Environmental Impacts of the UNC Co-Generation Facility (11-5-05)

I have been considering the issue of the effects of the co-generation facility at UNC-CH, on several key environmental indicators. My conclusions are summarized here. Please feel free to use them in any way needed, and to contact me for details or to conduct follow-on assessments.

As a summary (repeated after the analysis below), I conclude that the health risks from mercury emissions from the co-gen are well below (by at least a factor of 10) those considered targets by regulators, and that carbon dioxide emissions from the co-gen are significantly lower (by about 30%) than the emissions that would be produced by purchasing the same energy from Duke Power.

The methodologies used here are the ones I and my students use at the Carolina Environmental Program (CEP) field sites in Salzburg, Austria (see www.unc.edu/~dcrawfor/salzburg.htm) and Cambridge, England (see www.unc.edu/~dcrawfor/cambridge.htm). At the Salzburg site, the client for our student Capstone project (a team-based, interdisciplinary project required of our seniors in the environmental programs here at Carolina) is the City of Salzburg. The City has been moving in the past decade towards greater use of renewables, including biomass, and towards use of natural gas to avoid dependence on oil. They have had our students conduct assessments of the relative health risks from different fuels in the City's co-gen facilities (Austria chose co-gen as their preferred designs for energy facilities in their major cities, as the efficiencies can be significantly improved over traditional facilities). At the Cambridge site, our client has been the Cambridge City Council, which wants to move towards a reduction in carbon dioxide emissions over the next several decades. Our analysis for them also has moved them towards considering a co-gen facility.

I approached the issue of the UNC-Chapel Hill co-gen facility from the following angle:

1. My assumption is that the co-gen facility already exists (as it does) and that the energy it produces (heat and electricity) would otherwise be provided by Duke Power.
2. I then assumed that there were two kinds of emissions of concern: (i) emissions that are of global interest, where the location of the emission is not important and (ii) emissions that are of local interest, where the location of the emissions with respect to populations does matter.
3. For the first category (global issues), I am interested in whether the total emission of the global pollutant is higher or lower if the same amount of energy is

produced by the co-gen facility for use on campus, or by the mix of Duke Power sources and transmitted to campus.

4. For the first category, I use emissions of greenhouse gases as the point of reference. In this assessment, the greenhouse gas considered is carbon dioxide, as it represents approximately 65% of the total radiative forcing of greenhouse gases from energy producing facilities.
5. For the first category, the question is: *Does generation of energy from the co-gen facility result in higher or lower emissions of greenhouse gases (carbon dioxide) than would be the case obtaining that same quantity of energy (for heat and electricity) from Duke Power*?
6. For the second category (local issues), the health impact does not depend solely on the emission rate from the two energy sources (co-gen and Duke Power). It depends also on the location of those sources with respect to the relevant human population.
7. I assume here that this "relevant human population" is the citizenry of Chapel Hill.
8. In this case, it is not relevant to compare health risks produced by the co-gen against those produced by Duke Power, as the two populations exposed are different.
9. Instead, I calculated the health risk from the co-gen facility alone and asked: *Is the health risk from emissions of pollutants from the co-gen facility acceptable or unacceptable as defined by the relevant regulatory authority (here, the USEPA)*? Both cancer and non-cancer health effects were considered.

Category 1: Global Emissions of Carbon Dioxide

For the Cambridge field site, the task of our student-faculty team was to help the City of Cambridge assess alternative strategies to control carbon dioxide emissions (towns in England are required to develop plans for a 60% reduction in such emissions by 2050). The results of the past two years of study can be found at www.unc.edu/~dcrawfor/newhome.htm.

A significant conclusion from the studies in Cambridge (and a conclusion supported by the Cambridge Town Council) is the need for the town to move towards development of a co-gen facility. The reason for that movement is that such facilities, if well designed, significantly reduce the emissions of carbon dioxide per unit energy produced. This reduction comes about because heat produced during electricity generation, and normally lost as waste heat (passing out with stack gases or with cooling water returned to rivers), is recaptured and either used for further electricity generation or as steam for heating local buildings. The City of Salzburg has converted all of its electricity facilities to co-gen, supplying approximately half of the heating needs of buildings with this re-captured waste heat. Since heating accounts for approximately 80% of the energy use in a building in both England and Austria (slightly less in the U.S. due to our reliance on air conditioning in the summer), there is a significant reduction of fuel use when that heating occurs through a co-gen facility's recapture and transmission of waste heat. For the UNC-

Chapel Hill co-gen facility, approximately 86% of the energy produced is steam for heating.

The UNC-Chapel Hill co-gen facility is quite similar to the ones in Salzburg, which have approximately a 67% efficiency of energy use. Due to design improvements at the UNC-Chapel Hill facility, however, the efficiency is closer to 81%. This contrasts with the overall efficiency of approximately 33% of Duke Power for electricity generation. The emissions of carbon dioxide from a facility can be estimated as follows:

Emissions = Energy Need x Release Factor / Efficiency

where Energy Need is the total amount of energy (for lighting, heating, etc) consumed by people or institutions connected to the system (units of BTU per year); Release Factor is the amount of carbon dioxide released per unit of fuel consumed (units of tons of carbon dioxide per BTU)- this depends on the type of fuel; and Efficiency is the efficiency with which the energy is produced. The units of Emissions then are tons of carbon dioxide per year.

We can then ask whether (purely from the perspective of greenhouse gases, represented here by carbon dioxide) it is preferable to produce electricity and heat for the campus using the co-gen facility, or to purchase electricity from the regional energy provider (Duke Power) and convert most of it back to heating on campus. The Efficiency of the co-gen facility is significantly higher than that for electricity provided by Duke Power and converted to heat here on campus. This is in part offset by the higher Release Factor for the co-gen facility, since Duke Power has a significant component of nuclear power, which does not produce greenhouse gases.

I assume here (using figures provided by Energy Services, which reports coal, fuel oil and natural gas combustion for boilers 6, 7 and 8) that the co-gen facility released 345,335 tons of carbon dioxide in 2004, based on the assumption that all carbon in the fuel was oxidized to carbon dioxide. Given the ratio of efficiencies noted above (81% for UNC-Chapel Hill and 33% for Duke Power), the use of electricity from Duke to provide all of the energy currently supplied by the co-gen would result in 345,335 x 81 / 33 = 847,640 tons of carbon dioxide if all of that energy were supplied by the burning of coal. However, Duke Power has a mix of sources, with approximately 50% being nuclear (which does not release carbon dioxide). As a result, the energy supplied by Duke Power would, under this mix, result in half of the carbon dioxide emissions mentioned above, or 847,640 / 2 = 423,820 tons of carbon dioxide per year. This calculation assumes the electricity from Duke Power can be converted to heat for buildings with 100% efficiency. If more realistic conversion efficiencies (from electricity to heat) are assumed, even using the current state-of-the-art equipment, the energy supplied by Duke Power would produce approximately 472,989 tons of carbon dioxide per year.

The net result is that use of the co-gen facility to produce electricity and heat for the campus at current rates is a reduction in total carbon dioxide emissions of between 78,485 tons of carbon dioxide per year (423,820 – 345,335 = 78,485) and 127,654 tons *of carbon dioxide per year (472,989 – 345,335 = 127,654) relative to what would have been produced had this energy been generated regionally and transmitted to the campus (and converted primarily back to heating). In short, all other things being equal (cost, economic development, technological availability, etc), it is preferable to generate campus electricity and steam at the co-gen facility than to import that energy in from a regional provider, at least with respect to this global issue of climate change.*

It is important to note that this conclusion does not depend on the scale of operations of the co-gen facility. It applies to each unit of energy produced, and so will continue to hold regardless of whether energy use on campus increases or decreases.

Category 2: Human Health Risk

For the Salzburg field site, the task of our student-faculty team was to help the City of Salzburg assess alternative fuels and emissions control systems for their co-generation facility (towns in Austria are required to move to co-generation over the next decade). That task required developing a mathematical model of the emissions, dispersion, exposure and health risks to pollutants from the facility, examining the impact on the citizens of Salzburg. The results can be seen in a series of reports on our web site at www.unc.edu/~dcrawfor/salzburg.htm. The core tool of that research is an EXCEL model (which can be downloaded from the same site). In the research for the UNC-Chapel Hill co-gen plant, I modified that model to reflect the emissions characteristics, air pattern, etc, characteristic of Chapel Hill. The resulting EXCEL model is called uncch.xls and is appended to this report.

For emissions from facilities such as the co-gen facility in Chapel Hill, mercury is the "regulatory driver". This means that emissions of mercury dominate compliance with regulatory limits associated with human health impacts. Approximately 80 to 90% of the total human health risk is produced by the mercury emissions (see the EPA Mercury Study Report to Congress at www.epa.gov/mercury/report.htm). As a result, this report focuses on mercury emissions and their potential health impact. The assumption here is that, if the mercury emissions produce acceptable levels of health risk (as defined by the regulatory authorities- here, the USEPA), then the other pollutants will be similarly below health risk concern (again, because the total risk is dominated by the risk from mercury). In all of the following calculations, I have used the precautionary principle: *when an assumption is in doubt, I have used the value likely to lead to an overestimate of risk just to be sure I haven't inadvertently produced an underestimate of risk*.

To estimate the risk, mercury emissions from the co-gen facility under current operating conditions were obtained from the campus Energy Office. They are based on measurements of mercury in the stack as the stack gas exits, and so already reflect any influence of emissions control systems. The time-weighted average emission rate is approximately 4.37 pounds per year or 62.9 micrograms per second (the unit required by the EXCEL model). Wind Rose data (data on the fraction of time the wind blows in a particular direction, and the average velocity) was taken from the weather station at RDU airport. The effective stack height was equal to the actual stack height of the co-gen facility plus a plume rise of 18 meters. This represents a conservative estimate of risk; the actual value of the effective stack height is likely to be higher and result in lower health risks than those predicted here. All parameter values needed by the model for the movement of mercury through the environment and to human populations are those provided by the USEPA for their national calculations of mercury risks from industrial facilities, summarized in their Mercury Report to Congress. Results are contained under the Results tab of the EXCEL file uncch4.37.xls.

I have considered a precautionary case for exposure of the population. People are assumed to have a backyard garden, and to grow all of their vegetables in that garden (and to consume those vegetables). They are assumed to consume soil when they work in, and eat crops from, that garden. They are assumed to fish in University Lake (the nearest fishable water body) and to consume all those fish (an important consideration, as fish consumption is the dominant exposure pathway for mercury). Other pathways are water ingestion (assuming all water arrives from University Lake untreated) and air inhalation. Beef is not considered because there are no cattle produced and consumed within the airshed. If present, this pathway would be expected to increase the overall risk by about 10%.

Two measures of health risk were considered. For cancer effects, the lifetime excess probability of cancer was calculated. This is the additional probability of cancer, spread over a lifetime, resulting from the mercury emissions from the co-gen facility alone. This value should not rise above 1×10^{-4} (one chance in ten thousand). In this calculation, I used the maximum plausible risk coefficient from the studies cited by the USEPA in their IRIS database (see the database at www.epa.gov, then Search for IRIS). The USEPA has not determined a cancer risk coefficient to date because the data are judged insufficient to determine whether mercury actually poses a cancer health risk at environmental levels. I am assuming here that it does pose a cancer risk, again using the precautionary principle.

For non-cancer effects, I have used a Hazard Quotient (HQ). This is the ratio of the actual rate at which mercury is entering the body of an individual (taking into account inhalation and ingestion via all pathways I mentioned above), divided by the rate the USEPA has established as safe. The latter rate is called the Reference Dose or RfD. From the IRIS database, the RfD for methylmercury (the toxic form) is 0.1 micrograms per day per kilogram of body weight. It is assumed here that all of the mercury from the co-gen is in this toxic chemical form (again, a precautionary assumption). Also, the EPA established this value of 0.1 by applying a safety factor of 10 to the existing epidemiological and animal data. Again, this is done to satisfy the precautionary principle. The result is that the non-cancer health risks reported here will tend to be overestimates as they reflect this safety factor. Values of HQ below 1 indicate no concern for non-cancer effects.

All of the results of these calculations can be seen in uncch4.37.xls. They are summarized on the Results worksheet of that file. The two relevant results are:

1. The maximum lifetime excess probability of cancer from mercury in the populations of Chapel Hill and Carrboro, considering all pathways of exposure for this “extreme case”

individual (an individual that has a backyard garden and fishes in University Lake for all of his or her fish consumption) is 3.0 x 10^{-6} (3 chances in a million over a lifetime), a factor of 33 below the value of 1 x 10^{-4} mentioned above. Bear in mind that this is for a hypothetical individual who has a backyard garden; consumes all of his or her vegetables from that garden; and obtains all fish from University Lake (the only waterbody significantly impacted by mercury emissions from the co-gen facility). It also assumes that the USEPA will establish mercury as a carcinogen at some point in the future.

2. The maximum HQ value for mercury in the populations of Chapel Hill and Carrboro, considering all pathways of exposure for this "extreme case" individual (an individual that has a backyard garden and fishes in University Lake for all of his or her fish consumption) is 0.015, a factor of 67 below the regulatory limit of 1.0.

I also considered a more extreme case in which the co-gen facilitated emitted mercury at its permitted rate (it currently is significantly below this rate due to the pollution control devices installed). In that case, the emission rate for mercury would be 8 pounds per year. The results of this calculation are in a second EXCEL file, uncch8.htm. The two relevant results are:

1. The maximum lifetime excess probability of cancer from mercury in the populations of Chapel Hill and Carrboro, considering all pathways of exposure for this "extreme case" individual (an individual that has a backyard garden and fishes in University Lake for all of his or her fish consumption) is 5.6 x 10^{-6} (5.6 chances in a million over a lifetime), a factor of 18 below the value of 1 x 10^{-4} mentioned above. Bear in mind that this is for a hypothetical individual who has a backyard garden; consumes all of his or her vegetables from that garden; and obtains all fish from University Lake (the only waterbody significantly impacted by mercury emissions from the co-gen facility). It also assumes that the USEPA will establish mercury as a carcinogen at some point in the future.

2. The maximum HQ value for mercury in the populations of Chapel Hill and Carrboro, considering all pathways of exposure for this "extreme case" individual (an individual that has a backyard garden and fishes in University Lake for all of his or her fish consumption) is 0.028, a factor of 36 below the regulatory limit of 1.0.

From these results, I can see no reason for concern over human health risks from air toxics from the co-gen facility under current operating conditions, as they currently provide an ample margin of safety.

Best regards,

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