

Electric Transportation is the Future

The Sooner the Better

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Introduction

The Earth is finite. The thin surface layer of the Earth available for minerals extraction is very much smaller. The amount of crude oil and natural gas available for extraction from the thin surface layer of the Earth is very much smaller than the sum of minerals.

For a century crude oil and natural gas have been the source of fuels for transportation of humans and matter of interest to humans. The finiteness of such fossil fuels needs to be accounted for in planning for long-term human civilization on Earth. This article shows that that available finiteness can be calculated in a reasonable way and that the fast increase in human population and increase in fuel consumption per capita will cause the need to find a sustainable source of “fuel” for transportation to be urgent.

Crude oil and natural gas are not only used for transportation fuel; they are very important for making useful items, including components of transportation vehicles and transportation infrastructure. So, using crude oil and natural gas for fuels needs to stop long before available crude oil and natural gas are depleted.

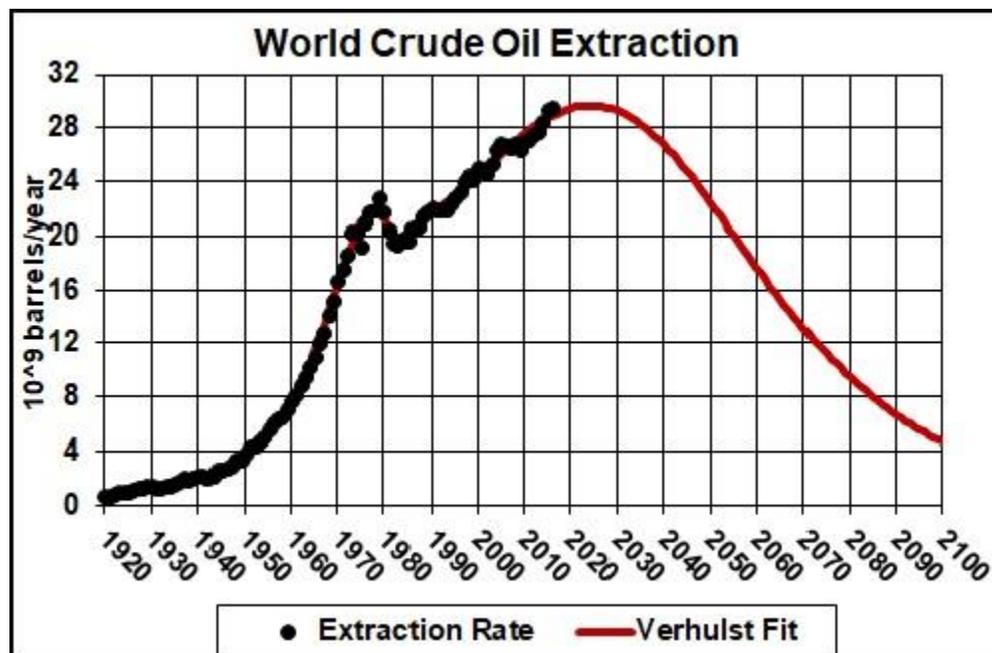
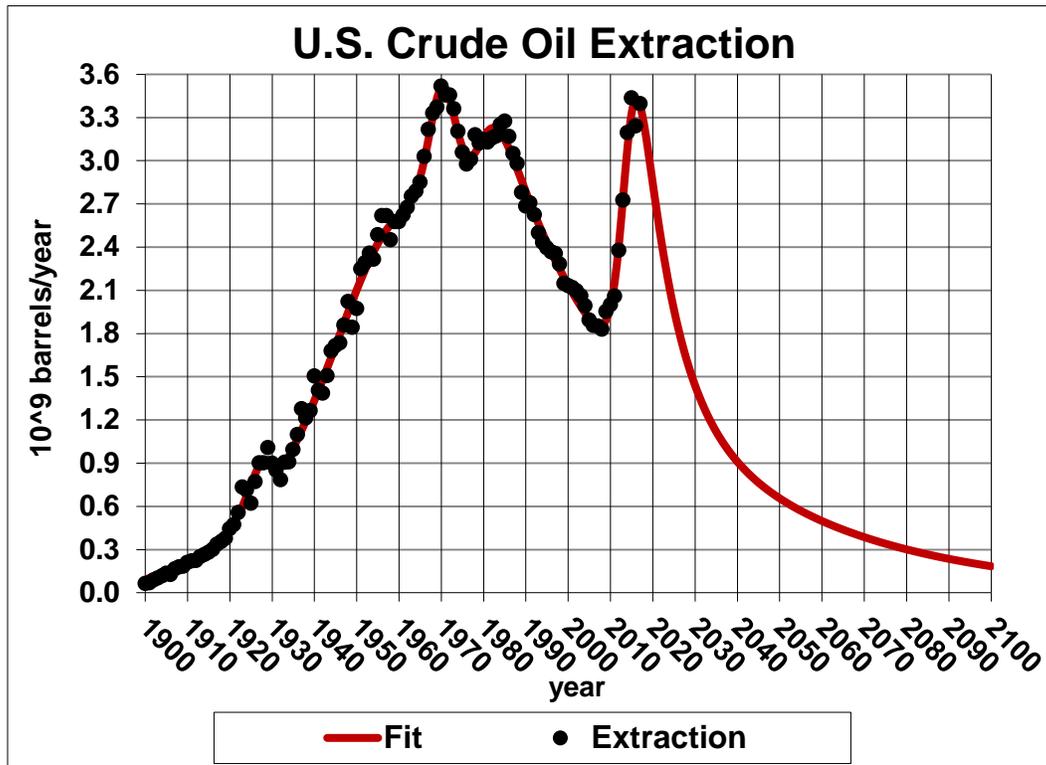
Fuel-cell vehicles may be better than electric vehicles in some situations as long as the hydrogen is made by electrolysis using renewable energy sources.

The only sustainable fuel for transportation is electricity generated from renewable energy, mostly solar and wind.

Another equally important reason for the world changing transportation from fossil-fuels energy to renewable energy is [global warming](#). (I use the term “global warming” rather than “climate change” because it indicates the direction of change.)

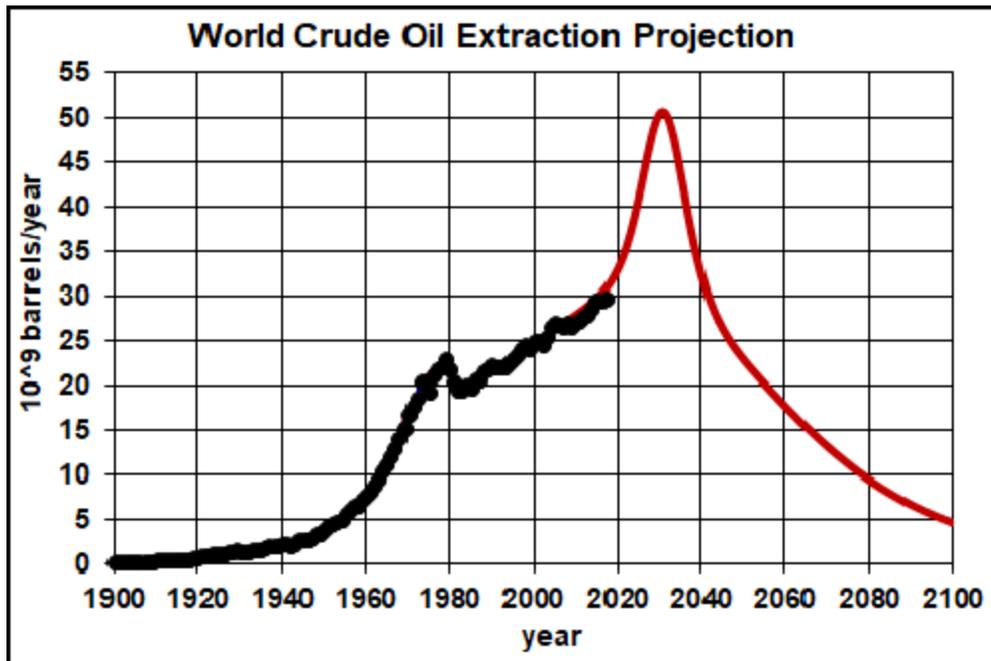
Crude Oil Depletion

Data for crude-oil extraction in countries and for the world have been available for over a century. An excellent source of the data is the [U.S. Energy Information Agency](#). The following two graphs show the crude-oil-extraction data and future projection for the [U.S.](#) and the [world](#):



The red curves in the graphs are calculated by fitting a mathematical function to the black extraction data points with the future projections determined by the [proved reserves](#) increased by about a factor of 2 to be optimistic.

Note the second peak in the U.S. extraction data and curve due to [fracking for tight oil](#). Possibly a similar future fast-rising narrow peak will occur for the world; here is an educated guess as to what might occur:



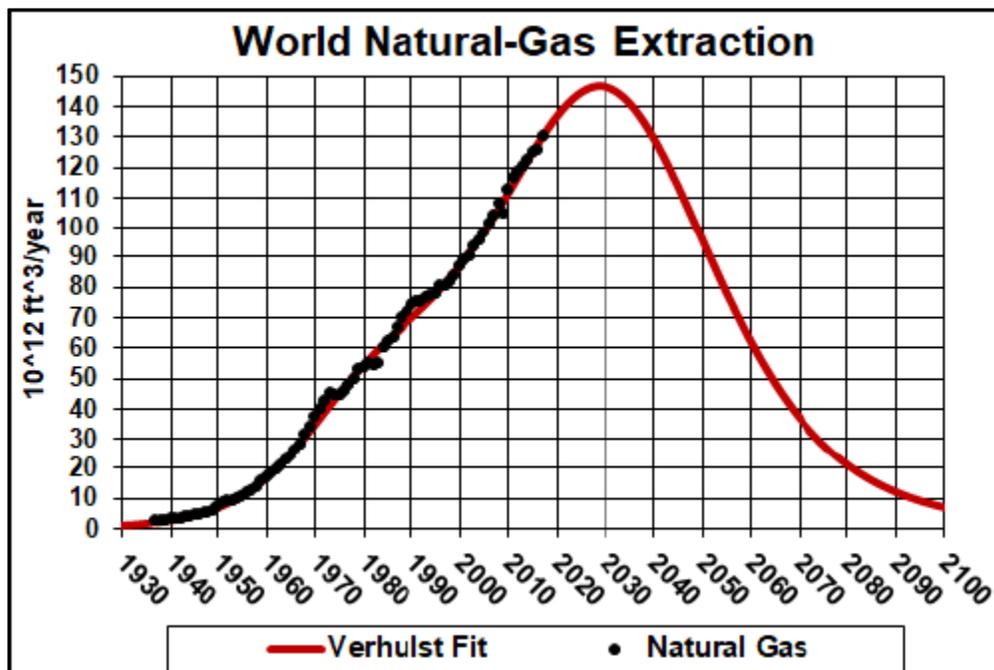
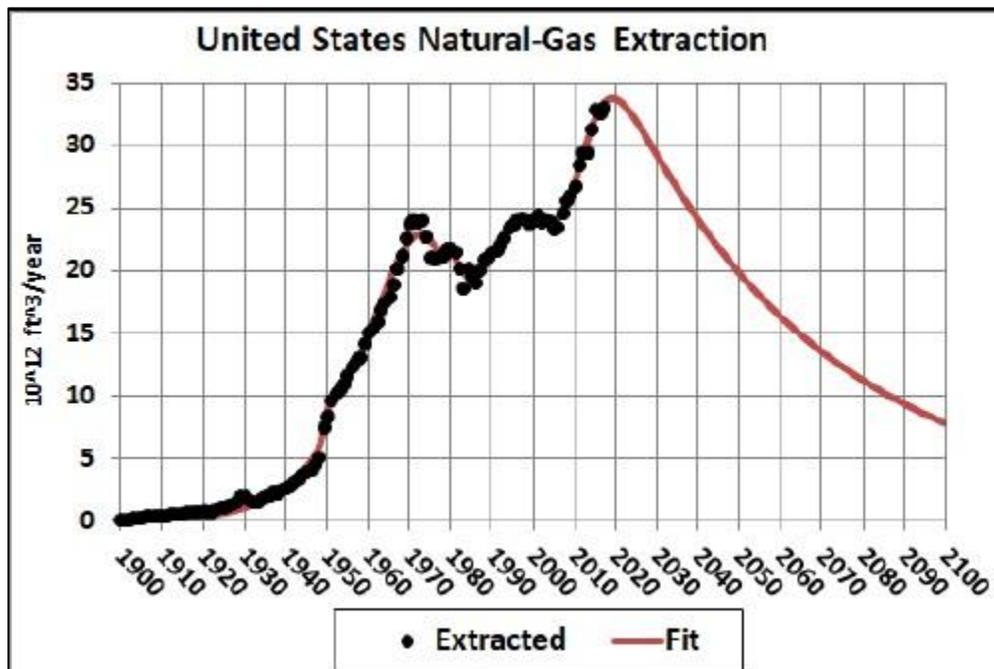
The U.S. graph shows that now is definitely the time in the U.S. to quickly move from using fossil fuels for transportation to electricity generated from solar and wind energy. The world graph indicates that maybe a decade delay can be tolerated for the world before quickly moving to electric transportation.

Note that I use the term "extraction" instead of the usual "production" term. We do not produce crude oil, we extract it. We "produce" gasoline/diesel from crude oil at refineries.

Natural-Gas Depletion

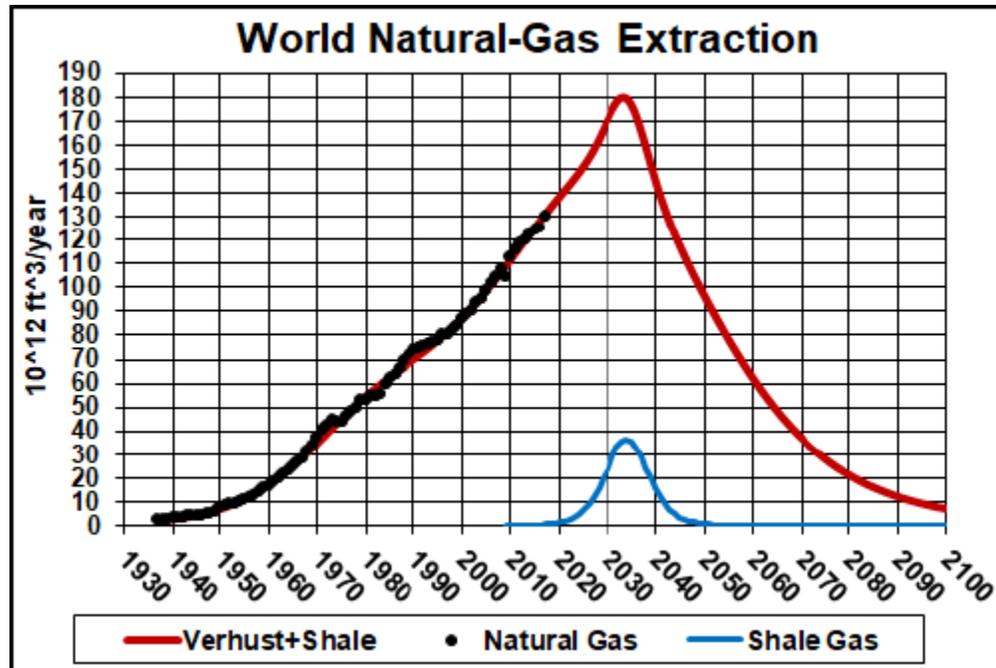
How about changing transportation from gasoline/diesel energy to natural-gas energy?

Data for natural-gas extraction in countries and for the world have been available for over a century. An excellent source of the data is the [U.S. Energy Information Agency](#). The following two graphs show the natural-gas-extraction data and future projection for the [U.S.](#) and the [world](#):



The red curves in the graphs are calculated by fitting a mathematical function to the black extraction data points with the future projections determined by the [proved reserves](#) increased by about a factor of 2 to be optimistic.

Note the second peak in the U.S. extraction data and curve due to fracking for [shale natural gas](#). Possibly a similar future fast-rising narrow peak will occur for the world; here is an educated guess as to what might occur:



[Natural gas transportation](#) between continents is dangerous and expensive.

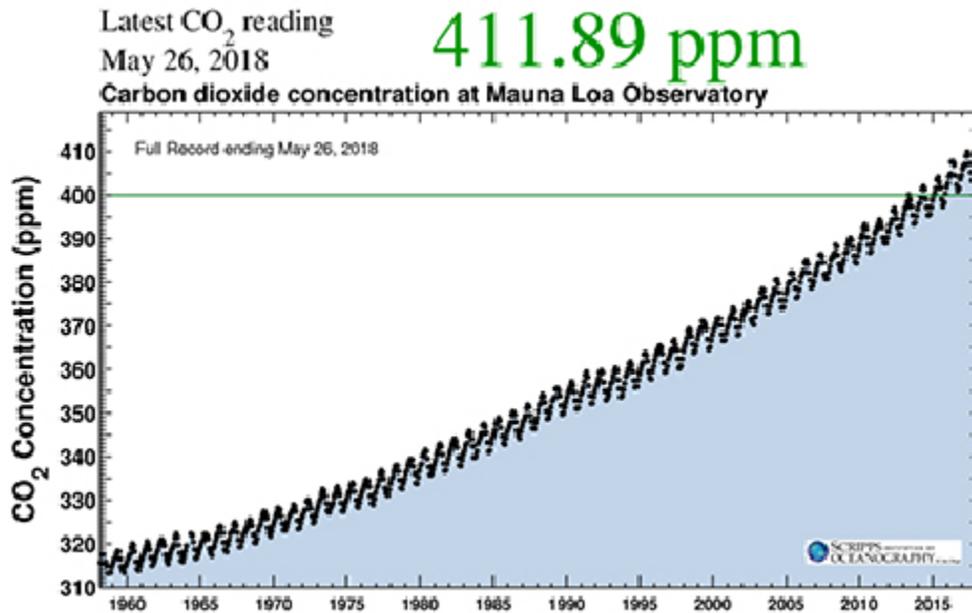
The last two graphs show that natural gas is not a viable replacement for gasoline/diesel for future transportation, especially in the United States.

The current U.S. source of natural gas for burning is fracking for [shale natural gas](#), which is much worse for global warming than burning gasoline/diesel because of [methane leaking \(fugitive methane\)](#) at natural-gas and crude-oil well heads, by pipelines and at fueling stations. [Fracking drilling is environmentally destructive](#), also.

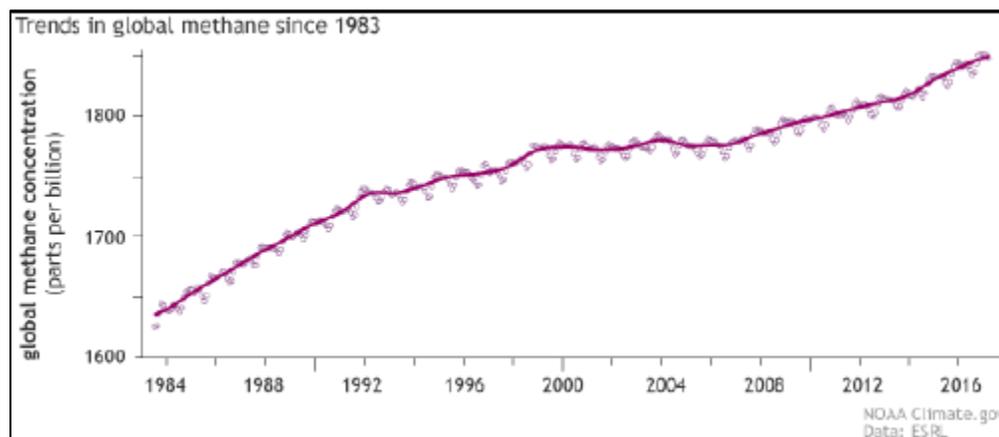
A major use for [natural gas is producing nitrogen fertilizer](#) for agriculture.

Global Warming

Burning a liquid (gasoline/diesel) or gas (natural gas) in internal-combustion engines (ICEs) for transportation emits carbon dioxide into the atmosphere, which is a major cause of global warming. There are [many other sources of carbon-dioxide](#). This graph shows how [carbon dioxide has increased with time for the world](#):

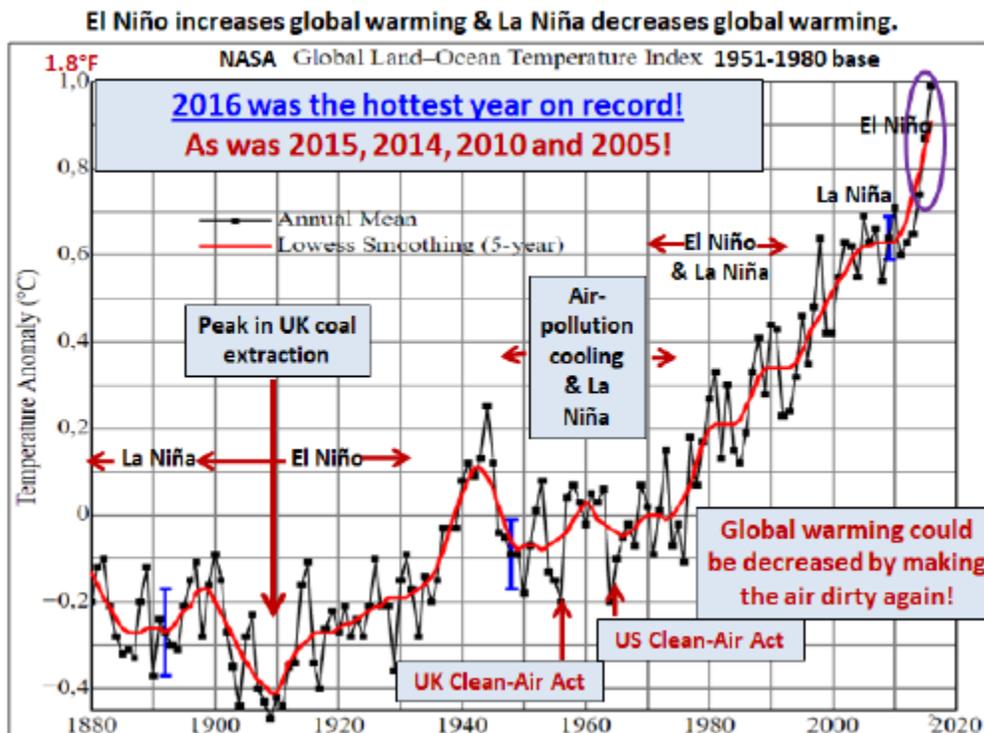


Another important gas emission that increases global warming is [methane emissions](#):



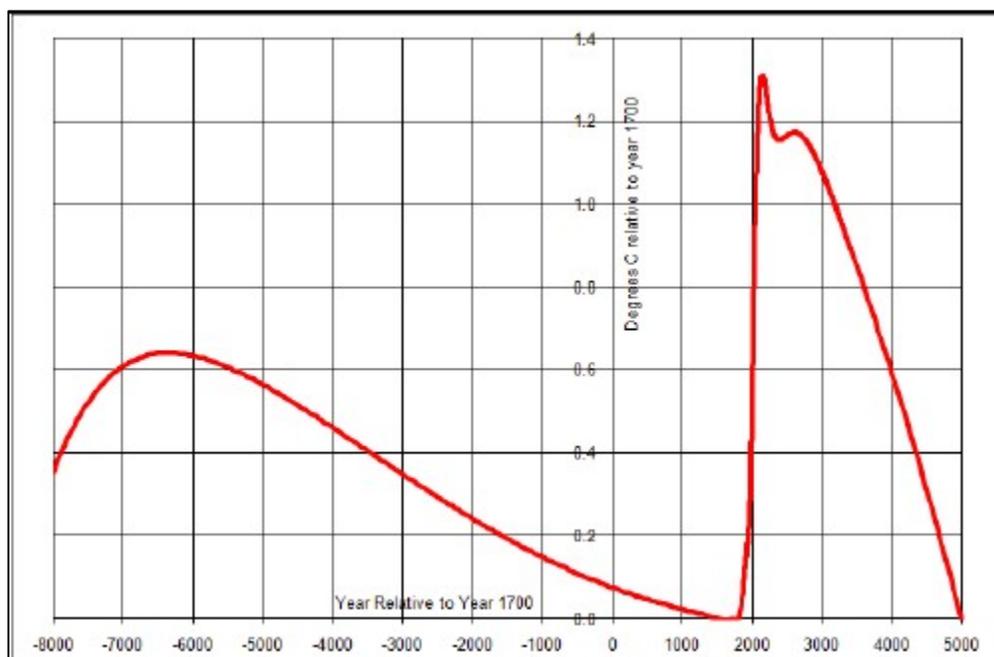
[Methane's lifetime in the atmosphere is about 10 years](#); it reacts with oxygen to produce carbon dioxide.

These and other gas emissions, forest destruction and other human activities cause [global warming](#):



If fossil fuels were not discovered in the Earth, extracted and burned, the Earth would be well into [the next ~130,000-years major ice age](#). After fossil fuels are depleted it is likely that the Earth will plunge into the next major ice age faster than it would have without fossil fuels being burned. If human civilization were intelligent it would [be storing the carbon dioxide produced by burning fossil fuels to be released into the atmosphere later to ameliorate the fall into the next major ice age](#).

This is [my rough projection](#) of how Earth average temperature will vary in the future as it plunges into the next major ice age:



Future Electric Transportation

The major modes of transportation are:

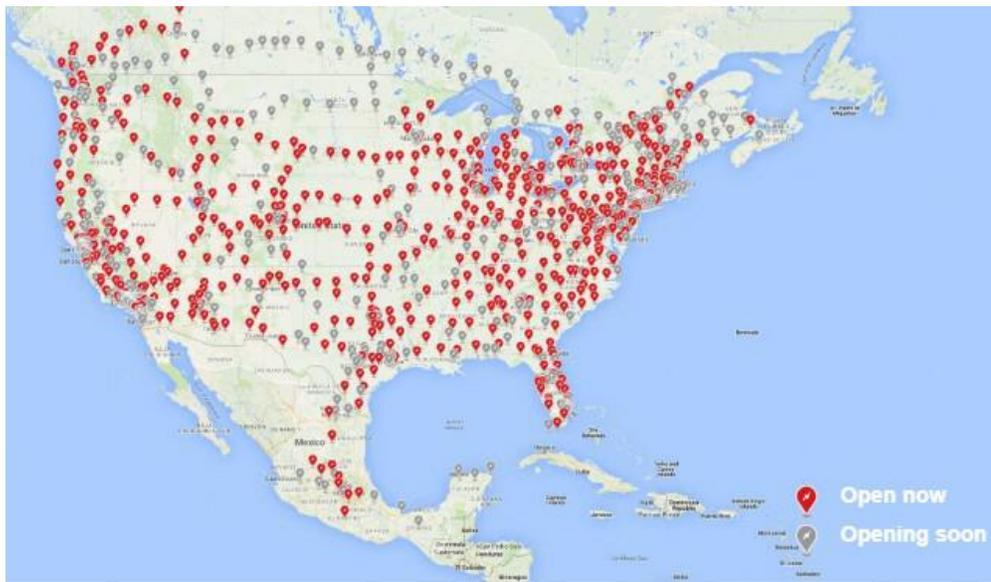
- Personal or shared cars and pickups.
- Local, regional and long-distance buses.
- Local, regional and long-distance trucks.
- Local and long-distance trains.
- Electric ships.
- Regional and long-distance airplanes.
- Space rockets.

Electric Cars and Pickups

For cars to change from ICEs to BEVs the currently best batteries are lithium-ion. Some cars can be for local or regional travel using batteries from 24 to 40 kWh capacity. For long trips, which are important for large countries such as the U.S. and China, require batteries from 50-150 kWh capacity.

Also, for long trips fast-charging stations need to be at about 100-miles intervals along major highways and in cities.

Tesla is leading in this with its [Supercharger network](#):



[Nissan](#) and [Tesla](#) have been the leading car companies marketing battery-electric cars. Other companies are now coming forward with long-range BEVs:

Future Long-Range BEVs (Range > 200 miles)

BEV	kWh	Drive	EPA Range	MPGe	0-60 (sec)	Cost
Tesla S 75D	75	AWD	259	103	4.2	\$65,200
Tesla S 100D	100	AWD	335	102	4.1	\$84,700
Tesla S P100D	100	AWD	315	98	2.5	\$135,000
Tesla X 75D	75	AWD	238	93	4.9	\$83,000
Tesla X 100D	100	AWD	295	87	4.7	\$99,500
Tesla X P100D	100	AWD	289	85	2.9	\$140,000
Tesla 3 ST	50	RWD	220		5.6	\$35,000
Tesla 3 LR	75	RWD	310	130	5.1	\$49,000
Tesla 3 LRD	75	AWD	310	116	5.1	\$55,000
Tesla 3 LRPD	75	AWD	310	116	3.5	\$64,000
Chevrolet Bolt EV	60	FWD	238	119	6.5	\$37,495
Nissan LEAF LR	64	FWD	225			
Kia Niro EV	64	FWD	260		7.8	
Hyundai Kona EV	64	FWD	258	120	7.6	
Jaguar i-Pace	90	AWD	234	76	4.5	\$69,500
Audi e-tron EV	95	AWD	249		5.5	\$74,800
Mercedes EQC	80	AWD	250		4.9	\$80,000
Volvo Polestar 2	75		350?			\$40,000
Chrysler Portal Van	100		250			\$60,000
VW I.D.			~259			
VW I.D. Buzz	83	RWD	~200			
VW I.D. Buzz LR	111	AWD	~270		< 5	
VW I.D. Crozz	83	AWD	~218			
VW I.D. Vizzion	111	AWD	~289			
BMW iNext	90	AWD	~239			
BMW iNext LR	120	AWD	~305			

[Tesla is leading the other companies](#) in producing the largest number of long-range BEVs and is increasing the number quickly with the Model 3.



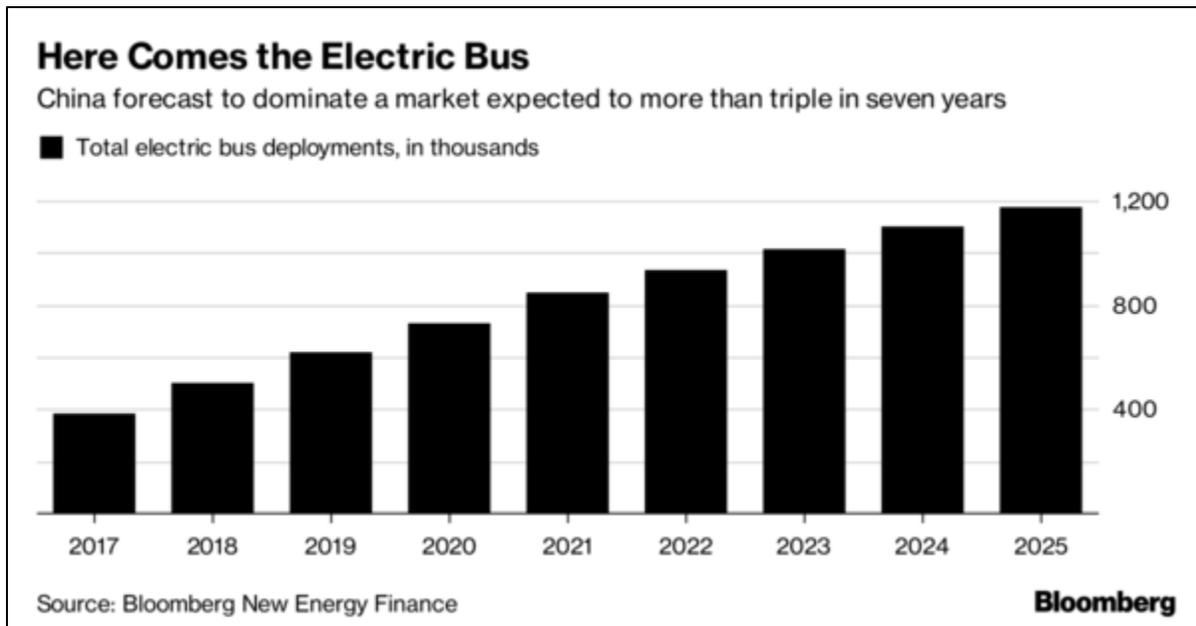
Tesla plans to start building a [large BEV AWD pickup truck](#).

[Rivian](#) plans to build a BEV pickup. [Workhorse](#) plans to build a BEV pickup. [EcoTuned Automotive](#) is converting Ford F150s into BEVs.

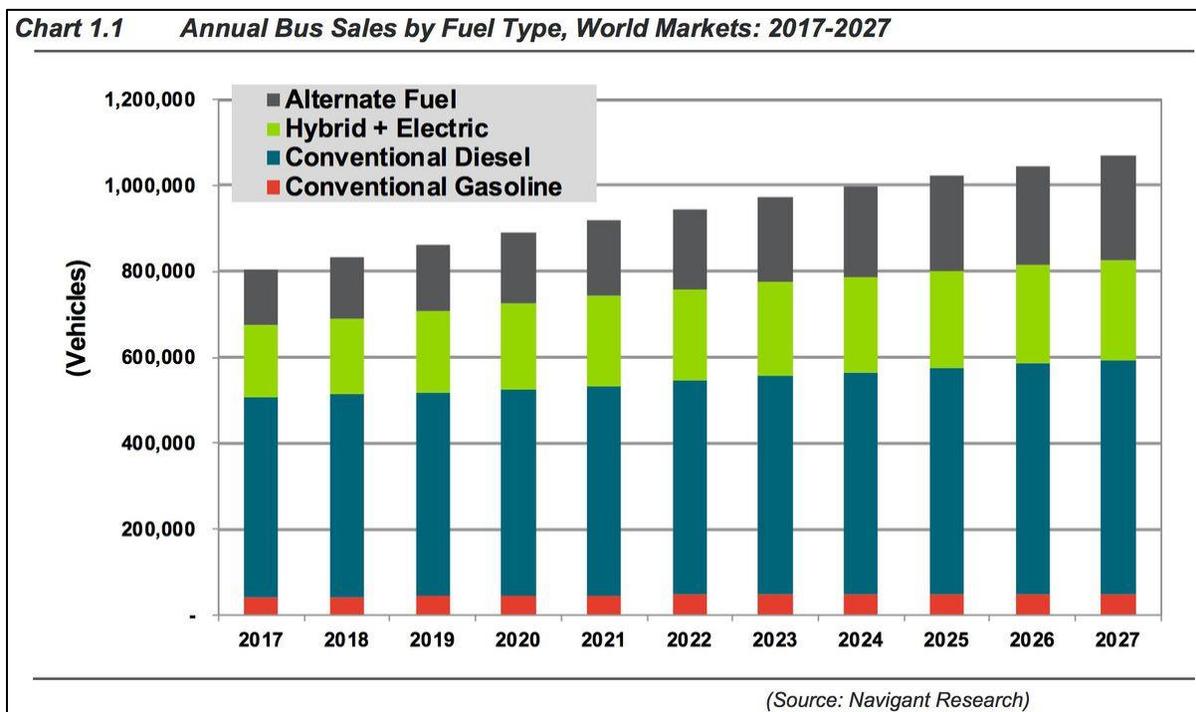
Local, Regional and Long-Distance Buses

Electric Buses

Many cities around the world are beginning to restrict ICE vehicles from the city's roads. Electric buses are being adopted at an accelerating rate, [especially in China](#):



Here is [Navigant Research's projection of future global bus types](#):



I think it under estimates the number of electric buses.

[Fuel-cell buses are in experimental or demonstration stages](#). They may be better for long-distance travel than electric buses.

Local, Regional and Long-Distance Electric Trucks

Local or “last mile” trucks may be the first electric trucks to be marketed: Daimler, Thor, Mercedes-Benz.

- [Electric Trucks Begin Reporting for Duty, Quietly and Without All the Fumes](#)
- [Electric Trucks to Power Fleets’ Urban, Regional Needs First](#)



Several major companies are working on BEV semi-trucks, led by [Tesla](#):



Another company planning to market a BEV semi-truck is [Nikola](#):



Other truck companies working on electric semi-trucks are: [Daimler](#), [Volvo](#), [Peterbilt](#), [Thor](#), [VW](#) and probably others.



[Thor](#):

Apparently [General Motors is considering a fuel-cell truck](#). Trucks are better vehicles for fuel-cell propulsion than cars are. See <https://electrek.co/2017/10/26/toyota-elon-musk-fuel-cell-hydrogen>.

Local and Long-Distance Electric Trains

The U.S. is virtually not in the game with high-speed (>120 mph) long-distance electric trains.

Existing miles of high-speed rail

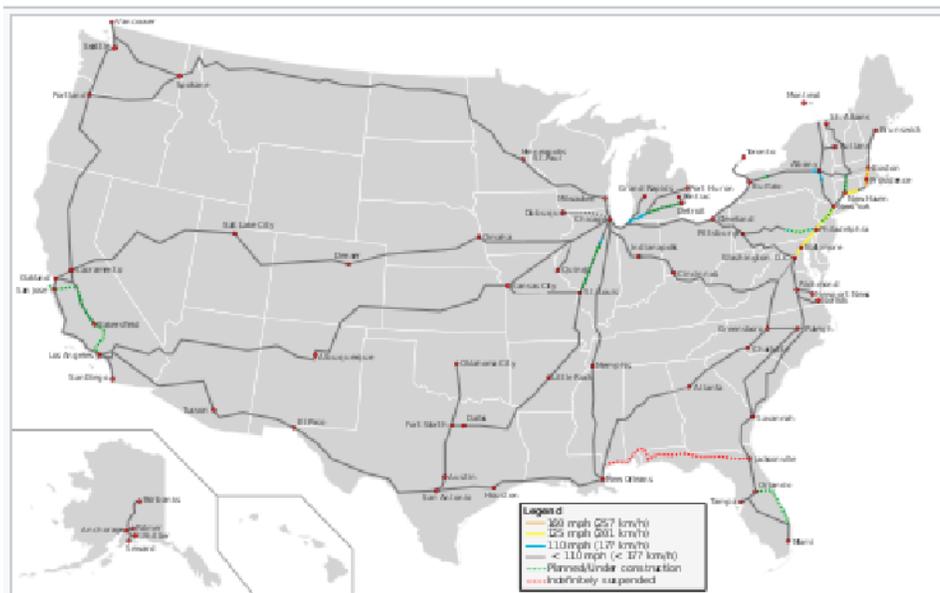
China	Europe	Russia	Japan	India	U.S.
17,000	9651	2677	~2000	508	456?

The Europe number only includes one Russian line.



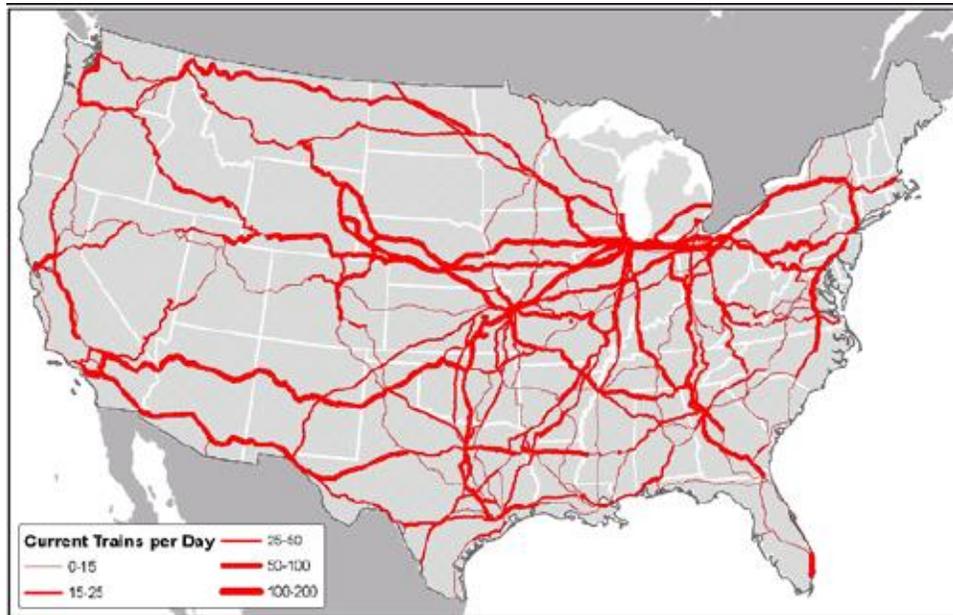
Japan and China high-speed trains.

[The Japanese Maglev: World's Fastest Train](#) (375 mph)

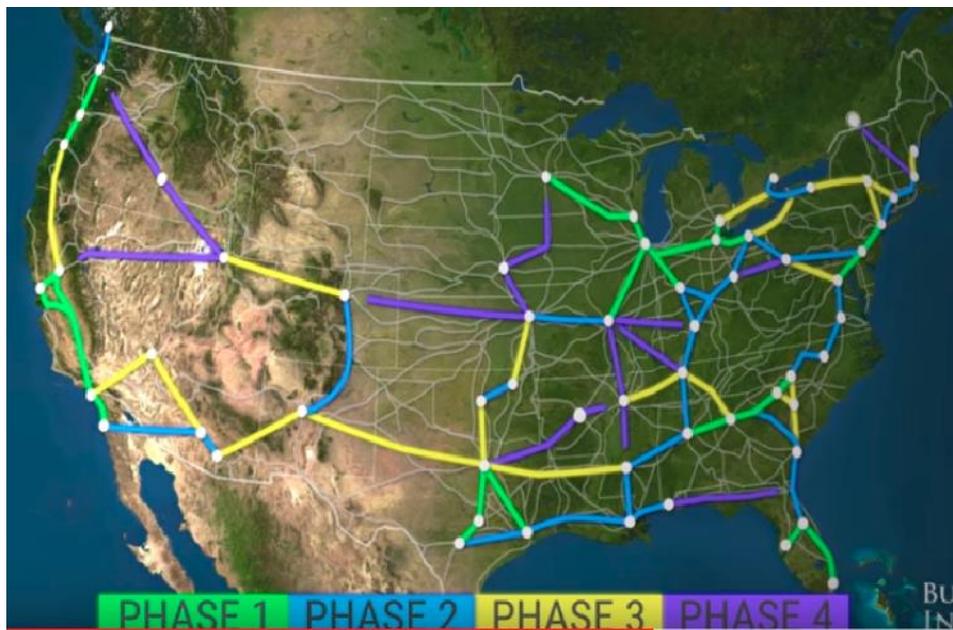


Map showing passenger lines in the United States. High-speed section shown in yellow.

Major U.S. Freight Rail Lines:



Proposed U.S. high-speed train system:



Electric Ships

Here are some references about the development of electric ships:

- [The electric revolution is coming to freighters and cruise ships.](#)
- [Are electric vessels the wave of the future in shipping?](#)
- [Electric vessels are making waves.](#)
- [A new all-electric cargo ship with a massive 2.4 MWh pack launches in China.](#)
- [All-electric ships on the horizon as Rolls adds battery business.](#)
- [Electric boat-Wikipedia](#)

Regional and Long-Distance Airplanes

This is the most difficult mode of transportation to propel by electricity because of the weight of lithium-ion batteries. Perhaps a much lighter [solid-state battery](#) will be developed in the future that will all regional electric airplanes. Currently perhaps [hybrid-electric regional airplanes](#) can be viable.

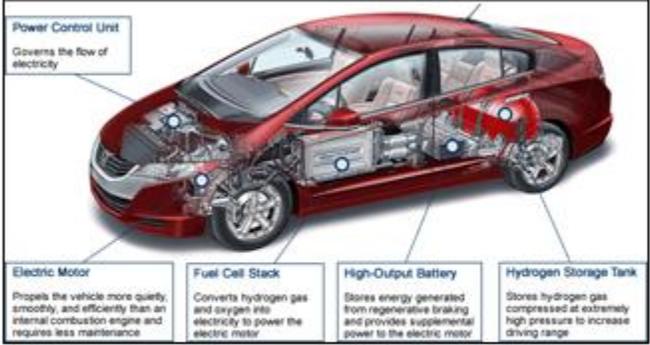
Fuel-Cells in Transportation?

Fuel-cell Vehicles

Two slides from [my talk about BEVs](#):

Why Not Fuel-Cell Cars?

- They are very complicated:



The diagram shows a red car with various components labeled. The Power Control Unit is located in the front, governing the flow of electricity. The Electric Motor is at the rear, propelling the vehicle. The Fuel Cell Stack is in the middle, converting hydrogen and oxygen into electricity. The High-Output Battery is also in the middle, storing energy from regenerative braking. The Hydrogen Storage Tank is at the rear, storing hydrogen gas compressed at high pressure.

- Requires a lithium-ion battery similar to a PHEV!
- Hydrogen fuel is not easy to obtain. Most is made from methane and water, which produces carbon dioxide with the hydrogen! Should be made by solar!
- Better for heavy-duty vehicles, such as trucks.

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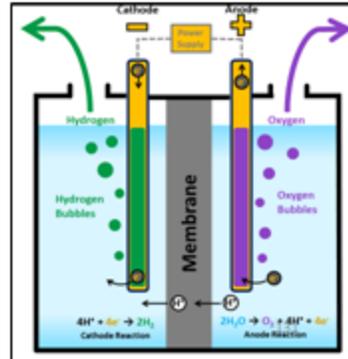
Comparing the Toyota Mirai fuel-cell car to the Tesla Model 3 Long-Range BEV:

Car	MPGe	Range (miles)	Weight (lbs)	Annual Fuel Cost
Toyota Mirai	67	312	4075	\$1250
Tesla Model 3 Long-Range	130	310	3838	\$500

Making Hydrogen for Fuel-Cell Cars

- Steam-methane reforming:
 $\text{CH}_4 + \text{H}_2\text{O} (+ \text{heat}) \rightarrow \text{CO} + 3\text{H}_2$
- Partial oxidation of methane:
 $2\text{CH}_4 + \text{O}_2 \rightarrow 2\text{CO} + 4\text{H}_2 (+ \text{heat})$
- Electrolysis of water
 $2\text{H}_2\text{O} + \text{electricity} \rightarrow 2\text{H}_2 + \text{O}_2$

The oxygen is released into the atmosphere.



Problems with producing hydrogen for fuel cells:

- Two of the three methods require methane, a nonrenewable fuel.
- The best method is the third method which requires water and electricity, which must be generated by renewable energy. The incoming water is put out into the environment when the fuel cell generates electricity to charge the battery which propels the vehicle.

Fuel cells work best for stationary objects, such as buildings, and large vehicles, such as large ships, trains, buses and trucks. Fuel-cell long-distance buses and trucks may be better than electric versions.