STAFF SUMMARY

TO: Board of Directors
FROM: Frederick A. Laskey, Executive Director
DATE: May 25, 2022
SUBJECT: Combined Heat and Power Study – Deer Island Treatment Plant
Black & Veatch Corporation
Contract 6963A

COMMITTEE: Wastewater Policy & Oversight

X INFORMATION
VOTE

David F. Duest, Director, Deer Island Treatment Plant
Richard J. Adams, Manager, Engineering Services
Christian A. Murphy, Program Manager I&C
Preparer/Title

David W. Coppes, P.E.
Chief Operating Officer

RECOMMENDATION:

For Information only.

DISCUSSION:

Figure 1- On-Site Thermal Power Plant (Location of Existing CHP)

Deer Island meets approximately 57% (by energy) to 65% (by cost) of its energy requirements through onsite generation primarily from a combined heat and power system (CHP). Sludge collected from its primary and secondary treatment processes is digested in up to 12 three-million gallon egg-shaped digesters. The biogas generated within the digesters is then consumed in one of the two high-pressure boilers to create high-pressure steam. The steam passes through two steam turbine generators to generate electricity. The generator steam is discharged into a heat exchanger, which heats a hydronic (water) heat loop that distributes process and building heat throughout the Deer Island Treatment Plant. The boilers can also operate on No. 2 ultra-low-sulfur fuel oil if digester gas is not available or when supplemental fuel is required to meet Deer Island's thermal demand. (Refer to Figure 2.) The existing CHP was placed into operation in 1997.

As part of the long-term planning process for combined heat and power system infrastructure, the Board authorized the award of Contract 6963A, Combined Heat and Power Study, to Black & Veatch Corporation on March 20, 2019. The contract goal was to evaluate the existing Thermal/Power Plant and develop recommendations to reliably and economically meet Deer Island's long-term energy needs, while also maximizing onsite generation and reducing the

purchase of electricity. This information was deemed essential in order to accurately develop future capital projects for Deer Island's combined heat and power system.

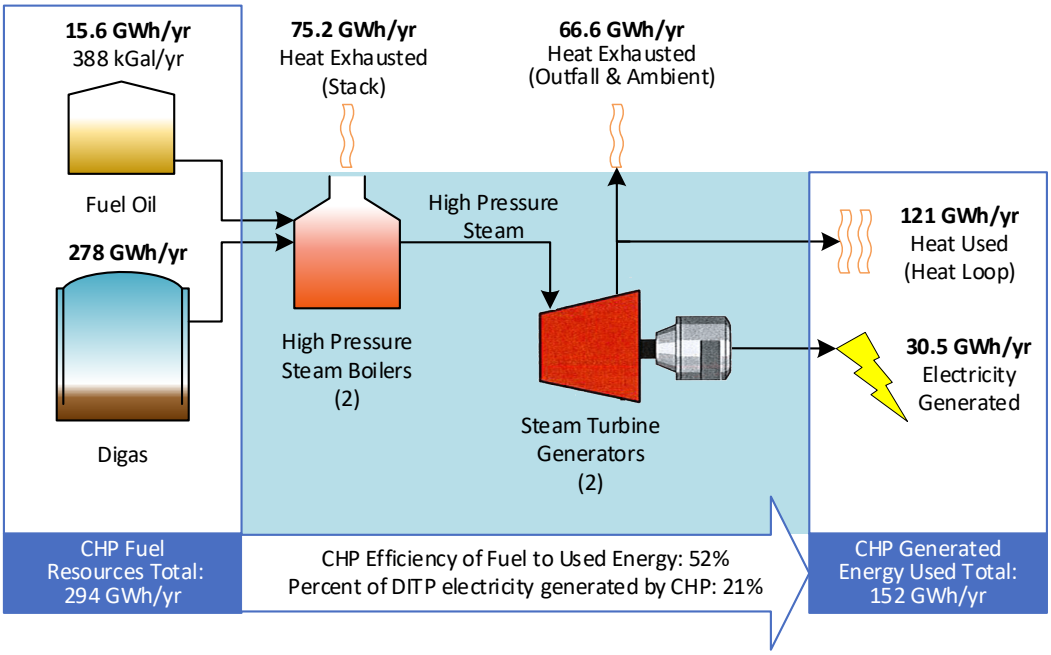

Figure 2– Schematic of Deer Island's Existing CHP

The scope of Contract 6963A consisted of the following major components:

- **Existing Energy System Asset Condition Assessment**: The remaining useful life of Deer Island's existing Thermal/Power Plant assets was estimated based on a review of maintenance history, condition inspections, similar equipment industry averages and feedback obtained from manufacturers.

- **Existing Thermal/Power Plant System Economic Evaluation:** The economic performance of the existing Thermal/Power Plant system was evaluated and used as a baseline to compare to the performance of the new combined heat and power system.

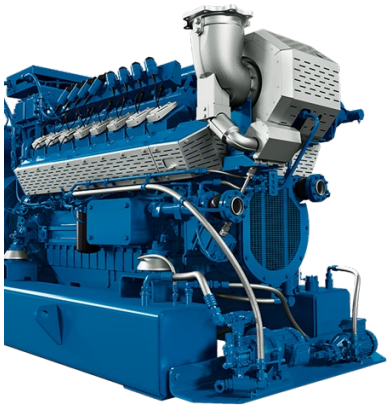

Figure 3 – Typical CHP Reciprocating Engine

- **Evaluation of CHP Technologies:** Current combined heat and power technologies were evaluated to determine their applicability for use at Deer Island. Reciprocating engines and combustion turbines were the two primary technologies that were evaluated. These two technologies were found to be the primary options due to their improved efficiency, combined with their technological maturity and commercial availability at the size required. Based on this evaluation, spark ignition reciprocating engines were selected.

- **CHP Alternatives Analysis:** An evaluation of multiple combined heat and power system alternatives was performed using the selected combined heat and power system technology. The evaluation performed for each alternative included a conceptual design to confirm engineering viability, a performance simulation to predict system operation and an economic analysis. The new combined heat and power system was then compared to the existing Thermal/Power Plant system during the same 25-year analysis period.

The new CHP that proved to be most promising based on Black & Veatch's analysis is shown in Figure 4. The existing Thermal/Power Plant steam-based system would be replaced with three hot water (hydronic) boilers fueled primarily with digester gas and supplemented with fuel oil. Electricity would be generated by an array of five spark ignition reciprocating engines fueled only with digester gas. These engines use pistons with the fuel being ignited by a sparkplug – similar to an automotive engine. Heat recaptured from the exhaust of these engines combined with the output of the new boilers would enable Deer Island to fully meet its thermal demand.

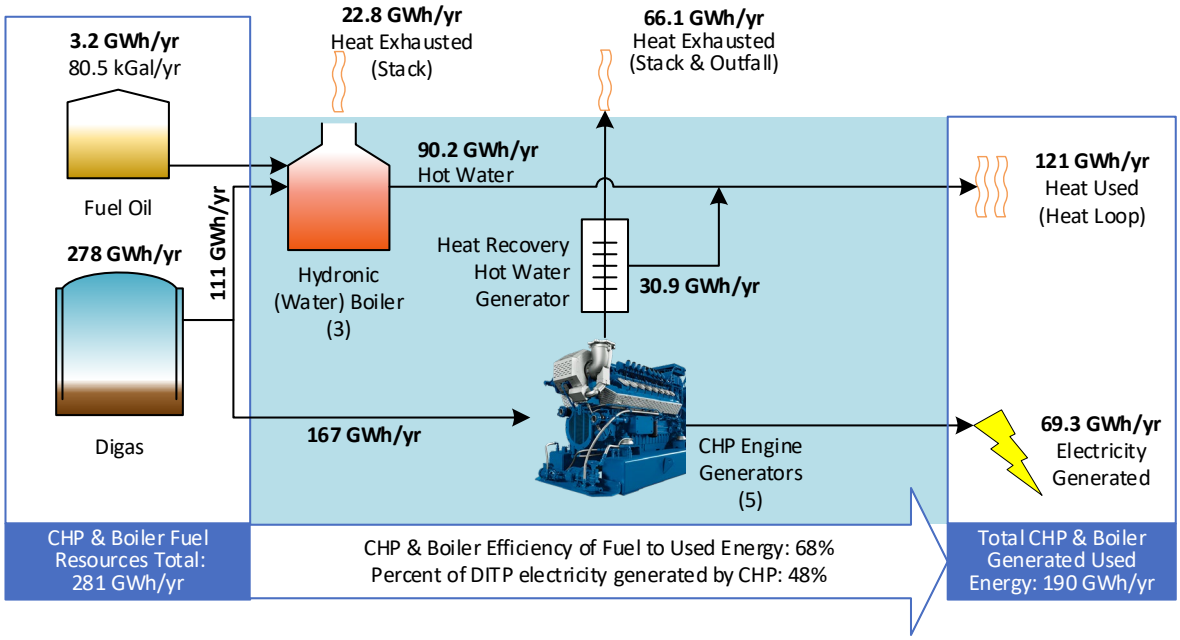

Figure 4 – Schematic of Deer Island's Proposed new CHP

The CHP alternatives analysis performed by Black & Veatch contained a performance simulation that determined the system energy flows. The simulation predicted improvements in efficiency and increases in thermal and electrical demand met from onsite resources with the new combined heat and power system.

A 25-year economic analysis was performed to determine the net present value of operating the existing Thermal/Power Plant and new combined heat and power system, as well as purchasing electricity and boiler fuel oil. The costs to design and construct the new combined heat and power system were also included in the analysis. The net present value was determined by discounting future money to a base year (2021) value using a 6% discount rate. This allowed for the comparison of monetary values over multiple years.

The results of Black & Veatch's analysis were submitted in a report and presented to staff on February 8, 2022. Based on its analysis, Black & Veatch determined, at this time, that continued use of the existing Thermal/Power Plant system would be the most cost effective alternative given that its 25-year net present value is approximately $13.1 million lower ($213.7 million vs. $226.8 million) than the new combined heat and power system.

Subsequent to the submission of Black & Veatch's final report, staff identified a number of topics that should be expanded upon due to their possible impact on net present value results. To accomplish this, staff developed a simulation using Wolfram's Mathematica software, utilizing millions of Deer Island operational data elements and manufacturer performance curves to model the new combined heat and power system. This simulation, which was used by staff to produce an independent analysis while also building upon Black & Veatch's work, identified and further refined the following issues.

- **Adjustment to Estimated Operation and Maintenance Costs**: Black & Veatch's operations and maintenance cost estimates for the Thermal/Power Plant were based on average costs per kilowatt and the amount of electricity generated, rather than a summation of historical maintenance, contract and staff costs for the facility. Staff revised these costs in its analysis. For the new plant, staff utilized the same operations costs as Black & Veatch, but used a lower maintenance cost based upon input received by CHP experts from the University of Maine. These adjustments contributed to an overall increase in the net present value of both the existing Thermal Power Plant and the new combined heat and power system with a greater impact to the existing Thermal Power Plant.

- **Adjustment to Discount Rate:** MWRA's cost of money (discount rate) is a key component of the net present value calculation. In accordance with MWRA's Life Cycle Cost Analysis guidelines, Black & Veatch used a discount rate of 6% to determine net present value. Based on follow-up discussions with MWRA's Finance Department staff, it was determined that an adjusted discount rate of 4% was a more representative figure, while still accounting for recent interest rate volatility.

- **Adjustment to Useful Life of Existing Boilers:** The existing Deer Island boilers have an industry standard design life of 40 years. Black & Veatch estimated that the boilers may have a useful life of 50+ years without the need for interim capital expenditures. Black & Veatch made this determination based on the maintenance history and current condition of the boilers. The extended boiler useful life moved its replacement costs just outside the economic analysis timeframe. Based on staff's experience with other equipment's ability to withstand the harsh conditions at Deer Island, the industry standard of 40-year design life was determined to be a more representative estimate of useful life. This also aligns with a prior assessment that was performed by Brown & Caldwell during a Thermal/Power Plant equipment condition survey performed in 2017.

The modeling performed by staff indicates that these adjustments impact the difference in the 25-year net present value between the existing Thermal/Power Plant system and the new CHP by approximately $56.2 million (from $13.1 million in favor of the existing Thermal/Power Plant to $43.1 million in favor of the new CHP) and are summarized in Table 1.

Table 1 – Results of Staff Modeling

	Consultant Results	Staff Preliminary Results		
Alternative		O&M Adjustment	Discount Rate Adjustment	Boiler Useful Life Adjustment
Existing CHP NPV	$ 214M	$ 233M	$ 290M	$ 328M
New CHP NPV	$ 227M	$ 239M	$ 284M	$ 284M
NPV	**$ +13.1M 6%**	**$ +5.8M 3%** →	**$ -6.5M* 2%** →	**$ -43.1M** 13%**

* Includes O&M adjustment
**Includes O&M and discount rate adjustments

The key metric of Table 1 is NPV , which is the difference between the existing Thermal/Power Plant and the new CHP net present values. A positive NPV indicates that the existing Thermal/ Power Plant is more cost effective than the new CHP over the analysis period, while a negative NPV indicates that the new CHP will be more cost effective. The analysis performed by staff indicates that the cost to construct and operate the new CHP is approximately $43.1 million less than the cost to replace and operate the existing Thermal/Power Plant over the 25-year analysis period.

In addition, staff also considered the following non-economic factors when comparing the existing Thermal/Power Plant to the new CHP:

- **Greenhouse Gas Emissions Reduction:** The new CHP would reduce the greenhouse gas emissions of Deer Island by reducing the amount of fuel oil consumed and electricity purchased. This does not account for renewable energy certificate purchases and sales, the inclusion of which would further decrease overall greenhouse gas emissions reduction. The reduction in greenhouse gas emissions expressed in metric tons per year and, to put it into perspective, the number of miles one would have to drive an automobile are summarized as follows:

  - Fuel Oil Consumed: 300,000 gallons/year reduction = 3,000 metric tons greenhouse gas /year = 8 million car miles/year
  - Electricity Purchased: 40 GWh/year reduction = 13,800 metric tons greenhouse gas /year = 34 million car miles/year
  - Total Reduction in Greenhouse Gas Emissions: 16,800 metric tons greenhouse gas /year = 42 million car miles/year

  Further, the social cost of carbon was estimated in an attempt to quantify the adverse economic impacts resulting from carbon in greenhouse gas emissions. While it is not revenue that MWRA would receive, it instead represents the potential benefit to the public of not emitting carbon. The rate is based on the results from a U.S. Presidential Interagency Working Group convened in 2009 to develop a social cost of carbon metric for the use of federal agencies. Using this rate the new CHP would result in a reduction of approximately $775,000 per year in Deer Island's social cost of carbon impact.

- **Increase On-Site Generation:** Along with greenhouse gas reduction is the goal of increasing the percentage of energy used at Deer Island that is generated on site. Currently, Deer Island generates 57% (by energy) to 65% (by cost) of its energy demand from onsite resources. With the new CHP, Deer Island would generate approximately 74% (by energy) to 78% (by cost) of its energy demand from on-site resources.

- **Fuel Oil Use Reduction:** Executive Order 594, Leading by Example: Decarbonizing and Minimizing Environmental Impacts of State Government sets as one of its goals the reduction of fuel oil use for heating. The new CHP will reduce Deer Island's fuel oil consumption by approximately 300,000 gallons per year, which will result in the elimination of 30 tanker truck deliveries per year.

Figure 5 - Fuel Oil Delivery at Deer Island

- **Elimination of High Pressure Steam System:** The switch to water-based hydronic boilers will eliminate hazards that accompany the operation of high-pressure steam boilers. This may also reduce operator licensing requirements making it easier to fill staffing positions that have been historically difficult to fill.

The combination of the analyses performed under Contract 6963A and the follow-up analyses performed by staff play a critical role in the development of the capital planning process for Deer Island's CHP. Staff have gained a better understanding of the performance of the existing Thermal/ Power Plant while also providing confirmation that a new CHP is viable from both an economic and environmental standpoint.

Next Steps:

The recommended next step is to procure the services of a consultant to prepare a detailed design for the new CHP. This effort would also include a conceptual design to confirm the results of staff's investigation as well as determine the location and optimal number of combined heat and power system units.

BUDGET/FISCAL IMPACTS:

The proposed FY23 CIP includes two projects related to the new CHP: 1) Contract 6730 CHP Design/Engineering Services during Construction and Resident Engineering ($11.4 million) and 2) Contract 6964 Combined Heat and Power System construction ($95.0 million). Black & Veatch estimated the design and construction cost of the new CHP to be $82.3 million.