Combined Heat and Power: Heat Consumption and Total Electrical Output in Nova Scotia

David Fright

Combined Heat and Power: Heat Consumption and Total Electrical Output in Nova Scotia

38% of Nova Scotia's electricity can be supplied by decentralized combined heat and power systems. When replacing centralized coal-fired power plants, combined heat and power, or CHP, can reduce overall provincial electrical greenhouse gas, or GHG, emissions by 36%. Combining the production of heat and electricity makes use of heat that is normally wasted in centralized electricity production and, therefore, greatly increases electrical production efficiency. In comparison to the amount of fuel that would have been consumed in order to produce the same amount of heat as the waste heat captured by CHP, the amount of fuel that is needed to produce electricity is reduced by 51%. All things being equal, this also produces a 51% decrease in GHG emissions. However, by switching from centralized power plants burning coal, to a much cleaner "fuel mix", such as is typically used by the residential, commercial, and industrial sectors, emissions are further reduced by 31%. Combined, this represents a 66% reduction in GHG emissions compared to centralized coal-based production in Atlantic Canada.[1] When natural gas is used instead of the "fuel mix", 73.5% total emissions reductions are produced.

There is general consensus that an approximate 80% reduction in annual GHG emissions is necessary to stave off the worst of global warming. Therefore, to solve the climate crisis, it is not necessary to eliminate the use of fossil fuels, but reduce their use to sustainable levels. Decentralized CHP systems can take the place of conventional power plants and offer the same benefits of a continuous power source but with much lower levels of emissions due to increased efficiency and cleaner fuels. In an age when natural gas is available to the doorsteps of many residential, commercial, and industrial buildings, centralized electricity production no longer makes sense. CHP is a practical means of dramatically reducing electrical GHG emissions to sustainable levels by using non renewable sources more efficiently until the day that were are able to generate all our electricity from zero emissions sources.

To perform this analysis, I will first calculate the total amount of heat demand within Atlantic Canada by the residential, commercial/institutional, and industrial economic sectors. To get a sense of how much associated electrical power can be produced by CHP, I will employ "utilization factors" of 25% and 50% for all heat energy within Nova Scotia supplied by CHP. I arrived at the figure of 38% of all electricity being produced in Nova Scotia by CHP by assuming a 50% heat utilization factor for the industrial sector and a 25% utilization factor for the rest of the economy. As I will discuss, this figure is quite realistic and does not require mass adoption of CHP systems beyond the large firms operating within each of the economic sectors. In Denmark, through widespread use of district heating systems, much larger amounts of heat are produced by CHP for use within the residential and commercial sectors and 50% of all electricity is generated by CHP systems including centralized power plants connected to the district heating systems. With a cold climate and a relatively large industrial sector, it is reasonable to expect that Nova Scotia could make equal use of CHP to produce a large amount of its electricity.

[1] Cover Photo: Steam vapour in New York, 1901, from district heat supplied by CHP systems. Today, CHP produces 50% of New York's district heat. https://en.m.wikipedia.org/wiki/New_York_City_steam_system

The analysis of heat consumption and electrical output is based off of energy use within Atlantic Canada. There is no similar data available for the individual Atlantic provinces. On average, if 38% of Atlantic Canada's electricity is generated by CHP, 38% of each of the provinces' electricity will also be generated by CHP. The numbers will vary according to the relative use of heat energy within each economy, but generally the analysis will hold across all provinces. Nova Scotia, with no nuclear power and smaller amounts of hydroelectric power than other Atlantic provinces, will likely benefit more from CHP and, so, an analysis based on average energy use within Atlantic Canada will not overestimate its potential.

The analysis of GHG emissions reductions within Nova Scotia is based off of the Canadian Energy Regulator's Provincial "Market Snapshot" which describes electricity production within each Canadian province.[2] The analysis of heat consumption within each economic sector in Atlantic Canada provides the average amount of electricity that can be expected to be generated by CHP within that sector based on a given amount of heat consumption. Provincial electrical production figures provide the amount of GHG reductions that can be expected to be produced by CHP in comparison to current levels of emissions for provincial electrical production. The same method can be applied to the other Atlantic province and should provide a reasonable estimate of provincial emissions reductions for Nova Scotia within the bounds of normal variation between provincial heat consumption patterns.

Combined Heat and Power Systems

The combustion of fuel to produce electricity also produces heat. In centralized power plants, this heat is largely wasted. Modern generating stations often recapture some amount of heat using "heat to power systems" but this is a small percentage of the total amount of heat that is lost.

Combined heat and power systems, however, capture a large percent this waste heat for use in practical applications such as hot water, heating interior spaces, or driving commercial and industrial processes. The industrial sector, by far, is the greatest consumer of heat of the four major sectors shown in Table 1 and its demand for heat is almost double that of all other sectors. This large demand for heat provides a ready source of consumption for the waste heat that is currently produced by the electrical sector.

Therefore, one of the simplest ways of immediately reducing electrical sector energy consumption and greenhouse gas emissions is to simply decentralize the production of electricity as much as possible to better make use of the heat that is currently wasted. In Nova Scotia, 63% of electricity is currently produced by coal and coke. Of the remaining 37% of total production, 33% is generated by relatively clean sources --9% natural gas, 12% wind, 9% hydro, and 3% biomass.[3] To reduce the bulk of Nova Scotia's emissions due to electrical production, only the 63% of electricity that is produced by centralized coal and coke-fired plants needs to replaced with cleaner forms of electrical production.

With the switch from centralized coal plants to decentralized CHP systems, there will also likely come a switch in the fuel used to generate the heat and electricity. Coal is a very small source of energy outside

[2] https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-nova-scotia.html
[3] See Figure 1. Bio-mass isn't necessarily "clean," but is assumed to be so in the government's data.

of the electrical production sector. The overwhelming majority of heat consumed in the four major economic sectors comes from other, much cleaner, sources and will result in much larger emissions reductions than would simply occur with a switch to CHP and no change in fuel source.

Nova Scotia Electricity Production

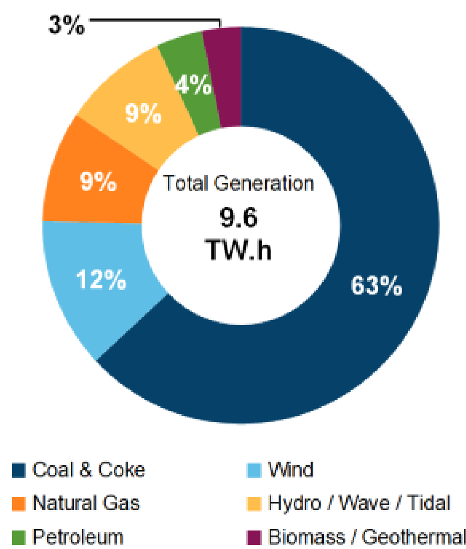

Figure 1[4]

Therefore, combined heat and power plants not only produce electricity more efficiently, they also produce cleaner electricity and can facilitate the rapid replacement of the oldest and most inefficient power plants that use the most polluting fuels and produce the greatest amounts of emissions.

Heat Consumption and CHP Electrical Output

The US Energy Information Agency uses the simple model shown in Figure 2 to describe the increase in efficiency that results from a switch to CHP from separately generated electricity and heat.

The typical centralized power plant is only 33% efficient whereas the typical commercial heating system has a much higher level of efficiency at 80%. Together, their combined efficiency is 51% whereas the combined efficiency of the typical CHP plant is 75%. The increase in average efficiency of 24% for the production of heat and electrical power for the CHP systems results in a 32% decrease in combined fuel consumption along with an equal reduction in average greenhouse gas emissions. If the switch to CHP involves a change for a cleaner source of fuel, the emissions reductions are much larger.

Using these parameters, I generated Table 1 based the demand for heat within the residential, commercial and institutional, industrial, and agricultural sectors. By capturing waste heat generated in the production of electricity, CHP systems eliminate the need for additional fuel consumption to

[4] https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-nova-scotia.html

produce heat using a separate system. Therefore, the fuel consumed by a CHP system to produce electricity can be determined by subtracting the amount of fuel that would have been required to produce heat with a separate heating system from the CHP system's total fuel consumption.

Combined Heat and Power Versus Separate Generation

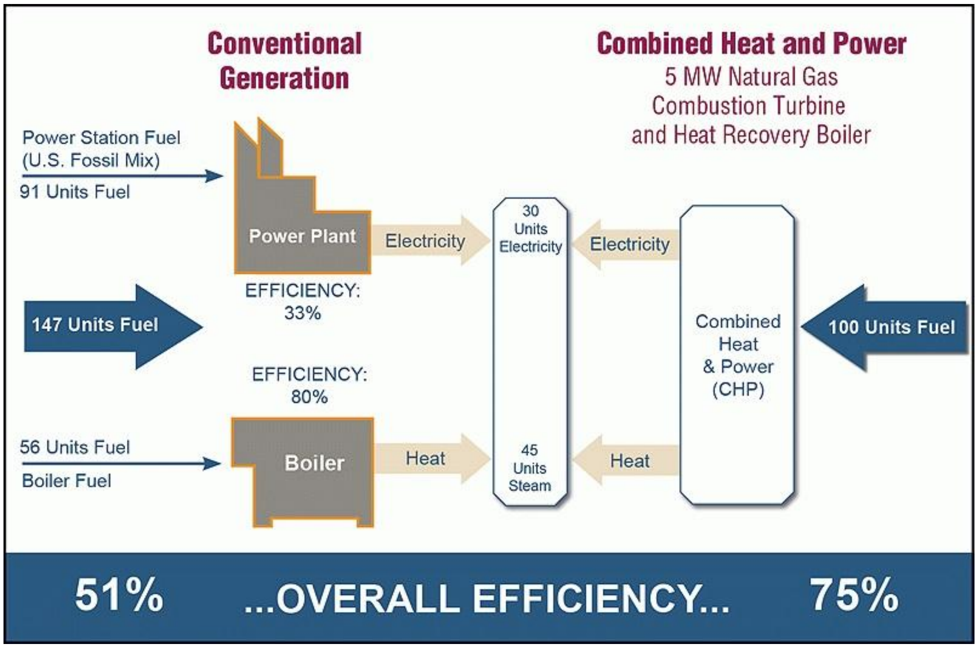

Figure 2[5]

To determine the amount of electricity that can be generated by CHP, and the resulting fuel savings, the amount of heat actually consumed by each of the sectors listed in Table 1 must first be calculated. The energy-use figures provided by the National Research Council of Canada used in Table 1 actually represent "heat energy fuel consumption" and not the actual amount of heat consumed.[6] Although most heating systems are typically quite efficient at 80%, this still results in a 20% heat loss and thus the amount of heat energy actually consumed is less than the amount of energy used to produce it. Based on Figure 2, the total output of a typical CHP system is 40% electricity and 60% heat. The maximum electrical output of CHP is limited by the amount of heat that can be consumed. If 100% of each sector's heat requirements are to be supplied by CHP, CHP heat output, which represents 60% of total CHP output, must be equal to total heat demand within each sector. The maximum electrical output of a CHP system within a particular sector is then equal to the remaining 40% of total CHP output. I have included the National Research Council data tables in Appendix A.

[5] https://www.epa.gov/chp/chp-benefits

[6] Note, for this analysis, any energy consumed that is NOT electricity is assumed to be for heat. The National Energy Survey from which the NRC data is drawn separates fuel that is used for transportation or is consumed as feedstock for various processes. Since very few commercial or industrial firms presently generate their own electricity, any energy consumed that is not electricity is generally used in some sort of heat process.

Sectoral Heat Demand and CHP Electrical Output

	Residential	**Commercial/Institutional**	**Industrial**	**Agricultural**	**Total**
Electrical Energy Consumption	54.3	36	39.6	2.1	132
Heat Energy Fuel Consumption	59.6	20.8	146.2	1.2	
Heat Energy Consumption	47.7	16.6	117	.96	183.3
Total CHP Power Production	79.5	27.7	195	1.6	
CHP Electrical Production	31.8	11.1	78	.64	121.5
Equivalent Heat Energy Fuel Consumption	59.6	20.8	146.2	1.2	
CHP Electrical Energy Fuel Consumption	46.4	16.1	113.8	0.9	
Equivalent Electrical Energy Fuel Consumption	96.4	33.6	236.4	1.9	**Total Electrical Demand Supplied by CHP:**
Total Electrical Energy Fuel Consumption Savings	51.9%	52.1%	51.9%	53%	**92%**

Table 1[7]

The amount of fuel that would have been used to produce a given amount of electricity at 33% efficiency using a centralized power plant can be compared to the amount of fuel consumed by a typical CHP system to produce the same amount of electricity by calculating the amount of fuel that would have been consumed by a typical heating system to provide the same amount of heat and subtracting it from total CHP fuel usage. In other words, net CHP electrical fuel consumption is equal to the amount of additional fuel that is consumed by a CHP system in comparison to the amount of fuel that would have been consumed to produce the same amount of heat using a separate heating system:

1.) Heat Energy Consumption = Heat Energy Fuel Consumption/.80
2.) CHP Electrical Production = (Heat Energy Consumption/.60) * .40
3.) Total CHP Fuel Consumption = (Heat Energy Consumption/.60) / .75

[7] https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm

4.) CHP Electrical Production Fuel Consumption = Total CHP Fuel Consumption – Separate Heat Energy Fuel Consumption
5.) Equivalent Centralized Electrical Production Fuel Consumption = CHP Electrical Production /.33
6.) CHP Electrical Production Fuel Savings= (Equivalent Centralized Electrical Production Fuel Consumption – CHP Electrical Production Fuel Consumption)/Equivalent Centralized Electrical Production Fuel Consumption

Heat Utilization Factors and Total Potential CHP Output

While it is difficult to get an accurate estimate of the total amount of each sector's heat demand that could be supplied by CHP without a detailed study of the firms operating within each sector, "heat utilization factors" offer a way to get a sense of how much electricity can be produced by CHP within each sector given range of CHP heat output. The European Cogen Association has set the goal of supplying 25% of Europe's total heat-energy demand with CHP by the year 2030.[8] CHP currently represents 12% of total electricity generation in the United States, and under Barrack Obama it had the goal of increasing the amount of electricity produced by CHP by 50% by the year 2020.[9] In Finland, 30% of total electrical production comes from CHP, and in Denmark 50% comes from CHP.[10],[11]

While it is unlikely that all of the economy's heat energy can be supplied by decentralized CHP systems, 25% of heat production likely represents the low-end of CHP's potential and 50%, given Denmark's sustained commitment to CHP over the past 40 years, likely represents its high-point. All things being equal, a 50% decrease in CHP heat production (a 50% utilization factor) will result in a 50% decrease in CHP electrical production. A 75% reduction in CHP heat production (a 25% utilization factor) will cause a 75% decrease in CHP electrical production. The corresponding levels of CHP electrical production for each heat utilization factor are listed in Table 2. Line one represents the 100% heat utilization factor used to produce Table 1 where all heat comes from CHP systems producing 92% of all electricity. At a 50% "heat utilization factor", 46% of the economy's total electricity demand is supplied by CHP. At a 25% "heat utilization factor", 23% of total electricity demand is supplied by CHP.

The true potential for CHP-based electrical production in Nova Scotia likely falls somewhere between 23% and 46%. A reasonable estimate of the upper bounds of CHP's true potential can be obtained by allowing for CHP to supply 50% of the industrial sector's heat and 25% of all heat within the remaining sectors. This results in 38% of the province's electricity being supplied by CHP.[12]

23% of total electrical production likely represents the minimum amount of electrical power that can be supplied by CHP in Nova Scotia. Nova Scotia has a large industrial sector which consumes twice the amount of heat-energy as all other sectors combined. 66.5% of the industrial sector's heat-energy

---

[8] https://www.cogeneurope.eu/about/our-vision
[9] Combined Heat and Power: A Clean Energy Solution", P. 4. U.S. Department of Energy & The United States Environmental Protection Agency. August, 2012.
[10] https://energia.fi/en/energy_sector_in_finland/energy_production/combined_heat_and_power_generation
[11] "Cogen in Denmark", https://www.oecd.org/env/cc/2045811.pdf
[12] 58PJ (50% industrial) + 11.9PJ (25% residential) + 4.2PJ (25% commercial) + .24PJ (agricultural=74.3PJ; 74.3PJ/.6*(.4)=CHP Electrical output=49.5PJ; 49.6PJ/132PJ=37.8% total electrical output.

consumption comes from the refining and pulp and paper industries alone.[13] With a high demand for heat concentrated within a small number of producers, the potential for CHP to supply a large percentage of the industrial sector's total energy demand is quite high. The remaining electrical output coming from a heat utilization factor of 25% within the other sectors is quite modest. For the residential sector, this results in 14.7% of its electricity being generated by CHP. For the commercial sector, this results in 7.7% of its electricity being generated by CHP. More than 14.7% of the residential sector's electricity is likely consumed by large residential developments, and more than 7.7% of the electricity consumed by the commercial sector likely comes from large office towers and retail centers, so converting some percentage of these types of buildings alone would likely meet the 25% target.

CHP Electrical Output as a Percentage of Total Sector Electricity Demand

	Residential	**Commercial/Institutional**	**Industrial**	**Agricultural**	**Total**
% of Electricity Supplied by CHP (100% Heat Utilization)	58.6%	30.8%	197%	30.4%	92%
% of Electricity Supplied by CHP (50% Heat Utilization)	29.3%	15.4%	98.5%	15.2%	46%
% of Electricity Supplied by CHP (25% Heat Utilization)	14.7%	7.7%	49.25%	7.6%	23%
% of Electricity Supplied by CHP (50% industrial heat utilization, 25% others)	14.7%	7.7%	98.5%	7.6%	37.8%

Table 2

CHP Electrical Output and Total Emissions Reductions

The average GHG emissions produced per unit of electrical power can easily be determined by dividing the total amount of annual GHG emissions emitted in the production of electricity by the total amount of electrical power produced each year. However, and shown in Figure 1, 21% of Nova Scotia's electricity is generated using "primary sources" of power such as wind, hydro, and tidal power, which produce no emissions. The remainder is generated using "secondary sources" of power, such as natural gas, oil, and

[13] National Research Council, Industrial Energy Use; Table 2: Energy by Industry: [13] https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm

coal, that are the source of all of Nova Scotia's annual electrical GHG emissions. Of the rest of Nova Scotia's electrical power shown in Figure 1, 63% is generated by coal and coke, 9% by natural gas, and 4% by petroleum distillates. Of total non-primary production, coal and coke represents 79.7%, natural gas represents 11.4%, and petroleum distillates 5.1%. Because coal and coke produce much higher levels of GHG than other fuel sources, an "emissions factor" must be used to weight the average emissions per unit of electrical power that can be attributed to coal based on the annual amount of power it produces.

This can be calculated using the NRC's emissions statistics for electrical production in Canada.[14] The total amount of emissions and the total amount of power produced by each fuel source are given in two separate tables. By combining the tables, the relative emissions factor for each fuel source can be determined. These figures represent averaged emissions by each fuel source to produce a given amount of electricity. They do not weight the emissions in terms of the amounts of each fuel consumed and so can be used to compare emissions between various fuel sources in Nova Scotia even though they are based on national data. In this case, a large data set helps generate better estimates since emissions levels and energy consumption by fuel type are not based on a small number of samples.

	Natural Gas	**Coal**	**Light Fuel Oils**	**Heavy Fuel Oil**	**Total**
Energy use (PJ)	328.5	1082.8	7.8	114.8	1533.9
C02 Emissions (MT)	16.7	101.7	0.6	8.6	127.6
Emissions Intensity (MT/PJ)	0.0508	0.0939	0.0769	0.0749	0.0831

Table 3

However, because Atlantic Canada does not have access to large amounts of inexpensive natural gas like many other jurisdictions in Canada, its fuel mix contains a higher percentage of heating oils with natural gas making up only a small percentage of total energy use. A representative Atlantic "fuel mix" must be used to more accurately estimate CHP GHG emissions reductions. I compiled the representative fuel mix for Atlantic Canada using the same data supplied the NRC of Canada from which Table 1 was generated.[15] By adding up energy use across each sector for natural gas, light fuel oils, and heavy fuel oils and then dividing by the total emissions produced by each fuel across each sector in table 4, the representative "fuel mix" emission factor can be determined based on the proportions each fuel is used.

Energy Consumption by Fuel (PJ)	**Residential**	**Commercial**	**Industrial**	**Agricultural**	**Total**
Natural Gas	.9	10.2	20.3	0	31.4
Light Fuel Oil	30.6	7	17.4	1.1	56.1
Heavy Fuel Oil	0	0	12.9	0	12.9
GHG Emissions (MT)	2.2MT	1M	3.2MT	.1MT	6.5
Emission Factor	.0698	.0581	.0632	.0900	.0647

Table 4

[14] https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/handbook/handbook_egen_00.cfm

[15] https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm

Outside of the industrial sector, the fuels used to provide heat in Atlantic Canada are cleaner than coal. Most energy is supplied by fuel oils and a smaller percent by natural gas. Approximately 40% of the industrial sector's energy comes from sources equivalent to coal or worse. 60%, however, does not. Since less than 50% of industrial sector heat demand is expected to come from CHP, all growth in the use of CHP can be accommodated by firms burning cleaner fuels. Since CHP offers a chance for industrial firms to "add value" to their fuel consumption by also producing a marketable commodity like electricity, the use of CHP may provide an additional incentive for firms to switch to cleaner fuels.

Under scenario 1, when 23% of the economy's electricity is produced by CHP, a 24% reduction in total electrical emissions is produced when this switch to CHP includes replacing coal with the Atlantic Canadian "fuel mix". Under scenario 2, where 46% of the economy's heat is supplied by CHP systems, a 48% reduction in emissions resulting from the production of electricity is achieved. Under Scenario 3, where 37.8% of Nova Scotia's electricity is produced by CHP, total electrical sector emissions are reduced by 36% when including a switch from coal to the Atlantic Canadian fuel mix.

To arrive at this figure, the amount of GHG emissions resulting from the use of coal and coke to produce electricity must be determined. The CER website lists the annual output of GHG emissions resulting from electrical production in Nova Scotia to be 6.5MT.[16] All 6.5MT of GHGs emitted by electrical production in Nova Scotia come from the secondary power sources mentioned above. In terms of average emissions per unit of electrical output, 79.7% of emissions are from coal. However, as a fuel source, coal produces higher emissions levels than the other fuels also used to generate electricity in Nova Scotia. Therefore, an emissions factor must be applied to the average emissions arising from coal-based power production in terms of total power output to account for its greater emissions intensity. This is performed by dividing the emissions factor for coal over the average emission factor for electrical production and is equal to 1.13. When multiplied by the 79.7% of emissions arising from coal in terms of average power production, it produces a figure of 90.1% for the equivalent share of total emissions arising from coal within non-primary electrical production. 90.1% of non-primary emissions is to 5.85MT of the total 6.5MT of emissions produced in Nova Scotia annually for electrical production.

25% of total electrical production is equal to 31.6% of the secondary electrical power that represents 79% of total electrical production. This is equal to 39.6% of output of the 79.7% of secondary electrical production which comes from coal. 39.6% of the 5.85MT of emissions that are produced by the use of coal in centralized power plants is equal to 2.32MT of annual emissions that are eliminated. These are replaced by the emissions from decentralized CHP systems which are 51% lower due to increased efficiency and are further reduced by 32% for a switch to the cleaner Atlantic Canadian fuel mix.

This results in a net reduction of total GHG emissions equal to:

6.5MT * 79.7% * (1.13) = 5.85MT,

5.85MT * 39.6% = 2.32MT,

[16] https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-nova-scotia.html

2.32MT * 0.49 * (.0647/.0939)=.783MT,

6.5MT – 2.32MT + .783MT= 4.96MT,

(6.5MT-4.96MT)/6.5MT=24%.

This figure doubles to 48% when 46% of electricity is produced using decentralized CHP systems. When 37.8% of Nova Scotia's electricity is produced by CHP based on an industrial sector heat utilization factor of 50% and heat utilization factor of 25% for all remaining sectors, total emissions are reduced by 36%. In this case, 37.8% of Nova Scotia's electricity is equivalent to 60% of its coal-based electricity. Following the same calculations, 3.51MT of coal emissions due to centralized electrical production are eliminated and replaced with 1.19MT of emissions from decentralized CHP plants burning cleaner fuels, 36% less. If natural gas is used as the replacement fuel instead of the Atlantic Canadian fuel mix, the relative emissions factor for natural gas instead of coal (.0508/.0939) would be used instead of the relative emissions factor of the fuel mix compared to coal used in the calculations above (.0647/.0939)--46% lower versus 31%. Total electrical emissions are reduce by 39% instead of 36%

The industrial sector is especially suited to the adoption of CHP en mess: heat is a primary component in many industrial processes, the industrial sector consumes as much heat as the remaining sectors combined; the industrial sector contains a disproportionate amount of large producers with access to deep capital reserves and sources of borrowing compared to other sectors; many industrial firms have direct experience owning and operating complex power systems. Data by the NRC on end fuel-use by industry reveals that 66.5% of industrial heat energy usage in Atlantic Canada comes from the pulp and paper and petroleum refining industries alone.[17] Based on electricity usage rates within the entire sector, 78.6% of industrial energy use is in the form of heat rather than electricity. Therefore, 78.6% of the 66.5% of total industrial energy use which is attributed to the pulp and paper and refining industries is in the form of heat, or 52.2%, and is greater than the 50% total industrial heat utilization factor used in the scenario where 37.8% of electricity is produced by CHP. These industries are operated out of only a small number of facilities. Therefore, it would only take a small number of CHP systems across enterprises such as these that consume large amounts of heat and electricity to meet the 50% target.

Conclusion

Based on my analysis, approximately 37.8% of Nova Scotia's electricity can be generated by decentralized combined heat and power systems in place of centralized coal-fired power plants. The expected gain in fuel efficiency for CHP electrical production versus centralized production is 51% and will result in an equivalent decrease in greenhouse gas emissions reductions. In addition, a switch from centralized coal plants to the Atlantic 'fuel mix' used in decentralized CHP plants will result in a further 31% decrease in GHG emissions per unit of electrical power. Combined, this represents a net decrease of 66% in greenhouse gas emissions due to electrical production for decentralized CHP systems versus centralized coal plants and a total emissions reductions for electrical production in Nova Scotia of 36%.

[17]Industrial Energy Use; Table 2, Energy Use by Industry:
https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm

This analysis is based upon an assumed 50% “heat utilization factor” for the industrial sector and a 25% heat utilization factor for all other sectors. Because of the industrial sector’s high demand for heat, there is a significant cost-incentive to reduce heat-energy fuel consumption by using waste heat from the production of electricity. All industrial firms consume electricity. What they cannot consume themselves, they can sell. Over 60% of the industrial sector’s heat energy demand comes from the refining and pulp and paper industries alone. These industries, in turn, are comprised of a small number of facilities which allows the 50% industrial heat utilization target to be achieved with only a small number of CHP projects. Outside of these industries, if more industrial firms were to adopt CHP systems, the sector’s heat utilization factor could actually be higher. For the residential and commercial sectors, a 25% heat utilization factor represents an achievable goal since this amount of heat is consumed by a small number of large developments for which the adoption of CHP would be comparatively easy.

This scenario represents the “mid-point” figure of my analysis. Under a 25% heat utilization factor scenario, 23% of the economy’s electricity is produced by CHP and a 24% reduction in total electrical emissions is produced when this switch to CHP includes replacing coal with the Atlantic “fuel mix”. Under a 50% heat utilization scenario, where 46% of the economy’s heat is supplied by CHP systems, a 48% reduction in total electrical emissions is produce. These two scenarios represent the “low-point” and “high-point” for CHP in Nova Scotia. In Denmark, where there has been a concerted effort to expand the use of CHP since the early 1980s following the energy crisis of the late 70s, CHP currently makes up 50% of all electrical production. Waste heat is used by decentralized consumers within various sectors of the economy and is also used to feed district heating systems serving entire towns.

In the early days of electricity, before the advent of large-scale centralized power plants, a large amount of electricity was generated by CHP systems. Large apartment buildings and office towers often generated their own electricity and used the waste heat. Early power stations, like Thomas Edison’s Pearl Street power station, produced electricity and sold their waste heat to nearby buildings. Manhattan’s district heating system has been in operation for over 1882 years, and 50% of its annual steam generation comes from CHP systems (greater than my 25% residential heat utilization factor).

Waste heat can also be used to provide cooling and refrigeration through the use of absorption chillers. Combined heat, cooling, and power plants (CCHP) achieve levels of 90% efficiency. Waste heat can be used to provide refrigeration year round in large commercial operations. Waste heat that is not used for space heating in the winter, can be used to provide air conditioning in the summer. In fact, cooling is another service provided by New York’s district steam-heating system.

The decentralized nature of CHP systems has further advantages for the reduction of GHG emissions. A greater number of decentralized power plants are able to function in combination to produce more or less electrical power in finer amounts as compared to a single centralized power plant. This has advantages for the integration of “intermittent” alternative energy sources like wind and solar. As more or less alternative energy is available, CHP plants can be produce more or less electricity as needed.

Combined heat and power represents an opportunity to rapidly reduce fuel consumption, fuel costs, and greenhouse gas emissions using established technology and readily available fuel stocks.

Appendix A

Industrial Sector – Aggregated Industries
Atlantic[1]
Table 1: Secondary Energy Use and GHG Emissions by Energy Source

	2000		2017	2018
Total Energy Use (PJ)	**226.8**		**185.0**	**185.8**
Energy Use by Energy Source (PJ)				
Electricity	58.5		40.5	39.6
Natural Gas	7.3		17.7	20.3
Diesel Fuel Oil, Light Fuel Oil and Kerosene	15.1		17.0	17.4
Heavy Fuel Oil	47.5		14.6	12.9
Still Gas and Petroleum Coke	38.1		X	36.7
LPG and Gas Plant NGL	4.2		2.0	2.5
Coal	3.5		X	3.2
Coke and Coke Oven Gas	3.9		X	0.0
Wood Waste and Pulping Liquor	42.5		42.6	49.9
Other[2]	6.2		X	3.3
Shares (%)				
Electricity	25.8		21.9	21.3
Natural Gas	3.2		9.6	10.9
Diesel Fuel Oil, Light Fuel Oil and Kerosene	6.7		9.2	9.4
Heavy Fuel Oil	20.9		7.9	7.0
Still Gas and Petroleum Coke	16.8		X	19.8
LPG and Gas Plant NGL	1.9		1.1	1.4
Coal	1.6		X	1.7
Coke and Coke Oven Gas	1.7		X	0.0
Wood Waste and Pulping Liquor	18.8		23.0	26.9
Other[2]	2.8		X	1.8
Total GHG Emissions Excluding Electricity (Mt of CO_2e)	**8.1**		**6.5**	**5.9**
GHG Emissions by Energy Source (Mt of CO_2e)				
Electricity	–		–	–
Natural Gas	0.4		0.9	1.0
Diesel Fuel Oil, Light Fuel Oil and Kerosene	1.1		1.2	1.2
Heavy Fuel Oil	3.6		1.1	1.0
Still Gas and Petroleum Coke	2.1		X	2.4
LPG and Gas Plant NGL	0.3		0.1	0.2
Coal	0.3		X	0.2
Coke and Coke Oven Gas	0.4		X	0.0
Wood Waste and Pulping Liquor	0.0		0.0	0.0
Other[2]	0.0		X	0.0

Commercial/Institutional Sector
Atlantic[1]
Table 1: Secondary Energy Use and GHG Emissions by Energy Source

	2000		2017	2018
Total Energy Use (PJ)	**57.2**		**57.4**	**56.8**
Energy Use by Energy Source (PJ)				
Electricity	29.9		34.9	36.0
Natural Gas	0.0		9.6	10.2
Light Fuel Oil and Kerosene	15.6		9.7	7.0
Heavy Fuel Oil	7.2		0.0	0.0
Steam	0.0		0.0	0.0
Other[2]	4.5		3.1	3.6
Shares (%)				
Electricity	52.3		60.8	63.4
Natural Gas	0.0		16.8	17.9
Light Fuel Oil and Kerosene	27.3		16.9	12.3
Heavy Fuel Oil	12.6		0.0	0.0
Steam	0.0		0.0	0.0
Other[2]	7.8		5.5	6.4
Activity				
Total Floor Space (million m^2)	41.9		49.3	49.3
Energy Intensity[3] (GJ/m^2)	**1.35**		**1.15**	**1.14**
Total GHG Emissions Excluding Electricity (Mt of CO_2e)	**1.9**		**1.3**	**1.2**
GHG Emissions by Energy Source (Mt of CO_2e)				
Electricity	–		–	–
Natural Gas	0.0		0.5	0.5
Light Fuel Oil and Kerosene	1.1		0.7	0.5
Heavy Fuel Oil	0.5		0.0	0.0
Steam	0.0		0.0	0.0
Other[2]	0.3		0.2	0.2

Residential Sector
Atlantic[1]
Table 1: Secondary Energy Use and GHG Emissions by Energy Source

	2000		2017	2018
Total Energy Use (PJ)	**116.0**		**111.2**	**113.9**
Energy Use by Energy Source (PJ)				
Electricity	43.4		52.8	54.3
Natural Gas	0.0		0.9	0.9
Heating Oil	40.1		29.6	30.6
Other[2]	1.7		1.2	1.4
Wood	30.7		26.7	26.6
Shares (%)				
Electricity	37.4		47.5	47.7
Natural Gas	0.0		0.8	0.8
Heating Oil	34.6		26.6	26.9
Other[2]	1.5		1.1	1.2
Wood	26.5		24.0	23.4
Activity				
Total Floor Space (million m^2)	113.5		151.1	153.0
Total Households (thousands)	885.8		1,010.0	1,015.0
Energy Intensity (GJ/m^2)	**1.02**		**0.74**	**0.74**
Energy Intensity (GJ/household)	**131.0**		**110.1**	**112.2**
Total GHG Emissions Excluding Electricity (Mt of CO2e)	**3.7**		**2.8**	**2.9**
GHG Emissions by Energy Source (Mt of CO2e)				
Electricity	–		–	–
Natural Gas	0.0		0.0	0.0
Heating Oil	2.8		2.1	2.2
Other[2]	0.1		0.1	0.1
Wood	0.7		0.6	0.6