Proposed CHP Emissions Credits for the NYC Carbon Challenge

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Guidelines for Evaluating GHG Benefits of On-Site Generation

- Columbia has proposed a GHG emissions credit for CHP
- For consideration by New York City Office of Sustainability (formerly Office of Long Term Planning & Sustainability(OLTPS))
  - Started in 2011 under Mayor Bloomberg
  - Most recent discussions in early February 2016
- Applicable to
  - Grid-connected CHP projects
  - "PlaNYC Mayoral Challenge Participants"

Outline

- NYC Carbon Challenge
- Proposed Project
- Problem: Current Accounting Protocol
- Solution: Proposed Emissions Credit
- Conclusions & Next Steps

- Guidelines & Simplifying Assumptions
- Steps to Calculate Emissions Credit

PlaNYC Carbon Challenge

- In 2007, Mayor Bloomberg released PlaNYC, including the goal to reduce citywide GHG emissions 30 % by the year 2030.
- Mayor Bloomberg asked the city's universities and hospitals to match City government's goal to reduce its own GHG emissions at an accelerated pace of 30% in 10 years.
- 17 universities (including Columbia) and 11 hospital systems accepted and became "Mayoral Challenge Participants"

Mayoral Challenge Participants

MAYORAL CHALLENGE PARTICIPANTS	
Current participants – Universities (30%)	**Current participants – Hospitals (30%)**
•Barnard College	•Continuum Health Partners
•Berkeley College	•NYC Health + Hospitals
•City University of New York	•NYU Lutheran Medical Center
•Columbia University	•Maimonides Medical Center
•The Cooper Union for the Advancement of Science and Art	•Memorial Sloan-Kettering Cancer Center
•Fashion Institute of Technology	•Montefiore Medical Center
•Fordham University	•The Mount Sinai Medical Center
•The New School	•NewYork-Presbyterian/Queens*
•New York School of Interior Design	•NewYork-Presbyterian Hospital
•New York University	•Northwell Health
•Pace University	•NYU Langone Medical Center
•Polytechnic Institute of New York University	
•Pratt Institute	
•The Rockefeller University*	
•School of Visual Arts	
•St. John's University	
•Weill Cornell Medical College*	

Participants who have met the 30 percent goal:

Institutions which have committed to the 50 percent reduction goal by 2025

Source: Gotham Energy 360, LLC

Of 28 Challenge Participants, 6 have met the 30% goal, 8 have committed to a 50% reduction

PlaNYC Mayoral Challenge Implications for Columbia

- As a Mayoral Challenge Participant, Columbia University volunteered to reduce GHG emissions
  - by 30 percent per Gsf from the baseline year of July 2005-June 2006 (FYE 2006)
- Implies achieving GHG emissions averaging 10.1 metric tonnes of carbon dioxide equivalent (MtCO2e) per 1,000 Gsf
- Translates to an annual reduction of about 45,000 MTCO2e

PlaNYC Initiative 9 to Expand Clean Distributed Generation ("Clean DG")

PlaNYC recognizes the value of CHP

"We will increase the amount of Clean DG by 800 MW

> …Clean DG can be even more efficient when it utilizes the waste heat from electrical generation to create hot water, heating, and cooling for buildings, so it is often called Combined Heat and Power (CHP)…
>
> The City will work with Con Edison and relevant agencies to reduce the financial, technical, and procedural barriers…"

It also recognizes the value of district energy

> "We will promote opportunities to develop district energy at appropriate sites in New York City"

Source: "PLANYC2030"
http://www.nyc.gov/html/planyc2030/html/plan/energy_clean-generation.shtml

NYC Leadership in Carbon Accounting

- The City of New York has become a global leader in the development and implementation of new carbon accounting methodologies.
- OLTPS represents the City and municipal governments in general on steering and advisory committees responsible for developing standards for regional, national, and international carbon accounting.

Columbia Proposed CHP Project

- Columbia is developing a 15 MW CHP project
- Results in efficient use of fossil fuel:
  - Fuel consumption increases by ~ 800,000 MMBtu
  - Electricity purchases decline by ~ 122,000 MWh
    - Equivalent to an NG power plant operating at an efficiency of over 50%, or with a heat rate of about 6,500 Btu/kWh
    - Half is distributed by Con Edison to "campus" loads (not directly connected to CHP)
- 60% Design has been completed

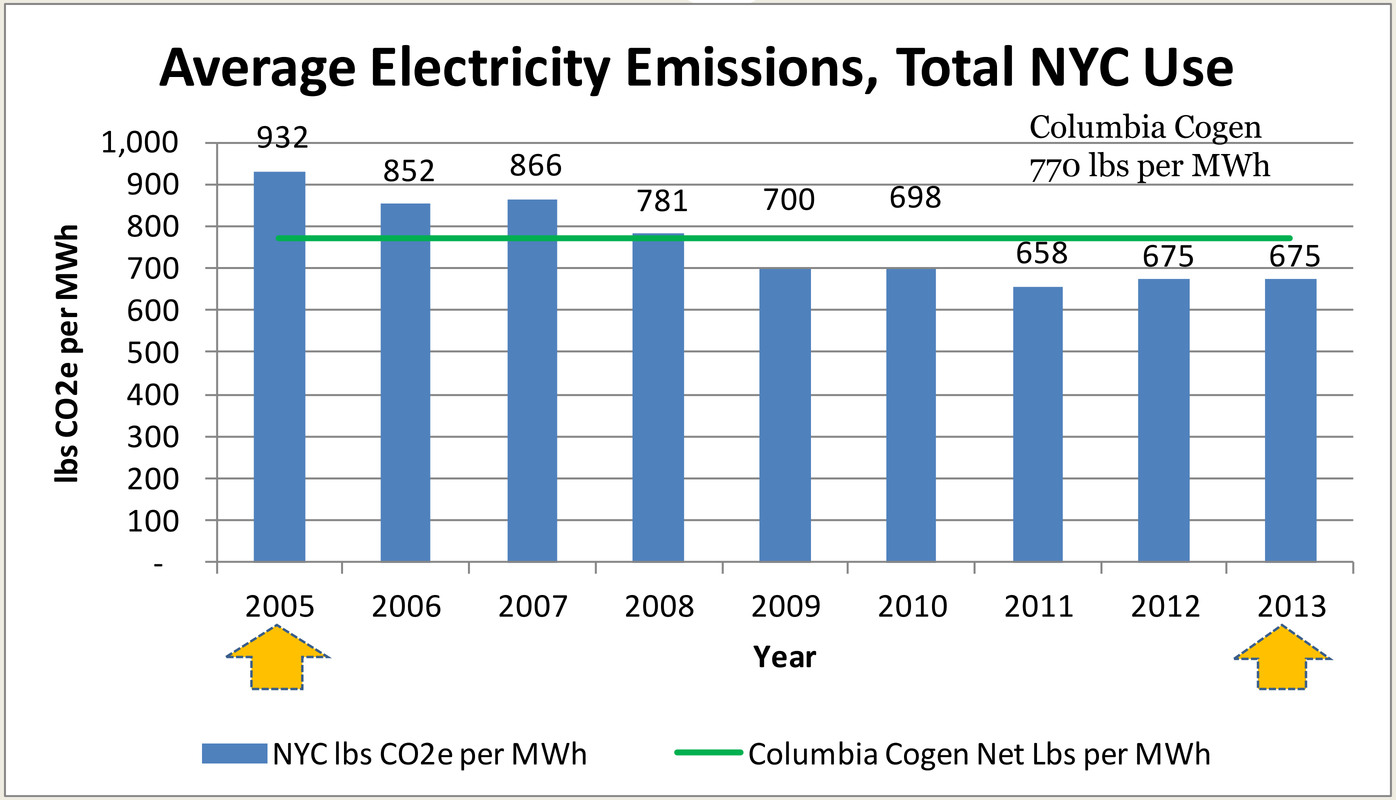
Current Accounting Protocol for Challenge Participants

- CHP Projects are assumed to displace grid purchases having the average electricity emissions coefficient for all grid power used by New York City
- NYC has developed its own electricity emissions coefficient, rather than using the U.S. Environmental Protection Agency's (EPA) eGRID coefficient
  - Largely based on detailed hourly data
  - Updated annually including for prior years
- 2005 electricity factor is to be used in all years and has been frozen for that purpose

Problems with Current Accounting Protocol

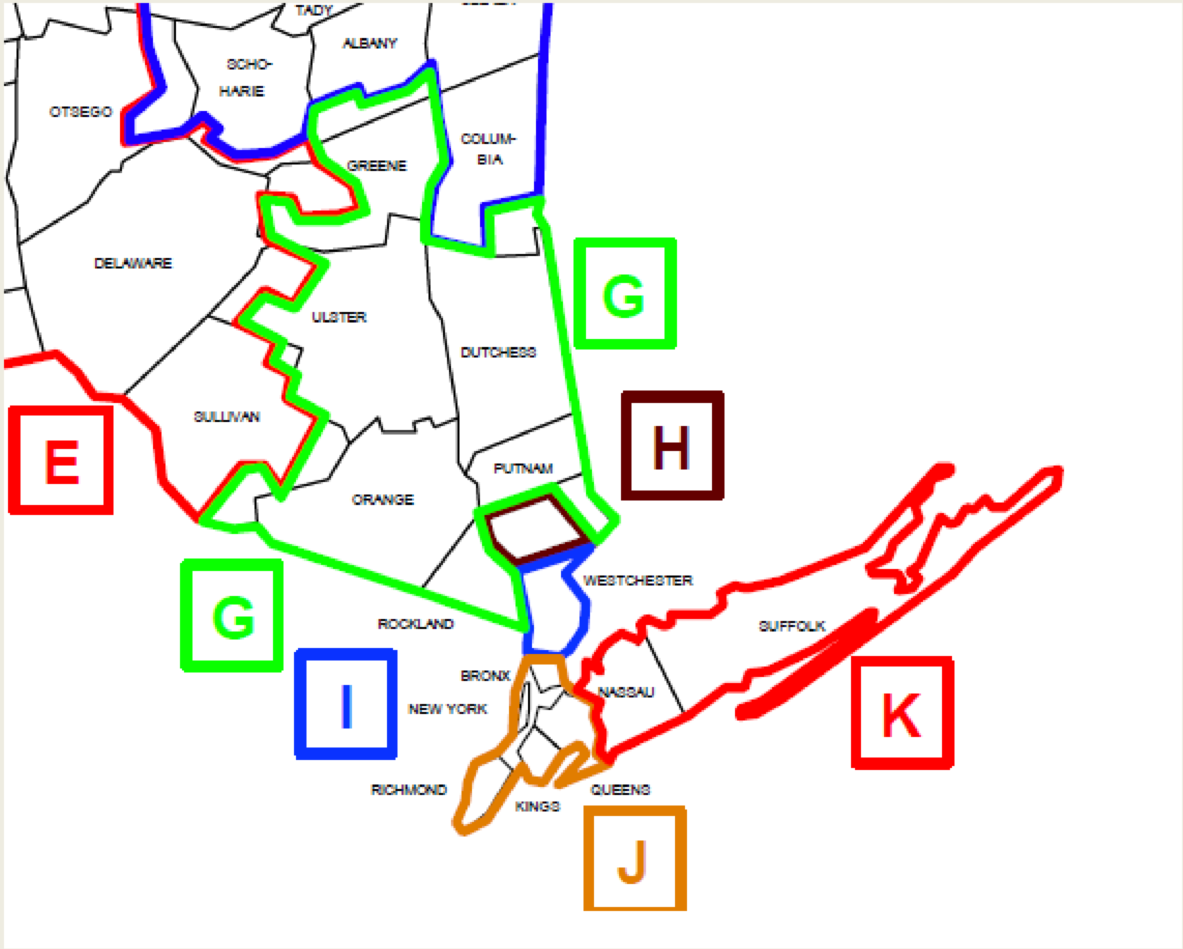
- Does not accurately reflect project impact on NYC GHG emissions
  - Does not account for changes in grid power over time
  - Average carbon intensity does not reflect the portion of the grid generation impacted by the project operation
  - Significantly understates the benefit
  - Undermines investment

Average Electricity Emissions



For 2005, value was frozen for accounting by NYC for Challenge Participants. Other years are from the "Inventory of New York City Greenhouse Gas Emissions", November 2014. All NYC values include transmission & distribution losses. Columbia Cogen value assumes annual generation of 122,350 MWh and incremental NG of 802,300 MMBtu.

New York Control Area Load Zones



Composition the 2005 Average Electricity Emissions Coefficient

NYC Generation & Electricity Emissions Coefficient		
Category	% of Total Generation	Lbs CO2e per MWh
In City	46%	1,250
Contract	32%	257
Market Procurement (G,H,I)	22%	1,180
Total Generation	100%	921
Transmission and Distribution Loss	-4.8%	
Total NYC Electricity Use	95.2%	958

Source: "Inventory of New York City Greenhouse Gas Emissions", November 2014

Note: The 958 value above for 2005 reflects continued revisions to the 2005 inventory after the emissions factor for that year was frozen at 932 for accounting purposes.

Calculated GHG Benefit: Current NYC Method

SAMPLE CALCULATION OF GHG BENEFIT				
	BENEFIT BEFORE CHP EMISSIONS CREDIT			
1	**2005 Average Grid Electricity Emissions Coefficient**	Lbs per MWh	**932**	Multiplied by
2	**Annual Project Generation**	MWh	**122,350**	Divided by
3	**Lbs per Metric Tonne (MT)**	Lbs	**2,204.6**	Equals
4	**Decrease in Grid Power Emissions MTCO2e**	MTCO2e	**51,720**	
5	**Emissions Factor for Natural Gas**	MTCO2e per MMBtu	**0.053156**	Multiplied by
6	**Annual Incremental Natural Gas Consumption**	MMBtu	**802,300**	Equals
7	**Increase in Fuel Emissions**	MTCO2e	**42,650**	
8	**Net GHG Emissions Benefit from CHP - Current Method**	MTCo2e	**9,070**	(4-7)

Calculated GHG Benefit: Current Average Grid

	SAMPLE CALCULATION OF GHG BENEFIT			
	BENEFIT USING AVERAGE CURRENT GRID EMISSIONS			
1	**2013Average Grid Electricity Emissions Coefficient**	Lbs per MWh	**675**	Multiplied by
2	**Annual Project Generation**	MWh	**122,350**	Divided by
3	**Lbs per Metric Tonne (MT)**	Lbs	**2,204.6**	Equals
4	**Decrease in Grid Power Emissions MTCO2e**	MTCO2e	**37,460**	
5	**Emissions Factor for Natural Gas**	MTCO2e per MMBtu	**0.053156**	Multiplied by
6	**Annual Incremental Natural Gas Consumption**	MMBtu	**802,300**	Equals
7	**Increase in Fuel Emissions**	MTCO2e	**42,650**	
8	**Net GHG Emissions Benefit from CHP - Current Method**	MTCo2e	**-5,190**	(4-7)

Proposed CHP Project Emissions Credit

Rationale:

- Demand and supply must be equal at any point in time.
- When an on-site generator comes on line, another resource on the grid must back down.
- It is the emissions of the marginal generator being ramped that determines the actual intensity of the GHG emissions offset

Proposal: compare the project against what it displaces on the grid as it operates; apply a ***marginal*** (not average) grid rate to determine the benefit

Challenge Participants would receive a "CHP Emissions Credit" for each MWh of generation by a CHP project

- Equal to the difference between the average grid emissions factor in 2005 (932 lbs per MWh) and the calculated factor for generation at the margin.

Precedent for "Marginal" Accounting

There is precedent for using a marginal accounting approach:

- "quantifying a project's GHG emissions is done by subtracting actual GHG emissions associated with a project's implementation from an estimate of GHG emissions under its "baseline scenario" (referred to as "baseline emissions")…
- The baseline emissions for a grid-connected project activity are estimated by determining the GHG emissions of the sources of electricity that the project activity displaces or avoids…the estimation requires identifying which power plants are providing electricity at the margin (i.e., the last to be switched on-line or first to be switched off-line) during times when the project activity is operating".

Source: "The Greenhouse Gas Protocol, Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects" (WRI Protocol), World Resources Institute.

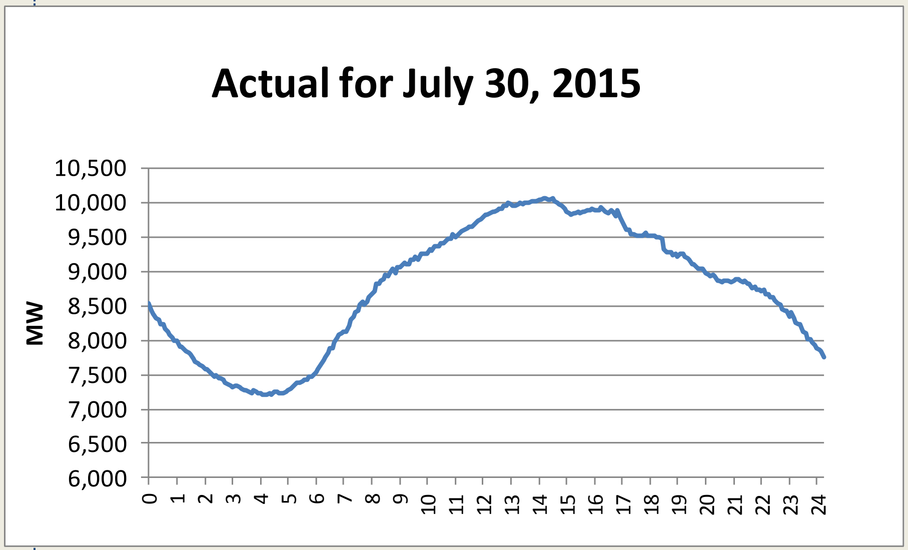
Proposed Approach
Power Markets 101 - Demand

Demand

Changes from moment to moment

With each change a generator adjusts its output up or down

Sample Hourly Zone J Load (5 minute interval data)

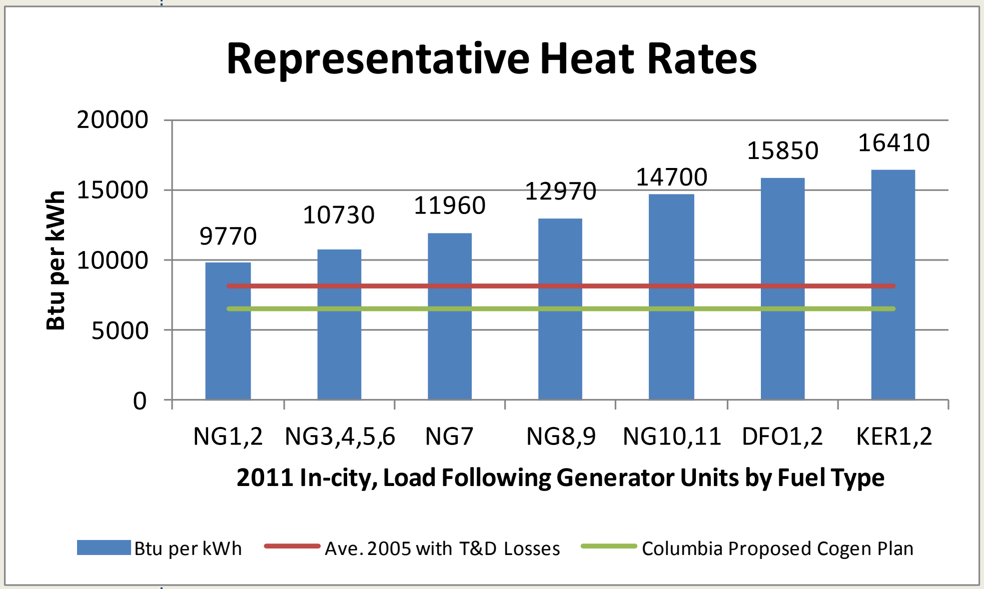


Proposed Approach
Power Markets 101 - Supply

Supply

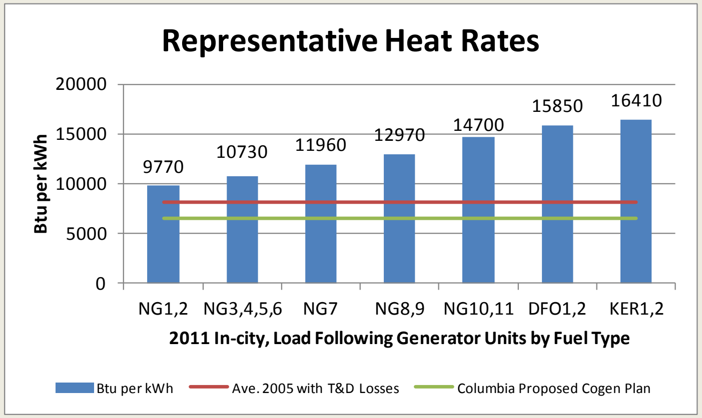
Sample "Load Following" Generators Available to Ramp up or Down, lbs CO2e per MWh

- Simplistically, each generator makes an offer at a price. The market stacks the offers by price and selects the lowest priced generator that meets demand at the margin.
- Prices are determined largely by heat rate (Btu/kWh) and fuel type (e.g., natural gas, oil)
- Heat rates and fuel types correlate to GHG emissions rates

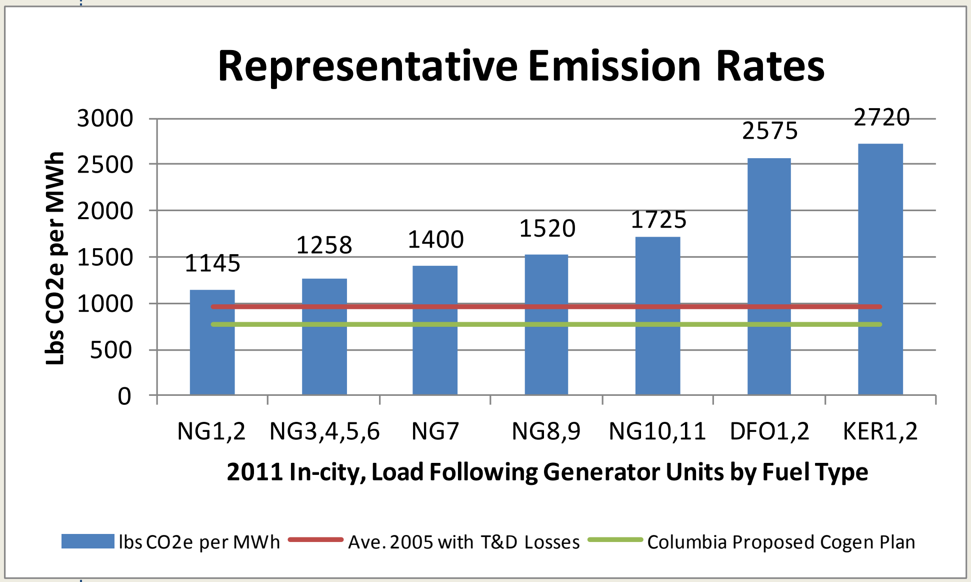


Correlation among Dispatch Order
Heat Rates & Fuel Types & Carbon Intensity

"Load Following" Generators Available to Ramp up or Down, Btu/kWh



"Corresponding Carbon Intensity, lbs CO2e per MWh



Steps to Calculate the "CHP Project Emissions Credit"

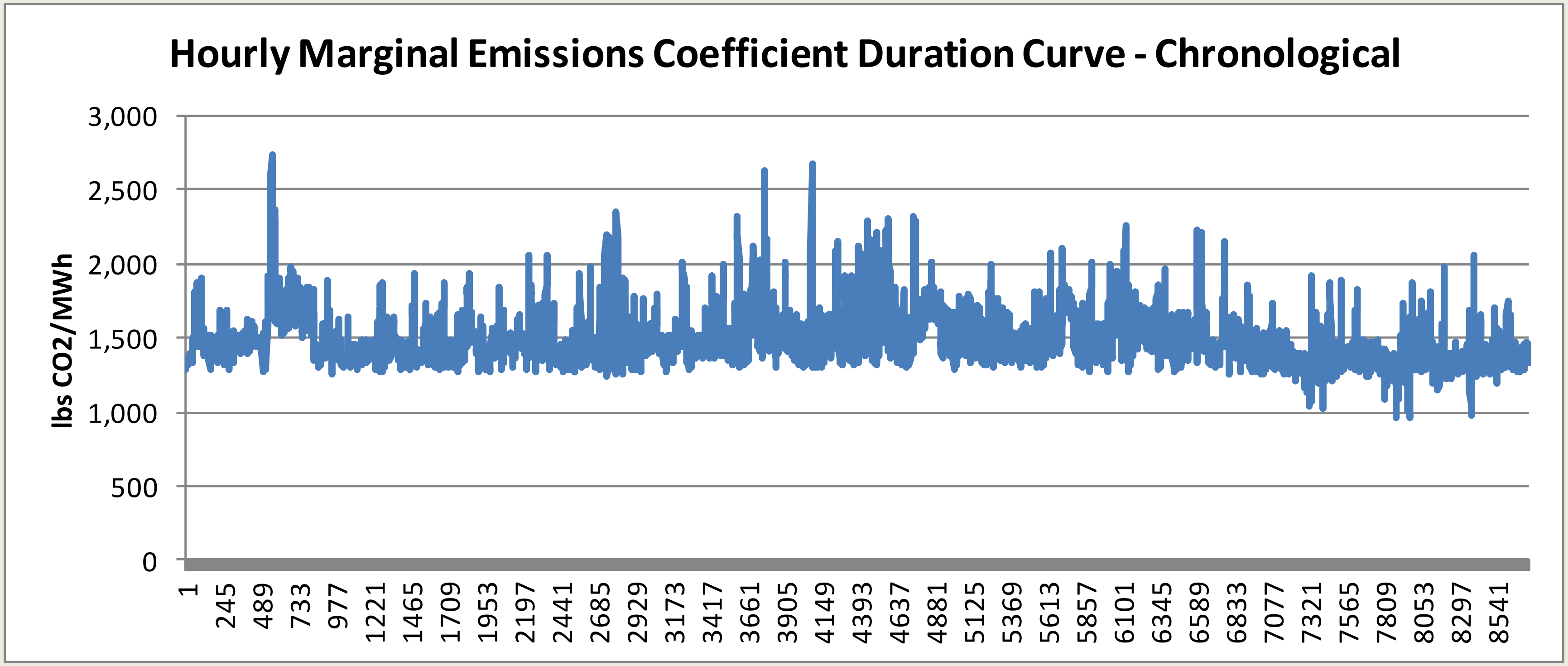
1. *Determine the amount of generation (in MWh) from each "In-City" (NYISO Zone J) power source on the grid (plant and unit), by hour for 2005*
2. *Determine the associated GHG emissions for each power source on the grid, by hour*
3. *Determine the dispatch order for each power source on the grid*
4. *Stack the generation from each power source in each hour according to the dispatch order*
5. *Calculate the marginal emission rate matched to the project activity's generation in each hour*
6. *Calculate the standard CHP Project Emissions Credit*

Sample Hour – Jan 1, 2011 Hour Starting 16:00

Plant Name	Unit	Sum Net Generation MWh - Modeled	Net Heat Rate Btu/kWh - Modeled	Capacity Factor % - Modeled	Primary Fuel Code	Dispatch Type	Step 5a Displaced Marginal Generation MWh	Step 5b Displaced Marginal CO2 Emissions tons	Step 5c Displaced Marginal CO2 Emissions lbs/MWh
Astoria Energy		424	6215	69.9	NG	Must Run			
Linden Cogen Plant		118	7097	57.9	NG	Must Run			
Linden Cogen Plant		131	7129	43.3	NG	Must Run			
Linden Cogen Plant		110	7129	36.2	NG	Must Run			
Charles Polletti Power Plant		381	7517	76.7	NG	Must Run			
Ravenswood		198	7606	78.2	NG	Must Run			
Kennedy International Airport		103	8328	71.7	NG	Must Run			
Brooklyn Navy Yard Cogeneration		106	12507	77.2	NG	Must Run			
East River		170	10769	92.1	NG	Peaking			
East River		171	10770	92.3	NG	Peaking			
Joseph J. Seymour Power Project		2	16750	3.6	NG	Peaking			
Pouch		1	20414	2.1	NG	Peaking			
Astoria		0	172948	0.1	NG	Peaking	191	128	1,340

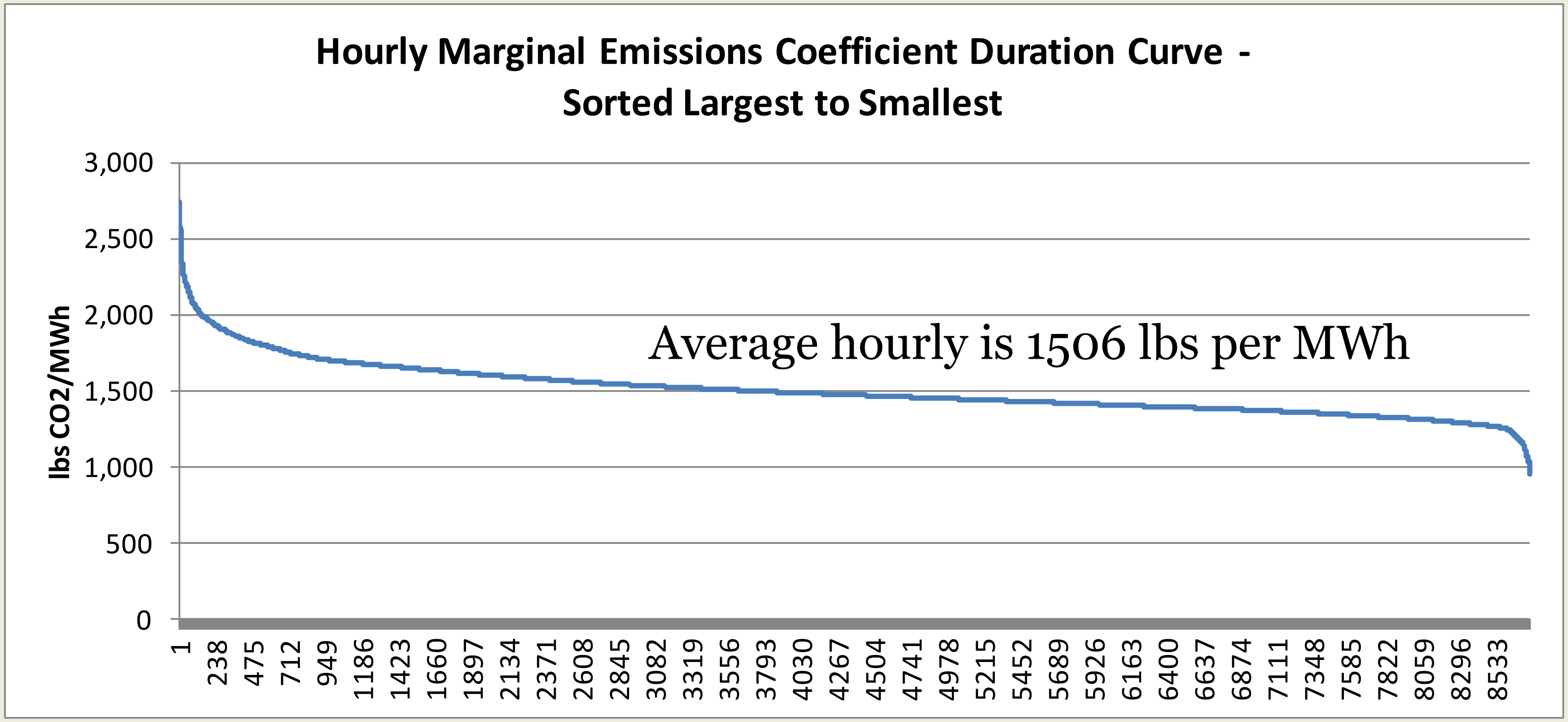
(2011 data for "In-City" generation was made available by NYC & used as to illustrate the concept)

Proposed Approach - Determine Emissions of the Marginal Generation by Hour



Based on 2011 data used by NYC for power sources located in NYISO Zone J, i.e. “In-city”. “Marginal generation” is calculated as the last 10% dispatched.

Hourly Emissions of the Marginal Generation Sorted Largest to Smallest



Based on 2011 data provided by NYC for power sources located in NYISO Zone J, i.e. “In-city”. “Marginal generation” is calculated as the last 10% dispatched.

Sample Calculation of GHG Benefit with CHP Emissions Credit

	SAMPLE CALCULATION OF GHG BENEFIT WITH CHP EMISSIONS CREDIT			
	BENEFIT BEFORE CHP EMISSIONS CREDIT			
1	**2005 Average Grid Electricity Emissions Coefficient**	Lbs per MWh	**932**	Multiplied by
2	**Annual Project Generation**	MWh	**122,350**	Divided by
3	**Lbs per Metric Tonne (MT)**	Lbs	**2,204.6**	Equals
4	**Decrease in Grid Power Emissions MTCO2e**	MTCO2e	**51,720**	
5	**Emissions Factor for Natural Gas**	MTCO2e per MMBtu	**0.053156**	Multiplied by
6	**Annual Incremental Natural Gas Consumption**	MMBtu	**802,300**	Equals
7	**Increase in Fuel Emissions**	MTCO2e	**42,650**	
8	**Net GHG Emissions Benefit from CHP - Current Method**	MTCo2e	**9,070**	(4-7)
	PROPOSED CHP EMISSIONS CREDIT			
9	**Marginal Grid Electricity Emissions Coefficient**	Lbs per MWh	**1,506**	Less
10	**2005 Average Grid Electricity Emissions Coefficient**	Lbs per MWh	**932**	Equals
11	**CHP Emissions Credit**		**574**	Multiplied by
12	**Annual Project Generation**	MWh	**122,350**	Divided by
13	**Lbs per Metric Tonne (MT)**	Lbs	**2,204.6**	Equals
14	**GHG Emissions Benefit from CHP Emissions Credit**	MTCO2e	**31,860**	
15	**TOTAL GHG EMISSIONS BENEFIT FROM CHP**	MTCO2e	**40,930**	(8+14)

Theoretical Guidelines & Simplifying Assumptions

In practice, it is complicated to identify which power plant(s) would have been displaced by a project

However, key concepts and alternative methods for estimation are well documented

- Governed by Available Information
- Balancing Act
- Operating Margin vs. Build Margin
- Generic Methodology
- Static vs. Dynamic
- Grid Boundary
- Single vs. Customized Rates

Conclusions & Next Steps - Columbia

- Important to Columbia's ability to justify the CHP capital commitment
- Next steps
  - NYC agreement to concept
  - Assure alignment on principles and simplifying assumptions
  - Apply methodology to data and agree to credit amount

Time is of the essence to support the capital appropriation process

Conclusions – Broader Implications

- Projects' GHG emissions impact will become more and more important to capital appropriation
- Average grid carbon intensity will continue to decline
- GHG emissions accounting based on average grid intensity provides a "false" metric and understates the benefit of efficient, on-site generation
  - May even imply falsely an increase in GHG emissions
- Accounting based on displaced marginal generation
  - More accurate
  - Practical
  - Reflects positively on efficient, on-site generation
- NYC adoption could serve as catalyst to broader implementation

Notes for More Detailed Discussion

- THEORETICAL GUIDELINES
- SIMPLIFYING ASSUMPTIONS
- STEPS TO CALCULATE

Theoretical Guidelines & Simplifying Assumptions

<u>Governed by Available Information</u>

- It is proposed that the same hourly generation data be used as was used to calculate the electricity emissions factor for 2005 for the "PlaNYC Inventory of New York City Greenhouse Gas Emissions"
- 2011 generation data for the NYC inventory was modeled using the Ventyx, Velocity Suite based on data reported by generators to the EPA, Nuclear Regulatory Commission, and the EIA.
- For each plant and generation unit by hour, this data includes:
  - Primary Fuel Code
  - Heat Input (MMBtu)
  - Net Generation (MWh)
  - CO2 Emissions (Measured Tons) (partial)
  - Dispatch Type (Must Run, Cycling, or Peaking).

Theoretical Guidelines & Simplifying Assumptions

<u>Balancing Act</u>

The guidelines proposed herein for CHP Projects attempt to balance:

- Accounting principles (i.e. relevance, completeness, consistency, transparency, accuracy, and conservativeness) with
- The objectives of simplicity and of incentivizing Challenge Participants to implement clean CHP generation.

The following slides discuss some of the principles & simplifying assumptions we adopted

Operating Margin vs. Build Margin

We assume that CHP Project activity will affect only "operating margin"; it will have no effect on "build margin"

- Note: a CHP project may "displace or avoid the operation of existing grid-connected power plants and/or the construction and operation of new power plants...Generation displaced from existing power plants is referred to as the "operating margin" (OM). Generation from potential new capacity, whose construction is avoided due to the project activity, is referred to as "build margin" (BM)." (WRI Protocol)

Theoretical Guidelines & Simplifying Assumptions

Generic Methodology

The WRI Protocol sets forth four generic methods for estimating the operating margin emission factor:

- 1) average load-following: "calculates the average annual emissions of load following power plants"
- 2) average marginal: "uses a load duration curve analysis to calculate weighted average emissions of resource types that are on the margin for specific time periods"
- 3) marginal historic: "uses an analysis of historical data…to determine a marginal emission rate for each hour the project activity operates", and
- 4) marginal modeled: "uses dispatch modeling to determine marginal emissions for each hour the project activity operates".

The guidelines proposed herein apply a ***marginal historic methodology based on 2005 Zone J electricity generation***. This method involves an analysis of historical data to determine the dispatch order for grid power plants during each hour of a year. The CHP Project activity's generation (or avoided consumption) could then be matched to the marginal generation mix in each hour to calculate an OM emissions rate which could be aggregated into an average hourly OM emissions rate.

Theoretical Guidelines & Simplifying Assumptions

<u>Static vs. Dynamic</u>

The proposed "OM" emission factor would be ***"static".***

"An OM emission factor can either be "static", i.e. calculated upfront and applied for the duration of the project activity's baseline scenario…, or "dynamic", i.e. updated over time to reflect changes in grid composition and operation…" (WRI Protocol)

Theoretical Guidelines & Simplifying Assumptions

Grid Boundary

The "grid boundary" for calculation of the OM emission factor corresponds with the ***"In-City" grid power sources*** as the term is used in the "PlaNYC Inventory of Greenhouse Gas Emissions"

- "In-City" is from grid power sources located within New York Independent System Operator (NYISO) Zone J

The WRI Protocol emphasizes that "accurately calculating both BM and OM emissions requires defining the boundaries within which electricity generation is displaced or avoided…the geographic area within which to evaluate baseline emissions will be determined by grid boundaries, not legal or political boundaries"

Theoretical Guidelines & Simplifying Assumptions

<u>Single vs. Customized Rates</u>

A single, ***standard*** marginal emission rate for will be applied to all CHP Projects.

This is contrasted with a customized rate that would reflect the unique operating patterns of individual projects.

Step 4: Stack Generation from Each Power Source by Hour

- We proposed applying the following "generic" set of rules:
  - Identify power sources for which the dispatch type is not "load following". In general practice such plants would include base load, must run, and intermittent generation facilities. The order in which not load following power sources are dispatched does not affect the calculation of the standard baseline marginal generation emissions rate. However, for the purpose of sorting hourly data, it is assumed "must run" resources have higher merit than "cycling" facilities and that within each "dispatch type" the order of dispatch is by ascending net heat rate.
  - The remaining power sources are considered to be ***"load following".*** In this instance, it is proposed that load following power sources be units identified as being a "peaking" "dispatch type" consistent with the available data. The dispatch order for "peaking" units would be governed by the following generic rules:
    - ***First sources for which the primary fuel is natural gas are dispatched in order of ascending net heat rate (Btu/kWh)***.
    - ***Then sources for which the primary fuel is a petroleum product***, i.e. kerosene, distillate fuel oil, No. 2 fuel oil, diesel, and residual fuel oil. As a simplifying principle, it is assumed these sources are dispatched in ascending order of net heat rate.

Step 5: Calculate the Marginal Emissions Rate Matched to Project Activity's Generation in Each Hour

- The WRI Protocol identifies two approaches: 1) assume the same emission rate as the last unit dispatched, or 2) calculate the average emission rate of power sources providing the "top" x percent of generation in each hour, as determined by the dispatch order in Step 4. "Top" relates to last dispatched.
- The WRI Protocol states the latter method is generally preferred since the apparent precision of the first method can be somewhat illusory depending on the data used and variations in actual grid dispatch in response to the project activity.
- In addition, it is intended that the CHP Emissions Credit by applied to all Challenge Participant projects and the PlaNYC initiative targets 800 MW of capacity
- Accordingly, ***the average emission rate of power sources providing the top 10 percent of generation in each hour*** is proposed to calculate the marginal emissions rate.

Other Individuals Involved

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Miscellaneous Assumptions

"Default Emissions Factors"

Primary Fuel (Code)	Corresponding "INYCGHG" Stationary Source	Symbol	CO2e Unit	CO2e kg/unit	MMBtu Unit	MMBtu per unit HHV	MTCO2e/ MMBtu	lbs CO2e/ MMBtu	
Distillate fuel oil (DFO)	#2 fuel oil (industrial)	DFO	liter	2.69627	gallon	0.1385	0.0736931	162.5	Assumed the same as #2 FO
#2 fuel oil (FO2)	#2 fuel oil (industrial)	FO2	liter	2.69627	gallon	0.1385	0.0736931	162.5	
Kerosene (KER)	Kerosene (industrial)	KER	liter	2.68187	gallon	0.135	0.0751999	165.8	
Natural Gas (NG)	Natural gas (industrials)	NG	GJ	50.25326	GJ	0.9478171	0.05302	116.9	
Residual fuel oil (RFO)	#6 residual fuel oil (industrial)	RFO	liter	2.9759	gallon	0.1532	0.0735314	162.1	
				Appendix J, page 31	PlaNYC New York City Greenhouse Gas Emissions, December 2012				

Other General Assumptions used in Methodology

MWh per GJ	0.277778
lbs per kg	2.204623
liters per gallon	3.785412
kg per MT	1000
lbs per MT	2204.623
lbs per ton	2000

Marginal generation as % of total hourly generation 10%