A LOOK AT COMBINED HEAT AND POWER ENERGY SYSTEMS IN CANADA

By Manfred Klein

The physical and climatic nature of Canada's ten provinces and three northern Territories lends itself well to Combined Heat and Power (CHP) energy systems. Heavily populated areas have a wide annual temperature range, from - 30oC to + 30oC. This then requires both heating and cooling systems in many areas, at the same time that electrical demands are increasing, and industrialized provinces such as Alberta and Ontario are beginning to implement electricity restructuring and privatization, with some environmental constraints. Opportunities abound for establishing industrial, commercial and municipal cogeneration projects, including district energy.

BENEFITS OF CHP SYSTEMS

The benefits of local CHP to society are numerous and significant. The obvious ones are the economics of fuel savings and conservation, energy diversity and reliability, fewer losses and power transmission avoidance. Retirement of some aging coal fired plants can provide the opportunity to move the energy generation back to the local community (as it was originally in the 1880's).

Environmental concerns such as air pollution from acid rain, smog, particulates, mercury and toxics, greenhouse gas emissions, CFC ozone depletion, and land/water use issues have focused a new look at cleaner energy choices. Energy conservation practices, and CHP systems with clean fuels, tend to prevent all emissions at the same time. Waste heat can be used for cooling during summer, thus reducing CFCs and electricity use.

ENVIRONMENTAL AIR EMISSIONS

The graphs in Figures 1 and 2 compare approximate air pollution and CO_2 emissions from various fuel-based energy sources, such as coal, oil and gas steam plants, gas combined cycles and CHP, sustainable biomass boilers, and coal gasification. The large, multiple pollution prevention benefits of cogeneration are evident.

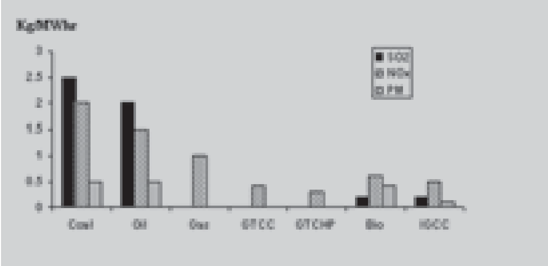

Figure 1: Comparison of Air Pollution Emissions from Various Energy Generating Plants [kg/MWhr]

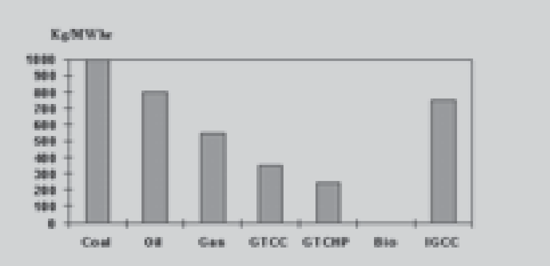

Figure 2: Comparison of CO_2 Emissions from Various Energy Generating Plants [kg/MWhr]

ELECTRICITY INDUSTRY

Several issues associated with relatively clean large hydro and nuclear developments will be dealt with by Canadians over the coming decades. It will thus be essential to recognize the local conservation, and environmental/health, benefits from combining industrial/commercial thermal energy with additional electricity production. This is especially true when regional concerns over hydro flooding, and nuclear energy issues, may tend to restrict these important low emissions, high capital cost choices. Despite increased implementation of cogeneration projects, it still only provides a small percentage of Canada's current electricity production and industrial thermal energy.

INDUSTRIAL AND COMMERCIAL ENERGY

The same places that need large amounts of electricity, will also need to burn a lot of high cost natural gas fuel to provide process heating and cooling. By providing several major energy products at the same time, 20% to 40% savings can be made. In assessing this concept, the quality of energy is important, as the maximum benefit can be obtained from the same fuel by cascading energy output in a descending order from high quality electricity to low grade space heat.

1. Electricity & Shaft Power
2. Industrial Process Heat
3. Cooling
4. High Pressure Steam
5. Hot Water
6. Space Heating

There are an estimated 4000 large- and medium-sized boilers (> 10 GJ/hr) used by primary industries today, but many of them are older needing life extension upgrades and pollution controls over the next decade. Similarly, there are 3000 commercial boilers, and about half a million small commercial boilers in use in Canada. The eventual replacement (or relegation to standby status) of some of these units can be managed economically as gas and electricity prices rise, when CFC chillers need replacement, and as energy restruc-

Approx. Stationary Energy Profile, Canada, 2001

Energy	**Electricity (TWhrs)**	**Industrial Heat (PJ)**	**Commercial Heat (PJ)**
Hydro	330		
Nuclear	72		
Coal / Oil	125	1070	150
Natural Gas	33	1300	500
Other	8	630	-
Total	**568**	**3000**	**650**

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turing proceeds. A variety of large and small gas turbines, reciprocating engines, woodwaste boilers, fuel cells, absorption chillers, and renewable energy systems can then contribute to significant air pollution and GHG emission reductions, and savings in avoided capital cost.

Our 1998 eastern Canadian ice storm, and the recent extensive power failure, resulted in millions without power and heat/cooling for several days or weeks. Yet those with access to CHP did not lose heating — this is an important benefit of well designed CHP. Some of the barriers to be resolved by government initiatives are described below.

PUBLIC OUTREACH

One of the most apparent barriers to developing better CHP infrastructure is that most people do not know that various qualities of energy, in the form of electricity, heating and summer cooling, can often be produced from the same fuel source, in various technology choices. Many engineers are still designing on the basis of separate thermal and mechanical energy production, and basing a plant location and size on electricity instead of local thermal needs. The balanced assessment and long term planning of cleaner energy options, and related environmental impacts, is also not well understood in society.

CORPORATE TAXATION INCENTIVES

Class 43.1 is a federal energy efficiency incentive (Accelerated Capital Cost Allowance) to defer some tax payments into the future. This now provides a writeoff at 30% on a declining balance basis, if the qualifying energy plant (cogen, waste heat, landfill gas, flare gas, some renewables) maintains an annual heat rate of less than 6.3 GJ/MWhr. At this point, district energy piping for commercial heat is not eligible. More recent tax changes have now increased the normal Class 1 depreciation rate for new power and heat facilities from 4% to 8% to stimulate investment. Additional improvements are being evaluated to promote effective investments in better CHP and renewable energy.

FULL FINANCIAL QUANTIFICATION OF LONG TERM BENEFITS

Economic feasibility often dismisses several of the tangible benefits of distributed CHP, including;

1. Avoided costs of replacing aging utility, industrial, and commercial boilers, and long power transmission lines
2. The impending phaseout costs of CFC chillers,
3. The energy security provided by local power and district energy loops,
4. The prevention of all air emissions, and cooling water impacts.

On the last point, it may be usual to quantify the monetary impact on GHGs, without also adding the common reductions in regional acid rain, smog and air toxic emissions, plus less cooling water usage. Certainly, clean-fueled CHP can provide all of those benefits, and portions of capital and operating costs should be allocated to each emission reduction to show multi-pollutant $/tonne cost-effectiveness.

The ability to carry out financial analyses that are robust in the long term is also a hindrance. Short term planning and fast paybacks may not provide good solutions. Societal infrastructure, such energy and transportation, must be viewed as a long term investment for our children.

AIR EMISSIONS REGULATIONS

Many environmental rules are still based on pollution control, using a variety of single pollutant, backend control methods, each of which has other drawbacks. The concentration based (ppmv or mg/m3) or the fuel input based standard (g/GJin) is also still common. Neither of these methods promotes energy efficiency nor pollution prevention.

Environment Canada and a multi-stakeholder working group developed a 1992 NOx National Emission Guideline for stationary gas turbine plants, using a 'mass flow per energy output' methodology. It provides for a Power Output Allowance, and a Heat Recovery Allowance, with NOx limits expressed in gramsNOx per output GigaJoule, or Megawatt. Energy efficiency to minimize CO2 emissions was deemed to be equally important, as well as considerations of pollution prevention, operational reliability and cost-effectiveness. It promotes cogeneration applications, without the need for ultra-low NOx levels requiring back-end SCR cleanup and ammonia problems.

CHP TERMINOLOGY

The characterization or sizing of a CHP plant in terms of Megawatts, electric (MWe) leads to common problems of lack of thermal balance, and too much combined cycle capacity on large plants. (The electricity restructuring regulatory system tends to exacerbate this issue in not properly promoting thermal opportunities.) Cogeneration should be rated both on ther-

CHP in action: Above, Markham District Energy, a 3.3 MWe, heating/cooling system.

mal and electrical load at the design point, so that both are treated as important. A method, such as a MWth/MWe rating system, should be developed.

Many large 'cogeneration' plants are mostly combined cycle which, without low grade heat recovery, are not necessarily environmentally sound, as they tend to reject large amounts of otherwise usable low-grade heat to lake or air condensers. They are more applicable to repowering of existing coal/oil power sites which do not have thermal hosts.

SUMMARY OF COGENERATION AND DISTRICT ENERGY IN CANADA

The pulp & paper and chemical sectors have many boiler and backpressure steam turbine CHP systems. The first Canadian gas turbine cogen plants were built for radar sites in the Arctic in the early 1960's. Over the last 30 years, about 150 large and small CHP plants have been built, or are in the works, across Canada for industrial and commercial applications.

There is over 6500 MWe of natural gas and woodwaste cogen plant installed mostly since 1990, with about 3000 MWe installed or planned for 2004-2008. Based on Canada's industrial/commercial fuel consumption, there is a potential for another 20 000 MWe of gas and biomass cogen for Canada for 2020, to provide about 500 PJ of thermal energy.

Most large cities have some central heating and cooling district energy system in sizes of about 50 to 300 MWth, although few of these generate electricity. Since 1993, cities such as Ottawa, Cornwall, Sudbury, London, Markham and Windsor have established gas CHP systems at about 3-5 MWe each, while small northern communities such as Fort MacPherson in the North West Territories, are powered with a diesel fueled 1.8 MWe reciprical engine plant. There are about twelve microturbine CHP plants for buildings. Woodwaste district energy will also become a popular form of generation over time.

Several universities and hospitals in Ontario and Alberta have also installed small gas turbines or recips, depending on steam or hot water based system design. The world's first 68 MWe GE LM6000 based plant, built by TransAlta Energy in 1992, provides heat and cooling services at a major Ottawa hospital. The federal government has three GT units in National Defence and the National Research Council facilities. Several Ontario food processing and paper plants using process steam have small gas turbine steam-based facilities.

CONCLUSIONS

There is a significant Canadian CHP potential in many applications across Canada, using different types of equipment. This could supply over 20 percent of our electricity and thermal needs, while resulting in major reductions in air pollution and GHGs as older systems are replaced. Increasing energy costs and energy security concerns should provide an impetus. There are still some remaining non-technical barriers to be addressed such as awareness of opportunities, proper financial incentives, thermal balance sizing, government policy recognition, and cross sectoral cooperation.

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