Global Apollo KleanGas

Joint Venture

GLOBAL APOLLO KLEANGAS LTD

" Solutions for Tomorrow's Problems Today"

THE GLOBAL APOLLO KLEANGAS POWER PLANT

- The Power Plant operates as a Parallel System in a house, farm or commercial establishment with the Lead Cobalt Battery supplying power directly to the DC to AC Inverter 24-hours a day and the Fuel Cell charging the battery. The battery can supply excess power to the grid during peak hours at the command of the electric utility company which controls this function.

- A Photovoltaic Cell operates in daylight hours and supplies power to a Battery Conditioner or an Electrolysis Unit for generating hydrogen. This is an optional device which may be used to enhance the system operation.

- The Fuel Cell charges the battery at various rates of charge throughout the day and night, but may be shut down part of the day and all night, as controlled by the Microprocessor. It can also supply power to the grid during peak hours, by-passing the battery. It can supply heat for a continuous flow of hot water at 800C.

- A Silver Volt Electric Vehicle contains a Power Plant which may also supply power to the grid during peak hours by plugging into a special receptacle.

- The Power Plant can be utilised in an infinite number of ways, depending on its size. Six sizes, Models 101-B, 102-C, 104-C, 115-C, 120.5-A and 127-C, have been designed so far to handle different situations for various customers. Other combinations of fuel cell and battery can be designed for other applications.

- One operating scenario for **Model 101-B** is shown below. It supplies 51.6 kWh per day to a large house and 48 kWh a day to the grid, for a total supply of 99.6 kWh. (**Its maximum capacity is 276 kWh per day**).

- **Supply to large house:**
- 100-amps x 1-hour = 100 ampere hours
- 5-amps x 23 hours = 115 ampere hours
-
- Total 215 ampere hours x 240 volts = 51.6 kWh

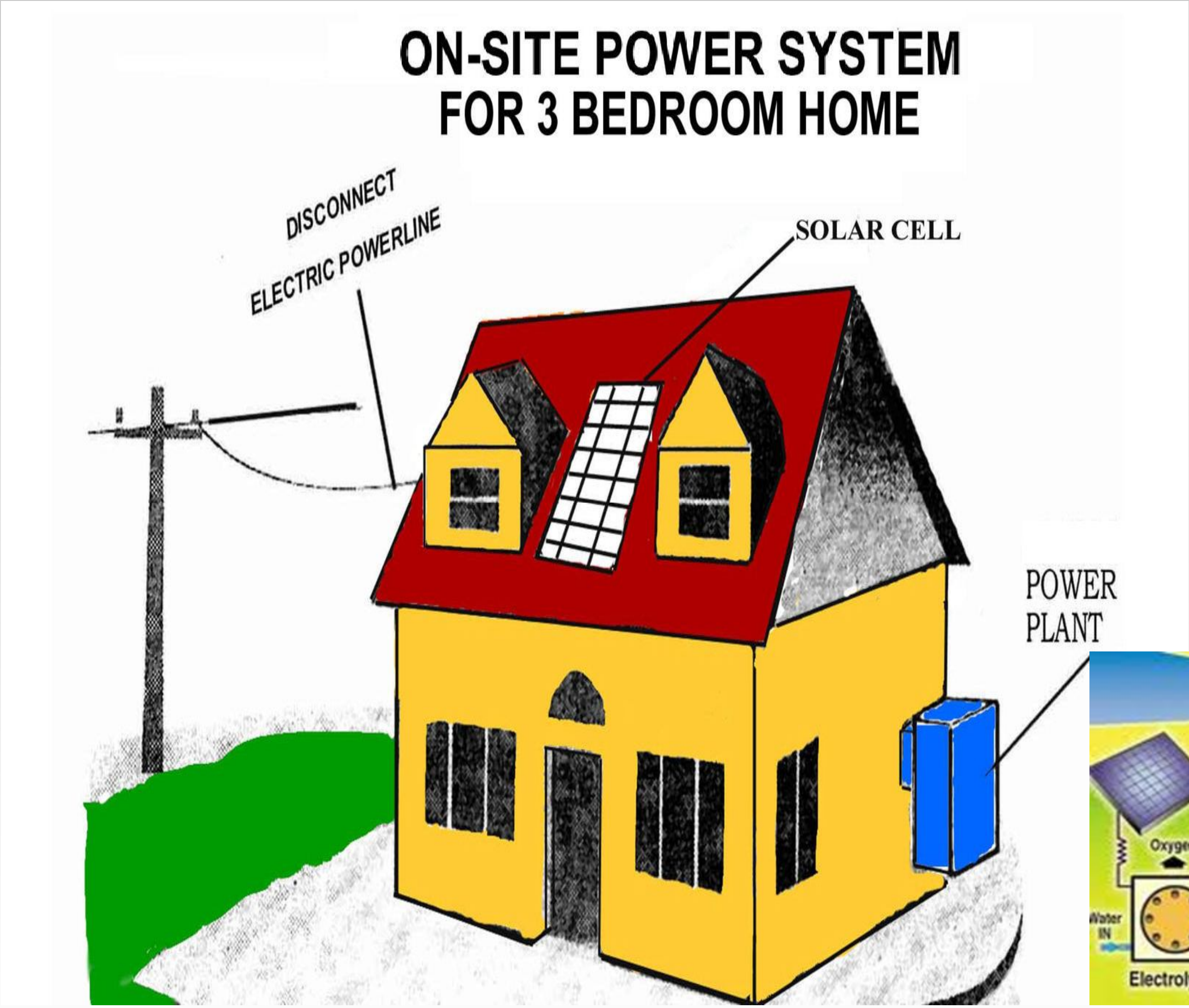
- **Additional supply to the grid:**
- 40-amps x 5 hours = 200 ampere hours x 240 volts = 48.0 kWh

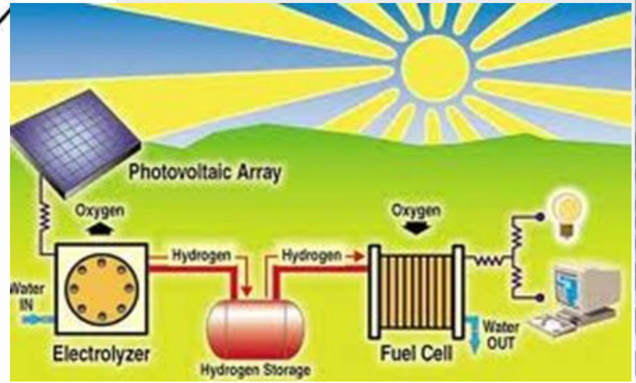
- **415 ampere hours = 99.6 kWh**

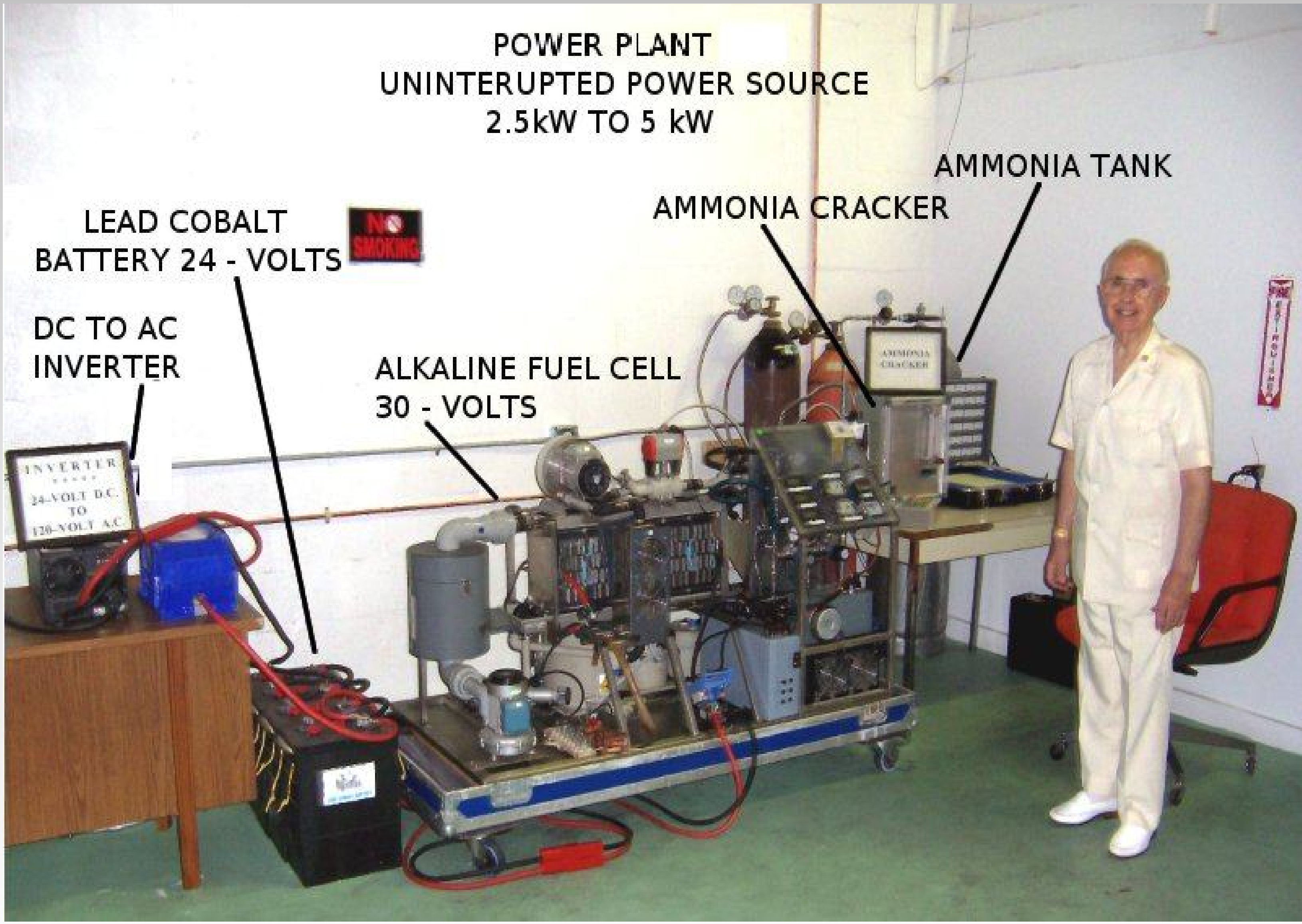
- **Average charging rate for Fuel Cell when charging battery:**
- 19-amps x 24 hours x 288-volts (on-charge battery voltage) = 131.33 kWh
- To replace 415 ampere hours: 415 + 41 = 456 a.h. [456 a.h. x 288-volts = 131.33 kWh]

- **DAILY FUEL CONSUMPTION FOR FUEL CELL IS 131.33 kWh IN THIS EXAMPLE AND CAN BE SUPPLIED BY VARIOUS FUELS AS SHOWN ON THE FOLLOWING PAGES.**

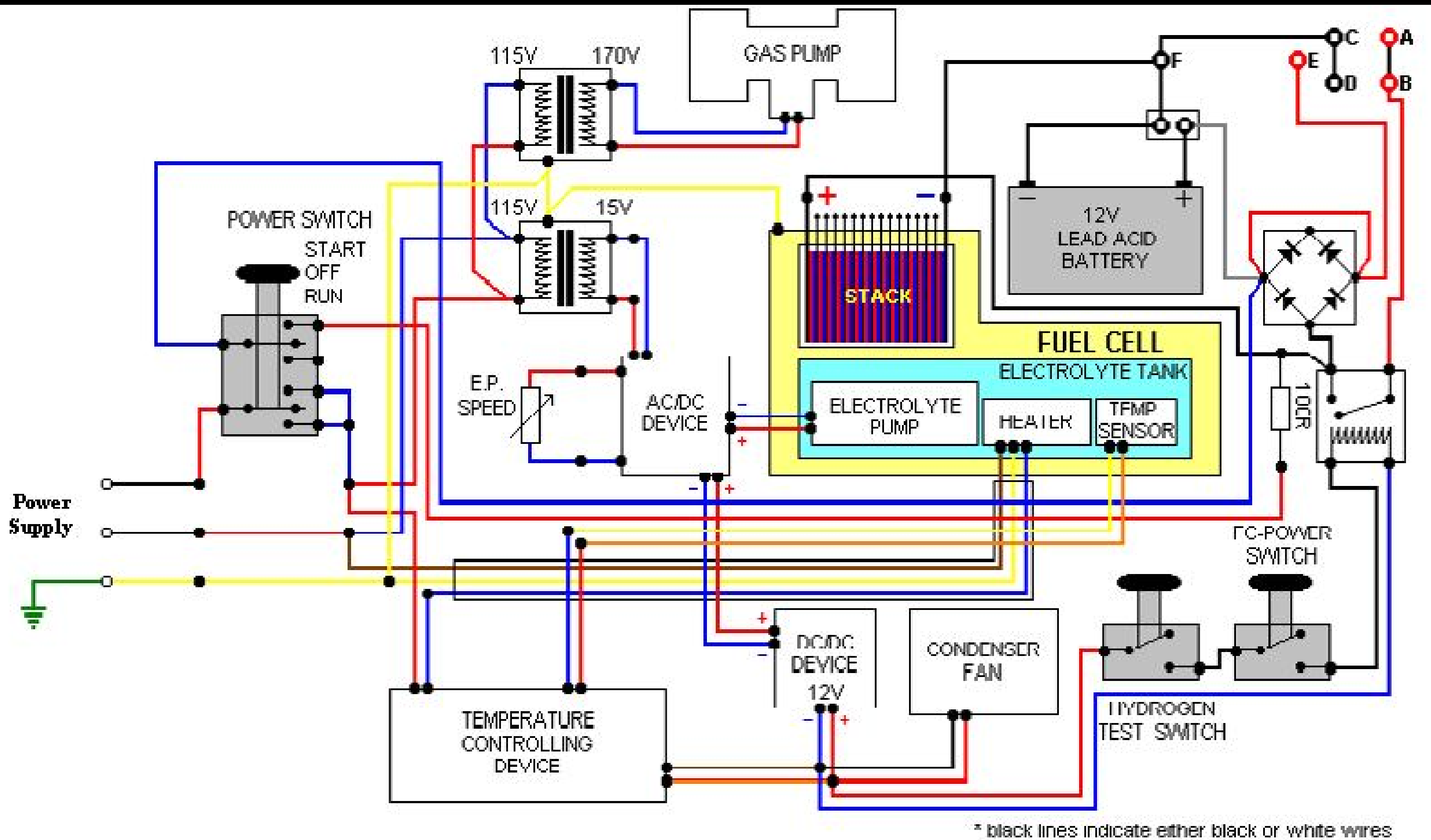
- **MODEL 101-B COULD SUPPLY UP TO 276 kWh OF POWER PER DAY.**


ON-SITE POWER SYSTEM
FOR 3 BEDROOM HOME
DISCONNECT
ELECTRIC POWERLINE
SOLAR CELL
POWER
PLANT


Photovoltaic Array
Oxygen
Oxygen
Hydrogen
Hydrogen
Water
IN
Electrolyzer
Hydrogen Storage
Fuel Cell
Water
OUT


POWER PLANT
UNINTERUPTED POWER SOURCE
2.5kW TO 5 kW
AMMONIA TANK
AMMONIA CRACKER
LEAD COBALT
BATTERY 24 - VOLTS
NO SMOKING
DC TO AC
INVERTER
ALKALINE FUEL CELL
30 - VOLTS
INVERTER
24-VOLT D.C.
TO
120-VOLT A.C.
AMMONIA
CRACKER


ALKALINE
FUEL CELL
With Silver Catalyst
240 VOLTS
DANGER
HIGH VOLTAGE



ALKALINE FUEL CELL SCHEMATIC

72 kWh POWER PLANT

- **Application:** 24-Hour Power Supply for Home, Farm or Commercial Establishment for Heating, Lighting and operation of Appliances independent of outside power line (utility grid) supplied by electric utility company. Will operate an 8-HP AC Electric Motor on a continuous 24-hour basis.

- **Specification of Power Plant**

- **Lead Cobalt Battery.** 240-volt @ 300-amps 1/C -- **72 kWh** Battery supplies power to Inverter.

- **Fuel Cell.** 342-volts open circuit (360 cells @ 0.95 volts/cell). 288-volts (@ 0.8 volts per cell) under 19-amp load = **5.47 kW.** Fuel cell charges battery at 288-volts @ 19-amps.

- **Maximum Heating & Lighting Energy:** 5.47 kW x 24-hours = **131 kWh** x 30 days = 3,930 kWh.

- **DC to AC Inverter for supplying power to 72.00 kW**
- **Overload protection for one minute 600 amps @240 volts 144 kW**
- **Input** from battery: 288 VDC, 19-amps -- 5.47 kW
- **Output:** 240 VAC, 50/60 Hertz, 21.6-amps -- **5.200 kW**
- 230 VAC, 50/60 Hertz, 22.6-amps -- **5.200 kW**
- 120 VAC, 50/60 Hertz, 43.3-amps -- **5.200 kW**
- **Microprocessor for control of entire system.**
- **Cable, conduit, plumbing, sensors, cabinets for system integration**
- **FOB Factory**
- **Hydrogen Generation Equipment**

HOME HEATING & LIGHTING -- COMMERCIAL. 5.47 kW FUEL CELL & 72 kWh BATTERY with 144 kW OVERLOAD PROTECTION

Fuel Consumption

For Model 106 - B

FUEL CELL OPERATING COST - PRELIMINARY

for Power Plant Hybrid Model 106-B

FUEL >	Hydrogen (Liquid)	Hydrogen (Liquid)	n-Butane	Methanol	Ammonia Anhyd.	Ammonia 29.0%	Methane	Natural Gas	LPG (Propane)
Chemical Symbol	H	H	C_4H_{10}	CH_3OH	NH_3		CH_4	96% CH_4	96% C_3H_8
Power consumption (kWh/day)	131.3	131.3	131.3	131.3	131.3	131.3	131.3	131.3	131.3
System efficiency (%)	66.0	66.0	40.0	42.0	50.0	45.0	40.0	40.0	40.0
Fuel consumption (kWh/day)	199.0	199.0	328.3	312.7	262.7	291.8	328.3	328.3	328.3
Fuel consumption (MJ/day) (1 kWh = 3.6 x 10^6 J)	716.3	716.3	1182.0	1125.7	945.6	1050.6	1182.0	1182.0	1182.0
High Heat Value (HHV) (MJ/kg)	143.4	143.4	49.5	21.8	20.9	5.8	56.1	56.1	48.0
Fuel (kg)	5.0	5.0	23.9	51.6	45.2	181.0	21.1	21.1	24.6
Fuel (ft^3 as gas)	2114.2	2114.2	338.0		2075.0		1096.6	1096.6	468.0
Fuel (liters as liquid)	72.8	72.8	41.5	65.3	74.3		49.5	49.5	49.5
								Values = Methane	Value = Propane
Fuel Cost Information	$0.320 per lb.	$1.00-$1.40 per lb.		$0.185 per liter ($.70/gal)	$0.09-$0.10 per lb.	$0.04-$0.06 per lb.		$5-$10 per 1000 ft^3	$0.90-$0.95 Per gal.
	H2 Info Net as Liquid at producer site	H2 Info Net as Liquid delivered and stored		Methanex Barge Price FOB port	CF Ind. In 40,000 lb. Tanker FOB dist	LaRoche In 44,000 lb. Tanker FOB dist		EIA Charts Ave. Resid. 96% CH_4	Teco Bulk undelivered 96% C_3H_8
Calculation	$0.32	$1.20		$0.185	$0.095	$0.05		$7.50	$9.25
Cost Per Day	$3.52	$13.20		$12.08	$9.45	$19.95		$8.23	$12.10
Cost Per 30-Day Month	$105.60	$396.00		$362.42	$283.50	$597.30		$246.74	$363.00

Fuel Consumption Ia

	Hydrogen	Butane	Propane	Methanol	Ammonia
Power consumption [kWh/day]	131.3	131.3	131.3	131.3	131.3
System eff. [%]	66	40	40	42	50
Fuel consumption [kWh/day]	199.0	328.3	328.3	312.7	262.7
Fuel consumption [MJ/day]	716.3	1,182.0	1,182.0	1,125.7	945.6

GLOBAL APOLLO KLEANGAS J.V.

Fuel Consumption Iia

	Natural Gas	Ammonia 25%	Ammonia 40%	Ammonia anhydr.
Power consumption [kWh/day]	131.3	131.3	131.3	131.3
System eff. [%]	40	45	45	50
Fuel consumption [kWh/day]	328.3	291.8	291.8	267.7
Fuel consumption [MJ/day]	1,182.0	1,050.6	1,050.6	945.6

Fuel Consumption Ib

	Hydrogen	Butane	Propane	Methanol	Ammonia anhydr.
Power consumption [kWh/day]	131.3	131.3	131.3	131.3	131.3
Fuel consumption [MJ/day]	716.3	1,182.0	1,182.0	1,125.7	945.6
HHV [MJ/kg]	143.4	49.5	48.0	21.8	20.9
Fuel [kg]	5.0	23.9	24.6	51.6	45.2
Fuel [ft^3]	2,114.2	338.8	468.0	-	2,075.0
Fuel [liter]	72.8	41.5	49.3	65.3	74.3

GLOBAL APOLLO KLEANGAS J.V.

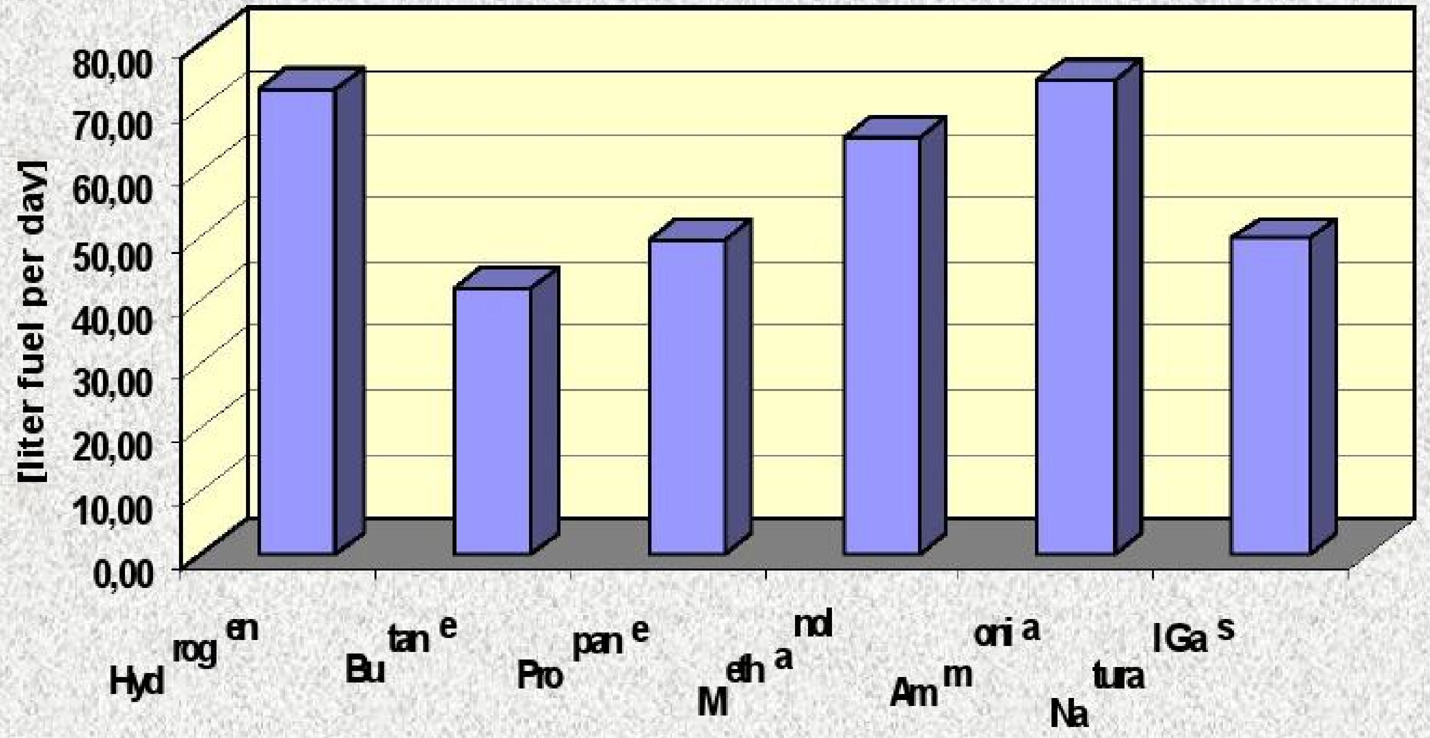
Fuel Consumption Iib

	Natural Gas	Ammonia 25%	Ammonia 40%	Ammonia anhydr.
Power consumption [kWh/day]	131.3	131.3	131.3	131.3
Fuel consumption [MJ/day]	1,182.0	1,050.6	1,050.6	945.6
HHV [MJ/kg]	56.1	5.2	8.4	20.9
Fuel [kg]	21.1	201.1	125.7	45.2
Fuel [ft^3]	1,096.6	-	-	2,075.0
Fuel [liter]	49.5	220.9	147.0	74.3

GLOBAL APOLLO KLEANGAS J.V.

Fuel Consumption

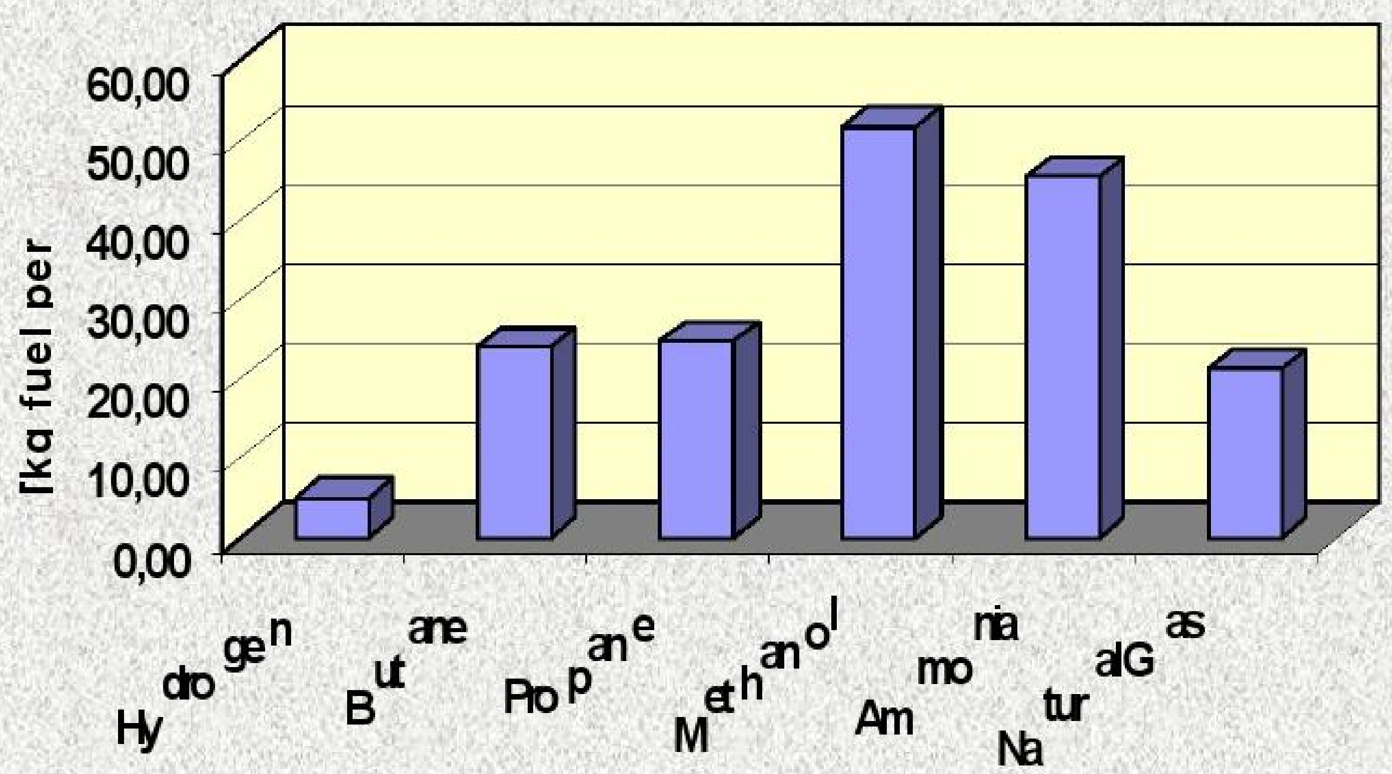
BASED ON POWER CONSUMPTION OF 131.3 Kwh/day



GLOBAL APOLLO KLEANGAS J.V.

Fuel Consumption

BASED ON POWER CONSUMPTION OF 131.3 kWh/DAY



POWER PLANT MODEL 115-C

for Residential / Commercial Use

Cabinet on left will house 26.4 kWh Lead Cobalt Battery (240-volts @ 110-amps I/C)

Cabinet in center will house 15.8 kW Fuel Cell (288-volts @ 0.8 volts/cell

under 55-amp load) Cabinet on right will house DC to AC Inverter,

Microprocessor and Miscellaneous Equipment Output: 240 VAC, 50/60 Hertz, 62.7-

amps 230 VAC, 50/60 Hertz, 65.4-amps 120 VAC, 50/60 Hertz, 125.4-amps One-

minute power surge: 330.0-amps @ 288-volts

Fuel Cell can be shut down at night while battery continues to operate the system

POWER PLANT MODEL 5200

51.8 kW FUEL CELL & 86 kWh BATTERY with 891 kW OVERLOAD PROTECTION

APPLICATION: 24-Hour Power Supply for Homes

- **Required equipment for back-up Power Plant:**

- **Lead Cobalt Battery.** 240 volts @360 amps 20/C – **86.40 kWh**
- One-minute power surge: 1,440 amps. Battery supplies power directly to Inverter.
-
- **Fuel Cell.** 288 volts (303 cells @ 0.95 volts/cell) @180-amps – **51.84 kW**

- **DC to AC Inverter, Grid-Tie, for supplying power to load.**
- **Input** from battery (continuous): 360 VDC, 360 amps -- 86.400 kW
- One minute surge power: 1,440-amps @ 240 volts 345.600 kW

- **Output:** 240 VAC, 50/60 Hertz, 216 amps -- 51.840 kW
- 230 VAC, 50/60 Hertz, 225.39 amps -- 51.840 kW
- 120 VAC, 50/60 Hertz, 432 amps -- 51.840 kW

- **Microprocessor for control of entire system. Grid feedback controlled by utility company.**
- **Cable, conduit, plumbing, hydrogen sensors, cabinets for system integration.**
-

	Per Power Plant
Price FOB Factory -- For 4 Power Plants	**US$147,531**
For 300 Power Plants	**US$ 118,519**
For 5,000 Power Plants	**US$ 94,258**
For 200,000 Power Plants	**US$ 67,600**

- **Water Electrolyser**

POWER PLANTS - MW SIZE (Prices are all inclusive of transport, delivery to site, and installation but does not include VAT)

Size of Power Plant		Gallons NH3 per 24 hours	Square Feet Installation	Cubic Feet Fuel Tank	Replacement of F.C. Stacks**	Annual Maintenance	Replacement of Batteries#**	Selling Price
100 kW		39	16	7	$24,502	See note ##	$9,620	$129,012
1,000 kW (1 MW)		393	1,600	70	$245,024	See note ##	$96,720	$1,289,600
10 MW		3,936	16,000	700	$2,450,240	See note ##	$967,200	$12,896,000
20 MW		7,872	32,000	1,400	$4,900,480	See note ##	$1,934,400	$25,792,000
25 MW		9,840	40,000	1,750	$6,110,000	See note ##	$2,418,000	$32,240,000
40 MW		15,744	64,000	2,800	$9,800,960	See note ##	$3,868,800	$51,584,000
50 MW		19,680	80,000	3,500	$12,220,000	See note ##	$4,836,000	$64,480,000
100 MW		39,360	160,000	7,000	$24,440,000	See note ##	$9,672,000	$128,960,000

**Replacement of Fuel Cell Stacks every 7-1/2 years

One day per week inspection by an engineer + worker plus $1,000 per week for spare parts.

#**Replacement of Batteries every 5-years

Fuel Cell Chart

	Phosphoric Acid Fuel Cell	Proton Exchange Membrane Fuel Cell	Liquid Molten Carbonate Fuel Cell	Solid Oxide Fuel Cell	Alkaline GAK Fuel Cell (1)	GAK Direct Methanol "MARS" Fuel Cell (2)
	PAFC	**PEM**	**MCFC**	**SOFC**	**AFC**	**DMFC**
Electrolyte	Liquid Phosphoric Acid	Ion Exchange membrane (solid polymer)	Liquid Molten Carbonate	Ceramic	Potassium Hydroxide	Potassium Hydroxide-
Catalyst	Platinum	Platinum	Nickel	Perovskites	Silver Alloy	Silver Alloy
Cell Operating Temperature (degrees C)	205 C	Room temperature to 80°C	650 C	800-1000 C	Room temp. to 80°C	Room temp- To 70°C (3)
Electrical System Efficiency (% LHV)	36-45	32-40	43-55	43-55	50-60	>50
Some Applications Cogeneration	✓	✓	✓	✓	✓	
Utility Power	✓		✓	✓	✓	
Distributed Power	✓	✓	✓	✓	✓	
Utility Repowering	✓		✓	✓	✓	
Passenger Vehicles		✓			✓	✓
Heavy Duty Vehicles	✓	✓		✓	✓	✓
Portable Power		✓			✓	✓
Specialty Power		✓			✓	✓

1. The GAK FUEL CELL
   Alkaline Fuel Cell with circulating electrolyte, which can be shut down when not in use. This extends life of the electrodes and allows for maintenance. It has a higher voltage than the other types of Fuel Cells. Patents have been applied for by AES on this fuel cell and a working model is in operation at AES's laboratory in Fort Lauderdale florida.

2. The GAK MARS FUEL CELL
   Direct Methanol Alkaline Fuel Cell with circulating electrolyte and a polyethylene separator (proton exchange membrane separator not needed). The anode catalyst draws hydrogen from the liquid methanol, eliminating the need for a refsormer. The carbon dioxide produced stays in the electrolyte as a liquid carbonate (K^2 C0 [or Na^2C0^3 if sodium hydroxide is used instead of potassium hydroxide]), which can be pumped out periodically and exchanged for fresh potassium hydroxide (or sodium hydroxide). There are no $C0^2$ or, other emissions from the alkaline DMFC (there are C02 emissions from the acidic [H^2SO] DMFC). Cell voltage of the alkaline DMFC is higher than the acidic DMFC. Patents have been applied for by Apollo™ Energy Systems, Inc. on the Direct Methanol And Alkaline Fuel Cell.

3. Or higher temperature if methanol vapor is used.

Ammonia Consumption of a 5 kW Fuel Cell System

Premises

Nominal rated power	5 kW
Cell voltage	0.65 V
Cell current	40 A
Hydrogen use efficiency	66%

Results

Mass related ammonia demand	0.71 g s^{-1}
	2.5 $^{-1}$
	5.5 lb/h
Volumetric ammonia demand	3.1 l h^{-1}
	0.82 gal/h

- **Summary of technical possibilities, Global Projections, Ammonia Fuel**
- The use of ammonia as hydrogen source for alkaline fuel cells with circulating liquid electrolyte was already
- demonstrated with low-cost crackers built in 2000. **Figure 1** shows the diagram of an AFC system with an
- ammonia cracker. **Figure 2** shows a picture of an operating system. We discuss and model the use of ammonia
- and crackers together with alkaline fuel cells, analyzing the gains in efficiencies and in savings by using lowcost
- accessories and offering green house environmental advantages. The immediate commercial global
- availability is emphasized. Several companies in USA and the European Union continue to develop alkaline
- fuel cells (AFCs) with liquid electrolyte for mobile and stationary applications. At the University of Technology
- Graz, Austria, the Union Carbide Corp. Fuel Cell System has been improved in power output and life in on-off

Alkaline Fuel Cell–Hybrid Systems with NH3 Cracker as H2-Producer

K. Kordesch*, G. Faleschini, V. Hacker, M. Cifrain, G. Koscher, T. Hejze
Univ. of Technology Graz, A-8010 Graz, Austria. *)
Robert R. Aronsson, Apollo Energy Systems, Inc., Pompano Beach, FL.

- In recent A**utomobile-Hybrid Systems**, the combined operation with batteries has been emphasized in order to
- reduce the size and cost of fuel cells and improve their peak performance. The key questions still remains:
- Where should the hydrogen come from and how should it be stored and transported. To solve this urgent
- question of the fuel supply, the use of ammonia as hydrogen source for alkaline fuel cells was demonstrated at
- the University of Technology Graz in cooperation with Apollo Energy Systems, Inc. (AES Inc.) in Florida.
- The AFC's of AES Inc. optimally operate at a temperature around 70 deg C, with a liquid circulating alkaline
- electrolyte which also serves as heat- and water management system. The operation is essentially at
- atmospheric pressure of hydrogen and air. As needed, the hydrogen is produced by an Ammonia Cracker
- System on demand. Important for this fuel cell set-up which avoids any amount of hydrogen in storage or
- transportation, is also the operation as a hybrid with a rechargeable battery in parallel. It takes care of peak
- performance requirements and delays after shut down and restarting. A new ammonia cracker (Pat. appl. for)
- operates very efficiently at temperatures which make it possible to build it from low cost steel components.
- Commercial liquid ammonia, which is stored in low pressure tanks, can be delivered by existing international
- and national ammonia networks and therefore, a global hydrogen carrier infrastructure is already well
- established. The safety aspects of ammonia are commercially established (ice-rinks, refrigerator industry,
- fertilizer). The global production of ammonia steadily increases with the world population.

- **A global distribution for H2-fuel** can be guaranteed by using ammonia which is produced in quantities of
- hundreds of million tons per year and is distributed by boats, tank cars and even pipelines. There is no problem
- with gas stations if ammonia will be distributed to the customers in liquefied form like propane, in low-pressure
- exchangeable tanks, for heating or for farm and recreation vehicles.
- distribution station. The distribution at “gas stations”, like e.g. propane, can be proposed without building
- costly electrolyzing stations, supplying liquefied hydrogen or using highly pressurized hydrogen. Investigations
- have been started in Florida and California, they may lead to factual demonstrations by auto companies (e.g.
- SMART). At AES Inc., preparations for a production of different types of ammonia crackers have been started.
- System studies, modelling of cell stack configurations and designs of Balance of Plant (BOP) accessories are
- made. The goal is a high speed mass production at a reasonable cost, getting down to a few $ 100 per kW, for
- electric vehicles even lower. To use low-cost ammonia crackers with PEM-FC’s, an additional NH3 trace
- cleaner is required. However, the high temperature SOFC Systems need no cracker, they can operate on NH3
- directly. Cracker systems can be completely electrically heated for simplicity reasons. However, for fuel cell
- system-cracker combinations it is desired to use the exhaust from the fuel cell to participate in heating the
- cracker. For such a more efficient combination a hydrogen enrichment step is required.

- **Ammonia - A high energy density, inexpensive fuel**
- Ammonia tends to follow natural gas prices (which are approaching record levels now). Ammonia is a zero
- carbon fuel that can generate hydrogen in a simple, cheap reactor. Ammonia is 17.5% by weight hydrogen.
- It has a higher hydrogen density (~6.56 lb/ft3) than liquid hydrogen (~ 4 lb/ft3). Domestic production is about 20
- million tons per year. Presently in the USA, the cost of ammonia is higher than natural gas, but considering
- different shipping ports and larger quantities it can become competitive, considering its use in fuel cell cracker
- systems offering a higher energy conversion efficiency than combustion engines.
- About 140 MM Tons are produced annually, and farmers, both in the US and in third world countries, routinely apply it directly to the
- soil as a fertilizer. Its range of flammability is so narrow that it is classified as non-flammable by the DOT.
- It was used as a fuel in the X15 rocket plane. Ammonia is also catalytically decomposed to produce a reducing
- gas for treating metals and it is the most widely used industrial refrigerant..

- **Internal combustion engines**
- can operate on cracked ammonia with no reduction in power, ideal for telecommunications, emergency and
- remote site applications. Several AES fuel cell stacks have operated on ammonia cracker effluent. Ammonia is
- a severe poison to PEM cells and great care must be taken to eliminate all traces of ammonia from the cracker
- effluent. A fuel cell system operating at 80 % hydrogen utilization could supply the effluent low hydrogen nitrogen
- mix to the burner of the ammonia cracker, preferably using a low-cost membrane type diffusion based
- H2-enrichment step (a low-cost simple method is under development at the TU-Graz).

- **Ammonia as competitive Hydrogen Carrier and Fuel Source**
- Ammonia has been identified as a suitable hydrogen carrier. Ammonia is essentially non flammable and is
- readily obtained and handled in liquid form. It contains 1.7 times more hydrogen than liquid hydrogen for a
- given volume. Ammonia therefore offers significant advantages in cost and convenience as a vehicular fuel.
- Procedures for safe handling have been developed in every country. Facilities for storage and transport by
- barges, trucks and pipelines from producer to ultimate consumer are available throughout the world. Therefore
- liquid anhydrous ammonia is an excellent storage medium for hydrogen. Compared with methanol/water mixes,
- the fuel capacity per weight of ammonia is higher and the price per kW/hr is far lower.

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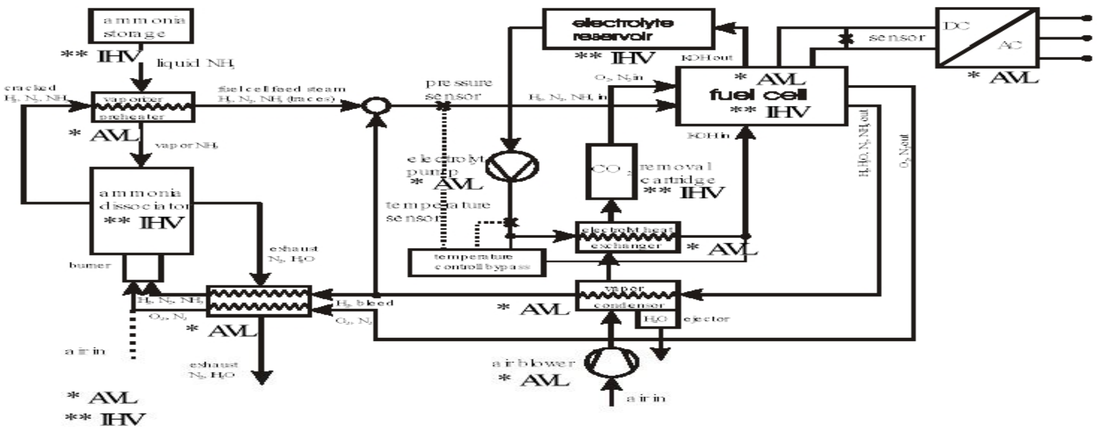
Figure 1. Combination of an AFC-System and an Ammonia Cracker

HV: Cracker Design by High Voltage Institute, TU - Graz,

AVL: System Simulation by AVL-List GmbH, Graz, Austria



GLOBAL APOLLO KLEANGAS LTD

Global Apollo KleanGas
Airport House. Purley Way
Croydon, Surrey. CR0 0XZ
United Kingdom

Telephone: Intl + 44-78942-62399
Email: info@gek-ltd.com