Is Hydrogen Energy Storage Ready for Prime Time on the North American Grid? A Guide for Bankers and Investors

AUTHOR

Michael STAVY MBA-Kellogg Day Program, Illinois-CPA (inactive), Senior Advisor on Renewable Energy Finance, USA

michael@michaelstavy.com www.michaelstavy.com M: 1-312-523-8328

SUMMARY

A bulk electric energy storage plant can be used on the North American electric grid for the daily, weekly or seasonal storage of solar electricity (energy) and/or to provide ancillary services. The goal of this paper is to help bankers and investors determine whether hydrogen (H_2) energy storage is ready for prime time[1] on the North American grid.

To determine this, the author has developed a H_2 energy storage plant (HSP) levelized cost of storage (LCOS)[2] financial algorithm for a model HSP. To compute the LCOS, the paper's HSP LCOS financial algorithm[3] requires 22 HSP specifications (specs) [metrics]. These 22 HSP specs (metrics) [independent variables] are defined using a standard set of SI H_2 energy units. This HSP LCOS algorithm is used by the

1 Is currently commercially viable
2 not to be confused with the levelized cost of energy (LCOE). See reference [5]
3 hereafter referred to as the HSP LCOS algorithm

author for sensitivity analysis and to confirm published HSP specifications (specs). This algorithm is presented on the paper's Excel[4] HSP LCOS Financial Algorithm Workbook. The paper discusses H_2 storage (HS) technology, focusing on the three phases of all HSP; one, the production of the H_2 using solar electricity, two, the storage of the solar electricity as H_2, three, the use of the stored H_2 as the fuel to regenerate the solar electricity. The HSP LCOS algorithm uses "project accounting" to compute a separate LCOS for each HSP phase; charging, storage and discharging.

The author used the paper's HSP LCOS algorithm and "datasets" of compiled HSP specs to do sensitivity analysis. The author has found that both low round trip HSP efficiency (η) and high Total HSP CapEx do not allow a HSP to operate commercially in North America. The cost of capital[5] was not a factor. This is confirmed by the fact that currently there are no commercial HSP operating on the North American grid.

1. THE HSP LCOS ALGORTHUM AND ITS EXCEL WORKBOOK

For the reader to follow this paper's narrative, the reader must download (@ **no cost**) the paper's Excel[4] HSP LCOS Financial Algorithm Workbook. https://tinyurl.com/Stavy-SPI-19 . This paper refers to worksheet (WS) lines on the four WS of the Excel HSP LCOS Financial Algorithm Workbook[6]. A Glossary is on page 12. Table # 1 with the 22 clearly defined HSP specs is on page 13. A List of References is on page 14.

Putting the algorithm on an Excel workbook allows the author (and the reader) to quickly do sensitivity analysis. By selecting different realistic values for the 22 HSP specs, it has become clear to the author that there are two key values that determine whether a HSP is ready for commercial development. These are the HSP Round Trip efficiency (η) and the Total[7] HSP CapEx.

A H_2 Electrolyser (HE) is used in the HSP charging phase; a H_2 "Tank" in the HSP storage phase and a Fuel Cell (FC) in the HSP discharging phase. The Excel HSP LCOS Workbook has four WS: three WS are for the three HSP phases: WS # 1, Charging-H_2 Electrolyser, HE; WS # 2, Storage-H_2 Storage "Tank"; WS #3, Discharging-Fuel Cell, FC. WS # 4 is the Summary Page. WS # 4 is on pages 9, 10 & 11 and is a summary of the model HSP base case. The reader who studies the base case on WS # 4 will see, for example, that the cost of the solar electricity to be stored is US$50/MWh (€43.63), that the HSP is designed to store 300 MWh/day of solar electricity, that the efficiency (η) of each storage phase (HE, H_2 "Tank" and FC) is set at 90% and that for each storage phase the interest rate/ROE is set at 6%.

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[4] a fully functioning Excel Workbook
[5] discount rate
[6] hereafter referred to as the Excel HSP LCOS Workbook
[7] Total CapEx refers to the sum of the CapEx of each of the three phases

Fig. 1 (page 13) is a Schematic of the Model HSP. The HSP LCOS Financial Algorithm's "project accounting" allows the Workbook user to "fine tune" a sensitivity study. "Project accounting" also allows the Workbook user to do a sensitivity study of each phase separately. For each HSP phase (charging, storage and discharging), a separate partial LCOS is computed. Each WS in the Excel HSP LCOS Workbook has notes to explain each of the 22 specs and each of the computed values.

The lines and values for the 22 HSP spec values (the independent variables) and for the 74 computed dependent variable values [lines A→VVV]) that are referred to in this paper are listed on WS # 1, HE, WS # 2, H_2 "Tank", and WS #, 3 FC, and are summarized on WS # 4.

The reader who has downloaded the paper's Excel[4] HSP LCOS Workbook can enter their own 22 HSP spec values on the Excel Workbook and check their results. While this paper discusses the 22 HSP specs (metrics), there is no case study to discuss how to compile the 22 HSP specs from the current authoritative data sources. The author was unable to locate any commercial bulk HSP on the North American grid. Readers who want to learn how to compile the 22 HSP specs should read the Cabin Creek Pumped Storage Plant compilation case study that is found in the author's WindEurope 2018 Paper [1].

A HSP can be designed for a daily, weekly (seven days) or seasonal (180 days) storage cycle. The paper's model HSP is basic. It is designed to have a daily energy storage cycle. The paper's LCOS HSP algorithm only computes the LCOS (US$/MWh; €/MWh) for the <u>daily</u> storage of solar electricity. Two of the 22 HSP specs (metrics) specify how many hours a day are used in the daily charging and discharging phases. In the base case (WS # 4, page 6), the daily charging phase and the daily discharging phase are each set at 8 hours. The remaining 8 hours of the day are automatically assigned to the storage phase. The three phases of the model HSP do not operate at the same time. A HSP can be designed to have all three phases operate at the same time.

A bulk energy storage plant (ESP) can be engineered to provide energy storage and/or ancillary grid services (voltage and frequency control and reactive power [var]) for the grid. This paper's model HSP is not designed to provide ancillary services.

The Excel HSP LCOS Workbook also requires a FX value (US$/€) to convert US$ LCOS values into € values. In the base case, the FX value is US$1.14610/€ {13/01/19} [d/m/yr] [2]. Workbook users can change this FX value.

2. STANDARD (SI) HYDROGEN UNITS

The 22 HSP specs (metrics) are defined using standard SI H_2 energy units. HSP specs can be presented using any of these standard SI units: (MJ_{H2}; kg_{H2}; Nm^3_{H2}; MWh_{ELECT}; MWh_{H2}). There are standard conversion factors for converting[8,9] MJ_{H2} into kg_{H2}; into Nm^3_{H2} into MWh_{ELECT} and into MWh_{H2}.

The key conversion factor in the HSP LCOS algorithm is

$1\ MWh_{ELECT} \equiv 1\ MWh_{H2}$

MWh_{ELECT} and MWh_{H2} are equal SI energy units regardless of the type of energy[10] or the authoritative SI source cited[11] for the standard conversion factors. This is because they are both the same quantity of energy.

The model HSP's energy flow[12,13] using SI units is as follows:

First, during HPS charging phase, MWh_{ELECT} of solar electricity from the grid go to power the HE. The HE produces MWh_{H2} that are then put into H_2 Tank. Second, during the HSP storage phase, MWh_{H2} are stored in the H_2 Tank. Third, during the HSP discharging phase, MWh_{H2} from the H_2 Tank power the FC. The FC consumes the MWh_{H2} to regenerate MWh_{ELECT} of solar electricity that are then put back on the grid.

Here are some other key energy units for the reader to have:

$1\ MWh_{ELECT} = 1\ MWh_{H2} = 3.1420\ mmBtu_{elect}$ [3]

$1\ MWh_{ELECT} = 1\ MWh_{H2} = 3{,}600\ MJ$ [3]

$1\ MWh_{ELECT} = 1\ MWh_{H2} = 333.3\ Nm^3$ [4]

$33.33\ kWh_{ELECT} = 1\ kg_{H2}$ [4]

$1\ MWh_{ELECT} = 1\ MWh_{H2} = 30.3\ kg_{H2}$ [author's unit analysis]

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[8] or for the reverse conversion
[9] and for the conversion into US "English" standard units and for the reserve conversion
[10] here kinetic energy such as solar electricity or potential energy such as H_2
[11] examples, the IEA or EIA
[12] HE produces H_2; H_2 Tank stores H_2; FC consumes H_2
[13] a Schematic of the Model HSP is on page 13

3. THE THREE PHASES OF THE HSP

This paper discusses H_2 storage technology focusing on the three phases of all HSP; one, the production of the H_2 with solar electricity, two, the storage of the H_2, three, the use of the stored H_2 as the fuel to regenerate the solar electricity. In a HSP, H_2 is used as the energy carrier[14].

In the HSP base case, the HE spec values, WS #1, Lines 6, 7, 8 & 9, have also been used as the H_2 Tank spec values, WS # 2, Lines 12, 13, 14 & 15, and as the FC spec values WS # 3, Lines 19, 20, 21 & 22. A specific example is WS # 1, Line 9, cost of capital, interest rate/ROE [WACC] which is 6%, so are WS # 2, Line 15 and WS # 3, Line 22. This is done to have a straightforward base case. The Excel HSP LCOS Workbook allows the reader to use different spec values for each HSP phase.

In the paper's model HSP, solar electricity from the North American grid powers a HE. The HE uses the solar electricity to separate H_20 into H_2 and O_2. When the HE is producing H_2 with solar electricity, the HSP is charging. Currently no H_2 electrolyser format is the most mature technology. The paper's LCOS algorithm measures the "financial maturity" of HE with different technologies. The most important algorithm HE values are WS # 1, Line 1, HE-hrs per Day Charging, WS # 1, Line A, HE capacity (MW_{ELECT}), WS # 1, Line 3, HE CapEx-US$/$MW_{ELECT}$ (€/MW_{ELECT}) and WS # 1, Line 4, HE efficiency (η) .

In the paper's model HSP, the solar electricity is stored as H_2 in a generic H_2 "Tank". When the H_2 is in the storage H_2 "Tank", the HSP is storing the solar electricity. There are various technologies for storing H_2. These include pressurized H_2 storage tanks, liquefied H_2 storage tanks, H_2 salt caverns (another type of H_2 storage tank), as ammonia (NH_3), with other H_2 rich chemicals or in metal hydrides. NH_3, metal hydrides, other types of material storage, and H_2 in salt caverns are not yet mature enough technologies for a commercial North American HSP. High pressure and liquefied H_2 storage tanks are currently the most technically mature and most widely used technologies for industrial H_2 storage. The paper's HSP LCOS algorithm measures the "financial maturity" of different H_2 "Tanks" (technologies). The most important algorithm H_2 Tank values are WS # 2, Line I, H_2 Tank size (MWh_{H2}), WS # 2, Line 10, H_2 Tank CapEx-US$/$MWh_{H2}$ (€/MWh_{H2}), and WS # 2, Line 11, H_2 Tank efficiency (η).

In the paper's model HSP, the H_2 is taken out of the H_2 Tank and is consumed as the fuel to power a FC that regenerates the solar electricity which is then put back on the North American grid. When the FC is generating electricity with the stored H_2 as the fuel, the HSP is discharging the solar electricity from storage. There are various technologies for using the stored H_2 as the fuel to regenerate the solar energy as electricity. These include FC of various technologies and H_2 powered electric turbines in various formats (H_2 peaker turbine ≈ NG peaker turbine; combined cycle H_2 turbine ≈ combined cycle NG turbine

[14] and is potential energy

[CCGT]). For a daily storage cycle, only a H_2 peaker turbine can be considered, but the H_2 peaker turbine is not a mature technology. This leaves FC of various technologies with different technical and financial maturities. The paper's HSP LCOS algorithm measures the "financial maturity" of different types of FC. The most important algorithm FC values are WS # 3, Line 16, FC-hrs per Day Discharging, WS # 3, Line XX, FC capacity (MW_{ELECT}), WS # 3, Line 17, FC CapEx-US$/$MW_{ELECT}$ (€/MW_{ELECT}), and WS # 3, Line 18, FC efficiency (η).

In the model HSP, the hours per day that the solar electricity is in storage as H_2 is completely determined by the HE-hrs per Day Charging (WS # 1, Line 1) and by the FC-hrs per Day Discharging (WS # 3, Line 6).

4. CONCLUSIONS

a. The Primary Conclusion

In the base case, WS # 1, Line 5, Cost of the Solar Electricity to be Stored, US$50.00/MWh (€43.53), is a model solar plant's LCOE[15]. On WS # 3, Line LLL, the LCOS in the base case is US$152.71[16]/MWh (€133.25). This 205.4% increase from US$50.00 is too high for the market. Perhaps a carbon constrained North American grid would accept a time of day 20% increase to US$60.00 (€52.35) for stored solar electricity but not much higher.

b. The First <u>Base Case</u> Modification-Increasing the HSP's Physical Life

If the physical life of the HE (WS # 1, Line 8), H_2 Tank (WS # 2, Line 14) and FC (WS # 3, Line 21) are each set at 25 years instead of 20 years[17], the LCOS would be US$144.30/MWh (€125.91). This is a 5.5 % LCOS reduction from the base case of US$152.71 for a 25% increase in the physical life of the HSP. It is doubtful that a HSP would have a physical life of 25 years.

c. The Second <u>Base Case</u> Modification-Reducing the HSP's WACC

If the interest rate/ROE [WACC] of the HE (WS # 1, Line 9), H_2 Tank (WS # 2, Line 15) and FC (WS # 3, Line 22) are each set at 4% instead of 6%[17], then the LCOS would be US$139.79/MWh (€121.97). This is a 8.5% LCOS reduction from the base case US$152.71/MWh for a 33.3% decrease in the WACC. It is doubtful, however, that bankers or investors would fund a HSP at even 6% with the current state of HSP technical development.

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[16] on WS # 4, the LCOS is also US$152.71
[17] and if all 19 of the other 22 specs remain the same

Sensitivity analysis shows that currently the two key HSP specs (metrics) in determining the HSP LCOS are the HSP Round Trip Efficiency (η) (too low) and the Total HSP Total CapEx (too high).

d. **The Third Base Case Modification-Reducing the HSP's Round Trip Efficiency-** η-%

On WS # 4, HSP Round Trip η-%, 72.9% is the product of 90% (WS # 1, Line 4, HE-η) X 90% (WS # 2, Line 11, H_2 Tank-η) X 90% (WS # 3, Line 18, FC-η). This is a very optimistic HSP Round Trip η because HE and FC do not actually operate at η = 90%. If the bulk H_2 storage tank were, in actuality, a high pressure H_2 storage tank or a liquefied H_2 storage tank, the storage phase η would be at most in the 70% range. If the phase η of the HE, H_2 Tank and FC are now each set at 80% instead of 90%[17] (an 11.1% reduction), the HSP Round Trip η would decline from 72.9% to 51.2% (a 29.8% decrease) while the LCOS would increase from the base case US$142.21 to US$199.78/MWh (€174.31), an 30.8% increase.

e. The Forth Base Case Modification-Reducing the HSP's Total[7] CapEx

WS # 4, Total[7] HSP CapEx, US$75,825,000 (€66,159,148) is the sum of US$21,487,500 [WS # 1, Line D, Total HE CapEx] plus US$27,000,000 [WS # 2, Line BB, Total H_2 Tank CapEx] plus US$27,337,500 [WS # 3, Line AAA, Total FC CapEx].

The Total HE CapEx (WS # 1, Line D) is computed by multiplying the 37.5 MW_{ELECT} of HE Capacity (WS # 1, Line A) times the HE CapEx of US$573,000/$MW_{ELECT}$ (WS # 1, Line 3). The HE CapEx value was published by a prominent European HE manufacturer[18]. The 37.5 MW_{ELECT} (WS # 1, Line A) is computed by dividing the 300 MWh_{ELECT} of solar electricity that charges the HSP each day (WS # 1, Line 2) by the 8 hrs per day that the HE operates (WS # 1, Line 1).

The Total H_2 Tank CapEx (WS # 2, Line BB) is computed by multiplying the 270 MWh_{H2} H_2 Tank size (WS # 2, Line I) times the H_2 Tank CapEx of US$100,000[19]/$MWh_{H2}$ (WS #2, Line 10)

The Total FC CapEx (WS # 3, Line AAA) is computed by multiplying the 27.3 MW_{ELECT} of FC capacity (WS #3, Line XX) times the FC CapEx of US$1,000,000[20] /$MW_{ELCT}$ (WS # 3, Line 17). The 27.3 MW_{ELECT} (WS # 3, Line XX) is computed by dividing the 218.7 MWh_{ELECT} (WS # 3, Line YY) discharged by the HSP each day by the 8 hours per day that the FC operates (WS #3, Line 16).

If the CapEx of the HE (WS # 1, Line 3), H_2 Tank (WS #2, Line 10) and the FC (WS # 3, Line 17) are each reduced by 20%[17], the Total[7] HSP CapEx would be $60,652,000 (€52,920,687), a 20% reduction from the base case Total HSP CapEx of US$75,825,000. The LCOS would be US$136.05/MWh (€118.70), a 10.9%

18 the published value is €500/kWh_{H2} (US$573/$kWh_{H2}$) [6]
19 The H_2 Storage "Tank" CapEx based on a projected US$100/kWh CapEx for the Tesla Li-ion battery
20 this is equal to a FC CapEx of US$1,000/kW

LCOS reduction from the base case of US$152.71 (€133.24). This result is caused by the 20% decrease in the CapEx of each HSP phase. For the base case, the HSP Total CapEx will have to go down by more than 50% for the model HSP to become commercially viable.

f. The Reader's "Homework" Assignment

The author assumes that you, the reader, have downloaded (@ no cost) the paper's Excel[4] HSP LCOS Financial Algorithm Workbook. https://tinyurl.com/Stavy-SPI-19 . Now use your Excel[4] HSP LCOS Financial Algorithm Workbook to compute the Forth Base Case Modification with the HSP's Total CapEx reduced by 50% instead of 20%. Is the LCOS now US$ 60/MWh or less (<=20% higher) the than base case cost of the solar electricity to be stored (US$ 50/MWh)? The author will have the answer at his poster presentation. **Stop by!**

5. RECAP

If you are a banker or investor asking, is hydrogen energy storage ready for prime time on the North American grid?

The author's answer is NO!

The author bases his answer on the following facts.

1. There are no commercial HSP on the North American grid.
2. HSP specs (metrics) for commercial HSP were not found in any current authoritative data source.
3. The author complied specs for a model HSP. With the paper's LCOS algorithm, the author computed the LCOS but it was too high for the current development of a commercial North American HSP
4. Sensitivity analysis showed that the HSP Round Trip η is not realistically presented by the author. He is too optimistic. HSP Round Trip η is currently more realistically in the 60% range; not the computed 72.9%.
5. Sensitivity analysis showed that the Total HSP CapEx is also not realistically presented by the author. He is again too optimistic. Total HSP CapEx was too high for the LCOS to be less than 20% more than the cost of the solar electricity being stored but too low to reflect current HSP CapEx values.
6. Readers might want to compare the LCOS for current PSP as a benchmark for future HSP [1].

WORKSHEET # 4, EXCEL HSP LCOS ALGORITHM SUMMARY WORKSHEET

		d/m/y				
US$/€	$1.14610	13/01/19			From WS # 1	
	WS # 1	WS # 2	WS # 3		From WS # 2	
	HE	H_2 Tank	H_2 FC		From WS # 3	
Quick key to HSP energy flow→	HE produces H_2	H_2 Tank stores H_2	FC consumes H_2		Result	
Phase→	Charge	Storage	Discharge	HSP-η-%	Side Column Result	
HSP Phase-η-%	90%	90%	90%	72.9%	In €	
MWh_{ELECT}/day-in	300.0					←MWh_{ELECT}/day solar electricity stored
MWh_{H2}/day-out	270.0					←MWh_{H2}/day produced by HE
MWh_{H2}/day-in		270.0				←MWh_{H2}/day H_2 stored
MWh_{H2}/day-out		243.0				←MWh_{H2}/day H_2 released
MWh_{H2}/day-in			243.0			←MWh_{H2}/day consumed
MWh_{ELECT}/day-out			218.7			←MWh_{ELECT}/day solar electricity regenerated
		proof	72.9%			←round trip HSP η-%
MWh_{ELECT}/yr solar electricity stored	109,500	72.9%	79,826			MWh_{ELECT}/yr solar electricity put back on grid

Phase→	WS # 1 Charge	WS # 2 Storage	WS # 3 Discharge		
Phase Operating hrs/day	8	8	8	24	
	Only one phase operates at a time; HSP operates 24 hr/day; 365/yr				
$\$/\text{MWh}_{ELECT}$-in	$50.00	←US$/MWh cost of stored solar energy			
$\$/\text{MWh}_{H2}$-out	$74.92	←US$/MWh HE LC to produce H_2			
$\$/\text{MWh}_{H2}$-in		$74.92	←US$/MWh LC of H_2 stored		
$\$/\text{MWh}_{H2}$-out		$110.19	←US$/MWh LC of H_2 released		
$\$/\text{MWh}_{H2}$-in			110.19	←US$/MWh LC FC H_2 fuel	
$\$/\text{MWh}_{ELECT}$-out			$152.71	← US$/MWh LCOS solar energy	
	HE Power		205.4%	←% LCOS increased cost	
	MW_{ELECT} ↓	Tank Size			
	37.5	MWh_{H2} ↓	FC Power	€/MWh ↓	
HE CapEx-US$/$\text{MW}_{ELECT}$-in	$573,000	270	MW_{ELECT} ↓	€ 499,956	
Tank CapEx-US$/$\text{MWh}_{H2}$		$100,000	27.3	€ 87,252	
FC CapEx-US$/$\text{MW}_{ELECT}$-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	$21,487,500	$27,000,000	$27,337,500	$75,825,000	
HSP CapEx-€/Phase	€ 18,748,364	€ 23,558,154	€ 23,852,631	€ 66,159,148	

Phase→	WS # 1 Charge	WS # 2 Storage	WS # 3 Discharge
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%

Glossary

CAES =	compressed air energy storage	mmBtu =	million British thermal units
CCGT =	combined cycle gas turbine	MW =	megawatt
CCHT =	combined cycle H_2 turbine	MWh =	megawatt hour
CHES =	compressed H_2 energy storage	NG =	Natural gas
EIA =	Energy Information Administration (US)	Nm^3 =	nominal cubic meter-H_2
ES =	energy storage	O_2 =	oxygen
ESP =	energy storage plant	PSP =	pumped storage plant
FC =	fuel cell	ROE =	return on owner's equity
gal =	US gallon-H_2	scf =	standard cubic foot-H_2
H_2 =	hydrogen	SI =	Système International d'Unités
HSP =	hydrogen storage plant	SMR =	steam methane reformation
IEA =	International Energy Agency (OECD)	WACC =	weighted average cost of capital
kg =	kilogram-H_2	WS =	worksheet
LC =	levelized cost	η =	efficiency
LCOE =	levelized cost of energy		
LCOS =	levelized cost of storage		
MJ =	megajoules		

FIGURE # 1 Schematic of the MODEL HSP

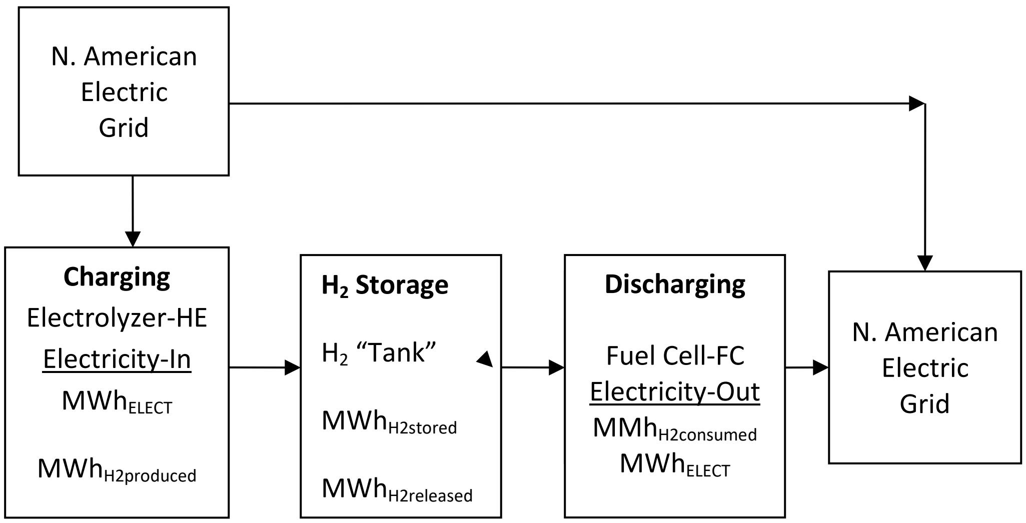

Table # 1 THE 22 SPECIFICATIONS (METRICS) OF THE HSP LCOS ALGORITHM

spec #	Charging HE	spec #	Storage H_2 Tank	spec #	Discharging Fuel Cell
1	HE hrs/Day Charging	10	H_2 Tank CapEx-US$/MWh$_{H2stored}$	16	FC hrs/Day Discharging
2	Solar Energy to be Stored MWh$_{ELECT}$/Day	11	H_2 Tank Efficiency-η	17	FC CapEx-US$/MW$_{ELECT}$
3	HE CapEx-US$/MW$_{ELECT}$	12	Annual Fixed O & M-% H_2 Tank total CapEx-US$/$H_2$ Tank	18	FC Efficiency-η

spec # 	Charging HE	spec # 	Storage H_2 Tank	spec # 	Discharging Fuel Cell
4	HE Efficiency-η	13	Variable O & M-US$/MWh$_{H2released}$	19	Annual fixed O & M-% FC Total CapEx-US$/FC
5	Cost of the Solar Energy Stored-US$/MWh$_{ELECT}$	14	H_2 Tank life-yrs	20	FC Variable O & M-US$/MWh$_{ELECT}$
6	Annual Fixed O & M-% HE Total CapEx-US$/FC	15	H_2 Tank Interest/ROE rate-%	21	FC Life-yrs
7	HE Variable O & M-US$/MWh$_{H2produced}$			22	FC Interest/ROE rate-%
8	HE Life-yrs				
9	HE Interest/ROE rate-%				

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