SG H2 Energy global - Enzen Australia

Up-cycling Waste to Renewable Hydrogen
For
TASMANIA

COMMENTS ON THE TASMANIAN HYDROGEN ACTION PLAN

UWTH2 - EXECUTIVE SUMMARY

SG H2 ENERGY GLOBAL , LLC & ENZEN AUSTRALIA

SG H2 Energy Global, LLC (" SGH2") is a wholly owned subsidiary of the Solena Group created based in Washington D.C. to develop, build, own and operate Solena's proprietary Upcycling Waste to Renewable Hydrogen ("UWTRH2") facilities to produce green H2 worldwide.

Enzen is a global solutions business headquartered in the UK and India. It provides its global client base solutions in the energy and water sectors. Today the firm has 4000+ employees and operates in 19 countries.

SGH2 has partnered with Enzen Australia to promote and develop UWTRH2 projects in Tasmania and Australia. For both businesses the elimination of the global waste challenge in a manner that delivers a sustainable and renewable enegy source is an enduring objective.

The UWTH2 solution utilizes Solena's proprietary plasma enhanced gasification system to convert low-value hydrocarbon products (waste/biomass residue) into highest value renewable Hydrogen. It is not an incineration process but rather a gasification process. Solena's UWTH2 system is a thermal catalytic conversion (high temperature, fixed- bed, counter current gasification) process utilizes Plasma arc torches which have been used at commercial scale for decades to increase the temperatures of fixed bed gasifier in order to optimize the efficiency of producing syngas and hydrogen from solid opportunistic renewable feedstocks such as waste, recycled mixed papers and mixed plastics and used tires, normally destined for landfills.

GLOBAL HYDROGEN MARKET

40% of the global energy market and the CO2 production are due to the industrial processes, heat requirements and transport / mobility sector , the latter of which include cars, trucks, buses, trains, shipping and planes. It is 95% oil dependent and the transport sector is responsible for the 23% of CO2 emissions worldwide. Standard renewable energy such as solar and wind generated electricity, albeit a great solution to replace dirty coal fired power plant and Nat gas generated electricity, cannot address this very important transport energy sector. Consider that it would be necessary to double the size of the electric network of Beijing to supply just 10% of the its car fleet if they are all converted to electric vehicles. One viable alternative solution is bio based liquid fuel such as ethanol, biodiesel and or BioJetFuel. However, these alternative fuel solutions carry agricultural risks, which is weather, water, and fertilizer dependent as well as create a fuel vs. food dilemma.
Currently, the only completely zero carbon fuel that has the capacity to replace liquid petroleum products in the transport sector is Hydrogen, either in gaseous form or in liquid form. With the advanced and commercialization of fuel cell based transportation systems, hydrogen is becoming the fuel of choice for major car manufacturers due to its (1) compact and lightweight, (2) fast

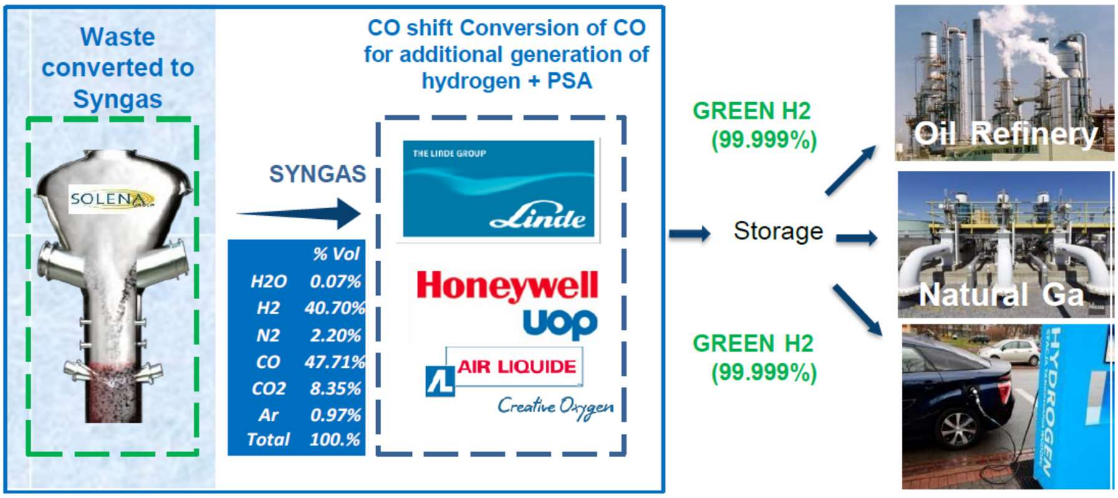
charging/fueling within few minutes, and (3) capacity to provide enough electricity for ranges up to 500 miles similar to gasoline/diesel fueled vehicles. As an energy carrier, Hydrogen has an energy density of 40 kWh/kg, diesel and LPG at 13 kWh/kg and battery at just 0.05 kWh/kg which makes battery 800 times less favorable than Hydrogen per kg as an energy carrier. Further, it should be appreciated that in order to meet the definition of Green or Renewable Hydrogen (RH2), it must be produced with zero greenhouse gas emissions.

With the advance and successful commercialization of fuel cell technology, Hydrogen can provide instant power for electric vehicles providing long ranges, lighter and more efficient vehicles without the need for bulky and heavy batteries. A Fuel Cell Vehicle (FCV) with a H2 tank and a Fuel cell pack * which weighs 80 kg) can be charged with 5 kg go H2 in 3-4 minutes and has a range of up to 500 miles; a Tesla S (Electric Battery Vehicle) has a battery that weighs 550 kg, takes 5 hours to charge and has a range of 220 miles. Some of the largest car manufacturers such as Toyota, Audi, Hyundai, BMW, Honda, Volkswagen and Mercedes Benz have all committed to stop producing combustion gas Engines (CGE) by 2030, and are focusing on the development of FCVs with Hydrogen as the fuel of choice over batteries. Similarly, top oil companies such as Shell and Chevron has adopted H2 as the futures fuel of choice and are installing H2 fueling pumps at their respective gas stations worldwide, staring with California, the United Kingdom and Germany.

Today almost 95% of the hydrogen produced is “Grey” Hydrogen, so named because it is generated from fossil fuels – especially natural gas and coal. Several decarbonization pathways exist, including blue hydrogen (capturing carbon emissions at the point of production) and green power-to-gas (generating hydrogen with an electrolyzer), driven by renewable electricity.

However both of these decarbonization pathways are facing severe challenges: (A) to produce blue hydrogen by capturing carbon emissions would require the utilization of yet to be proven energy intensive technology of carbon capture and then there is the challenge of the disposition of the captured CO2 in a cost efficient manner; (B) green power-to-gas or electrolytic hydrogen is considered green only if renewable energy such as solar and wind are used; however the process still faces several key challenges: (i) intermittent production (ii) high intense parasitic load (iii) high costs of solar and wind electricity (iv) limitation of electrolytic equipment capacity makes the production of green renewable electrolytic hydrogen very expensive. **A strong additional candidate for the production of cost effective RH2 in Tasmania that can be done at large scale is the conversion of biogenic fraction of MSW as renewable feedstocks into RH2.**

Below we have illustrated SG H2 Energy’s proprietary gasification process that is utilized in the UWTH2 Project.



The solid waste feedstock is converted into a "bio-syngas" (BSG) with temperature exiting the gasifier in the range of > 1250 °C whereby the feedstock's organic hydrocarbon chains are completely broken down. The resulting BSG is free of tar/soot, heavy metals, and other long chain hydrocarbons (CxHy) which are precursors for the carcinogenic dioxins and furans (SVOCs) . The BSG is then processed with a waster gas shift unit to produce more H2 which is then purified through PSA units to produce 99.999 pure renewable H2. The production is estimated at 11 tons of green H2 per day from 120 tons of Waste feedstocks per module. Additional modules can be added for larger capacity. The costs of production of RH2 from this process are 3 times cheaper than by Electrolysis of water and compatible with the costs of reformation of Natural gas to H2 (in the US where NatGas are cheap).

Brown H2 produced from Nat gas has a very heavy carbon footprint: Production of one ton of Brown H2 requires 3 tons of NatGas and generates 10 tons of CO2. Generating green H2 by electrolysis requires large amount of H20 and renewable electricity, which makes it too expensive and not competitive to today's NatGas based H2, requiring subsidies.

SGH2 CONSORTIUM:

SGH2 has partnered with the world's best of class companies and institutions in the Hydrogen industry including:

- SHELL NEW ENERGIES
- FLUOR GROUP
- HYET H2
- HEXAGON PURUS
- THERMOSOLV
- LAWRENCE BERKELEY NATIONAL LABORATORY
- UNIVERSITY OF CALIFORNIA BERKELEY
- UNIVERSITY OF CALIFORNIA IRVINE
- WESTERN RESEARCH INSTITUTE

- HATCH GROUP
- HONEYWELL/UOP

RESEARCH & DEVELOPMENT OF HYDROGEN:

The SGH2 academic and institutional R&D team includes the US Department of Energy Fuel Cell land Hydrogen Department, it's Lawrence Berkeley National Laboratory, the Western Research Institute and the UC Berkeley and UC Irvine , and can collaborate with the Australian Blue Economy Cooperative Research Center and the University of Tasmania to continue the promotion and development of the Hydrogen Economy in Tasmania.

UWTRH2 GREEN HOUSE GASES BENEFITS:

- **Green House Gas Emissions and CO2 credits;** For the WTRH2 facility, the Hydrogen produced is renewable due to its feedstocks composition. As part of the proposed developments of a WTRH2 project in Tasmania, the **Lawrence Berkeley National Laboratory / University of California, Berkeley** team shall perform a detailed Life Cycle Assessment of the Hydrogen produced to quantify the carbon footprint and the associated CO2 credits. Based on preliminary LCA work performed, it is estimated that, on a per-ton basis, the Hydrogen produced at the UWTRH2 facility will earn: (1) offset 10 tons of CO_{2e} in CO2 credits, which is equivalent to CO_{2e} emitted from the production of one ton of H_2 from natural gas and (2) earn an additional 13.2 - 19 tons of CO2 credits from the avoidance of fugitive landfill methane that would otherwise result if the waste feedstocks were landfilled. This totals to a combined 23.2 – 29 tons of CO2 earned per ton of Hydrogen produced by the UWTRH2 facility.
- **Carbon Intensity (CI)**: The CI is the key number whereby renewable energy fuel source are calculated based on the Life cycle assessment of the fuel production and compared to fossil fuel. Renewable Hydrogen produced by electrolysis with only renewable energy earned a CI of Zero (0) kgCO2eq/kg of H2, while the CI of RH2 produced by UWTRH2 is measured at (Minus) -188 kgCO2/kg of H2 based on the LCA as explained above. Therefore the utilization of RH2 produced from UWTH2 will reduce significantly more GHG than other forms of RH2 and help Tasmania achieve its CO2 reduction goals much faster.

ADVANTAGES OF SGH2 TECHNOLOGY FOR THE PRODUCTION OF RH2 in Tasmania :

- Uses abundant low costs waste feedstocks in Tasmania with sustainable waste management practices and zero landfill solution
- Base-load production of RH2 at lowest costs of production for local uses and/or export
- Local employment of 40 permanent jobs per facility
- Foreign Direct investment for Tasmania
- Joint US and Tasmania R&D with University of California systems and US DOE laboratory
- Technology Transfer for the Proprietary SPEG technology (Solena Plasma Enhanced Gasifier) which key advantages include: (I) very high operating temperature allowing complete gasification of fixed/volatile carbons, elimination of tar formation, and capacity to handle complex solid feedstocks; (II) atmospheric pressure operation allowing simple feeding system, less feedstock preparation, and lower operating costs, construction and maintenance; (III) no polluting emissions of ash or char, (IV) base load 8000 hours per year operation resulting in significantly lower production costs of RH2.
- Best available technology: The fact that large scale gasification technology has been built and

operated globally for the production of H2 using diverse feedstocks from coal, Coke to biomass is a strong indication that Gasification is a viable technology for the prosecution of Hydrogen at scale. The proposed UWTRH2 gasification technology has been vetted by top gasification experts minimize any development risks.

SGH2 UWTH2 PROJECTS UNDER DEVELOPMENT GLOBALLY

In addition to Tasmania,, SG H2 Energy Global, LLC is currently developing the UWTH2 Projects globally including Australia, California, Netherlands, Poland, Ukraine, Russia, Japan, Korea, Brazil, Saudi Arabia and China.

SGH2 PROJECT DESIGN BLOCK FLOW & ECONOMICS

The UWTRH2 can be designed and built at the Bell Bay Advanced Manufacturing facility, with production of RH2 to be transported by Hexagon Mobile pipeline systems to the Ports for export or for injection into the Tasmanian HDPE pipeline to reduce Tasmania CO2 footprint.

The WTRH2 facility is estimated to cost 55 Million US$ and can be constructed in 18 months upon permitting, and can have an off-take agreement with Shell for mobility HRS or export and or an offtake agreement with the AUS Nat Gas Networks for injection up to 10% into the NatGas pipeline. The Project will be financially feasible at half of today's market costs of H2. A Block Flow Diagram of a Completely integrated UWTRH2 facility in shown below, and can be sited on a 1 hectare industrial site.

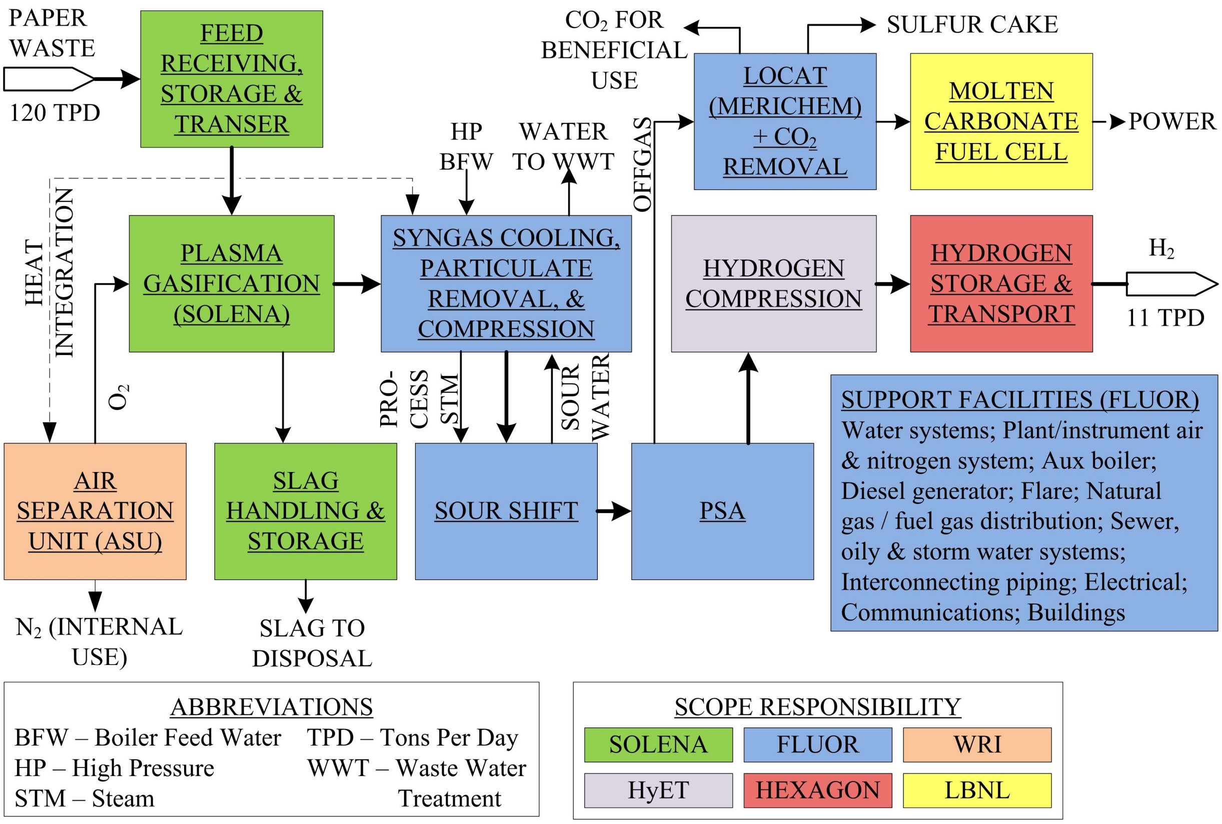


Figure 1. Block Flow Diagram of the WTRH2 production facility

PROJECT'S ECONOMICS

The Lancaster WTRH2 facility will produce 11,000 kg per day or 3,800,000 kg of RH2 per year , sufficient to fill up 2200 FCVs per day and or injected into the NatGas pipeline. With an estimated Capital costs of US$55 Million and a 30%/70% equity/debt ratio, the project will generate a revenue stream of over $ 25 M and an after tax Return on Investment (After Tax ROI) of est. 23.5% and after Tax Return on Equity (After Tax ROE) of over 45% with an offtake agreement for 7$ per kg with Shell, which is half the market price for H2 in California (* current 2018 price at the pump in CA is 16$ / kg) and no anticipated tipping fees received for waste disposal.

Each UWTH2 projects are developed via Special Purpose Companies , created and registered in each country, in partnership with local strategic partners. The SPCs will be responsible for the complete Build , Own and Operation of the UWTH2 Projects.

Return	Before Tax	After Tax	CAPEX (US$)	Grant (US$)	RDF Treated (MT/Year)	Tipping fees ($/MT)	Production H2 (Kg/year)	Hydrogen Price ($/Kg)
ROI	29.04%	23.51%	$55,042,523	0	40,000	0.0	3,800,000	$7.00
ROE - 30% Equity ratio	55.26%	45.03%						

COSTS OF PRODUCTION OF RH2 FROM SGH2 FACILITY:

The costs of production of RH2 from the Gasification of waste feedstocks are based on the combined costs of waste tipping fees and the operational costs of the UWTRH2 facility. The table below demonstrated the costs of production and its sensitivity based on varying tipping/gate fees and the varying Capital costs which depends on the site and local conditions.

These costs are 3-4 X lower than the costs of production of RH2 from electrolysis today around the world. Certainly, with the abundance of cheaper renewable energy in Tasmania, the costs of electrolytic RH2 will be lower than at other locations; however, due to the intermittent availability of solar and wind energy, as well as the high electricity demand to electrolyze water of 41 KWh to produce one kg of H2, the costs of RH2 by electrolysis will still be significantly higher than from the gasification of biogenic waste feedstocks. Therefore, UWTRH2 is an important and additional alternative to the Hydrogen Action plan for Tasmania, which shall provide additional utilization of local resources (waste biomass), produce RH2 at competitive pricing, and potentially attract local direct investment to Tasmania.

H2 PRODUCTION COST with Solena Plasma Gasification		
Tipping Fees	**20 Years Average - US$/Kg**	**PV @ 7% - US$/Kg**
0 US$/T	$2.02	$1.19
35 US$/T	$1.76	$1.02
45 US$/T	$1.57	$0.97
55 US$/T	$1.47	$0.92
65 US$/T	$1.37	$0.86

H2 PRODUCTION COST with Tipping fees @ 45US$/T, H2 @ 7US$/Kg		
CAPEX	**20 Years Average - US$/Kg**	**PV @ 7% - US$/Kg**
-10%	$1.43	$0.88
-5%	$1.50	$0.92
0%	$1.57	$0.97
5%	$1.64	$1.01
10%	$1.70	$1.05