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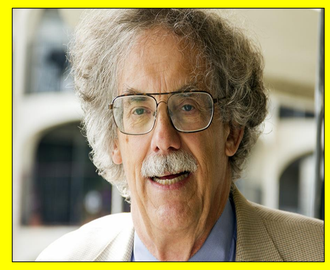
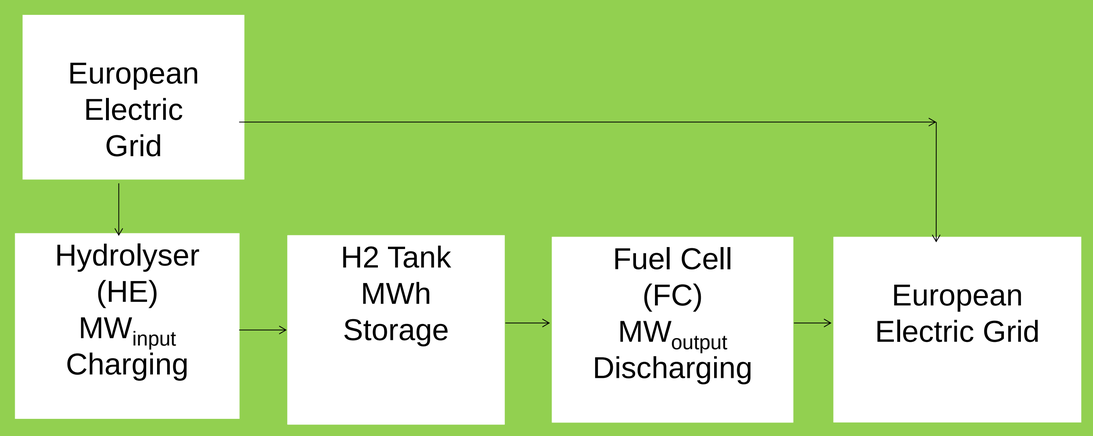
Is Hydrogen Energy Storage Ready for Prime Time On the European (Northern American) Grid?

Michael Stavy. MBA Kellogg, CPA Illinois (Inactive)
Senior Advisor on Renewable Energy Finance
michael@michaelstavy.com



HYDROGEN (H2) ENERGY STORAGE FACTS

- Wind electricity is energy and is measured in MWh_{ELECT}
- Wind power is measured in MW_{ELECT}
- Energy storage capacity is measured in MWh_{ELECT} (MWh_{H2})
- Energy storage input and output power are both measured in MW_{ELECT}
- Energy storage capacity can also be measured by time duration (i.e. hours at full output power)
- Bulk energy storage (>1,000 MWh/cycle) can provide ancillary services, daily, weekly (7 days) or seasonal (180 days) wind energy storage
- This paper only studies daily storage



Schematic of a Hydrogen Storage Plant (HSP) on the European Grid

H2 STORAGE PLANT (HSP) LEVELIZED COST OF ENERGY STORAGE (LCOS) FINANCIAL ALGORITHM

- Author's goal is to determine whether H2 energy storage is ready for prime time (is cost effective) on the European grid
- Paper discusses H2 storage technology focusing on the three phases of all HSP; one, charging, using wind energy to produce H2; two, storage of the H2; three, discharging, using the stored H2 as fuel to regenerate the wind electricity
- To compute the LCOS, the algorithm uses 22 HSP specifications (specs; metrics). These 22 HSP (specs) are defined in standard H2 SI units
- 1 MWh_{ELECT} = 1 MWh_{H2} = 3.1420 $mmBtu_{ELECT}$ = 3,600 MJ_{H2} = 333.3 $N_{H2}M^3$
- The LCOS algorithm uses "project accounting" to compute a separate LCOS for each HSP phase; 1. charging with wind electricity powering a H2 electrolyzer (HE) to produce H2, 2. H2 storage in a H2 tank, 3. discharging using the stored H2 to power a fuel cell (FC) to regenerate the wind electricity
- The paper was to use the LCOS algorithm to compute the HSP LCOS based on published European HSP specs and for sensitivity analysis using different published spec values. The author could not find published European HSP specs.
- Below ↓↓↓ is a HSP Sensitivity Study Summary which shows the specs used, the flow of energy, costs and LCOS through the HSP financial algorithm
- In his sensitivity studies, the author found that both the HPS low efficiency (η) and high HSP CapEx are the major specs that do not allow a HSP to operate commercially, With a 6% interest rate/ROI, the cost of capital was not a factor. The HSP operating life is 20 years. A 25% increase in operating life (20→25 years) only reduces the LCOS by 5.3%. (€126.41→€119.70/MWh).
- The author concluded that NO, H2 energy storage is not yet ready for prime time (commercial operation) on the European grid. The author based his conclusion on the paper's sensitivity studies, his inability to locate European HSP specs and the lack of any actual commercial HSP on the European Grid.

A HSP Sensitivity Study Summary

US$/€	$1.14610	01/13/19			
	WS # 1 HE	WS # 2 H2 Tank	WS # 3 H2 FC		
Phase→	Charge	Storage	Discharge	HSP-η-%	
HSP Phase-η-%	90%	90%	90%	72.9%	COLOR CODE
MWh/day-in	3,000.00	←MWh/day wind energy stored			From WS # 1
MWh/day-out	2,700.00	←MWh/day H2 produced by HE			From WS # 2
MWh/day-in		2,700.00	←MWh/day H2 stored		From WS # 3
MWh/day-out		2,430.00	←MWh/day H2 released		Result
MWh/day-in			2,430.00	←MWh/day FC H2 fuel	Side Column Result
MWh/day-out			2,187.00	←MWh/day FC electricity	in €
			72.9%	←% round trip HSP η	
Phase Operating hrs/day	10	4.00	10	24	
	Only one phase operates at a time; HSP operates 24 hr/day; 365/yr				€/MWh↓
$/MWh-in	$50.16	←US$/MWh cost of stored wind energy			€ 43.77
$/MWh-out	$71.28	←US$/MWh HE LC to produce H2			€ 62.19
$/MWh-in		$71.28	←US$/MWh LC of H2 stored		
$/MWh-out		$106.14	←US$/MWh LC of H2 released		€ 92.61
$/MWh-in			106.14	←US$/MWh LC FC H2 fuel	
$/MWh-out			$144.88	← US$/MWh LCOS wind energy	€ 126.41
	HE Power MW_{in} ↓		188.8%	←% increase wind energy cost	
	300	Tank Size-MWh_{H2} ↓		€/MWh ↓	
HE CapEx-US$/$MW_{in}$	$573,000	2,700	FC Power MW_{out} ↓	€ 499,956	
Tank CapEx-US$/$MWh_{H2}$		$100,000	243	€ 87,252	
FC CapEx-US$/$MW_{out}$			$1,000,000	€ 872,524	
CapEx -US$/kWh	$573	$100	$1,000		
CapEx -€/kWh	€ 500	€ 87	€ 873		
				Total HSP CapEx	
HSP CapEx-US$/Phase	$171,900,000	$270,000,000	$243,000,000	$684,900,000	
HSP CapEx-€/Phase	€ 149,986,912	€ 235,581,537	€ 212,023,384	€ 597,591,833	
Fixed O&M Cost-% Phase CapEx	0.05%	0.05%	0.05%		
Variable O & M Cost-US$/MWh	$0.25	$0.25	$0.25		
Physical Life -Years	20	20	20		
Interest/ROE Rate-%	6.00%	6.00%	6.00%		02/04/19

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