Regenerative fuels via molten salt electrolysis for energy storage

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Electric vehicles (EVs) are increasingly visible in road, but will they replace fuel powered cars? In fact, EVs are not new. Edison introduced Ni-Fe battery cars more than 100 years ago to Ford, but they actually developed successfully petrol powered cars for a good reason: the liquid fuel offers much higher energy density than the Ni-Fe batteries [1]. Will including CO_2 emission and renewable energy in the equation change the prospect of battery cars? It seems not to be so promising if one compares the energy capacity of less than 300 Wh/kg for the best battery in the market, the lithium -ion battery, with the thermodynamic data of non-carbon fuels as shown in Table 1.

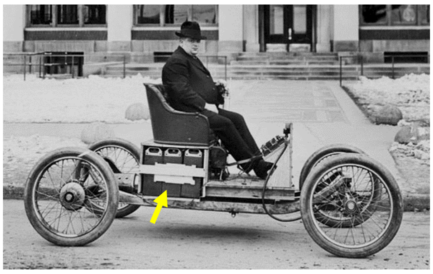

Figure 1. A 1913 Ford-Edison battery car. The arrow points to a bank of batteries [1].

However, unlike carbon and hydrocarbon fuels whose crude precursors exist in the earth's crust, all non-carbon fuels listed in Table 1 do not form naturally. Therefore, the key to utilization of non-carbon fuels is to produce and regenerate them after use via a commercially affordable and sustainable technology that can be enabled by renewable energy. In the scientific term, the reactions listed in Table 1 are all spontaneous oxidation of the fuels. Reversing these reactions regenerate the fuel, requiring input of energy, ideally from a renewable source. In this way of cycling, these non-carbon fuels are termed as **regenerative fuels**, whilst the process of regeneration is in fact an energy storage process. The benefits of regenerative fuels are multifold, such as high energy capacity (fossil fuels comparable), non-carbon nature (zero emission), solid state (easy storage and transport), and abundant natural resources (immune to geopolitics). A regenerative fuel technology is proposed based on **molten salt electrolysis** of oxides of metals, semi-metals and carbon [2], calling for further research, including thermodynamic analysis and modelling.

Table 1 Maximum Specific Work ($-\Delta G^o$) for different fuels at 1000 ^oC

Reaction number	Fuel combustion / energy conversion reactions	$-\Delta G^o$ (kWh/kg)	
		Inc. oxygen	Exc. oxygen
1	$H_2 + O_2 \rightleftharpoons H_2O(g)$	2.75	24.67
2	$C + O_2 \rightleftharpoons CO_2$	2.50	9.25
3[a]	$C_8H_{18} + 12.5O_2 \rightleftharpoons 8CO_2 + 9H_2O(g)$	*ca.* 3.1	*ca.* 13.89
4	$4Li + O_2 \rightleftharpoons 2Li_2O$	3.97	8.56
5	$Al + O_2 \rightleftharpoons Al_2O_3$	3.47	6.53
6	$Si + O_2 \rightleftharpoons SiO_2$	3.17	6.75
7[b]	$LiCoO_2 + C \rightleftharpoons Li_xC + Li_{1-x}CoO_2$	< 0.3	< 0.3

[a] Petrol, estimated values. [b] Lithium ion battery, kWh/cell mass, room temperature.

[1] G. Blazeski, In 1912 Henry Ford & Edison came together to conceive a low-priced electric car, ***The Vintage News***, 18, Oct, 2016. https://www.thevintagenews.com/2016/10/18/in-1912-henry-ford-edison-came-together-to-conceive-a-low-priced-electric-car/
[2] L. Xia, G. Z. Chen, High density electrochemical energy storage via regenerative fuels, ***Chin. J. Catal.***, 40 (s1) (2019) 111-119. (In Chinese at http://www.cjcatal.org/CN/Y2019/V40/Is1/111).

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