Cogeneration-based Eco-Business Zones & Eco-Industrial Networks Provide Environmental & Economic Benefits

What follows Explains

USING RECOVERED HEAT TO DISPLACE FOSSIL FUEL

There is a Need for An Incentive To Buy Cogenerated Electricity thus to facilitate making recovered heat available for use in industrial processes or for space heating to displace fossil fuel

Single purpose thermal electric power plants reject some 50% of fuel heat to water bodies or the atmosphere. Cogeneration systems use this recovered heat to displace fossil fuel

Canada provides no incentive to buy cogenerated electricity in terms of the price paid for it. Prices paid to generators for electricity from wind or solar sources are much higher than the market price. Generators of cogenerated electricity are paid no more than the market price for cogenerated electricity. The environmental benefit justifies providing a significant incentive in terms of the price paid for cogenerated electricity. With appropriate arrangements Cogeneration systems can be islanded to keep key processes operating during grid failures. This adds to the value of cogenerated electricity. If costs are correctly allocated both the electricity and the process or space heat cost less.

Cogeneration-based[2] Eco-Business Zones & Eco-Industrial Networks Provide Environmental & Economic Benefits

Cogeneration

Single purpose thermal electric power plants reject some 50% of fuel heat to water bodies or the atmosphere, potentially causing thermal pollution. Cogeneration systems use this recovered heat for purposes such as industrial processes (e.g. paper drying, chemical processing, food processing) and space heating or cooling (i.e. with absorption chillers). Cogeneration hence enhances industrial competitiveness and environmental performance through cost reduction, reduced emissions and better resource use efficiency.

Basis for Eco-Business Zones and Eco-Industrial Networks

In Canada, Eco-Business Zones, Eco-Industrial Parks and Eco-Industrial Networks (referred to collectively herein as EBZs) exist across the country and have enjoyed some success. A well-known example is Burnside Industrial Park, in Halifax, NS. With support from Dalhousie University?s Eco-Efficiency Center, more than 1,500 businesses in Burnside have been improving their environmental performance and developing profitable partnerships.

One of the familiar characteristics of EBZs is that outputs (including recovered heat) from one process/business facility become inputs to other processes/businesses in the network. As an example, a business in Burnside Park that used to have a problem disposing of pallets from supplies packaging found another business in the EBZ network that could use the pallets. [3]

Another feature of EBZs is the significant cooperation taking place among industries, organisations and institutions for a wide range of services and amenities. For example, participants in a EBZ can share the following:

- Effluent treatment and reuse
- Cooling water
- Demineralised water
- Hydrogen, Nitrogen, Oxygen, Carbon dioxide, Compressed air
- Maintenance Service
- Environmental Monitoring
- Cafeteria, Training and Meeting Space
- Energy Systems (e.g. heat storage such as a hot water tank or a Ruth?s Steam Accumulator, electricity storage such as a compressed air system)
- Purchasing contracts
- Logistics
- Ability to island so the cogen system can keep all processes operating

Thus EBZs have potential for many location synergies. For example, a profitable arrangement could be to locate a machine shop, a spare parts warehouse and a maintenance worker headquarters in an EBZ. This reduces travel time and related energy impact. It could also be logical to locate an industrial training school or a department thereof in the EBZ to facilitate on-the-job training mixed with classroom training.

Cogeneration-Based EBZ

"Cogeneration-based Eco-Business Zones are the right road to Sustainable Industrial Development"

Description

This concept involves co-locating groups of industrial processes using electrical and thermal energy with a single cogeneration facility producing electric power and heat.

A great example of an institutional EBZ based on a cogeneration system is happening on the General Campus of the Ottawa Hospital. The TransAlta 70-MW combined cycle cogeneration system supplies thermal energy via recovered heat (steam, hot water and chilled water) to a large hospital complex. One of the buildings, located over a kilometre away from the cogeneration plant, is both heated and cooled

Ottawa Health Science Centre
Image credit: Transalta

by a single low-temperature hot water loop.
Absorption coolers handle summer air conditioning

Benefits

Cogeneration systems in EBZs feature a more efficient distribution system and reduced pressure on large-scale utilities because:

- Transmission losses are reduced.
- Surplus recovered heat from the Cogen system or proceses can be used in other processes or nearby district heating systems.
- Thermal energy can now be used for both heating and cooling (trigeneration), which can help reduce both summer and winter peak loads on the grid.
- Proponents of new processes need not invest in new utilities because they can use those used by existing processes
- The cogen system can be islanded so it can keep all processes operating during grid failures

The fact that a single cogeneration plant serves the entire network achieves economies of scale in both capital and operating cost associated with energy supply, which represents a major advantage of EBZs. The following tabulation demonstrates the potential of larger systems[4] .

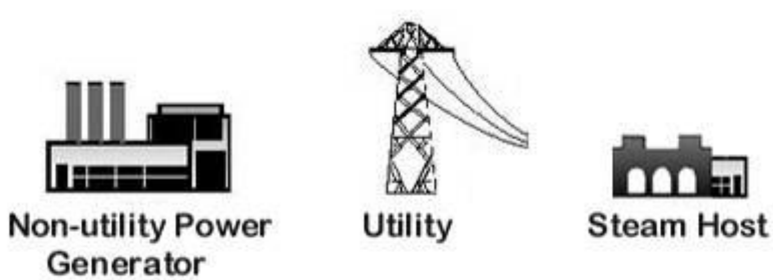
Capacity (MW)	Estimated Cost ($/kW)
20	900
40	800
75	700
120	600
150	500

EBZ networks can be islanded (i.e. work independently from the grid) so the cogeneration plant can continue to supply electricity despite grid failures. The concept suits both heavy and light industrial parks and can help attract new industrial plants or add more processes to existing plants in an EBZ. For example, representatives from Syncrude shared with COGENCanada that one of the main reasons they use cogeneration is to keep the processes running during grid failures, since it can take days or weeks to restart some processes following an unplanned shutdown. Because the electricity generation facility requires a certain minimum load when the system is islanded, attracting a mix of heat intensive and electricity intensive processes to an EBZ is important.

Considerations for Cogeneration in EBZs

Collaboration

Among the main challenges to completing a cogeneration project is having all the players work together ? the cogen system may be owned and operated by the steam user, an Independent Power Producer or the Utility that distributes the power along its power lines. The operators of the Cogen system and the steam host or heat user (factory or building owner) must cooperate. Firm electric power (available when required) is worth far more than power available only part of the time. To provide firm power a combined cycle Cogen system must have an extraction condensing steam turbine so the electrical output does not depend on the fluctuating process steam requirement. The distributor will likely impose a penalty standby charge) when the Cogenerator cannot deliver the electricity under contract. Regulators should ensure that this is reasonable. The Cogenerator will likely be able to help meet peak demand. Cooperartion among steam heat user, distributor, cogenerator and regulator is essential.



Flexible Output Rates

Overall efficiency can be affected if more electricity is generated than that which can be cogenerated but this may be justified. Electricity is a lot more valuable than steam heat. Larger cogeneration systems achieve economies of scale. Generating more electricity may mean having more potential steam than the steam host can use. With only a fraction of the steam from the steam turbine going to the host, the rest goes to a condenser where heat is lost but the value of the electricity during peak electrical loads may justify this. It also allows for adding heat using processes

All natural gas combined cycle systems should have a base-loaded cogeneration component. Flexible combined cycles provide firm power, peaking power, and spinning reserve. The flexibility is provided by using an extraction condensing steam turbine. The condenser rejects heat at a

Ontario Market Facts

The Ontario Power Authority pays 13.5 cents per kWh for wind-generated electricity. Higher prices are proposed for other forms of ?Green Electricity?.

temperature so low that it has limited use. There may be processes in the network which can use this very low grade heat in cold weather. Steam should be lost at the condenser only during peak loads.

Because the demand for electricity varies during the day (from less than 13,000 MW at 3 AM to more than 18,000 MW at 6 PM), market prices vary accordingly between about 3 cents to 5 cents per kWh.

A good way to have the cogeneration system follow the steam host's steam load is to use a burner between the gas turbine and the heat recovery steam generator (HRSG). The amount of duct burning follows the steam load. In one case the steam turbine has a capacity of about 12 MW without auxiliary firing and 30 MW when the auxiliary burner between the gas turbine and the HRSG is fully on. The gas turbine exhaust is roughly 15% oxygen so combustion air need not be heated. As a result the natural gas is burned at an efficiency some 10% higher than it would be with a conventional boiler. As well, the additional air otherwise needed would have exited the stack at a temperature higher than outdoor temperature ? a wasted heat load.

Distance from Cogeneration Facilities

Given the technical capabilities of heat transmission systems, COGENCanada encourages Economic Development Corporation to facilitate networking between businesses and light industrial parks nearby an EBZ. Neighbours could take advantage of recovered heat coming from processes or from the Cogeneration system to meet their heating and cooling requirements.

Optimizing Recovered Heat Use

If there are two recovered heat sources at different temperatures and two uses at different temperatures more heat can be recovered if the highest temperature source is used for the highest temperature use and the lowest temperature source goes to the lowest temperature use.

The temperature of a source can be slightly increased to match a use with the help of an absorption heat pump or a steam compressor

Heavy industrial parks

Paper machines, chemical processes, oil refining, food processing, etc., are well suited to relatively large-scale cogeneration-based Eco-Industrial Networks due to their large thermal energy requirements. Good examples of chemical/ petrochemical/ oil refining networks are:

- TransAlta?s 400-MW combined cycle system serving 4 large petrochemical complexes in Sarnia, ON
- The 450-MW cogeneration plant serving a major petrochemical complex in Joffre, AB.
- The several major combined cycle cogeneration systems in the Alberta Industrial Heartland near Edmonton, AB

Examples of Forest products complexes with cogeneration are:

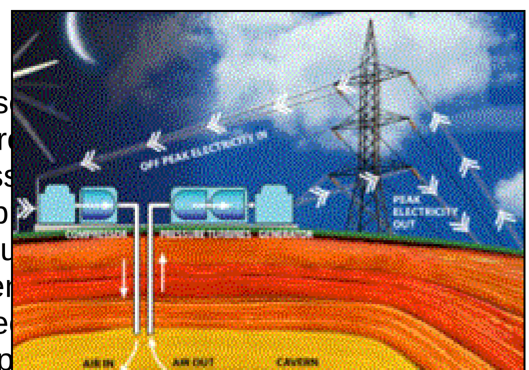
- Catalyst in Campbell River, BC
- Bowater in Thunder Bay, ON
- Irving Pulp and Paper/Irving Tissue in St John, NB Cogeneration should also be encouraged for light industrial parks where non-energy synergies may be more important. Reciprocating engines using light liquid fuels or natural gas can cogenerate for smaller systems. For example, the Burnside Park in Nova Scotia could potentially benefit from a cogeneration system.

Advanced Technologies

Fuel Cells
Fuel Cells produce both electricity and reject heat (cogeneration) using hydrogen. A cogeneration system could produce hydrogen by electrolysis at night, and the hydrogen would be used by a fuel cell to produce electricity during peak periods. Using cogenerated electricity at night can be a problem. Polygeneration is an alternative.

Compressed Air Electricity Storage

Compressed Air Electricity Storage (CAES) helps s
night when the electrical load is very low. One appr
compressor driven by an electric motor to compress
period when surplus electricity available. The comp
underground caverns. The compressed air is then u
turbine driving a generator to supply electricity whe
is needed during the day the compressed air is use
gas turbine the compressor uses about half of the p
required so much less fuel is required. If the storage system is locate
transmission losses are minimized



Compressed Air Storage
Image source Gaelectric Energy Storage Ltd.

Bio E

Bio E
pulpin
cogen

electrical output of the cogeneration plant. Most pulp and paper mills use wood residues such as bark or surplus wood chips to fuel steam boilers supplying steam turbines to generate electricity. Lumber mills produce surplus chips using slabs cut off to square logs to be made into lumber. Chips from the slabs and other residue should be used as fuel usually in a nearby pulp mill to generate electricity.

Biomass steam generation without cogeneration produces no more emissions per unit of fuel burned than would be produced if the material were incinerated or allowed to decay. Biomass cogeneration displaces fossil fuel otherwise used to generate electricity at single purpose plants as well as to generate the process steam. This reduces emissions. Much more electricity could be produced when if biomass could be gasified for use in a gas turbine combined cycle ? a likely development in the near future.

Anaerobic Digesters
Biogas from anaerobic digesters can be used in cogeneration systems based on municipal waste treatment, manure, etc.

Nuclear Cogeneration
Steam can be extracted from the steam turbines of nuclear power plants for use in industrial processes. This was done at the Bruce nuclear power plant in Tiverton, ON. A standby fossil fuel plant can be used if the nuclear plant is shut down or during periods of peak loads on the grid. The CANDU reactor can provide low-grade heat from the moderator coolant with no reduction in electrical output.

Polygeneration

Lambton Generating Station
Image source: Ontario Power Generation

Polygeneration adds a new dimension to chemical, pe complexes. Integrated Gasification Combined Cycle (petroleum coke and other inputs to produce electricity hydrogen which can be converted to ammonia used to products such as nitrogenous fertilizer. This approach Sarnia, where the coal fired Ontario Power Lambton C handling facilities. An IGCC polygeneration plant coul pure CO2. According to a recent study of Sarnia by sequestration experts, this CO2 can be sequestered by pipeline. Carbon dioxide capture and storage (CCS) is being widely studied. Hydrogen could be used for fuel cells and in nearby chemical plants and oil refineries. There are opportunities in Alberta. In one case bitumen is being gasified to produce the mixture of hydrogen and carbon monoxide to fuel a combined cycle supplying electricity, process heat and hydrogen for an insitu oil sands project.

Green Houses
Eco-Industrial Networks are ideal for greenhouses because the gas turbine exhaust or engine exhaust can be a source of CO_2 to promote the growth of plants. In smaller systems engine exhaust can be used. As well, heat from the cogeneration system can be used to heat the greenhouse allowing operation in cold weather. In addition to vegetables etc. tree seedlings can be grown to produce trees which will absorb carbon dioxide thus reducing the greenhouse effect.

About COGENCanada

COGENCanada also maintains training and advocacy functions and is assisted with training efforts by Ray Cote, a world-class authority on eco-industrial networking and energy. Some 33 Cogeneration Technology Courses and four Cogeneration Conferences have been delivered. We now plan to add webinars, class room courses with some people attending via the internet. Our course/worships are technical but conferences are of general interest.

COGENCanada has the support of the government of Canada.

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1 Cogeneration and Combined Heat and Power (CHP) are synonyms. COGENCanada uses cogeneration, a bilingual, euphonic word.
2 Cogeneration and Combined Heat and Power (CHP) are synonyms. COGENCanada uses cogeneration, a bilingual, euphonic word.
3 Example presented by Ray C?t?, professor at Dalhousie University.
4 These are prices for equipment only.

Cogeneration and Emissions Trading

This article will be published on the web sites www.Enerhope.com and www.cogencanada.org in January, 2011.

The following uses an example where where 90% of the fuel heat is rejected. Modern single purposes thermal electric plants reject 40% to 50% so a larger fraction of the fuel heat is converted to electricity. The illustration emphasizes the benefit of cogeneration.

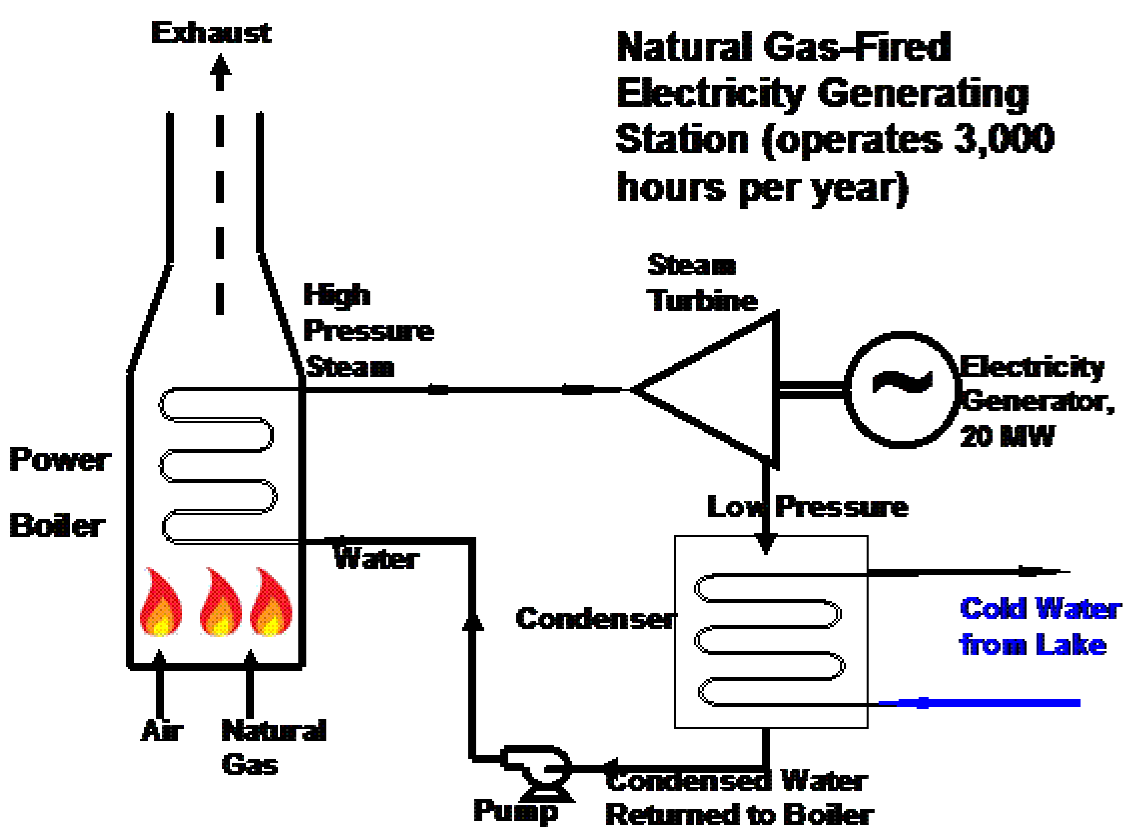
What is Cogeneration?

- **Cogeneration is the sequential production of useful mechanical power and useful heat in the same engine.**
- **Often stated as, "electricity and steam from the same engine"**
- **Sometimes identified as, <u>Combined Heat and Power</u>**

Your car is a cogeneration system because it generates power at the wheel and heat in the passenger compartment in winter.

<u>Here is an Example of A Cogeneration Project.</u>

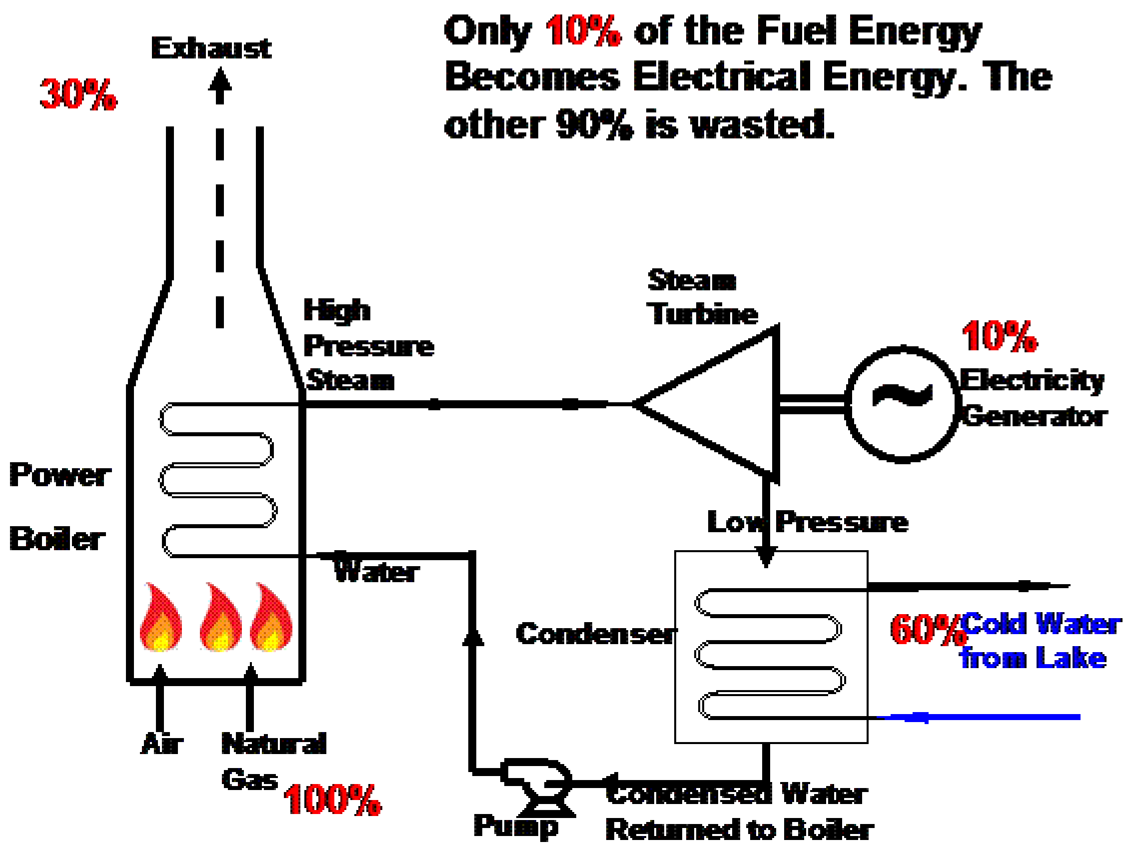
An old steam power plant will be turned into a cogeneration system.



This natural gas-fired generating station is located on the waterfront of a city. The plant is operated continuously for 3,000 hours, every winter.

The high-pressure steam from the power boiler drives a steam turbine, which drives a 20 megawatt electricity generator. The low-pressure steam leaving the turbine is condensed to liquid water by cold lake water in a condenser, and then pumped back into the boiler.

This is not an efficient generator of electricity. Only 10% of the fuel energy of the natural gas is transformed into electrical energy. The other 90% of the fuel energy is wasted as heat in the exhaust and in the condenser.

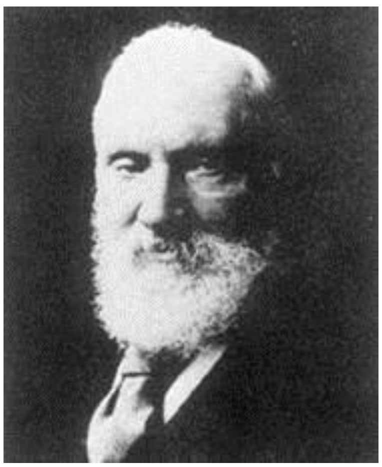


How unfair! Only 10% of the fuel energy is transformed into useful electrical energy. The other 90% of the fuel energy is wasted heat.

Why the wasted heat? Why the low efficiency?

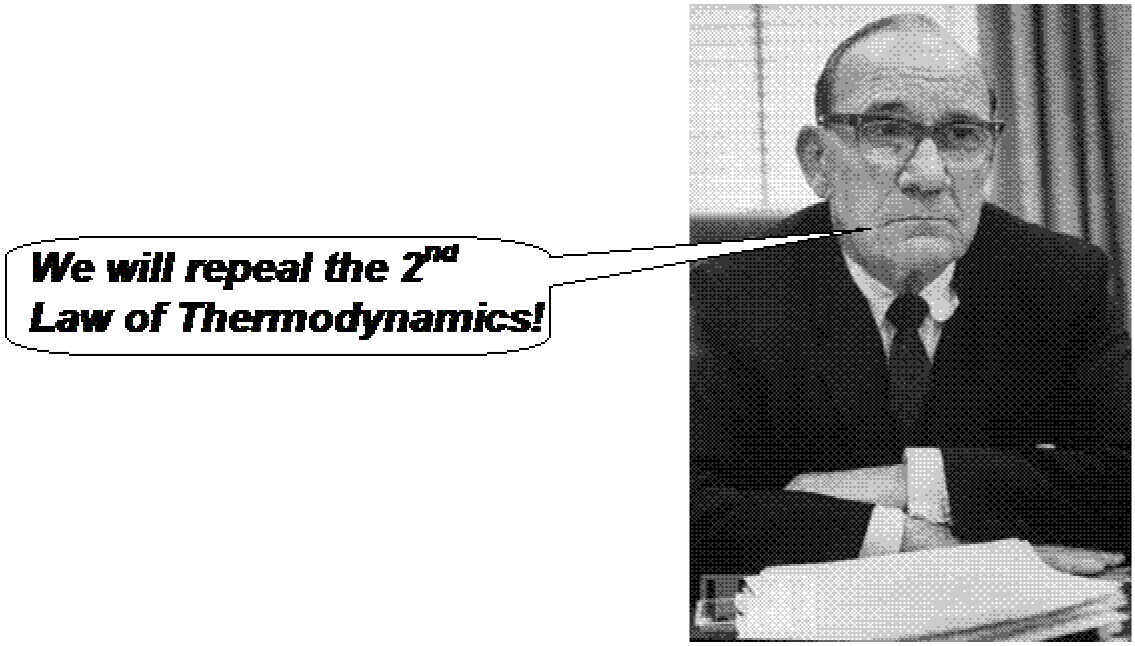
<u>Cogeneration: Whence cometh the heat?</u>

The low efficiency of our power station is a consequence of the <u>2nd Law of Thermodynamics</u>, first written by William Thompson, Lord Kelvin, in 1851, an inescapable physical law, like the Law of Gravity.



In plain language, the 2nd Law of Thermodynamics says that an engine cannot transform heat energy into mechanical energy without releasing heat to its surroundings.

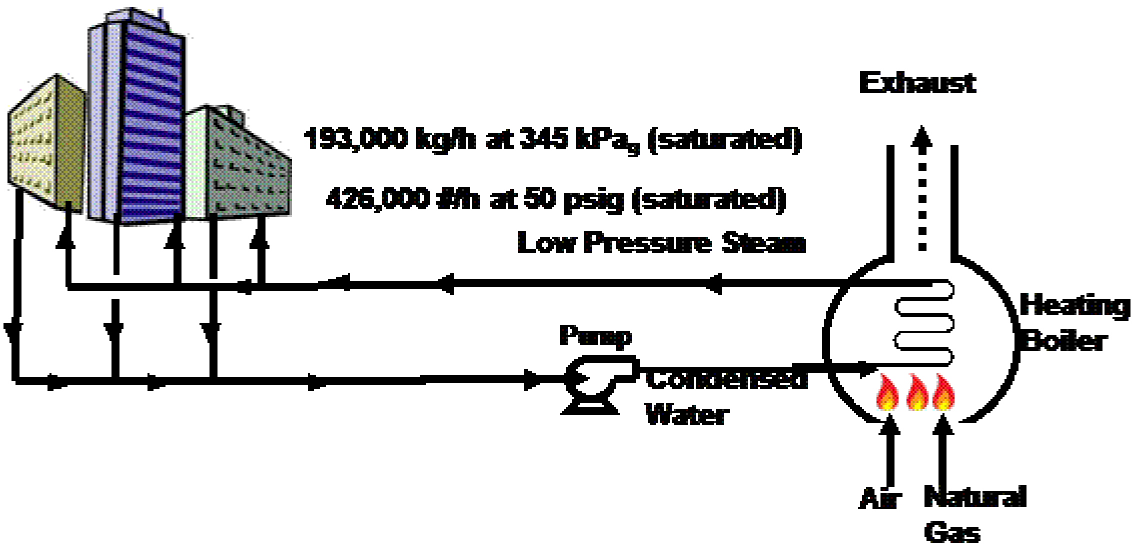
Not everyone understands the 2nd Law of Thermodynamics. In the 1970's, US Senator John McClellan threatened to repeal the 2nd Law.



US Senator John McClellan,
1896-1977

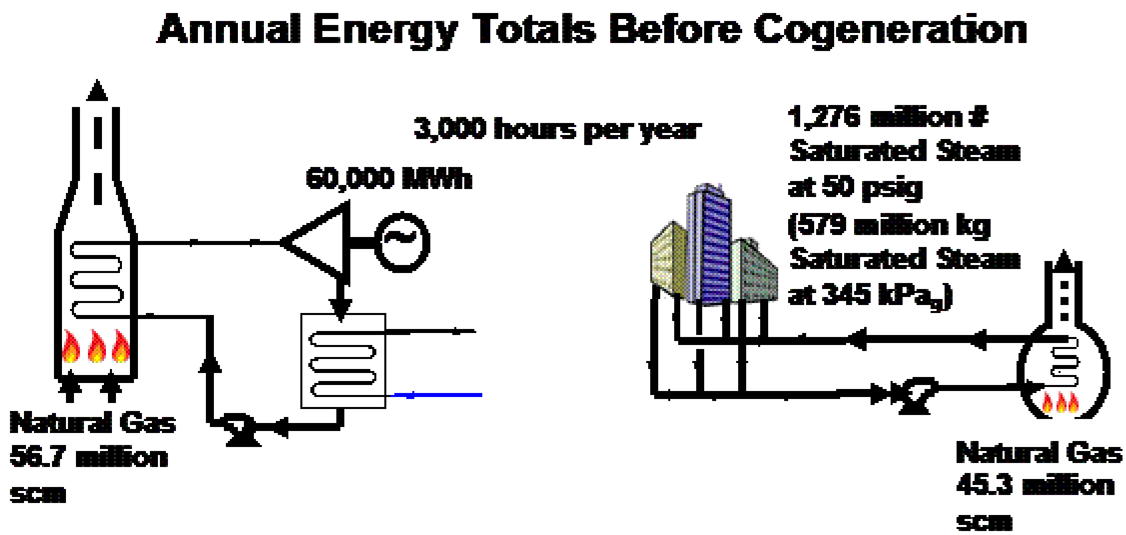
What a shame! We labour under the cruelty and unfairness of the 2nd Law of Thermodynamics! In our lakeside power plant, 90% of the fuel energy is wasted as heat. Can we find some practical use for the heat?

Scarcely two blocks away from the power plant is the central boiler for a <u>District Heating System</u>, providing steam to heat dozens of downtown buildings, during the same 3,000 hours, every winter.



The steam delivered by the district heating system is at the same pressure and flow rate as the steam wasted by the turbine into the condenser, during the same hours. What an amazing coincidence!

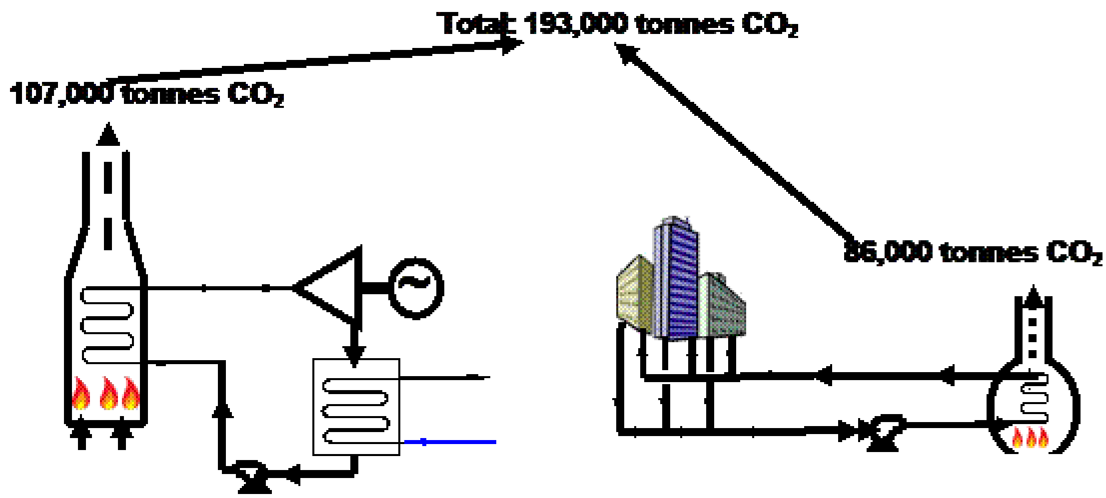
Here are the annual energy totals for the power plant and the district heating plant.



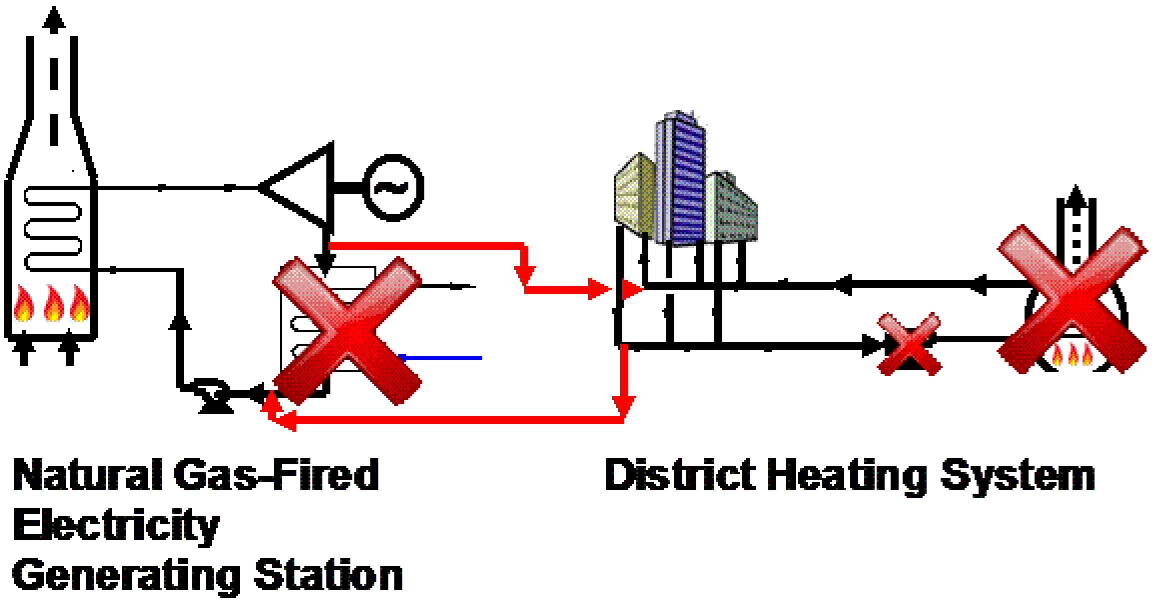
The total natural gas consumption for the two systems during the 3000 hour operation is 56.7 + 45.3 = 102.0 million scm.

Here are the annual total greenhouse gas emissions for the two systems.

Annual Greenhouse Gas Emission Totals Before Cogeneration



And now, the Cogeneration Project.

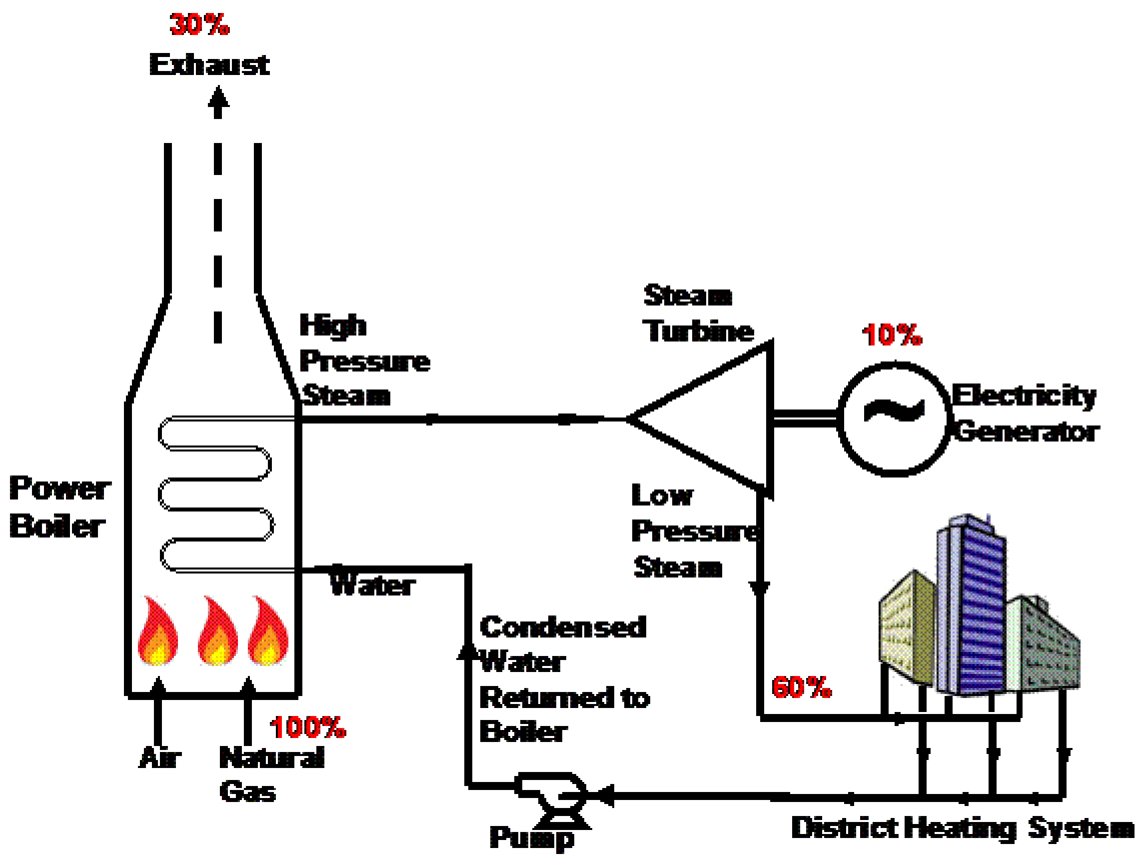


- **The Condenser is removed.**
- **The District Heating Boiler is removed.**
- **The Turbine outlet is connected to the low-pressure steam District Heating System.**
- **The Condensate Return from the District Heating System is connected to the Power Station Condensate Return.**

Et voila, Cogeneration!

Cogeneration: Whither goest the heat?

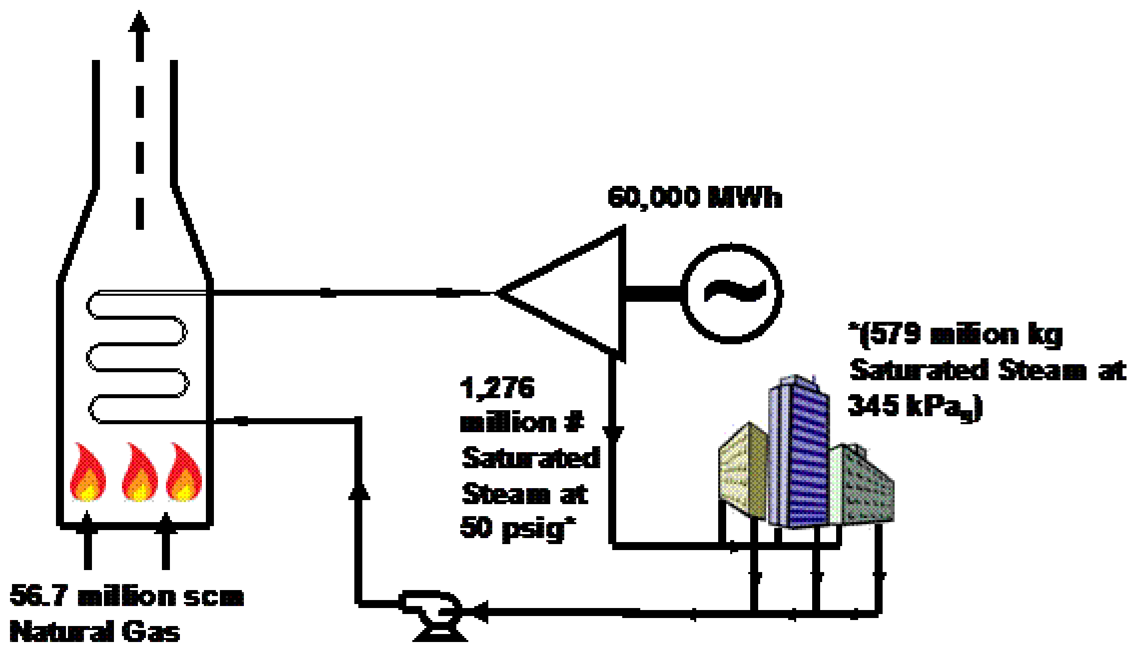
The cogeneration system is now providing all of the heat that the old heating boiler provided to the district heating system.



The new Cogeneration System has a 70% overall efficiency.

70% of the fuel energy is put to good use.

Here are the Energy Totals for the new Cogeneration System, during the 3,000 hour annual operation.

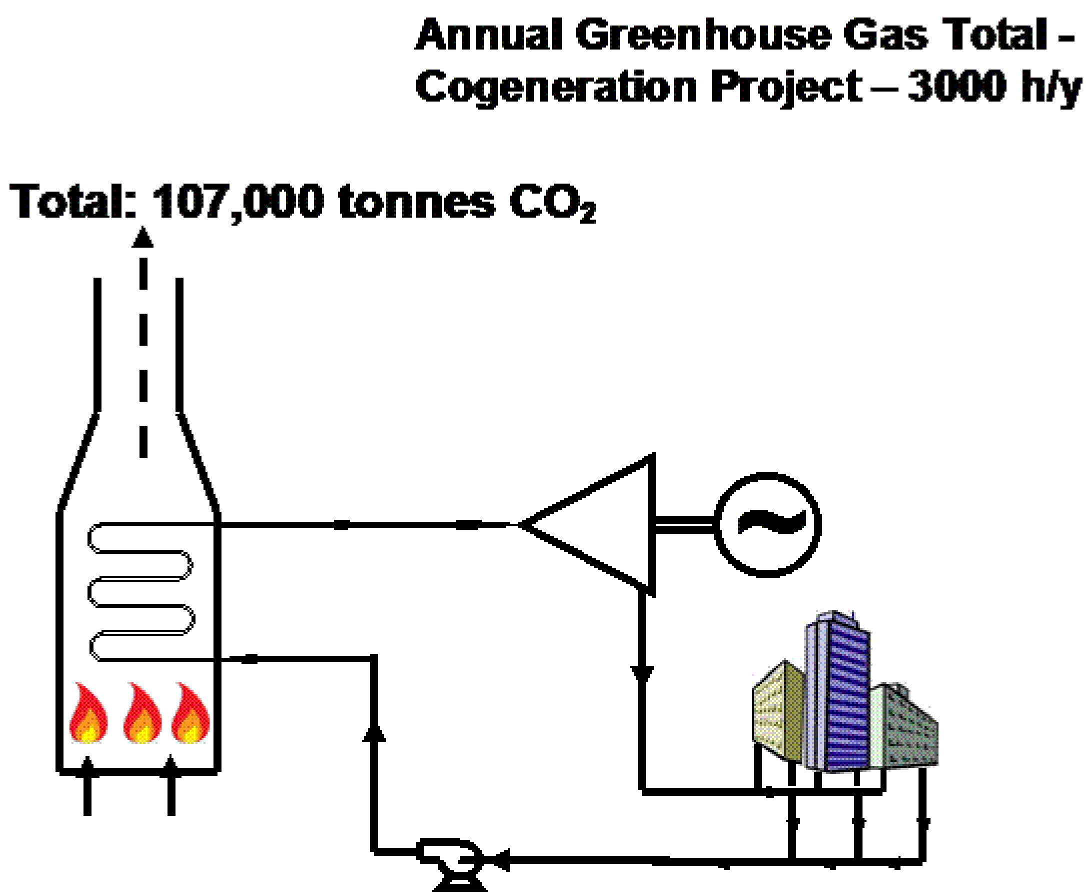


The Cogeneration Project generates 20 MW of electric power and all the steam needed to heat the buildings during the 3,000 hour annual operation, while consuming only 56.7 million scm of natural gas.

Before the Cogeneration Project, the two separate systems consumed a total of 102.0 million scm of natural gas during the same 3000 hour annual operation.

Net Energy Savings from cogeneration are 102.0 - 56.7 = 45.3 million scm of natural gas per year.

Switching to cogeneration has also caused some important reductions in greenhouse gas emissions.



In this case, switching to cogeneration has caused an annual greenhouse gas emission reduction of

193,000 - 107,000 = 86,000 tonnes CO_2 .

Cogeneration is very common in industrial plants that require both heat and power, e.g. petroleum refineries, pulp and paper mills. These large facilities have many boilers, many uses for the heat, and many power machines and electricity generators.

Emissions Trading ("Cap-and-Trade")

Because cogeneration reduces air emissions, greenhouse gas emissions trading systems are highly interested in cogeneration.

What is emissions trading (or, if you prefer, "cap-and-trade")?

What is Cap-and-Trade?

A market-based policy tool that establishes an aggregate emission cap on total emissions from a group of sources and creates a financial incentive to reduce emissions. The emission cap is expressed as allowances distributed to individual emission sources that must surrender allowances to cover their emissions. The program provides flexibility for sources with low-cost reductions to reduce even further and sell allowances to others with higher costs of control, resulting in achievement of the environmental goal at lowest cost.

(Source:

Tools of the Trade: a Guide to Designing and Operating a Cap and Trade Program for Pollution Control, USEPA, June 2003)

http://www.epa.gov/airmarkt/resource/docs/tools.pdf

Here is another description of an emissions trading system. This description appears in the web site www.Enerhope.com , which includes a short YouTube video course:

1.The Government passes a <u>Regulation</u>.

2.Specified <u>Capped Facilities</u>: major direct GHG emitters, e.g. fossil fuel electricity generators - will be "<u>under the Cap</u>" - must participate in emissions trading.

3.The <u>Cap</u> a specific, regulated maximum tonnes of GHG emissions from the total of the Capped Facilities in each specified year, e.g. 300 million tonnes in 2015, 290 million tonnes in 2016, 280 million tonnes in 2017..The Cap should be smaller than last years total emissions by the Capped Facilities, and smaller than the Business as Usual Forecast for these facilities. The Cap should become smaller and smaller, from year-to-year.

4.<u>Registry</u> like a bank ledger, visible to the public. Each Capped Facility will have an <u>Account</u> on the Registry. The Government will have its own Account on the Registry. Brokers are allowed to open Accounts on the Registry. The <u>Retirement Account</u> on the Registry will be the graveyard for Allowances which have been used up.

5.<u>Allowances</u> An Allowance is a permit to emit something into the environment. Each year, in January, the Government will create Allowances for GHGs, one Allowance for each kilotonne of GHG in the Cap. Each Allowance will have a certificate with a unique serial number. At the beginning of the year, (starting in e.g. 2015) the Government will deposit the new Allowances in its own Account.

6. <u>Allocation</u> At the beginning of each year, beginning in e.g. 2015, the Government will distribute the new Allowances to the Capped Facilities, according to a fair scheme. The government will transfer the allocated Allowances from its own Account to the Accounts of the Capped Facilities. (Free Allocation to Capped Facilities)

7.<u>Monitoring and Reporting</u> Each Capped Facility must monitor its direct GHG emissions during the year, completely, accurately and honestly. At the end of the year, each Capped Facility must report to the government its total direct GHG emissions for the year.

8.<u>Offsets</u> An Offset is a reward for emission reductions outside the Capped Sector. An organization which is not a Capped Facility can complete an emission reduction project and apply to the Government for creation of Offsets, to reward the emission

reductions. If the Government agrees that the emission reductions were real and satisfy program requirements, the Government will create a specific number of kilotonnes of Offsets and transfer these new Offsets to the applicants Account in the Registy.

9.Offsets and Allowances are both Tradeable Units in the Registry.

10.Trading At any time, any Account holder can buy Tradeable Units from, or sell Tradeable Units to, any other Account holder. (Exception The Tradeable Units in the Retirement Account never leave the Retirement Account.) The transfer of Tradeable Units from one Account to another must be recorded in the Registry, with the serial numbers.

11.Retirement At the end of each year, each Capped Facility must Retire (transfer to the Retirement Account) enough Tradeable Units to equal its reported annual direct GHG emissions.

If you are interested in a short, basic course in the mechanics of emissions trading, in print or by a YouTube video, go to www.enerhope.com

Emissions Trading: Why?

Reduces direct emissions by Large Direct Emitters: At the end of each year, each Capped Facility must retire (scarce) Allowances plus Offsets equal to its annual emissions.
Minimum cost to the economy: The market for Allowances and Offsets quickly finds the lowest-cost emission reduction activities and technologies.
Easier to enforce than Command and Control
Gives options to large emitters: Reduce emissions, or buy more Allowances and Offsets; Reduce emissions, or pay someone else to reduce emissions.

USA Success with Emissions Trading

The USA is the home of three of the most successful emissions trading systems to date. The Ozone Transport Commission NOx Budget Program (1990-2001) and the NOx State Implementation Plan (2002-present) reduced emissions of oxides of nitrogen from fossil-fuel generation of electricity in the northeastern states by 70% by 2009. The Acid Rain Program reduced sulfur dioxide

emissions from fossil fuel generating stations by 5.5 million tonnes per year between 1990 and 2005, a 35% reduction.

http://www.epa.gov/capandtrade/

Greenhouse Gas ET Schemes

Current, operating greenhouse emissions trading (ET) systems include the European Union (EU) system, the UNFCCC system (largely for developing nations), the RGGI system in the northeastern US states, and the New Zealand ET system. Plans for ET systems have been stopped in the USA, Japan, Canada and Australia. The Canadian province of Alberta is operating a Baseline and Credit system for large emitters. California and British Columbia have definite plans to implement ET systems. China, India, Taiwan and Korea are planning ET systems. The Western Climate Initiative is planning an ET system for 7 US states and 4 Canadian provinces.

How can industries and building owners benefit from cogeneration in an emissions trading scheme?

(These examples are real cogeneration systems which could benefit if emissions trading were implemented in their locations.)

Capped Facility Inside the Fence

A capped facility which generates its own power and steam can reduce its annual emissions significantly by switching to cogeneration. After implementing cogeneration, the facility will not need to retire as many Allowances at the end of the year. The emissions trading system may feature a cogeneration credit scheme, to reward cogeneration by capped facilities.

Abitibi Bowater, in Thunder Bay, Ontario, cogenerates its own power and steam.

Capped Facility Selling Energy to Another Capped Facility

e.g. Sarnia Regional Cogeneration

A capped facility which sells power or steam to another capped facility is helping that customer to reduce its annual emissions. During retirement at the end of the year, the customer will not require as many Allowances as if it had operated its own boiler plant. The contract between the seller and buyer of energy should

recognize the value of emission reductions in the emissions trading system.

Uncapped Facilities

e.g. Cornell University combined heat and power

An uncapped facility is not required by regulation to participate in emissions trading. However, an uncapped facility may choose to implement cogeneration, and then apply for Offsets to reward the emission reductions. If a successful recipient of Offsets, the uncapped facility can then sell them to a capped facility.

A Capped Facility Sells Energy to an Uncapped Facility

e.g. TransAlta Ottawa Health Sciences Centre Cogeneration

This cogeneration plant sells electrical energy to the Ontario electrical grid, and sells steam and chilled water to local hospitals.

In buying steam from the cogeneration plant, the customer has reduced its emissions, and could apply for Offsets to reward the reduction. The energy contract between the cogeneration owner and the customer should consider the Offsets value of these reductions.

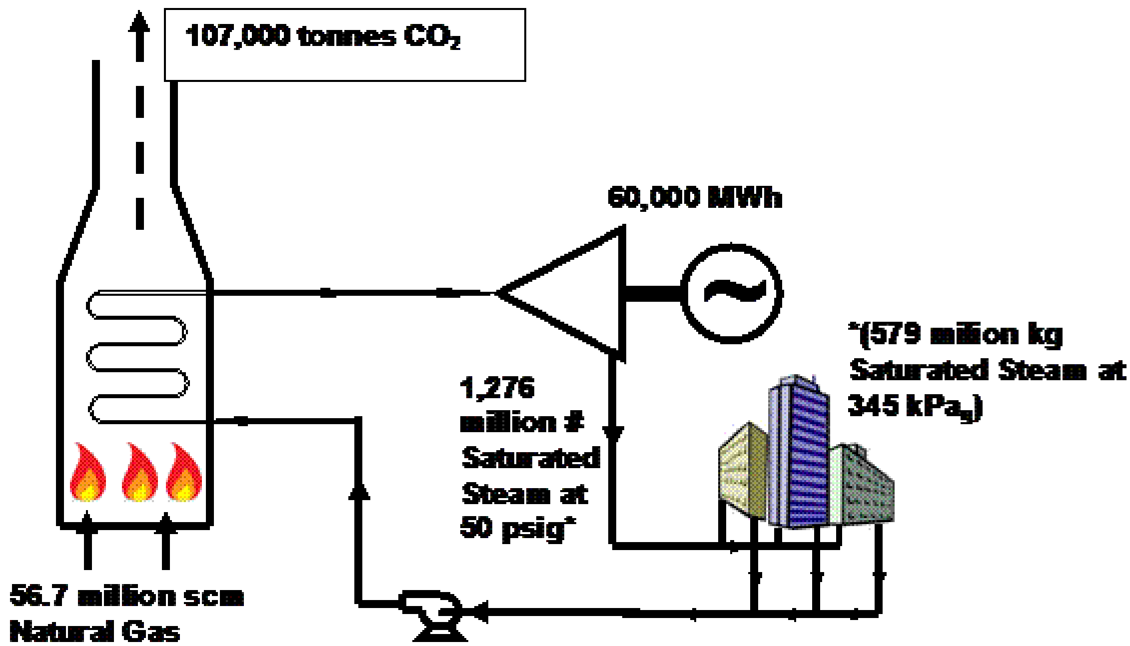
Cogeneration and Emissions Trading: How to Divide the Emissions between Produced Electricity and Produced Steam

From the cogeneration system, how many tonnes of CO_2 were emitted to generate electricity? How many tonnes were emitted to generate steam? How many tonnes for other forms of energy? Try answering these questions for a petroleum refinery, with 20 different boilers, and 20 different steam-driven machines and electricity generators.

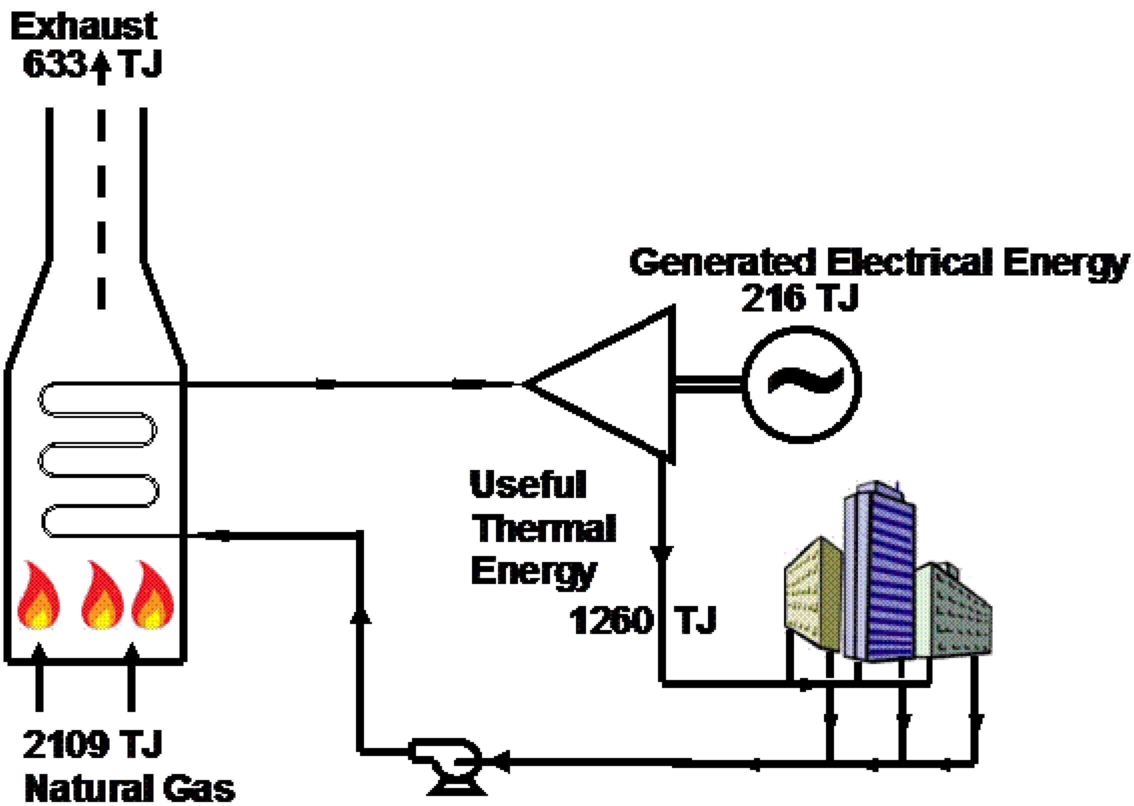
The owner of the cogeneration system must answer these questions, because mechanical energy and thermal energy are treated differently by the emissions trading system, especially where one form of energy is used by the owner, and the other is sold to a customer.

Here is a possible method for dividing the emissions between electricity and steam for the cogeneration project described at the beginning of this article.

1.Report annual totals for all energy quantities, and greenhouse gas emissions.



2.Express each annual energy quantity in universal metric units.



3.Calculate how many % of total useful energy are thermal, how many % are mechanical or electrical.

$$\% \text{ Useful Thermal} = 100 \times \frac{1260}{1260 + 216} = 85.4\%$$

$$\% \text{ Useful Electrical} = 100 \times \frac{216}{1260 + 216} = 14.6\%$$

4. Apply these percentages to total greenhouse gas emissions, to calculate how many tonnes of emissions are attributable to useful thermal energy, and how many tonnes attributable to useful electrical energy.

Annual Thermal Energy Emissions = 85.4 % of 107,000 tonnes

= 91,300 tonnes CO_2

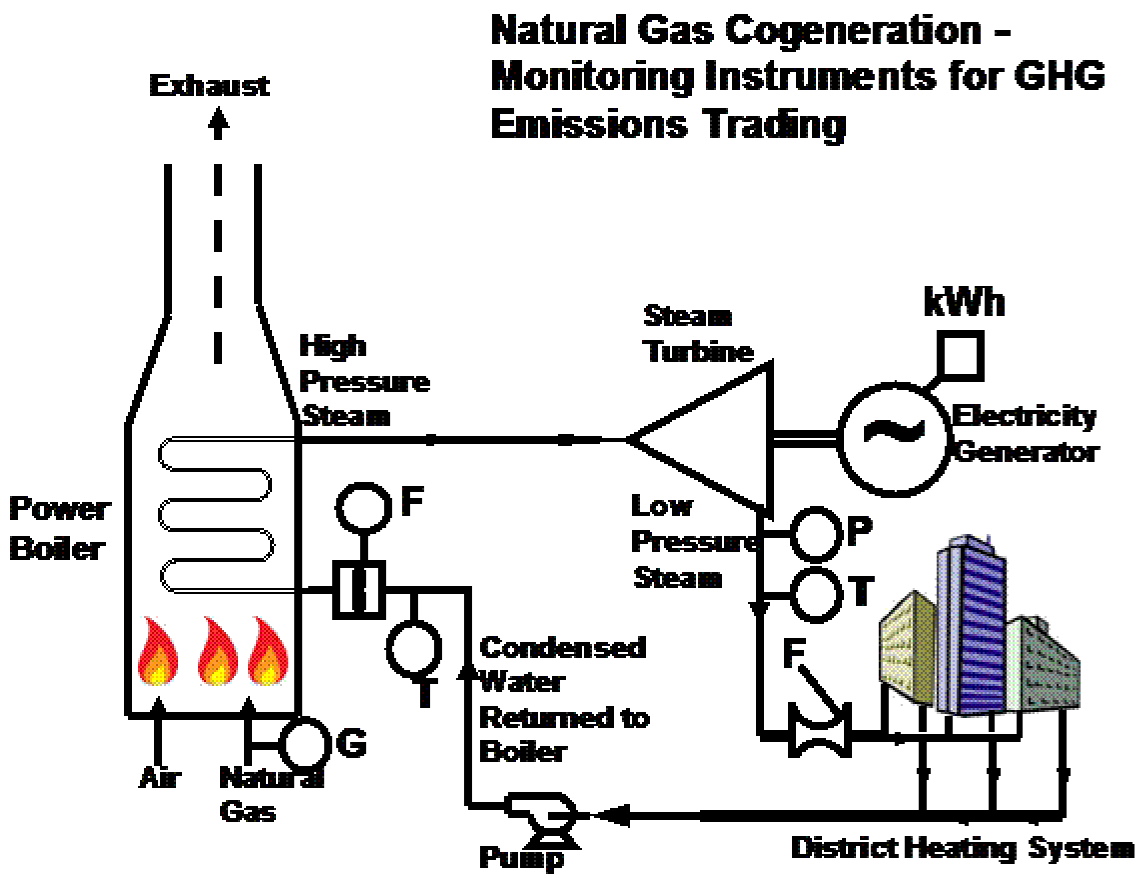
Annual Electrical Energy Emissions = 14.6% of 107,000 tonnes

= 15,700 tonnes CO_2

Cogeneration and Emissions Trading: The Need for Monitoring

Together, cogeneration and emissions trading require accurate, complete monitoring and reporting of energy and emission quantities.

Here is the monitoring system required for the cogeneration project described above:



The monitoring instruments provide information to a computerized, continuous energy and emissions monitoring system. At the end of the year, the monitoring system shows the totals for all significant energy flows and air emissions during the year.

In this example, wheres the CO_2 meter? How do we know how many tonnes of CO_2 were emitted by the gas-fired cogeneration system during the year? The highly accurate gas meter transmits the exact number of standard cubic meters of natural gas which

are burned during the year. The computer can convert this total consumption of natural gas, a fuel of standard chemical composition, to total CO_2 emissions, by calculating a mass balance. Combustion of each standard cubic meter of natural gas emits 1.89 kg of CO_2.

Cogeneration and Emissions Trading in the UNFCCCs Clean Development Mechanism

The Clean Development Mechanism (CDM)of the United Nations Framework Convention on Climate Change creates CER Offsets for emission reduction projects in developing countries. The Offset owners can then sell these Offsets to Capped Facilities in the EU emissions trading system. The Capped Facilities can retire these Offsets to supplement their retirement Allowances.

As of December 21st, 2010, the CDM projects list includes 90 approved cogeneration projects, credited with over 5.8 million tonnes per year of greenhouse gas emission reductions.

Here is the URL of a document which describes one of the cogeneration projects approved for CERs by the CDM.

Cogeneration in Alberta

The Canadian province of Alberta, with its growing oil sands industry, has become a world leader in natural gas cogeneration, and could minimize the greenhouse gas emissions from oil sands projects through effective use of cogeneration.

The oil sands process requires large amounts of steam to separate the bitumen from the sand, either in the ground, or after mining of the oil sands. This steam is provided by natural gas cogeneration plants, which also provide electric power to the refineries.

Currently, for the entire Province of Alberta, most of the electricity generating capacity is provided by coal-fired boilers, which are high emitters of greenhouse gases. An excellent 2007 article from Power Gen Worldwide outlines the role of cogeneration in the oil sands, and the opportunities for cogeneration to supplement Albertas existing electricity generation system. http://www.powergenworldwide.com/index/display/articledisplay/303182/articles/cogeneration-and-on-site-power-production/volume-8/issue-4/features/cogeneration-and-the-alberta-oil-sands-cogeneration-benefits-are-maximized-with-extraction-and-upgrading-integration.html

In Alberta, 36 new natural gas cogeneration projects were built between 1998 and 2009, increasing the provinces generating capacity by 1869 megawatts, or 16%.

http://www.energy.alberta.ca/Electricity/682.asp

If high capacity electricity transmission lines were built from the oil sands area to the south, most of the coal-fired generation could be replaced by natural gas cogeneration, with massive reductions in overall greenhouse gas emissions.

A 2010 Report for the Alberta Energy Research Institute by Jacobs Consultancy and Life Cycle Associates shows that cogeneration in the oil sands could bring the net greenhouse gas emissions per barrel of synthetic crude oil to within a few percent of emissions

from typical conventional crude petroleum from Nigeria or the US Gulf Coast. However, the study did not examine the mechanism for transfer of the emission reductions to the provincial electricity system through emissions trading.

http://www.albertainnovates.ca/media/15753/life%20cycle%20analysis%20jacobs%20final%20report.pdf

Cogeneration in Albertas Baseline and Credit System

The regulated baseline for greenhouse gas emissions from cogeneration in Alberta is described in the document, SPECIFIED GAS EMITTERS REGULATION : ADDITIONAL GUIDANCE ON COGENERATION FACILITIES, OCTOBER 1, 2007

http://environment.alberta.ca/documents/additional_guidance_on_cogeneration_facilities.pdf

In the Alberta baseline and credit system, in the first year, each megawatt-hour of generated electrical energy is allocated 0.418 tonnes of CO_2 baseline. The allocation of baseline for cogenerated thermal energy is based on a boiler efficiency of 80%, although the boiler fuel is not specified.

Applying these criteria to our above example, the Alberta baseline allocation would be:

For generated electrical energy:

0.418 x 60,000 = 25,080 tonnes CO_2/year

For cogenerated thermal energy from natural gas fuel:

1,260 TJ x 50.8 tCO_2/TJ x 100/80 = 80,010 tonnes CO_2/year

(Natural gas combustion emits

50.8 tonnes of CO_2 per terajoule of fuel energy.)

Total Alberta baseline in the first year:

25,080 + 80,010 = 105,090 tonnes CO_2/y

This project, with its total emissions of 107,000 tonnes CO_2/year, if located in Alberta, would exceed its baseline by 107,000 - 105,090 = 1,910 tonnes of Alberta emission performance credits, in the first year. The owner would need to improve the efficiency of the cogeneration system, or buy and retire 1,910 tonnes of emission performance credits in the first year. In subsequent years, with lower baseline allocation intensities, the project would probably emit even more than its baseline.

The Alberta regulation does not appear to offer any guidance to the operator of the district heating system, who might be eligible for Offsets, for replacing its boiler plant with purchased, cogenerated steam.

The Case for Cogeneration and Cogen based Eco-industrial Networks Printable version

Single purpose thermal electric power plants reject between 50% and 65% of the fuel heat to rivers, lakes, the ocean or the atmosphere. The heat rejected by single purpose thermal power plants may cause thermal pollution. Cogeneration systems use this rejected heat for purposes such as paper drying, chemical processing, food processing etc., as well as space heating or cooling (absorption chillers). **Cogeneration enhances industrial competitiveness through cost reduction. It reduces emissions.**

Many industrial and institutional plants use interruptible natural gas with sulphur bearing Heavy Fuel Oil (HFO) as an alternate. **The HFO has a far greater adverse environment impact that does natural gas**. When gas turbine or combined cycle cogen takes over the HFO is gone.

Cogeneration produces given amounts of electricity plus process heat with much less fuel than when they are produced separately. Significant reductions in GHG and other emissions are assured. Transmission losses are reduced. With appropriate arrangements Cogeneration systems and selected loads can be kept running during grid failures (blackouts) avoiding costly shutdowns.

Many cogeneration systems serve a single steam user such as an industrial plant, a university or a hospital. The aim should be to group thermal energy users in Eco Industrial Networks. This achieves economies of scale. in the cogen system serving the network.

Cogeneration-based Eco - Industrial Networks are the right road to Sustainable Industrial Development. This concept involves co-locating electric power producing facilities near groups of industrial processes using electrical and thermal energy. Outputs and waste from one process become inputs to other processes in the network. A single cogeneration Page 2 plant serves the entire network achieving Economies of Scale as noted..

Steam cannot be transmitted more than 4 or 5 km. However, heat can be transported much further in low temperature hot water, or higher temperature heat transfer fluids such as Dow Therm, Therminol or hot oil. Some processes more distant from Cogen system and industrial waste heat sources can be included in the network. Industrial Development people should locate Businesses and Light Industrial parks or near plants with available recovered heat to take advantage of the recovered heat and heat from the Cogeneration system for heating and cooling.

Natural gas, coal, wood residues, garbage, heavy (residual) fuel oil, petroleum coke, byproduct gases, liquid biofuels etc. can be used for steam turbine cogeneration. A much better approach, if the fuel can be used in a gas turbine, is to use the gas turbine exhaust to generate high pressure steam for an extraction condensing steam turbine. This combined cycle approach yields much more electricity worth about 3 times as much as the heat equivalent. Reciprocating engines fit some situations.

The case for flexible natural gas combined cycle cogeneration. All natural gas combined cycle systems should have a base loaded cogeneration component. Flexible combined cycles provide firm power, peaking power and spinning reserve. The flexibility is provided by using an extraction condensing steam turbine. The condenser rejects heat at the at a temperature so low that it has limited use. There may be processes in the network which can use this very low grade heat in cold weather. Steam should be lost at the condenser only during peak loads The flexibility of a combined cycle system can be substantially increased by using a burner between the gas turbine and the heat recovery steam generator (HRSG). In one case the steam turbine has a capacity of about 12 MW without auxiliary firing and 30 MW when the auxiliary burner between the gas turbine and the HRSG is fully on. The gas turbine exhaust is roughly 15% oxygen so combustion air need not be heated. As a result the natural gas is burned at an efficiency some 10% higher than it would be with a conventional boiler.
Gas turbine exhaust can be used directly in Yankee dryers on paper machines and some other drying processes such as clay drying.
Heavy industrial parks - Paper machines, chemical processes, oil refining, food processing etc. are well suited to relatively large scale Cogeneration based Eco Industrial Networks. Good examples of chemical/ petrochemical/ oil refining networks are the TransAlta, Sarnia 400 MW combined cycle system serving 4 large petrochem. complexes and the Joffre AB, 450 MW cogen plant serving a major petrochemical complex.

The Alberta Industrial Heartland near Edmonton has several major combined cycle cogeneration systems. Examples of Forest products complexes with cogeneration are Catalyst in Campbell River, Bowater in Thunder Bay and Irving Pulp and Paper/Irving Tissue in St John NB.

Polygeneration - adds a new dimension to chemical, petrochemical and oil refining complexes. Integrated Gasification Combined Cycle IGCC Systems can gasify coal, petroleum coke and other inputs to produce electricity and process heat as well as hydrogen which can be converted to ammonia used to produce a variety of chemicals products such as nitrogenous fertilizer. Pure sulphur can also be produced. This approach is particularly well suited to Sarnia where the coal fired The Ontario Power Lambton Generating station has major coal handling facilities An IGCC ploygenration Page 3 plant could be built on that site. . Pure CO2 would flow from the stack. This can be sequestered by pipeline according to a recent study of Sarnia by sequestration experts. The Hydrogen could be used for fuel cells and in nearby chemical plant and oil refineries.. .

Perhaps the best example of an Institutional Eco Industrial network is the General Campus of the Ottawa Hospital. A TranAlta 70 MW combined cycle cogeneration system supplies thermal energy to a large hospital complex. One of the hospitals more than a kilometre away from the Cogen plant is both heated and cooled by a single low temperature hot water loop from the cogen plant. Absorption coolers handle summer air conditioning.

Cogeneration should also be encouraged for light industrial parks where non energy synergies or symbiosis may be more important. There are many of these. An example is the Burnside Eco-Industrial Park in Dartmouth (Halifax) Nova Scotia. Thermal energy can now be used for both heating and cooling (trigeneration) which can help reduce both summer and winter peak loads on the grid. Reciprocating engines using light liquid fuels or natural gas can cogenerate for smaller systems.

Bio Energy can be used for steam turbine cogeneration by burning wood residues or pulping liquor. There are many of these in pulp and paper mills. A system by Dynamotive and Orenda in West Lorne Ontario uses liquid fuel made from saw mill residues in a gas turbine cogeneration system producing The outputs are 2.5 MW of electricity and steam for the lumber kiln. The benefit of cogeneration depends on the fuel displaced from a single purpose power plant by the electrical output of the cogeneration plant. Hydro will not be displaced due to storage and export options. Biomass steam generation without cogeneration produces no more emissions per unit of fuel burned than would be produced if the material were incinerated or allowed to decay. Biomass cogeneration displaces fossil fuel otherwise used to generate electricity at single purpose plants. It reduces emissions. Much more electricty can be produced when biomass can be gasified for use in gas turbine combined cycles. Likely in the near future.

Anaerobic Digesters. Biogas from these can be used in cogeneration systems based on municipal waste treatment, manure etc.

Fuel Cells produce both electricity and reject heat (cogeneration). They can use byproduct hydrogen from petrochemical processes. Nuclear plants can produce hydrogen off peak. It can be made from natural gas, coal etc. There are many applications.

Nuclear Cogeneration. Steam can be extracted from the steam turbines of nuclear power plants. This was done at Tiverton, Ontario at the Bruce nuclear power plant. A standby fossil fuel plant can be used during periods of peak loads on the grid.

Cogeneration Project Challenges Among the main challenges to complete a cogeneration or combined heat and power project, is having all the players work together- the nonutility power generator(NUG) who owns the project, the Utility that distributes the power along its power lines and the steam host or heat user(factory owner or the building owner). The Utility may not want to buy the power or may put large restrictions or costs to connecting to the grid such as a standby charge in case the NUG can't meet its power supply obligation. The steam host may have fluctuating heat or steam requirements which the cogeneration system may have difficulting following. The cogeneration system might have to have a large condenser to take the steam that the factory steam host can't take and generate more electricity instead. A good way to have the cogeneration system follow the steam host's steam load is to duct burner,burning more natural gas between the gas turbine and HRSG(boiler). The amount of duct burning follows the steam load. It is efficient because, with 15% oxygen in the gas turbine exhaust, no additional air needs to be added(unless the duct burning is extremely high). The additional air would have exited the stack at a temperature higher than outdoor temperture - a wasted heat load.

Another concern is lower overall efficiency because too much electicity is generated. Because electricity is a lot more valuble that heat or steam, the tendancy is to make a cogeneration system that is too large - generating too much electricity, and thus having a lot more potiential steam than the steam host can use. With only a fraction of the steam from the steam turbine going to the host, the rest goes to a condenser where heat is lost.

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***COGENCanada** is a federally incorporated not for profit association dedicated to promoting cogeneration, heat recycling, energy cascading, Eco Industrial Networking and sustainable industrial development. Helping Canadian industrial and institutional energy users, electricity generators, Industrial Development Authorities and suppliers of related goods and services is an objective. COGENCanada has the support of the government of Canada. There are training & advocacy functions. Cogeneration and Combined Heat and Power (CHP) are synonyms. COGENCanada uses cogeneration, a bilingual, euphonic word. The COGENCanada Board of Advisors includes **world class authorities**. Some 28 Cogeneration Technology Courses delivered.*