Environmental Enterprise:
Carbon Sequestration using Texaco Gasification Process

Jeff Seabright
Arthur Lee
Richard Weissman, PhD.
Texaco Inc.
White Plains, New York

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ABSTRACT

Coal Integrated Gasification Combined Cycle (IGCC) is a commercially proven clean coal technology that offers significant environmental and economic benefits today, including decreased air and solids emissions. It also offers the potential to capture and sequester carbon dioxide. Coal IGCC provides electric utilities strategic options in meeting today's growing demand for energy products (electricity, fuel, chemicals) while protecting public health and the environment and providing a pathway to zero emissions coal-based power generation.

Conventional coal plants do not have the capability to extract the CO_2 without extremely costly post-combustion measures. The pre-combustion CO2 removal capability of the Texaco Gasification Process (TGP) configuration can, however, produce a high pressure, high quality CO_2 stream. This CO_2 can be injected into oil wells for enhanced oil recovery, injected into saline aquifers where it will dissolve naturally, or injected into coal beds for methane recovery.

The new lower cost and simplified gasifier design under development by Texaco should further reduce CO2 recovery costs. This design utilizes higher pressure gasifiers with direct water quench cooling that will reduce the cost of water gas shifting of CO to H2, CO2 recovery and CO2 compression. This concept of removing CO2 has already been demonstrated in operating TGP ammonia projects, where the hydrogen is used for ammonia production, and a portion of the CO2 is separated and combined with the ammonia to produce urea, a solid fertilizer product.

INTRODUCTION

World energy demand is expected to double over the next several decades, largely as a result of population growth and increased standards of living in the developing world. If this demand is to be met in an environmentally sustainable manner, new and cleaner energy technologies will have to be developed and deployed. While promising advances are being made in development of cost effective renewable energy technologies and hydrogen-based energy systems, the transition to a zero emissions hydrogen based future will take decades.

Newly developing economies will not wait for a hydrogen economy before they seek economic growth. 37% of the world's electricity is currently generated from coal and the greatest demand growth for electricity will come from developing countries where coal is the number one fuel source.

For the foreseeable future, coal will certainly continue to play a key role in fueling economic development around the world. The critical challenge is to use coal in an environmentally sustainable manner. Not only can Integrated Gasification Combined Cycle (IGCC) allow cleaner use of coal today, it can also be a cornerstone of a fossil fuel based "zero emissions" energy system, as envisioned in the DOE's Vision 21. The environmental benefits of IGCC include:

- Reduced particulates and solids production/emissions
- Significant air emission reductions, both SOx and NOx emissions are reduced by 70%-80% compared to other older coal technologies
- Reduced CO_2 emissions due to its higher efficiency
- The ability to recover CO_2 at relatively low cost for sequestration or other uses

SEQUESTRATION: MEETING THE CLIMATE CHANGE CHALLENGE

Texaco believes that enough is known about the science of climate change to merit a serious and constructive response by energy companies and government. Meeting the challenge of climate change will require the human, financial and technological capital of energy companies in the US and abroad.

Texaco has set out a portfolio of activities in business development and technology development that can reduce Texaco's own emissions and also help Texaco's customers reduce their emissions. In addition to the gasification portfolio, Texaco has an equity interest in and joint venture with Energy Conversion Devices (ECD) in their fuel cell, advanced battery, and hydrogen storage technologies. Texaco has integrated greenhouse gas emissions management into business planning with:

- Annual Emissions Inventory ('97-'00) with third party verification;
- Mandatory greenhouse gas projections in the review for new projects;

- Greenhouse gas projections in strategic planning cycles for all business units.

With the more than twenty years of experience in enhanced oil recovery with CO_2 in West Texas and more than fifty years commercial history in gasification, Texaco was motivated in 2000 to become a founding member of a joint industry project with other industry leaders in the CO_2 Capture Project (CCP). CCP aims to reduce the cost of capturing CO_2 emissions when fossil fuels are burned. Founding project team members include BP, Statoil, Chevron, Suncor, Shell, and Norsk Hydro with ENI and Pan Canadian Resources joining in 2001. This is a 3½ year, $15 to $20 million technology development program focusing on CO_2 capture and safe storage in geologic formations.

The objectives of this team are as follows:

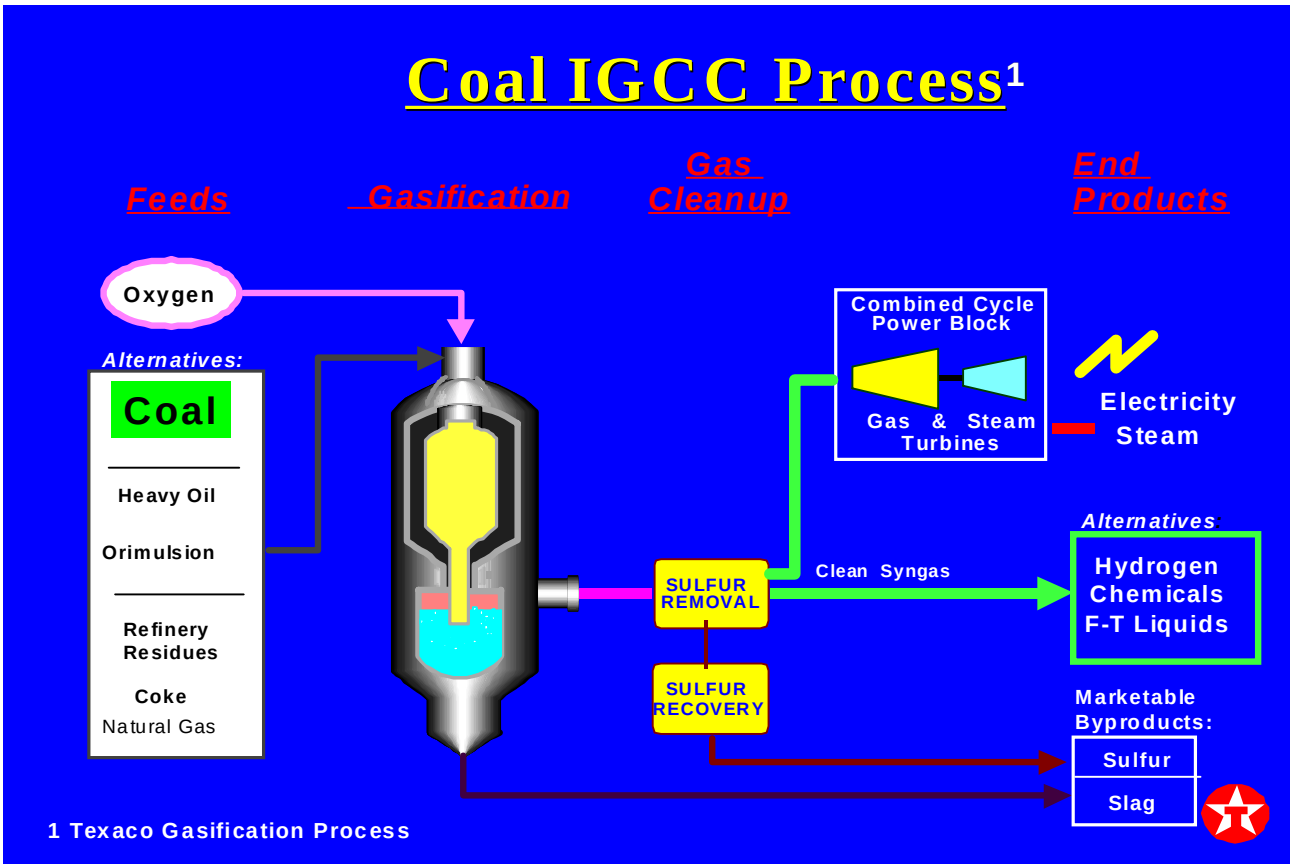
- Develop new, breakthrough technologies to reduce the cost of CO_2 separation, capture, and geologic storage from combustion sources such as turbines, heaters, and boilers.
- Perform bench-top R&D to prove the feasibility of advanced CO_2 separation and capture technologies, specifically targeting flue gas scrubbing, pre-combustion decarbonisation (including gasification and hydrogen production), and oxyfuel approaches.
- Develop guidelines for maximizing safe geologic storage, for measuring and verifying stored volumes, and for assessing and mitigating storage risks.
- Develop an economic model to establish baselines of CO_2 separation, capture and storage costs and a common approach to compare costs across separation technologies and storage methodologies.
- Actively transfer the new technologies to industry via publications, presentations, conferences, an Internet Website, patent licenses and commercial services.
- Reach out to all stakeholders, including environmental groups and governments, to inform the dialogue on CO2 separation technologies and safe storage in geologic formations.

Texaco believes that gasification technology can be an "Environmental Enterprise", and provide an attractive option for carbon sequestration. We we are working with our partners in the CO2 Capture Project to further develop this option for power systems.

WHAT IS COAL IGCC / COAL GASIFICATION?

The Texaco Gasification Process is a commercial technology with over 50 years of commercial application around the world. The process can gasify coal, heavy oil, petroleum coke, refinery residue, and Orimulsion®. The coal gasification process converts coal into a synthesis gas (syngas) composed primarily of carbon monoxide and hydrogen. This syngas can be used as a clean fuel to generate electricity or steam, or used as a basic chemical building block for a large number of uses in the

petrochemical and refining industries, including the production of ammonia/urea fertilizer and hydrogen. Texaco has licensed its technology to seventy-two (72) such facilities, sixty (60) of which are operating, while twelve (12) more are in under construction or in detailed engineering.



If the syngas is to be used to produce electricity, it is typically used as a fuel in an Integrated Gasification Combined Cycle (IGCC) power generation configuration. Coal IGCC is the cleanest, most efficient means of producing electricity from coal. The combined cycle system has two basic components. A high efficiency gas turbine, widely used in power generation today, burns the clean syngas to produce electricity. Exhaust heat from the gas turbine is recovered to produce steam to power steam turbines, creating additional power.

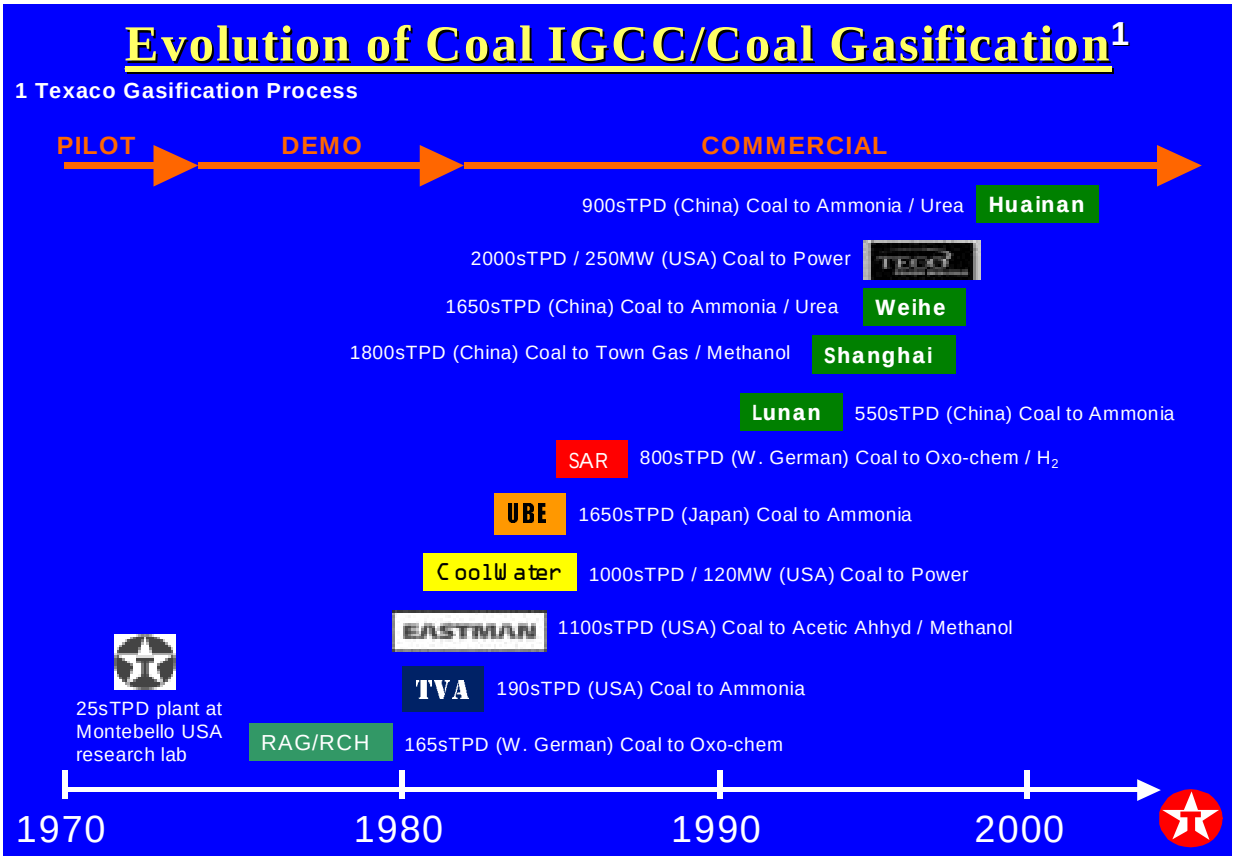
As with conventional coal plants, there are also gaseous emissions from the Texaco Gasification Process (TGP), but the TGP provides a significant reduction in those emissions. Both SOx and NOx emissions are reduced by 70%-80% compared to other older coal technologies. The reduction of air emissions including particulates by the TGP will bring the plant into compliance with the more stringent regulations currently proposed in many areas that would otherwise require significant and expensive modifications.

Below is a table summarizing the comparison of air emissions from a natural gas combined cycle facility, TGP, and a conventional coal plant.

Table 1. Air Emissions Comparison

	Natural Gas Combined Cycle	Coal TGP	Conventional Coal Plant
NOx	3 ppm	<9 ppm	150 ppm
Sulfur Recovery	—	>98%	95%
CO_2 (lb/kWh)	0.81	1.95	2.26
SCR	Yes	No	Yes
Stack Gas Scrubber	No	No	Yes

Texaco Power & Gasification (TP&G) has been developing coal IGCC / coal gasification products and services for over 50 years. Our proven gasification technology is at the forefront of commercial applicationsOver 6,200 Megawatts (MW) of IGCC power generation is TGP licensed or under active development by Texaco.



During the past few years, several projects have been constructed around the world using the TGP, including twelve new start-ups in 2000[i]. Four IGCC power plants produce over 1500 MW of clean power from refinery residues. Three of these plants were non-recourse project-financed for a total of approximately $3.1 billion, reflecting growing financial industry confidence in the technology. The coal fired 250 MW Tampa Electric Company IGCC in Polk Country, Florida, USA has exceeded 24,000 operating hours on syngas since start-up in 1996, generating more than 7.0 million MWhours of clean electricity.

While the cost of IGCC has in the past been a deterrent to widespread application in the US and abroad, several factors have converged to argue for a re-look at this promising technology.

- Lessons learned from the large number of recent start-ups, industry experience in construction and operation of IGCC's, and continued cost reduction efforts have resulted in reduced IGCC capital and operating costs. The operating experience of plants such as Tampa Electric has been instrumental in the reduction of these costs for projects now under development.

- Broad consensus that natural gas prices in the US are unlikely to remain at the historic lows experienced in the late 1990s. Growing demand for clean fuels and constraints on access and infrastructure suggest that continued upward pressure on natural gas prices will continue.

- Growing appreciation of the need for a diversified energy supply in the US as part of a broad national energy policy. Abundant US coal reserves make the clean use of that fuel an attractive option to enhance US national energy security.

- Growing concerns about local, regional and global air emissions. Criteria pollutants and greenhouse gas emissions will continue to play a critical role in shaping future energy choices. Pressure to include the environmental externalities associated with fossil fuel use will increase.

- Awareness of the global nature of energy technology markets and opportunities. Those countries and companies that lead in advanced clean energy technologies will prosper from the huge demand surge anticipated primarily in developing countries.

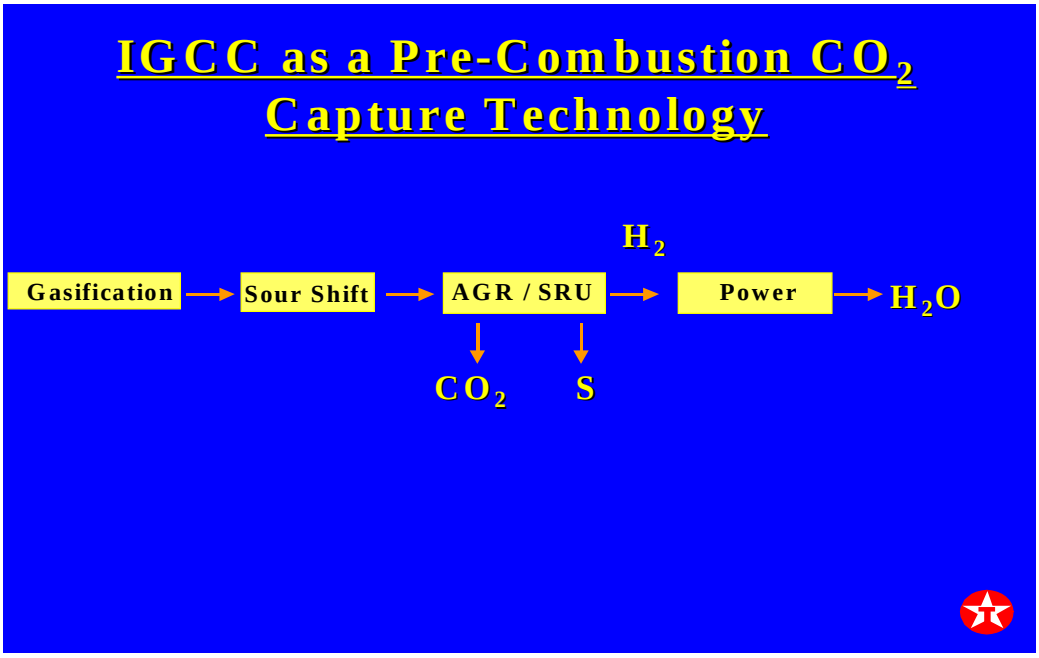
Overlay all of the above trends with the enormous indigenous reserves of coal in the US, India and China (to mention the largest markets) and it becomes clear that finding cost-effective and environmentally preferable ways of transforming coal into electrons is a critical pathway to a clean energy future.

CARBON DIOXIDE CONTROL/SEQUESTRATION OPPORTUNITY

The TGP reduces CO_2 emissions due to its higher efficiency compared to baseline alternatives. It also offers the plant owner an opportunity to recover CO_2 at relatively low cost for sequestration or other uses. Thus TGP provides a natural hedge for future CO_2 emissions controls.

In the TGP, when CO_2 combined with syngas is fed to the combustion turbines, two benefits are realized by the power plant. First, the CO_2 lowers the flame temperature, reducing NOx generation. Second, the CO_2 adds more mass per unit volume to the syngas, which increases the power output of the combustion turbine. If the CO_2 is removed then steam injection, nitrogen injection or syngas saturation would replace CO_2 for NOx suppression and power augmentation

Another option is to convert the syngas to hydrogen (sour gas shift) and remove the CO_2 from the process entirely prior to combustion and use it elsewhere. TGP has the capability to capture the CO_2 from the syngas before sending the gas to the combustion turbines, because the sulfur removal process used in the TGP can produce a by-product CO_2 stream.



This concept of removing CO2 has already been demonstrated in eight (8) operating TGP ammonia projects in China, where the hydrogen is used for ammonia production, and a portion of the CO2 is separated and combined with the ammonia to produce urea, a solid fertilizer product.

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Recent analysis performed by SFA Pacific and Transalta found that a modest (approximately $10) price for the CO2 offtake could make the use of coal-based power with CO2 recovery competitive with natural gas combined cycle plants when gas prices are greater than $3/MBTU. This analysis also found that of the CO2 recovery options, coal gasification with CO2 capture has advantages over a Pulverized Coal (PC) retrofit flue gas scrubber or O2 combustion. PC retrofits reduce capacity and efficiency by about a third, whereas coal IGCC increase both. O2 combustion requires 4.5 times more O2 per net MWe coal capacity.[iii] A market for carbon offset credits would further enhance the economic benefits of CO2 capture.

The TPG process has a specific advantage over other gasification options because it generates high pressure CO2 that can be cost effective for enhanced oil recovery (EOR) or coal bed methane recovery (CBM). Typical EOR uses 6,000 scf CO_2 per

incremental BBL crude production and already over 28 million metric tons per year (mt/yr) of CO2 are sequestered in EOR in North America, the equivalent of 4,000 MW of coal fired generation. This includes 1.8 million mt/yr CO2 from an existing North Dakota coal gasification plant. The North American market for CO_2 sequestration for EOR and CBM is expected to expand, offering unique opportunities where power generation and EOR/CBM can be co-located.

CONCLUSIONS

Coal IGCC is a commercially proven clean coal technology that offers significant environmental and economic benefits today, including decreased air and solids emissions. It also offers the potential to capture and sequester carbon dioxide. Coal IGCC provides electric utilities strategic options in meeting today's growing demand for energy products (electricity, fuel, chemicals) while protecting public health and the environment --and a pathway to zero emissions coal-based power generation.

[i] For more detail, see W. Preston, "Texaco Gasification Startups and Future Directions", presented at 2000 Gasification Technologies Conference, San Francisco, CA, October 2000.

[ii] W.F. Fong, "Texaco 550 MWe for Coal or Oil via 9H IGCC", presented at 2000 Gasification Technologies Conference, San Francisco, CA, October 2000.

[iii] D. Simbeck and M. MacDonald, "Analysis of Retrofit CO2 Control Options for Existing Coal-Fired Power Plants", Electric Utilities Environmental Conference, January 10, 2001.