids. The mixture can be spread in a wide area around the rig, possibly leaching through the soil to a freshwater aquifer or running off into nearby surface waters. The blowout may also result in a well fire.

Oil refinery operations emit pollutants. Emissions occur throughout refinery operations, arising from "thousands of potential sources, such as valves, pumps, tanks, pressure relief valves, and flanges." According to the report:

> Relatively large volumes of wastewater are generated by the petroleum refining industry, including contaminated surface water runoff and process water. Accidental releases of liquid hydrocarbons have the potential to contaminate large volumes of groundwater and surface water, possibly posing a substantial risk to human health and the environment.

The transportation of oil causes air pollution, as well as risk of leaks and spills, even large-scale disasters like the 1989 Exxon Valdez spill.

Combustion of petroleum-based fuels causes tailpipe emissions, including VOCs, nitrogen oxides (NOx), sulfur dioxide (SOx) particulate matter, and carbon dioxide (CO_2), along with other air toxics, such as benzene and formaldehyde.

The NAS uses vehicle miles traveled (VMT) as a way of calculating and comparing external damages for highway transportation. The report, which considers not only transportation energy but also electrical-generation energy and other categories, generally assigns dollar-value damages based on the source's negative impacts on human health and life. The following chart shows the general dollar-value damages calculated for petroleum-based highway transportation fuels, along with carbon footprint, expressed as carbon dioxide equivalents. Damages are estimated based on conditions and technologies in 2005. (This chart is a simplification of what appears in the NAS report, so if you want more detail, see the original reference.)

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Type of Vehicle and Fuel	Damages From Non-GHG Emissions, Dollars per VMT	Carbon Dioxide Equivalents per VMT
Light-duty automobile, gasoline	\$.013 - \$.014	487 - 611
Light-duty automobile, diesel	\$.015 - \$.018	476 - 537
Truck, light-duty, classes 2-3, gasoline	\$.061 - \$.072	1,095 - 1,187
Truck, light-duty, classes 2-3, diesel	\$.032 - \$.036	969 - 1,071
Truck, medium-duty, classes 4-6, diesel	\$.039 - \$.065	1,224 - 1,433
Truck, heavy-duty, classes 7-8, diesel	\$.080 - \$.104	1,650 - 2,007

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So the more-or-less obvious conclusion here is that petroleum fuels for transportation cost anywhere from 10 cents to 1 dollar per mile in environmental damages, and generate anywhere from 500 to 2,000 carbon-dioxide equivalents in GHG emissions. The amount of damage correlates with vehicle size. This doesn't necessarily mean that trucks are wicked; the damages are a function of size, but, to be fair, a large truck does a lot more work per mile than a passenger automobile.

Petroleum Fuels and Their Loveable Environmental Quirks

For our purposes, the NAS study is possibly the most useful assessment of environmental costs for transportation, because it doesn't just focus on petroleum fuels. In following articles, I'll bring in the environmental costs the NAS has calculated for other energy sources -- natural gas, biofuels, electricity, and hydrogen. However, even though it can be hard to compare apples to apples for all kinds of environmental impacts, it's good to note that each of these energy sources raises its own unique environmental concerns.

According to Dr. Jean-Paul Rodrigue of Hofstra University, New York, in *The Geography of Transport Systems*, the environmental impacts of transport systems go far beyond the assessment of the NAS. Rodrigue cites:

- Damage to structures and infrastructure by ozone, smog, particulates, and acid rain, resulting in loss of useful life and repair costs;
- Loss in labor productivity due to health damages from vehicle emissions;
- Loss in agricultural productivity;
- Reductions in fishery productivity from air pollution, discharges and spills, and other effects;
- Losses in recreational value of facilities and natural areas due to pollution;
- Costs of water purification required to correct for pollution, discharges, and spills;
- Cleanup costs from accidents and spills;
- Loss in property values from transportation noise pollution;
- Public health costs from illness, injury, and reduction in life expectancies among affected populations; and

- Damages to ecosystems due to loss of biological diversity, loss of habitat, damages to natural processes such as water regeneration and purification by wetlands, and similar losses of ecosystem services.

Given the current dependence of transportation systems on petroleum fuels, these kinds of environmental damages are reasonably attributed to that energy source.

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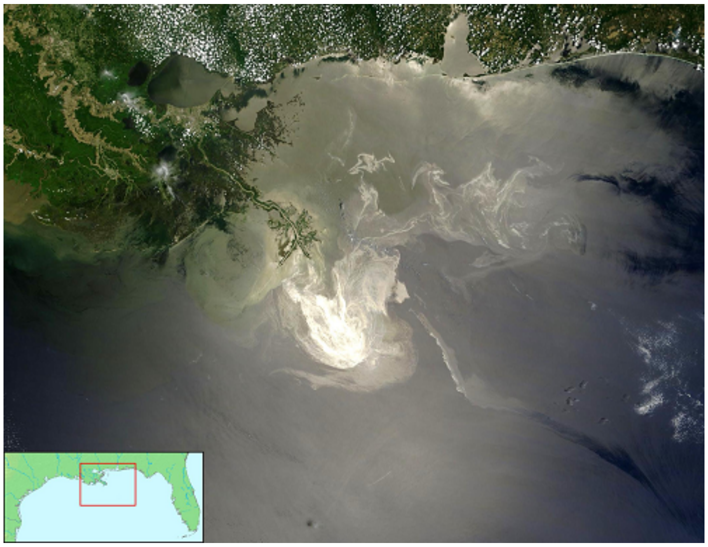

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A report from the independent think tank [Resources for the Future] (RFF) stresses the unique problems of petroleum in transportation:

> Vehicles are a major contributor to air pollution around the world. Vehicles account for most of the carbon monoxide (CO), and a large share of the hydrocarbons (HC), nitrogen oxides (NOx), and particulates in major urban areas. Much of the effort to reduce pollution from vehicles to date has been in the form of increasingly strict emissions standards on new cars sold in the developed countries. These controls have reduced emissions of CO, HC, and, to a lesser extent, NOx despite large increases in the number of vehicles and miles driven. Although new cars have become dramatically cleaner over time, many highly polluting vehicles are still on the road, including trucks, buses, motorcycles, and older cars.

RFF's report, while somewhat dated (2003), aggregated several studies of the external costs of driving, with the following findings:

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External Costs of Driving per Mile	
Infrastructure	$.030 - $.070
Congestion	$.040 - $.150
Air pollution	$.010 - $.140
Climate change	$.003 - $.011
Noise	$.001 - $.060
Water	

	$.001 - $.030
Accidents (external)	$.010 - $.100
Energy security	$.015 - $.026
Parking	$.020 - $.090

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Since these figures represent a number of different studies based on different assumptions, we see a range in the per-mile costs associated with the various kinds of external effects. The important takeaway here is that transportation has environmental and social costs that are not necessarily reflected in the user's direct cost -- externalities. If the transportation system can seek out less-polluting sources of energy, it can reduce the environmental damage of its operations.

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