

# Circulating Fluidized Bed technology burns coal to produce electricity

by Robert Giglio and Justin Wehrenberg

The convenience and value of electricity has not gone unnoticed by consumers. According to the U.S. Department of Energy, electricity is the fastest growing form of energy in the world and over the next 20 years the world will likely consume twice as much of it as it does today.

In 2008, we consumed almost 20,000 terawatt hours of electricity globally. That's enough electricity to light over two million baseball stadiums or power over 11 billion computers continuously for an entire year. No matter how you look at it, we consume an incredible amount of electricity.

The United States has the dubious distinction of being the largest consumer of electricity in the world with enough power to provide each American with over three kilowatts of electricity – that is about twice the power currently available to Europeans, eight times the power available to the Chinese, and over 25 times the power available to India.

Yet the U.S. represents less than five percent of the world's population. Further, an astounding 1.6 billion people (almost a quarter of the world's population), doesn't have access to electricity at all.

The rest of the world has a long way to go to catch up; and if they ever do, we would need over five times more power plants than we currently have in the world today.

## Electricity and the environment

Electricity is not an energy source by itself; rather it is produced from primary energy sources like: fossil fuels, nuclear and renewable energy. Today most of our electricity, about 67 percent, is produced from fossil fuels (coal, natural gas and oil), with coal being the largest single contributor producing about 43 percent of the total electricity in the world.

To feed our tremendous hunger for electricity, we will need to tap deeper into all of our world's primary energy sources. Most projections show that coal will maintain its leading role in producing the world's electricity as shown by the U.S. Department of Energy's projection in Figure 1.

There are good reasons for coal playing such a large role in our power generation. It is the most abundant primary energy source in the world, capable of supporting our energy needs for over 300 years at our current usage rate, as compared to oil or natural gas which is projected to be exhausted in about 30-50 years. It is located in or near our largest population centres and our largest industrialized countries like the U.S., UK, Germany, China, and India. It can also be easily transported and produces reliable and affordable electricity.

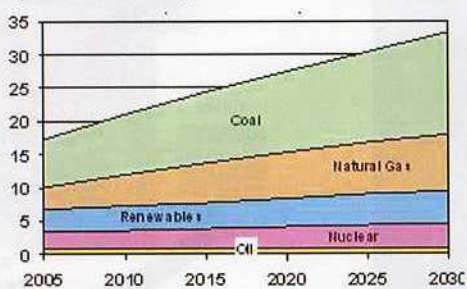
However, coal also carries a significant environmental cost with its use.

When coal is burned to produce electricity it emits air pollutants in the form of sulphur, nitrogen and carbon oxides into the atmosphere. Sulphur and nitrogen can contribute to acid rain and smog. Carbon dioxide (CO<sub>2</sub>) is a greenhouse gas that contributes to global warming.

## Steam generator technology

At the heart of every coal plant is the steam generator, which converts the energy stored in coal into high-quality steam

Figure 1: World Electricity Generation (Terrawatt-Hours)



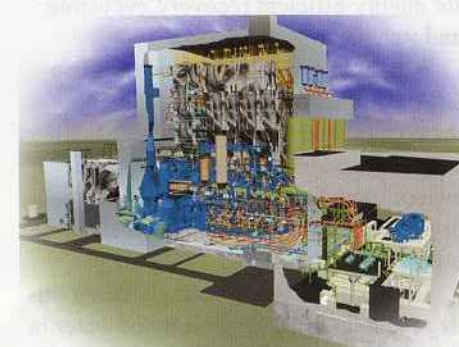
needed to drive a steam turbine generator for efficient production of electricity.

The steam generator is the most critical component in our energy future since it allows us to unlock the energy value of coal, but also determines the environmental impact or cost we pay for this value. Improving its environmental performance is the most important thing we can do for the environment.

## CFB technology

Foster Wheeler has developed a different steam generator technology called Circulating Fluidized Bed (CFB) as shown in Figure 2. Unlike conventional steam generators, which burn the coal in a massive high temperature flame, CFB technology doesn't have burners or a flame within its furnace. It utilizes fluidization technology to mix and circulate the fuel particles with limestone as they burn in a low-temperature combustion process.

Figure 2: 500 Mw Circulating Fluidized Bed Power Plant



The limestone captures the sulphur oxide pollutants as they are formed during the burning process, while the low-burning temperature minimizes the formation of the nitrogen oxide pollutants.

The fuel and limestone particles are recycled over and over back to the proc-

ess which results in high efficiency for burning the fuel, capturing pollutants, and for transferring the fuel's heat energy into steam used to produce power.

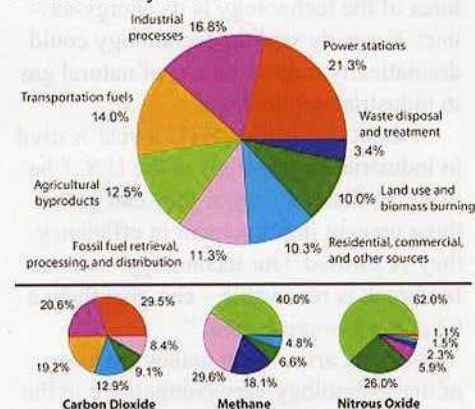
Due to the vigorous mixing, long burning time and low temperature of its combustion process, CFBs can cleanly burn virtually any combustible material, greatly surpassing the fuel limitation of conventional combustion processes. Unlike conventional steam generators, CFBs capture and control harmful pollutants during the burning process and don't rely on pollution control equipment.

To further improve the CFB's environmental report card, the company has applied vertical-tube, supercritical steam technology to its utility scale CFB designs. Supercritical steam technology allows more of the fuel's energy to be transferred to the steam. This improves power plant efficiency, reducing the amount of fuel needed for electricity production and further reducing emissions.

## The carbon issue

Global warming and the emission of greenhouse gases like CO<sub>2</sub> is a relatively new concern. Significantly reducing our carbon footprint while maintaining or improving our standard of living is probably the biggest challenge the human race has ever faced, since almost everything we do, from heating our homes, putting food on our tables, powering our businesses, travelling, as well as breathing, emits CO<sub>2</sub>.

Figure 3: Annual Greenhouse Gas Emissions by Sector



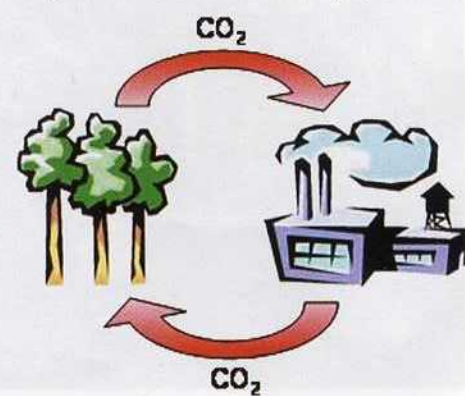
CO<sub>2</sub> is not normally harmful to any life forms. In fact, it is an integral part of nature's life cycle. Humans and animals breathe in oxygen and exhale CO<sub>2</sub>, while plant life does the opposite. Burning large amounts of fossil fuels in our power, transportation and industrial sectors has upset nature's CO<sub>2</sub> balance, causing the level of CO<sub>2</sub> to rise in the atmosphere. Since CO<sub>2</sub> is a greenhouse gas that holds the sun's heat, it contributes to global warming. As shown in Figure 3, the production of electricity is a significant source of greenhouse gas emission, contributing about 21 percent to the total greenhouse gases we emit to the atmosphere. Unlike other pollutants, CO<sub>2</sub> is

an essential by-product of the fossil fuel combustion process and can only be reduced by burning less fossil fuel.

## Addressing carbon with CFB fuel flexibility

Due to its ability to burn carbon neutral fuels like biomass, CFB technology offers a unique solution to the CO<sub>2</sub> issue. Biomass is considered carbon neutral since it absorbs and stores carbon from the atmosphere during its growth cycle through the natural photosynthesis process. When biomass is burned, it releases the same carbon back to the atmosphere, resulting in nearly no net carbon emission

Figure 4: Biomass Power CO<sub>2</sub> Cycle



to the atmosphere (Figure 4).

However, due to the world's limited and undeveloped biomass supply chain, biomass power plants are practically limited to about 25-50 megawatts. The plant's small scale, coupled with its fuel supply limitation, translates into electricity costing about 20-30 percent more than conventional fossil fuel power plants.

Again, the CFB offers a solution. Due to its fuel flexibility, a large scale (300 Mw or larger) CFB power plant can be built to burn a combination of coal and several types of biomass. This solution captures both the environmental benefit of reducing CO<sub>2</sub> emissions and the economic benefit of providing affordable electricity. It is also flexible enough to utilize more biomass when it is available or fall back on coal when it is not meeting consumer demand.

This concept can produce a substantial reduction in CO<sub>2</sub> emissions. As Figure 5 shows, a supercritical 600 MW CFB plant burning 20 percent biomass is estimated to produce 32 percent less CO<sub>2</sub> than a conventional coal plant. The good news is that this can be done today while still producing affordable electricity.

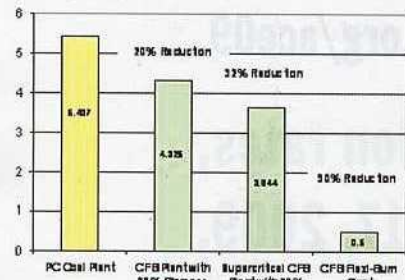
## Addressing carbon with CFB Flexi-Burn Technology

While a 30 percent reduction in CO<sub>2</sub> emissions is a big step in the right direction, projections show that we need to do much more to significantly reduce the risk of global warming. What makes this task so challenging is that CO<sub>2</sub> emissions are tied to energy use and to realize any

reduction in CO<sub>2</sub>, we must first offset all new emissions connected to the growth in energy use.

To take carbon reduction to the next level, Foster Wheeler is developing Flexi-Burn CFB technology. Flexi-Burn will allow the CFB to produce a CO<sub>2</sub>-rich-flue gas and be part of a practical carbon capture and storage

Figure 5: CO<sub>2</sub> Emissions from a 600 Mw Plant (megatons/yr)



solution (CCS). The technology has the potential to reduce coal plant CO<sub>2</sub> emissions by over 90 percent while minimizing the cost impact and technology risk to consumers.

As Figure 6 shows, instead of using air in the CFB combustion process, Flexi-Burn technology uses a mixture of oxygen and recycled CFB flue gas. By doing this, the flue gas becomes rich in CO<sub>2</sub> (containing over 90 percent CO<sub>2</sub> on a dry basis), rather than rich in nitrogen as when air is used. Since its flue gas is nearly all CO<sub>2</sub>, Flexi-Burn CFB technology doesn't need expensive and energy intensive equipment to remove the CO<sub>2</sub> from its flue gas and has the potential to produce carbon free electricity at a very low cost as compared to other technologies.

But the challenge goes well beyond capturing CO<sub>2</sub> from coal power plants. Transporting and storing CO<sub>2</sub> in underground locations, like saline aquifers, is not proven and requires years of study to understand the cost and risks. And no one really knows how much consumers are willing to pay for (or can afford) truly carbon-free electricity. Due to the uncertainty of carbon regulation, the cost and risk of CCS technology, and consumer behaviour, it is nearly impossible to predict when widescale market acceptance of CCS power plants will occur.

To cope with the market uncertainty from a technology aspect, Flexi-Burn has been designed for market flexibility. The plant can operate in either economical air mode (as all coal plants operate today) providing affordable and competitive electricity to today's market, or in CCS mode without requiring any significant modification to the plant. This gives power producers the flexibility to adjust plant operation with a changing and uncertain market for carbon free electricity and will likely allow faster adoption of CCS technology.

Flexi-Burn also provides investment flexibility by allowing the plant to be built in stages. The plant can be built first for full functionality in the economical air mode, allowing power generators to defer the CCS portion of the plant's capital investment until it is

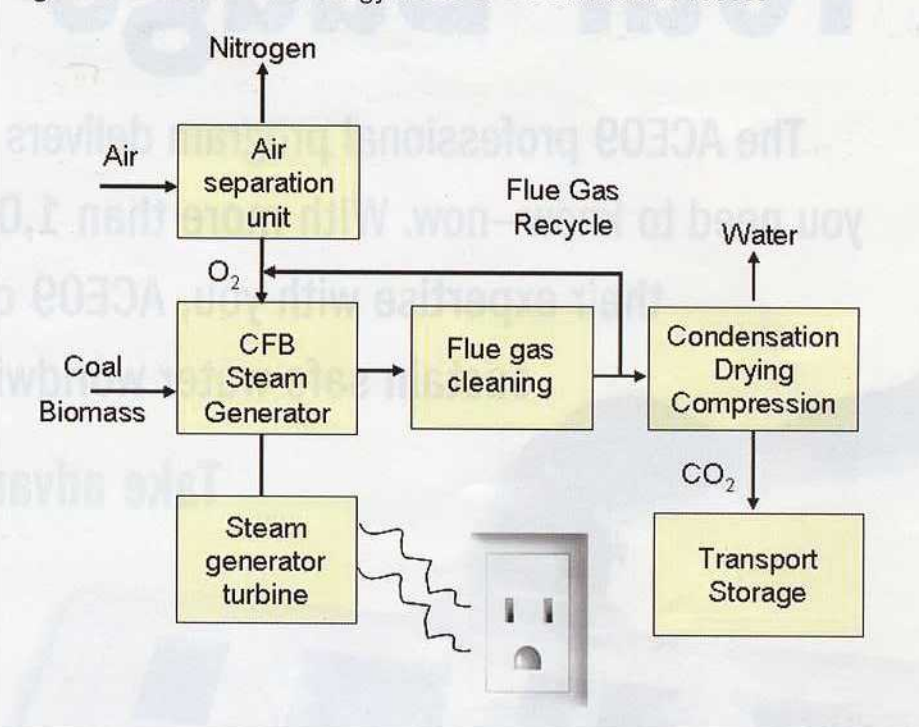
justified by market and policy conditions. This flexibility will allow investment in the power capacity needed to meet growing demand while giving investors the flexibility they need when facing uncertain carbon markets.

As we are seeing today, the uncertainty surrounding the carbon issue is preventing needed investment in our power generation infrastructure. This hurts not only the consumer but the environment as well. Without new modern power plants coming onto the grid, power generators have no choice but to keep relying on old, inefficient and polluting power plants to meet consumer demand.

Circulating fluidized bed technology is an important part of the solution to meet the world's energy needs while conserving natural resources and preserving our environment.

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Figure 6: Flexi-Burn Technology in the CFB Combustion Process



## Biogas projects under review in B.C.

Proposals in British Columbia to generate biogas from algae growth and pine beetle-killed wood are two of nine projects being reviewed by Terasen Gas in response to a call for expressions of interest in clean, renewable biogas production. Other potential projects include recovering biogas from agricultural and municipal biowaste, and several proposals targeting meat, vegetable and food waste.

"We are very pleased with the calibre of projects submitted for consideration," said Doug Stout of Terasen Gas. "Developing these types of projects will increase the province's production of clean, renewable energy and help to reduce emissions from waste methane, which is 21 times more powerful in warming the atmosphere than CO<sub>2</sub>."

Last fall, Terasen Gas issued a request for expressions of interest to municipalities, waste management companies, farms and other businesses to bring forward opportunities whereby new facilities could be built, or existing ones upgraded, to allow the production of biogas and its conversion into a clean, renewable energy source.

The proposed projects range from Prince George to Delta, and are in line with Terasen's aim to encourage the production of biogas for purchase and upgrading to renewable natural gas for injection into the Terasen Gas system. That energy can then be used to heat homes and businesses, and provide a source for water heating, household appliances and transportation. The Terasen Gas biogas initiative expands on an existing innovative pilot project underway to capture and purify biogas from West Vancouver's Lions Gate wastewater treatment plant, which will heat 100 homes.

Successful projects will result in Terasen Gas purchasing the raw biogas by way of a contract with the producer. A detailed review of the submissions is now underway. As this is the first phase of what is an ongoing search for alternate, renewable energy solutions that could potentially heat 45,000 homes in B.C., Terasen Gas will continue to explore the interest in B.C. for developing these and other biogas proposals.

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