Plug-in Hybrids: The Cars of the Future?

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on Plug-in Hybrid Vehicles
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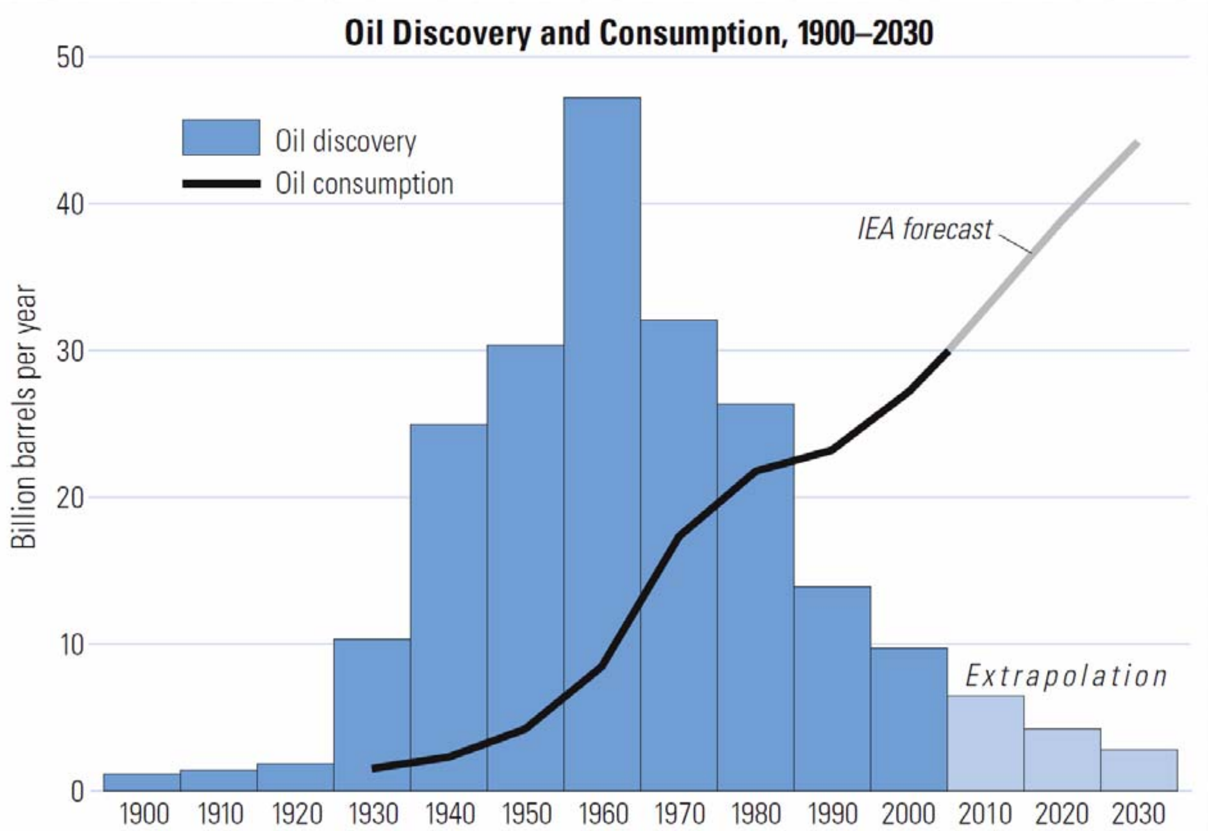
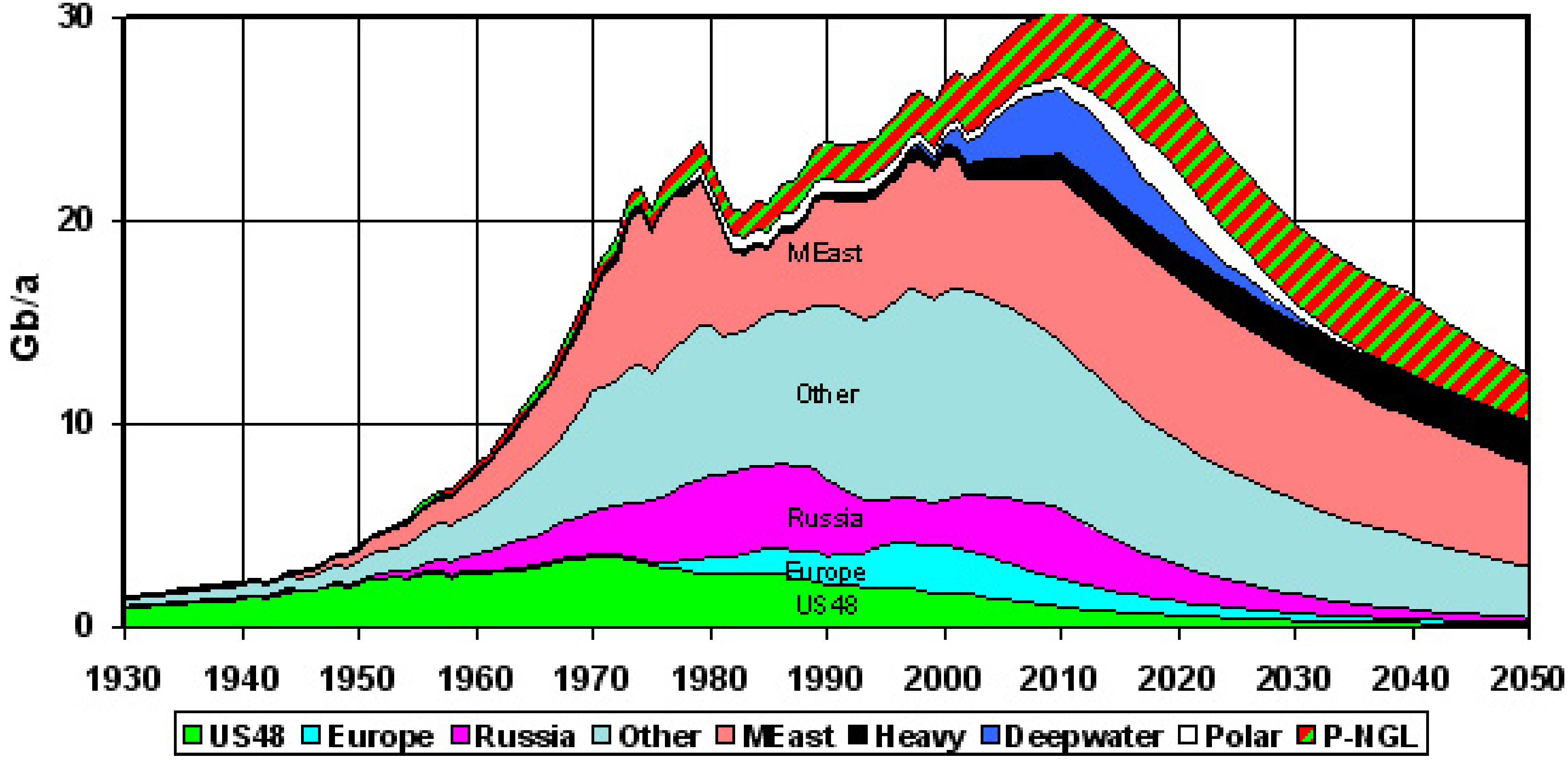
Here's the nub of the oil problem: world discoveries are not keeping up with world consumption (cannot keep up with?)



Source: Kjell Aleklett, Oil: a bumpy road ahead. *World Watch*, 19(1), 10-12, 2006

This is IEA's 2004 forecast. IEA's 2005 forecast is for 2030 consumption of 42.1 rather than 44.3 billion barrels per year

Actual to 2004 and best estimate thereafter of world production of all petroleum liquids, by region, billions of barrels per year, 1930-2050



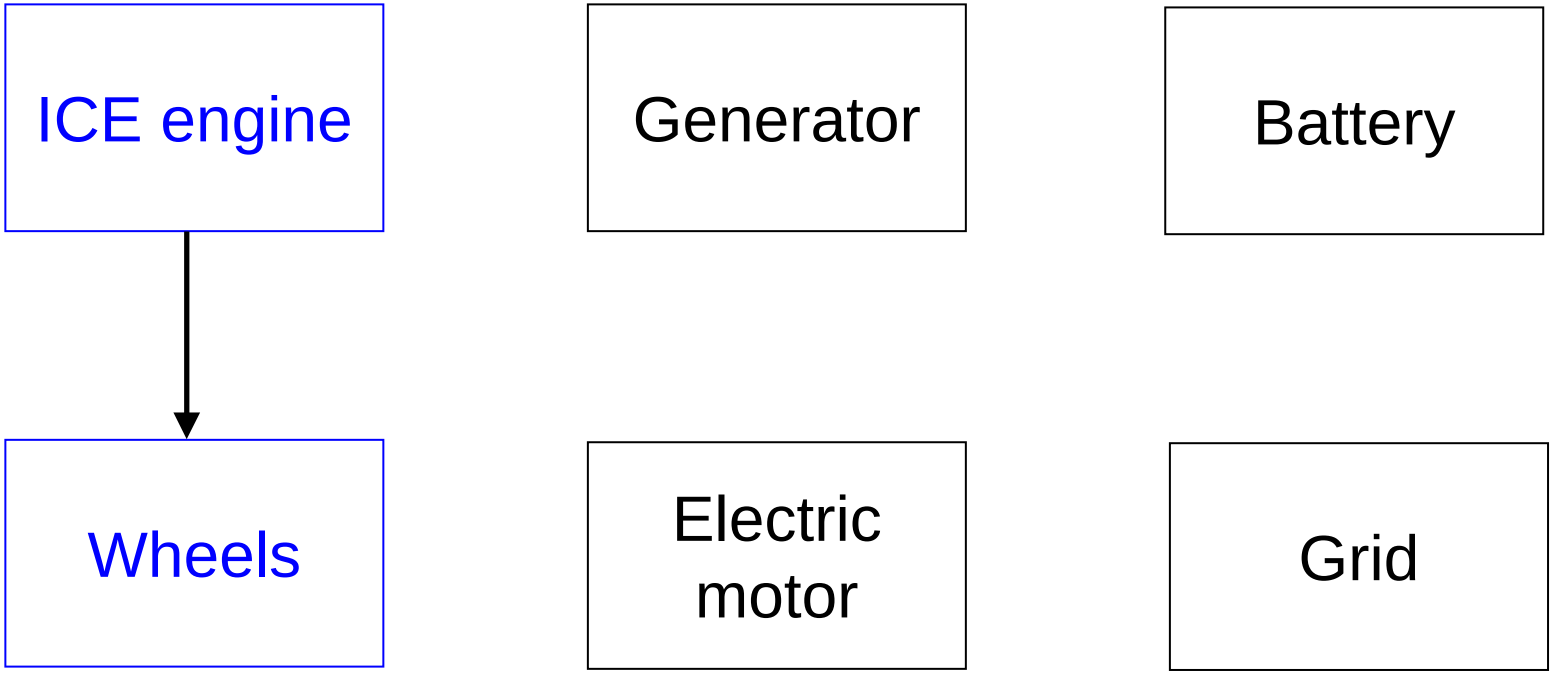
Source: Uppsala Hydrocarbon Depletion Group (2005)

Production of crude oil and equivalents—which provide >95% of transport fuels worldwide—may peak in 2012, causing very high prices unless measures are taken to reduce post-peak potential demand. Laherrère (2006) has more recently predicted a "bumpy plateau … in the 2010s … and chaotic oil prices". P-NGL = Plant Natural Gas Liquids.

Hybrid ICE-electric vehicles

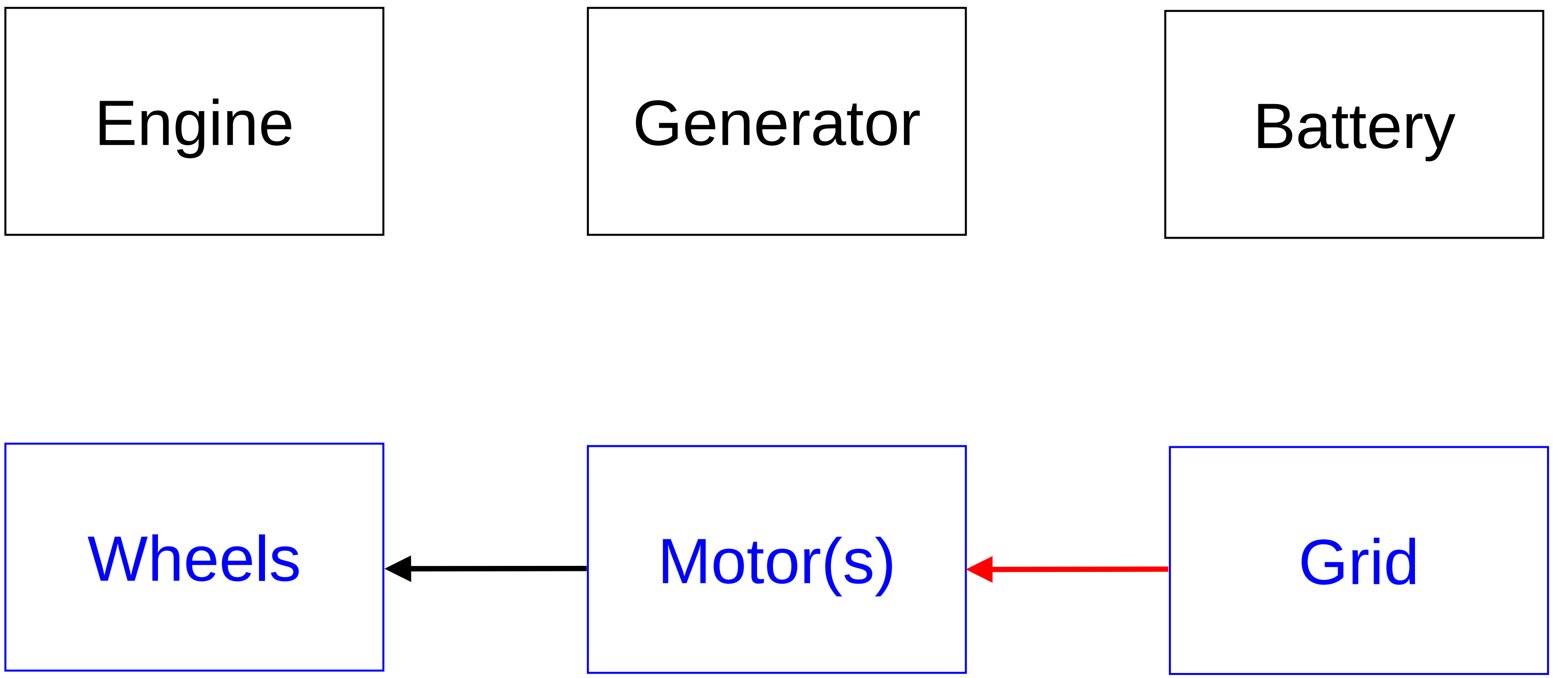
- Have an internal combustion engine (ICE) *and* an electric motor (EM) that provides traction.
- First appeared in the 1890s, including a record-breaking 1899 series-hybrid automobile designed by Ferdinand Porsche and built by Jacob Lohner.
- This vehicle had a one-cylinder gasoline-fuelled ICE that, through a generator, drove four wheel-mounted EMs.
- It took advantage, as do all later hybrids, of (a) EMs' superior performance, especially at low speeds, and little need for gearing, and (b) gasoline's high energy density.
- Current hybrids also allow ICEs to drive wheels, and they conserve energy through regenerative braking (RB).

ICE-only vehicle



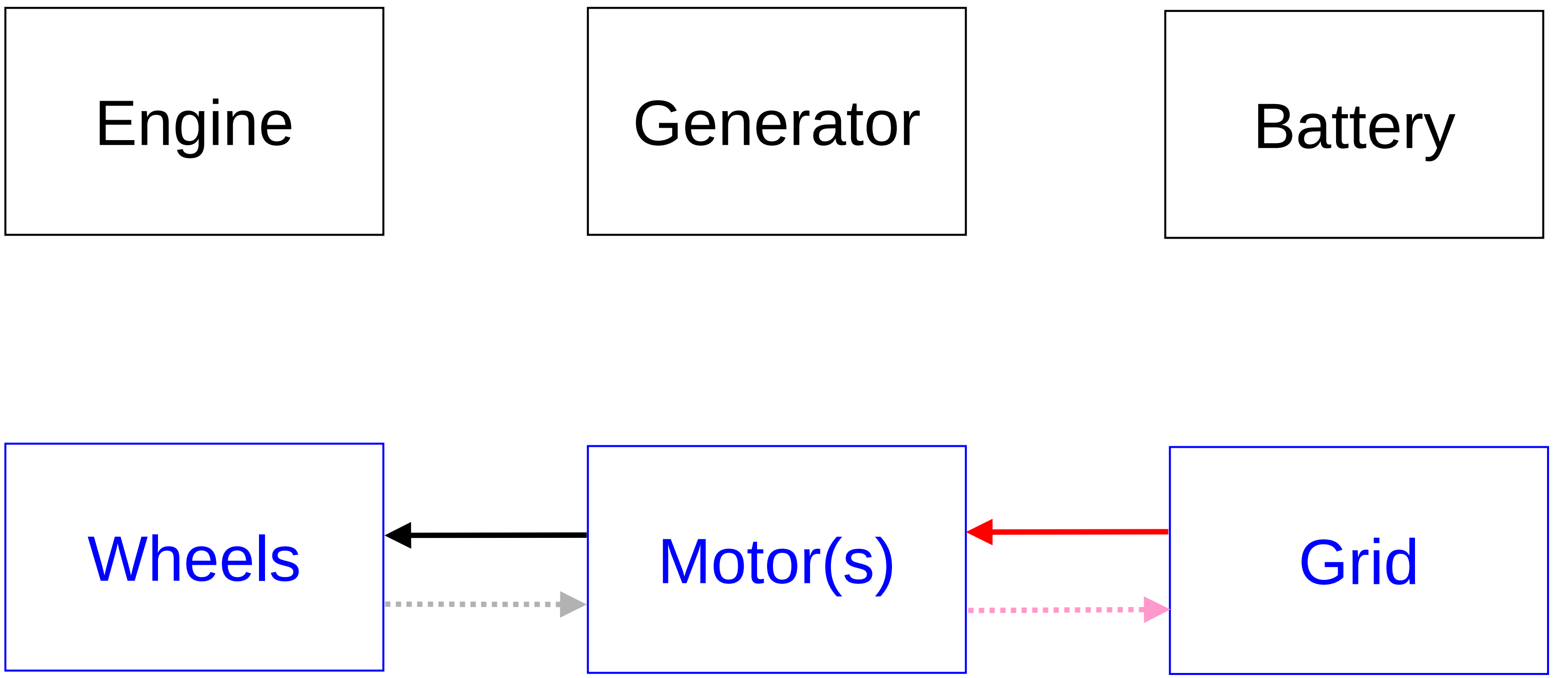
Active units are in blue; mechanical links are in black

Grid-connected vehicle (e.g., streetcar)



Electric paths are in red. Some grid-connected vehicles are dual-mode, e.g., the trolley buses in Hamilton, Ontario (until 1992) and Quito, Ecuador that have a small diesel engine allowing off-wire movement.

Grid-connected vehicle with regenerative braking



Regenerative braking assumed, where not shown, for most electric drives. About 40% of the vehicle's kinetic energy can be returned as electricity to the grid or battery.

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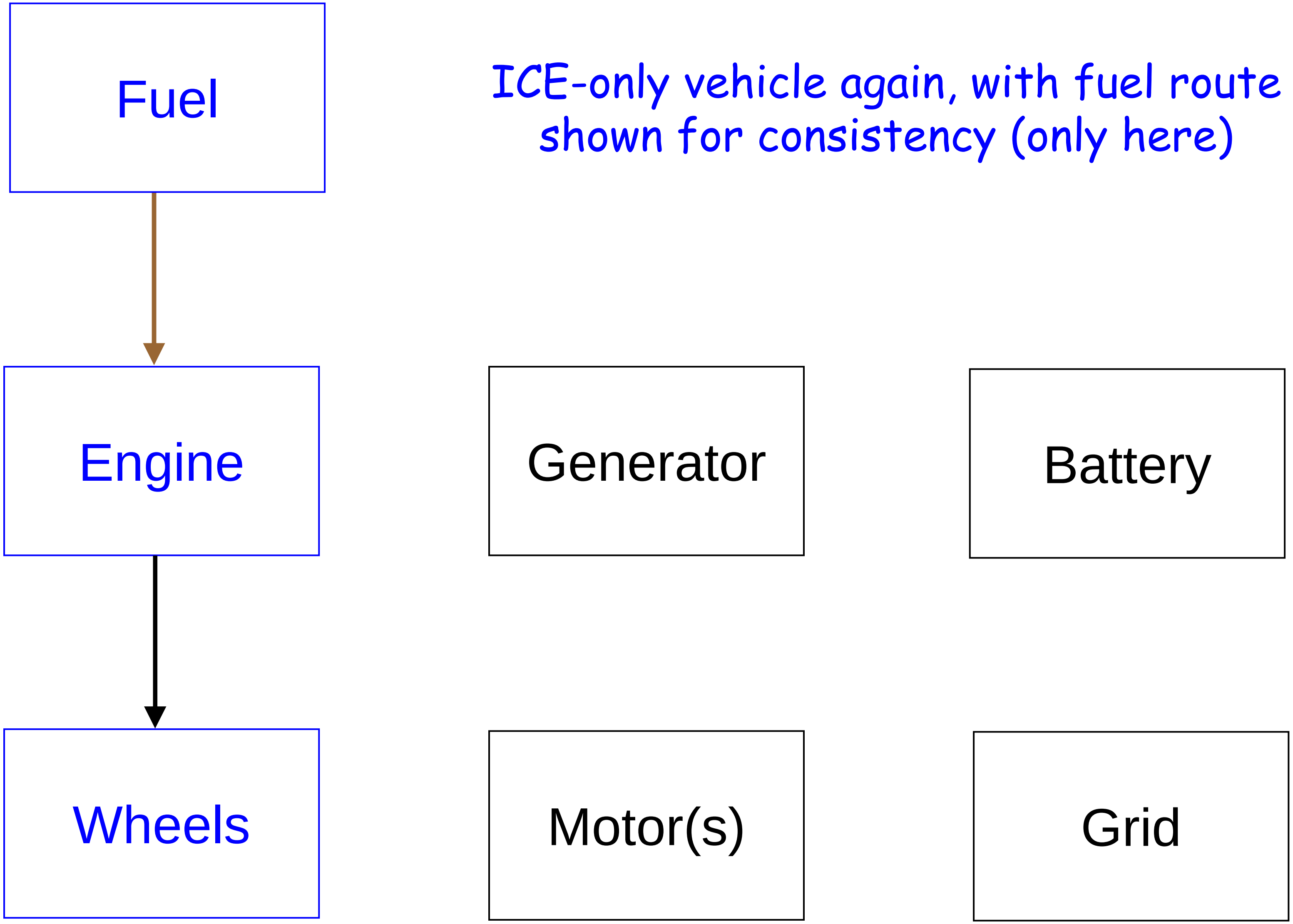

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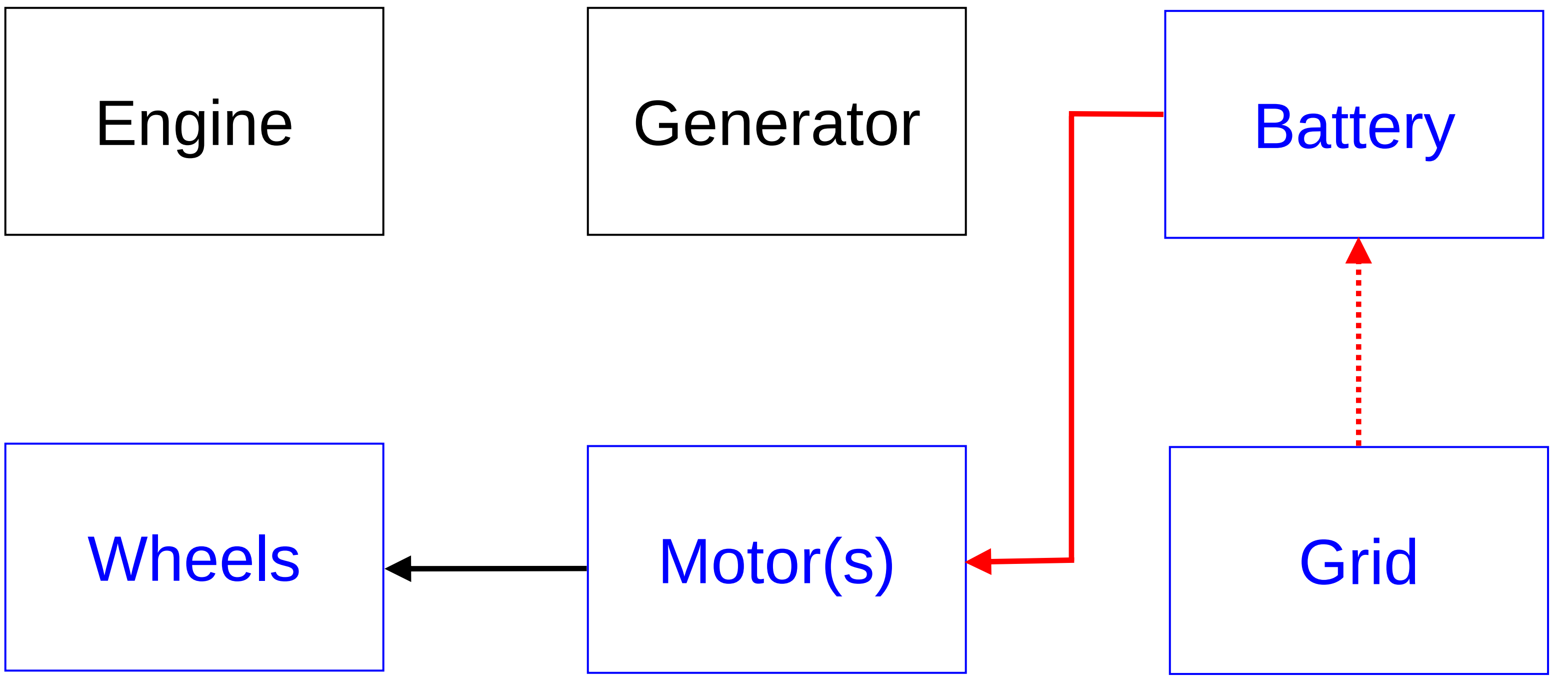
Battery electric vehicle



Dashed link means available while stationary only

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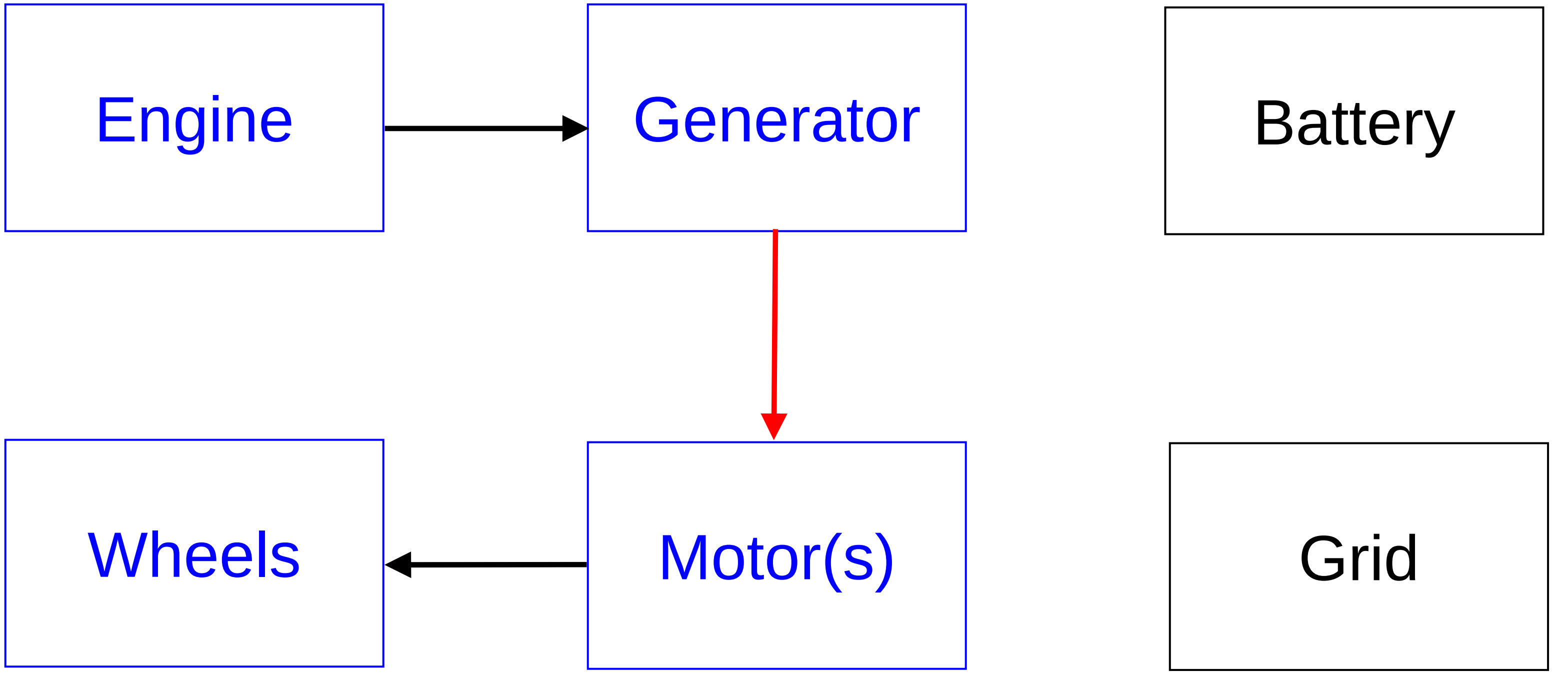
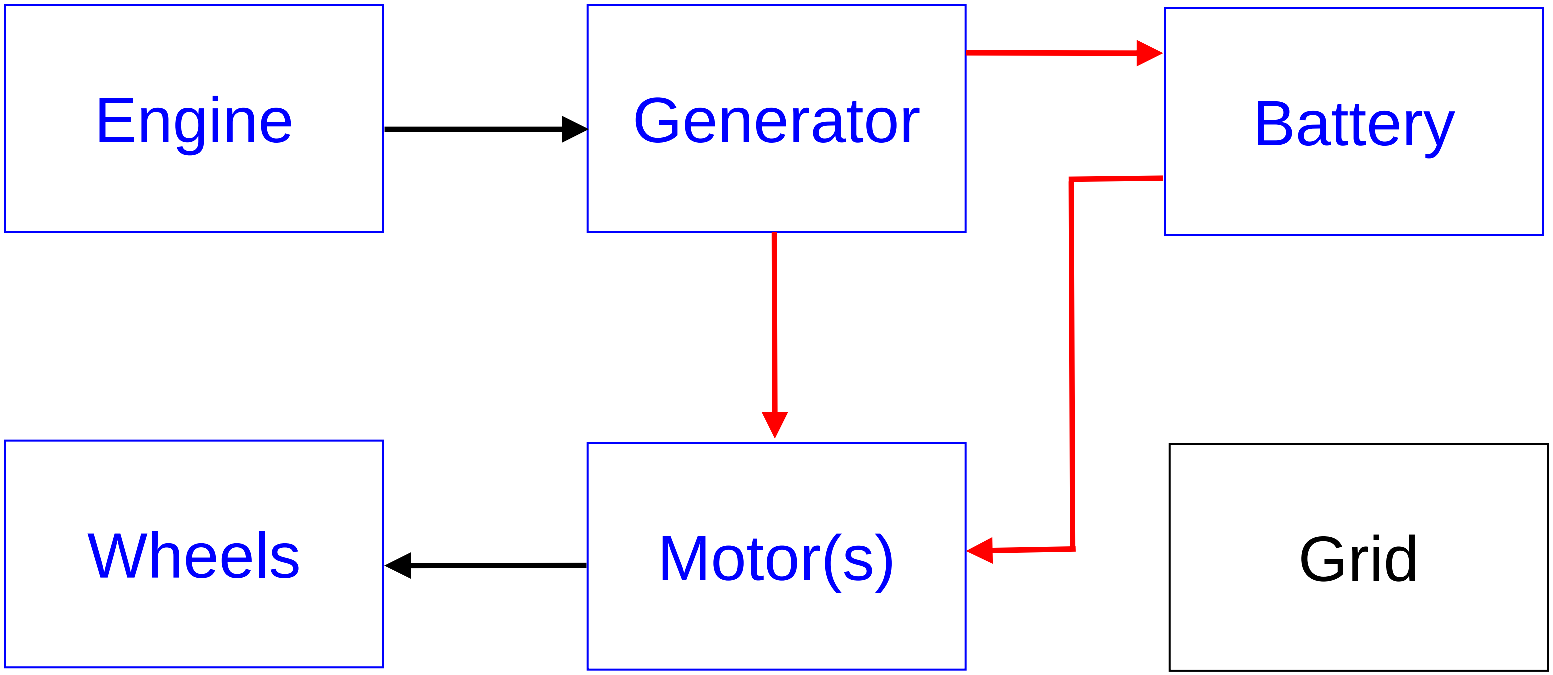
Diesel-electric locomotive, ship (no RB)



These were the 20th century's main hybrid vehicles

Series ICE-electric hybrid



Simple because needs little or no gearing (as for diesel-electric locomotive)

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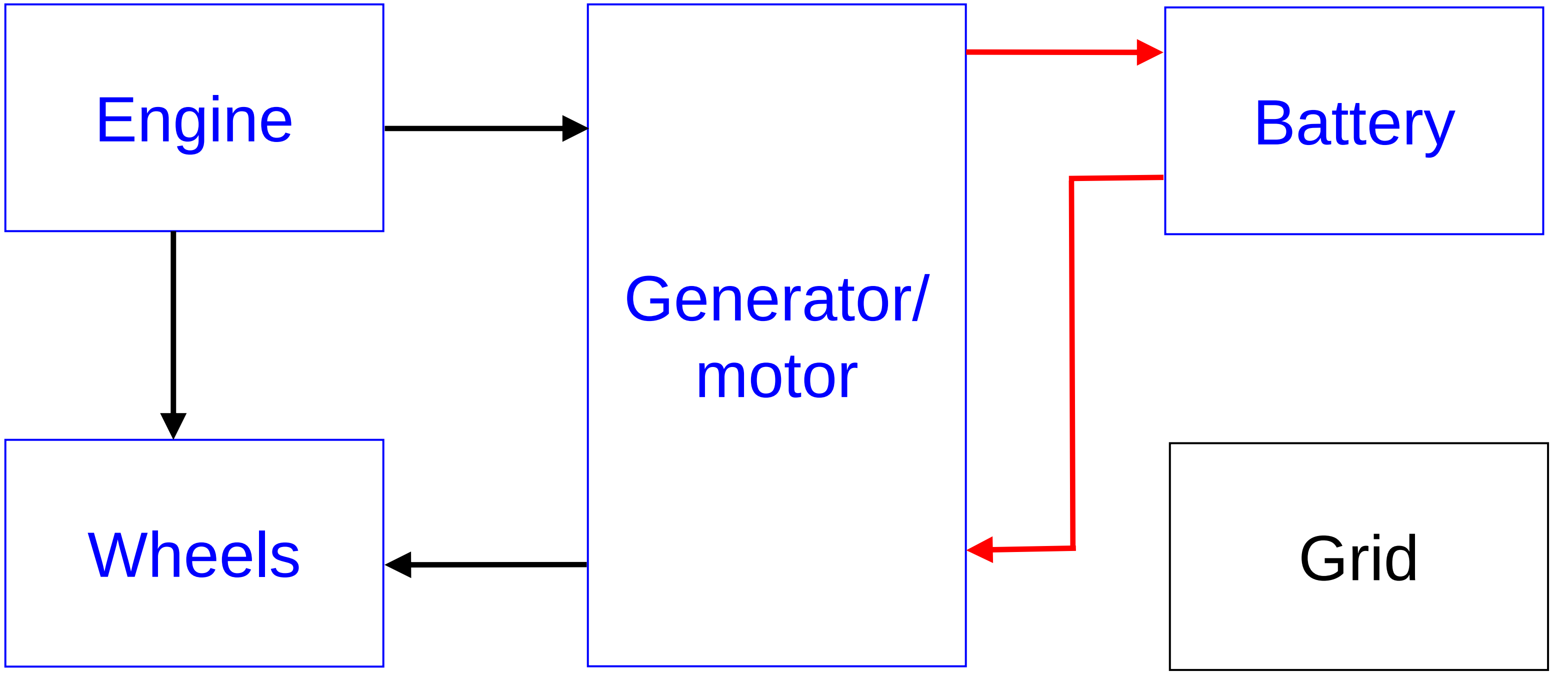
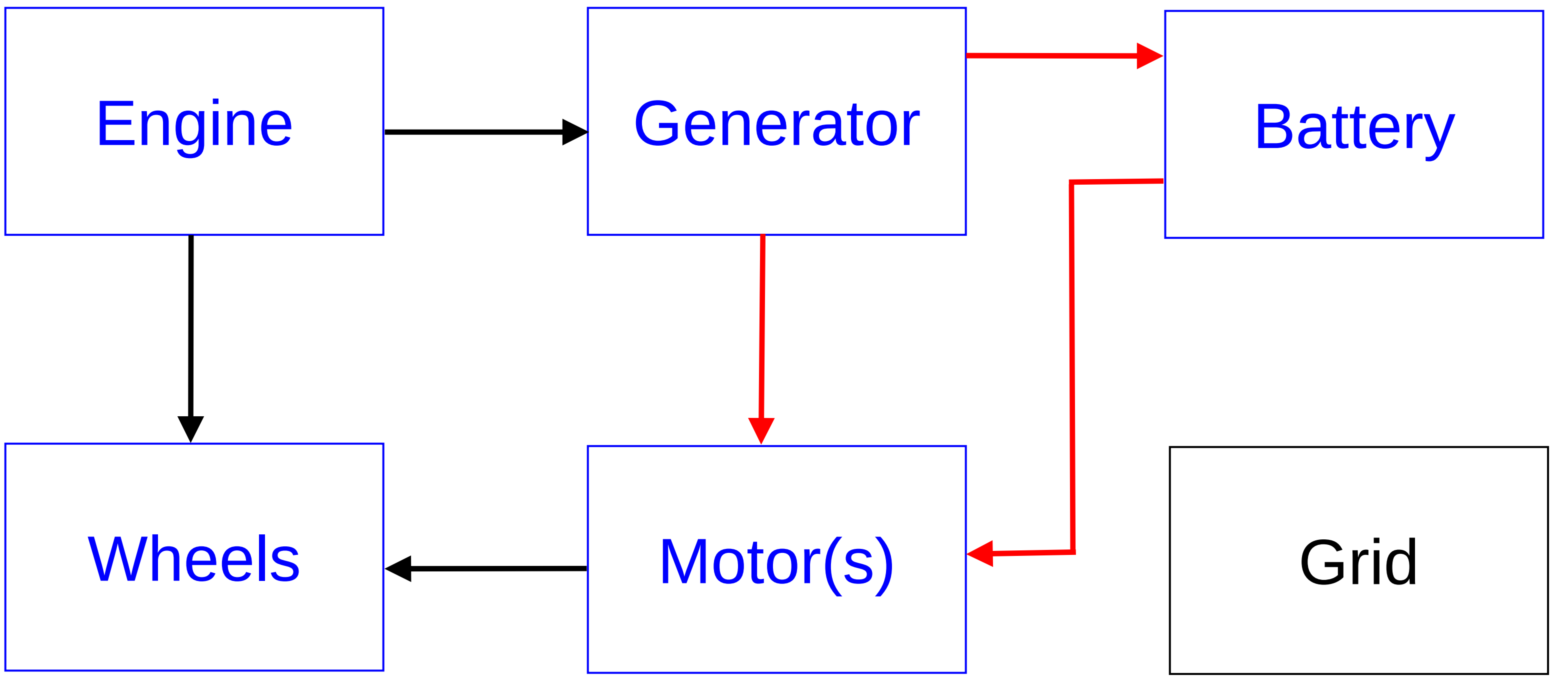
Parallel ICE-electric hybrid



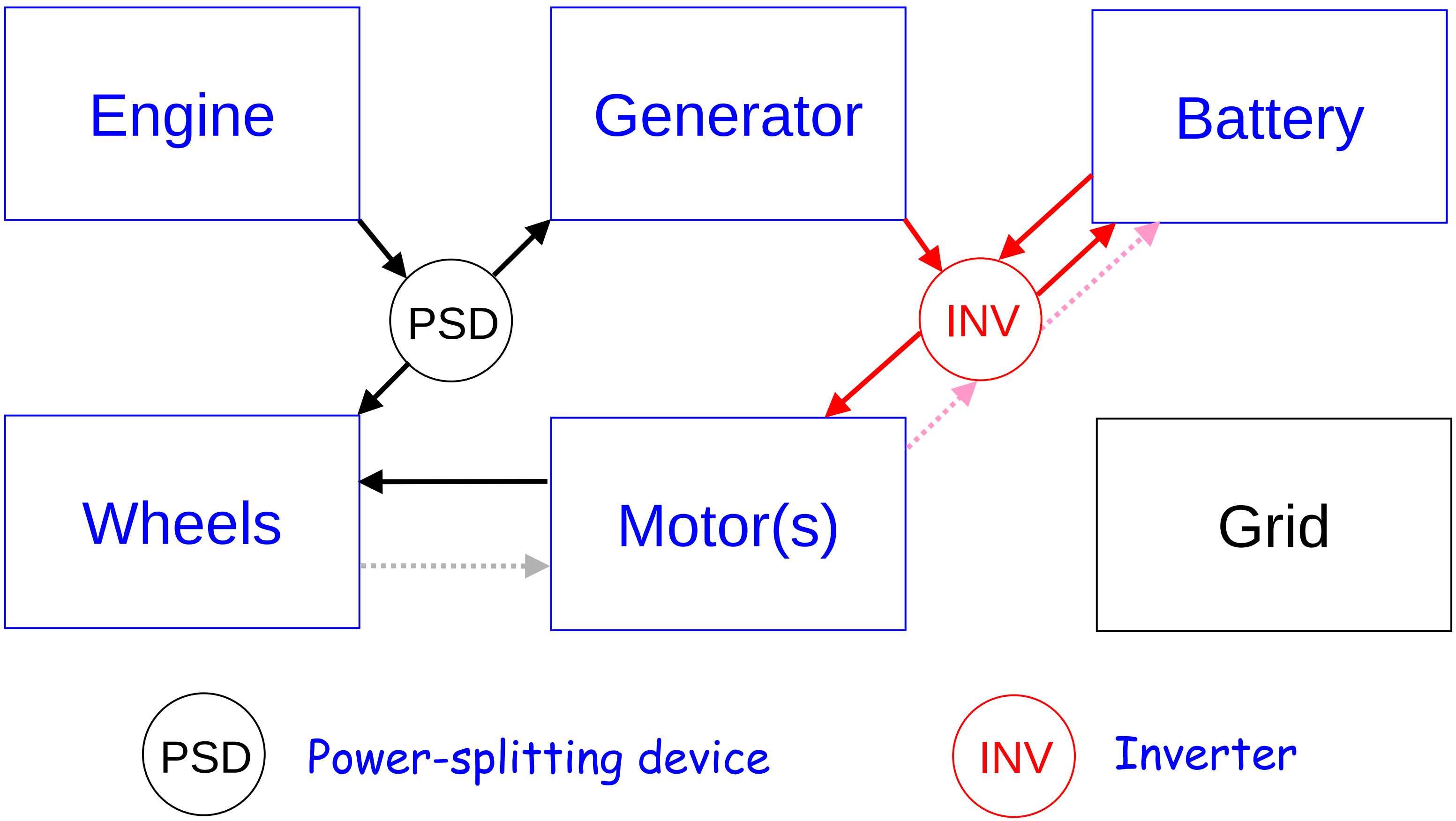
Simple because only one generator/motor; but this cannot charge battery and drive wheels at the same time

Series-Parallel ICE-electric hybrid (simplified)

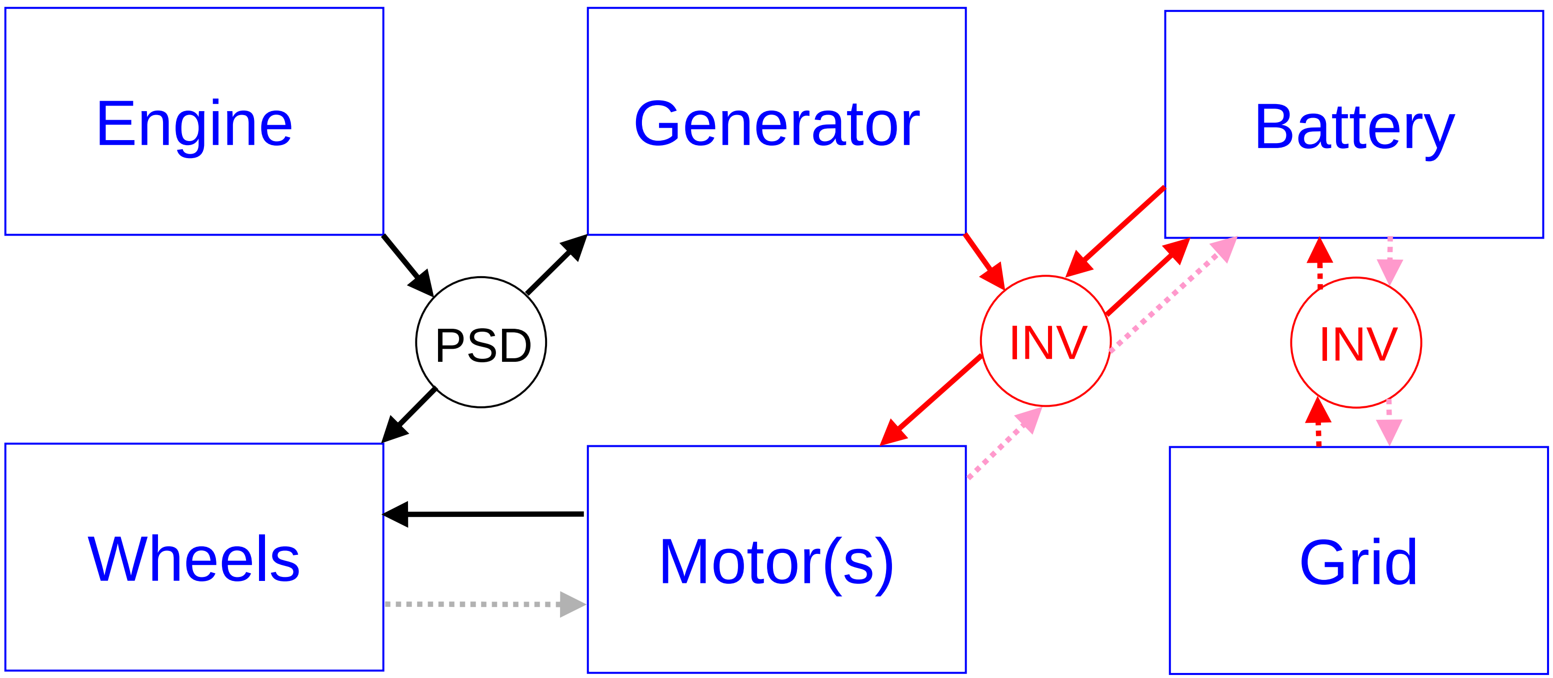


Most current hybrid cars (e.g., Prius, Civic) are versions of this arrangement.

Series-Parallel ICE-electric hybrid (less simplified)



E-hybrid (pHEV)

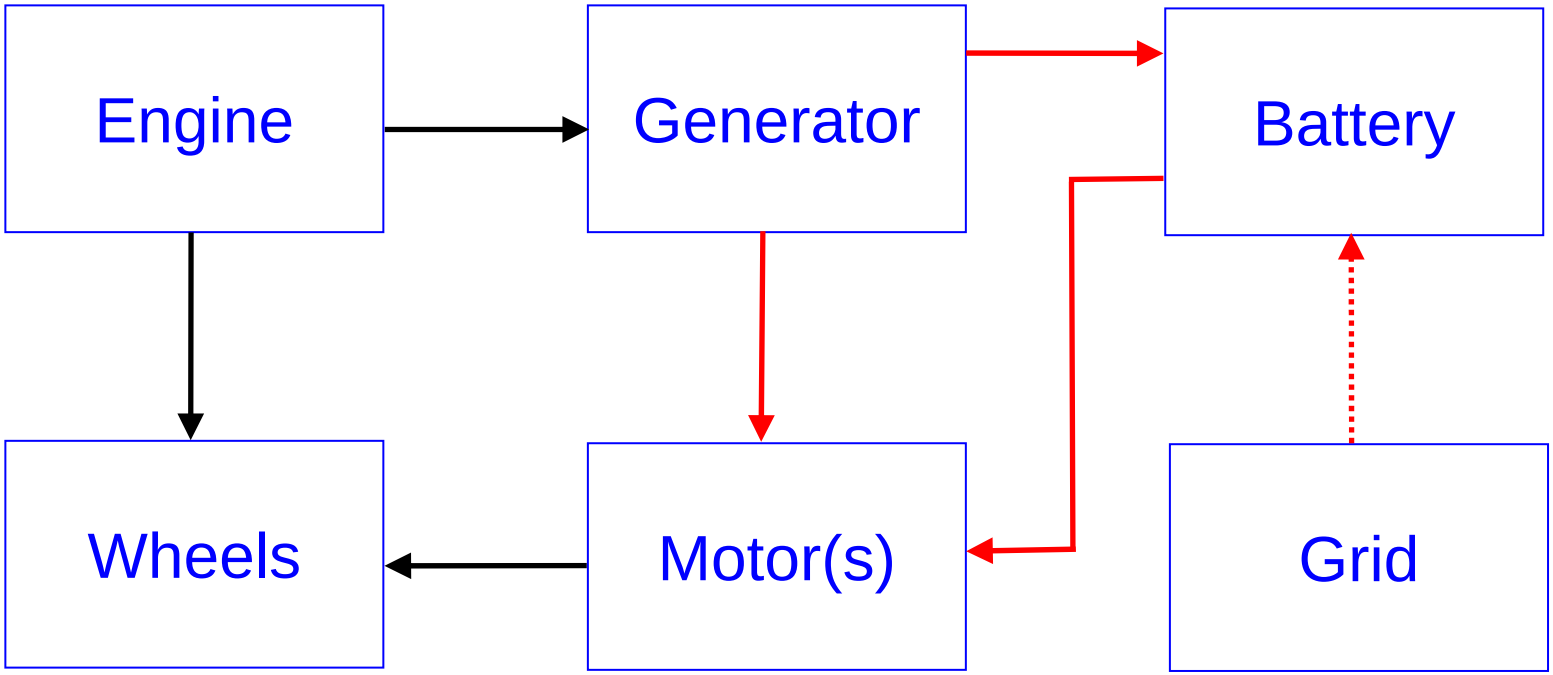


PSD Power-splitting device

INV Inverter

Battery to grid (V2G) is an optional, speculative feature, also proposed for fuel-cell vehicles

E-hybrid (simplified)



More on hybrids

- Hybrid vehicles were a focus of the 1993 U.S. Partnership for a New Generation of Vehicles, but no longer from 2001 with the hydrogen-focused FreedomCAR initiative. Japan then surged.

- Hybrids also save energy by running ICEs mostly at optimum speeds. Reduces wear on engines (and on brakes through RB).

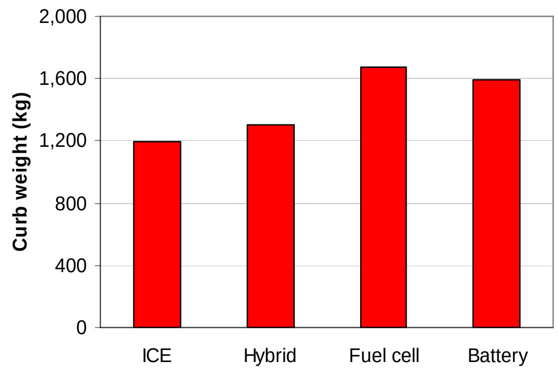
- In 'weak' hybrids (not in above diagrams), EM provides assist only. In 'strong' hybrids, ICE or EM or both can drive wheels.

- Toyota markets the Prius and other hybrids as not needing to be plugged in, but may now introduce an E-hybrid Prius.

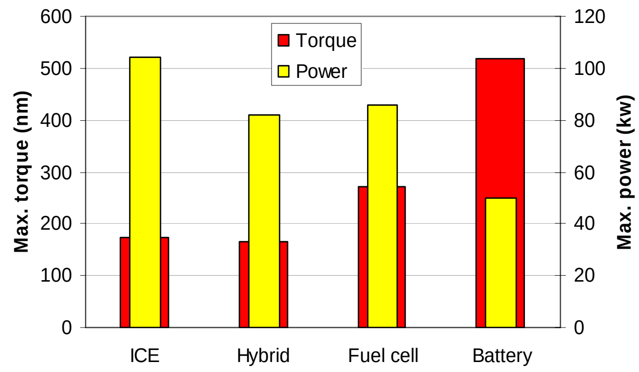
- Non-electric hybrid vehicle types: They differ according to how energy is converted or stored; include German diesel-hydraulic locomotives and French gasoline-pneumatic automobiles.

Comparable ICE, hybrid, fuel cell, and battery vehicles
(Honda Civic DX, Honda Civic Hybrid, Honda FCX, Mitsubishi Lancer Evolution MIEV)

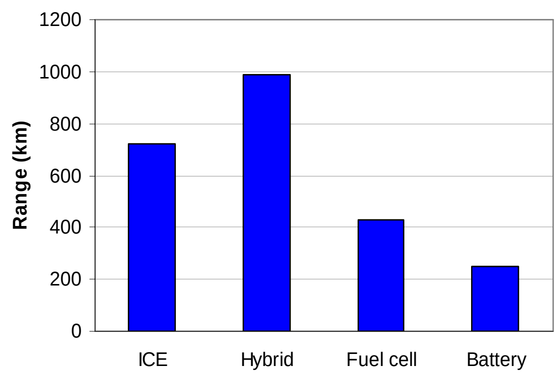
CURB WEIGHT



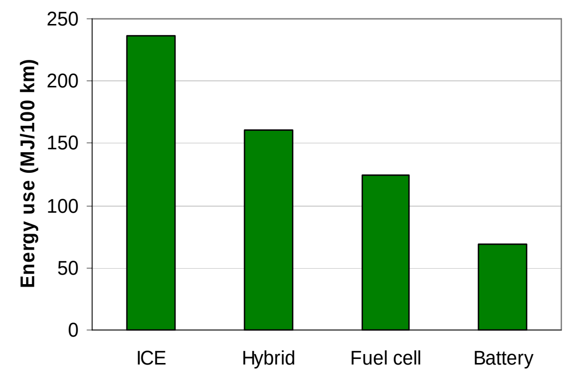
TORQUE AND POWER



RANGE



ENERGY USE AT VEHICLE



Sources: US EPA (2006); Honda (2006); Mitsubishi (2006); Bossel (2005)

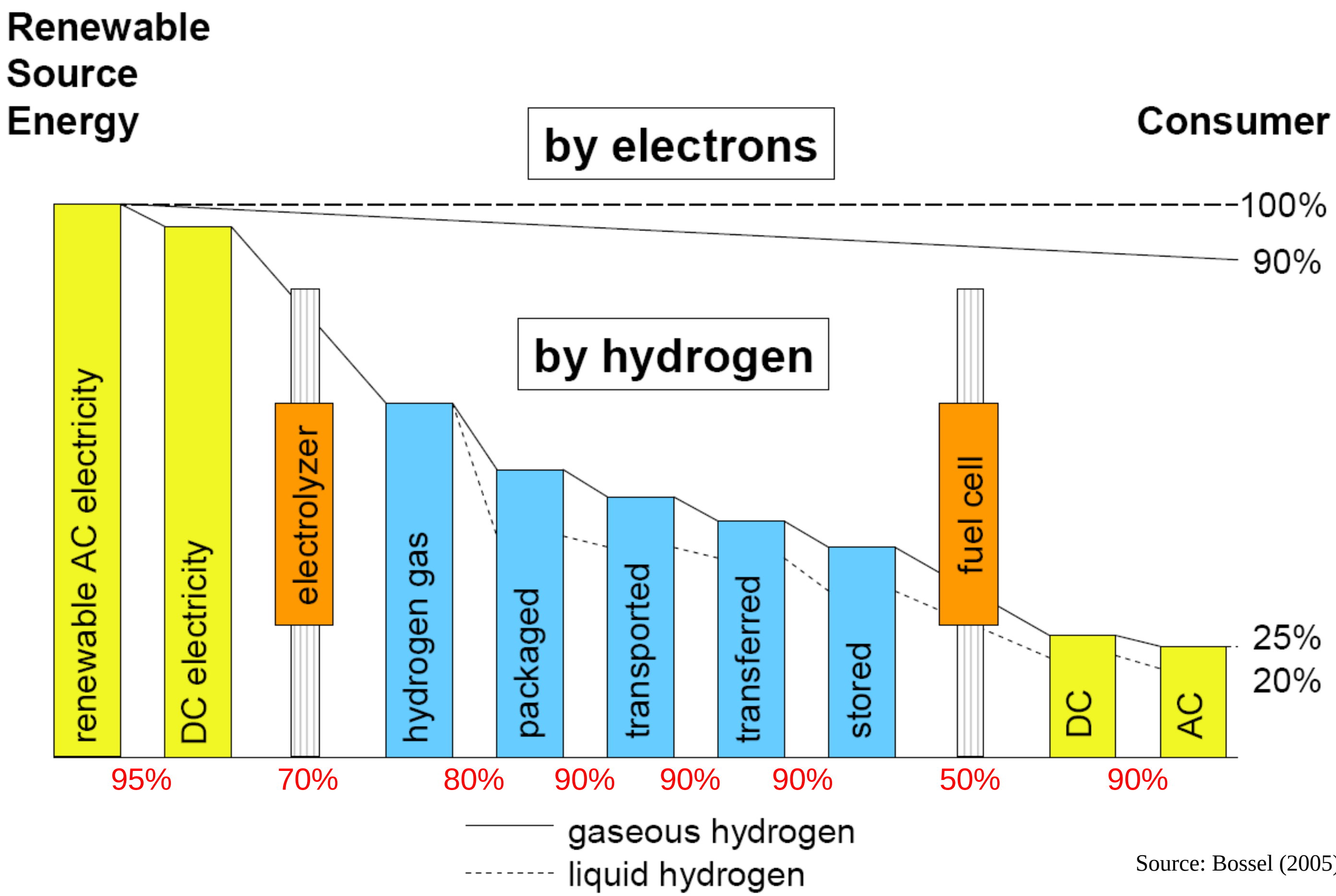
Hybrids may be challenged by very efficient ICE vehicles

Loremo
simple. clever. fun

Data	Loremo LS	Loremo GT
Engine	2-cylinder turbodiesel	3-cylinder turbodiesel
Output	15 kW / 20 HP	36 kW / 50 HP
Max. speed	160 km/h	220 km/h
Acceleration	20 sec. (0-100km/h)	9 sec. (0-100km/h)
Transmission	5-gear manual transmission	5-gear manual transmission
Drive	midship/rear wheel drive	midship/rear wheel drive
Consumption	1,5 l/100 km (51 MJ/100 km)	2,7 l/100 km (93 MJ/100 km)
Fuel range	1.300 km (20-l-tank)	800 km (20-l-tank)
Weight	450 kg	470 kg
Drag	Cw=0,20; Cw×A=0,22 m^2	Cw=0,20; Cw×A=0,22 m^2
Seats	2+2	2+2
Dimensions	384cm x 136cm x 110cm (l x w x h)	384cm x 136cm x 110cm (l x w x h)
Price	< 11.000 Euro	< 15.000 Euro
Standard	airbags, particle filter, radio	airbags, particle filter, radio
Extras	dashboard computer, air condition, MP3 player, navigation system	dashboard computer, air condition, MP3 player, navigation system

Current new light-duty vehicles sold in Canada have an average rating of 9.0 L/100 km (308 MJ/100 km)

Why the hydrogen fuel cell future won't work (but grid-connected vehicles will)



Source: Bossel (2005)

Approximate efficiencies of processes are in red.

Preliminary comparison of energy use
(with estimates for E-hybrid and PRT)

E-hybrid estimate assumes all 'urban' driving is on EM or EM-assist. Estimate here for Personal Rapid Transit (PRT) may be conservative. PRT vehicles would be lighter than BEVs (thus better accelerating and uphill), could travel in trains, and would have little stop-start.

Vehicle type	Delivered energy use in MJ/pkm: Hydro-carbon	Delivered energy use in MJ/pkm: Electri-city
ICE (Honda Civic)	1.58	
ICE (Loremo LS)	0.33	
ICE (Loremo GT)	0.62	
Hybrid (Honda Civic)	1.07	
FCV (Honda ZC2)	0.83	
BEV (Mitsubishi)		0.46
E-hybrid (estimated)	*0.70*	*0.20*
GCV (estimated PRT)		*0.43*
ICE (U.S. diesel bus)	1.49	
GCV (U.S. light rail)		0.49
GCV (U.S. trolley bus)		0.53

Note: Cars and PRT assume 1.5 persons per vehicle; transit vehicles use APTA occupancy data.

Sources: As for previous slides, Gustavsson (1995) for PRT, APTA for transit vehicles

Plug-in hybrids (E-hybrids)

- Joseph Romm (*Energy Policy*, in press) describes E-hybrids as "the car of the future", allowing 30-60 km on battery only, fuelled by 85% ethanol and the grid (while stationary), travelling "500 miles on 1 gallon of gasoline [~0.5 L/100 km] and 5 gallons of cellulosic ethanol".

- California-based EDrive Systems, for <US$12,000, is to offer a Prius E-hybrid conversion with a 9.0-kwh lithium battery weighing twice the installed 1.3-kwh NiMH battery (~70 vs. ~35 kg), with 50% more volume, requiring 9 hours for charging (at 110 or 220 v), allowing 80 km of EM or EM-assisted driving.

- Romm also promotes E-hybrids as load-levellers for the grid (V2G). But, use of a special-purpose battery bank may be more realistic (e.g., NaCl system for Halton Hills Hydro).

- Issues re. E-hybrids are cost (much lower with mass production?), complexity, weight, cold weather, battery disposal, and safety (some battery types).

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Why biofuels may not fill the liquid transport fuels gap

- Ethanol and biodiesel have some role as substitutes for present transport fuels.

- Ethanol production raises questions about required energy inputs and land requirements. The new Goldfield plant in Iowa uses about 100,000 tonnes of coal [!] a year to produce about 190 million litres of ethanol from about 500,000 tonnes of corn. The energy inputs in the form of coal and fuel to move the corn to the plant amount to about 75% of the energy in the ethanol, and more energy is required for farming and other necessary activities.

- There may be fewer energy questions re. production of ethanol from cellulose (Ottawa-based Iogen Corp. is a world leader), using wood and other wastes, but large-scale use may be distant because of sterility issues.

- A land-requirement question remains—ethanol corn is already competing with food corn—and a new question: in an energy-constrained world in which fertilizer production is limited by oil and natural gas availability, will not waste materials be needed to replenish land?

- It could make much more sense to use biofuels to cogenerate electricity.

Paths to personal grid-connected vehicles (PGCVs)

- Gilbert and Perl (*Energy Policy*, under review) support the E-hybrid focus, but see PGCVs as the 'car of the future', with E-hybrids as one path there.
- This path would see E-hybrid users liking their EMs and wanting grid connection while in motion, to power EMs or charge batteries. Governments or entrepreneurs could provide powering along routes through rails or wires, accessible by vehicles equipped with means of connecting to them.
- When such en-route powering is extensive, EVs with only batteries and grid-connectors could prevail over E-hybrids, evolving towards Personal Rapid Transit (PRT) on low-cost guideways.
- Another path to PRT could be supplementation or replacement of public transit by PRT, driven by PRT's low energy and infrastructure costs.
- One way or the other, grid-connected electric vehicles will prevail—plug-in or en-route, or both; personal or not—because transport must become renewably fuelled, and EMs can efficiently use any source of electricity.

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