Fresh Questions about Electric Vehicles 5.18.20
by Gary Olhoeft, PhD and Katie Singer

Gary Olhoeft, PhD, is Professor Emeritus in Geophysics, Colorado School of Mines, a Life Member of IEEE, and a DBS patient. Katie Singer is the author of *An Electronic Silent Spring* and a forthcoming book about the Internet's footprint. www.ourweb.tech.

Call us troublemakers. Call us advocates of due diligence with all new technologies. While COVID19 has shut down most auto factories, kept consumers from car dealerships, generated relief bills that support electric vehicles (EVs),[1] and led to an oil price drop that leaves no way for an EV to recover its manufacturing or operating costs, we propose re-evaluating EVs' true costs before anyone makes or buys another one.

Like the Internet, solar photo voltaic and wind turbine systems, people often consider electric vehicles (EVs) green, sustainable and carbon neutral. They assume that buying an EV reduces our ecological footprint. To determine whether or not these assumptions are true, we need a cradle-to-grave evaluation that includes the vehicle's ecological impacts and energy use during its construction, usable life, and disposal or recycling.

Currently, manufacturers develop new technologies faster than third-party regulators can evaluate them. While a vehicle's selling points focus on reliability, safety and energy use *after the point of sale*, attention is rarely given to energy consumption, conflict minerals or worker hazards during its construction.

For this brief, we offer questions for evaluating the mining and energy required to manufacture EVs *and* rarely-discussed safety issues:

What energy, raw materials, chemical, gas and particulate emissions does EV manufacturing require? How are workers, communities and wildlife impacted by mining, refining, shipping and assembling the vehicle's raw materials and parts?

Every vehicle's design and building begins with computer modeling. These 3D printers and/or robotics hold embodied energy and use energy to operate.[2] To clarify, *embodied* energy is the energy used in manufacturing a product, *before it is sold*. Likewise, toxins and greenhouse gases (GHGs) emitted during manufacturing are called *embodied* toxins and *embodied* GHGs.

EV batteries require myriad elements and minerals, including cobalt, coltan, lithium, graphite, copper, nickel, manganese and much more.[3] In 2019, leading scientists from the UK's Natural History Museum explained that "replacing all UK-based vehicles with electric vehicles...would take 207,900 tonnes cobalt, 264,600 tonnes of lithium carbonate, at least 7,200 tonnes of neodymium and dysprosium, and 2,362,500 tonnes of copper."[4]

"Energy costs for cobalt production are estimated at 7000-8000 kWh for every tonne of metal produced and 9000 kWh/t for copper."[5]

---

1. https://electrek.co/2020/03/18/egeb-new-mexico-ev-charging-stations-coronavirus-house-democrats-stimulus-package/
2. Strubell, Emma, A. Ganesh, A. McCallum, "Energy and Policy Considerations for Deep Learning in NLP," 5 June 2019; https://arxiv.org/abs/1906.02243
3. Sovacool, Benjamin K., et al., "Sustainable minerals and metals for a low-carbon future," *Science*, Vol. 367, Issue 6473, 3 January 2020.
4. "Leading scientists set out resource challenge of meeting net zero emissions in the UK by 2050," 5 June 2019; https://www.nhm.ac.uk/press-office/press-releases/leading-scientists-set-out-resource-challenge-of-meeting-net-zer.html
5. ibid.

Monica, a four-year-old cobalt miner in Democratic Republic of Congo. Photo credit: Sky News, https://www.youtube.com/watch?v=JcJ8me22NVs

Extracting and refining ores and elements endangers miners and ecosystems. Child-miners have been maimed and buried alive while mining for cobalt.[6]

Processing lithium takes water from communities and farmers.[7] Lithium from discarded batteries can contaminate water supplies, disturbing homeostasis during a woman's pregnancy and possibly increasing a community's suicide rates.[8] Because lithium batteries can short circuit and/or be charged improperly, they can explode. Fires and explosions happen, all too frequently.[9] To date, lithium batteries are not recyclable.

Mining and refining graphite without sufficient tarps and fans can cover nearby crops, waterways, livestock, trees, indoor spaces and people in black soot. Exposure to fine-particle graphite pollution is linked to breathing difficulties and heart attacks in people with heart disease.[10]

EV motors depend on neodymium and dysprosium, rare earth elements used as magnets. Extracting them leaves an uninhabitable wasteland.[11]

Embodied energy and GHGs are often unrecognized when a product's energy use and emissions are evaluated. Yet, 81% of a laptop's cradle-to-grave energy will be used before its owner turns the laptop on.[12] One EV can have fifty[13] or more computers, and each of these will have, like a laptop, consumed most of its total energy before the vehicle leaves the car dealership.

A computer can depend on 1000 substances,[14,15] each with its own supply chain. For example, production of electronic-grade silicon for transistors (which process and store data and provide memory, apps, GPS and more) starts with smelting quartz in a furnace kept at 1800°F for years at a time. Step 2, a vapor deposition process, also requires an energy-intensive, greenhouse-gas and toxic waste-emitting smelter. Smelters are powered by electricity typically generated by GHG-emitting coal.[16] Nuclear and/or hydro power (whose manufacture and operations disrupt ecosystems[17]) may also fuel smelters.

---

6. https://www.cbsnews.com/news/apple-google-microsoft-tesla-dell-sued-over-cobalt-mining-children-in-congo-for-batteries-2019-12-17/; https://www.theguardian.com/global-development/2019/dec/16/apple-and-google-named-in-us-lawsuit-over-congolese-child-cobalt-mining-deaths
7. Katwala, Amit, "The spiraling environmental cost of our lithium battery addiction," 8.5.18; https://www.wired.co.uk/article/lithium-batteries-environment-impact.
8. Choi, Hye-Bin, et al., "The impact of anthropogenic inputs on lithium content in river and tap water," *Nature Communications*, 2019.
9. https://www.washingtonpost.com/technology/2018/09/11/explosive-problem-with-recycling-ipads-iphones-other-gadgets-they-literally-catch-fire/?noredirect=on&utm_term=.1a455bbe165e
10. https://www.washingtonpost.com/graphics/business/batteries/graphite-mining-pollution-in-china/
11. https://www.bbc.com/future/article/20150402-the-worst-place-on-earth
12. https://spectrum.ieee.org/energy/environment/your-phone-costs-energyeven-before-you-turn-it-on
13. www.aamcocolorado.com
14. Needhidasan, S., et al., "Electronic waste--an emerging threat to the environment of urban India," *J. Environ Health Sci. Eng*., Jan. 20, 2014; http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3908467
15. www.ourweb.tech/campaign
16. Troszak, Thomas, "Why Do We Burn Coal and Trees for Solar Panels?" https://www.researchgate.net/publication/335083312_Why_do_we_burn_coal_and_trees_to_make_solar_panels

Manufacturing EV charging stations also requires extracting and smelting ores, transporting refined materials to assembly plants, and shipping the charger to its end-user.

Shipping materials between manufacturing stations matters. If cargo shipping were a country, it would be the world's sixth biggest GHG emitter.[18]

Because of the havoc manufacturing wreaks on waterways, communities and workers, we cannot rightly call EVs (or their infrastructure) "clean," "carbon neutral," "net-zero emitters," "conflict mineral-free" or "worker hazard-free."

Tibetans protest the Lichu River's poisoned water and dead fish in Eastern Tibet. The environmental damage is caused by chemicals discharged by mining lithium. Photos used with permission, https://freetibet.org/news-media/na/tibetans-protest-against-pollution-mining

DEFINITION OF RELEVANT TERMS

Conflict mineral An ore mined under abusive conditions and/or armed conflict.

Herman Daly Principle Do not extract materials faster than the Earth can replenish them or waste materials faster than the Earth can recycle them.

Due Diligence An appropriately thorough investigation of financial, environmental and other consequences (including energy use, extractions, emissions, public health and wildlife impacts) of manufacturing and operating infrastructure or a product.

Embodied Costs (also called Embedded Costs) Energy used during a product's design; energy used to mine, refine and ship a product's raw materials. Greenhouse gases and toxic wastes emitted during these steps and assembly. Public health and wildlife impacts of manufacturing. Ecological remediation of air, land and waterways affected by mining and manufacturing. Shipping the final product to its end-user.

Jevons Paradox From William Jevons' 1865 book, *The Coal Question:* energy efficiency *increases* energy demand, since a product's increased efficiency and lowered cost lead to increased production and thereby use more raw materials and energy.

Regulatory Lag When the speed of technological change outpaces any government agency or NGO's ability to provide adequate, third-party regulatory oversight.

Sustainability The ability to continue doing something within ecological limits indefinitely. (An unattainable practice for an industrialized society.)

Unintended Consequences Unanticipated outcomes of any action.

---

17. Fitz, Don, "What is Energy Denial?" 9.11.19; http://greensocialthought.org/print/1143
18. https://www.weforum.org/agenda/2018/04/if-shipping-were-a-country-it-would-be-the-world-s-sixth-biggest-greenhouse-gas-emitter

Do passengers, pedestrians, children and other vehicles keep safe while the EV operates and charges? Does operating it comply with the Americans with Disabilities Act? If the vehicle is self-driving, how does it respond to unanticipated encounters, including bicyclists, people in wheelchairs, hoverboards, black ice and/or sudden weather changes?

An EV's computers, power systems, motors, active sensors and antennas emit electromagnetic radiation (EMR). The FCC determined that EMR exposure from such devices is safe because it has no immediate, thermal effect. However, numerous studies show that EMR-exposure's non-thermal effects include DNA damage, brain tumors, heart schwannomas and more.[19]

An EV's EMR emissions can cause a deep brain stimulator (DBS) (a medical implant for neurological diseases like Parkinson's) to malfunction, shut off or reprogram.[20] We know a woman who drove her hybrid car after she had a DBS implanted. Each time the car's battery-charger turned on at stoplights, the computers' magnetic fields shut off her DBS.

In 2000, NIH reported that 8-10% of the U.S. population had an implant.[21] (Despite robust growth in use of medical implants, this is the last study that quantifies their use.) Few studies explore EMR exposure's effects on people with DBSs, pacemakers, insulin pumps or cochlear implants. While one study demonstrates that newer pacemakers are not disturbed by EVs, it does not consider people with older models.[22]

Because he has a DBS, this paper's co-author, Dr. Gary Olhoeft, would not ride in an electric vehicle.[23]

EV evaluations should include miners' and assembly workers' safety. Do manufacturers use benzene and n-hexane during production of the EV's computers? Found in solvents used to sterilize electronics, benzene can cause leukemia, and n-hexane has been linked to nerve damage.[24]

How does charging an EV impact our electric grid?

Scientists from UK's Natural History Museum report that charging EVs for (the currently driven) 252.5 billion miles annually would require a 20% increase in UK-generated electricity.[25]

Charging an EV during the day could disrupt a utility's efficient delivery of electricity; night-time charging could aid it. H*ow/could charging times be regulated?*

Operating an EV's charger likely puts harmonics on electric wires. Harmonics create dirty electricity, which "chops" our grid's 50Hz or 60Hz cycle. In turn, this increases wear and tear on motors. Magnetic fields from dirty electricity also disturb health.[26]

To extend an EV's available mileage (currently 250-300 miles per charge), building induction chargers into highways would allow EVs to charge while driving. *How much energy and GHGs do such chargers embody?*

Depending on their power, frequency and dosage, induction chargers could reprogram a deep brain stimulator. Reprogramming a DBS could be fatal to its user. We have no study to reference here, only Dr. Olhoeft's experience as an electrical engineer, DBS patient and physicist.

---

19. www.bioinitiative.org; www.saferemr.com; https://www.microwavenews.com/
20. Professor Olhoeft speaks on "Electromagnetic Interference and Medical Implants" at http://www.electronicsilentspring.com/electromagnetic-interference-medical-implants/
21. https://consensus.nih.gov/2000/2000medicalimplantsta019html.htm
22. Lennerz, Carsten, Lorenz Horlbeck, et al., "Patients with pacemakers or defibrillators do not need to worry about e-Cars: An observational study," *Technology and Health Care*, 13 January 2020.
23. Segell, Michael, "Electro Shocker," *Prevention Magazine*, January, 2010.
24. Professor Olhoeft speaks on "Electromagnetic Interference and Medical Implants" at http://www.electronicsilentspring.com/electromagnetic-interference-medical-implants/
25. https://www.cbc.ca/news/technology/apple-bans-toxic-benzene-n-hexane-from-iphone-ipad-final-assembly-1.2736214
26. "Leading scientists set out resource challenge of meeting net zero emissions in the UK by 2050," 5 June 2019; https://www.nhm.ac.uk/press-office/press-releases/leading-scientists-set-out-resource-challenge-of-meeting-net-zer.html

What agency would regulate induction chargers' embodied energy and their power, frequency and dosage? Would roadway chargers' impacts on pregnant women, children, and/or people with medical implants be studied before they are deployed?

What personal data do car manufacturers track? What happens to this data? How/can consumers opt out of it?
Programs such as Onstar connect with a new vehicle's GPS to record the vehicle's location at any given moment. While emergency responders can use this data to locate someone needing help, insurers may also buy it to monitor policyholder behavior.[27]

What agency ensures that software is designed and encrypted to prevent a car's computers and Internet connection from crashing or getting hacked? If the government will not regulate autonomous vehicles (as Transportation Secretary Chao announced in January, 2020[28]), how will owners, passengers and underwriters learn about updates to vehicle safety?
Many cars are recalled because of defects. No agency tests vehicles' software. Given that software problems caused recent Boeing crashes, shouldn't EV manufacturers provide due diligence with software?

Are the EV's parts easily replaced, affordable and recyclable?[29] Given that parts also hold embodied energy, does repair lower the vehicle's overall energy use? What energy, GHGs and toxins are involved in recycling? Is sending U.S. and European e-waste to Asia and Africa ethical, ecological or sustainable?
Annually, 44.7 million metric tons of e-waste are generated; this amount increases by about eight million tons each year, and yet only about 20% is recycled. Waste streams from EV batteries grow significantly. Further, while Europe and the U.S. are the main producers and consumers of EVs and other electronics, Africa and Asia are the main receivers or importers of e-waste.[30]

How would geoelectric storms affect EVs?
Since the 1850s, geoelectric storms have caused radio communication blackouts, fires in telegraph networks, and signaling problems along railways. A geoelectric storm in March, 1989 caused the collapse of Canada's Hydro-Quebec power grid.

A geoelectric storm can generate 1000 volts. Most vehicles' wiring is between 300 and 600 volts. A 1000-volt storm would burn out the average vehicle.

While the southern half of the U.S. has insufficient data collected to predict geoelectric storms accurately, researchers from the U.S. Geological Survey posit that four U.S. regions have notable geoelectric storm hazards: the East Coast, Pacific Northwest, Upper Midwest, and the Denver metropolitan area.[31]

Could manufacturers build vehicles robust enough to withstand 1000 volts? Would an extreme, geoelectric storm impact contemporary power distribution systems, including those that support electric vehicles and GPS systems?

---

27. Zuboff, Shoshana, *The Age of Surveillance Capitalism*, Public Affairs, 2018.
28. https://www.boston.com/cars/car-news/2020/01/09/new-u-s-plan-keeps-autonomous-vehicle-standards-voluntary
29. https://www.iisd.org/library/sustainability-and-second-life-case-cobalt-and-lithium-recycling
30. Sovacool, Benjamin K., "The decarbonisation divide: Contextualizing landscapes of low-carbon exploitation and toxicity in Africa," *Global Environmental Change*, 12 Dec 2019.
31. Lucas, G.M., J.J. Love, et al, "A 100-year Geoelectric Hazard Analysis for the U.S. High-Voltage Power Grid," *Space Weather*, 14 Dec., 2019.

Where can U.S. consumers go with questions about EVs?

Section 1502 of the 2010 Dodd-Frank Wall Street Reform and Consumer Protection Act requires U.S. publicly-listed companies to check their supply chains for tin, tungsten, tantalum and gold (commonly used in electronics). If a product contains one of these, then the company must report efforts to locate the mineral's source to the Securities and Exchange Commission (SEC). In 2017, the SEC suspended enforcement of this regulation. Still, companies are expected to file disclosures about the source of their products' minerals. (In January, 2021, The European Union Conflict Minerals Regulation will go into effect. Unlike Dodd-Frank, the EU's Regulation applies to mineral *importers*, rather than end-product manufacturers.)

The Insurance Institute for Highway Safety's ten parameters for assessing vehicle safety mostly refer to collision damage.[32] They do not evaluate security, privacy, or chemical or electromagnetic radiation (EMR) emissions.

The Environmental Protection Agency (EPA) evaluates the energy used and the fluids, gases and carbon monoxide emitted by a vehicle *while it operates*. EPA does not evaluate energy used or toxins emitted during design, extraction, refining, transporting or assembling of materials involved in manufacturing the vehicle's motor, computers, batteries, tires, brakes, suspension system, body or active sensors. The agency does not evaluate labor standards of corporations that purchase the raw materials. It does not evaluate the energy required to repair, recycle or dispose of the vehicle. It does not evaluate any vehicle's electromagnetic radiation (EMR) emissions. While some California agencies assess and regulate some of these things, we know of no federal agency that does.

The Federal Communications Commission (FCC) does not regulate EMR emissions from any vehicle's computers, sensors, smart systems or from networking between cars.

The Food and Drug Administration (FDA) oversees medical implants; the Access Board oversees the Americans with Disabilities Act. Neither regulates the impact of a vehicle's EMR emissions on patients with implants.

The National Highway Transportation Safety Administration (NHTSA) issues Federal Motor Vehicle Safety Standards and Regulations. NHTSA inspects hundreds of vehicle components including headlights, brakes, defogging systems, theft protection and door locks. It enforces vehicle recalls. It oversees regulation of children's car seats, but not the impacts of EMR emissions on children or adults. NHTSA's most recent, accessible safety standards booklet is dated 1998; it does not cover computers or sensors.[33] Our access to a more recent issue was denied, perhaps because it is incomplete.

Recent reviews of the true costs of powering EVs focus on purchase price and charging expenses. These reviews do not include the energy used, greenhouse gases or toxins emitted, or workers' hazards endured while manufacturing EVs or charging stations. They do not include the costs or hazards involved in disposal.[34,35]

In January, 2020, Transportation Secretary Elaine Chao announced that the U.S. will issue no regulations for manufacturers of self-driving vehicles.[36] The federal government will promote only voluntary standards. Of course, not all EVs are autonomous. However, taxis and 18-wheelers are expected to be self-driving by 2022.[37] Manufacturers are also working on self-driving boats, bikes, scooters and fighter jets. The lack of federal regulation (and inter-agency cooperation regarding these issues) means that consumers and municipalities can only evaluate EVs on their own.

---

32. www.iihs.org
33. https://one.nhtsa.gov/cars/rules/import/FMVSS/index.html
34. Edmunds, "The True Cost of powering an Electric Car, March 6, 2019; https://www.edmunds.com/fuel-economy/the-true-cost-of-powering-an-electric-car.html
35. Ulrich, Lawrence, "2020 Top 10 High Tech Cars," 31 March 2020; https://spectrum.ieee.org/transportation/advanced-cars/2020-top-10-high-tech-cars
36. https://www.boston.com/cars/car-news/2020/01/09/new-u-s-plan-keeps-autonomous-vehicle-standards-voluntary
37. https://evonomics.com/what-will-happen-to-truck-drivers-ask-factory-workers-andrew-yang/

Since internal combustion vehicles (ICVs) and electric vehicles both hold embodied energy, which kind has greater environmental impacts?

Some EV motors' magnets are made from neodymium and dysprosium, rare earths. According to the Chinese Society of Rare Earths, "Every ton of rare earth produced generates approximately 8.5 kilograms (18.7 pounds) of fluorine and 13 kilograms (28.7 pounds) of dust; and using concentrated sulfuric acid high temperature calcination techniques to produce approximately one ton of calcined rare-earth ore generates 600 to 12,000 cubic meters (339,021 to 423,776 cubic feet) of waste gas containing dust concentrate, hydrofluoric acid, sulfur dioxide, and sulfuric acid; approximately 75 cubic meters (2,659 cubic feet) of acidic wastewater, and about one ton of radioactive waste residue." Further, "all the rare-earth enterprises in (China's) Baotou region produce approximately ten million tons of all varieties of wastewater every year;" and most of that waste is "discharged without being effectively treated, which not only contaminates potable water for daily living, but also contaminates the surrounding water environment and irrigated farmlands." In the U.S., the EPA regulates such contaminants to keep emissions levels significantly lower.

EV motors also hold copper wiring. A U.S. Geological Survey study found that for every kilogram of copper mined, at least 21 kilograms of waste are generated.[38] ICV motors are primarily made out of steel and aluminum. While manufacturing steel and aluminum has significant environmental impacts, it is arguably less impactful than mining neodymium and dysprosium. ICV catalytic converters (part of the exhaust system) also have platinum and palladium, rare earths. EVs do not have catalytic converters.

An ICV has about 100 pounds of (typically) lead-acid batteries. One Tesla has 1200 pounds of batteries made from lithium and cobalt[39]; mining and refining them impacts waterways, land, and nearby communities' public health.

Electric vehicles have 50-100 computers. ICVs have 30-50 computers.[40] High end EVs and ICVs can have as many as 100 computers.[41] Every computer has its own energy-intensive, toxic waste emitting supply chain.

In use, electric vehicles' emissions are likely cleaner than ICVs. Meanwhile, Tesla has begun recycling lithium, cobalt, aluminum, copper and steel.[42] While recycling may have less impacts than "virgin mining," it still requires energy and emits GHGs and toxic waste. One percent of rare earths are recycled.[43] While Tesla advertises its supercharging stations as "free," these stations in fact have embodied costs with international environmental implications.

Our point here is that focusing only on a vehicle's emissions while it is used ignores the significant energy, GHGs, and toxic emissions embodied in its production and disposal (or recycling).

---

38. Goonan, Thomas G., "Flows of selected materials associated with world copper melting," U.S. Geological Survey, Open File Report, 2004-1395.
39. www.tesla.com
40. www.globeandmail.com
41. www.ceinetwork.com
42. www.greencarreports.com
43 www.thebalancesmb.com

Closing Questions

COVID19 has shown us the challenges of depending on international supply chains for basic needs like transportation. Along with lack of planning, inadequately accounted for hidden costs of modern technologies result in an unsustainable civilization.[44,45] To provide for a resilient future with decreased ecological impacts and unintended consequences (some self-driving golf carts already on the market do not let people take over the vehicle if something goes wrong[46]), let's ask and discuss:

What kind of transportation reduces overall energy consumption, extraction, ecological impacts and dependence on international supply chains?

Would improving public transportation reduce private vehicle ownership? Would this reduce overall energy consumption and mining?

How/could transportation ensure safety for a vehicle's riders as well as for nearby pedestrians and bicyclists?

How/could we prioritize due diligence over technological progress and profit? What federal regulations would ensure safety for a vehicle's passengers as well as nearby pedestrians and bicyclists? Could regulations limit manufacturing's ecological impacts? Could manufacturers provide safer conditions for workers throughout supply chains? Could they design easily repaired and recyclable vehicles?[47]

Rather than compare the energy used by vehicles powered by gas or electricity during their operation, could consumers and municipalities ask for transportation that reduces overall energy consumption, extractionism, and worker and public health hazards? Would powering some vehicles with biogas (methane generated by anaerobic digesting of landscape waste) reduce overall energy consumption?[48]

Would using what we already have impact ecosystems and public health less than buying new? Could we repair and maintain the vehicles and roads we have for as long as possible as part of truly resilient transportation systems?

Who will discuss these questions?

---

44. Brown, Harrison, *The Challenge of Man's Future*, Viking, 1954.
45. Catton, Jr., William R., *Overshoot: The Ecological Basis of Revolutionary Change*, University of Illinois Press, 1982.
46. https://medium.com/the-silicontrarian/google-s-first-fully-autonomous-self-driving-car-gives-up-drives-self-off-cliff-76ffb7a25523 "Google's First Fully Autonomous Car Gives Up; Drives-Self Off Cliff," Joe Bagel, Feb. 19, 2016.
47. Lepawsky, Josh, *Reassembling Rubbish: Worlding Electronic Waste*, MIT Press, 2018.
48. www.eesi.org.