

HOT DEAL OR HOT AIR? LIFE-CYCLE ANALYSIS OF PNEUMATIC CARS

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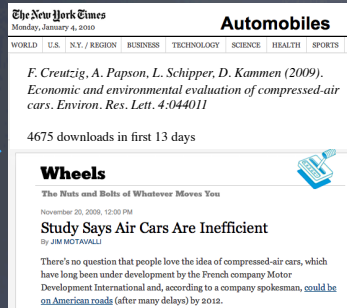
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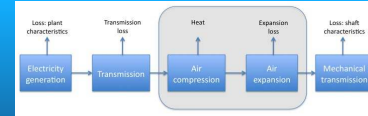
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Introduction

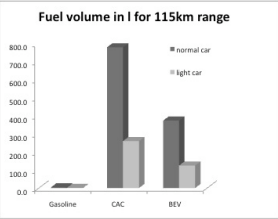
- Compressed-air cars have been proposed as environmentally-friendly car of the future
- In fact, compressed-air was used to power tram lines in the 19th century
- Does it hold promise as a zero-emissions vehicle? Or is the concept illusory?



Life-Cycle Analysis



Volume



Low energy density implies high tank volume!

Efficiencies and fuel weight

Table 1. Efficiencies for propellants. For the electric modes, specific power plant efficiencies must be added.

	Smart	CAC	Smart ed
Coal/well-to-wheel (%)	17.7	11.7	28.3
Wind/well-to-wheel (%)	17.7	29.2	70.8
Grid/pump-to-wheel (%)	21.2	26.7	77.5
Propellant-to-wheel (ε) (%)	21.2	34.6	90.0

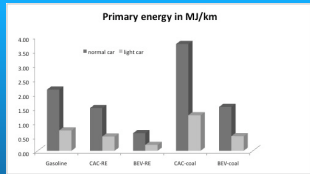
Table 2. Fuel weight.

Car weight (kg)	Gasoline (kg)	CAC (kg)	BEV (kg)
900	4.8	53.0	140.3
300	1.6	17.7	46.8

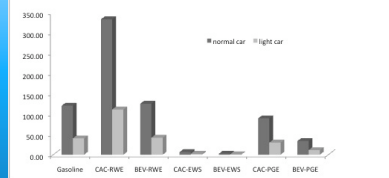
Model Specifications

- 100,000 l air compressed at 310 bar
- 2-stage diabatic (n=1.2) compression, 4-5 hours → Efficiency: 93.6%
- 2-stage adiabatic expansion → Efficiency: 49%
- Overall efficiency of storage: 45-7%
- Compared to Smart ed and Smart fortwo
- Car weight is 900kg, and hypothetical ultra-light car is 300kg
- Cruising range: 115km

CAC requires more primary energy than the gasoline car when running on electricity generated by coal, but less when electricity is generated by wind.



GHG Emissions in gCO₂/km



When powered by a coal-based mix, CAC has much higher GHG emissions than the BEV and the gasoline car. If cars can be powered by renewables, GHG emissions approach zero.

Marginal costs of fuels (CA, D)

Table 3. California: marginal price (¢ km⁻¹) with \$4/gal (\$2/gal).

	Gasoline	CAC	BEV
Normal fuel	5.5 (2.7)	—	—
Light fuel	1.8 (0.9)	—	—
Normal grid	—	5.2	2.3
Light grid	—	1.7	0.8
Break-even normal \$	300 (-2700)	3500 (400)	—
Break-even light \$	100 (-900)	1200 (100)	—

Table 4. Germany: marginal price (¢ km⁻¹) with \$8.4/gal (\$6.4/gal).

	Gasoline	CAC	BEV
Normal fuel	11.5 (8.8)	—	—
Light fuel	3.8 (2.9)	—	—
Normal grid	—	13.6	7.6
Light grid	—	4.5	2.5
Break-even normal \$	-2400 (-5400)	4300 (1300)	—
Break-even light \$	-800 (-1800)	1400 (400)	—

Conclusions

- Even under optimistic assumptions (2 expansion steps), the CAC has significant lower well-to-wheel efficiency compared to an electric car (27% vs 71%)
- Hence, volume (and/or range), greenhouse gas emissions and marginal costs are too high
- The CAC is neither economically nor environmentally viable
- See also: Papson, Creutzig & Schipper (10-3282)
- Model is online: <http://www.user.tu-berlin.de/creutzig/CACAMM.html>

Hybrid solutions

- Pneumatic-Combustion Hybrid
 - ICE plus valve and small air tank
 - Supercharged mode fills air tank
 - For peak load, expansion
 - May compete with battery hybrid
- Air engine hybrid
 - ICE constantly charges air tank
 - Waste heat used to heat up expanding air, increasing efficiency
 - Total efficiency of 33% claimed in modeling studies (Huang et al., 2005/2009)
 - No experimental verification up to now

Break-even costs as a function of gasoline price

