Biomass 2 Hydrogen Pathway

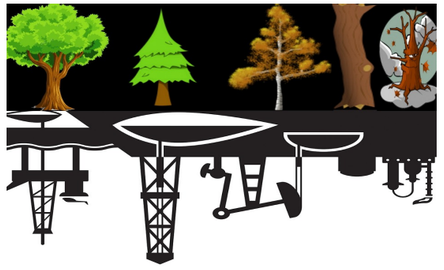
VrFarms Hydrogen 4 MicroGrids
EV SuperCharger Network

Forest Biomass 2 Hydrogen 4 SuperChargers for ZEV

We have the most Carbon Neutral Design to Power a MicroGrid + Charge an EV

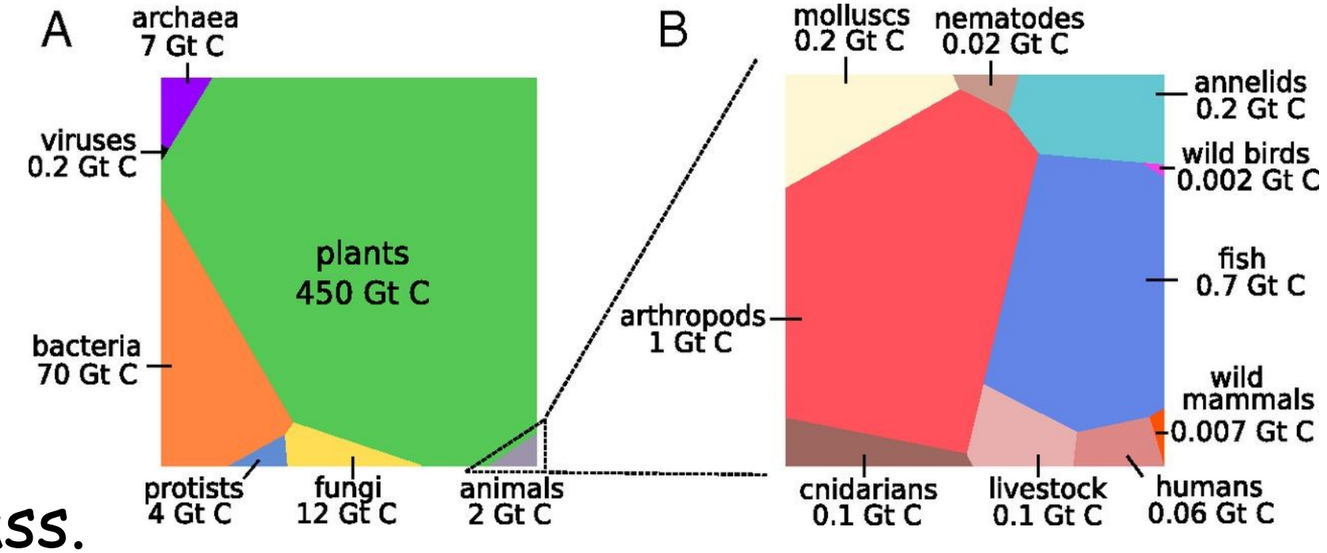
What's Cool about Biomass?

Trees – Upside Down Oil Wells



How much there is!

How much Energy it has
5000Btu/Pound
Biomass Captures CO2
Biomass is Renewable



https://www.pnas.org/content/115/25/6506

You can make Hydrogen from Biomass.

https://www.energy.gov/eere/fuelcells/hydrogen-production-biomass-gasification
https://www.energy.gov/sites/prod/files/2015/01/f19/billion_ton_update_0.pdf

What can you do with Hydrogen from Biomass?

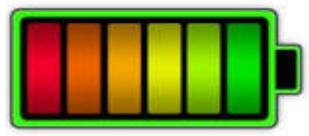
Forest & Urban Biomass is the Only
Global, Distributed, Manageable, Renewable, CO2 Capturing Energy Source from which you can Easily Produce Hydrogen

Make Managing (Not Clear Cutting) a Forest Cost Effective,
Charge Electric Vehicles, Power Greenhouses Everywhere,
Make the Grid More Efficient by Connecting at the Ends of the Grid,
Implement a Biomass 2 Hydrogen 2 Electric Economy

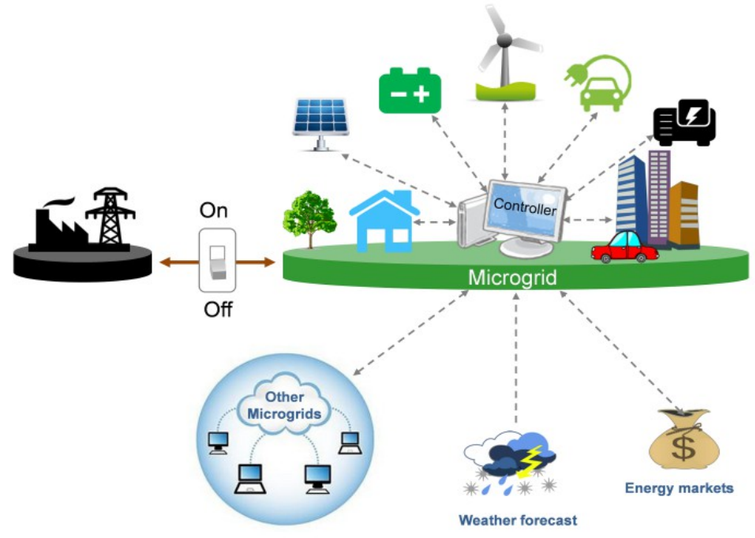
VrFarms
Hydrogen Production
Confidential and Proprietary

Charge Grid Scale Battery Banks

DC Electricity Out



2 Mwh Battery



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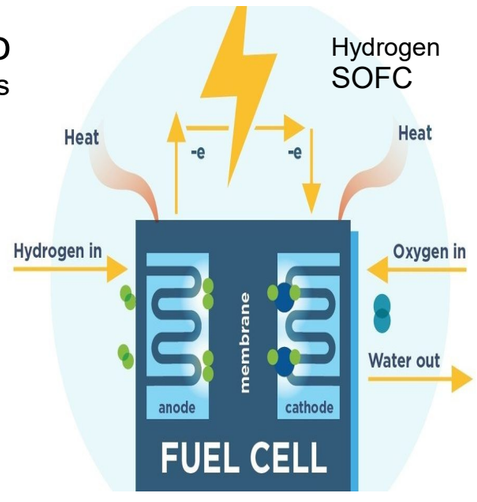
Use Mobile Pipelines to Truck it to

Grid Connected MicroGrid EV Charging Stations



MicroGrids

250kw Fuel Cells x 4
Plus Heat Out

VrFarms
Biomass2Hydrogen
Thermal Energy Storage (**TES**)
Confidential & Proprietary

5850 scfm capturing H2
12% - 702 scfm / 423.4 scf/Kg = 1.65 Kg/min
20% - 1170 scfm / 423.4 scf/Kg = 2.76 Kg/min

MgFeH6 Thermal Energy Storage TES
Continuous H2 Flow – 10 bar – 145 psia
400 C – 752 F

VrFarms
Hydrogen
Production
Confidential and Proprietary

Thermal Efficiency - 52%
41.6 MMBtu/hr In
21.7 MMBtu/hr Out
Plus Hydrogen

Ionic Liquid Piston Compressor
Electrochemical Compressor

Hydrogen
Capture

50% Nitrogen
Used for
ETFE Roof
+
Liquid Nitrogen TES

Nitrogen
Membrane
Separation

Ambient
Air In

40% N
40% O
?%CO2
Steam

Steam Reform
Water-Gas
Shift

Wood Biomass
Gasifier

Biomass In
5000 Btu/#
694444 Btu/min
41.6 MMBtu/hr
100 TPD

CO2
Feedback

H2 In
2 Kg/min

H2 In
1 Kg/min

Mg2FeH6

1 Kg/min
H2 Out

Temp-Pressure Curve

Heat
Exchanger

117315
Btu/min
To TES

H2 In
1 Kg/min

Mg2FeH6

1 Kg/min
H2 Out

Heat
Exchanger

117315
Btu/min
To TES

Hydrogen Out
Compressed Storage

2 Kg/min
120 Kg/hr

Site Working
Thermal Energy Storage
TES

Steam
Hi-Temp

Steam
Low Temp

Thermal
Fluid
Hi-Temp

Thermal
Fluid
Low Temp

Water
LowTemp

Water
Hi-Temp

Combined
BTUs
117315
117315
126360

360990 Btu/min
21.7 MBTU/hr

Syngas Heat
Capture To TES

126360
Btu/min

Fuel Cell Electric Vehicles (FCEV) Make No Sense

Therefore we propose

Biomass 2 Hydrogen 4 EV SuperChargers

Hydrogen Fuel Cell Electric Vehicles (FCEV)

Hydrogen Fuel Capacity – 4 Kg – 133 KWh
Driving Distance – 350 to 450 miles
Few and Expensive Fueling Stations
Hydrogen made by Electrolysis or Reforming
Most Hydrogen made using Fossil Fuel or Fossil Electric
Reformed H2 is Compressed and Trucked Long Distance
Less Efficient - No use for all the Heat Produced by Fuel Cell
Hydrogen to Fuel Cell to Electric to Battery to Electric Motor
FCEV 50% Fuel Cell Efficiency Loss is built into the Car

Electricity is Everywhere – Compressed Hydrogen is Not

Hydrogen Supercharger Network for Electric Vehicles (EV)

Electric Battery Capacity – 85 Kwh
Driving Distance already at 300 miles
20 minute Charge Time for 100 miles using H2 SuperChargers
Hydrogen produced from Biomass with 50 mile Radius of Delivery
Hydrogen Produced at 80% Efficiency with Heat Powering Greenhouses
Compressed Hydrogen Trucked under 50 miles to SuperChargers
Fewer Moving Parts – Battery and Electric Motor
Power Into Battery is what you get Out to Motor
EV More Efficient than FCEV at Car Level

Electricity is Everywhere

Biomass to Steam Boiler Cooling Tower to Electric Power Plants Make No Sense

We propose Biomass 2 Hydrogen Co-Generation

Biomass to Electric Power Plants (BPP)

Biomass Power Plants Generate Electricity at 20% Efficiency
60% of Biomass Energy is Wasted in Cooling Towers
BPP Sell Expensive (or subsidized) Electricity to the Grid
BPP Drives up Electricity Cost for Everyone
Biomass is hauled more than 50 miles
BPP Emit CO2 – So Technically Not Carbon Neutral
ZEVs are not ZEV if Charged by the Grid

Biomass 2 Heat + Hydrogen

Biomass is very good at making Heat for Heating Buildings
We Heat Greenhouses as a Heat Sink to replace Cooling Towers
Co-Generation increases Efficiency to above 60%
Biomass is good at making Hydrogen
Before now there were few ways to process Hydrogen
Metal Hydride, MOF, & Compressed Hydrogen now available
Hydrogen Fuel Cells are now available

VrFarms – Hydrogen for SuperChargers for EV (with Zero CO2 Emissions)

Heat Balance Biomass2Hydrogen – Confidential & Proprietary

Input - 100 TPD Biomass @ 5000 BTU/# (1 billion btu/day)
Produces approx 5850 scfm @ 1400F = 41.6 MBTU/hr = 683333 btu/min

VrFarms
Hydrogen Production
Confidential and Proprietary

Biomass to Grid Electricity Power Plants Make no Sense

plus emit CO2

We can put EV Charging Stations where there is no Grid

Biomass Power Plant Wood Gasifier Combustion to Heat to Electric

100 TPD 5850 scfm, (700C) 1292 F, GHV ~ 129 BTU/scf
Approx energy 129 BTU/scf x 5850 scfm **754650 BTU/min**, 45279000 BTU/hr

Sterling or Steam Rankine Cycle Generator Efficiency ~60%
452790 BTU/min to Electricity 269100 BTU/min to Cooling Tower or CHP

Steam Turbine Generator Efficiency ~40%
269100 BTU/min to Electricity 403650 BTU/min to Cooling Tower or CHP

Hydrogen Capture + Water-Gas Shift CO to Hydrogen

2 Kg/min of H2 Captured into Metal Hydride (@ 16% by vol of H2)
+
Flue Gas Heat Recovery from 1400F to 200F = 126360 BTU/min

Wood Gas Composition

Carbon monoxide	27.0%
Hydrogen	14.0%
Carbon dioxide	4.5%
Methane	3.0%
Oxygen	0.6%
Nitrogen	50.9%

H2 Capture into MH TES H2 – GHV = 325 BTU/scf 1 Kg of H2 = 423.4 SCF
5850 scfm capturing H2 into MH TES MgH2 = 71100 BTU/Kg
12% - 702 scfm / 423.4 scf/Kg = 1.65 Kg/min H2 at 12% = 117315 BTU/min
20% - 1170 scfm / 423.4 scf/Kg = 2.76 Kg/min H2 at 20% = 196236 BTU/min
30% - 1755 scfm / 423.4 scf/Kg = 4.15 Kg/min H2 at 30% = 294710 BTU/min
40% - 2340 scfm / 423.4 scf/Kg = 5.57 Kg/min H2 at 40% = 392947 BTU/min

Modeled on Concentrated Solar Power TES
Footnote 30 and Table 1 Pressure – Temperature Chart
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2662468/
MgH - 75 kJ/mol x 1000 mole/Kg
75000 KJ/Kg x 0.948 BTU/KJ = 71100 BTU/Kg

VrFarms
Biomass2Hydrogen
Thermal Energy Storage (**TES**)
Confidential & Proprietary

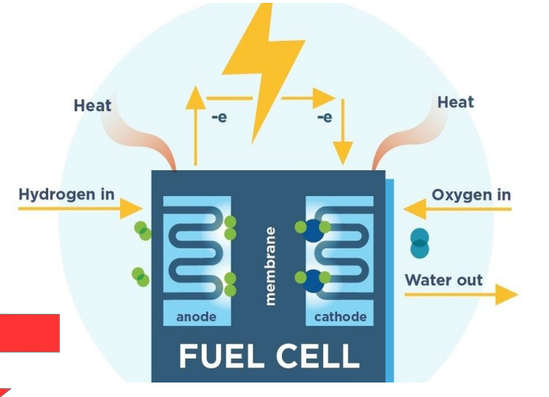
Hydrogen for Sale

Hydrogen Out
2 Kg/min
120 Kg/hr

Ionic Liquid Piston Compressor
Electrochemical Compressor

Compressed Hydrogen Storage

Hydrogen to Fuel Cell



Heat Back to **TES**

Hot Water Out
Back to **TES**

VrFarms

Hydrogen Production
Confidential and Proprietary

Electricity to Site Use

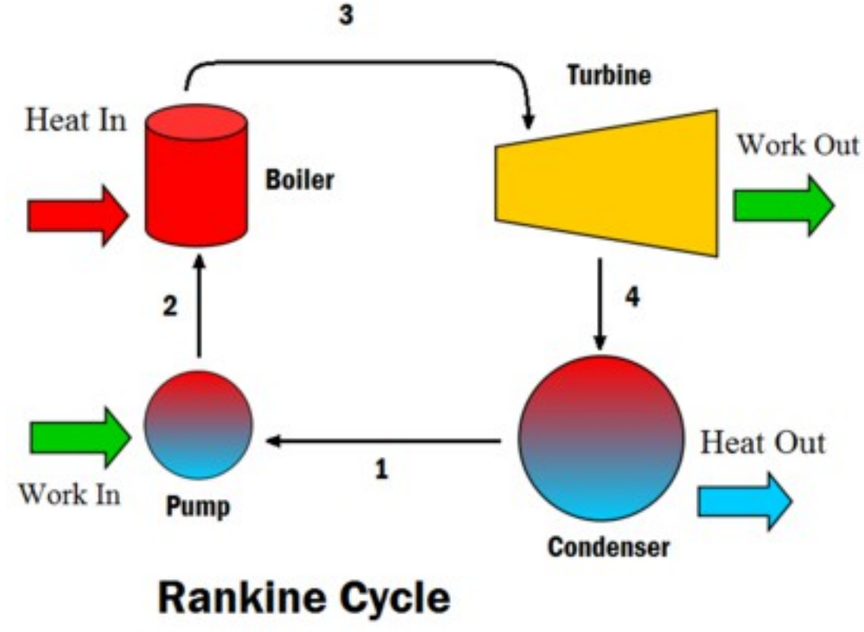
Site Working Thermal Energy (**TES**)

Combined BTUs
2 Kg/min into MH 234630
Flue Gas Heat Recovery 126360

360990 Btu/min
21.7 MBTU/hr

Steam Hi-Temp
Steam Low Temp
Thermal Fluid Hi-Temp
Thermal Fluid Low Temp
Water LowTemp
Water Hi-Temp

Steam In From **TES**



Electricity to Site

Cold Water In from **TES**

Hot Water Out
Back to **TES**

100 TPD Biomass In
Gasifier Output
41.6 MMBtu/hr

VrFarms
Biomass2Hydrogen
Thermal Energy Storage (**TES**)
Confidential & Proprietary

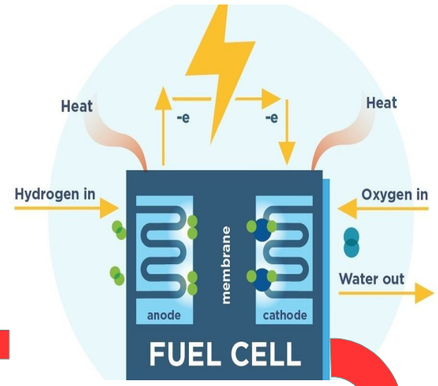
Hydrogen for Sale

Hydrogen In
2 Kg/min
120 Kg/hr

Compressed Hydrogen Storage

Hydrogen to

Onsite SOFC



Heat Back to TES

Hot Water Out Back to TES

VrFarms

Hydrogen Production
Confidential and Proprietary

Onsite Electricity

Nitrogen Filled ETFE Pillow Covered Greenhouses

Lease Greenhouse Space via Triple Net Leasing for Greenhouse Financing

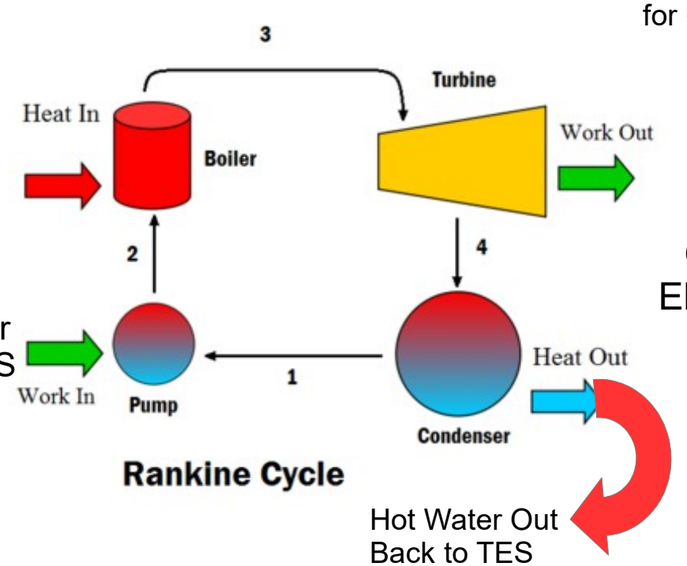
Working Thermal Energy

Heat In
Combined BTUs
117315
117315
126360

360990 Btu/min
21.7 MBTU/hr

Steam Hi-Temp
Steam Low Temp
Thermal Fluid Hi-Temp
Thermal Fluid Low Temp
Water LowTemp
Water Hi-Temp

Steam In From TES



Onsite Electricity

Hot Water Out Back to TES

Biomass In
694444 Btu/min
41.6 MMBtu/hr
100 TPD

Greenhouse Heating, Cooling, Humidity Control

VrFarms
Biomass2Hydrogen
Thermal Energy Storage (**TES**)
Confidential & Proprietary

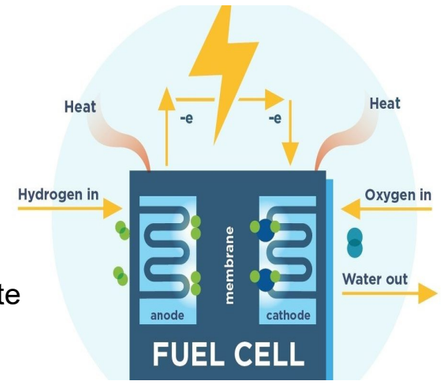
Onsite Hydrogen Production

Hydrogen for Sale
1000 Kg/day - $10/Kg

Hydrogen In
2 Kg/min
120 Kg/hr

500 bar
Compressed
Hydrogen
Storage

Hydrogen to On-Site
SOFC w/ CHP



On-Site Process
and Greenhouse
Electricity

Heat Back
to TES
~ 50% of
Input Energy

Onsite Working
Thermal Energy (TES)

Steam
Hi-Temp

Steam
Low Temp

Thermal
Fluid
Hi-Temp

Thermal
Fluid
Low Temp

Water
LowTemp

Water
Hi-Temp

VrFarms

Hydrogen Production
Confidential and Proprietary

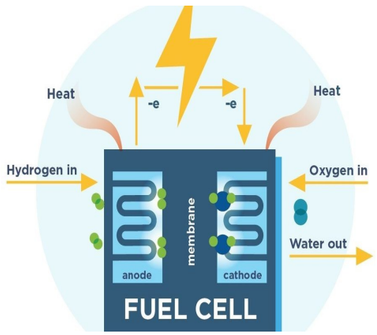
250 bar Hydrogen
Mobile Pipeline
350Kg Hydrogen - $360K

https://www.hexagonlincoln.com/mobile-pipeline/titan/titan

Wireless Electricity (no Grid required)

Hydrogen Delivered to EV Charging Stations

350Kg H2 - 11550 KWh
100 – 50KWh EV Charges
5000 Kwh delivered point A to B



Level 3 DC Fast Charging
4 x 250 KW SuperCharger
SOFC /w CHP
$1.5M

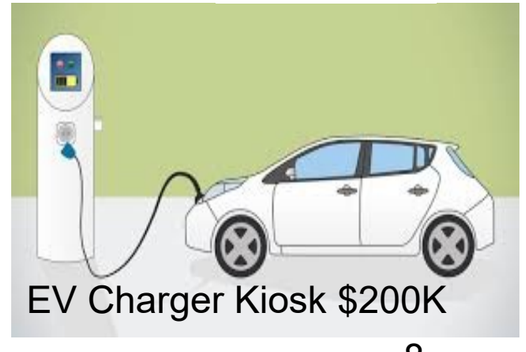
Hydrogen Converted to Electricity
at EV Charging Station Sites
Grid-less Electricity Delivered

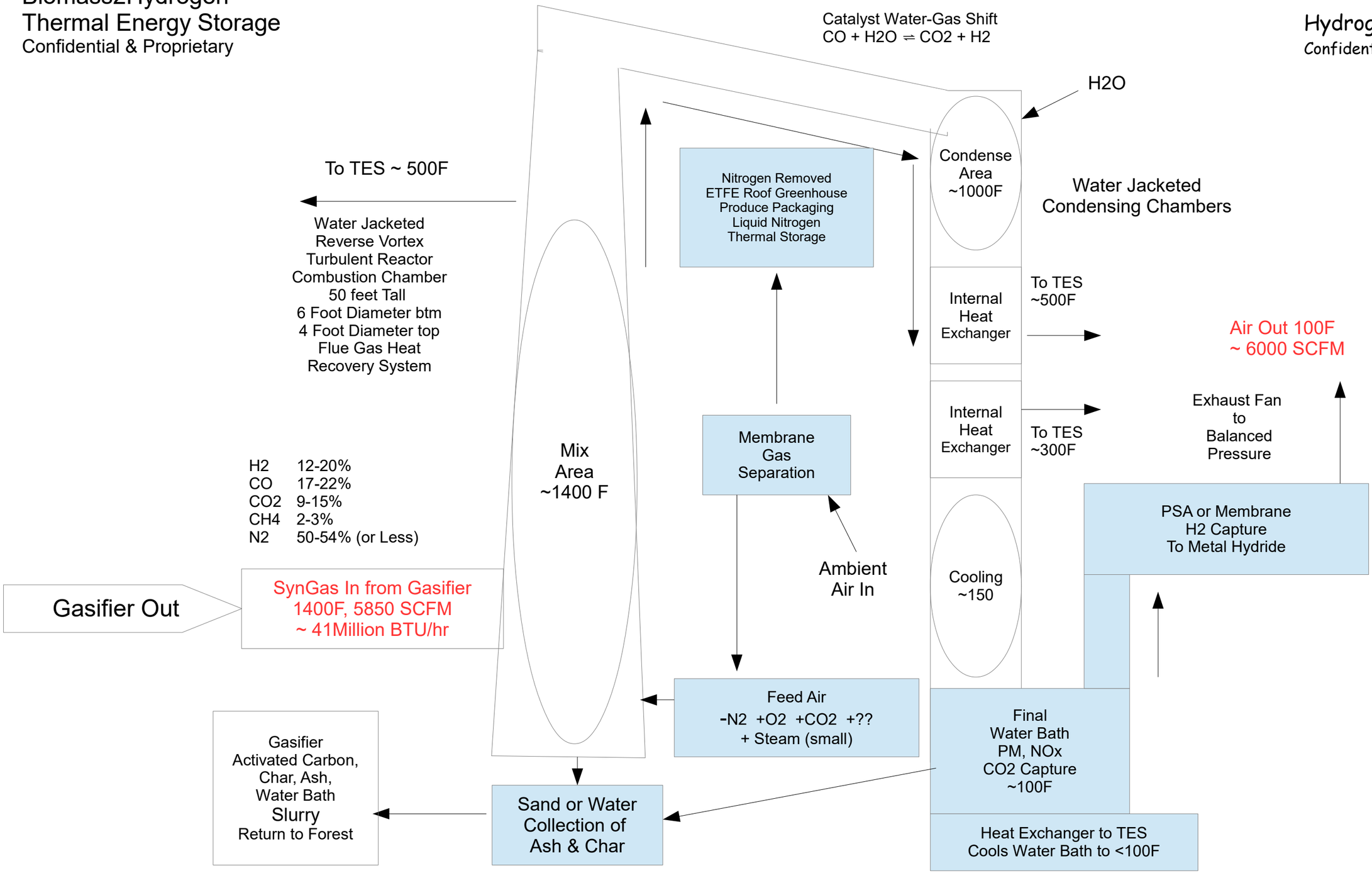
MicroGrid
Connected

2 MWH
Battery $1.5M

Hydrogen SuperCharger
Network

300 EV Charging Sites
1 Kg Hydrogen = 33 Kwh
Fuel Cell Eff – 50%
2.8 Kg H2 = 50 Kwh Charge
Retail $25 ($6 profit/chg)
$28 cost of Hydrogen
50 Kwh x .18/Kwh = $9
18 cent/Kwh Carbon Credit
18 cent/Kwh PPA BioMAT




Catalyst Water-Gas Shift
CO + H2O ⇌ CO2 + H2
H2O
To TES ~ 500F
Water Jacketed
Reverse Vortex
Turbulent Reactor
Combustion Chamber
50 feet Tall
6 Foot Diameter btm
4 Foot Diameter top
Flue Gas Heat
Recovery System
Nitrogen Removed
ETFE Roof Greenhouse
Produce Packaging
Liquid Nitrogen
Thermal Storage
Condense
Area
~1000F
Water Jacketed
Condensing Chambers
Internal
Heat
Exchanger
To TES
~500F
Air Out 100F
~ 6000 SCFM
Exhaust Fan
to
Balanced
Pressure
Internal
Heat
Exchanger
To TES
~300F
Membrane
Gas
Separation
Mix
Area
~1400 F
Ambient
Air In
PSA or Membrane
H2 Capture
To Metal Hydride
Cooling
~150
H2 12-20%
CO 17-22%
CO2 9-15%
CH4 2-3%
N2 50-54% (or Less)
Gasifier Out
SynGas In from Gasifier
1400F, 5850 SCFM
~ 41Million BTU/hr
Feed Air
-N2 +O2 +CO2 +??
+ Steam (small)
Final
Water Bath
PM, NOx
CO2 Capture
~100F
Gasifier
Activated Carbon,
Char, Ash,
Water Bath
Slurry
Return to Forest
Sand or Water
Collection of
Ash & Char
Heat Exchanger to TES
Cools Water Bath to <100F

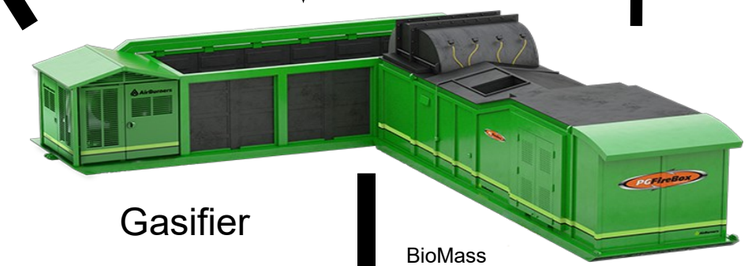
Trees Convert CO2 to Biomass

CO2 Reduced

Zero CO2 Emissions

Biomass In

Carbon Ash Back



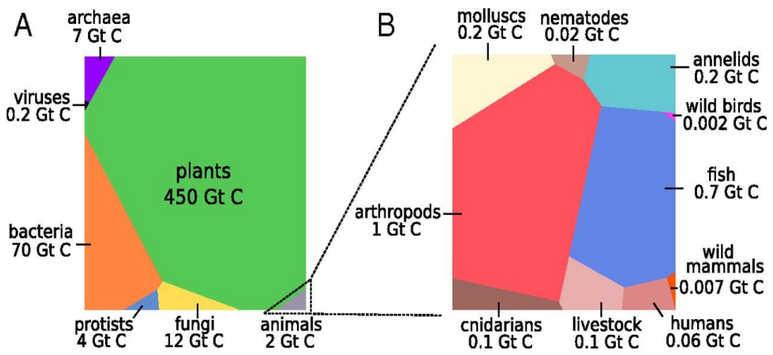
Gasifier

BioMass to HEAT + Hydrogen

BioMass Powered Hydrogen Production

Energy to Power Indoor Farming

Biomass on the Planet



BioMass 2 Hydrogen
BioMass Converted to Usable Energy On Same Site
Heating, Cooling, Electricity, 70% Efficient
10X Less Water to Grow Food
10X Less Trucking Food
Local Jobs, Local Food

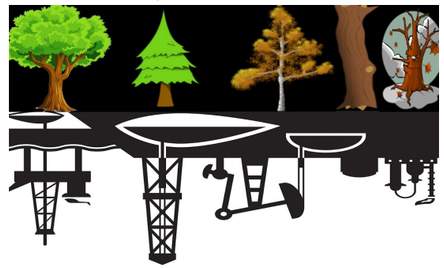
VrFarms

Hydrogen Production, Confidential and Proprietary

Forest Biomass 2 Hydrogen 4 EV SuperChargers

Executive Summary
September 9, 2019

Trees – Upside Down Oil Wells



We have the most efficient design to use Forest Biomass to make Hydrogen with Zero CO2 emissions plus almost 80% efficiency.
Our Design works since we have an onsite use for large amounts of Heat Created compressing and using Hydrogen in a Fuel Cell.
Biomass2Hydrogen for use in SuperChargers for EVs with Zero CO2 Emissions plus Power for a Greenhouse as an additional benefit.
The process uses a standard 100 ton/day wood gasifier used for hundreds of years and what is called a Water-Gas Shift Reaction discovered by Italian physicist Felice Fontana in 1780. The water gas shift converts Carbon Monoxide in Gasifier Syngas to Hydrogen. $CO + H2O \rightleftharpoons CO2 + H2$
https://en.wikipedia.org/wiki/Water-gas_shift_reaction

We Water-Gas Shift or Steam Reform Wood Gasifier Syngas to Capture Hydrogen rather than Burn the Syngas for Heat.
The Hydrogen goes into Metal Hydride TES and using Thermo-Chemical Reaction Creates Heat to Power the Greenhouse.
We produce excess Hydrogen for SuperChargers for EVs and for Thermal Storage Battery Backup for the Greenhouse.

We propose to Produce Hydrogen from Biomass for Sale for Transportation at 300 sites distributed around CA.

Zero Emission Vehicles (ZEV) are in need of Fuel. Most electricity for EV is from the grid which operates at 35% efficiency and emits CO2. We are able to produce Hydrogen from Forest Biomass. The Hydrogen will be used to power Tesla EV SuperChargers.

We change how Forest Biomass is used. Most Biomass is used to generate electricity to sell to the grid. It is expensive which hurts everyone, is only about 20% efficient, and emits CO2. Rather than combust Gasifier Syngas as is done in a Biomass Power Plant we produce Hydrogen.

We request $2.5M for Blueprints, Land, Permits, and Management Team to build our first site.

Grid Scale Battery Cost Models

https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf
https://www.energy.gov/eere/solar/articles/solar-plus-storage-101
https://www.nrel.gov/docs/fy19osti/74426.pdf

Glen Sawyer
VrFarms
916-470-5476

Hydrogen Production Site cost

Blueprints, Permits -	$2.5M
100 TPD Gasifier - Water-Gas Shift, Reform	$3.4M
Heat Recovery Chamber -	$2M
Hydrogen Recovery -	$1M
Metal Hydride, TES -	$4M
Compressors -	$2M
Fuel Cell, ORC -	$1M
On-Site Buildings -	$5M
Land -	$100K
Construction, Installations -	$4M

Hydrogen Production + Greenhouse Site +
Hydrogen Powered 1 MW MicroGrid EV SuperCharger - $30M

Hydrogen powered MicroGrid connected EV SuperCharger Network

200KW Fuel Cell w/ Heat Recovery -	$2M
Hexagon Mobile Pipeline – 350Kg Hydrogen Transport to SuperCharger sites -	$360K
EV Charging Station Kiosk	$200K
2 MWH Battery + Interconnect	$1.5M