AMMONIA (NH_3) is the FUEL for the HYDROGEN-ECONOMY

APOLLO ENERGY SYSTEMS, INC. and

TECHNICAL UNIVERSITY, GRAZ. AUSTRIA

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PPTs – Argonne Natl. Lab., Oct 14, 2005

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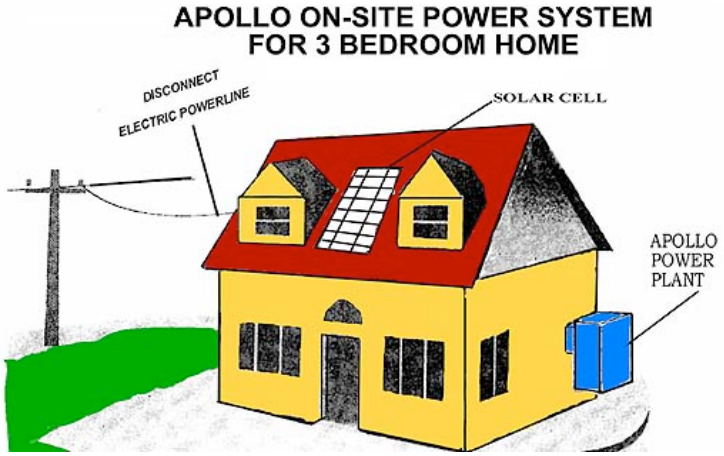
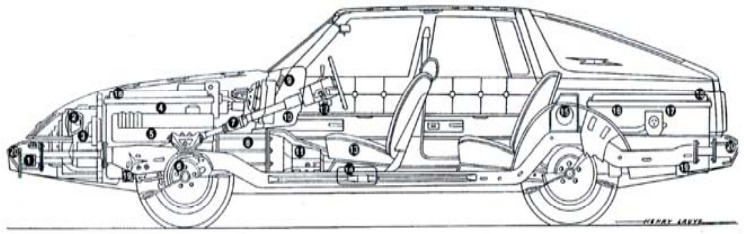




1. FAST CHARGE RECEPTACLE 400 AMPS
2. DUAL HALOGEN HEAD-LIGHTS
3. CONTROL SYSTEM FOR BATTERY
4. BATTERY, SEALED, FAST CHARGE
5. CONTROLLER FOR ELECTRIC MOTOR
6. POWER BRAKES
7. POWER STEERING
8. ELECTRIC MOTOR 144 KW, 240 VOLTS
9. AIR CONDITIONING
10. AM/FM STEREO RADIO WITH CD PLAYER
11. AUTOMATIC TRANSMISSION
12. POWER WINDOWS
13. POWER SEAT
14. PROPULSION FUEL TANK
15. CHARGER, ON-BOARD, 110/240 VAC
16. PROPULSION FUEL CELL
17. CHARGER RECEPTACLE, 110/240 VAC
18. FUEL CELL COVER
19. COLD-WEATHER HEATER
20. PLASTIC BUMPERS WITH STEEL BACKING

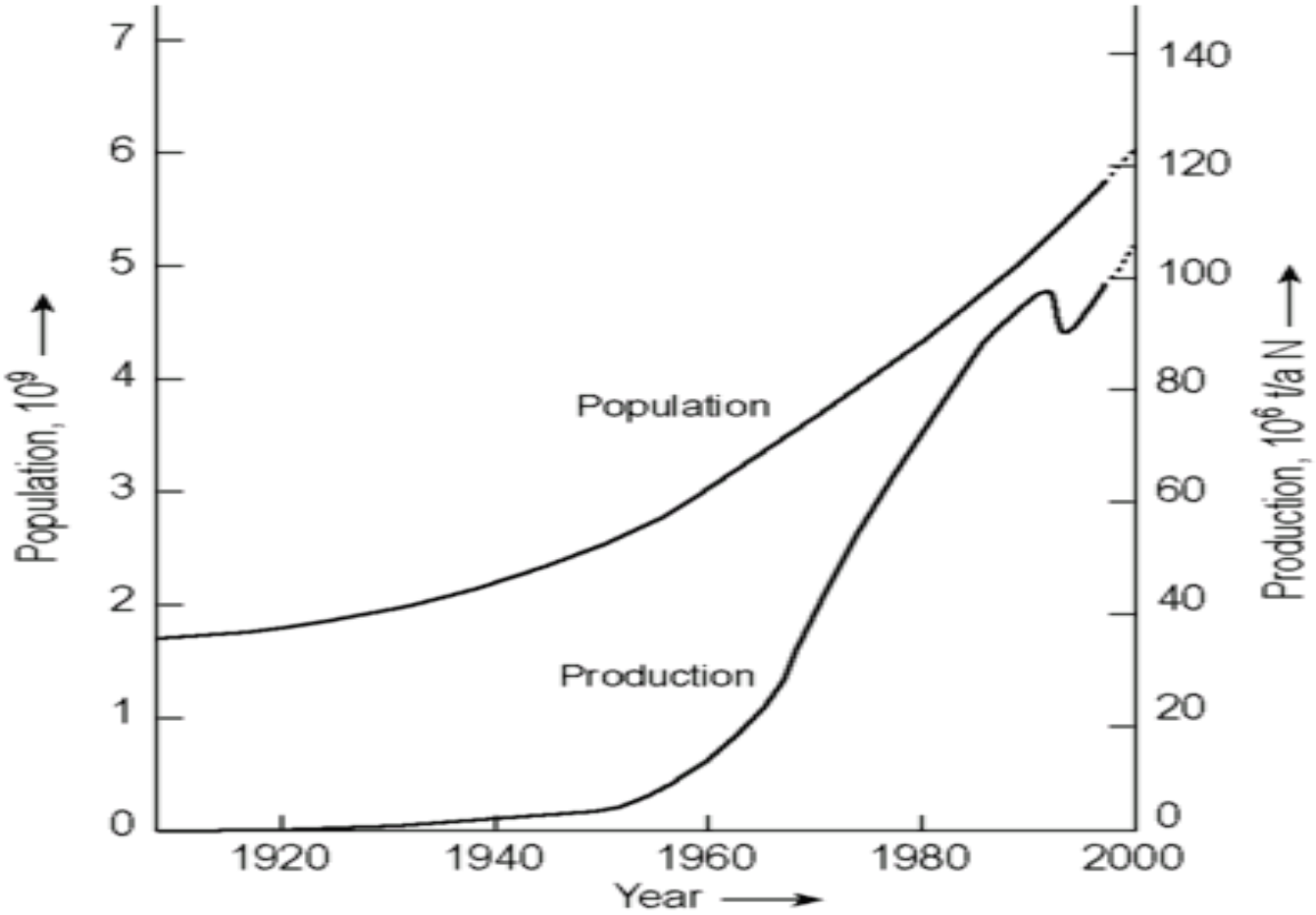
Objectives

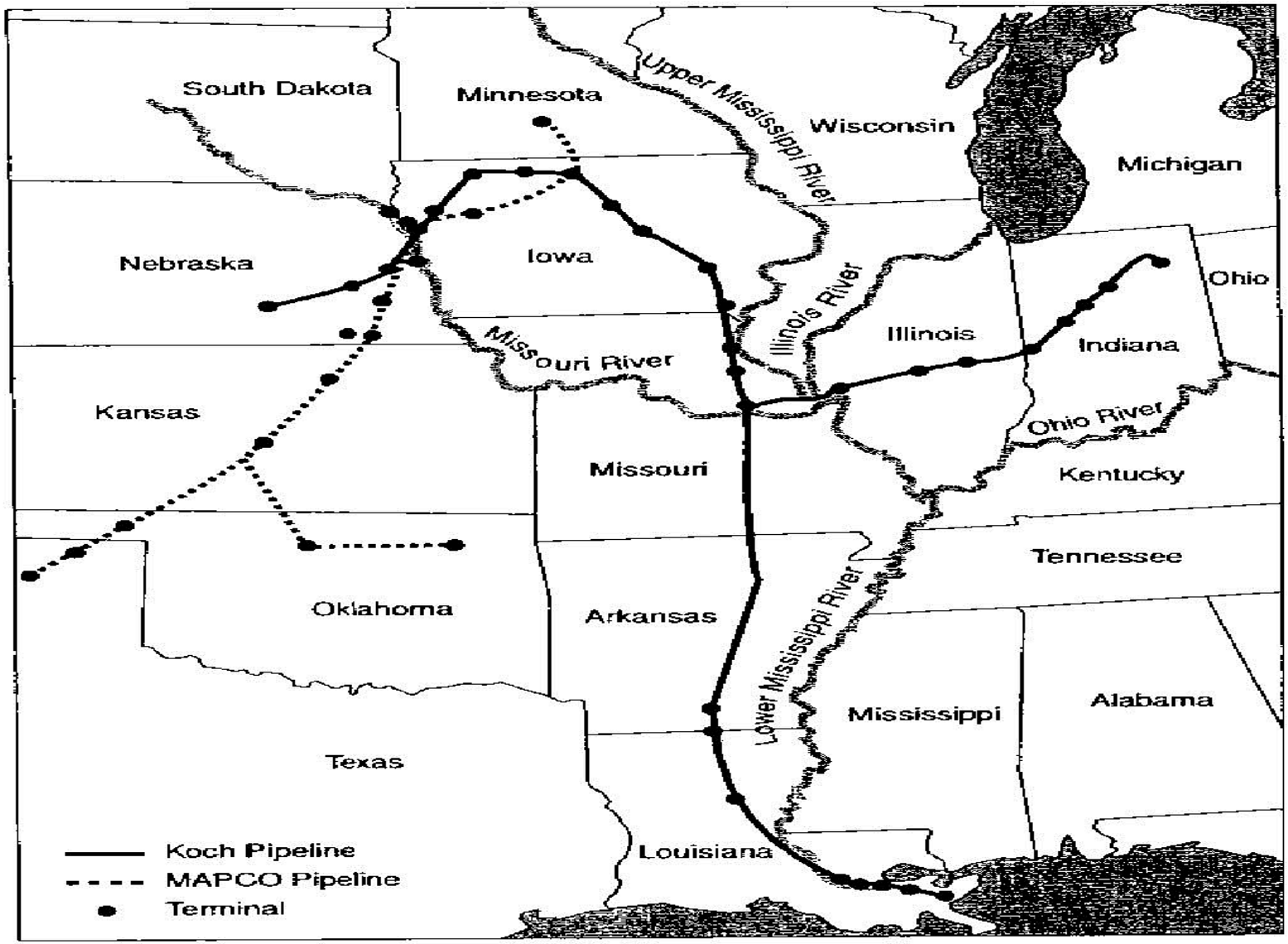
- Design of an Alkaline Fuel Cell System with circulating Electrolyte for vehicles in intermittent duty service and small units for uninterruptable hybrid power supplies.
- Development of low cost Ammonia Cracker
- Optimisation of System Performance & Life
- Cost Reductions for accessories, especially:
- Catalyst reduction, use of non-Pt catalyst

PROBLEMS

- New Energy Technologies like Fuel Cells and Fuel Cell Hybrids need Hydrogen
- The Handling and Storage of Hydrogen is questionable, dangerous and expensive
- Ammonia as Global Hydrogen Carrier may solve the Storage and Distribution Situation
- What other H_2 Carriers are to consider ?
- Are renewable Energy Sources available?

Development of ammonia production and world population





Ammonia shipped by Pipelines in the USA

Ammonia, NH_3

- Heating Values:

  Upper: 18.6 MJ/kg , Lower: 22.5 MJ/kg
- Storage as Liquid:

  Pressure: 8.6 bar at 20 ^{o} C

  Density: 0.61 kg / cm^3 (11.3 MJ / Liter)
- 1 Liter NH3 (lq) stores 1290 Liter H_2 (gas)
- 1 Mol Hydrogen corresponds to 22 Liter
- 22 Liter Hydrogen can produce 54 Ahrs.

Gas Station selling small Propane Tanks

Advantages of Ammonia

- Simple Storage as Liquid
- High Storage Density at low Pressure
- Does not burn easily, No CO_2 No NO_x
- Easy and efficient to Crack (reform)
- Great Experience in Industry and Farming
- Biologically completely safe (e.g. spilling)
- Poisoning by Inhalation completely reversible
- Lower Cost than Hydrogen or Methanol

Hydrogen Containing Feedstock for Ammonia Production

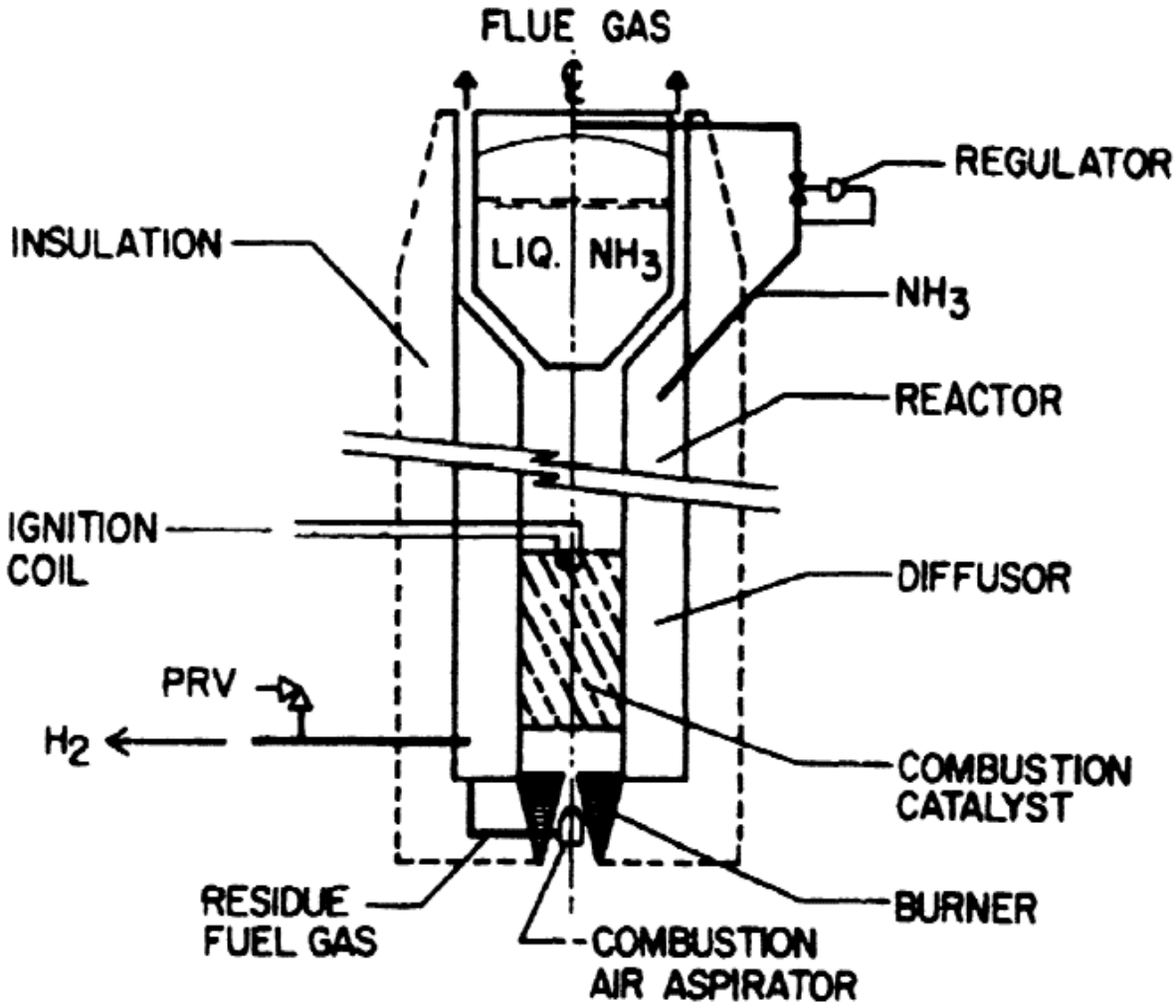
Feedstock distribution of world ammonia production capacity

	1962		1972		1983		1998	
	10^3t N	%	10^3t N	%	10^3t N	%	10^3t N	%
Coke oven gas and coal	2800	18	4600	9	7200	8	16500	14
Natural gas	7800	50	32100	63	66850	74	94300	77
Naphtha	2050	13	10700	21	9050	10	7300	6
Other petroleum products	2950	19	3600	7	7200	8	4400	3
Total	**15600**	**100**	**51000**	**100**	**90300**	**100**	**122500**	**100**

Reforming Ammonia is endothermic

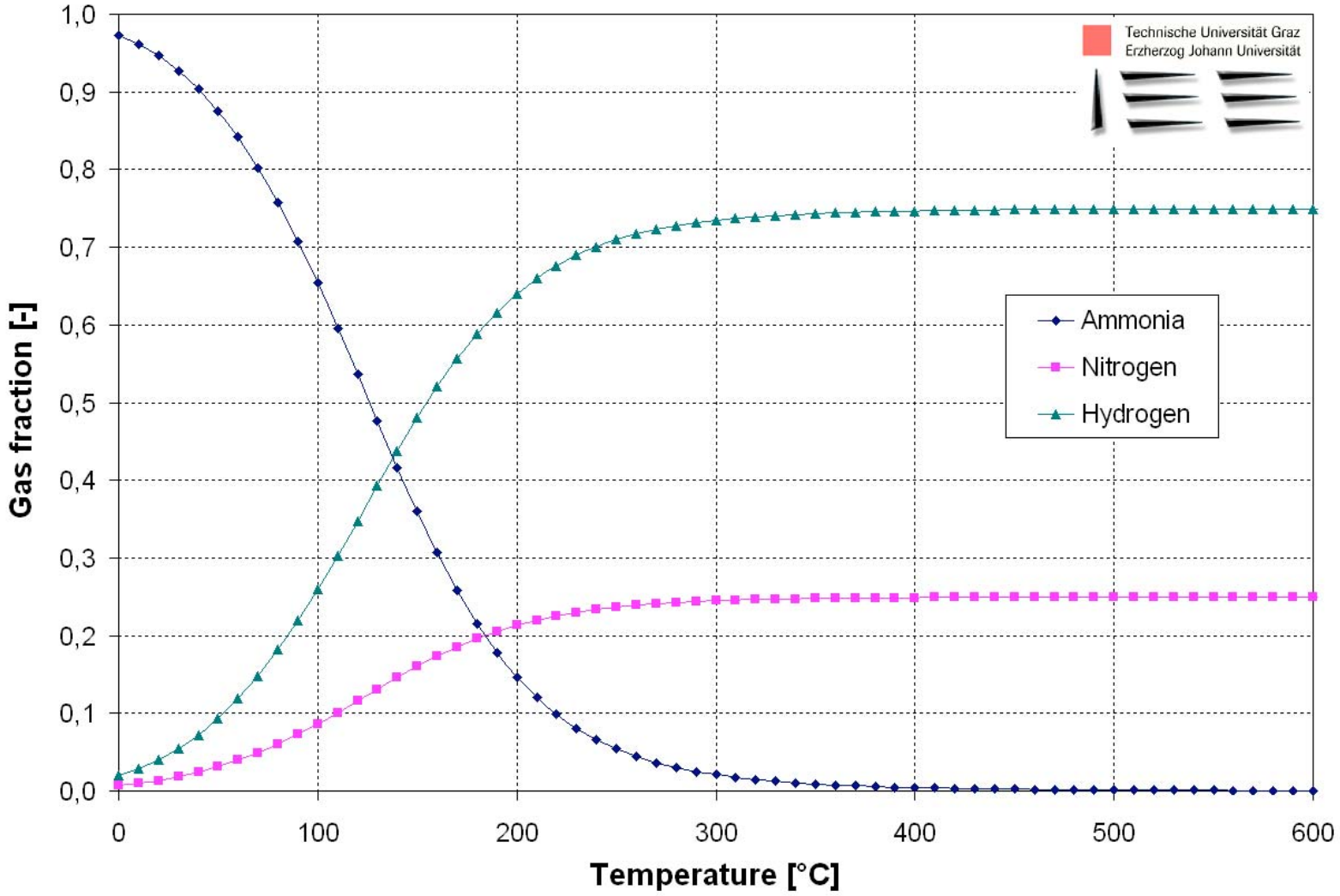
- 1 kW NH_3 plus Heat produces 1.15 kW H_2
- Residual NH_3 after reforming: 100 to 300 ppm, suitable for alkaline Fuel Cells, can be cleaned by adsorption to 1 or 4 ppm for PEM Fuel Cells
- Adsorption cleaning uses only 3 % of energy and is a simple and low-cost process

Temperature of reforming determines catalyst type, efficiency and cracker construction cost



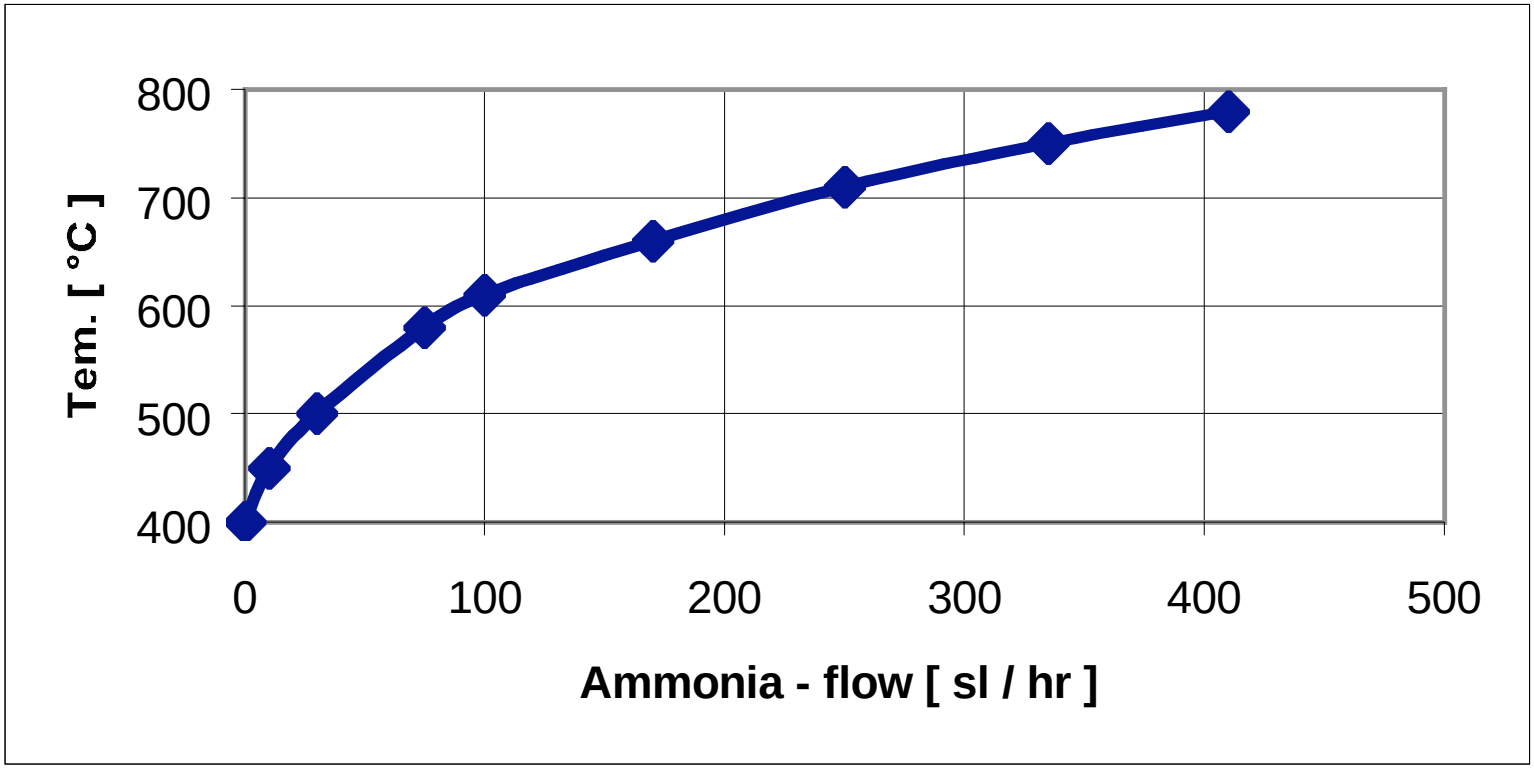
Principle of an Ammonia Cracker, UCC, 1970

Electrically heated NH3 Cracker
TU-Graz, AVL-List GmbH, 2003



Thermodynamic of the Ammonia Thermal Cracking Process

Cracking efficiency (> 99,99 conversion) with Ni-Ru - Catalyst

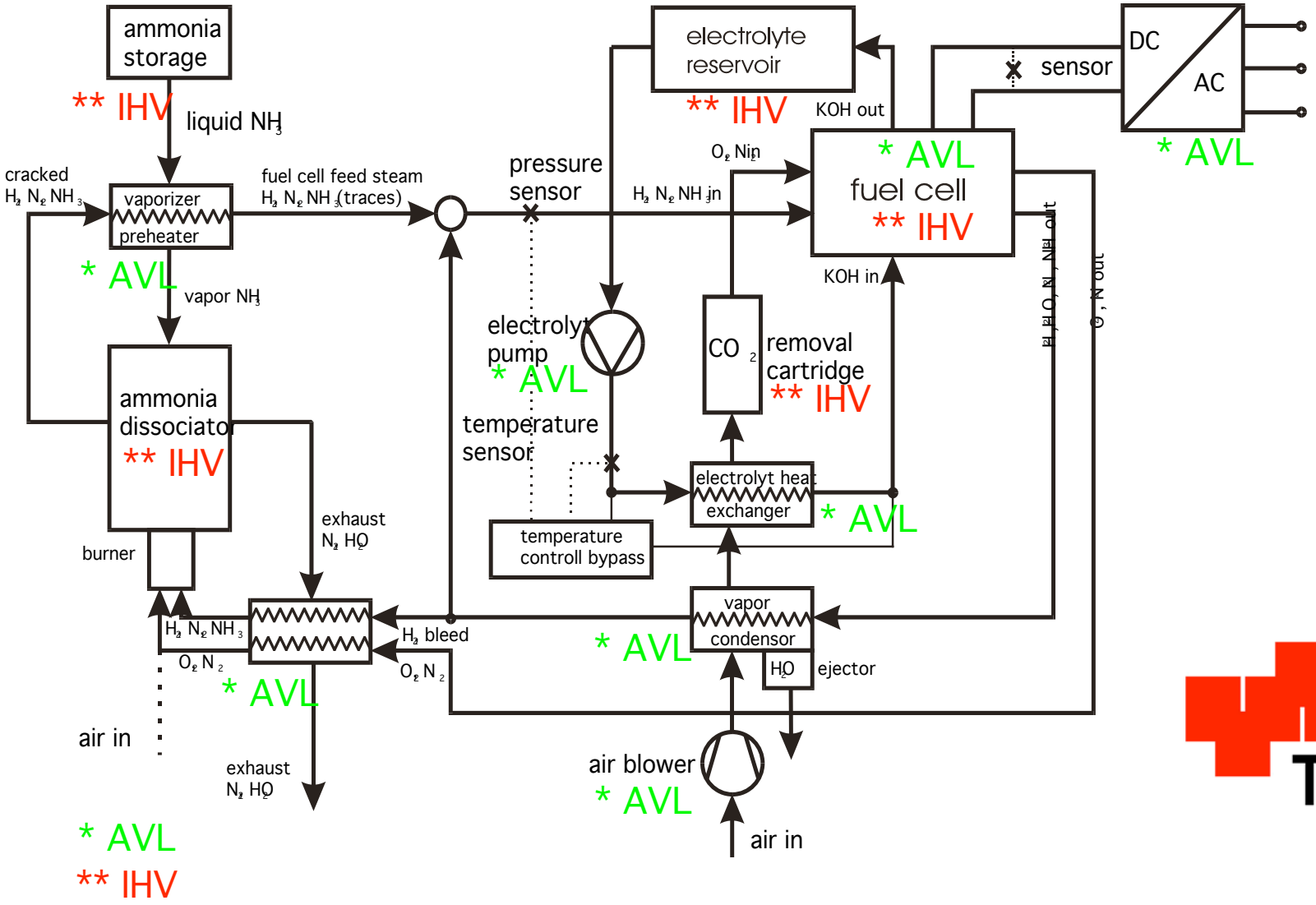


Properties of the AES System

- ☺ low cost electrodes (carbon-based, plastic-bonded)
- ☺ low cost monopolar stack design, no bipolar plates
- ☺ low cost commercial tools for operating the stack
- ☺ no humidifier, no compressors, no membranes
- ☺ fuel (H_2, pure or reformed) at ambient pressure
- ☺ air at ambient pressure
- ☺ easy startup (hybrid) within minutes
- ☺ simple shutdown
- ☺ self-regulating water and thermal management
- ☺ tolerates 150ppm CO_2 (air: 300ppm)

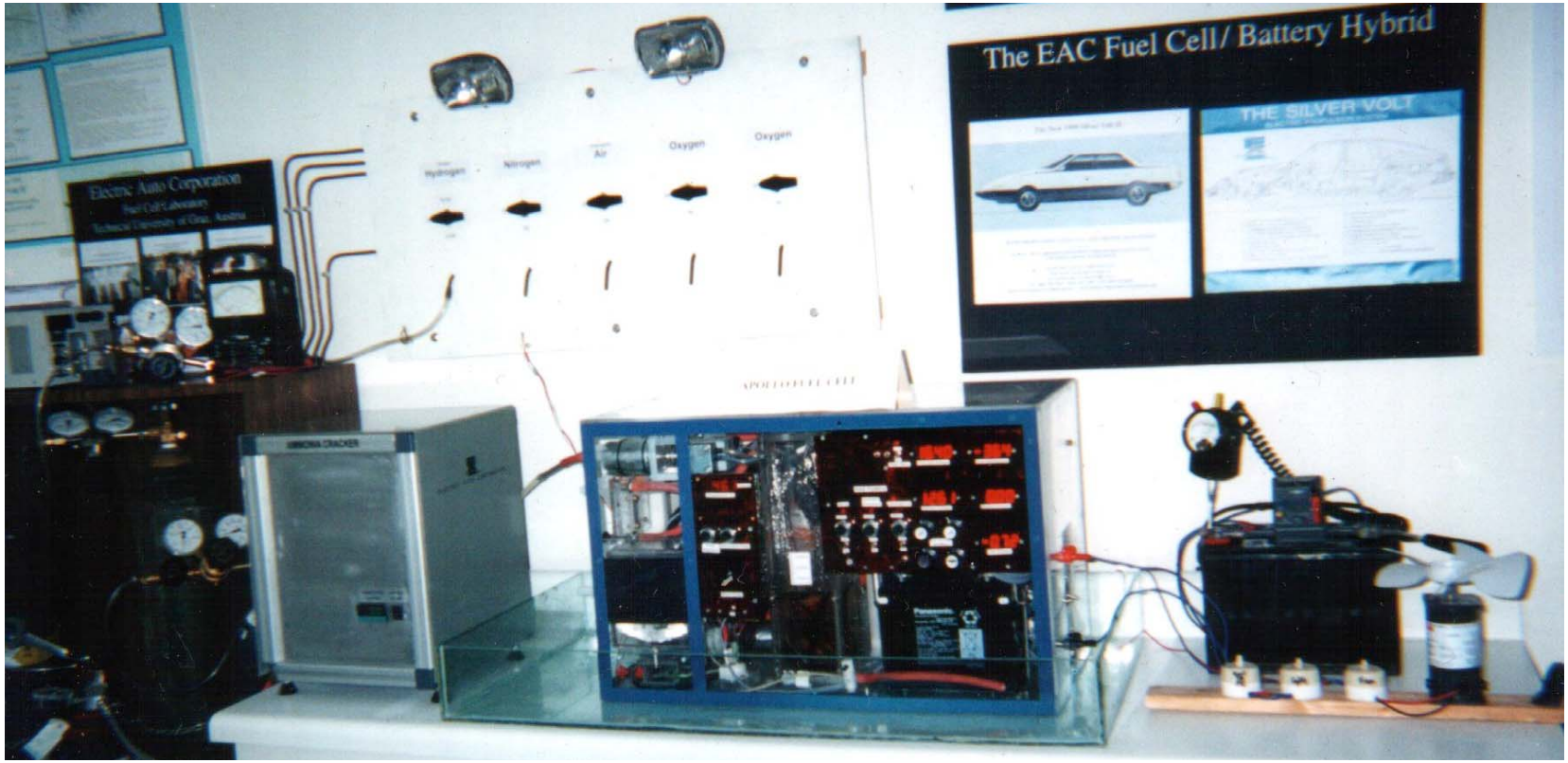
Liquid Removable Electrolyte

- easy thermal management
- easy water removal
- barrier against reactant gas leakage established
- opportunities for changing the electrolyte
- reduction of concentration gradient
- reactivation of catalysts noticeable
- lifetime of electrodes highly increased
- parasitic currents (in multi cell stacks)



Combination of an AFC and an NH_3-Cracker

Hybrid AFC running on NH3



Anhydrous Ammonia

Ammonia Cracker

Fuel Cell Module II

Hybrid battery (lead acid)

Electric Motor and Fan

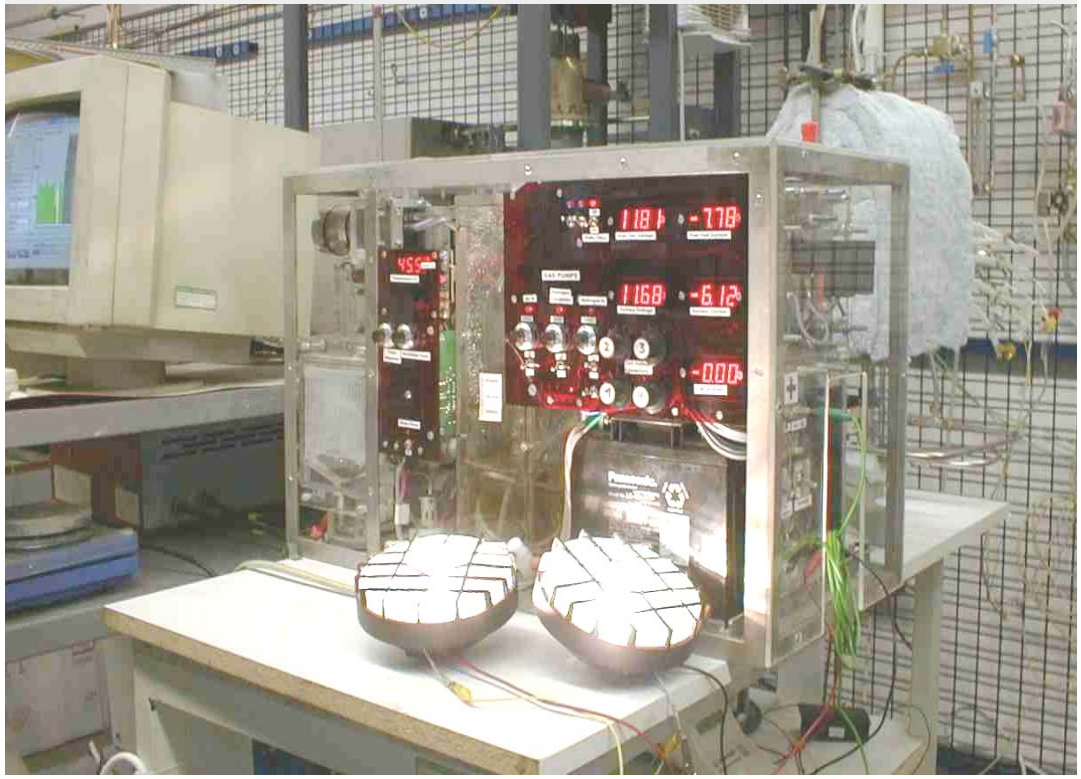
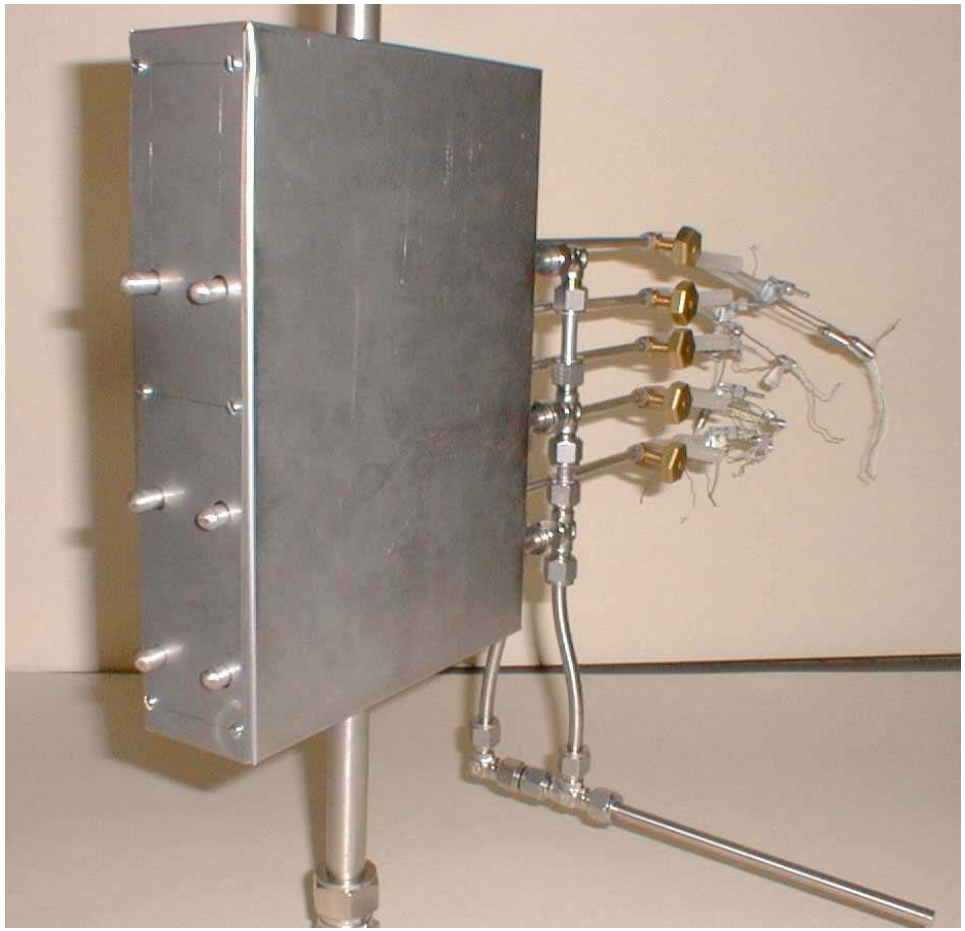


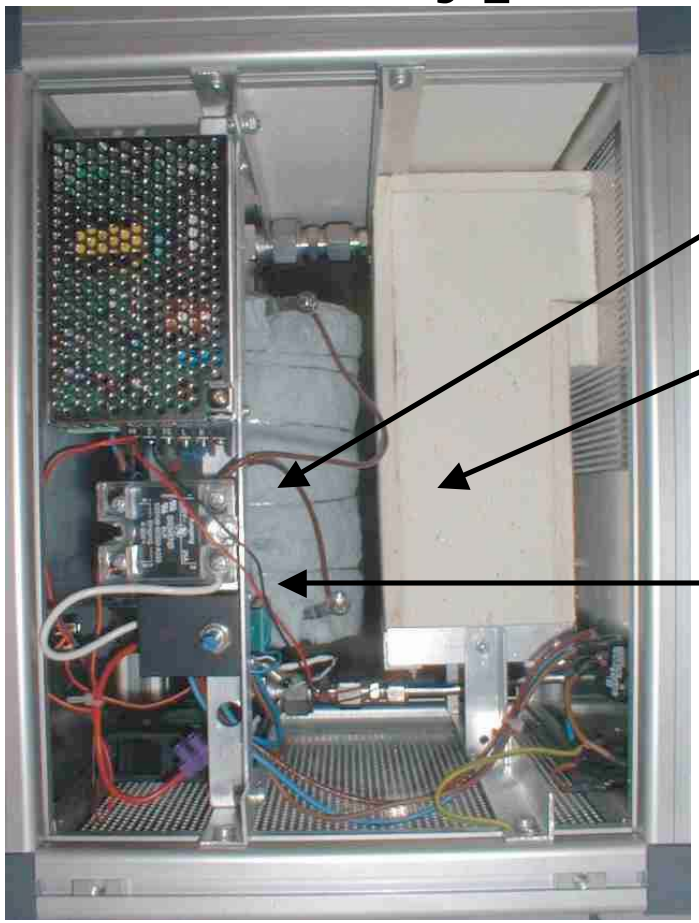
Abb.14: Demonstration des TU-Graz AFC-Systems mit NH_3 Cracker (niedrige Kosten und effizient)

The TU-Graz AFC with Ammonia Cracker

Cracker IV front and rear view



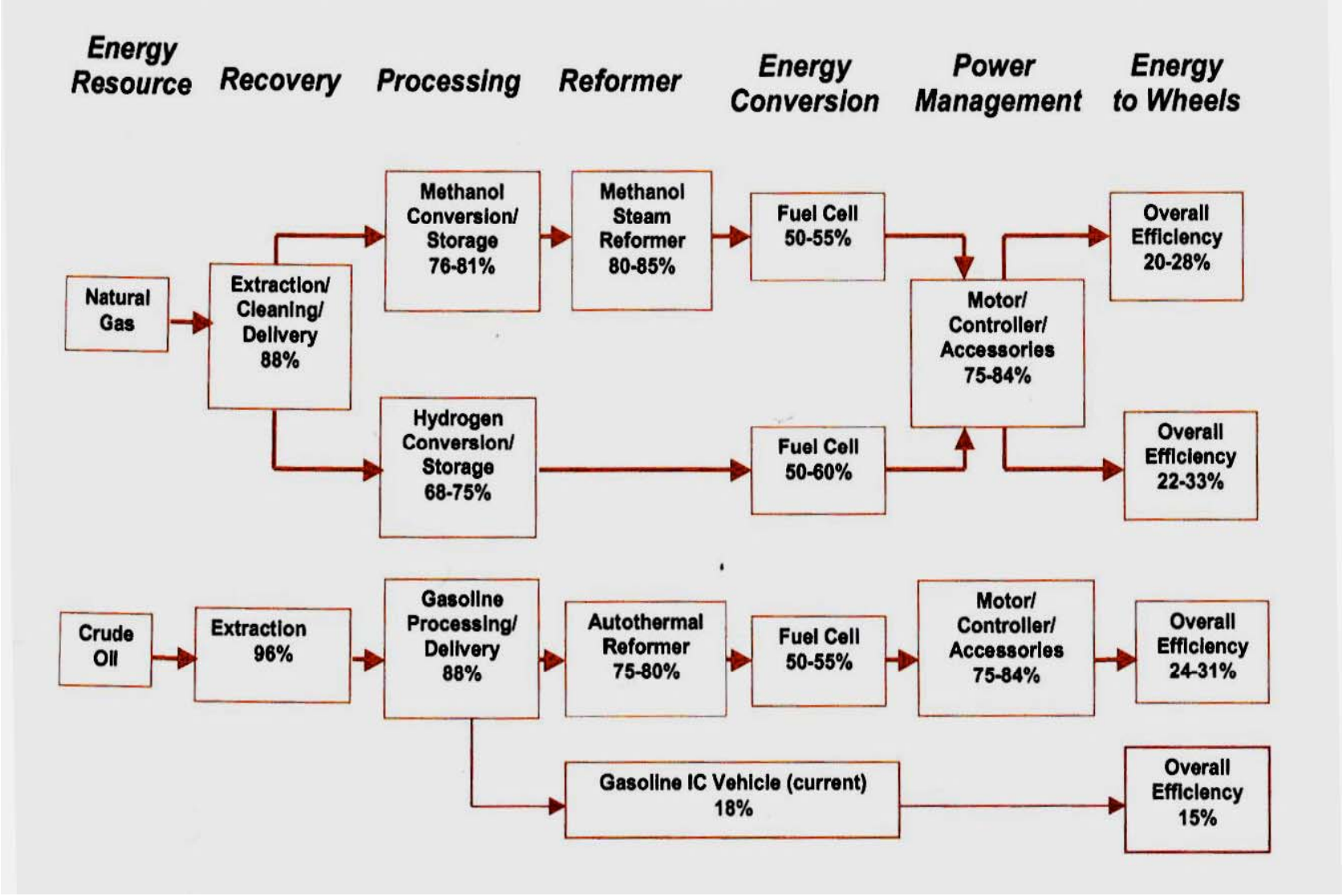
Prototype II - Components



isolated cracker

cooling unit

temperature control unit



"Well-to-Wheel" Efficiencies for Various Vehicle Scenarios

AMMONIA FOR SILVER VOLT ELECTRIC CAR

WITH 60 kW APOLLO FUEL CELL

DRIVING RANGE: 240 MILES

AMMONIA: 60.48 kg –80 Liters –21 Gallons

1 –Gallon of Ammonia weighs 5.1 –pounds

1 –Gallon of Gasoline weighs 6.1 -pounds

THE SILVER VOLT REPRESENTS OUR HERITAGE, OVER 25 YEARS OF RESEARCH AND DEDICATION TO ALTERNATIVE POWER