2020 Updated Feasibility Assessment of Combined Heat and Power (CHP) Systems For Douglass Homes

SELECTED EXCERPTS

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Submitted to:

Maryland Energy Administration

FY 21 Combined Heat and Power (CHP) Grant Program
Round 2

Submitted on Behalf of

Housing Authority of Baltimore City

Submitted by:

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I. BACKGROUND AND INTRODUCTION

Background

In 2016, The Housing Authority of Baltimore City (HABC) tasked TA Engineering, Inc. to assess the economic feasibility of applying combined heat and power (CHP) technology at HABC public housing developments. The interest in this prospect was driven by the potential for CHP technology to generate significant energy cost savings, thereby reducing utility costs for HABC's public housing stock. As such, CHP technology also may become a candidate for assisting HABC initiatives with developing (or adding to) energy performance contract projects.

The economic potential for a given CHP technology tends to be optimized when the electric and thermal interfaces with the chosen application are uncomplicated (keeping installation costs at a minimum), the CHP provided energy can be fully utilized, and the thermal energy costs are high thereby maximizing the value of the "waste heat" thermal energy available from the CHP system. HABC public housing development properties served by master electric and gas meters and relatively high cost district steam (centrally sourced space heating and domestic hot water generation) have the potential to match well with the above stated economic criteria.

2016 Feasibility Study Results

Two HABC public housing development sites (Douglass Homes and Cherry Hill Homes) were studied in detail to establish the basic economic feasibility of CHP technology for HABC properties utilizing district steam for space conditioning and domestic hot water thermal loads. Both sites were found to have promising potential to apply CHP technology with an estimated simple payback on investment of nominally 7 years exclusive of any potential utility rebate or State grant.

In the case of Douglass Homes, the appropriate solution was determined to be three (3) factory-packaged cogeneration units of approximately 50 to 65 kW each in order to reduce electric demand and consumption charges, and reduce if not eliminate steam charges associated with domestic hot water generation. This CHP system size range was found to meet the electric baseload for each of the blocks and, with the incorporation of existing DHW storage capability, also meet the entire summer DHW load. As a result, the CHP system would be able to gainfully contribute essentially all its electric and thermal output year-round.

Each of the three CHP systems will serve a separate "block" of the site and provide both base-load electricity and full domestic hot water service.

At the time of the 2016 Feasibility Study Douglass Homes was served with electricity from a single BGE master meter; however, plans were in preparation for a conversion to three master meters (one for each block). The HABC-owned electric distribution infrastructure included an electrical room (vault) for each block that contained medium-to-low voltage step-down equipment and switchgear. The electric vaults are in proximity to the central mechanical rooms for each site and the new BGE master meters/switchgear are expected to be sited similarly.

The CHP systems will provide their available cogenerated thermal energy for meeting domestic hot water (DHW) loads. Currently, DHW loads are met using steam generators/storage tanks and/or instantaneous type steam water heaters located in mechanical rooms, one for each block. Although the mechanical rooms with the DHW equipment and the electrical switchgear are not located together within each block, they are all relatively close to one another. Options for locating the CHP equipment include the existing mechanical rooms, abandoned electrical vaults (now empty), outside in weather-proof enclosures, or outside the mechanical rooms in a new stand-alone building.

Summer 2020 Feasibility Study Update

Since the 2016 Feasibility Study, HABC has implemented a self-directed energy performance contract project involving multiple HABC housing developments including Douglass Homes. This EPC project was initially implemented in April 2018 and did not involve a CHP project at Douglass Homes. Several housing developments have been removed from HABC's managed inventory and hence from the EPC project during 2019; as a result, a need arose to add additional energy savings projects to the EPC. A CHP project at Douglass Homes was identified as one of the more promising remaining prospects.

As a result, an update to the 2016 Feasibility Study was performed and is reported herein. The update includes an incorporation of a major electrical infrastructure upgrade at Douglass Homes that involved new HABC owned electric distribution infrastructure involving a separate system for each of the three "blocks" of Douglass Homes. As a result, Douglass Homes now has all new electric infrastructure and three utility master electric meters (rather than one), one for each block.

In addition, the ongoing EPC project includes three other energy saving measures involving Douglass Homes that impact CHP system sizing and potential savings. They are:

- Negotiation of a district steam tariff rate reduction (in effect),
- Addition of new DHW storage tanks (rather than utilize existing)
- Water saving low-flow plumbing fixtures for toilets, aerators, & showerheads (installation nearing completion fall 2020), and
- Efficient LED lighting fixtures (to be installed during 1st quarter of 2021).

Consideration of the impact of these changes and energy saving measures on the Douglass Homes CHP Project are addressed in this document.

Next Steps in the Implementation Process

HABC is currently in the process of soliciting pricing from design-build contractors to provide turn-key services to complete the final design and installation of the three CHP systems. In parallel with this process the DHW loads at Douglass Homes will be instrumented to confirm the final magnitude of the DHW loads post water saving fixture installation. The bidders are being requested to provide a specific recommended system and maintenance pricing for five (5) years. This information, and any MEA-grant/BGE rebate will be utilized to select the offer that best meets the financial objectives of HABC within its EPC project.

II. SITE CHARACTERISTICS AND UTILITIES

A. Site Characteristics

Douglass Homes is bounded by Orleans St. (North), and E. Lexington St./E. Fayette St. (South). Exhibit II-1 is an aerial photograph of the campus [Note: the apartment buildings are the buildings with the brown roofs]. As may be noted in Exhibit 1, city streets running North/South divide the campus into three (3) blocks, as follows:

- Block 1: Spanned by N. Eden St. (West) and N. Caroline St. (East)
- Block 2: Spanned by N. Caroline St. (West) and N. Bond St. (East)
- Block 3: Spanned by N. Bond St. (West) and N. Broadway (East)

Exhibit II-1. Location of Douglass Homes and Mechanical/Electrical

Douglass Homes is comprised of thirty-six (36) 2-story and 3-story garden apartment buildings of block and brick construction. There also is a community building on the site. Pertinent physical and demographic data are as follows:

- Douglass Homes – Physical and Demographic Data
  - 36 garden apartment buildings and a community building
  - Approximately 227,000 ft^2
  - Nominally 375 dwelling units and 661 tenants (per lease)

B. Utilities – Electricity, District Steam, and Natural Gas

1. Electric Service for Douglass Homes

Electricity service for Douglass Homes is provided by the Baltimore Gas and Electric Company (BGE) and is now delivered via three separate master-metered services, one for each block of Douglass Homes. Each service is located outdoors. The BGE account numbers/addresses (and corresponding HABC block) are as follows:

- BGE Service Address/Account Number (Block 1; BGE service near HABC Bldg.1-9)
  - R 225 Silver Ct./2083686541
- BGE Service Address/Account Number (Block 2; BGE service near HABC Bldg. 2-2)
  - R 226 N. Dallas Ct./6903633995
- BGE Service Address/Account Number (Block 3; BGE service near HABC Bldg. 3-3)
  - R 238 Bethel Ct./8252307655

2. Steam Service for Douglass Homes

Steam was originally provided to each of the three blocks by coal-fired boilers installed at a mechanical room in each block; domestic hot water was produced at each of the three mechanical rooms using steam from the boilers and then distributed to the buildings. At some point, these boilers were abandoned in-place and steam began to be generated at the HABC-owned Central Avenue Heating Plant (CAHP) located at North Central Avenue and May Street. Currently, steam is purchased from a non-regulated third-party (Vicinity Energy Baltimore Heating, LLP) who now owns and operates the CAHP; steam is distributed via underground piping to a pressure reducing station and Vicinity steam meter located in each of the three mechanical rooms at Douglass Homes. The district steam service addresses (and their corresponding HABC Building number) as they appear on the steam bills are:

- 1400 May Court (HABC Bldg. No. 1-6, Block 1),
- 1500 May Court (HABC Bldg. No. 2-6, Block 2),
- 1600 May Court (HABC Bldg. No. 3-6, Block 3).

Vicinity bills HABC for steam under a single assigned account number for all of the HABC developments provided with steam; the account number is:

- Vicinity Account Number: 0122222222

For each block, low pressure steam is distributed from the block's central mechanical room to each of the buildings and supplied directly to steam convectors in each apartment for space heating; steam is supplied for this purpose nominally from October 15 through April 15.

DHW for each block had been produced by a steam generator (steam coil inside of storage tank) also in the central mechanical room and then distributed to the other buildings located on the same block. The DHW steam generators/storage tanks were installed in 1940 and are now being replaced with instantaneous steam DHW heaters. To this end, a new system for Block 3 has recently been designed and installed and is currently in operation. Similar systems for blocks 1 and 2 are now entering design and will be installed as a separate activity from the CHP project. The instantaneous DHW heaters will become supplemental/back-up equipment as part of the new CHP system.

3. Natural Gas Service for Douglass Homes

Natural gas is of interest because it is envisioned to be the fuel of choice for the new CHP system.

Douglass Homes has a master metered BGE gas service and HABC-owned campus-wide distribution piping. The natural gas is used nearly exclusively for stoves/ovens at each apartment.

Natural gas is delivered to Douglass Homes by BGE via a single master-metered service located near the Northwest side of Block 1. The gas service location and the HABC gas pipeline distribution system is the same as originally installed (circa 1940). The gas service is located indoors at the old mechanical room for Block 1 in Building 1-6. The BGE account numbers/addresses (and corresponding HABC block) are as follows:

- 1415 Orleans St./6901792149

Two important questions require resolution as regards the natural gas service and distribution system at Douglass Homes; they are:

1. Can BGE provide the required increased gas capacity for the three CHP systems to their existing single master gas service; and
2. Can the HABC-owned natural gas piping distribution system accommodate the increased gas flow required for the three CHP system?

BGE was contacted regarding question No. 1 (above); a service application was submitted to request a formal BGE evaluation. BGE investigated the existing service, performed a gas load study, and determined the following:

- "No reinforcement would be required at this time if you were to add the generators on site. All that BGE would need to do is change out the meter." (via e-mail: Jarred D. Bowers, Senior Engineering Technical Specialist, New Business-Natural Gas Unit, BGE, August 6, 2020)

Regarding the issue of the adequacy of the existing natural gas distribution system to accomodate the increased flow, the piping system pipe sizes and routing were reviewed and a pressure drop calculation was performed to assess its capability to handle the increased gas loads under peak gas consumption conditions (i.e., maximum cooking loads and imposed full CHP gas loads). Exhibit II-2 illustrates the existing gas piping distribution network and Exhibit II-3 illustrates the results of the pressure drop analysis.

Exhibit II-2: Douglass Homes Natural Gas Distribution Piping

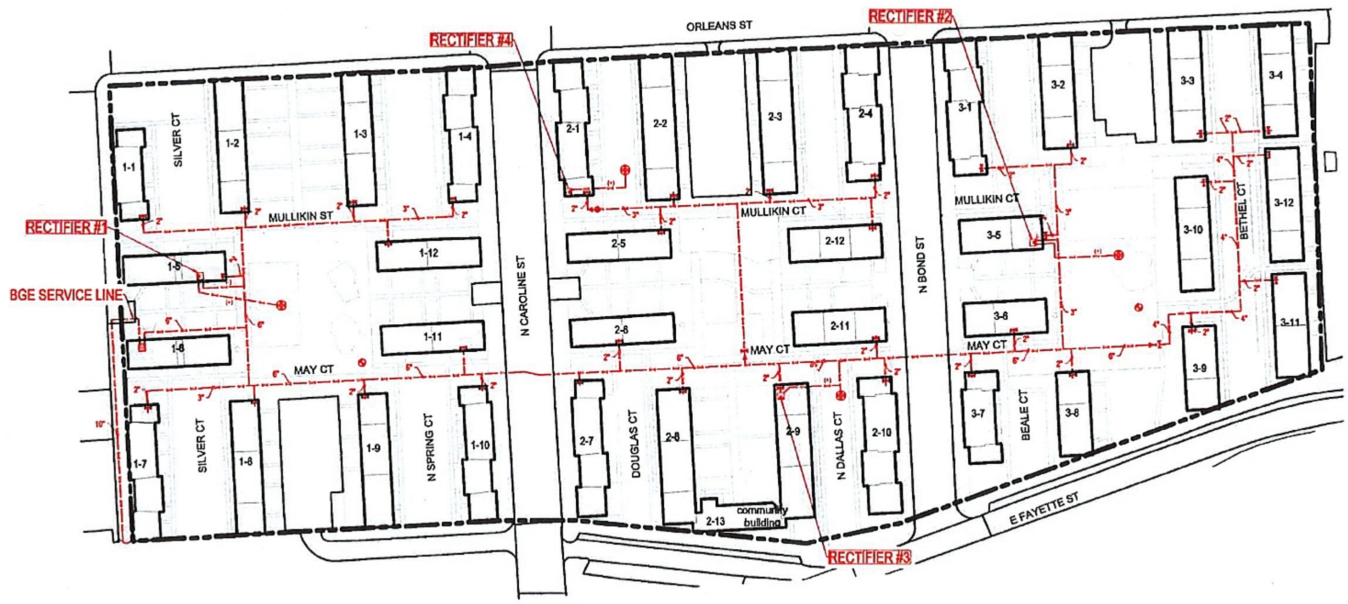


Exhibit II-3. Douglass Homes Natural Gas System -- Pressure Drop Calculation with Added CHP Loads

HABC Campus Pressure Drop Calculation
14" W.G. from meter

Pipe Diameter, D = (Q^0.381)/(18.93[(P1^2 - P2^2) x 0.9992/0.6094 x L]^0.206)
where: Q = gas flow in CFH
P1 = Upstream Pressure, psia
P2 = Downstream Pressure, psia
L = Equivalent length of Pipe

27.7076 in. W.G / psi

0.622	1/2"
0.824	3/4"
1.049	1"
1.380	1-1/4"
1.610	1-1/2"
2.067	2"
3.068	3"
4.026	4"
6.065	6"

			Flow, Q	Upstream P1			Downstream P2			Length, ft.		Pipe Diameter, in.		
Node	to	Node	CFH	in. W.G.	psig	psia	in. W.G.	psig	psia	Meas.	Equiv, L	D, Calc	Nom .Pipe	Comments
0	to	1	10,010	14.00	0.51	15.21	13.96	0.50	15.20	20	30	6.065	6"	Stoves 1-6
1	to	2	9,815	13.96	0.50	15.20	13.92	0.50	15.20	20	30	6.064	6"	Generator #1
2	to	3	9,033	13.92	0.50	15.20	13.76	0.50	15.20	90	135	6.065	6"	Stoves 1-1, 1-2, 1-3, 1-4, 1-5, 1-12
3	to	4	7,746	13.76	0.50	15.20	13.68	0.49	15.19	65	97.5	6.064	6"	Stoves 1-7
4	to	5	7,512	13.68	0.49	15.19	13.64	0.49	15.19	30	45	6.065	6"	Stoves 1-8
5	to	6	7,258	13.64	0.49	15.19	13.55	0.49	15.19	75	112.5	6.065	6"	Stoves 1-9
6	to	7	7,005	13.55	0.49	15.19	13.45	0.49	15.19	100	150	6.065	6"	Stoves 1-11
7	to	8	6,810	13.45	0.49	15.19	13.42	0.48	15.18	25	37.5	6.064	6"	Stoves 1-10
8	to	9	6,576	13.42	0.48	15.18	13.33	0.48	15.18	90	135	6.065	6"	Stoves 2-7
9	to	10	6,342	13.33	0.48	15.18	13.29	0.48	15.18	50	75	6.066	6"	Stoves 2-6
10	to	11	6,147	13.29	0.48	15.18	13.24	0.48	15.18	60	90	6.064	6"	Stoves 2-8
11	to	12	5,893	13.24	0.48	15.18	13.21	0.48	15.18	30	45	6.065	6"	Generator #2
12	to	13	5,111	13.21	0.48	15.18	13.20	0.48	15.18	25	37.5	6.065	6"	Stoves 2-1, 2-2, 2-3, 2-4, 2-5, 2-12
13	to	14	3,727	13.20	0.48	15.18	13.19	0.48	15.18	35	52.5	6.065	6"	Stoves 2-9
14	to	15	3,473	13.19	0.48	15.18	13.16	0.47	15.17	105	157.5	6.065	6"	Stoves 2-10, 2-11
15	to	16	3,064	13.16	0.47	15.17	13.14	0.47	15.17	80	120	6.065	6"	Stoves 3-7
16	to	17	2,908	13.14	0.47	15.17	13.13	0.47	15.17	45	67.5	6.064	6"	Stoves 3-6
17	to	18	2,752	13.13	0.47	15.17	13.12	0.47	15.17	55	82.5	6.065	6"	Stoves 3-1, 3-2, 3-5, 3-8
18	to	19	1,991	13.12	0.47	15.17	13.11	0.47	15.17	55	82.5	6.065	6"	Generator #3
19	to	20	1,209	13.11	0.47	15.17	13.08	0.47	15.17	110	165	4.027	4"	Stoves 3-9
20	to	21	1,053	13.08	0.47	15.17	13.06	0.47	15.17	90	135	4.027	4"	Stoves 3-11
21	to	22	858	13.06	0.47	15.17	13.04	0.47	15.17	100	150	4.027	4"	Stoves 3-10
22	to	23	644	13.04	0.47	15.17	13.04	0.47	15.17	30	45	4.026	4"	Stoves 3-12
23	to	24	429	13.04	0.47	15.17	13.04	0.47	15.17	20	30	4.027	4"	Stoves 3-3
24	to	25	215	13.04	0.47	15.17	13.03	0.47	15.17	30	45	2.066	2"	Stoves 3-4

Have Excel Solve "Column N" (Pipe Diameter) for known diameter by changing the value of "Column J" (downstream pressure) for each row starting with Nodes "0 to 1".
(Data Tab: What-If Analysis: Goal Seek)

It was determined that the existing natural gas distribution system can accommodate the increased gas load from all three of the CHP systems. The calculations indicate that the existing Douglass Homes Campus natural gas infrastructure is sufficient to support the added cogeneration gas loads if BGE can deliver the gas at a service pressure of approximately 0.5 psig (14” W.C.”) a pressure drop of approximately 1” W.C. is seen at the end of the distribution system.

III. CHP EQUIPMENT CHARACTERISTICS AND SYSTEM SIZING

A. Introduction

The required/desired CHP system size is influenced both by the fact there are three separate electric and themal distribution points (a pair for each block) and by the fact that HABC may elect to dispose of one of the blocks of Douglass Homes at some point in the future (possible, but unlikely in the time frame of the EPC).

As noted in Section I (Introduction), the 2016 Feasibility Study determined the appropriate solution to be three (3) factory-packaged cogeneration units of approximately 50 to 65 kW each in order to reduce electric demand and consumption charges, and reduce if not eliminate steam charges associated with domestic hot water generation. This CHP system size range was found to meet the electric baseload for each of the blocks and, with the incorporation of existing DHW storage capability, also meet the entire summer DHW load. As a result, the CHP system would be able to gainfully contribute essentially all its electric and thermal output year-round.

B. CHP Equipment Characteristics

As a practical matter, available CHP systems compatible with the electric baseload at Douglass Homes and an established track record are limited and basically include the following options:

- 65 kW System: microturbine
- 60 kW System: reciprocating engine
- 55 kW System – reciprocating engine
- 20 to 30 kW System: reciprocating engine and microturbine

1. Identification of Candidate CHP System(s) – 2016 Feasibility Study

Several vendors offer packaged cogeneration systems (including selected thermal interface components) in the size range of interest for Douglass Homes. For purposes of the 2016 assessment and given the size range of interest (i.e., nominally 50 to 65 kW), the following two products were selected as representative of the available products:

- Tecogen (reciprocating engine technology), and
- Capstone (microturbine technology).

Exhibit III-1 presents performance information for the above listed products as they were available at the time of the 2016 Feasibility Study.

Exhibit III-1. Selected Performance Data for the Three CHP Systems Considered-2016 Feasibility Study

HABC - Douglass Homes Summary of CHP Systems Considered - Selected Performance Data				
Items	Units	Machine 01	Machine 02	Machine 03
Description	NA	Tecogen CM-60	Capstone C65	Capstone C30 LP
Technology	NA	Engine	MicroTurbine	MicroTurbine
Nominal kW	kW	60	65	30
Actual kW*	kW	60	61	28
Net Heat Rate HHV	Btu/kWh	13,294	12,980	14,410
Fuel Input Rate	Btu/hr	797,640	843,700	432,300
Thermal Efficiency HHV	%	57.4%	45.0%	45.0%
Waste Heat Recoverable	Btu/hr	457,845	379,665	194,535
Selected number of machines	EA	1	1	2
Actual installed kW	kW	60	61	56
Thermal Output	Btu/hr	457,845	379,665	389,070
Fuel Input	Btu/hr	797,640	843,700	864,600

*Microturbines derated for low pressure gas (gas compressor is required)

2. Identification of Candidate CHP System(s) – 2020 Feasibility Study Update

For the 2020 Feasibility Study Update, the U.S. Department of Energy Combined Heat and Power website was reviewed including its compendium of CHP vendors. The discrete capacities (kW sizes) of CHP systems in the size range of interest did not change by much. Exhibit III-2 summarizes the available products and their technical performance characteristics.

It is notable that one of the offered products had a substantial shift in performance data. The Tecogen 60 kW product now has a reduced level of available thermal energy (and reduced gas input).

An analysis was performed to estimate the parasitic electric energy losses that will result from application of the products to Douglass Homes. Exhibit III-2 also reflects the results of that analysis.

Exhibit III-2. Selected Performance Data for Candidate CHP Systems Including Estimated Parasitic Power Losses-2020 Feasibility Study Update

Manfacturer:	Tecogen	Capstone	Yanmar	Tedom	Tedom
Gross Output, kW	**60.0**	65.0	35.0	35.0	55.0
Fuel Input, Btuh	**757,860**	842,000	407,114	419,750	592,600
Electrical Eff.	27.0%	26.3%	29.3%	28.5%	31.7%
Heat Output, Btuh	**407,000**	420,000	204,040	238,000	336,000
Thermal Eff.	53.7%	49.9%	50.1%	56.7%	56.7%
Total Eff.	80.7%	76.2%	79.5%	85.2%	88.4%
Radiator, kW	0.500	0.000	0.250	0.000	0.000
System Pump, kW	0.000	0.000	0.000	0.175	0.250
Heat Loop Pump, kW	0.175	0.250	0.175	0.175	0.250
DHW Pump, kW	0.175	0.175	0.175	0.175	0.175
Gas Compressor, kW	0.000	2.000	0.000	0.000	0.000
Net kW	**59.15**	62.58	34.40	34.48	54.33

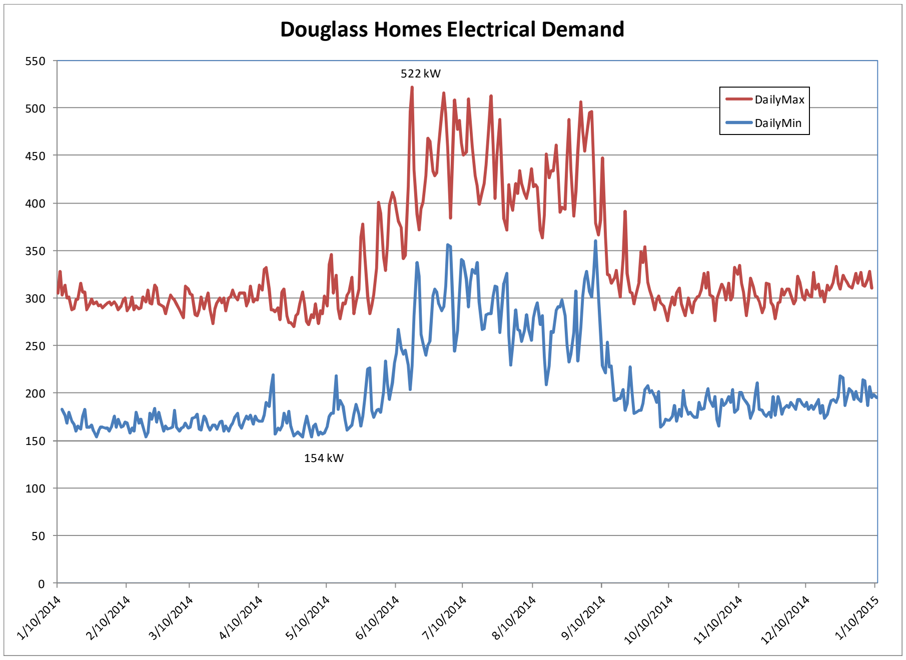
C. CHP System Sizing

1. Electric Baseload Sizing of a CHP System for Douglass Homes: 2016 Feasibility Study

Exhibit III-3 presents electric interval data (in 15-minute increments) for the Douglass Homes master meter electric account.

The data were obtained from BGE for another HABC project and are for calendar year 2014. It may be observed that the peak kW in 2014 was about 522 kW. The minimum sustained kW load in Exhibit III-3 would suggest a CHP system size of about 155 to 175 kW. Assuming each block is relatively equivalent (for purposes of this assessment), this would suggest a CHP system size of about 50 to 60 kW for each of the three blocks of Douglass Homes. A system of this size would appear able to run virtually continuously at or very near rated load without back feeding electricity into the BGE grid.

Exhibit III-3. BGE Interval Data for Douglass Homes – 2014



2. <u>Electric Baseload Sizing of a CHP System for Douglass Homes: 2020 Feasibility Study Update</u>

Electric interval data were obtained during the summer of 2020 for each of the three new master electric meters for Douglass Homes. At that time, data were available from when the new meters were installed/operational (August 2019) to current. Hence, electric interval data (15-minute periods) were analyzed for the period of August 19, 2019 to June 9, 2020 and have been used to estimate the base available electric load for a CHP system for each of the three (3) blocks at Douglass Homes.

Exhibit III-4 has been prepared from the electric interval data. The hours that each block's electric load was below various levels was determined and tabulated. The data were short of a full year (by 2-1/2 months) so the ratio of hours at load was assumed to remain equivalent for the missing months. The exhibit shows how many kW-hrs per year can be used for each block and the percent of total kW-hrs that could have been generated via load following (i.e., no export/sell back of electricity) for three CHP system sizes, 65 kW, 50 kW and 30 kW, neglecting parasitic electric loads created by the new CHP systems. As shown:

- a 65 kW CHP system can contribute 93.5% to 98% of its potential output, by Block
- a 50 kW CHP system can contribute 99.7% to 100% of its potential output, by Block
- a 30 kW CHP system can contribute 100% of its potential output, by Block

These relatively high levels of gainful use of CHP output are since the preponderance of operating hours will be at electric consumption levels well above the daily minimum (typically middle of the night during non-summer operation).

Section I (Introduction) notes that an energy efficient lighting project (for the apartments) is about to be implemented and will result in a net reduction in electric load. However, this is not expected to materially affect the daily minimum peak loads which tend to occur in the middle of the night when there is minimal use of lighting.

Exhibit III-4. Analysis of 2019/2020 BGE Electric Interval Data by Block at Douglass Homes Versus CHP System Size

Electric	Block 1					Block 2					Block 3				
Demand, kW	Hours below	% Hours	65 kW Unit kWh	50 kW Unit kWh	30 kW Unit kWh	Hours below	% Hours	65 kW Unit kWh	50 kW Unit kWh	30 kW Unit kWh	Hours below	% Hours	65 kW Unit kWh	50 kW Unit kWh	30 kW Unit kWh
65	3,970.500	56.0%	311,317.50			2,053.5	29.0%	435,922.50			4,205.5	59.5%	296,042.50		
64	3,692.500	52.1%	17,792.00			1,795.5	25.3%	16,512.00			3,955.0	56.0%	16,032.00		
63	3,490.500	49.2%	12,726.00			1,563.5	22.0%	14,616.00			3,705.0	52.4%	15,750.00		
62	3,269.500	46.1%	13,702.00			1,357.6	19.1%	12,765.80			3,432.0	48.6%	16,926.00		
61	3,011.000	42.4593%	15,768.50			1,136.0	16.0%	13,517.60			3,159.0	44.7%	16,653.00		
60	2,744.500	38.7%	15,990.00			906.5	12.8%	13,770.00			2,881.0	40.8%	16,680.00		
59	2,740.000	38.6%	265.50			730.0	10.3%	10,413.50			2,613.5	37.0%	15,782.50		
58	2,231.500	31.5%	29,493.00			583.5	8.2%	8,497.00			2,357.5	33.4%	14,848.00		
57	1,964.500	27.7%	15,219.00			446.5	6.3%	7,809.00			2,080.0	29.4%	15,817.50		
56	1,698.000	23.9%	14,924.00			332.5	4.7%	6,384.00			1,793.5	25.4%	16,044.00		
55	1,432.000	20.2%	14,630.00			233.0	3.3%	5,472.50			1,541.0	21.8%	13,887.50		
54	1,173.500	16.5%	13,959.00			154.0	2.2%	4,266.00			1,307.0	18.5%	12,636.00		
53	934.000	13.2%	12,693.50			104.5	1.5%	2,623.50			1,071.0	15.2%	12,508.00		
52	725.000	10.2%	10,868.00			62.0	0.9%	2,210.00			845.5	12.0%	11,726.00		
51	540.500	7.6%	9,409.50			34.0	0.5%	1,428.00			651.0	9.2%	9,919.50		
50	395.500	5.6%	7,250.00	418,225.00		20.5	0.3%	675.00	436,975.00		483.5	6.8%	8,375.00	413,825.00	
49	266.000	3.8%	6,345.50	6,345.50		12.0	0.2%	416.50	416.50		331.5	4.7%	7,448.00	7,448.00	
48	168.500	2.4%	4,680.00	4,680.00		2.5	0.0%	456.00	456.00		218.5	3.1%	5,424.00	5,424.00	
47	108.500	1.5%	2,820.00	2,820.00		1.5	0.0%	47.00	47.00		132.0	1.9%	4,065.50	4,065.50	
46	64.000	0.9%	2,047.00	2,047.00		1.5	0.0%	-	-		64.5	0.9%	3,105.00	3,105.00	
45	26.500	0.4%	1,687.50	1,687.50		1.5	0.0%	-	-		49.5	0.7%	675.00	675.00	
44	13.000	0.2%	594.00	594.00		1.5	0.0%	-	-		28.5	0.4%	924.00	924.00	
43	5.000	0.1%	344.00	344.00		1.5	0.0%	-	-		12.5	0.2%	688.00	688.00	
42	2.000	0.0%	126.00	126.00		1.5	0.0%	-	-		5.0	0.1%	315.00	315.00	
41	1.000	0.0%	41.00	41.00		1.5	0.0%	-	-		2.5	0.0%	102.50	102.50	
40	1.000	0.0%	-	-		1.5	0.0%	-	-		1.5	0.0%	40.00	40.00	
39	1.000	0.0%	-	-		1.5	0.0%	-	-		1.0	0.0%	19.50	19.50	
38	1.000	0.0%	-	-		1.5	0.0%	-	-		1.0	0.0%	-	-	
37	1.000	0.0%	-	-		1.0	0.0%	18.50	18.50		1.0	0.0%	-	-	
36	1.000	0.0%	-	-		1.0	0.0%	-	-		1.0	0.0%	-	-	
35	1.000	0.0%	-	-		1.0	0.0%	-	-		1.0	0.0%	-	-	
34	1.000	0.0%	-	-		1.0	0.0%	-	-		1.0	0.0%	-	-	
33	1.000	0.0%	-	-		1.0	0.0%	-	-		1.0	0.0%	-	-	
32	1.000	0.0%	-	-		1.0	0.0%	-	-		1.0	0.0%	-	-	
31	1.000	0.0%	-	-		1.0	0.0%	-	-		1.0	0.0%	-	-	
30	1.000	0.0%	-	-	262,770.00	0.5	0.0%	15.00	15.00	262,785.00	1.0	0.0%	-	-	262,770.00
29	0.500	0.0%	14.50	14.50	14.50	0.0	0.0%	14.50	14.50	14.50	1.0	0.0%	-	-	-
28	0.500	0.0%	-	-	-	0.0	0.0%	-	-	-	1.0	0.0%	-	-	-
27	0.000	0.0%	13.50	13.50	13.50	0.0	0.0%	-	-	-	1.0	0.0%	-	-	-
26	0.000	0.0%	-	-	-	0.0	0.0%	-	-	-	0.0	0.0%	26.00	26.00	26.00
25	0.000	0.0%	-	-	-	0.0	0.0%	-	-	-	0.0	0.0%	-	-	-
			534,720.50	436,938.00	262,798.00			557,849.90	437,942.50	262,799.50			532,460.00	436,657.50	262,796.00
			93.91%	99.76%	100.00%			97.97%	99.99%	100.00%			93.51%	99.69%	100.00%

Given the 2016 Feasibility Study recommendation of a CHP system in the 50 to 65 kW range, the Exhibit III-2 results suggest the same applies and further suggest that other considerations will dictate final system size/product selection (e.g., CHP product price & available thermal energy and life-cycle considerations such as maintenance/periodic re-build costs).

3. Thermal Base Load for a CHP System for Douglass Homes: 2016 Feasibility Study

The next step in the CHP sizing process is to verify whether a CHP system sized at or near the base electric load for the site can have its waste heat productively utilized.

Exhibit III-5 was prepared using vendor bills for district steam service for Douglass Homes. The bills although combined with Perkins Homes for determining price, also show metered steam use for each of the three blocks of Douglass Homes. Data from 2013 were used since all the meters were read for each month of the entire year; recent bills contain estimated readings for many of the months.

Exhibit III-5. Monthly Steam Consumption for Douglass Homes, by Block

HABC

Douglass Homes Steam Consumption

Nominal mm/yy	k-lb per month			
	1400 May Ct	1500 May Ct	1600 May Ct	Total
05/13	619.6	705.0	666.3	1,990.9
06/13	413.9	332.5	352.3	1,098.7
07/13	355.3	320.5	323.6	999.4
08/13	517.4	376.4	451.1	1,344.9
09/13	330.4	344.8	461.3	1,136.5
10/13	499.6	319.3	556.5	1,375.4
11/13	1,006.8	789.0	1,024.3	2,820.1
12/13	1,249.4	1,304.8	1,202.0	3,756.2
01/14	1,460.3	1,452.6	1,276.5	4,189.4
02/14	1,742.5	1,944.2	1,718.1	5,404.8
03/14	1,654.3	1,624.9	1,588.4	4,867.6
04/14	1,196.5	873.6	816.0	2,886.1
Total Annual k-lb	11,046.0	10,387.6	10,436.4	31,870.0
Minimum k-lb/month	330.4	319.3	323.6	999.4

From Exhibit III-5, the minimum monthly district steam use, by block, was 319.3 k-lbs (there were 34 billing days in the month with the minimum use). This has an average hourly energy use rate of:

- Average Minimum monthly thermal energy use (load) = 999.4/3 = 331.1 k-lbs/block
  - 331.1 k-lbs/month*month/34 days * 1,000/k * 1,000 Btu/lb * day/24 hours
  - 408,252 Btuh

Notably, a prominent 60 kW CHP system product offers nearly the identical available thermal load (Tecogen 60 kW at 407,000 Btuh). In fact, since minimum steam use (per block) was used, the average DHW load is actually higher, on average and may be substantially higher during the non-summer months as delivered city water temperatures drop as a function of average ambient temperature (Baltimore area water is stored in reservoirs exposed to ambient temperatures).

Thus, it appears that a 50 to 65 kW CHP system remains a good match for each of the three blocks of the Douglass Homes site with respect to thermal loads as well. Thermal storage will be required since the available load is domestic hot water (only). It may be possible to generate some level of steam and contribute to the winter space heating load, if necessary, to utilize available waste heat.

4. Thermal Base Load for a CHP System for Douglass Homes: 2020 Feasibility Study Update

Section I (Introduction) notes that an energy efficient plumbing fixture project (for the apartments) is about to be implemented and will result in a net reduction in DHW load.

HABC is in the process of completing a project at Douglass Homes to replace all bathroom and kitchen faucet aerators with low flow aerators and all showerheads with low flow showerheads. Approximately 75% of the conversions occurred during June/July 2019. The remainder are being performed during the Fall/winter of 2020/2021 (beginning during late September). Flowrate data assumed for savings estimates are as follows:

- Showerheads:
  - Existing: 2.31 gpm, on average
  - Upgrades: 1.25 gpm (1.5 gpm for UFAS units and handheld showerheads)
- Kitchen Faucet Aerators:
  - Existing: 1.9 gpm, on average
  - Upgrades: 1.0 gpm
- Bathroom Faucet Aerators:
  - Existing: 1.34 gpm, on average
  - Upgrades: 0.5 gpm

From the EPC savings analyses for the water energy conservation measure, the Douglass Homes steam savings due to aerators and showerheads is estimated at 128 k-lbs/mo, on average.

As a separate but related matter, it has been observed over the years that the Douglass (and Perkins) steam bills have numerous estimated readings and otherwise questionable consumption quantities (typically most apparent during the summer periods). The past eleven years of steam bills were reviewed (2009 through 2020) and only two years (2013 and 2016) had no estimated bills for the summer and relatively stable readings for the entire year. The summer portion of these two years of data are presented here as Exhibit III-6. The summer periods are shown as they represent only the DHW loads (i.e., zero steam space heating loads).

The following can be calculated from an analysis of the data in Exhibit III-6:

- Average monthly steam consumption over the two years of data: 430 k-lbs/month
- Average minimum steam consumption over the two years of data: 309 k-lbs/month

Exhibit III-6. Selected Monthly Steam Data by Block for Douglass Homes

Month	Service Dates		No. Days	Mlbs Steam 1400 May Ct. Bldg 1-6	1500 May Ct. Bldg 2-6	1600 May Ct. Bldg 3-6
Jun-13	5/21/2013	6/17/2013	27	413.9	332.5	352.3
Jul-13	6/17/2013	7/18/2013	31	355.3	320.5	323.6
Aug-13	7/18/2013	8/20/2013	33	517.4	376.4	451.1
Sep-13	8/20/2013	9/17/2013	28	330.4	344.8	461.3
Jun-16	5/12/2016	6/16/2016	35	611.4	616.0	544.8
Jul-16	6/16/2016	7/14/2016	28	446.3	516.3	423.0
Aug-16	7/14/2016	8/16/2016	33	481.7	568.2	486.2
Sep-16	8/16/2016	9/15/2016	30	284.2	414.0	398.9

The overall average monthly steam consumption may be adjusted for the expected Water Fixture ECM (i.e., reduced flow aerators and showerheads) as follows:

	Summer k-lbs/mo
2013/2016	430
DHW savings	(128)
Net	302 k-lbs/mo

The overall average monthly summer domestic hot water steam load may be expressed as follows:

302 k-lbs/mo *(mo/30.4 days)*(days/24 hours)*(1000/k)*(1000 Btu/lb)

= 413,925 Btu/hr (overall average DHW load, adjusted for water ECM savings)

Notably the above "overall average" value is higher than the total available thermal energy from the 55 kW and 60 kW CHP products listed in Exhibit III-2 and slightly lower than the 65 kW product.

A similar analysis was performed using the minimum overall average monthly values from Exhibit III-6, as follows:

The minimum overall average monthly steam consumption may be adjusted for the expected Water Fixture ECM (i.e., reduced flow aerators and showerheads) as follows:

	Summer k-lbs/mo
2013/2016	309
DHW savings	(128)
Net	181 k-lbs/mo

The overall minimum average monthly summer domestic hot water steam load may be expressed as follows:

181 k-lbs/mo *(mo/30.4 days)*(days/24 hours)*(1000/k)*(1000 Btu/lb)

= 248,080 Btu/hr

Notably the above "minimum overall average" value is lower than the total available thermal energy from the 55 kW (74%) and 60 kW (61%) CHP products listed in Exhibit III-2 and lower than the 65 kW (60%) product.

It may be observed that there appears to be periods of time where the CHP products anticipated to be candidates (in the 55 to 65 kW range) may not contribute all their thermal energy to the DHW loads.

An analysis was performed for each of the three CHP products that appear to be under consideration and the following was determined:

- 55 kW CHP product: Most of the months remain above the required load (Tedom product: 245 k-lbs + 128 k-lbs = 373 k-lbs). Two or three of the months (depending on the block) in Exhibit III-6 are below this quantity; but on average may still gainfully contribute 76% to 95% of available waste heat during the 3 months below the required load.

- 60 kW CHP product: Half of the months remain above the required load (Tecogen product: 297 k-lbs + 128 k-lbs = 425 k-lbs). Four or five of the months (depending on the block) in Exhibit III-6 are below this quantity; but on average may still gainfully contribute 67% to 97% of available waste heat during the 3 months below the required load.

- 65 kW CHP product: Half of the months remain above the required load (Capstone product: 306 k-lbs + 128 k-lbs = 434 k-lbs). Four or five of the months (depending on the block) in Exhibit III-6 are below this quantity; but on average may still gainfully contribute 65% to 97% of available waste heat during the 3 months below the required load.

As already noted, it is expected that winter DHW loads will be higher than summer and the water ECM savings may or may not be fully realized.

Going forward, HABC is in the process of instrumenting the DHW loads to determine their magnitude after complete installation of the water-saving ECM under the EPC. This information will be used to support an analysis similar to the electric interval analysis (see Exhibit III-4) to estimate the likely usable thermal energy from the selected CHP product; and assist in final selection of the product to be installed.