Status of and Prospects for Biomass Gasification

Presented at

STCBC

by

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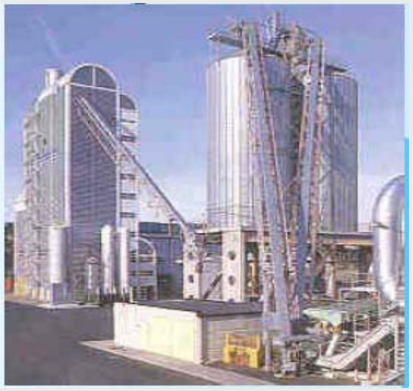
Technical Advances & Promising Research

- **High Pressure Feeders**: TKE staged piston & SRI feeders
- **Gasification**: Gasification of mixed wastes (ex: Lahti & SVZ), Separation of drying, devolatilization, gasification, and combustion zones and thermal integration to decompose condensables (ex: Güssing, Choren/Carbo-V, Viking, TKE 3-stage), Production of MCV-gas with & without oxygen, low-T gasification (730 C) for low-ash fusion materials, and co-gasification (Nuon).
- **Gas Clean-up**: Catalytic tar cracking (i.e: Olivine, Ni Monolith), separation of particles prior to tar removal, wet ESP, catalytic barrier filters, organic liquid scrubbers, no waste water
- **Ion Transport Membrane Separation**: Removal of H2 as it is formed in the gasifier or in gas conditioning systems
- **Materials:** Corrosion resistant superheaters in co-firing
- **Automated Gasifiers:** ex: Viking Gasifier
- **Integrated Operation with Gas Engines:** several examples

Successful Niche Applications & Demonstrations

1. Wisaforest CFBG: 1983, 35 MWth
2. Bioneer MBG: 1985-86, 4-5 MWth
3. Choren/Carbo-V 2-Stage EGP:1993, 1 MWth
4. B&W Volund MBG: 1994, 5 MWth
5. SVZ Schwarze Pumpe MBG/BGL/ EFG: 1994/ 2000, 420 MWth
6. Ruedersdorf CFBG: 1996, 100 MWth
7. Exus Energy MBG: 1998, 80kWe, 400 kWth (design)
8. Essent/AMER Lurgi CFBG: 80 MWth
9. NUON Shell GP: 2000, 85 MWe (BM)
10. Rural Generation:1997, 100 kWe

Värnamo PCFBG
1993-1999
6MWe, 9MWth



Güssing FICFB
2000
2 MWe, 4,5 MWth

Lahti CFBG
1998, 45 MWth

Viking, 2-stage BMG
2002, 20 KWe

Technical Advances – large-scale systems

1. **Sydkraft AB/Värnamo**: 8500 hrs of pressurized operation with HGCU, inc. 3600 hrs w/GT, with low-emissions, Successful feeding of mixtures of bark & wood as well as 100% straw, and 50%RDF and 50% wood Extensive testing with hot-gas filtration, N2 purging, and filter failure
2. **FWE**: 8 plants, 3 to 70 MWth, for firing lime kilns and boilers, Lahti plant (45 MWth)>6 years of operation, >30,000 hours, reached >97% availability, 3300 hours of slip-stream gas clean-up with sorbents abnd HGCU; Corenso plant (50 MWth)>3 years of operation, >15,000 hrs, aluminum metal recovery: Ruien Plant (50 MWth), in operation since May, 2003
3. **TUV, Güssing** : 10000 hrs of operation to produce MCV/synthesis gas, operation in CHP-mode with gas engine
4. **Essent/Amer Lurgi CFBG**: 85 MWth for co-firing in 600 MWe PC Boiler
5. **Nuon- Shell GP**: Co-gasification with coal, experience with sewage sludge, chicken litter, and demolition wood; upto 30% by wt. biomass, and impact of contaminants in waste materials on gas and ash quality
6. **Choren/Carbo-V 2-Stage EGP:** Pyrolysis followed by entrained slagging gasification process, tar-free gas, >12,000 hours of operation, present focus on BTL: MeoH and FTL

Technical Advances – Small-scale Systems

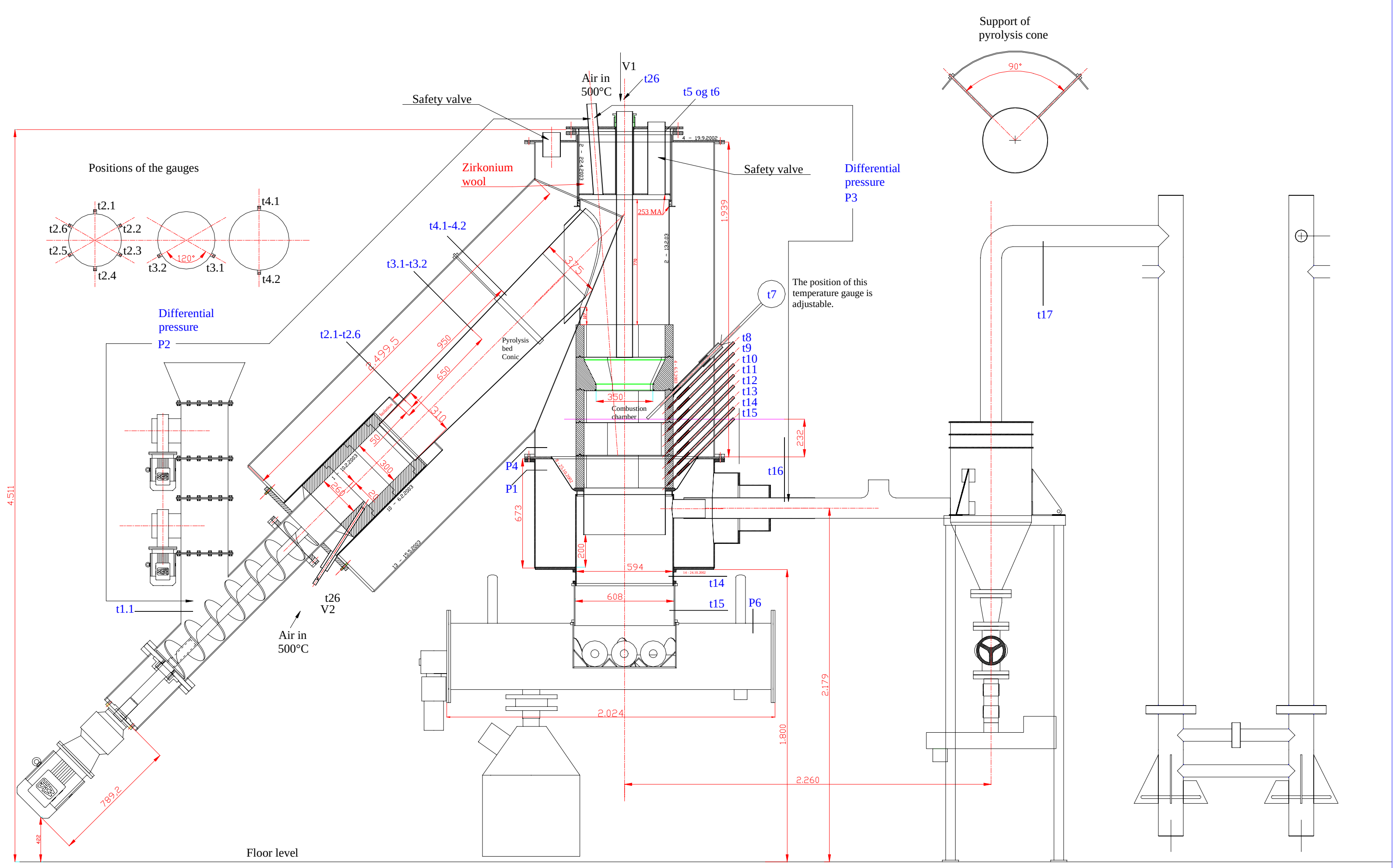
1. Several moving-bed processes coupled to gas engines (B&W Volund, DTU-2 Stage/Viking Project, Rural Generation, Exus Energy, TKE-3 Stage, IISc, CPC, etc.,)

2. **B&W Volund**: 5 MWth, Operation started in 1993,Updraft with total gas quenching with wet ESP, now in successful operation with 2 Jenbacher engines (2x648 KWe), portions of tar reinjected into the gasifier or used for peak-shaving

3. **DTU-2 Stage**: Success with tar destruction to <1mg/NCu.m, Identified reactor materials and solved hot-ash discharge & automation

4. **IISc-Open-top DD**: Basic research on the effect of Dp provided the basis for air nozzle design, experience with crop residues, dual fuel gas engine operation

5. **Community Power** – Open-top DD: Portable and skid mounted unit



Three Stage TKE Gasifier

Itemref	Quantity	Title/Name, designation, material, dimension etc			Article No./Reference	
Designed by		Checked by	Approved by - date	Filename	Date	Scale
TK Energi A/S			Samlingstegning			
			4		Edition 18 - 10.06.2003	Sheet

Synthesis Gas & Value-added Products

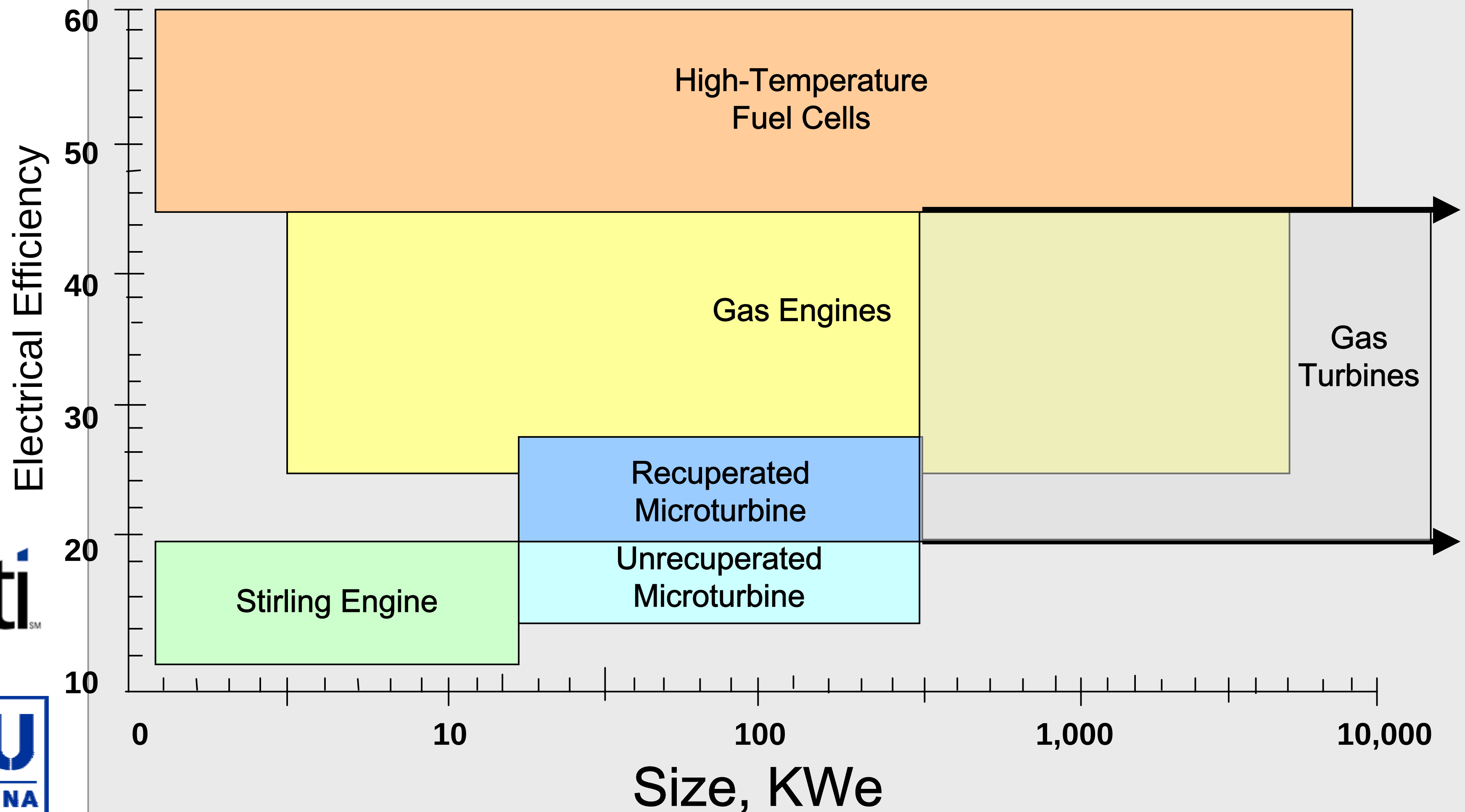
- 1923- BASF CO+H2 to MeOH & higher alcohols: part of the continuing R&D into hydrogenation of CO
- 1930-FT (CO insertion or chain building to produce long chain HC – Hydrogenation & hydrocracking could be used to control product selectivity (SMDS, Bintulu : 600 MMSCFD NG)
- **20-30% conversion per pass leads to co-production options: Fuels, chemicals, and power**
- Two-thirds of final product cost is for producing clean synthesis gas from biomass, hence the need for maximizing scale of operation
- Synthesis gas applications need 1-2 orders of magnitude less tar compared to what is generally present in BMG raw gases

Examples of Recent Coordinated RD&D Initiatives

- **Global Climate and Energy Project at Stanford University, Stanford, CA, USA: Feb 2003** - $225 MM/10 yrs from Exxon,Mobil,Toyota, Schlumberger,& GE – pre-commercial research to develop technology options with reduced GHG emissions, ex: characterizing char behavior during gasification
- **Vaxjo Värnamo Biomass Gasification Center (WBGC), Värnamo, Sweden: Dec 2003 –** Värnamo Energi AB, Vaxjo Energi AB – Focus on steam-oxygen pressurized gasification of biomass, RDF, wastes, TDF, to demonstrate IGCC, CHRISGAS (clean H2 & Synthesis gas), production of motor fuels & fuel cells
- **FUTURE ENERGY Gmbh, Freiberg, Germany: Jan 2003-** RD&D technical & project management services for pressurized gasification and synthesis gas production; all types of carbonaceous materials including biomass. (CHOREN gasification process to produce tar-free synthesis gas and vitrified ash. BTL options: MeOH, FT Liquids, co-production of power)

Prime Movers for Bio-power Applications

1 Tonne dry BM = 15 to 19 GJ or 4170 to 5280 KWh (thermal)



Where Do Fuel Cells Fit ?

	Recip. Engines	*Micro-turbines*	*Low-Temp. Fuel Cells*	*High-Temp. Fuel Cells*
Baseload	◓	○	●	●
CHP	◓	◓	◓	●
Peaking	●	●	○	○
Standby/Backup	●	●	◓	○
Power Quality	◓	◓	●	◓

Source: ADL

Suitability: Low ○ — ● High

A Path to Commercialization

- *Biomass is the largest source of fungible renewable energy*
- *Commercial success demonstrated with: Small-scale systems coupled to gas engines, CHP applications, and co-firing*
- *BMG fuel gas could substitute for natural gas or oil in several industrial applications (i.e., Process heat, boilers, co-generation, and HVAC)*
- *In USA : 5Q/yr. of new Bioenergy could conserve >20% of natural gas or ~20% of oil used at present*

Build-up BM feedstock supply infrastructure, explore co-firing with natural gas, and accelerate process optimization with present commercial opportunities and industrial applications while developing efficient BMG Processes

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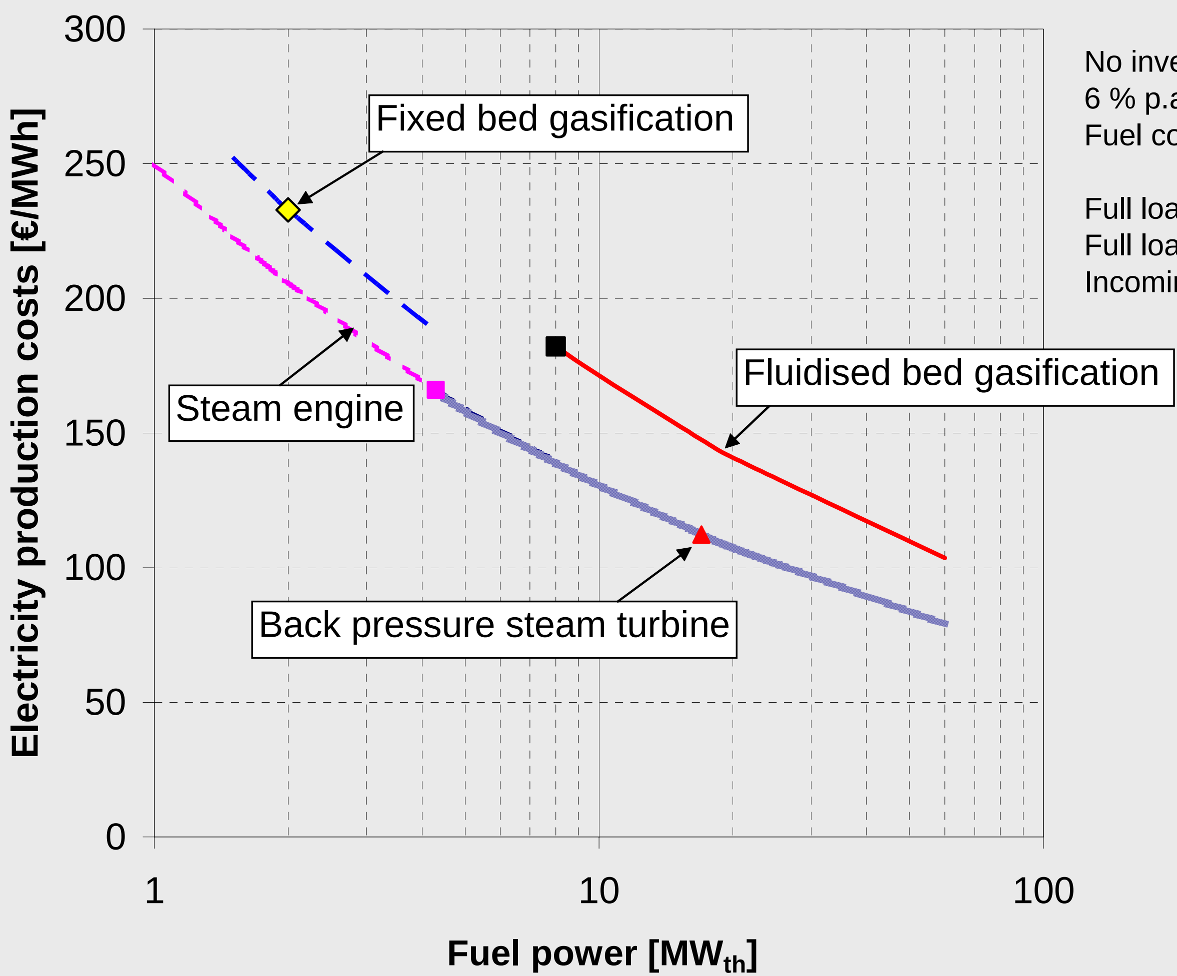
The Case for CHP Plants in Austria

Situation in Austria:

- Biomass has a long tradition (11 % of total energy demand) and is favored by political decisions
- High feed-in tariffs for green electricity (100 – 160 $/MWh) depending on size of the plant and type of fuel (wood chips, waste biomass)
- Competitive technologies: Steam process (steam engine and turbine), ORC-process, gasification&gas engine
- Typical size range of CHP-plants: 0.5 -5 MWel

The Case for CHP Plants in Austria, ctd.



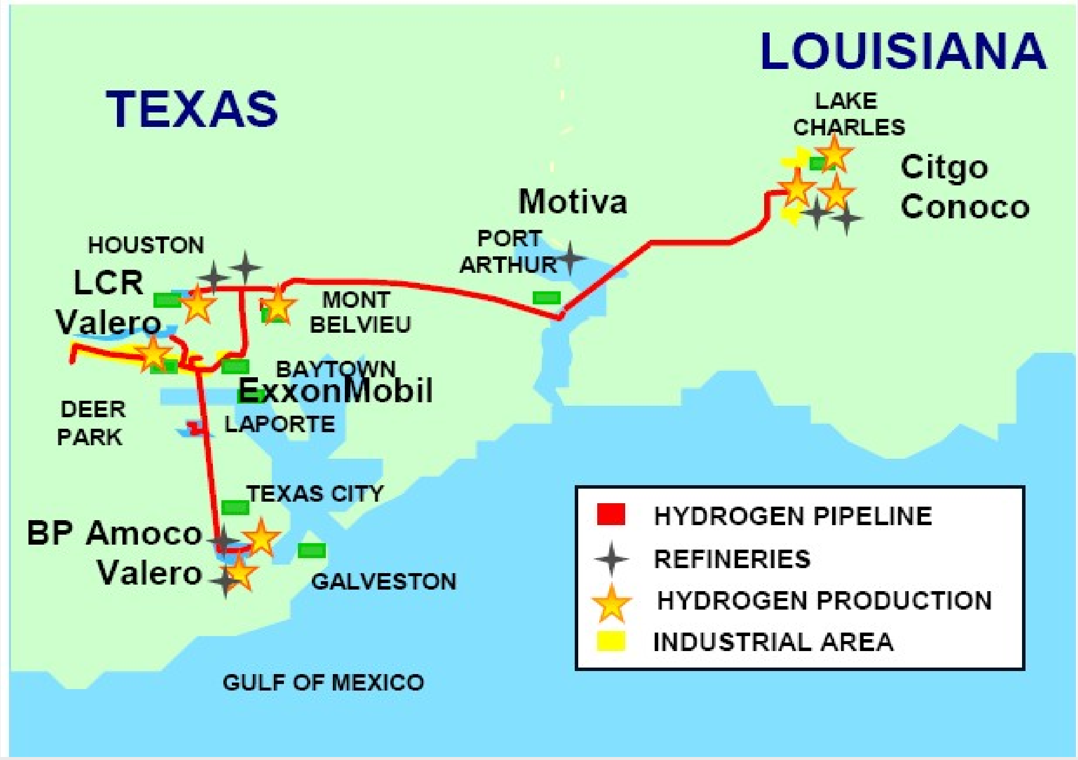
No investment subsidies
6 % p.a for 13 years
Fuel costs: 14 €/MWh

Full load capacity heat: 4000 h
Full load capacity electricity: 6000 h
Incoming heat leads : 20 €/MWh

Hydrogen Pipeline

"..Conventional mild steel pipelines in the Ruhr district of Germany have carried hydrogen between producers and consumers since 1938 without safety problems.."

..25 to 30 cm pipes at 10-20 bar…



…North America has at least 700km….

"…there is a 170km system in Northern France and a total of some 1500km in Europe as a whole…"

Progress of coal gasification over decades & the evolution of biomass gasification

- Early town gas plants were displaced by natural gas and oil
- Clean Coal Technologies are under development to utilize the abundant resources of coal and conserve natural gas and oil
- High efficiency biomass gasification is an essential part of viable portfolio of clean and renewable energy technologies

Town Gas Plants

Tampa Electric Polk Power Plant

Status of Gasification in general....

- 130 gasification plants in operation + 35 in various stages of development
- Most in the 250-300 MWe range to more than 1000 MWe capacity
- Estimated contribution is approximately ~1% of global energy use
- IGCC provides cost-effective emissions control and 15-20% less CO_2 (mostly due to a similar increase in efficiency) w/CO_2 sequestration option
- *Commercial value of gasification is based on its strong environmental performance & its ability to convert a diverse low-grade fuels into a fairly uniform commercial product*
- *IGCC benefits are the motivation for 90% of the planned new US gasification capacity*

Hurdles: System integration and optimization to improve efficiency, reliability, and cost

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Coal Gasification Research Needs

CURC's Highest Priority R&D, 20 years, $12.6B

- Removal of Hg, other HAPS, SO2, particulates, integrated processes, >90% removal
- High-temp materials for boilers & steam turbines, extended component testing
- High-pr solid feed injection, slip stream testing of FC, 1000C metallic HEX, monitoring for trace elements, char combustion & gasification
- Synthesis gas to fuels and chemicals, new enabling technologies, system optimization, H2 production, CO2 separation & sequestration

OTHER R&D Needs

- Mechanism of ammonia formation & control, robust catalysts for WG shift to increase H2 production & advanced concepts to combine H2 separation and WG shift, membranes for H2 & CO2 separation, ion-transport membranes for O2 separation, co-gasification of biomass/coal/waste, alkali control & management, effect of process additives on ash and other effluents
- Improvements in gasifier design, materials/alloys (metal candle filters now operate at 450C for 1-year), ceramic filters, refractories, feed system injector materials, robust instrumentation (Thermocouples now last for 30-45 days), steel with low-temperature (around 110C) corrosion characteristics to design leak-proof air and gas heaters, and removal of trace elements by ESP
- Sensors and controls

Besides Technology, tax incentives are essential....

- In spite of low capital costs ($500/kW) for NG technologies, their economics are further improved by tax incentives (ex: write-off period for E&P & % depletion allowances)
- A California study shows that BM projects require $0.075/kWh in additional revenues or a 22% capital cost reduction to have the same financial return as natural gas power option

Investments made to develop fossil fuels during the first-half of 20th Century led to economic prosperity during the latter half of 20th Century

Investments made now for renewables, biomass in particular, should lead to environmental, energy, and economic prosperity in the future

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