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2009 International Wind-Diesel Workshop

Using Hydrogen Energy Storage in Remote Communities

June 1, 2009

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- Hydrogen Storage
- Hydrogenics Experience
- HES Case Study

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Hydrogenics in Brief:

- A world leading manufacturer of electrolyzers and fuel cells
- Canadian-based company with offices in Toronto, Belgium and Germany:
  - On Site Generation Systems: HySTAT™ Electrolyzers for industrial hydrogen and energy applications
  - Power Systems: HyPM ™ Fuel cells for backup power and mobility applications
  - Renewable Energy Systems: Hydrogen system applications for community energy storage and smart grid
- 1,700 + hydrogen products deployed worldwide since 1948

Hydrogen Storage

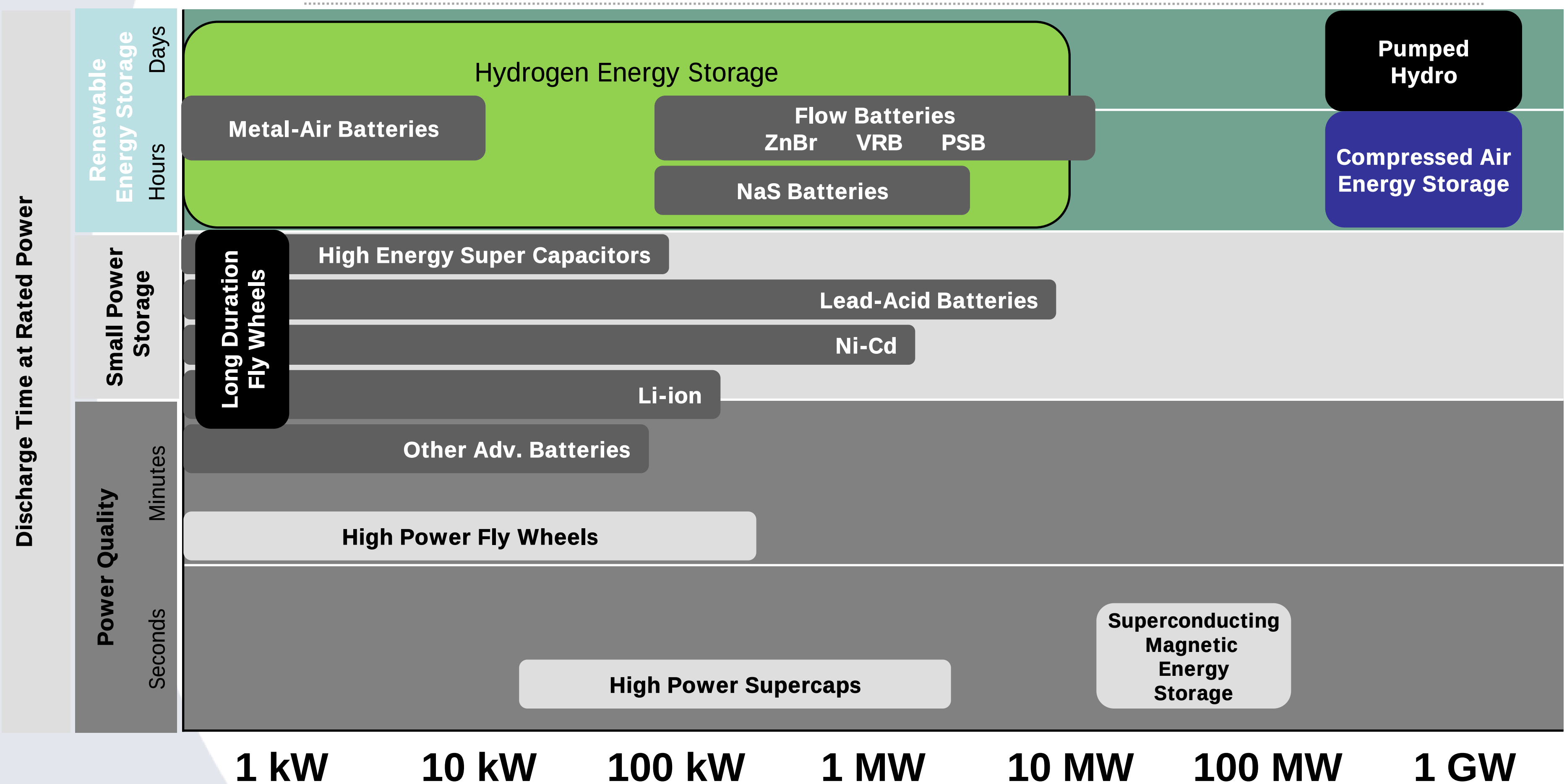
The Energy Storage Problem

100% Diesel
Diesel fuel cost driver
Imported energy
Diesel emissions

100% Wind
Capital drives cost
Fully self-sufficient
Zero-emissions

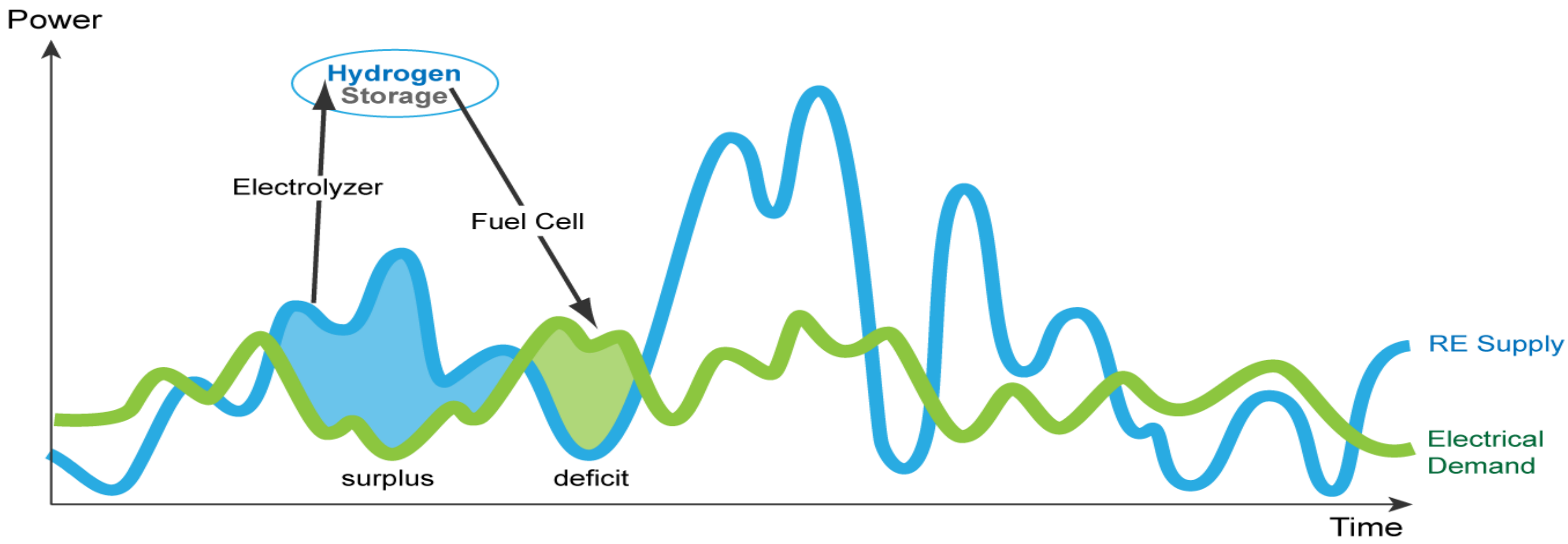
- Wind and solar are intermittent
- Diesel gensets currently provide power stability
- Energy storage is needed to maximize wind penetration
- Hydrogen storage is a good match to long-term energy storage needs for remote communities

Energy Storage Technologies



Source: Electricity Storage Association

Renewable Energy + Hydrogen Storage



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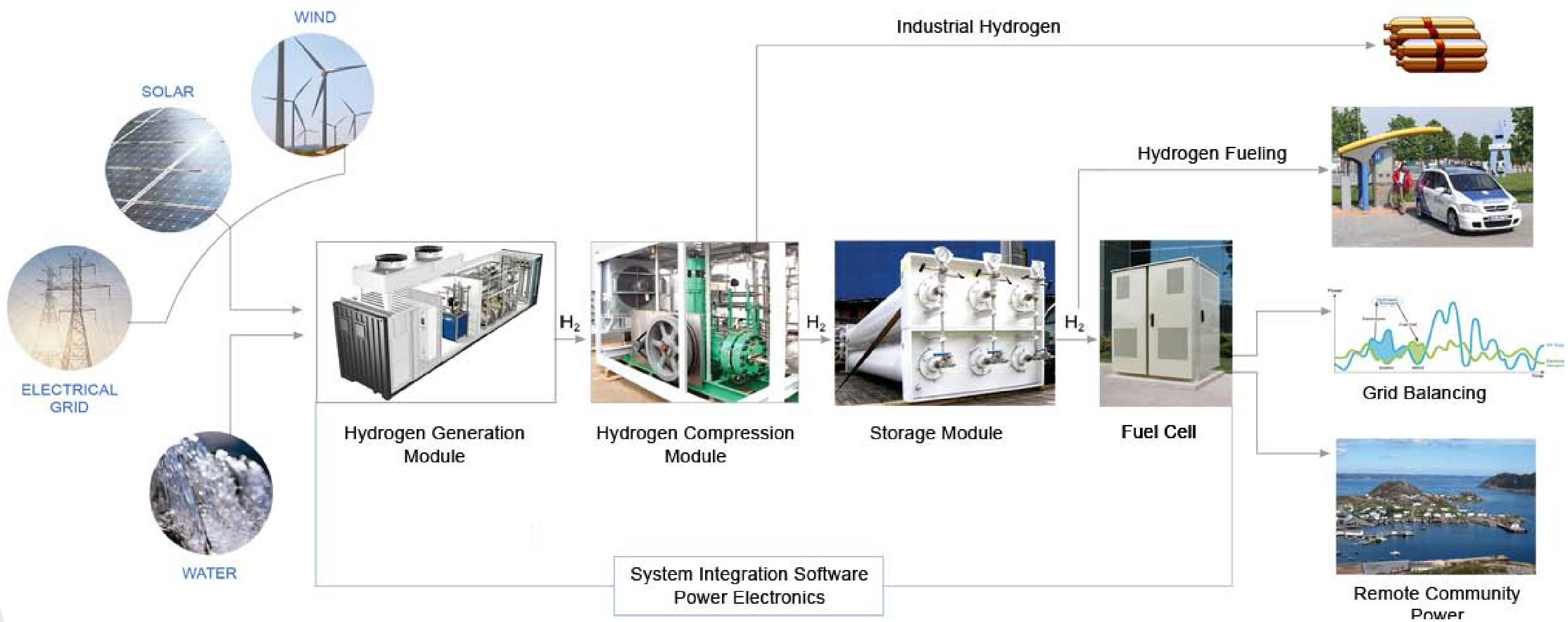
Hydrogen Advantages

- Hydrogen can store energy for long periods
  - Incremental hydrogen storage costs are a fraction of other technologies
  - No power dissipation over time
- Dissociation of charge, discharge and storage capacities
- Flexibility for use in many applications such as fueling
- Zero emissions through entire system
- Hydrogen technology continuing to develop

Hydrogen Energy System



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The HySTAT™ Electrolyzers

- Mature product serving industrial gas and fueling markets
- On-demand, onsite high purity hydrogen production
- Automated, reliable, efficient and low maintenance

HySTAT™-15

15 Nm^3/h, 1.4 kg/h

10 or 25 bar

HySTAT™-30

30 Nm^3/h, 2.7 kg/h

10 or 25 bar

HySTAT™-60

60 Nm3/h, 5.4 kg/h

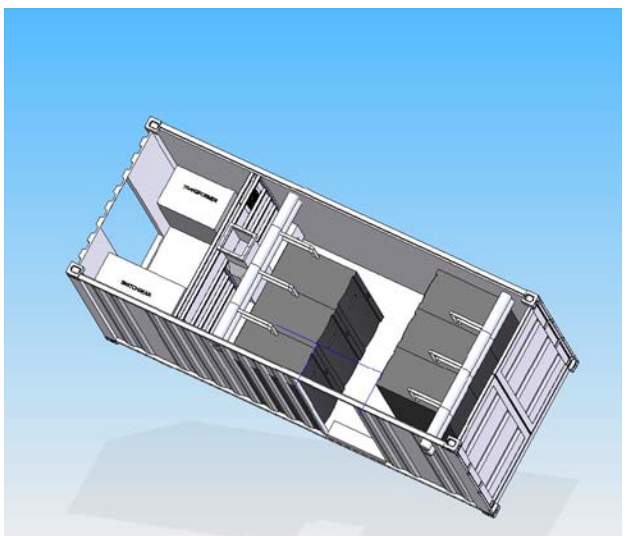
10 bar

Energy Storage – Low Incremental Cost

- Tube trailer can deliver 6 MWh from fuel cell
- No leakage and no parasitic losses over time
- Storage costs of less than $100/kWh

Containerized Fuel Cell Module

- HyPM XR rack serves backup power market
- Reliable and scalable power for critical systems
- Zero-emission, compact and highly efficient



HyPM 150KVA Fuel Cell System (20’ ISO container)

Proterra Fuel Cell Plug-in Hybrid Bus

Length	35 ft (10.7 m)
Type	Low floor
Seats	37
Max speed	60 mph (96 km/h)
Autonomy	300 mi (480 km)
Drive	32 kW PEM Fuel Cell
Motor	150 kW
Fuel	Hydrogen (99.99 %)
Hydrogen storage	30 kg
Energy storage	Li Titanate Batteries

2 x HyPM HD 16s
Hydrogenics Fuel Cells

Hybrid Midi Bus Demonstration Vehicle

Length	17 ft (5.3 m)
Type	Low floor
Seats	8 + standing
Max speed	20 mph (33 km/h)
Autonomy	125 mi (200 km)
Drive	12 kW PEM Fuel Cell
Motor	25 kW
Fuel	Hydrogen (99.99 %)
Hydrogen storage	5.8 kg
Energy storage	NiCd Batteries

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Hydrogen Experience

Renewable Energy Projects To Date

Name	Year	RE Source	Country	Equipment
West Beacon	2003	Wind + Solar	UK	HySTAT 8 + FC
Gas Natural	2007	Wind	Spain	HySTAT 60 + FC
Hychico	2007	Wind	Argentina	HySTAT 60 (x2) + H2ICE genset
Univ. of Glamorgan	2008	Wind + Solar	Wales	HySTAT 10 + FC
Basin Electric	2008	Wind	US	HySTAT 30 + storage
China Lake	2008	Solar	US	HySTAT 1 +HyPM
BC Hydro	2009	Small Hydro	Canada	HySTAT 30
Ramea	2009	Wind	Canada	HySTAT 30

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Renewable Energy Projects

- Glamorgan, Wales
- Gaz Natural SDG, Spain
- Hychico, Argentina

Glamorgan, Wales

Gas Natural SDG, Spain

Hychico, Argentina

Renewable Energy Projects

- Basin Electric, N.Dakota
- Powertech Labs, BC
- Ramea, Nfld.

Basin Electric, N. Dakota

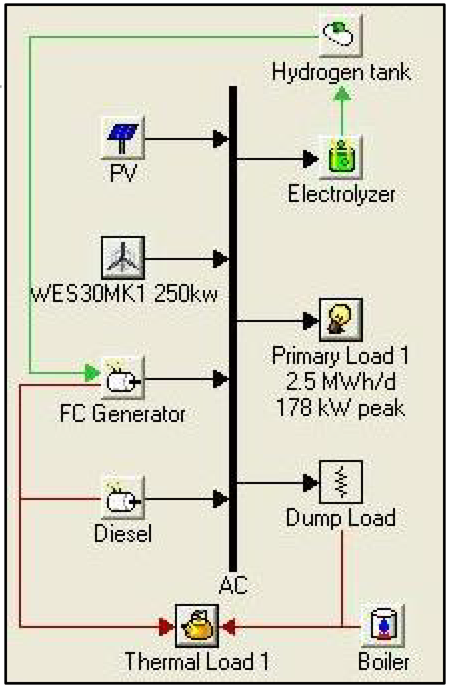
Bella Coola, BC

Ramea Is, Nfld

Wind-HES Case Study

Model Inputs

- Site Profile using Alaska Data
  - 178kW peak load, 2.5 MWh/d
  - 7.9m/s average wind speed
  - Low diesel price of $1/L
- Case A – Existing Diesel
  - Emissions based ultra low sulphur diesel
- Case B – Wind/Diesel
- Case C – Wind/PV/Hydrogen + Diesel
  - Reduced diesel consumption
- Case D – Wind/PV/Hydrogen only
  - Elimination of diesel



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Model Component Sizing

		Diesel Only	Wind Diesel	Wind/Diesel + HES	Wind + HES
Diesel	kW	190	190	190	
PV	kW		50	0	50
Wind	kW		2x250	3x250	5x250
Fuel Cell	kW			150	300
Electrolyzer	Kg/day			32	128
Storage	Kg			50	500

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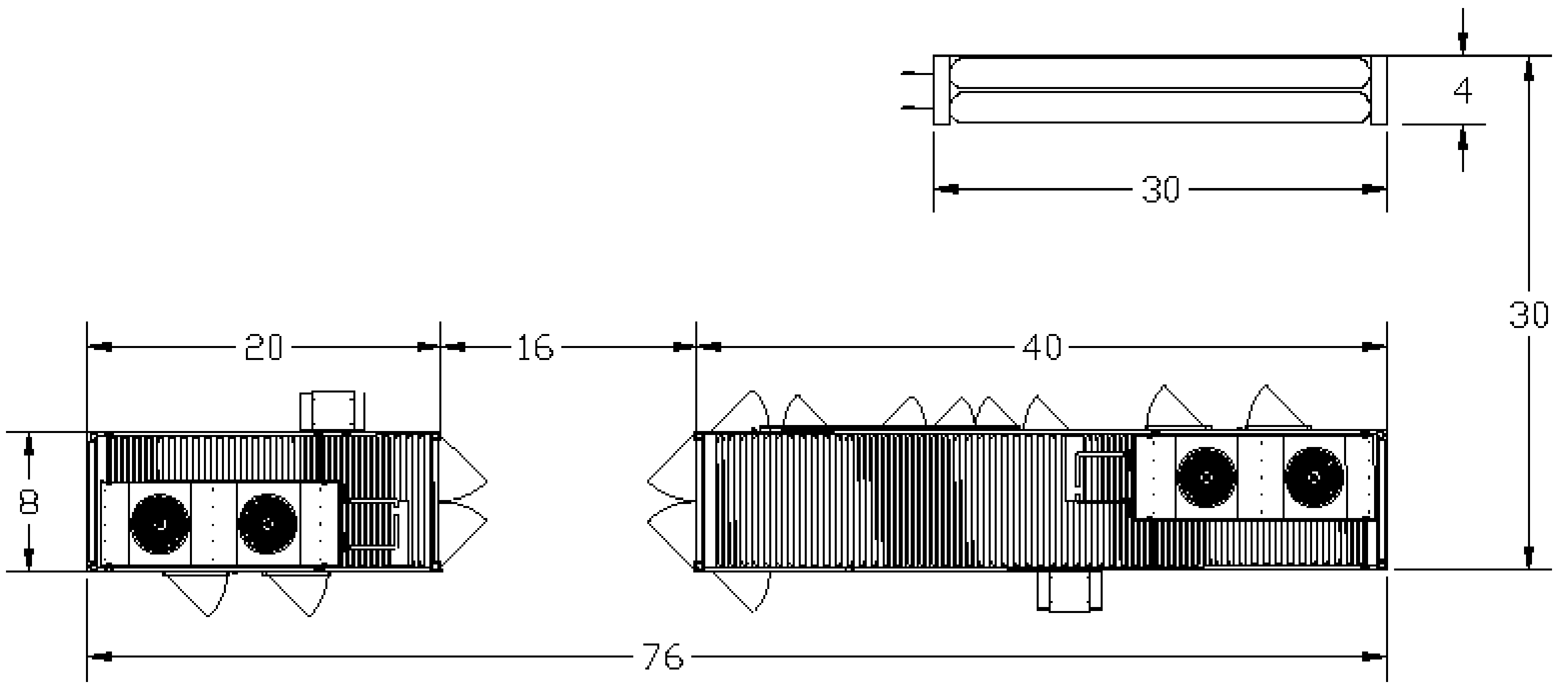
Wind/Diesel + HES Site Layout



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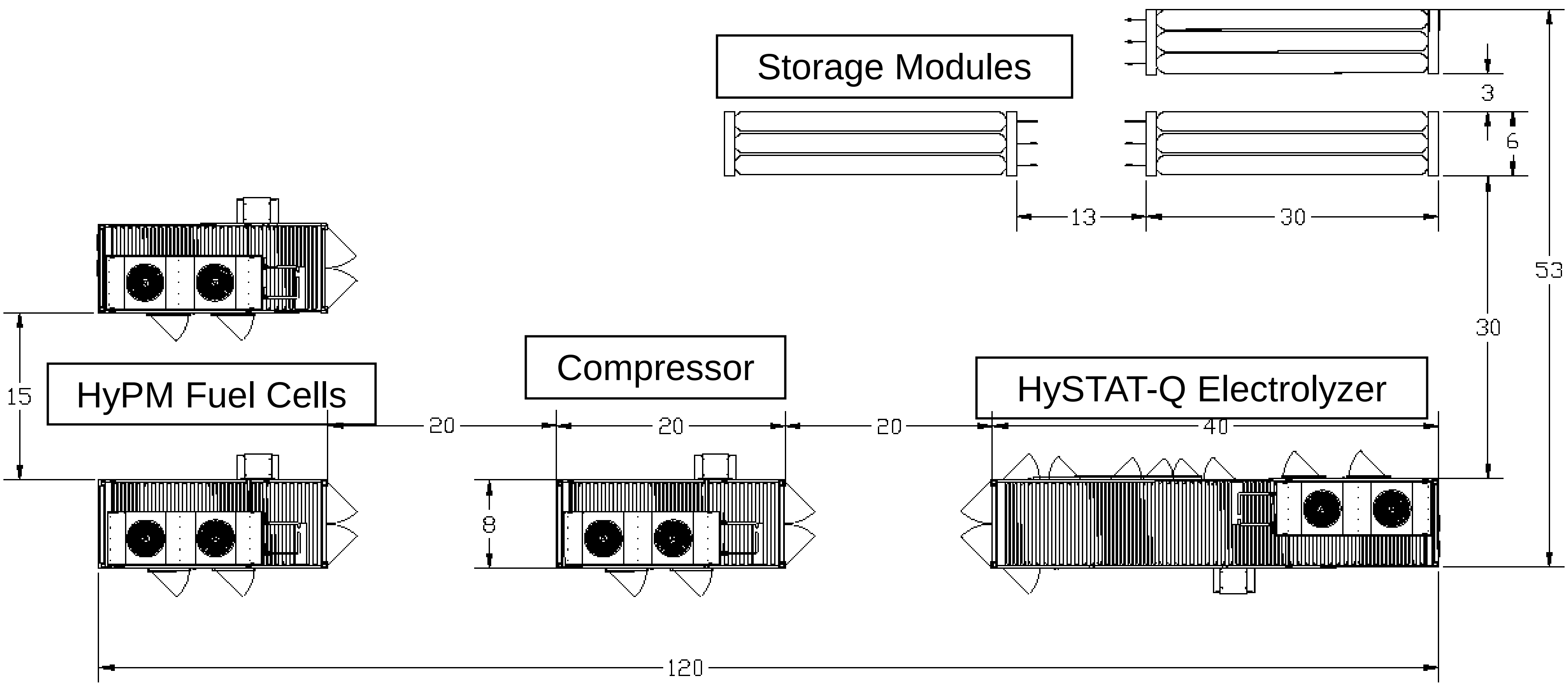
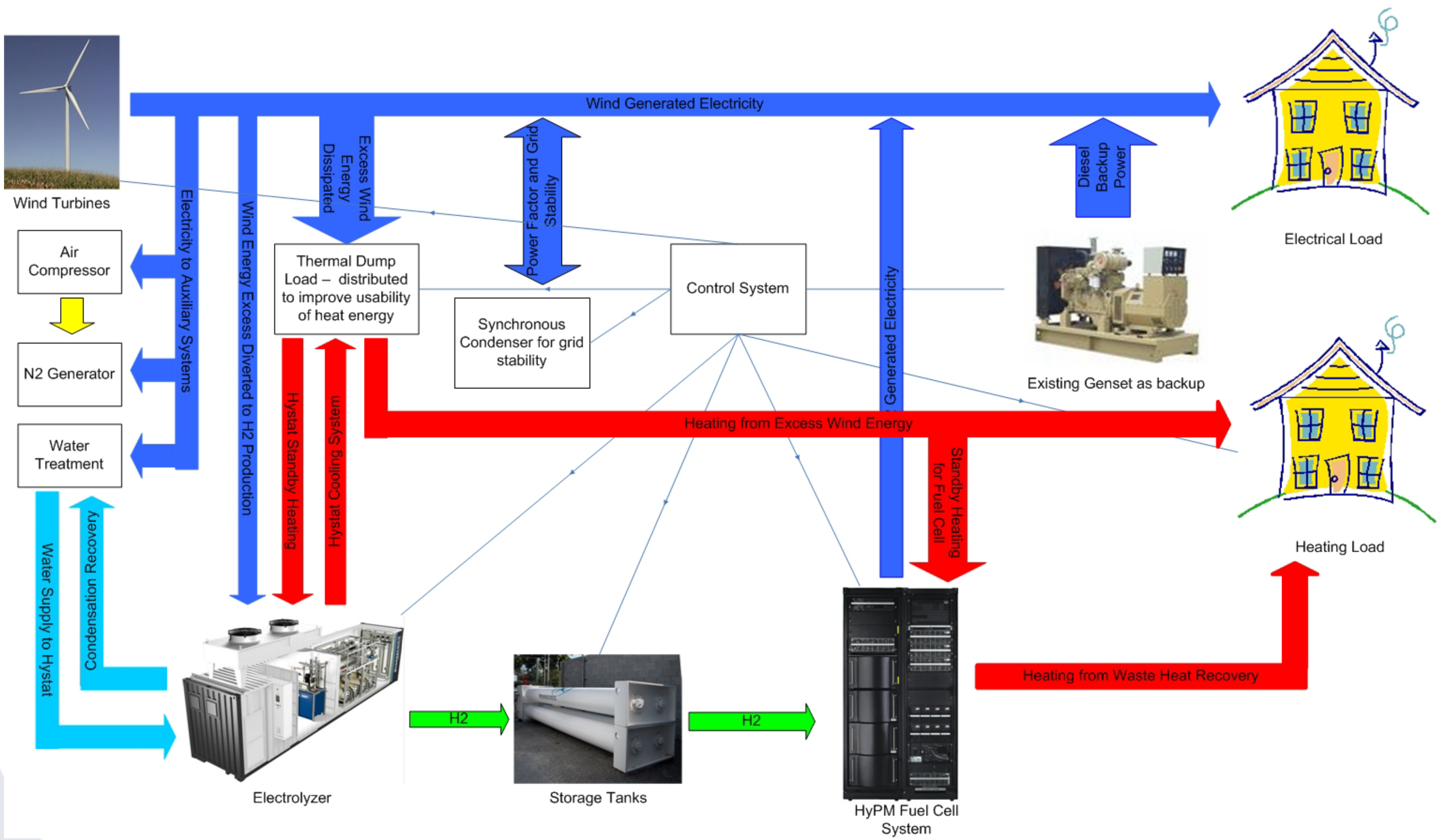
Wind HES Site Layout



Community Hydrogen System



Model Results

		Diesel Only	Wind Diesel	Wind/PV/HES + Diesel	Wind/PV/HES
Initial Capital Cost	$'000	1,570	3,214	5,660	9,850
Net Present Cost	$'000	8,430	7,119	9,399	15,576
Operating Cost	$'000/yr	487	277	265	406
Cost of Generation **(Diesel @ $1/L)**	**$/kWh**	**0.510**	**0.408**	**0.585**	**1.063**
Diesel Usage Generation	L/yr	318,000	113,170	68,900	0
Diesel Usage Thermal	L/yr	53,700	32,380	42,390	48,880
CO_2	kg/yr	959,815	375,792	287,752	127,122
CO	kg/yr	4,424	1,573	958	0
HC	kg/yr	239	85	52	0
PM	kg/yr	25	8.8	5.3	0
SO_2	kg/yr	9	3.5	2.7	0
NO_x	kg/yr	2,531	900	548	0

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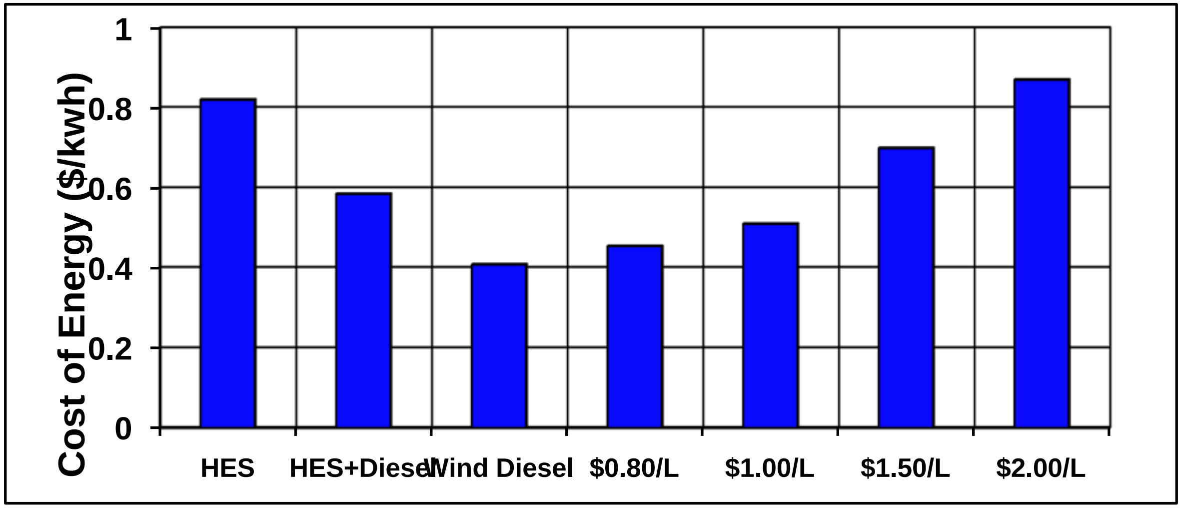
Model Economic Comparison

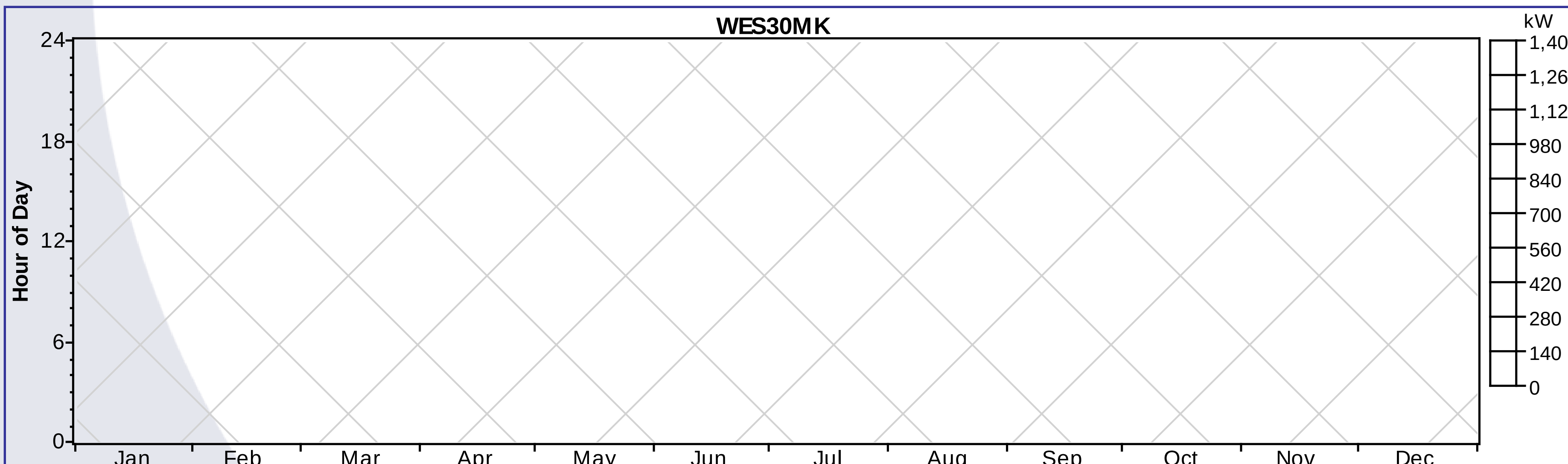
	Current Diesel	Wind Diesel	Community HES + Diesel	Community HES
Cost of Generation ($/kWh)	$0.45/kWh @ $0.80/L			
	$0.51/kWh @ $1.00/L	$0.41/kWh	$0.59/kWh	$0.82/kWh
	$0.70/kWh @ $1.50/L			
	$0.87/kWh @ $2.00/L			
Maintenance ($/yr)	$90,000/yr	$125,400/yr	$131,547	$205,000/yr



Model Results: Wind

Variable	Value	Units
Total rated capacity	1,250	kW
Mean output	507	kW
Capacity factor	40.6	%
Total production	4,443,010	kWh/yr

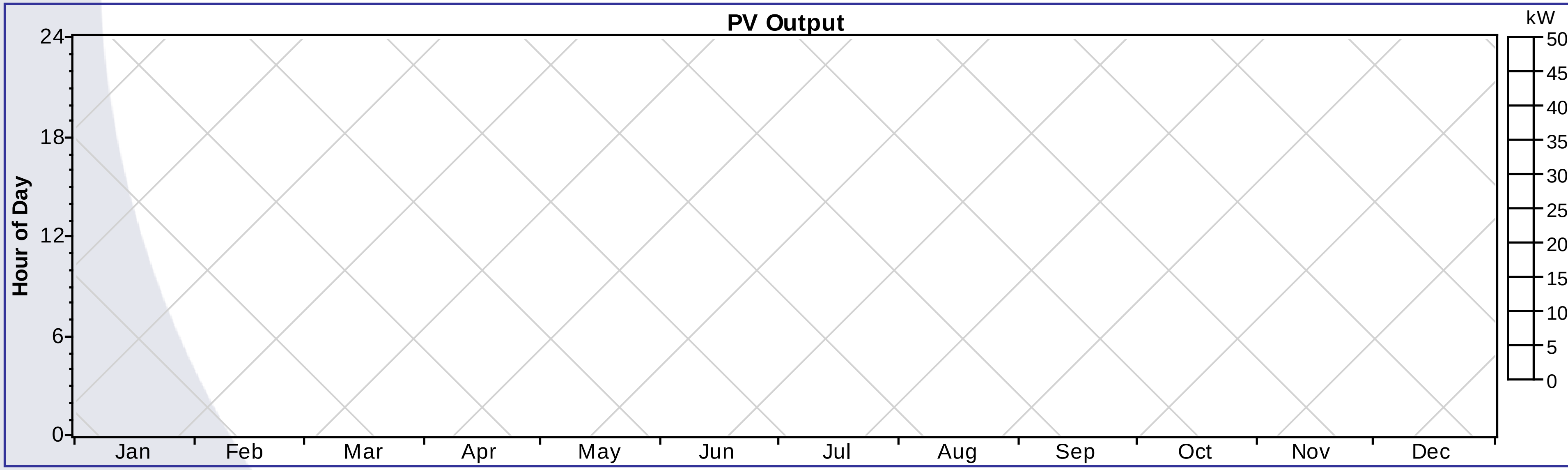
Variable	Value	Units
Maximum output	1,246	kW
Wind penetration	485	%
Hours of operation	8,390	hr/yr
Levelized cost of energy	0.0702	$/kWh



Model Results: Solar

Variable	Value	Units
Total rated capacity	50	kW
Mean output	4.6	kWh/dy
Capacity factor	9.11	%
Total production	39,905	kWh/yr

Variable	Value	Units
Maximum output	49.7	kW
PV penetration	4.36	%
Hours of operation	4,382	hr/yr
Levelized cost of energy	1.05	$/kWh



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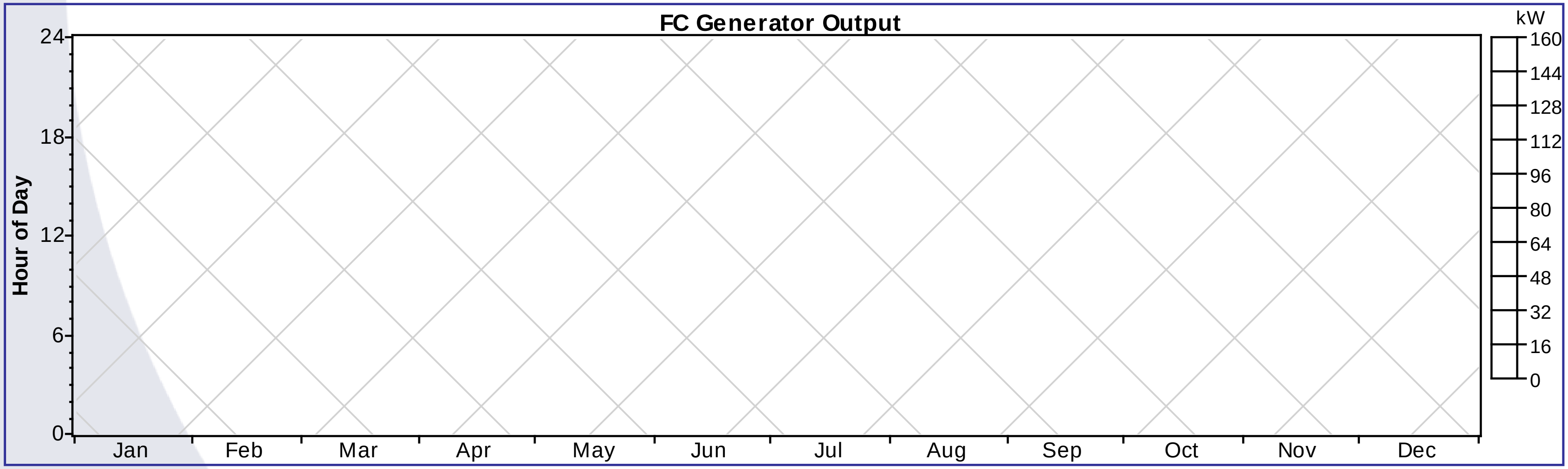
Model Results: Fuel Cell

Quantity	Value	Units
Hours of operation	1,530	hr/yr
Number of starts	956	starts/yr
Capacity factor	5.96	%

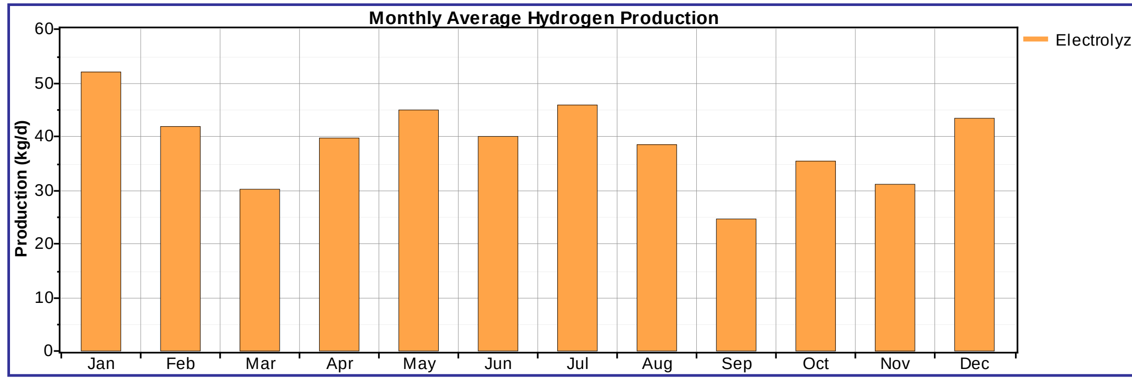
Quantity	Value	Units
Electrical production	78,306	kWh/yr
Mean electrical output	51.2	kW
Min. electrical output	7.5	kW

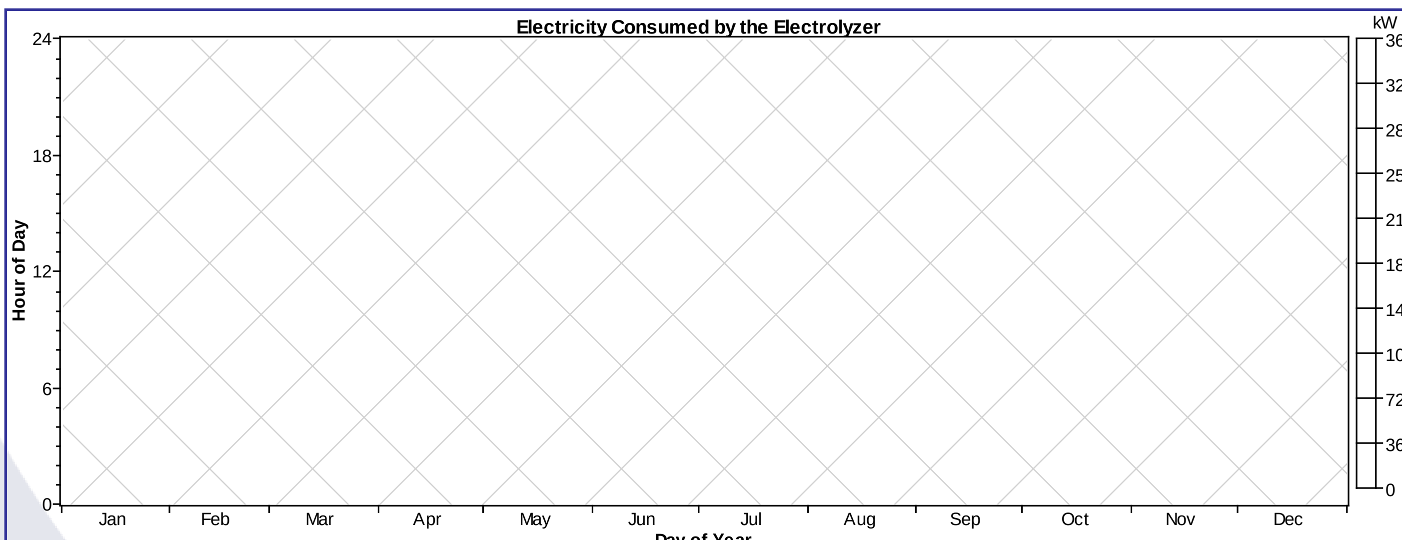
Quantity	Value	Units
Hydrogen consumption	6,688	kg/yr
Specific fuel consumption	0.085	kg/kWh
Fuel energy input	222,940	kWh/yr



Model Results: Electrolyser

Variable	Value	Units
Electrolyzer Capacity	64	Kg/day
Electrolyzer Utilization	30.2	%
Annual H2 Production	14,213	Kg/yr





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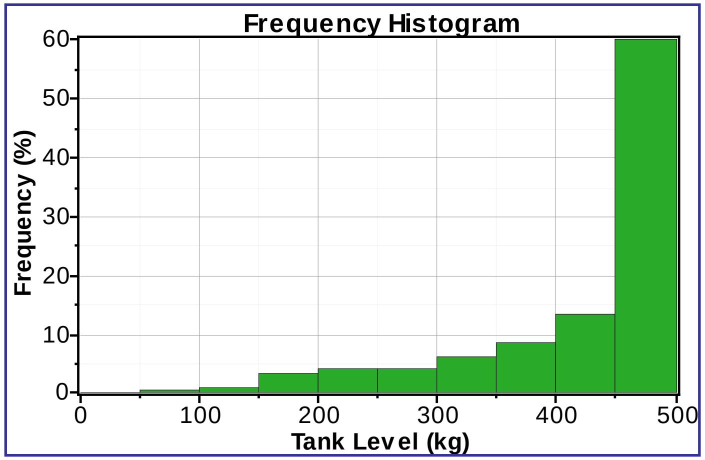
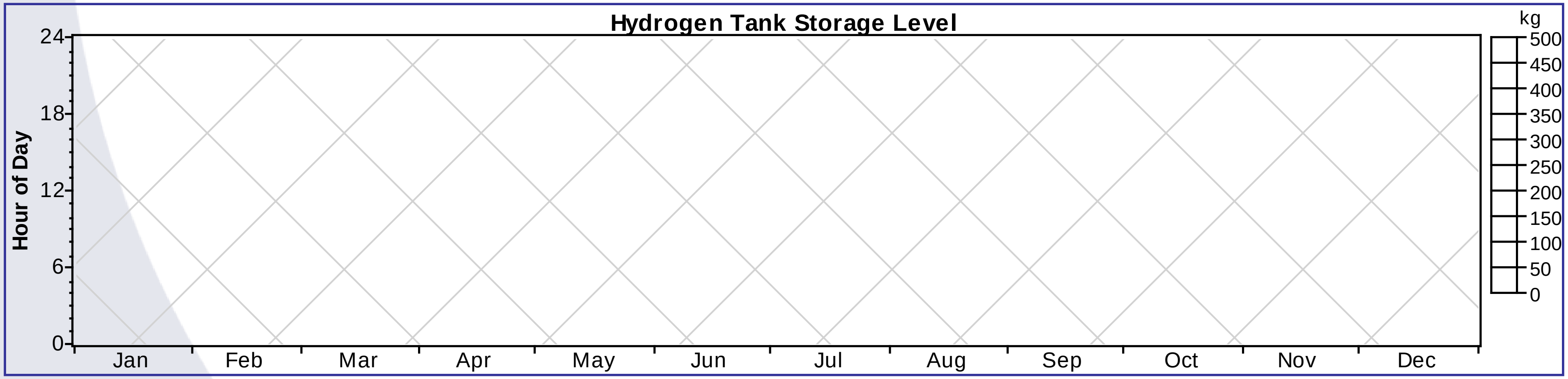
Model Results: Hydrogen Storage

Variable	Value	Units
Hydrogen storage size	50	kg
Hydrogen tank autonomy	159	Hours
Energy Stored (gross)	1.65	MWH





Hydrogen Energy System Advantages

- Protects against future diesel price increases
- Diesel emissions significantly reduced or eliminated
- Better system reliability
  - Redundancy of the system with minimal extra capacity
  - Highly modular and improved start-up reliability
- Fuel cell high efficiency over entire operating range
- Potential for heating to residential or industrial buildings located nearby
- Future fueling infrastructure upgrade

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Case Study Conclusions

- Wind/PV/HES + Diesel
  - Cost competitive with diesel today on a $/kWh basis
  - CO_2 emissions reduced from 960,000kg/yr → 288,000kg/yr representing a reduction of 70%
- Wind/PV/HES Only system
  - Total elimination of emissions to a true zero-emission solution
  - Diesel gensets can remain as an emergency backup
  - Predictable future costs of energy

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Summary

- Secure and sustainable source of energy to the community
  - Stable and predictable cost for energy
  - Zero-emission
  - Self-sufficient energy
- Wind HES can be cost effective relative to diesel
  - Hydrogen provides economic storage for large amounts of energy
- System is based on mature commercial products
  - Current products serve 10kW - 500kW – and growing

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Thank you