Two GlidArc technologies for biogas processing

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Two GlidArc technologies for processing of poor biogas and its contaminants

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Biogas (BG) or Landfill Gas (LFG), product of anaerobic digestion of almost any biomass or organic waste, is available at relatively small scale but in numerous local sources.

Sometimes it can be quite poor (< 50% of CH_4) and polluted by H_2S, mercaptans, ammonia, siloxanes, other organics...

Release it to our atmosphere?
Burn it in flares?

No!!! Valorize it rather *via*:

1) **Burning – but in special gas turbines for Combined Heat & Power (CHP) generation**
2) **Boosting by Hydrogen for CHP generation in gas engines**
3) **Upgrading to clean Bio-Methane**

Ad 1)

ECP + Partners will offer in a very near future some special GlidArc™-assisted 0.1 – 1 MWe Gas Turbines

Ad 2)

ECP proposes a direct H_2 generation inside any BG or LFG by an in-situ reforming of such natural $CH_4 + CO_2$ mix using our GlidArc™ reactor

Ad 3)

ECP proposes a destructive valorization of any concentrated mixture of CO_2 + extracted pollutants by their direct GlidArc™- assisted removal using our SulfArc™ process integrated to any extraction method

Ad 3) cont.

Clean and local Bio-Methane opens the way to a small- or medium-size:

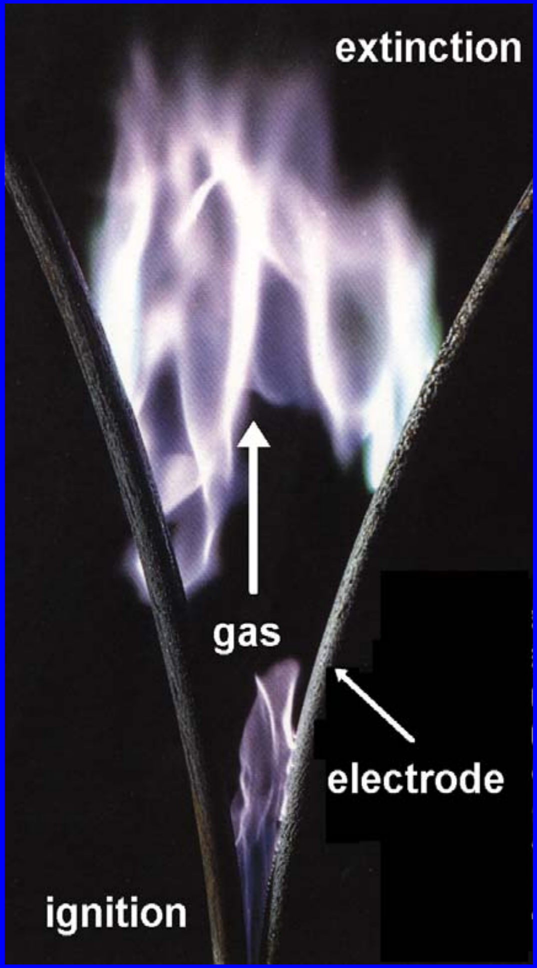
- **car and trucks fueling using compressed Bio-Methane**
- **Biomethane-to-Liquid (BTL) plant providing local green gasoline and diesel oil**
- **injection to natural gas grid**

Such BTL process asks first for the Bio-Methane reforming into Synthesis Gas, a mixture of CO and H_2 being elementary bricks for the Fischer-Tropsch (FT) synthesis.

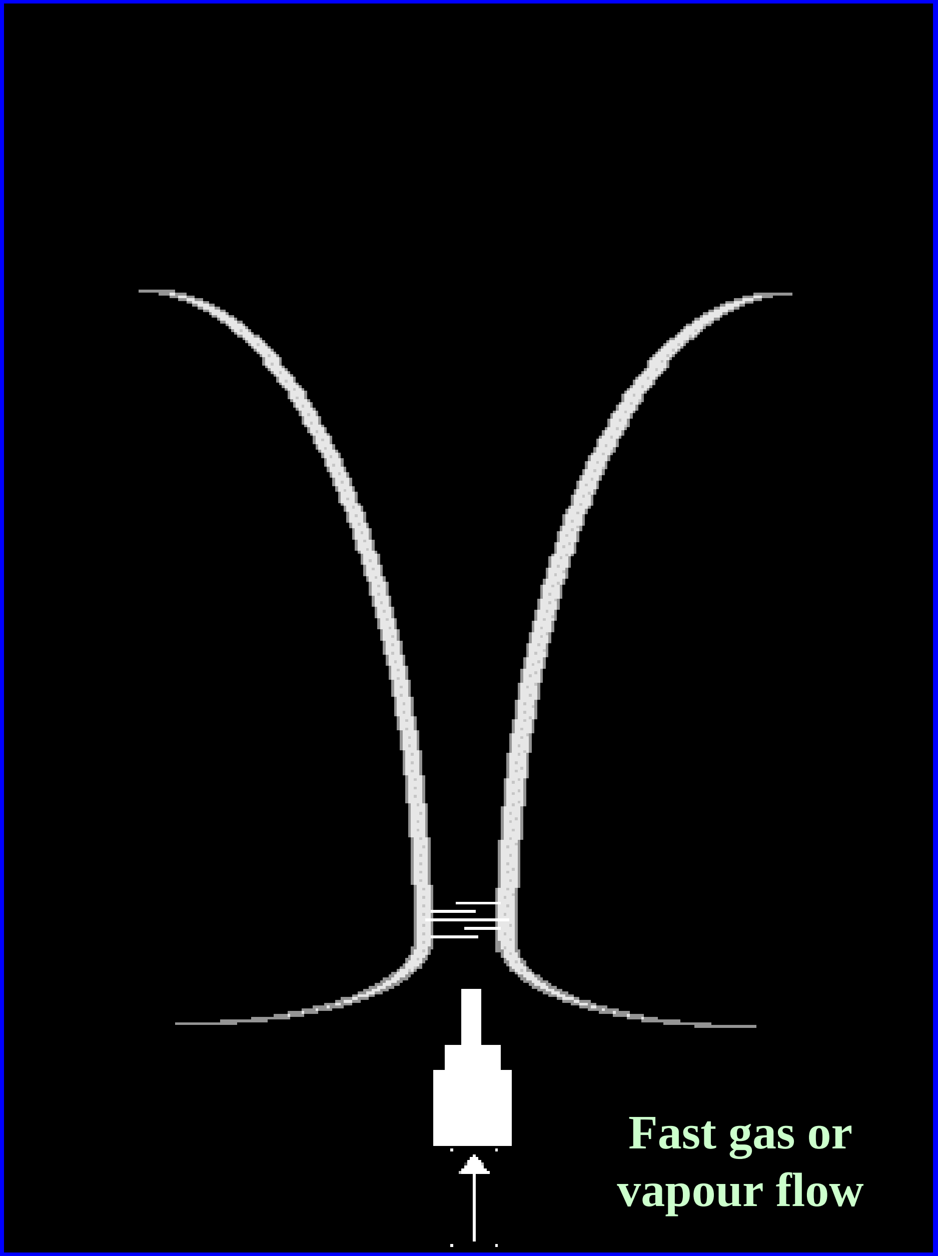
There are two challenges (and ECP's solutions)**:**

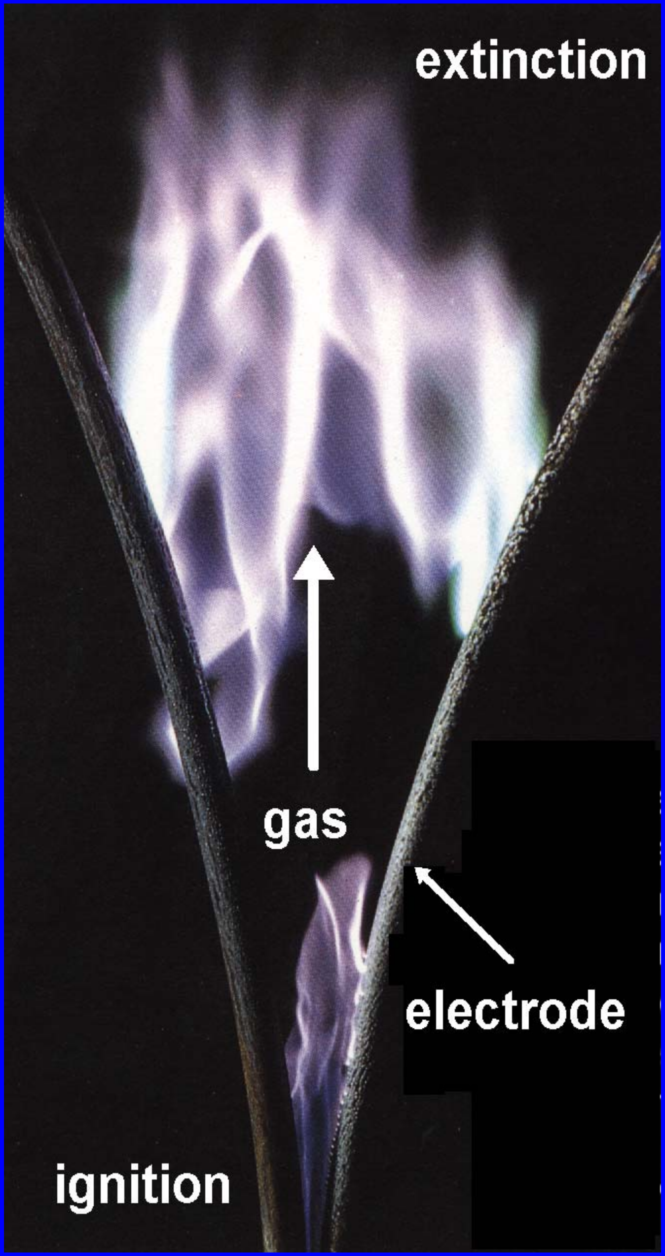
a) small scale Bio-Methane reforming into syngas using GlidArc™-assisted Partial oxidation (POX)

b) small scale FT plant (we propose our FT multiple-plate compact reactor and related high-temperature catalysts)



How GlidArc I operates:





GlidArc features:

cold electric discharge, 5 – 15 kV, < 5 A, 0.05 to 50 kW

0.03 - 12 bar

enhances and stabilizes exothermic processes *via* active catalytic species

bring active energy to endothermic processes

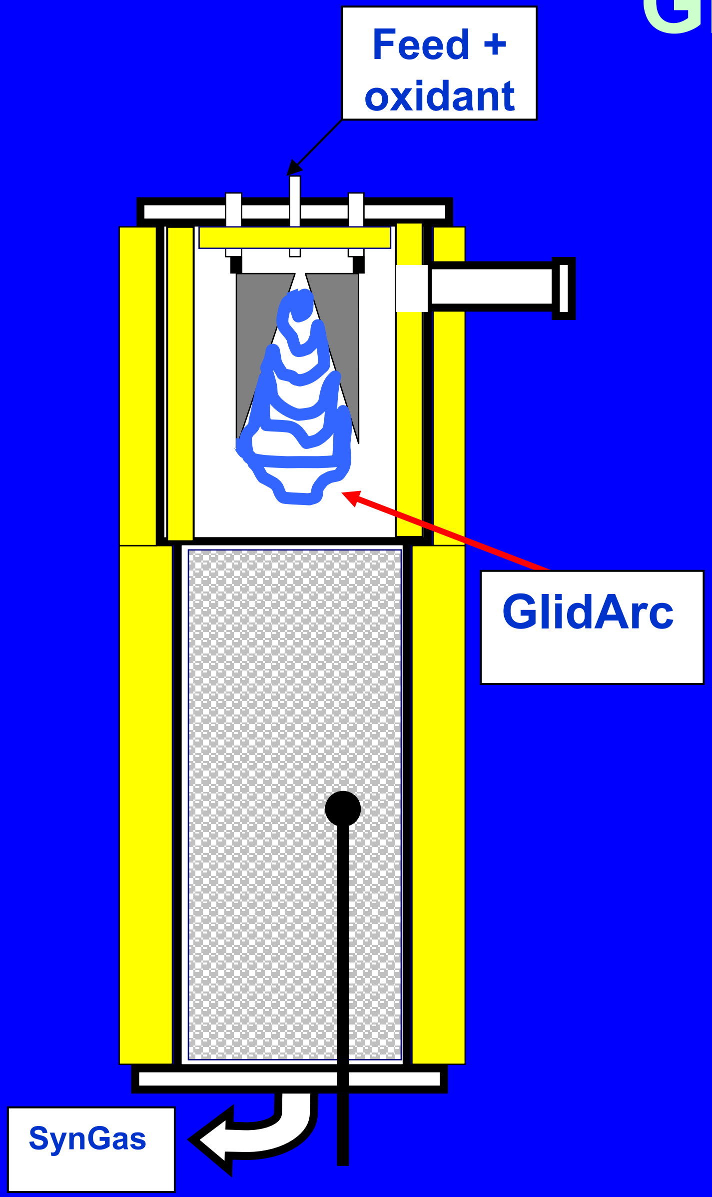
not cooled electrodes

any gas, vapor, droplets or dust accepted

any initial feed temperature accepted

multiple-discharge/electrode system can be installed for a large scale

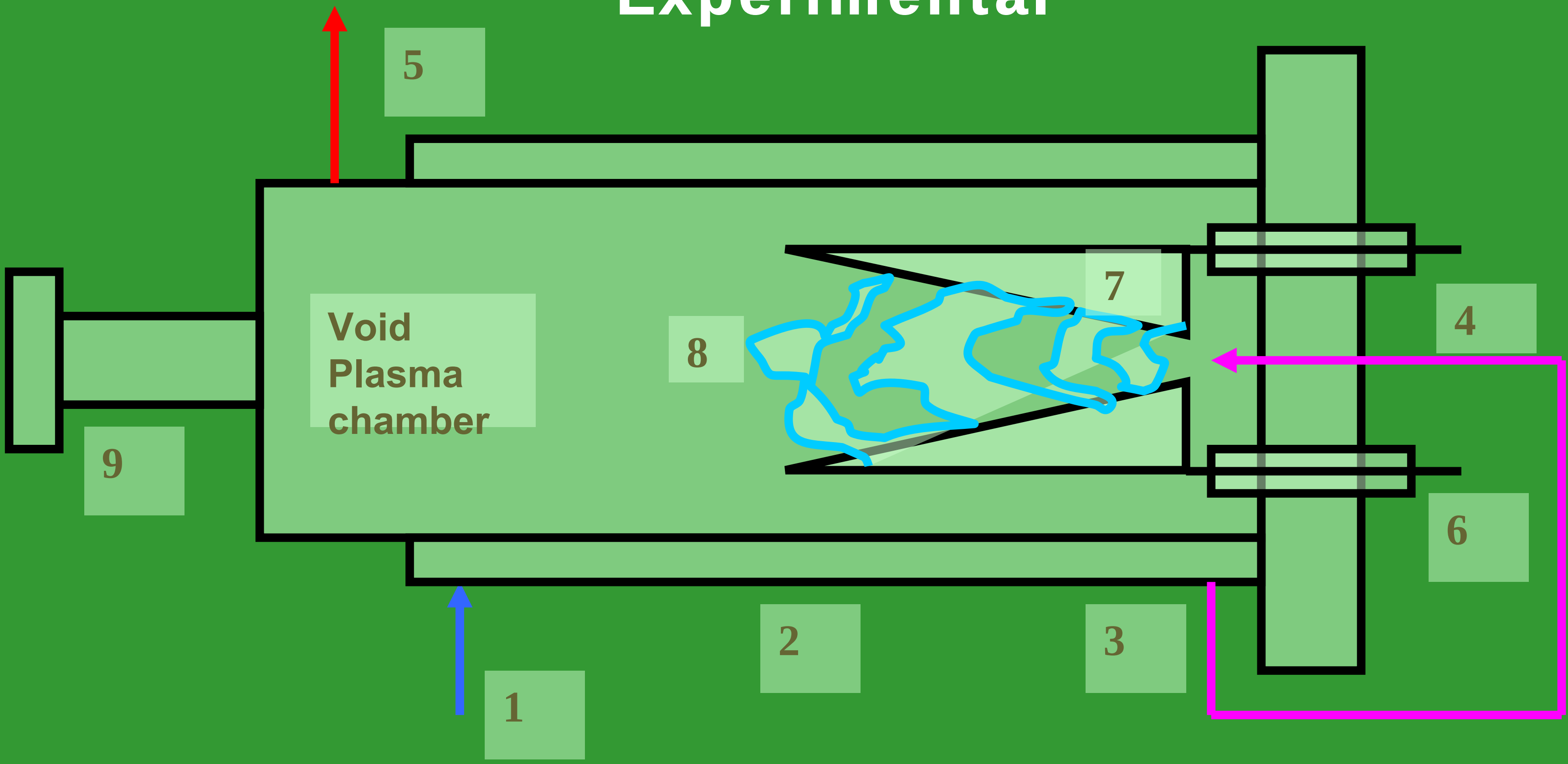
GlidArc reformers



Ad 2)

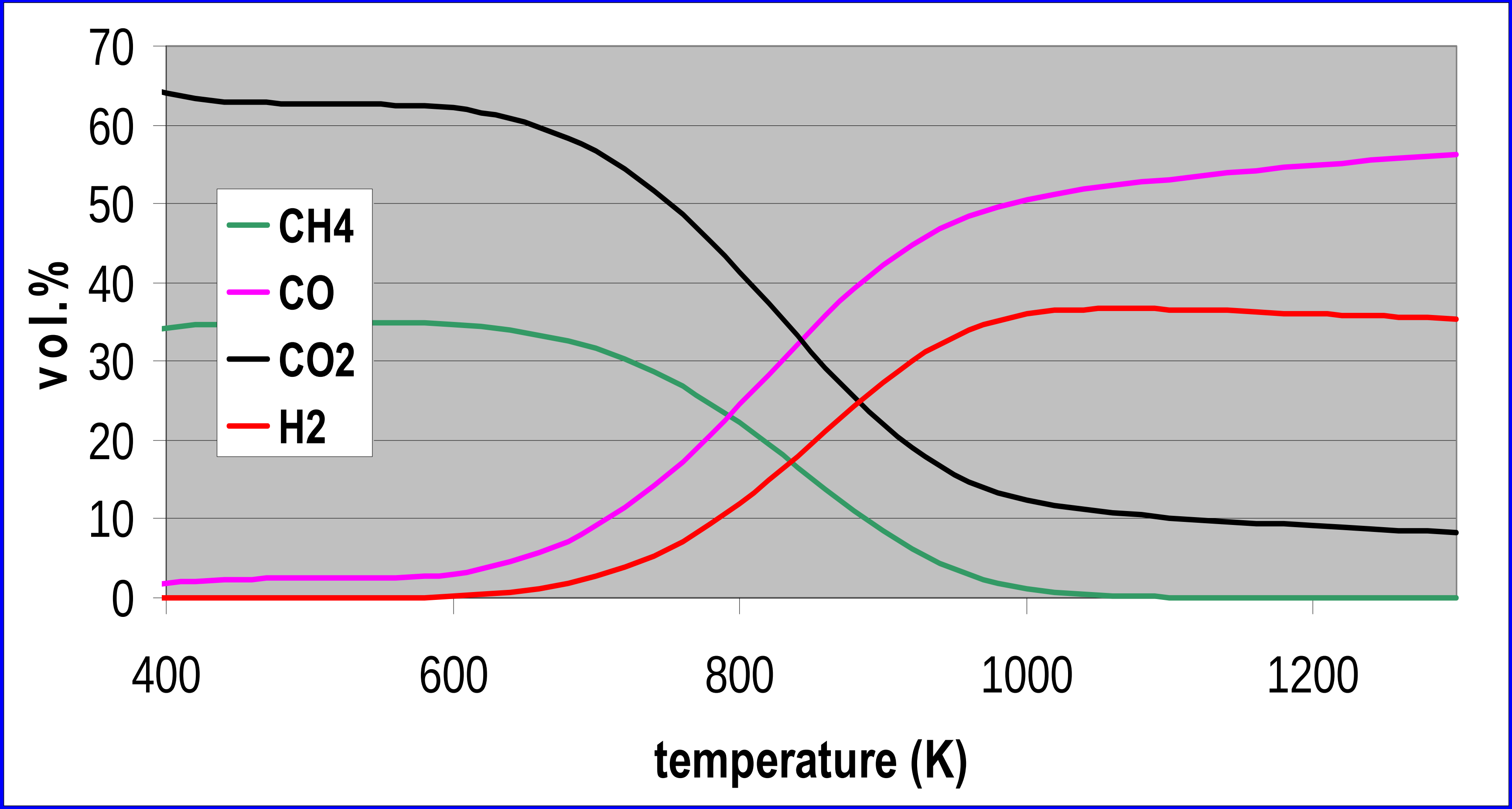
We propose a very simple <u>biogas upgrading</u> process *via* an input of very active electric energy. Such energy and stream of catalytic species (electrons, ions, excited, atoms, molecules, radicals and UV photons) generate some amounts of H_2+CO increasing dramatically any <u>biogas flammability</u>.

Experimental



Schematic view of the reformer: 1 - cold biogas entry, 2 - preheat chamber, 3 – preheated biogas exit, 4 – entry of the preheated biogas into the plasma chamber, 5 – exit of the upgraded biogas, 6 – high-voltage connectors to the electrodes, 7 – electrodes (three), 8 – gliding electric discharges, 9 – observation window

Input			
CH_4 content in biogas		35 – 50	vol.%
Flow rate		15 – 27	L(n)/min
Thermal power of biogas (LHV)		4.8 – 7.3	kW
Added electric power		0.48 – 0.58	
Added electric power		6.6 – 12	%
Output			
Gas temperature		120 – 220	°C
Flow rate		17 – 28	L(n)/min
Thermal power (LHV)		5.0 – 7.4	kW
Gas composition (dry)	CO_2	38 – 55	vol.%
	CH_4	25 – 35	
	H_2	6.3 – 14	
	CO	5.3 – 11	
	(H_2 + CO)	(12 – 25)	
	C_2H_6	1.5 – 2.0	
	C_2H_2	0.07 – 1.4	
	C_2H_4	0.11 – 0.22	
	C_3	0.24 – 0.33	
Electric energy expense to produce 1 m^3(n) H_2 + CO		2.1 – 2.5	kWh



Equilibrium composition at 1 atm of the dry output gas as a function of temperature when the input poor biogas is composed of 68 vol.% CO_2 and 32% CH_4

Comparing the upgraded biogas composition obtained in the GlidArc reactor at 200°C and calculated equilibrium composition one sees quite wide difference:

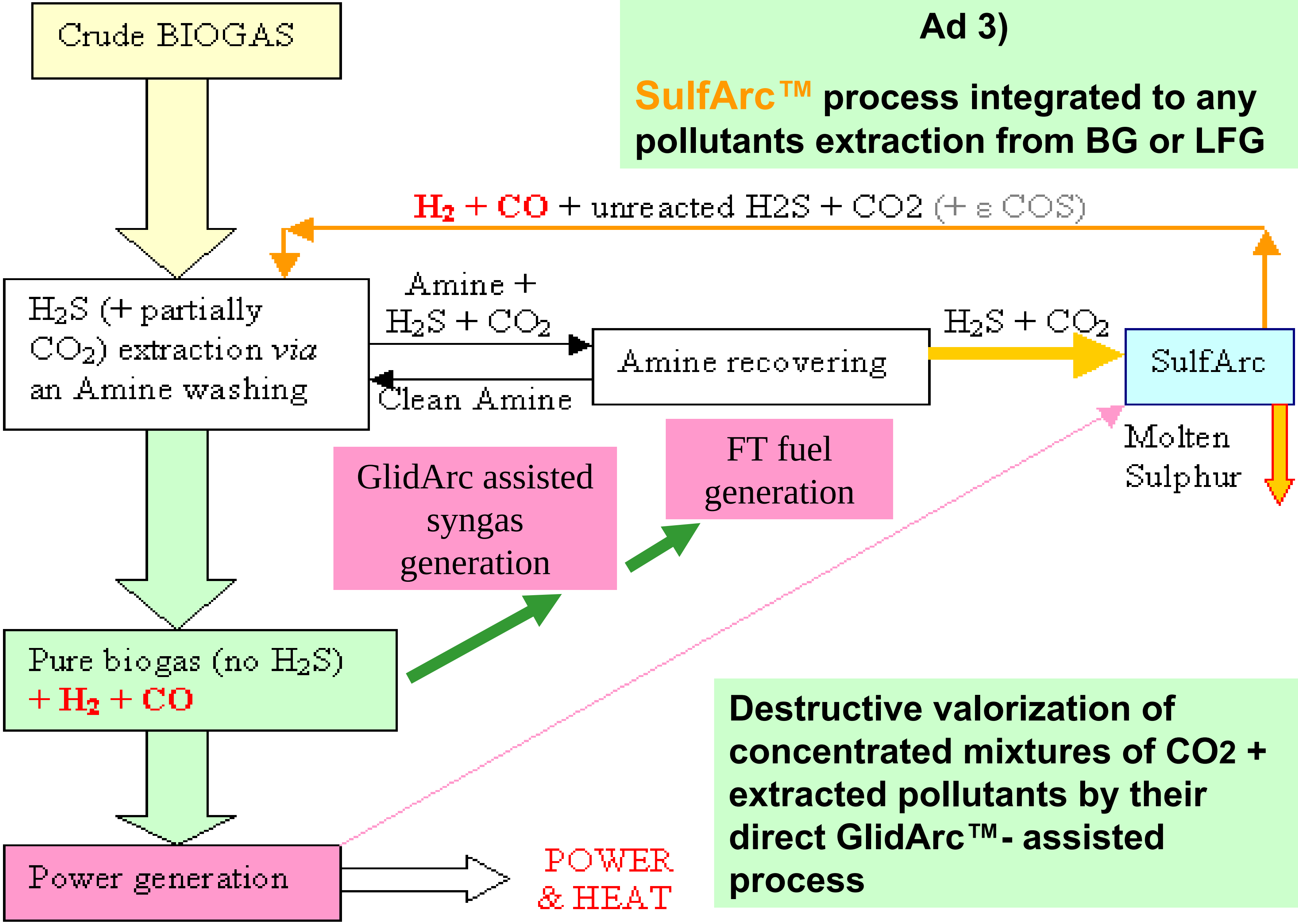
The concentrations of species that we obtain experimentally would ask for much higher equilibrium temperatures in the 430-500°C range

Moreover, at such moderate temperatures one could not obtain the equilibrium composition without a highly active catalyst!

Our GlidArc™ process is driven by a non-equilibrium, cold, and highly catalytic plasma!

Ad 3)

SulfArc™ process integrated to any pollutants extraction from BG or LFG



Destructive valorization of concentrated mixtures of CO2 + extracted pollutants by their direct GlidArc™- assisted process

Chemistry

$H_2S \rightarrow H_2 + S$ $\Delta H° = +20.6$ kJ

(14 times less than the water electrolysis)

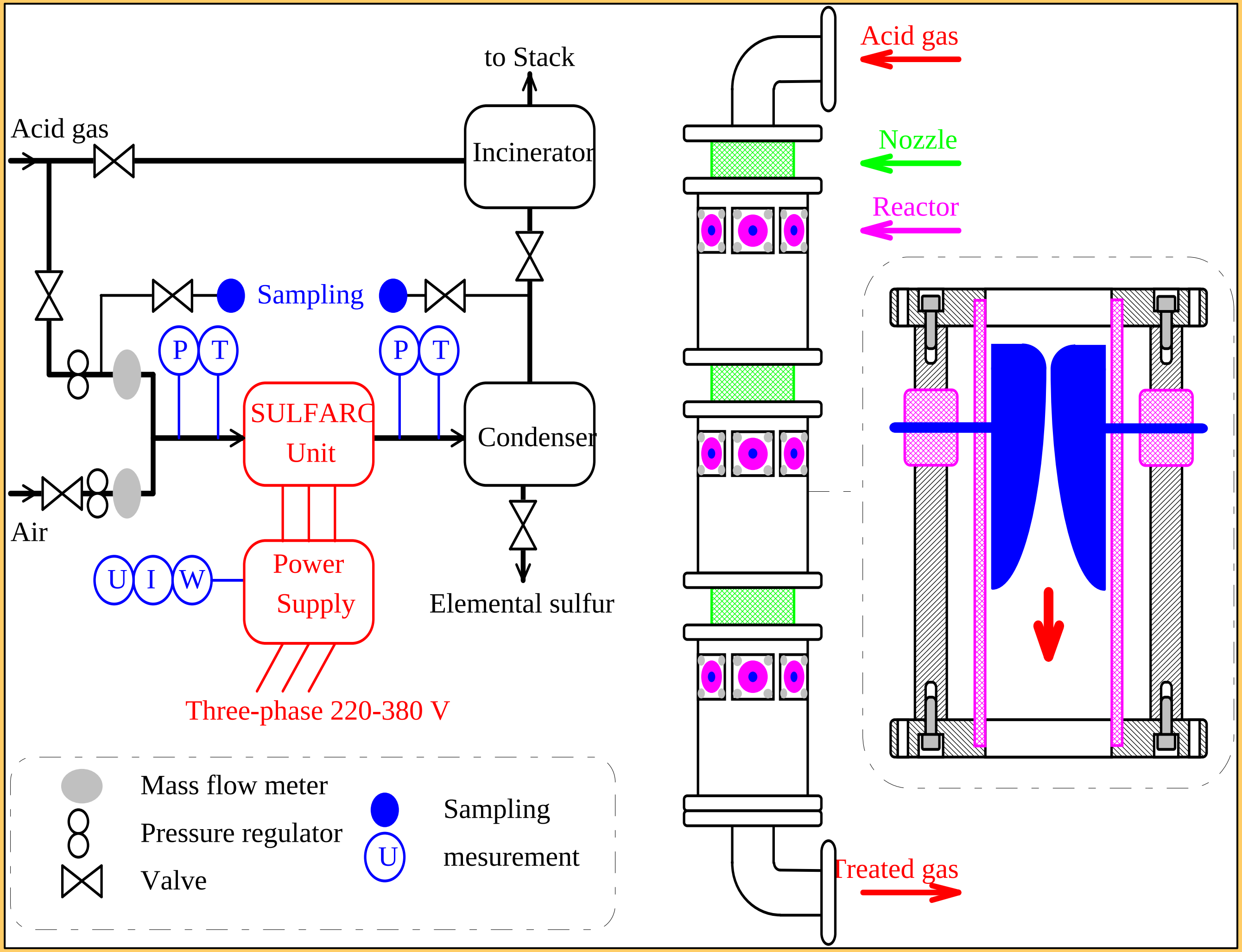
$H_2 + CO_2 = H_2O_{vap} + CO$ $\Delta H° = +41.1$ kJ/mol

$CO + S = COS$ $\Delta H° = -31.5$ kJ/mol

$$H_2S + x\,CO_2 = (1-x)\,H_2 + (1-y)\,S + x\,H_2O_{vap} + (x-y)\,CO + y\,COS$$

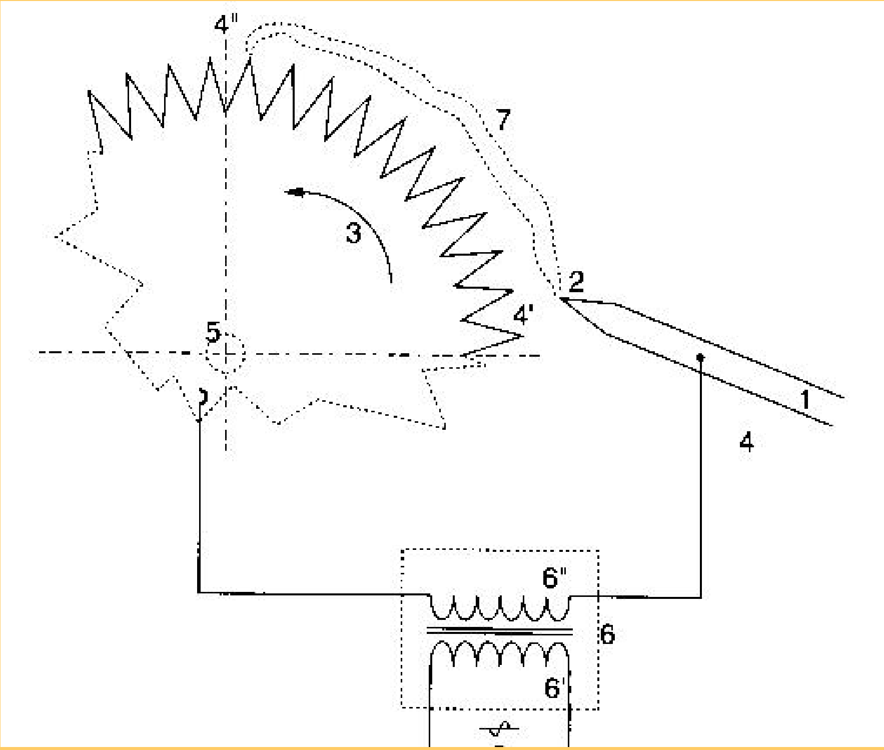
SulfArc™ provides the synthesis gas (H_2 + CO) from wastes extracted from any H_2S-rich mixture without prior gas separation!

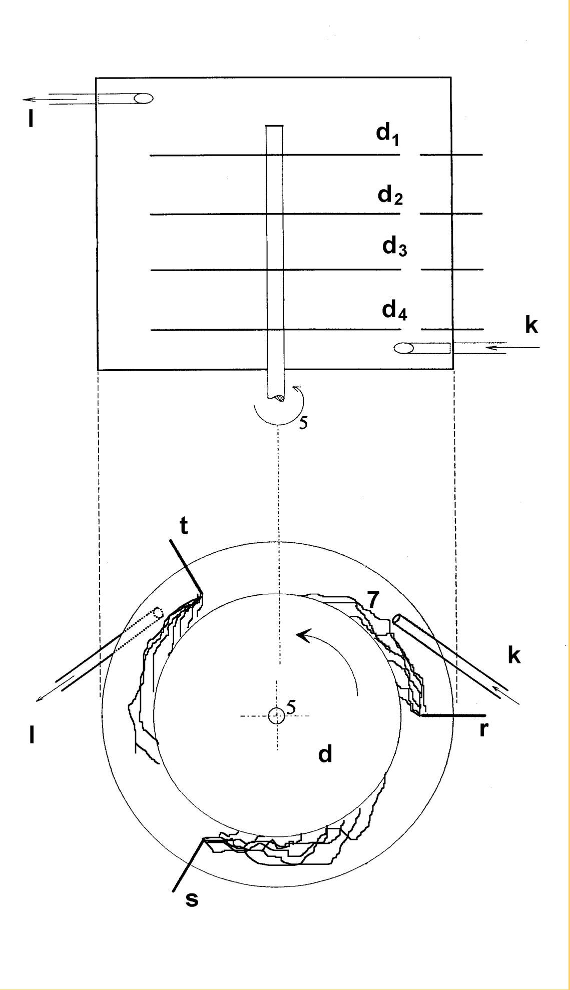
Schematic view of the pilot installation of SulfArc™ for 60 m³/h sour gas processing in Poland



New developments

Multiple stages/electrodes GlidArc-II reactor: r, s, t – three-phase-supplied stationary electrodes, k, l – input and output of the processed gas, d – rotating electrodes





Principle of the GlidArc-II device: 1 – stationary electrode, 3 – rotating electrode, 6 – power supply, 7 – high-voltage discharge

A 60-L SulfArc™ reactor was built by ECP for H_2S-rich gases processing. This reactor contains 9 stages, each of them being powered by 3 stationary electrodes so that 36 active electrodes are present (including central electrodes)

Entries	
Power in kW	1 – 3
Temperature of the reactor in °C	82 – 330
Vol. % of H_2S	36 – 91
Total flow rate in L(n)/min	11 – 43
Specific Energy Input in kWh/m^3(n)	0.4 – 3.9
Outputs	
Vol. % of H_2	7 – 49
Vol. % of CO	3 – 38
Vol. % of COS	< 0.3
Flow rate of Hydrogen in L(n)/min	0.6 – 9
Conversion rate of H_2S into H_2 (%)	13 – 53
Total conversion rate of H_2S (%)	18 – 91
Conversion rate of CO_2 into CO (%)	18 – 80
Total conversion rate of CO_2 (%)	18 – 80
Energy Requirement for H_2 production in kWh/m^3(n)	3.6 – 76
Energy Requirement for H_2+CO production in kWh/m^3(n)	2.9 – 12

SulfArc™ advantages

- Electricity as unique source of energy
- Pollutants as unique reactants so that the products do not contain ballasts of added reactants
- No catalyst
- Process does not depend on the chemical composition of the feed
- One can treat even weak quantities of H_2S produced by small industrial units
- Energy expense is low
- No thermal inertia, good resistance to corrosion
- Elemental molten Sulfur as valuable neutral product

Conclusion

- Biogases are partially reformed at high energetic efficiency and **without soot production**
- Any **polluted biogas**
- The upgraded biogas can be produced at a constant flow-rate and at **any syngas content**
- **Low-temperature** upgrading
- The **process starts immediately** and drastic changes of all parameters can be done in few seconds
- We limit the electric power consumption to about 10% of the LHV power of processed biogas. Such low-power recycling is a worthy compromise: Instead of using a catalyst that asks for a very clean biogas and a high temperature reformer we dedicate a small part of the upgraded biogas power to support a non-catalytic reforming of crude biogas… that otherwise would remain worthless!

ECP is ready to build GlidArc™ and SulfArc™ processors

more on our activity:

www.glidarc-tech.com