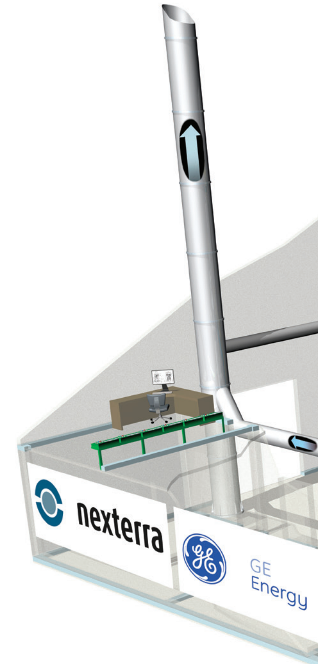
Gasification REDUX



A renaissance in gasification is brewing thanks to a partnership between The University of British Columbia and Nexterra Systems Corp.

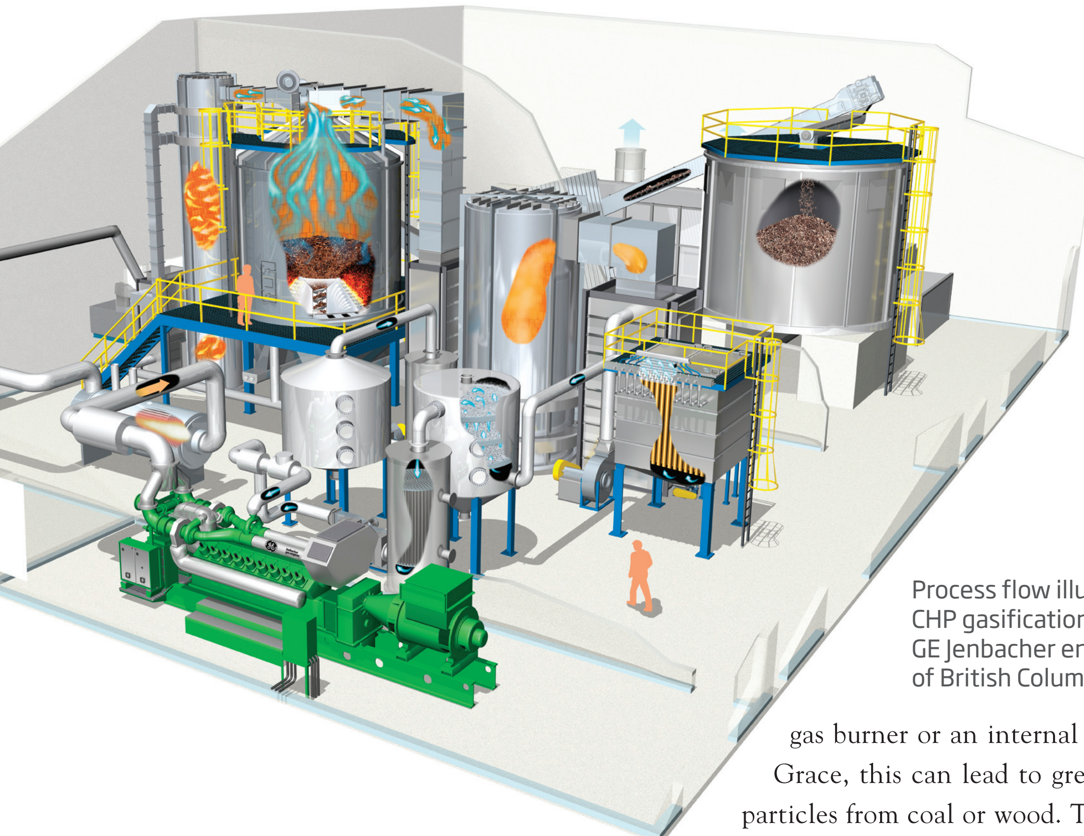
By **Roberta Staley**

"As the gleam of the street-lamps flashed upon his austere features, I saw that his brows were drawn down in thought and his thin lips compressed. I knew not what wild beast we were about to hunt down in the dark jungle of criminal London... ."
- "The Adventure of the Empty House," The Best of Sherlock Holmes.

During the 18^{th} century's chemical revolution, chemists first realized that air was not merely an element but a mixture of many gases. It followed that the gases could be captured, manufactured, purified and used for a variety of purposes, morphing quickly from scientific discovery into a utility. By the 19^{th} century, combustible gases such as carbon monoxide, hydrogen and ethylene were in wide use as a source of energy for heating and illumination, casting somber pools of light not only on the fictional exploits of Sherlock Holmes and Dr. Watson but the real-life horror of Jack the Ripper's murderous rampage upon the demimonde of London.

The source of combustible materials for manufacturing gas during the Victorian era and into the early 20^{th} century was diverse and included biomass such as wood, coal and oil. Wood gasification was embraced by farmers to run their internal combustion engines, especially during the fuel shortages of the early 20^{th} century and, later, the Second World War. But a heady era of cheap oil and gas followed and gasification, except for some specialized applications, was relegated to the back burner. Now, however, with the spectre of peak oil looming, a renaissance in gasification is brewing. And the epicentre of this redux is — perhaps not surprisingly — Canada's West Coast, with its seemingly endless supply of biomass from vast forests and British Columbia's lumber and pulp and paper industries. This includes huge amounts of wood waste: bark, sawdust and tree trimmings, as well as about 17.5 million hectares of dead timber killed by pine beetles.

Nestled between pine and Pacific shoreline is The University of British Columbia (UBC). Here is found the cramped office of John Grace, a chemical engineering professor in the Department of Chemical and Biological Engineering. Grace, the Canada Research Chair in Clean Energy Processes, says that the renewal



Process flow illustration of the CHP gasification system with the GE Jenbacher engine at The University of British Columbia.

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of interest in gasification is driven by several key concerns: the need to reduce carbon dioxide (CO_2) emissions and the rising demand for cleaner burning fuels which produce fewer secondary pollutants like nitrogen oxides (NOx) and sulfur oxides (SOx). A third factor is the growing energy demand among developing countries for liquid and gaseous fuel. In China, for example, oil is in short supply, but coal is abundant. Gasifying this coal creates a number of advantages over burning it directly.

At its core, gasification is the process of reacting carbon-based fuels at high temperatures and low oxygen to create synthesis gas, also known as syngas, a mixture of mainly carbon monoxide and hydrogen. After being cleaned up, syngas can be fired into a conventional gas burner or an internal combustion engine. According to Grace, this can lead to greater efficiency than burning solid particles from coal or wood. The cleanup step cuts down on the emissions of secondary pollutants derived from impurities in the original wood or coal. Another option is that that instead of being burned, syngas can also be converted to larger molecules via the Fisher-Tropsch process, creating liquid fuels or commodity chemicals like methanol, ethanol and alkanes.

Today, gasification is considered to be one of most versatile and efficient ways to convert low-cost wood waste and other biomass fuels into thermal energy or electricity. It is also a key technology in helping to achieve global greenhouse gas-emission reduction objectives, says Grace, who is chair of the 3rd International Symposium on Gasification, held in conjunction with the 62nd Canadian Chemical Engineering Conference Oct 14-17 in Vancouver. “Our dependence on fossil fuels is still so great that we must find ways to decarbonize them and reduce emissions associated with their usage,” Grace says. He points to global trends indicating rising fossil-fuel consumption due to improved living standards in developing nations, increasing populations, as well as the West’s reluctance to trim its prodigious energy appetite. “We need to manage our carbon better and find alternatives — preferably renewable energy resources.”

Grace’s scholarship includes the study of fluidized bed gasification, a technology dating back to the 1920s. Along with a UBC team that includes Tony Bi, Naoko Ellis, Jim Lim and Paul Watkinson, Grace is seeking fluidized bed reactors that can do more with less. One example is a dual fluidized bed steam gasification system. Most gasifiers contact fuel with a sub-stoichiometric amount of air, which is mostly nitrogen. The inert nitrogen dilutes the final gas stream, decreasing its calorific value. Replacing the air with steam leads to a better final product, but steam gasification is endothermic and requires an external heat source. The UBC group's challenging solution is to combine a steam gasifier with a seperate combustion chamber that burns the char left over from the original fuel. By recirculating hot solids from the combustion chamber back to the gasifier, the heat balance is satisfied, allowing the system to make better use of the same fuel.

A further innovation being explored involves circulating solid sorbents like calcium oxide (CaO) through both chambers. In the gasifier, CaO reacts with CO_2 molecules to become calcium carbonate ($CaCO_3$). The carbonation reaction is exothermic so it also provides heat to the gasifier as well as shifting the water gas shift equilibrium to produce more hydrogen. In the combustion chamber, the higher temperature decomposes this sorbent material back into CaO and CO_2, thus regenerating the sorbent and creating a relatively pure CO_2 stream that can be compressed and sent to storage.

Another project, supported by an NSERC grant and a collaboration with the universities of Toronto and Calgary, is investigating the co-feeding of different fuels, for example, combining biomass with coal and coke. Finally, Grace is a member of a $52-million research endeavour backed by Carbon Management Canada (CMC) and including contributions from universities from across the country. That project will create a pilot plant at UBC's Pulp and Paper Centre that will integrate carbon capture into the gasification process.

UBC researchers are also collaborating with the dynamic young Vancouver-based company Nexterra Systems Corp. on another ambitious gasification project that is sure to turn heads when it officially opens in mid-year. Nexterra and GE Energy of Mississauga, Ont. partnered to create a combined heat and power (CHP) system for generating steam and energy on campus. The CHP system marries Nexterra's gasification and syngas cleanup and conditioning technologies with a GE high-efficiency internal combustion engine built by Jenbacher, a world leader in specialty gas engines. Woody biomass will be gasified and converted into clean syngas that will be directly fired into the gas engine. Nexterra CEO Mike Scott says that he expects that the engine will perform at the same level as if it was fuelled by natural gas.

The process will significantly reduce UBC's annual carbon footprint, creating two megawatt electrical (MWe) and three megawatt thermal (MWt) of steam, equivalent to taking 1,000 cars off the road, Scott says. UBC consumes about 40 MWe a year and the institution is looking to become even more self-sufficient. "They have been a fantastic partner in this whole process," Scott says from the 13th floor of his Vancouver office, which looks out on a downtown core hooded by low-lying, slate grey rain clouds. "This biomass research project is one of the lynchpins of their living lab concept."

Scott says that Nexterra researchers are collaborating with Grace and one of his master's students to advance this technology even further, upgrading clean, engine-grade syngas into pure hydrogen. "To go from biomass into green hydrogen and make it part of the hydrogen economy — that would be remarkable," Scott says.

Nexterra's large-scale gasifiers have sprouted up at other institutions and

(1) Nexterra Systems's 5 MWt thermal gasification energy system at the University of Northern British Columbia in Prince George, B.C. (2) Nexterra's bioenergy project at The University of British Columbia will generate clean steam and electricity. (3) University of Northern British Columbia President George Iwama lights up the Nexterra gasification system that supplies heat for the Prince George campus.

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in other industries. The University of Northern British Columbia (UNBC) Prince George, B.C. campus is benefitting from a $15-million retrofit that was launched in January 2011 as an alternative to natural gas. Fuelled by wood waste from a local sawmill, the system was forecast to save the university $850,000 a year in natural gas, Scott says. (Recent record low natural gas prices have reduced that initial estimate.) The project netted UNBC first place — shared with Harvard University — for Campus Sustainability Projects in North America from the Association for the Advancement of Sustainability in Higher Education.

Gasification does have challenges to overcome. The low cost of natural gas and the operational hurdles associated with switching to biomass gasification are deterring a nation-wide embrace of the process. "It simply isn't as easy as using natural gas," Scott admits. Nevertheless, Nexterra has had significant success selling gasification engines to institutions and industries across North America with the foresight to prepare for long-term energy needs. Just down the road in New Westminster, B.C. is Kruger Products Mills, the first pulp and paper mill to fire syngas from a Nexterra system directly into a boiler. Other clients include the U.S. Department of Energy's Oak Ridge National Laboratory in Tennessee, which projects reductions of greenhouse gas emissions by 20,000 tonnes a year, equivalent to taking 4,500 cars off the road. The Veterans Affairs Medical Center in Michigan is also adopting a Nexterra system that is projected to reduce the hospital's carbon footprint by 14,000 tonnes annually, equal to parking 2,500 cars, Scott says.

It is unlikely that early proponents of biomass gasification envisioned that the process would have the potential to outlive the global dependence upon fossil fuels. However, gasification, thanks in larger part to researchers like Grace and companies like Nexterra, are helping forge a path into a brave new world of clean and sustainable energy for the planet.