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semiconductor industry, where the particles that most need to be filtered out are especially small; in medical and home-use contexts, there is no benefit to using an ULPA filter instead of HEPA, which remains the industry standard in medicine and biology.

Air-purifying systems equipped with a HEPA filter usually employ other processes as well to complete their work. For instance, there is the high-energy ultraviolet light mentioned above for degrading bacteria and viruses, and a fan or other forced-air system to ensure the air passes through the filter. Activated carbon is often used to adsorb small volatile chemical molecules, converting them to a solid state from a gaseous one—this has the additional effect of odor control. Ionizer purifiers, frequently sold for home use, generate electrically charged gas ions that attach to airborne particles and cause them to stick to a collector plate, usually as an alternative to HEPA filtration.

See Also: Environmental Remediation; Green Chemistry; Green Nanotechnology; Membrane Technology.

Further Readings

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Hybrid/Electric Automobiles

Although hybrid/electric vehicles (HEV) make up only a small portion of the market (approximately 5 percent), sales have been steadily increasing. J. D. Power predicts U.S. hybrid sales will triple between 2008 and 2015. In Canada, sales of hybrids tripled from 2004 to 2006. The U.S. Department of Energy (DOE) points out that while HEVs have a long history in the automobile and motorcycle niche market, their recent popularity is the result of advances in electric-drive technologies that have enabled the major automakers to mass produce these vehicles by integrating internal combustion engines (ICE) with standardized batteries and electric motors. The draw for the consumer is that HEVs typically get better city and combined fuel economy than their equivalent ICE counterparts and roughly the same or somewhat less highway economy. The Toyota Prius presently has the top fuel mileage according to the U.S. Environmental Protection Agency (EPA), garnering 51-miles-per-gallon (mpg) city and 48-mpg highway ratings. At the same time, hybrid motorcycles achieve more than double the best HEV automobiles. As a result, hybrids have developed a market niche as “green” or “environmentally friendly” vehicles, a reputation that this entry will demonstrate is not presently supported by empirical life-cycle analysis (LCA).
Notwithstanding, hybrids are just one in a range of automotive technologies aimed at reducing the car’s ecological and carbon footprints. Dennis Simanaitis (2009) identified 10 different types of automotive technologies aimed at the environmentally conscience buyer, including the following:

- **Advanced gasoline:**
  Technological improvements to the ubiquitous gasoline ICE (e.g., direct fuel injection, variable valve timing, turbo/super charging) have improved fuel mileage and reduced carbon and emissions associated with photochemical smog (relative to an equivalent-sized vehicle),

- **Diesels:**
  Diesels typically get better fuel mileage than equivalent-sized gasoline ICES, and their emissions have dropped significantly with new technologies such as “urea injection.” Diesel sales are much larger in Europe than North America.

- **Flex fuel:**
  These vehicles use E85 (85 percent ethanol, 15 percent gasoline) but can switch to standard gasoline. In the United States and Canada, ethanol is typically distilled from corn, and much controversy exists about the use of “food for fuel” and the life-cycle impacts of corn ethanol. The DOE claims 0.87 million Btu of fossil energy is required to make 1 million Btu of ethanol at refueling stations, while standard gasoline needs 1.23 million Btu for 1 million Btu of gasoline at the station. On the contrary, Harro von Blottnitz and Mary Ann Curran (2007) reviewed 47 published assessments that compare bio-ethanol production to gasoline on a life-cycle basis. They found contradicting results, with some studies favoring ethanol in terms of emissions and others finding greater impacts over various environmental parameters. Further, many critics, activists, and environmentalists have blamed the production of ethanol from food sources for the shortages and soaring costs of basic foods and the resultant riots that occurred in various locations around the world.

- **Micro-hybrids:**
  These vehicles use a larger 12-volt alternator/motor that works in tandem with the ICE for start-and-stop driving. Typically, they use regenerative braking to help recharge the batteries.

- **Parallel-hybrids:**
  These are the most popular and are the only hybrids mass-produced by the major automakers; they are readily available in dealerships around the world. Honda’s Insight (now Civic) was the first to be introduced to the market in 1999, and the best-selling Toyota Prius is the most well-known example. Parallel-hybrids are the more sophisticated versions of HEVs and use two engines—an ICE and an electric motor. “Full” or “strong” variants can run only on the electric motor for a limited range (e.g., Toyota) and recharge their batteries through regenerative braking and onboard ICE recharging systems. Some systems use the ICE and electric motor running simultaneously (e.g., Honda), never running solely on their electric motor.
• **Parallel plug-in hybrids:** This HEV can run 5 to 10 miles on the electric motor only. They are plugged into the grid to recharge their battery packs. Emissions associated with the electric range are determined by the local hydrogrid. Because 45 percent of the grid in the United States is generated by coal, carbon and photochemical smog emissions are directly correlated to pollutants generated by electrical generating plants on the grid. None of the major manufacturers widely available has plug-ins on the market to date. However, the Nissan LEAF, with a claimed 100-km-plus range, is available in small numbers to a few select markets and if an online reservation is made.

• **Series plug-in hybrids, or extended range electric vehicles:** The ICE engine in these hybrids serves only to act as a generator to charge the batteries—the car drives solely on the electric motor. Trade-offs have to be made in terms of battery size, weight, range, and cost. Chevrolet released its plug-in hybrid electric Volt model in December 2010—the most fuel-efficient car sold in the United States as of early 2011. However, the vehicle has limited availability. Widespread sales across all of Canada and the United States was expected in mid-2012.

• **Battery electric vehicles (BEVs):** the major auto manufacturers are planning to release BEVs to the market in the near future. Presently, only small niche manufacturers are in this market. BEVs have no internal combustion engines and operate on a plug-to-plug basis. In 2010, the range was short and performance was modest with the then-current technology. Emissions associated with BEVs are determined by the local hydrogrid. In all vehicles in the United States were converted to BEVs, essentially almost half of all the cars would be running on coal, which is not a “clean” fuel. Furthermore, the significantly larger battery packs over a standard ICE vehicle are associated with increased LCA impacts from raw material extraction and processing. Notwithstanding, electric motors are more efficient mechanically than internal combustion engines, which will offset some of the increased emissions, especially when charged by renewable energy sources. The niche market Tesla Motors (2010) claim their BEV Roadster is 88 percent efficient while most conventional ICE-equipped automobiles are 20 to 25 percent efficient (BEV = 1.14 km/MJ, Hybrids = 0.56 km/MJ, conventional ICE car = 0.48km/MJ). Further, recharging BEVs using a “smart grid” electricity network and using vehicle-to-grid when they are parked will also do much to reduce impacts.

• **Fuel cells:** unlike batteries that store electricity, fuel cell vehicles typically convert hydrogen to create electrical energy. There are some fuel cell demonstration automobiles and commuter buses in use but no commercially available automobiles. In the operation phase of a vehicle life cycle, fuel cells generate electricity inside the cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. Hydrogen fuel cells use atmospheric oxygen as their oxidant. Fuel cells produce zero or very low emissions, depending on the source of the hydrogen.

Unfortunately, most hydrogen is produced from applying steam to methane, with the steam sourced from burning fossil fuels. Joseph Romm (2010) points out the following:

For this reason, we do not escape the production of carbon dioxide and other greenhouse gases. We simply transfer the generation of this pollution to the hydrogen production plants. This procedure of hydrogen production also results in a severe energy loss. First we have the production of the feedstock methanol from natural gas or coal at a 32 percent to 44 percent net energy loss. Then the steam treatment process to procure the hydrogen will result in a further 35 percent energy loss.

Hybrids: The Fashionable Environmental Statement

Notwithstanding all of the above, parallel-hybrids, henceforth in this article referred to as hybrids or HEVs, have become de rigueur or fashionable among celebrities and politicians
who are buying the car for the environmental statement it makes more than any other reason. What is clear from the scholarly research is that the increased popularity of hybrids is largely based on an image of environmental friendliness, rather than empirical evidence of environmental superiority. Heffner et al. (2007) points out the following:

Many households acknowledged purchasing their HEVs as a response to environmental concerns. However, most had only a basic understanding of environmental issues or the ecological benefits of HEVs. Rather than buying their HEVs with measurable environmental goals in mind, most of the individuals in this study bought a symbol of preserving the environment that they could incorporate into a narrative of who they are, or who they wish to be.

Unfortunately for those who bought hybrids in order to make an environmental statement, a recent study by CNW Marketing Research (2007) indicates that the environmental benefits of HEVs are overstated, by a significant margin, when an LCA is used to benchmark their environmental performance. The emphasis to date has been on relying solely on fuel mileage as the only indicator of net environmental impacts. MacLean and Lave (2003) pointed out in their work that only one previous LCA had been conducted on automobiles and that 73 percent of carbon emissions associated with a Ford Taurus resulted from the use phase; the remainder was associated with the manufacturing, recycling, and disposal phases of the product life cycle.

CNW’s LCA, claimed to have no outside organization, company, or enterprise fund in whole or in part any portion of their study, compared over 100 makes and models of cars and trucks. CNW used 4,000 “data points” for each car in a “cradle-to-grave” approach, including the following:

- Energy consumed in research and development
- Energy consumed in junkyard disposal
- Energy needed to produce parts
- Greenhouse gas emissions
- Fuel mileage
- Vehicle life span

These data were compiled and normalized into currency to make the result more understandable. The top five vehicles in terms of life-cycle impacts include the following:

1. Smart: $0.583
2. Ion: $0.621
3. Focus: $0.621
4. Cavalier: $0.655
5. Wrangler: $0.656

All but one of these vehicles are lightweight subcompacts with small, fuel-efficient three- or four-cylinder engines. Oddly, the much heavier four-wheel-drive Jeep Wrangler, equipped with a 3.8 liter V6 engine, made the list—CNW reports that the Jeep uses less energy to manufacture, has a longer life span, and is easier to recycle. The worst offenders included the Rolls-Royce ($11.83), the VW Phaeton ($14.26), and at rank 283, the Maybach ($15.97).
CNW found that hybrids fared poorly because of a lower than average vehicle life span and because of the increased complexity of their battery technology and extra electric motor. Much controversy exists from critics of the “Dust to Dust” study in terms of assigning the Prius a life span of 109,000 miles. CNW also points out that in order to use nickel metal hydride (NiMH) batteries, significant environmental impacts from raw materials are accrued in the LCA. Toyota buys nickel mined and smelted in Sudbury, Ontario, Canada. This nickel is shipped to Wales for refining, then to China for further processing, and then to Toyota’s battery plant in Tokyo—a 10,000-mile trip, mostly by petrol-powered container ships and diesel-powered locomotives. These LCA impacts are expected to be mitigated somewhat by switching to lithium-ion batteries in the near future.

The top HEV on the 2008 list was the Toyota Prius, ranked 140th at $2.91 per mile. Hence, it is difficult from these data to make an argument that the Prius is “green” as the Toyota entails 3.8 times more life-cycle impact than the Mercedes Smart. These types of results are incongruous with the advertising campaigns associated with HEV. As part of a larger research project for presentation at a peer-reviewed conference, the author conducted an analysis of English-language hybrid vehicle television commercials found online in March 2009 by Charles Hostovsky. He conducted a Google and YouTube search and downloaded all available commercials. The study was qualitative, relying on thematic analysis, using grounded theory. A total of 19 commercials from four manufacturers were found and reviewed in detail, including Toyota (n = 9), Honda (n = 5), Ford (n = 4), and GM (n = 1). Examined were dominant images, themes, and slogans (catchphrases) used in the advertisements.

The largest category at 58 percent (n = 11) was dominated by images that involved the hybrid set in nature. Themes including images of the deep woods were common and also included scenes of mountains, glaciers, and lush river valleys as well as images of biodiversity (i.e., species at risk, rich and varied bird and plant life). A subset of 26 percent (n = 5) had a strong ecological restoration thematic, including images of the following:

- A seed planted grows into a tree bearing HEVs as fruit that fall to the ground and start to drive away
- Flowers follow the car and the city greens
- North America becomes green from space from HEV use
- Everything the hybrid passes on the road transforms to green
- Seedlings/flowers emerge through the asphalt freeway pavement

Some of the slogans associated with the hybrid in nature include Kermit the Frog saying, “It’s easy being green.” The most outrageous statement: the HEV represents “harmony between man (sic), nature and machine.”

The second largest theme, 26 percent (n = 5), involved “transformative technology.” Images of da Vinci, hybrid engines, and other transportation modes dominated these commercials. Typical slogans included: “one small step on the accelerator, one giant leap for mankind (sic)”; and “creating new alternatives … ones that won’t change the way we live, but rather the impact our lives have on the environment around us.”

Only 16 percent (n = 3) of the HEV commercials contained no environmental theme. Here the automakers’ marketers appealed to the vehicles’ utility as a hatchback and their excellent fuel mileage. The ads contained images of young adults loading their cars, parking in the city, and everyday driving. Slogans included “the hybrid for everyone is here” or “most fuel-efficient car in its class.”
The author’s analysis suggests the marketing of HEVs involves greenwashing. “Greenwashing is a term derived from whitewashing by environmentalists who claim that some corporations want to present an environmentally responsible public image by misleading consumers regarding their environmental practices or the benefits of their products or services,” according to Hostovsky. Connie Davidson (2009) points out that an important characteristic of greenwashing is the suggestive and manipulative use of information. Although poor environmental performance itself is not necessarily greenwashing, a false representation of a poor performance as environmentally friendly can be considered to be so. Clearly, in the case of television ads, HEVs’ environmental friendliness appears to exploit the common perception of hybrids but does not reflect the empirical LCA evidence—evidence that suggests HEV environmental performance is “middle of the pack” relative to other automobiles.

Hybrids and Transportation Demand Management

One of the major issues concerning HEVs for transportation planners revolves around transportation demand management (TDM). TDM, at its core, tries to get people out of their cars (i.e., personal occupancy vehicles [POV]) in order to walk, bicycle, use transit, carpool, create urban car-free zones and car-free days, combine trips, and so forth, thereby reducing vehicle miles traveled (VMT). However, TDM strategies can be thwarted by the “conservation rebound effect.” This phenomenon occurs when the consumer chooses to use more of the resource (increase demand) instead of realizing the energy and environmental savings. For example, a person with a more efficient home furnace may choose to raise the setting on the thermostat or a person driving a more efficient car may drive more often and farther. Since the commuter perceives an HEV as an “environmentally friendly” car, he or she may also choose to drive and switch from taking transit, a phenomenon known as “induced/latent travel demand.” Induced travel demand reduces freeway levels of service (LOS) and increases traffic congestion, resulting in greater carbon and photochemical smog emissions. Lorna Greening et al. (2000) reviewed the literature in terms of the conservation rebound effect. He reviewed 23 studies involving fuel-efficient automobiles and found that the conservation rebound effect ranged between 10 and 30 percent. Kenneth Small and Kurt Van Dender (2005) found short- and long-run rebound effects 5 percent and 22 percent with fuel-efficient vehicles. Very little research has been conducted to examine if the CRE exists for HEVs in particular. Peter De Haan et al. (2006) surveyed 367 buyers of the Toyota Prius 2 in Switzerland. They found that vehicle size did not increase when replaced with hybrids and that average household vehicle ownership remained stable. However, they were unable to determine if hybrid drivers will, in the future, drive more. In a follow-up study, J. Dickinson and de Haan (2009) found no increase in VMT with Swiss Lexus hybrid owners. Since this study involved a large SUV model equipped with HEV technology, and considering that European driving behavior differs substantially from the low-density sprawl-dominant North American context, it is difficult to extrapolate from Dickinson and de Haan for North American transportation planners.

Another problem for TDM strategies are misguided policies based on the perception that HEVs are “environmentally friendly.” Some governments are offering economic incentives by providing rebates or allowing single-occupancy vehicles in freeway high-occupancy vehicle (HOV) lanes. Some business and government offices have created HEV parking spaces in prime locations in parking lots, unfortunately creating initiatives to
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promote hybrids that may be counterproductive to transportation demand management (TDM) and transit-oriented development (TOD), that is, getting people out of their cars, which is fundamental to smart growth planning.

In summary, despite HEVs’ achieving among the highest fuel mileage of commercially available automobiles, miles per gallon is only one factor in a vehicle’s life-cycle ecological footprint. There is no empirical LCA–based evidence that hybrids are more environmentally efficient than standard cars with gasoline-powered internal combustion engines. The only comprehensive LCA conducted to date places HEV impacts as middle-of-the-pack in terms of the life-cycle phases of manufacturing, life span, operation (i.e., fuel economy), recycling, and disposal.

Hybrid marketing through television commercials exhibits a strong tendency toward greenwashing. Evidence of eco-smugness, likely as a result of deep corporate greenwashing, may dissuade commuters from practicing transportation demand management strategies and contribute to increased traffic congestion through induced travel demand. Unfortunately, governments and business appear to be reacting to the popularity of these vehicles with misguided programs, subsidies, and policies aimed at promoting HEVs, which work against TDM and smart growth. Much more research is required, especially in terms of the relationship between hybrids and the conservation rebound effect and induced travel demand.

Some of the important strategies of smart growth planning—transportation demand management and transit-oriented development, in particular—fundamentally require commuters to “get out of their cars” more often. When we can reasonably reduce our North American auto dependency, HEVs can play an important role by reducing carbon emissions, since driving is indeed a necessary evil. In order to fulfill that role, hybrid/electric vehicles need to improve their longevity as well as reduce the ecological footprint associated with their manufacturing processes.

See Also: Carbon Footprint Calculator; Sustainable Design; Technology and Social Change; Unintended Consequences.

Further Readings


Haddock, Vicki. “Oh, So Pious, Prius Drivers/Smugness Drifts Over the Warming Earth—Is That a Bad Thing?” San Francisco Chronicle (July 15, 2007).


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