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The Need for a Standard Index of Vehicular Pollution Intensity in the United States
by T.D. Daniel

The Need for a Standard Index of Vehicular Pollution Intensity in the United States

The Environmental Protection Agency is tasked with providing a guide to automobile consumers which indexes the smog output of a particular car and compares that car to others. The ratings system used is complicated and accounts for zero emissions vehicles (ZEVs) as well as large trucks and everything in between.[1] Unfortunately, this convoluted structure leads to a complexity which is simply not practical from the standpoint of the end user. The ad hoc addition of ZEVs clearly fails to produce any means by which to compare these against each other. In addition to being difficult to read, the current EPA Smog Rating system obscures data which are equally important to consumers who wish to make an informed decision. Hence, the EPA Smog Rating provides a model which is incapable of expressing the differences between the various technologies currently available to consumers. Rather than a smog index, it will be far more helpful to utilize an index of pollution intensity—an alternative I will provide a rough sketch of below.

Introduction:

Poised between potentially devastating fallout caused by pollution and the technological advancements of the age of information, it is necessary that humanity plan ahead its emissions and structure the economy of pollution engendered by the machines necessary to make information and transportation available. However, the United States Environmental Protection Agency (EPA) is seldom subjected to intense scrutiny and can be slow to change. "As a general rule, organizations that have a stake in a particular program do not want to jeopardize their interests by stepping back to evaluate whether the program is working."[2] The greenhouse gases (GHGs) emitted by motor vehicles, power plants, and cattle have seized the attention of people worldwide as initiatives such as the Kyoto Protocol seek to slow climate change. However, as early as the 1600's, it was known that air pollution was potentially devastating to the individual's health.[3] The current debate seems to have lost sight of the small-scale injuries caused by air pollution.

One major innovation, which may be able to reduce air pollution in all forms, is the electric vehicle (EV). EVs such as the Tesla Model S are listed as zero-emissions vehicles (ZEV) by the EPA because their operation results in no direct production of harmful exhaust gases. Others such as the Chevrolet Volt and BMW i3 are "plug-in hybrids" which use gas-powered generators to produce energy for an electric engine, expanding vehicle range. However, there is no means provided by the EPA to allow a

[1] "Smog Rating." *United States Environmental Protection Agency.* Last accessed: 5/2/15. http://www.epa.gov/greenvehicles/you/smog.htm
[2] J. Clarence Davies and Jan Mazurek, *Pollution Control in the United States,* (New York: Resources for the Future, 1998), 7.
[3] John Evelyn, "Fumifugium," (London: W. Godbid, 1661).

consumer to differentiate between these options. ZEV status is an ad hoc addition to an outdated smog rating system which must be updated to reflect current technologies in order to continue to serve its purpose.

In contrast to internal combustion engine (ICE) vehicles, EVs embody many improvements with regard to the control and potential elimination of pollution. However, it is difficult to assess precisely what the difference is. EVs still need to utilize an energy source, they still need to use coolant and tires and replaceable parts. My goal in this essay is to highlight the current difficulty in determining which option is more environmentally friendly and suggest a standard index of pollution intensity to accurately highlight the differences between platforms in terms of environmental impact.

I will highlight below three points which are of interest to an environmentally friendly car purchaser, and which should be made available by the EPA. These include first the difference between tailpipe emissions and CO2e, or carbon dioxide equivalent, which is significant because the former is only a problem due to location and the latter is a problem no matter where it occurs. The second problem is that the upkeep of the petroleum production and retail network produces a large amount of CO2e on its own, without even factoring in the cost of burning a gallon of gasoline (roughly 8800g CO2e) or diesel (roughly 10100g CO2e). The third and final point is that EVs are engineered differently from ICE-powered vehicles. The differences are manifold but they include far less hydraulic accessories—which begin to leak toxic fluids upon damage from collision, manufacturer defect, or even mere wear and tear.

Point of Interest: CO2 Footprint

A carbon footprint describes the sum of carbon emissions produced by the extraction, production, refinement and transportation of a commodity to the consumer who purchases it. The notion is important from a climate change standpoint, but less so when externalities such as lung cancer and smog are considered. There are two senses in which air pollution is problematic: 1) the abstract, global carbon economy which seems to be continuously moving further from equilibrium due to human impact and 2) the direct, observable changes which are readily apparent to joggers and bicyclists. Carbon footprint is a notion capable of dealing with 1 but not with 2 in any direct way. A gallon of gasoline produces roughly 8800g of CO2 when burned. However, its carbon footprint is dramatically higher when emissions caused by the extraction, transportation and refinement of petroleum are all taken into consideration.

The Problem Exposed:

An article which indirectly demonstrated the need for a Standard Index of Pollution Intensity was published by Nathan Weiss on May 9, 2013 at Seeking Alpha.[4]

[4] Nathan Weiss, "Is the Tesla Model S Green?" *Seeking Alpha*. 5/9/15, last accessed 5/2/15, http://seekingalpha.com/article/1418421-is-the-tesla-model-s-green.

The initial effort was then followed up by another piece, entitled "In Summary, the Model S is a Dirty Car." I have no intention of rebuffing this claim – the Model S is, in fact, responsible for a large amount of pollution. China is where graphite is produced to make anodes for the batteries which make the EV possible, and one result of the ever-increasing demand for graphite to make batteries is graphite-specific pollution such as graphite rain and the production of an excess of hydrochloric acid.[5] Additionally, the production of the Model S is extremely energy intensive, and charging is inefficient – resulting in carbon emissions increases at coal-burning power plants. The 'zero-emissions' technology exemplified by Tesla's Model S is not by any means completely clean. The question is whether it is cleaner than petroleum-based ICE applications, and the EPA currently does not address this question adequately.

The EPA model currently employed to inform consumers about the environmental friendliness of vehicles available for consumption engenders these concerns by failing to account for the production of energy and the various drawbacks of different production techniques. The criticism posed by Weiss of the Model S is a direct outcome of this failed methodology. Weiss begins his article by drawing attention to the financial benefits that Tesla is reaping from the government and other automakers because of the status of the Model S as an environmentally friendly vehicle in the public's eye. He then moves on to suggest that this evaluation is unfair and that the Model S is actually a greater cause of carbon dioxide emissions than large sport utility vehicles (SUVs), overlooking the fact that the Model S produces no drive-by emissions.

Weiss is careful to explore the fact that the Model S does not appear to be capable of its advertised 300-mile range in the real world, consistently delivering an actual range per charge of around 200 to 225 miles. These end-user data are then applied by Weiss to increase the CO2 footprint of the Model S to 216g; higher than the numbers he quotes for the Honda Civic Hybrid and Toyota Prius V. Next, the battery charging efficiency of the Model S is brought under scrutiny. A typical charger will add electricity to the battery with efficiency varying between about 78% and 88%, though Tesla rates peak charging efficiency at 92%. This means that between 8% and 22% of the energy drawn from the wall actually gets lost, while 78% to 92% winds up in the battery. With this factor taken into account, as well as a phantom "idle loss" which Tesla says can be addressed with software, the Model S actually has a carbon footprint of 394g per mile driven – over double the manufacturer's estimate! Add to the equation the energy-intensive construction process, and Weiss arrives at the final effective CO2 emissions figure for the Model S: 547g per mile, an average applicable for the life of the vehicle.

Given these ideas, it is readily apparent that the current efforts to quantify vehicle pollution are severely lacking. Policymakers evaluate the effectiveness of an agency in terms of its effectiveness and its efficiency: "Two commonly used criteria for judging the pollution control regulatory system are effectiveness (is the system meeting its goals) and efficiency (are system outputs being accomplished with the minimum necessary

[5] Andrew Meggison, "Graphite Mining Linked to EVs Causing Major Pollution in China." *Gas2.org*. 3/25/14, last accessed 5/2/15, http://gas2.org/2014/03/25/graphite-mining-linked-to-evs-causing-major-pollution-in-china/.

resources).”[6] The critical insight drawn from Weiss is therefore that the effectiveness of the EPA’s smog rating system is severely lacking, as the model has not been updated to reflect the different options currently available on the vehicle market. It is also less efficient to regulate petroleum than to advocate green technology. Two issues here are that the petroleum industry involves a constant supply chain and regulations to make gasoline cleaner are costly and time consuming.

<u>The Proposed Solution:</u>

It seems that the argument Weiss has put forth has opened a discussion of whether the Tesla’s emissions are being properly quantified. To solve both issues – that of the possible under-reporting of CO2e production in the life of a Tesla and that of the outmoded smog index employed by the EPA – I will contend that a new index of pollution intensity should serve as the standard moving forward.

EPA ratings currently serve to underline the point by Weiss: the Tesla could be responsible for the worst pollution of any vehicle on the index and yet the privilege given to it by the ZEV moniker would still show a perfect score. The smog rating system consists of a number between 1 and 10, with 1 being the worst and 10 the best, intended to convey the cleanliness with respect to smog production caused by the operation of a given vehicle. However, the exemption of ZEVs from this (by assigning a value of 10 to them) not only privileges these cars above even ICE-based vehicles which might be more efficient; it also eliminates any environmentalist market appeal to drive innovation to make them cleaner still.

I propose that a three-tier system replace the current smog rating. This will complicate matters by substituting three numbers for one, but this is a good thing because it will foster new innovation to make the cleanest tailpipe emissions vehicles even cleaner. The three tenets upon which new vehicles’ reputations for environmental friendliness should rest are as follows:

1. Drive-by emissions. The single greatest threat posed by vehicles is the smog and exhaust gases caused by the operation of millions of cars in densely populated urban areas, and the smog rating system is right to privilege this – to some extent.

2. CO2e emissions. Carbon dioxide equivalent is the best measurement of a vehicle’s responsibility for climate changing GHG production. I propose that this rating be varied by the locale in which the automobile is sold to provide the highest accuracy and incentivize EV manufacturers to contribute to renewable energy.

[6] J. Clarence Davies and Jan Mazurek, *Pollution Control in the United States,* (New York: Resources for the Future, 1998), 5.

3. Waterway risk. Lakes, streams, and the ocean are sources of recreational activity, food, and income to the largest portion of humanity. It is unacceptable to allow unnecessary pollution to enter the water system. This tier of the rating system will highlight the EV's under-observed benefits and help to raise awareness on the part of consumers as well as manufacturers.

These three criteria will be averaged equally to assign a final, single number to new vehicles which should be prominently displayed on the window sticker of cars on the showroom floor for maximum effect. The proposed model will also have an impact with regard to National Ambient Air Quality Standards (NAAQS) and potentially avoid the issues commonly discussed with regard to the Supreme Court case of *Whitman vs American Trucking Associations, Inc.* (2000).[7] The EPA, by providing vehicle consumers with more information about the environmental impact of available options, can motivate more environmentally friendly buying decisions and thereby avoid the inefficiencies of costly regulation.

Dangerous Assumptions:

A few dangerous assumptions underlie the EPA's continued usage of a smog rating index which must be dealt with: 1) This outdated model encourages readers to blur the line between abstract consequences pursuant to climate change and the quite concrete harms done to populations who are forced to inhale curbside emissions at their source. The Zero-Emissions Vehicle standard is an ad-hoc addition which does little to explain the various sorts of ZEVs or the emissions nonetheless caused by their operation. This is no minor error, as smog problems are most pervasive in densely populated urban areas throughout the world.[8] 2) Thought in these channels is seen to neglect the production CO_2 cost of gasoline. We cannot afford to assume that the carbon footprint of an ICE vehicle can be limited to tailpipe emissions plus the production CO_2 cost of the vehicle. 3) It is not the case that there are no differences in environmental impact between ICE vehicles and EVs in daily operation with respect to water quality. This is due to the runoff effect, an externality of ICE-based vehicle design which causes a significant amount of water pollution due to the overuse of hydraulic fluids, oils and other toxic compounds which spill in the event of excessive wear and tear on the vehicle, manufacturer defects, and/or collisions.

[7] M. Livermore and Richard Revesz, "Rethinking Health-Based Environmental Standards," *New York University Law Review* 89, no. 4 (2014) : 1184-1267.
[8] Zahra Hirji, "Nearly Half the U.S. Population Still Breathes Polluted Air." *Inside Climate News*. 4/30/15, last accessed 5/2/15. http://www.insideclimatenews.org/news/30042015/nearly-half-us-population-still-breathes-polluted-air-report-says

Tailpipe Emissions and Smog Formation:

Tailpipe emissions is a term which refers to the fumes which come out of the exhaust pipe of a car after the engine combusts its mixture of fuel and air. These gases are extremely hot, largely comprised of carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2) and nitrous oxides (NO_x). Sulfur dioxide is associated with acid rain, and the nitrous oxides are associated with smog and ozone formation in big cities. Side effects of nitrous oxide emissions include tropospheric ozone formation when a sufficient concentration of these gases is exposed to sunlight. These gases are what cause the smog problems in major cities. A recent Paris attempt to combat these effects consisted of efforts to control automobile traffic.[9] Additional impacts such as particulate matter (PM) release tend to vary by region and are therefore difficult to quantify precisely, though they pose a significant health risk.

The reason it is so unpleasant to jog next to a busy road in an urban area is this air quality impact, which is directly caused by tailpipe emissions. Even holding net CO_2 and other criteria pollutant emissions at a steady level with current production, if the source was relocated away from urban areas it is almost certain that cancer rates in these places would decline in years to come.[10] A widespread switch to EVs would directly reduce the smog levels in heavily trafficked urban areas.

A handful of strategies, such as tall stacks to pump exhaust high into the atmosphere or a focus on renewable solar and wind power could eliminate or reduce the immediate impact of these toxic gases upon urban populations. Coal-burning power plants could be relocated to strategic positions in order to minimize their carcinogenic and or smog-related impact until they were replaced by renewable energy sources. Hence, the impact of a fleet of electric vehicles as compared with the current ICE-based variety would be anything but negligible – it would provide air quality relief to heavily populated urban areas during high-traffic times of the day and reduce health impacts of smog including asthma, lung cancer, emphysema and chronic bronchitis in addition to improving the quality of life for even the healthiest of city dwellers.

Two years after the article by Weiss was released, a slew of victories for environmentalists: over ten percent of the energy used by the state of Texas was generated by renewable wind power facilities.[11] Additionally, forty percent of Denmark's energy demands were met by renewable wind sources, Costa Rica meets 100% of its energy needs with renewable sources including tidal power, and China is investing

[9] Liza Malykhina, "Paris briefly tops world charts for air pollution." *France 24.* 3/20/15. Last accessed 5/2/15. http://www.france24.com/en/20150320-paris-city-smog-pollution-plume-labs-hidalgo-public-transport-diesel/

[10] Sarah Bosely, "Air Pollution May Cause More UK Deaths Than Previously Thought." *The Guardian*. 2/4/15. Last accessed: 5/2/15. http://www.msn.com/en-gb/news/uknews/air-pollution-may-cause-more-uk-deaths-than-previously-thought-say-scientists/ar-AAalc6g

[11] April Lee, "Wind generates more than 10% of Texas Electricity." *U.S. Energy Information Administration.* 2/19/15. Last accessed 5/2/15. http://www.eia.gov/todayinenergy/detail.cfm?id=20051

heavily in renewable energy.[12][13][14] There is much room for improvement, still, but it is in fact the case that the world is rapidly moving toward renewable energy to meet its electricity needs. Smog monitoring models need to be able to take this into account; perhaps by assigning a regional value to electricity generation which then may be used to inform consumers about the real carbon footprint of the electricity the vehicle is likely to be responsible for generating.

The Real Carbon Footprint of a Gallon of Gasoline:

Carbon emissions of ICE-based vehicles comprise a complex web of varied factors which include A) the extraction of petroleum from the ground, B) refinement, and C) transportation. There is a laundry list of catastrophes associated with each of these steps, such as the burning of the oil fields at the end of Operation Desert Storm in 1991 or the Exxon-Valdez oil spill in 1989, not to mention the death toll due to the domestic trucking industry in the United States. However, it is difficult to separate the cost of transportation of oil and oil products necessary for only the upkeep and maintenance of the petroleum economy from the actual usage of said economy. For example, the carbon footprint of a gallon of gas purchased two thousand miles from its refinery is very much quantifiably higher than one purchased twenty miles away from its refinery, but the cost of this transportation of fuel is included in the EPA's transportation figure as a whole. This cost, assuming a 10mpg diesel tractor was used to deliver the fuel, is about 20,000g/CO2e (carbon dioxide equivalent) divided by a whole tank of fuel for the 20 mile trip. The two thousand mile trip, however, results in carbon emissions of 20,000,000g/CO2e – a substantial figure even divided by thousands of gallons of fuel.

A) CO2e and other dangerous chemical compounds are released by drilling, as well as by pumping oil from underground deposits. As such, the emissions produced can be expected to vary dramatically from location to location. A search of Texas State University's network of academic publications has netted only a handful of documents dealing with local, US-based oil production sites and not foreign oilfield emission numbers. It is currently impossible to quantify these emissions precisely, ostensibly because there is no agency in place to provide data or to oversee the worldwide production of these emissions. For this reason, scientists are limited to guessing and allowing reporters to bear the news to the public.[15] In fact, natural gas drilling and hydraulic fracturing are known to produce significant emissions and large amounts of

[12] Cassie Werber, "Denmark produces 40% of its power from wind—more than any other country on earth." *Quartz.* 1/9/15. Last Accessed 5/2/15. http://qz.com/323218/denmark-produces-40-of-its-power-from-wind-more-than-any-other-country-on-earth/

[13] Adam Epstein, "Costa Rica is now running completely on renewable energy." *Quartz.* 3/23/15. Last accessed 5/2/15. http://qz.com/367985/costa-rica-is-now-running-completely-on-renewable-energy/

[14] Jason Karaian, "China is driving a global renewable-energy rebound—but it might not last." *Quartz.* 10/3/14. Last accessed 5/2/15. http://qz.com/275577/china-is-driving-a-global-renewable-energy-rebound-but-it-might-not-last/

[15] Timothy Wheeler, "Study links air pollution outside Baltimore, DC to fracking outside Maryland." 4/30/15. Last accessed 5/2/15. http://www.baltimoresun.com/features/green/blog/bal-study-links-air-pollution-in-baltimore-to-fracking-outside-maryland-20150430-story.html

wastewater. However, as we lack any means of quantifying these emissions, it must suffice as a baseline statement that releases of organic compounds from drill sites are substantial and detrimental. Additionally, sources of emissions involved in extraction include the equipment used. Pumps, machines, and other engines all burn petroleum and therefore are sources of carbon emissions that will need to be quantified to provide a reliable estimate of the true carbon dioxide equivalent emissions of the production and use of a gallon of gasoline.

B) Refinery emissions are monitored and controlled in the United States. According to the EIA, each 42-gallon barrel of crude yields about nineteen gallons of gasoline and twelve gallons of diesel.[16] A generous estimate places the average barrel of crude as producing roughly one hundred pounds of CO2 during refinement.[17] Operating under this assumption, of the total processing yield – which is higher than the initial 42 gallons due to changes in density associated with the processing of petroleum – of 44.7 gallons, 70% is fuels. Thus, the appropriate amount of 100lbs of carbon emissions to assign to fuel refinement is 70%, or 70lbs. This is roughly 2.25lbs of CO2 per gallon of gas or diesel fuel produced. This 2.25lbs must be added to the 8800g of CO2 produced by actually burning a gallon of gasoline, increasing that figure to roughly 10,000g of CO2 emissions caused by using one gallon of fuel. This factor results in an increase of about 13% in carbon emissions for each gallon of gas produced and used as fuel, if evaporative emissions and spills are assumed to be insignificant.

C) has three parts and requires a bit more discussion to adequately explain. It involves C1) trucking as well as C2) shipping and C3) pipelines. The CO2e emissions involved in transportation range from likely negligible, in the case of the short trip delivery by eighteen wheeler or the pipeline which operates without leaking, to positively astonishing in the case of the highly speculative thesis that the oil shipping industry accounts for three eighths of global shipping emissions. It is thus impossible, currently, to arrive at a reasonable estimate of the carbon footprint of a gallon of gasoline. However, pipelines leak, causing extreme environmental damage to localized areas as well as significant CO2e evaporative emissions, which have a global impact. Oil tankers crash. However, these situations are relatively rare and difficult to predict and therefore impossible to quantify in advance. The diversity of to-refinery delivery methods is as significant as the diversity of drilling-site techniques and byproducts; oil transported via pipeline has an almost negligible carbon impact (at least during transit) and oil transport by supertanker is potentially one of the top sources of carbon emissions in the world.

C1) Oil tankers account for about three eighths of port-related carbon emissions at Rotterdam, emissions which are monitored only during the ship's berthing.[18] If oil

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[16] "How many gallons of diesel fuel and gasoline are made from one barrel of oil?" *United States Energy Information Administration.* 12/16/14. Last accessed 5/2/15. http:/www.eia.gov/tools/faqs/faq.cfm?id=327&t=9

[17] Greg Karras, "Oil Refinery CO2 Performance Measurement." 9/11. Last accessed 5/2/15. http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/oil-refinery-CO2-performance.pdf

[18] Hulskotte, et. al. "International survey of fuel consumption of seagoing ships at berth." (Rotterdam: Rotterdam Main Port University of applied sciences, 2014).

tankers accounted for three eighths of global shipping, the mere transportation of crude oil from one place to another would equal roughly half of global CO2 emissions in the year 1900. However, we lack support for the extension of this figure to the global shipping industry. Berthing is the process a ship undergoes as it is loaded or unloaded of cargo; it is docked for the duration. This means that its engines are not operating at maximum capacity during berthing, but a given ship can have a wide array of different engine types or even be utilizing a handful of different types of fuel – the emissions figures presented above are voluntarily submitted to student workers who conducted the survey, and the study shows that adherence to low-sulfur fuel standards is likely to be below-target. The EPA estimates global emissions of CO2 to exceed 30,000 teragrams.[19] The United States accounts for approximately 6700 teragrams of this emissions estimate.[20] 3-4% of global emissions are caused by the shipping industry as a whole, which is equal to 900-1200 teragrams of CO2 emissions annually, not to mention the fact that the "bunker fuel" which these ships burn is up to 2,000 times higher in sulfur than automobile gasoline.[21] This figure is greater than worldwide CO2 emissions in the year 1900.[22] There is simply not enough information to apply a reliable percentage of this impact to each gallon of gasoline.

C2) Another significant part of the real carbon cost of a gallon of gas purchased at a gas station is the cost of transporting this gasoline from the refinery where it was produced. The eighteen-wheelers that transport this fuel use fuel of their own, and trucks vary widely in terms of fuel economy depending, among other things, upon the load transported. Additionally, the distance from the refinery that gasoline must travel in order to be consumed is highly variable. However, there are 3.5 million professional truck drivers in the US[23] alone and each truck can travel over 100,000 miles per year.[24] Assuming a 10mpg diesel truck and round figures for each of these numbers, trucking in the United States results in (the combustion of one gallon of diesel emits 10151.4g of CO2, plus the refinement cost of 1020g) a staggering 1117g/mile of carbon emissions, spread over a total of 350 billion miles. The total emissions of the US trucking industry are here estimated at 390 teragrams of CO2, or between 5% and 10% of total American transportation emissions.[25] A substantial amount of this trucking industry is directly involved with supply chain maintenance related to ensuring the availability of gasoline,

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[19] "Global Greenhouse Emissions Data," *United States Environmental Protection Agency,* Last accessed 5/2/15, http://www.epa.gov/climatechange/ghgemissions/global.html.

[20] "Sources of Greenhouse Gas Emissions," *Environmental Protection Agency,* Last accessed 5/2/15, http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html.

[21] John Vidal, "Health risks of shipping have been 'underestimated,'" *The Guardian.* 4/9/09, Last accessed 5/2/15, http://www.theguardian.com/environment/2009/apr/09/shipping-pollution.

[22] "Global Greenhouse Emissions Data," *United States Environmental Protection Agency,* Last accessed 5/2/15, http://www.epa.gov/climatechange/ghgemissions/global.html

[23] "Truck Drivers in the USA," Last accessed 5/2/15, *Alltrucking.com,* http://www.alltrucking.com/faq/truck-drivers-in-the-usa/

[24] "Heavy-Duty Global Warming Emissions and Fuel Economy Standards," *Union of Concerned Scientists.* September, 2013, Last accessed 5/2/15, http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/HDV-emissions-fuel-economy-factsheet.pdf

[25] "Sources of Greenhouse Gas Emissions," *United States Environmental Protection Agency,* Last accessed 5/2/15.

but it is once again impossible to precisely quantify the percentage of the trucking industry which is directly related to fuel distribution.

C3) Pipelines are remarkable in the sense that their carbon cost is much lower than shipping or trucking crude oil from one place to another. However, the destruction frequently caused by their misuse and improper regulation is devastating to wildlife and costly in terms of economic impacts. In fact, there are over 300 of these spills annually on average.[26] Though pipelines are employed globally, these numbers are only inclusive of U.S. pipeline incidents.

In Summary:

It is highly probable that the estimate of 390 teragrams of CO2 is erroneous, but there are simply no figures to prefer. Perhaps the trucking and shipping of petroleum both account for a sizeable portion of world GHG emissions, but there are no firm numbers to provide a reliable estimate of the percentage of these emissions. These numbers are not available for EV delivery to dealership or production either, but this cost is non-recursive. Rather than maintaining a petroleum system in need of constant upkeep, transporting EVs to dealerships results in a much smaller amount of emissions in terms of CO2e.

Vehicular Hydraulics and Waterway Hazard:

Runoff from roadways has always been a significant source of local pollution to lakes and rivers, even posing risks to groundwater.[27] This occurs because a typical ICE involves a crankshaft system which utilizes a pulley to operate various hydraulic pumps. These systems include power steering, an alternator, a water pump to cool the engine, engine oil, transmission oil, and others depending upon model and application. Most of these systems utilize rubber hoses, which are prone to leakage and cracking when they reach a certain age, to say nothing of the spillage which occurs in conjunction with accidents. If these hoses are not replaced frequently enough, or if there is a failure in the hydraulic system in question, toxic chemicals such as power steering fluid or oil drip into parking lots and onto roadway surfaces to wait until rain can wash them into the water cycle. Accidents, floods, and other incidents common to motor vehicle operation all consistently contribute to the release of these toxic chemicals into water bodies.

Tesla’s Model S, by contrast, uses only battery coolant and a few sealed-fluid bearings in addition to a hydraulic brake booster system. The maintenance schedule is costly, but revolutionary. Vehicle owners are required to service the vehicles annually

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[26] Dierdre Fulton, “More than 300 a Year: New Analysis Shows Devastating Impact of Pipeline Spills,” *Common Dreams,* November, 2014, last accessed 5/2/15, http://www.commondreams.org/news/2014/11/17/more-300-year-new-analysis-shows-devastating-impact-pipeline-spills.

[27] “Controlling Nonpoint Source Runoff Pollution from Roads, Highways and Bridges.” *United States Environmental Protection Agency, Office of Water.* August, 1995. Last accessed 5/2/15. http://www.epa.gov/owow/NPS/roads.html

under the terms of the warranty, resulting in a preventive maintenance model which will greatly reduce the likelihood of a battery coolant or brake fluid spill.[28] However, the absence of a need for engine coolant, motor oil, transmission fluid, and power steering fluid will reduce the number of systems which require their own hydraulic fluid reservoirs and lines from at least five (engine oil, transmission oil, power steering oil, engine coolant, and brake fluid) to two (battery coolant and brake fluid), thereby simplifying the job of maintaining the vehicle and simultaneously reducing the number of potential pollutants to be released over the course of the vehicle's lifetime or in the event of its untimely death. Though yet imperfect and subject to potential mishaps, this design is a solid improvement over the current ICE in that the simplifications implicit in the electric motor have the added benefit of managing many vehicle systems with electricity rather than hydraulics.

A Better Way to Quantify Pollution:

The various costs and benefits of a large-scale switch from conventional to electric vehicles are difficult to compute. The general reaction to this conundrum seems to be to focus upon one particular area and base a decision around the result of this evaluation. However, we are much more likely to mistakenly overestimate the environmental damage or benefit of a given innovation if we succumb to this urge for simplicity. Throughout the course of this paper, I have highlighted the need to produce three kinds of different evaluative criteria by which to evaluate the sum of the environmental impact caused by vehicles in particular. The various environmental impacts of a technology must be taken into account. For ICE vehicles and EVs this includes local emissions impact, global or abstract emissions impact (carbon footprint), and toxic runoff caused by unintended spills of caustic fluid.

My proposal, then, is that an indexical system be utilized by the EPA in order to show three numbers to consumers: 1) Smog or local environmental air quality impact, caused directly by operation of the vehicle. 2) Global or GHG emissions impact caused by the production, operation, and transportation of the vehicle and the fuel needed to sustain it over the course of its service life. 3) The environmental impact of runoff or local water quality impact caused by operation of the vehicle. A blended rating of these three figures might be able to reduce the environmental impact of a given vehicle to a scale of 1-5, with results pursuant to the average new vehicle on the market.

A pickup truck or SUV might score a 1 on all three criteria if it is a diesel or low-efficiency gasoline engine model. Most new vehicles will average between 1 and 2 points on the scale, but plug-in hybrids such as the Chevy Volt, Nissan Leaf, and BMW 325i (currently classified as PZEVs, or partial ZEVs) will likely score a bit higher because of their ability to operate as ZEVs some of the time. The Tesla would have to be represented on the first scale with a 5 because of its zero-emissions status. The second criterion might net the Tesla a 2 or 3, as it is not likely to be the most efficient EV available for long. The third criterion might be a 3 or 4, showing improvement over the standard of the ICE-

[28] *Tesla Motors.* Last accessed 5/2/15. www.teslamotors.com.

based vehicle but still not meeting the zero-runoff status the scale must be designed to emphasize. The average of these three numbers might then result in an overall rating of 3.5 or 4 out of 5 for the Tesla on the Standard Pollution Intensity Index.

In addition to utilizing the market as opposed to regulation in the effort to promote healthy environmental practices, difficulties resulting from the legislative process i.e., "The statutory detail reflects a basic congressional mistrust of EPA. The mistrust is balanced: pro-environment members fear that the agency will not be ardent enough in defending the environment; anti-environment members fear that it will be too ardent."[29] It is likely that some of the reluctance evident in the outdated smog rating supplied to consumers by the EPA is the result of just this type of legislative road block. However, if legislative powers focus their efforts on ensuring the availability of information as opposed to the regulation of an obsolete power source there is much less potential for conflict.

The greatest hurdle to this index will continue to be the lack of transparency regarding transportation-related emissions data. It is likely that a greater degree of reporting of fuel usage is possible, from which consumption figures can be used to compute carbon emissions. Legislation to require companies to disclose their fuel purchases might quickly and easily make this data available, as most fuel purchasing is done with credit cards. A quantifiable carbon footprint for gasoline will provide transparency for consumers and make it easier for the EPA to estimate the real carbon impact of the potential switch to EVs. The assumption of this method is that vehicles are kept in good working order and emissions control equipment is not tampered with. However, gasoline is cleaner and more efficiently used than it has ever been before. In making informed choices regarding the future of our planet, we must resist the urge to base our opinions upon conjecture. The three-part index suggested in this paper will be more effective and more efficient than the current smog rating system in highlighting the need for transparency in some areas and making it possible to make the current vehicle market more environmentally friendly with a minimal need for true regulation.

[29] J. Clarence Davies and Jan Mazurek, *Pollution Control in the United States,* (New York: Resources for the Future, 1998), 13.

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