Proposed Combined Heat & Power (CHP) Plant - Emissions Calculations

September 23, 2016

Duke University
Facilities Management Department

Proposed Combined Heat & Power – Emissions Calculations

Duke University is a large and diverse campus with energy intensive research and medical facilities that require the highest level of dependability from its utility systems. The University has also committed to become a carbon neutral campus by 2024 and has developed a Climate Action Plan (CAP) to meet this ambitious goal. Much progress has been made since Duke made the commitment in 2007 to become climate neutral.

Duke is considering a proposal to partner with Duke Energy on a Combined Heat and Power (CHP) plant on campus to further reduce carbon emissions on campus and in North Carolina as well as increase the reliability of the University system. The following are estimates of the impact the CHP would have on emissions.

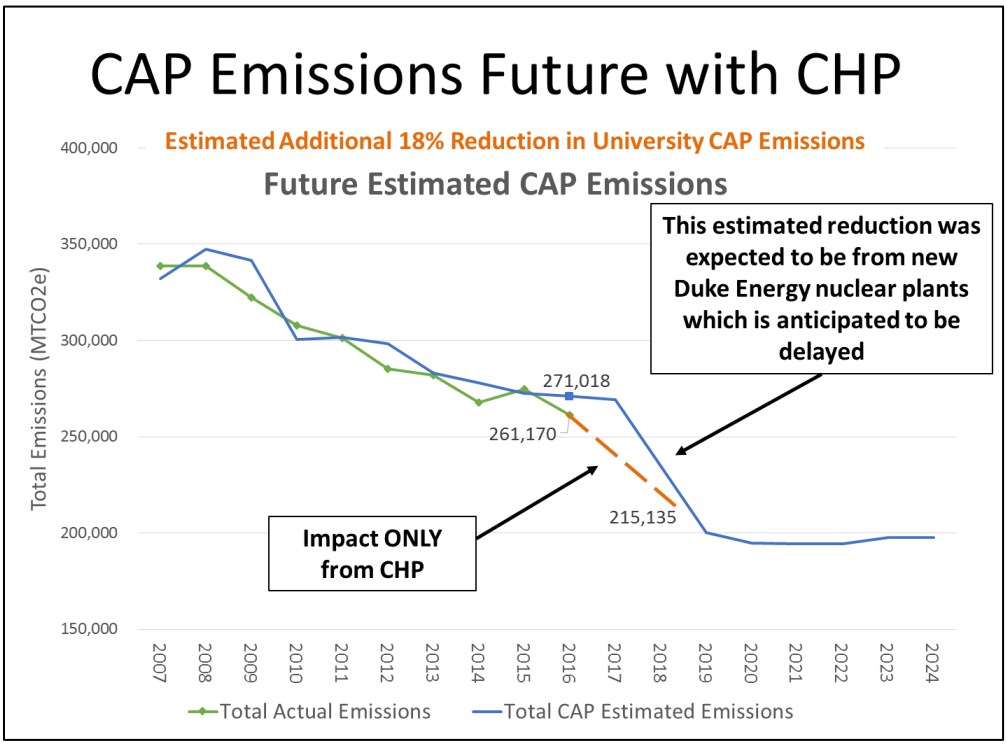
Emissions Impact from CHP

There are two main impacts regarding the emissions from the CHP:

1) Impact to Duke University's CAP emissions and
2) Impact to emissions in North Carolina.

University CAP Emissions Impact

Since the steam and hot water is generated from waste heat, it is considered carbon-free. The amount of the heat from the CHP is enough to reduce the annual production from the University's steam plant by 50%, thus reducing the amount of natural gas burned at the plants. This will result in an **18% reduction** in CAP emission for the campus.



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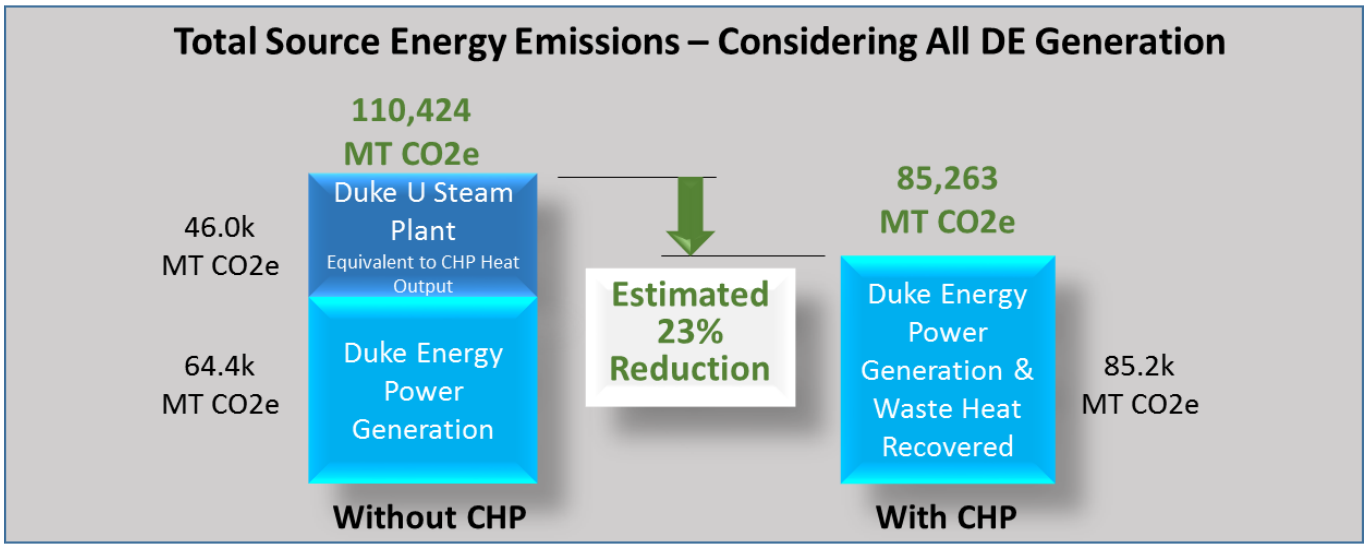
Impact to Emissions in North Carolina

In order to evaluate the impact to emissions to North Carolina, the total source energy emissions must be taken into consideration. Total source energy emissions is defined as the emissions from both Duke Energy's production of 20MW of power plus Duke University's production of steam equivalent to the CHP heat output and compared to the CHP's emissions. The generation is an offset since this electricity generation is not for any new demand, so there will be a corresponding reduction at one or more of Duke Energy's current generation stations. The most likely scenario is that a gas-fired or coal-fired power plant would need to produce 20MW less as a result of the CHP. Both Duke Energy and Duke University Facilities Management Department (FMD) staff have evaluated the impact. In addition, FMD requested the calculations be reviewed by Nicholas School faculty and engaged an engineering consultant, Affiliated Engineers Inc. (AEI), to perform independent emissions calculations under several scenarios to determine the impact. AEI was also the consultant that assisted with developing the original CAP.

Emissions Estimates were performed or reviewed by:

- Duke FMD: Estimated a 26% reduction
- Duke Faculty: Timothy L. Johnson, Associate Professor of the Practice in Energy & the Environment, EE Program Chair: Reviewed and concurs with FMD's estimate
- Duke Energy Carolinas: Estimated a 30% reduction
- Affiliated Engineers Inc., engineering consultant firm estimated 3 scenarios:
  1. Compared to Duke Energy's entire generation mix – a 23% reduction
  2. Compared to Duke Energy's natural gas generation mix – a 39% reduction
  3. Compared to Duke Energy's fossil fuel generation mix – a 49% reduction

Graphical Representation of AEI's Scenario #1



Proposed Combined Heat & Power – Emissions Calculations

AEI Scenario #1 – All Duke Energy Generation

Based on First Year Full Operation										Assumptions
Electrical Output (net)	20,213	kw	X	8350	hrs/yr	=	168,777,506	kwh/yr		Predicted runtime at full load
Thermal Output	87.1	mmbtu	X	8350	hrs/yr	=	727,123	mmbtu/yr		Delivered steam and hot water
Generator Efficiency							35.9%			Turbine Higher Heating Value efficiency
NG Input	191.94	mmbtu	X	8350	hrs/yr	=	1,602,723	mmbtu/yr		Predicted turbine fuel consumption
Business as Usual (BAU) Emissions										
Electrical Generation	168,777,506	kwh/yr	X	0.77	lb/kwh	=	59,072	MTCO2e		Duke Energy all generation sources
Elec. Transmission Losses	15,189,976	kwh/yr	X	0.77	lb/kwh	=	5,316	MTCO2e		Reported 9% grid losses to deliver power
DU Steam Generation	727,123	mmbtu/yr	X	117	lb/mmbtu	=	46,035	MTCO2e		Equivalent DU steam plant production
BAU TOTAL							**110,424**	**MTCO2e**		
CHP Emissions										
Turbine	**1,602,723**	**mmbtu/yr**	X	**117**	**lb/mmbtu**	=	**85,236**	**MTCO2e**		Total useful energy output
NET SAVINGS							**25,188**	**MTCO2e**		Difference between BAU & CHP
% Savings vs BAU							**23%**	**reduction**		

AEI Scenario #2 – Only Duke Energy's natural gas generation mix

Based on First Year Full Operation										Assumptions
Electrical Output (net)	20,213	kw	X	8350	hrs/yr	=	168,777,506	kwh/yr		Predicted runtime at full load
Thermal Output	87.1	mmbtu	X	8350	hrs/yr	=	727,123	mmbtu/yr		Delivered steam and hot water
Generator Efficiency							35.9%			Turbine Higher Heating Value efficiency
NG Input	191.94	mmbtu	X	8350	hrs/yr	=	1,602,723	mmbtu/yr		Predicted turbine fuel consumption
Business as Usual (BAU) Emissions										
Electrical Generation	168,777,506	kwh/yr	X	1.14	lb/kwh	=	87,457	MTCO2e		Offset only 35% efficient NG plants (1.14 lbs/kwh)
Elec. Transmission Losses	15,189,976	kwh/yr	X	0.77	lb/kwh	=	5,316	MTCO2e		Reported 9% grid losses to deliver power
DU Steam Generation	727,123	mmbtu/yr	X	117	lb/mmbtu	=	46,035	MTCO2e		Equivalent DU steam plant production
BAU TOTAL							**138,809**	**MTCO2e**		
CHP Emissions										
Turbine	**1,602,723**	**mmbtu/yr**	X	**117**	**lb/mmbtu**	=	**85,236**	**MTCO2e**		Total useful energy output
NET SAVINGS							**53,574**	**MTCO2e**		Difference between BAU & CHP
% Savings vs BAU							**39%**	**reduction**		

AEI Scenario #3 – Only Duke Energy's natural gas generation mix

Based on First Year Full Operation										Assumptions
Electrical Output (net)	20,213	kw	X	8350	hrs/yr	=	168,777,506	kwh/yr		Predicted runtime at full load
Thermal Output	87.1	mmbtu	X	8350	hrs/yr	=	727,123	mmbtu/yr		Delivered steam and hot water
Generator Efficiency							35.9%			Turbine Higher Heating Value efficiency
NG Input	191.94	mmbtu	X	8350	hrs/yr	=	1,602,723	mmbtu/yr		Predicted turbine fuel consumption
Business as Usual (BAU) Emissions										
Electrical Generation	168,777,506	kwh/yr	X	1.52	lb/kwh	=	116,226	MTCO2e		Duke Energy fossil fuel plants (coal and NG)
Elec. Transmission Losses	15,189,976	kwh/yr	X	0.77	lb/kwh	=	5,316	MTCO2e		Reported 9% grid losses to deliver power
DU Steam Generation	727,123	mmbtu/yr	X	117	lb/mmbtu	=	46,035	MTCO2e		Equivalent DU steam plant production
BAU TOTAL							**167,578**	**MTCO2e**		
CHP Emissions										
Turbine	**1,602,723**	**mmbtu/yr**	X	**117**	**lb/mmbtu**	=	**85,236**	**MTCO2e**		Total useful energy output
NET SAVINGS							**82,342**	**MTCO2e**		Difference between BAU & CHP
% Savings vs BAU							**49%**	**reduction**		

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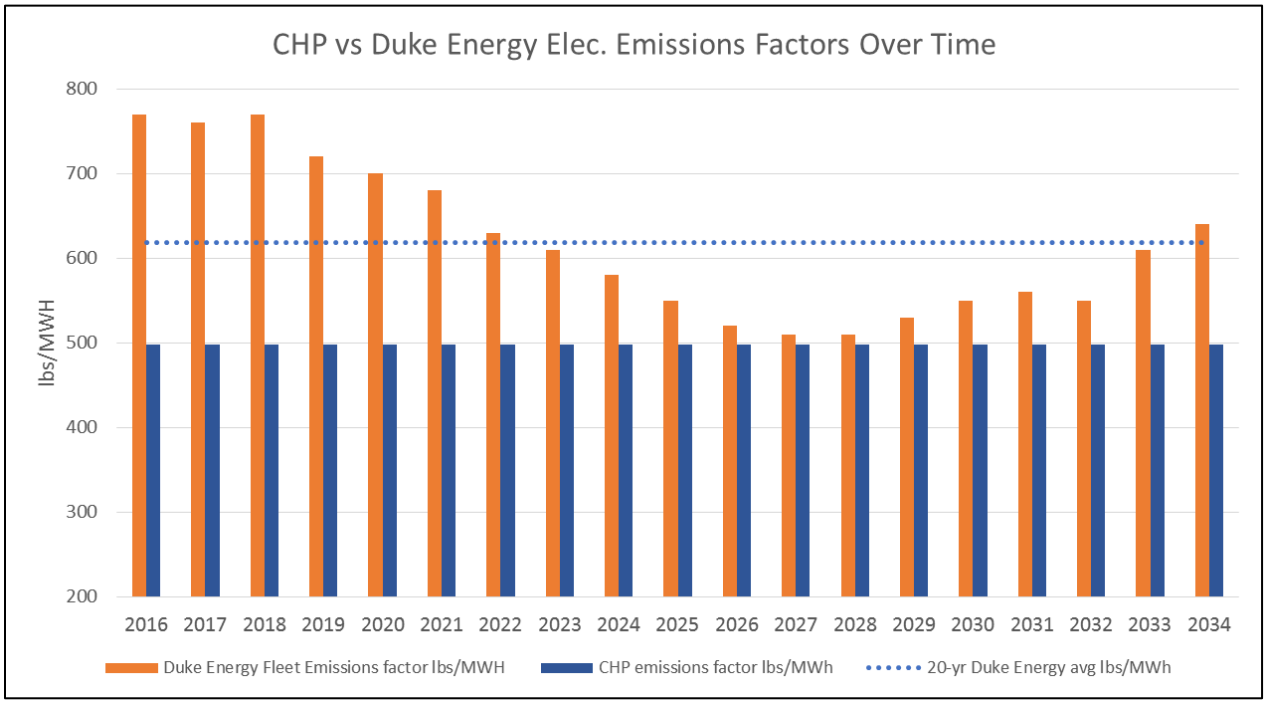
Since the most likely scenario for the generation offset from the CHP will be a Duke Energy fossil fuel plant(s), total source energy emissions are expected to be **reduced by 39% - 49%** versus separately produced power and steam.

Even when comparing the CHP to Duke Energy's published anticipated emissions (which include projections for new nuclear generation) over the next 20 years, Duke Energy is not expected to have fleet emissions factors lower than the proposed CHP.



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