Old Dominion University

Engineering Management and Systems Engineering Department

ENMA 605 Program Capstone

Final Project

# Analytic Hierarchy and Economic Analysis of a Plasma Gasification System for Naval Air Station Oceana-Dam Neck

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# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



1. REPORT DATE
**30 AUG 2014**

2. REPORT TYPE

3. DATES COVERED

4. TITLE AND SUBTITLE
**Analytic Hierarchy and Economic Analysis of a Plasma Gasification System for Naval Air Station Oceana-Dam Neck**

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited.**

13. SUPPLEMENTARY NOTES

14. ABSTRACT
**The overall objective of this project was to determine if a plasma gasification system is a possible alternative to the current system of MSW disposal and energy production for NAS Oceana.Through this analysis it is determined that the plasma gasification system can be provided with an adequate feedstock supply and results in a net positive financial return. Additional benefits may also be developed through new local employment opportunities and sustainable environmental practices.**

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | |
| **unclassified** | **unclassified** | **unclassified** | | **51** | |

**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

## Executive Summary

**Background:** Naval Air Station (NAS) Oceana-Dam Neck is a Master Jet Base located in Virginia Beach that currently has a population of over 28,000, this includes active duty military, family members and civilian employees. Currently the Public Works Department of Oceana maintains a contract with a municipal solid waste (MSW) Disposal Company for the collection of MSW generated on the base and disposal at a local landfill. Additionally the base receives its energy requirements from Dominion Virginia Power. In utilizing these services a substantial amount of financial resources must be committed to ensure an uninterrupted supply of these services and to maintain the infrastructure on base to supply them. Investment in a plasma gasification system allows for the opportunity to reduce the financial requirements of both of these demands as it provides for the disposal of MSW and in the process generates power for base usage. The plasma gasification system utilizes a plasma torch to ionize gas and organic matter, typically MSW, into synthetic gas and sag. The synthetic gas consists of carbon monoxide and $H_2$, which can be utilized as a liquid or gas fuel for electrical or thermal energy generation. Thus in utilizing a plasma system two problems are potentially solved by this one solution.

**Purpose and Objectives:** The overall objective of this project was to determine if a plasma gasification system is a possible alternative to the current system of MSW disposal and energy production for NAS Oceana. In order to determine this the following objectives were established:

1. Apply engineering management principles and techniques to determine if investment in a plasma gasification system would be a possible alternative to current practices.
2. Evaluate various models of gasifiers through a developed Analytical Hierarchical Process (AHP) model to determine the best model option.
3. Evaluate the economic benefits against economic costs to determine if investment in a gasification system is economically beneficial.
4. Make a final recommendation based on the findings of the analysis.

**General Approach:** The overall design of this project was to evaluate a new option for the disposal of MSW generated by NAS Oceana-Dam Neck. The approach used collected all non-classified data that could be made available from NAS Oceana-Dam Neck and other regional base public works departments regarding MSW produced and energy demands of the bases. Using the provided data on MSW, a comparison was made to the capabilities of several models of plasma gasifiers produced by the Westinghouse Plasma Corporation. Various attributes of the plasma gasifier models were applied to an Analytical Hierarchy Process (AHP) model. The attributes evaluated included cost, waste disposal capabilities, power generation capabilities and fossil fuel replacement capabilities. Once a model was selected an economic analysis was conducted to compare the initial investment costs to the operational lifetime savings. The economic model included potential savings on MSW disposal and electrical costs and calculated these savings to a net present value for comparison.

**Findings:** The results from the analysis show that the P5 plasma gasifier model, produce by Westinghouse Plasma Corporation, is the best choice for this project.

However, this recommendation is only valid if MSW is collected from several regional military bases, not just NAS Oceana.  By utilizing the P5 model of gasifier a positive return is found to be over $7.7 million.

**Recommendations:** Through this analysis it is determined that the plasma gasification system can be provided with an adequate feedstock supply and results in a net positive financial return.  Additional benefits may also be developed through new local employment opportunities and sustainable environmental practices.  It is therefore recommended that a full feasibility analysis of the capabilities, economic and environmental impact of a plasma gasification system for NAS Oceana be conducted.

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## ACKNOWLEDGEMENTS/DISCLAIMERS

While this project was to evaluate the possibility of constructing and operating a plasma gasification system on Naval Air Station Oceana-Dam Neck, no classified material was used in this report, nor does this report represent possible business opportunities at the air station.

The author would like to thank the members of the Public Works Department of Naval Air Station Oceana-Dam Neck, Joint Expeditionary Base Little Creek and Naval Medical Center Portsmouth for providing data regarding energy usage and municipal solid waste tonnage generated by the regional bases.

## BACKGROUND

### General Focus of the Project

The need for a military base to dispose of Municipal Solid Waste (MSW) and provide power for its buildings and operations will always be required of the base public works division. Due to a continuing need, variable energy costs and limited land availability for new landfills, the costs associated with these services can only be expected to rise. In order to control or reduce these costs alternative solutions must be evaluated. In Fiscal Year 2013 Naval Air Station (NAS) Oceana-Dam Neck generated over 4,800 tons of waste for disposal at a cost of over $766,000 and it is expected that this volume will increase along with the disposal costs. While the disposal of MSW is not directly related to mission readiness, its proper disposal can impact base appearance and sanitation. Additionally as the cost of disposal increases funds may be drawn from other areas such as training or housing, which could impact mission readiness. Another base service that requires a large amount of financial resources is electrical power. In Fiscal Year 2013 NAS Oceana-Dam Neck spent almost $15 million for electrical power. As global energy costs rise it can be expected that the NAS Oceana will also see an increase in energy costs.

This project will conduct an analysis of the volume of MSW generated by NAS Oceana-Dam Neck with the disposal capabilities of various models of plasma gasifiers. Upon selection of a suitable plasma gasifier model, an economic analysis will be done to evaluate the expected upfront investment costs versus the expected disposal and energy savings. These expected savings will then be applied to the planned operating life of the gasifer.

**Plasma Gasification**

Plasma gasification is a process that utilizes plasma to convert organic matter, hazardous waste and industrial waste into synthetic gas (Syn-Gas) and slag. For this study, the focus will be on the disposal of municipal solid waste. However, there is a range of materials that can be disposed of using plasma gasification, as described in the IUP Journal of Chemical Engineering (Mehti, Christian, Mistry and Mukhopadhyay, 2010):

> Plasma gasification can be used to treat a wide variety of wastes including municipal solid wastes, sludge from treatment plants, electric arc furnace dust, car fluff, municipal solid waste, automobile tires, biomedical waste, titanium scrap melt, waste coal, asbestos containing material, pathological wastes, contaminated soils, glass waste, hazardous fly ash, solvents, ceramic waste, incinerator ash, paints, cement manufacture waste, steel scrap, low level

radioactive waste, contaminated landfill waste, mixed source waste which is a combination of different waste source with municipal solid waste, ash, coal.

The plasma gasification system operates through various stages, with the primary stage being the plasma chemical reactor. It is here where the waste, otherwise known as feedstock, is supplied into the reactor from the top and gravitationally forced to the bottom. An article published in Applied Energy (Zhang, Dor, Fenigshtein, Yang and Blasiak 2012) provides details of the reactor process provided below. Additionally, the illustration in Figure 1 from The National Energy Technology Laboratory (National Energy Technology Laboratory, 2013) provides a visual of the process.

> The gasification agents, which are air and high-temperature steam (1000 °C), are injected into the lower part of the reactor from various nozzles. A part of the air, called plasma air, is injected into the reactor from four plasma torches, which are embedded into the reactor at the upper surface of the melting chamber. Electrical arcs are formed between electrodes at the tip of the plasma torches, so that air flowing through the arc is ionized and forms a plasma jet that extends beyond the tips of the torches. The temperature of the plasma jet may reach up to 6000 °C. The power of the plasma torches can be controlled by the central control system. Additional air, known as secondary air, is fed into the reactor from nozzles surrounding the plasma torches. High-temperature steam nozzles are located at the lower part of the gasifier. The feed rates of both secondary air and steam are adjustable and controlled by the central control system.

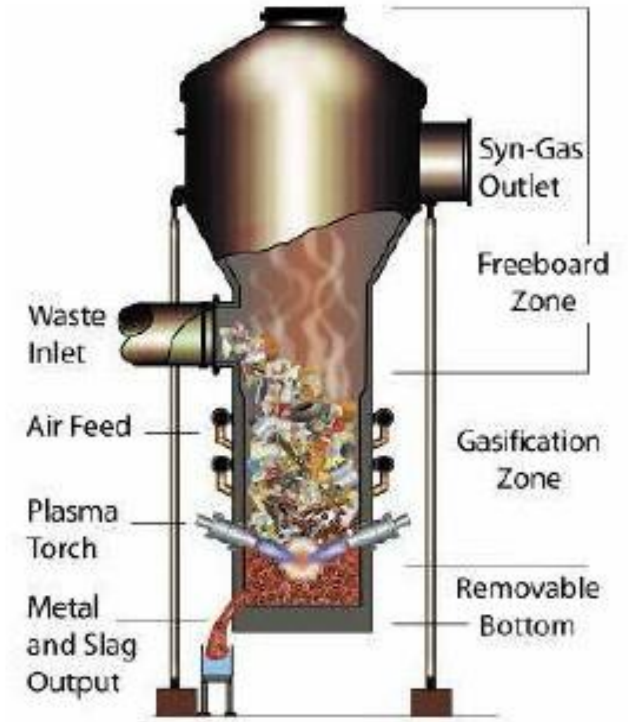


**Figure 1: Plasma Chemical Reactor**

The two primary by-products resulting from the gasification process are molten slag, which is collected through a portal at the base of the reactor, and Syn-Gas collected at the top of and within the reaction chamber (Zhang, Wu, Dor, Yang and Blasiak 2013):

> Reactions related to fixed-bed gasification occur in the waste column, and finally produces a combustible gas mixture known as syngas. The main combustible species in the syngas are CO, H2 and LHCs. At the syngas exit, the gas temperature is about 200–400 °C. By using the PGM (Plasma Gasification and Melting) technology, multiple objectives such as waste elimination, energy

recovery and benign slag product can be achieved in one single process chamber.

**Naval Air Station Oceana-Dam Neck**

Naval Air Station Oceana-Dam Neck is the Navy's East Coast Master Jet Base and is home to F/A-18 Hornet and Super Hornet squadrons.  The mission of NAS Oceana is to provide the facilities, equipment and personnel to support shore-based readiness, total force readiness and maintain operational access of Oceana based forces.  The base includes around 10,500 active duty personnel, 10,000 family members and 4,500 civilian personnel (CNIC).

**Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic**

The Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic Region provides base public works and contract support for Naval Air Station Oceana-Dam Neck through facility maintenance, management of base support contracts and services and management of construction projects.  The NAVFAC organization employs civilian, military and contractor personnel to complete this mission. While NAS Oceana is able to request assistance from NAVFAC for facility repairs, NAVFAC oversees project and maintenance budgets, scheduling and maintenance personnel management with minimal guidance from Oceana.

**Commander, Navy Installations Command (CNIC)**

The Commander, Navy Installations Command (CNIC) is responsible for the worldwide shore based installation support for the United States Navy under the Chief of Naval Operations.  By this direction the CNIC's mission is to support the Fleet, Fighter and Family. In supporting these three areas CNIC ensures that all instillation requirements that are necessary to operate fleets are maintained and ready. It also ensures that the installations are able to facilitate the manning, training and equipping of the Navy's personnel. Lastly it ensures the housing, safety and quality of life is supported on the installations

### Project Importance

As the US military faces continuing budget cuts, with a proposed reduction of over $75 billion for the next two years (Simeone, 2014), alternatives that can reduce base operating costs need to be evaluated. By analyzing the investment of plasma gasification technology for NAS Oceana-Dam Neck the possibility to see dramatic savings in MSW disposal and energy costs are promising. Plasma technology is not new to the US Navy and has already been accepted for the newest aircraft carrier. The USS Gerald R. Ford will operate a Plasma Arc Waste Destruction System (PAWDS) (Alexander, 2008) for its solid waste disposal at sea. By conducting this analysis of a plasma gasification system for a shore facility an opportunity to evaluate new technology that could ultimately lead to operating budget savings can be presented.

## PROJECT DEFINITION

### Purpose

The purpose of this project is to evaluate a plasma gasification system for Naval Air Station Oceana-Dam Neck and determine if the selected model's MSW disposal and energy savings will be enough to offset the high initial investment.

## Project Objectives

In order to complete the purpose of the project the following objectives must be met:

1. Apply engineering management principles and techniques to determine if investment in a plasma gasification system would be a possible alternative to current practices.
2. Evaluate various models of gasifiers through a developed Analytical Hierarchical Process (AHP) model to determine the best model option.
3. Evaluate the economic benefits against economic costs to determine if investment in a gasification system is economically beneficial.
4. Make a final recommendation based on the findings of the analysis.

## PROJECT SCOPE

While the original scope of this project was to be limited to evaluating the volume of generated MSW at NAS Oceana-Dam Neck and comparing this amount with the capabilities of various models of plasma gasification systems. Upon receiving actual data on the annual tonnage of MSW produced by Oceana it was found to be inadequate when applied to the capabilities of the various plasma gasifier models. Due to this limitation the MSW to be disposed of will be expanded to include not only NAS Oceana, but also Naval Station Norfolk, JEB Little Creek and the Norfolk Naval Shipyard. From the available gasifier models an analytic hierarchical analysis will be conducted to select the optimal model for the air station. Once the model is selected an economic analysis will be conducted to evaluate the initial investment costs with the predicted energy and MSW disposal savings.  This project scope did not include any environmental impact studies that would be required nor did it include any public opinion surveys for the construction of the gasification system.   Additionally, an analysis will not be conducted on the shut down and demolition of the gasifier at the end of its useful life.

**Assumptions**

Several assumptions were developed in the project proposal phase and they will be held to in the final phase.  Additional assumptions regarding the plasma gasification system's operational life, optimal operation times and maintenance schedules had to be made.  This was done after contact with the Westinghouse Plasma Corporation and this information could not be made available.  The following is an excerpt from an email by Westinghouse: "The information that you are asking for is proprietary and would require us to exercise our engineers for data. We can't do that at this time as we don't have the resources to support your request."

1. If the project was approved, adequate funding for construction and continual operation would be available for the life of the project.
2. The initial investment cost is to include design, permits, construction and initial start-up and training.
3. The cost of the plasma gasification system is based on information available on the Westinghouse Plasma Corporation's website.
4. The gasification system will perform as described by manufacturers, academic and scientific journals.

5. An expected operational life of 30 years will be expected with regular preventative maintenance.
6. An additional 5 years of useful operation is possible, but at a reduction of 10% efficiency per year after 30 years.
7. Optimal operation will be 14 hours daily with a one hour start up and one hour shut down, with a complete shutdown one day a month for maintenance.
8. A two week shutdown period (not congruent) per year will be required for upgrades and major maintenance.
9. MSW disposal costs will be assumed to be reduced by 80% as collection, transportation, operation and other overhead costs will still be required.

**Project Significance**

Locally, this project will impact NAS Oceana-Dam Neck, surrounding bases and the local community in the following ways:

1. A plasma gasification system has the potential to reduce the MSW disposal costs for NAS Oceana-Dam Neck and other regional bases.
2. A plasma gasification system could provide an alternative energy source for electrical requirements of NAS Oceana.
3. By disposing of MSW through the use of a plasma gasification system, less MSW will be put into other local landfills. This could result in extending the landfill life and reduce the need for new landfill development.

4. Implementing a plasma gasification system will result in a reduction of locally produced greenhouse gases by reducing transportation requirements and decomposing MSW in landfills.
5. This analysis could provide a model for other regional waste disposal options.
6. Additional jobs could be created for the construction and operation of the system.

This project has a potential to provide a global impact in the following ways:

1. This analysis could provide a potential model for other military bases and communities to evaluate a plasma gasification system.
2. A local reduction in greenhouse gas emissions can provide a global impact on the effects of climate change.
3. The implementation of a plasma gasification system will support the implementation of new technology throughout the world.

## PROJECT APPROACH

### Project Design Overview

The overall design of this project was to evaluate a new option for the disposal of MSW generated by NAS Oceana-Dam Neck. The approach used collected all non-classified data that could be made available from NAS Oceana-Dam Neck and other regional base public works departments regarding MSW produced and energy demands of the bases. Using the provided data on MSW, a comparison was made to the capabilities of several models of plasma gasifiers produced by the Westinghouse

Plasma Corporation. From this comparison and an analytical hierarchical analysis of various attributes of the models a best choice was determined. Upon selection of the best model an economic analysis was conducted that evaluated the required upfront investment in the gasifier to the expected savings in MSW disposal and energy over the operational life of the gasifier.

**Specific Project Design**

**Data Collection**

Throughout the planning, development and finalization of this report regular contact was made with members of the NAVFAC team at NAS Oceana-Dam Neck and JEB Little Creek. These team members provided valuable data regarding the tonnage of solid waste produced for the naval bases with in the region. They also provided data on the electrical costs and usage for individual buildings on NAS Oceana-Dam Neck.

Solid waste data was provided for Fiscal Year 2013 from the Integrated Solid Waste Management Plan (ISWMP) Supervisor who oversees MSW disposal for the regional bases. Table 1 show the total tonnage produced by each base in FY-13 and the associated costs for disposal.

| FY-13 MUNCIPAL SOLID WASTE PRODUCED | | |
|---|---|---|
| HAMPTON ROADS SITES | TONS | COST |
| Naval Station Norfolk | 12711.45 | $ 2,977,103.42 |
| JEB Little Creek/Fort Story | 4006.63 | $ 986,778.00 |
| Naval Air Station Oceana | 4861.79 | $ 766,464.00 |
| Norfolk Naval Shipyard | 3734.95 | $ 1,936,674.00 |
| | 25314.82 | $ 6,667,019.42 |

**Table 1: MSW Tonnage by Base**

Data regarding the electrical demand of individual buildings on NAS Oceana-Dam Neck was provided by the Power and Utilities Manager of the air station. This data listed the megawatt hours used per building by month, quarter and year. The data also provided the cost per megawatt hour as $102.55. The spreadsheet showing Oceana usage is included in Appendix A, only the FY total and Quarterly usage is shown due to the spreadsheet size.

Data regarding the capabilities of various plasma gasification system models was obtained through the Westinghouse Plasma Corporation's website. Table 2 and Figure 2 show the MSW disposal capabilities for various models of plasma gasifiers along with the electrical power generation capabilities. A request for more specific capabilities and requirements of the models was denied by Westinghouse as it was deemed proprietary.

| Gasifier Model | Capacity (tpd of MSW) | Syngas Produced ($NM^3$/hr) | Syngas Chemical Energy, HHV (GJ/yr) | Combined Cycle Power Plant (MW gross/net) | FT Liquids BPD / BPY | Fossil Fuel Replacement (bbls/year) |
|---|---|---|---|---|---|---|
| G65 | 1000 | 65,000 | 4,100,000 | 58 / 39 | 785 / 287,000 | 670,000 |
| W15 | 290 | 15,000 | 976,000 | 14 / 9 | 188 / 68,000 | 160,000 |
| P5 | 100 | 5,000 | 323,000 | 4.5 / 3 | 62 / 23,000 | 50,000 |

**Table 2: Plasma Gasifier Model Capabilities**

*P 5*
- Replaces up to 50,000 bbls/yr of fossil fuel
- 30 to 100 tpd of Waste
- Produces up to 5 MW electrical

*W 15*
- Replaces up to 150,000 bbls/yr of fossil fuel
- 100 to 290 tpd of Waste
- Produces up to 15 MW electrical

*G 65*
- Replaces up to 650,000 bbls/yr of fossil fuel
- 450 to 1000 tpd of Waste
- Produces up to 50 MW electrical

**Figure 2: Plasma Gasifier Model Capabilities**

Due to the costs of investment in a plasma gasifier being proprietary, every effort was made to develop an accurate estimate for the three models that will be evaluated. The Westinghouse Plasma Corporation lists prices as ranging from $30-$300 million for a plasma gasification system. Table 3 lists the estimated cost for the three models of plasma gasifiers that will be evaluated.

| Model | Estimated Cost |
|---|---|
| P 5 | $ 120 Million |
| W 15 | $210 Million |
| G 65 | $290 Million |

**Table 3: Plasma Gasifier Model Estimated Cost**

Data collection for the economic analysis of this project was gathered through publicly available information. The inflation rate used was 2.3% as this was the most current rate for 2013-2014 from the US Bureau of Labor Statistics. In calculating the net present value of the predicted costs and savings of the project a Minimum Acceptable Rate of Return (MARR) of 6% will be utilized. This is due to this project likely being a capital investment project (Lang & Merino, 1993).

### Data Analysis Plan

The three types of plasma gasification systems produced by the Westinghouse Corporation were evaluated in the Analytic Hierarchy Process (AHP) model. The process involves a decision maker establishing and ranking attributes related to a problem, and then analyzing them to find and prioritize decision alternatives and arrive at the best choice (Anderson, Martin, Sweeney, & Williams, 2008).

Utilizing an AHP begins with the definition of the problem. During this step, a three tier hierarchy is created that states the final goal, the attributes, and the alternatives for the problem. Comparison matrices are then developed that perform a pair-wise comparison to establish weights for the attributes. The weights are established through synthesization by the following steps: Sum values in matrix columns, divide each element value in the comparison by the column sum (normalized pair-wise comparison matrix), and calculate the average of the elements in each row of the normalized pair-wise comparison. The established weights are then applied to comparison matrices for the alternatives in order to normalize them. This last comparison provides a final score for each of the alternatives. The resulting highest score should provide the decision maker with the best decision (Anderson, Martin, Sweeney, & Williams, 2008).

The attributes of the plasma gasification systems that were applied to the AHP, through pair-wise comparison matrices, were the power generation capability, MSW disposal capability, fossil fuel replacement capability and initial purchase cost. These attributes and alternatives are shown in a three tier hierarchy tree in Figure 3. The attributes were evaluated through the AHP to normalize them and determine the highest weighted attributes for the model selection.

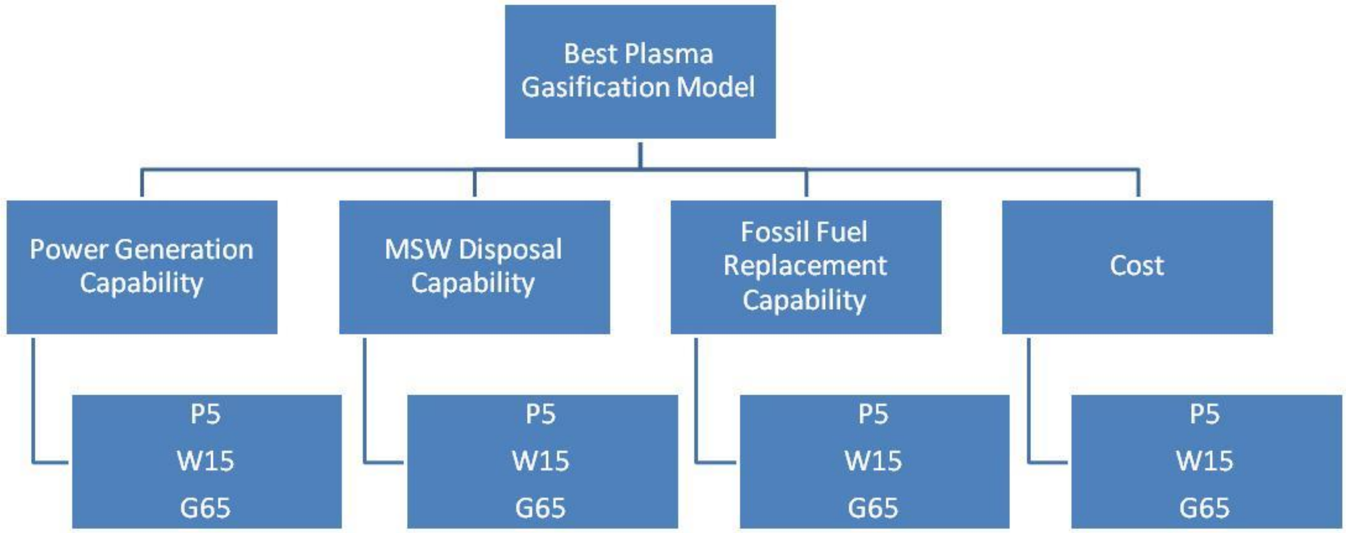


**Figure 3: Hierarchy Tree for Plasma Gasification Model**

The economic model utilized the data for costs of MSW disposal and electrical power for Oceana to determine total current costs and calculate expected future costs when adjusted for inflation. This calculation was done for both a 30 and 35 year period. The energy savings were found using the expected electrical generation capabilities of the plasma gasifier based on the expected tonnage per day for the gasifier. The expected electrical generation is based on the capabilities listed for the three models of gasifiers listed in Figure 2. Using this information and applying linear interpolation (Figure 4), with the expected tonnage, a value of daily megawatt was calculated.

$$\frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0}$$

**Figure 4: Linear Interpolation**

This daily megawatt output was then converted into annual megawatt hours by multiplying it to the daily hours of operation and to the days per year the gasifier is in operation. The days of operation were determined to be 289 days per year, with the following non-operational days put into the schedule: 14 day annual maintenance, 12 days for monthly maintenance conducted on Sundays when scheduled to be non-operational, 40 remaining Sundays and 10 federal holidays.

The calculated savings from MSW disposal and energy generation was then applied to the 30 and 35 five year periods previously discussed and a total savings for each year was found. A Net Present Value formula, see Figure 5, was then applied to these annual amounts with a MARR value of 6% to find the present value of these savings to be compared with the expected initial investment costs of the plasma gasification system.

$$\mathrm{NPV}(i) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

**Figure 5: Net Present Value**

**Results of Data Collection**

The AHP model for selecting the optimal plasma gasifier model found the P5 model to be the best choice for this project. The comparison rating used in the pairwise comparison of attributes is shown in Table 4.

| Intensity | Definition | Explanation |
|---|---|---|
| 1 | Equal Importance | Two Attributes Contribute Equally |
| 2 | Weak | |
| 3 | Moderate | Slight Favor of one over the other |
| 4 | Moderate Plus | |
| 5 | Strong | Strongly favor one over the other |
| 6 | Strong Plus | |
| 7 | Very Strong | Very Strongly favor over the other |
| 8 | Very, Very Strong | |
| 9 | Extreme Importance | Highest possible preference of one attribute over the other |

**Table 4: Attribute Comparison Rating**

When these ratings are applied to the pairwise comparison of attributes a calculated weight for each attribute is found and shown in Figure 6.

| | Power Generation Capability | Waste Disposal Capability | Fossil Fuel Replacement Capability | Cost |
|---|---|---|---|---|
| Power Generation Capability | 1.00 | 0.25 | 7.00 | 0.17 |
| Waste Disposal Capability | 4.00 | 1.00 | 8.00 | 0.20 |
| Fossil Fuel Replacement Capability | 0.14 | 0.13 | 1.00 | 0.13 |
| Cost | 6.00 | 5.00 | 8.00 | 1.00 |
| Sum | 11.14 | 6.38 | 24.00 | 1.49 |

| | Power Generation Capability | MSW Disposal Capability | Fossil Fuel Replacement Capability | Cost | Weight |
|---|---|---|---|---|---|
| Power Generation Capability | 0.09 | 0.04 | 0.29 | 0.11 | 0.13 |
| MSW Disposal Capability | 0.36 | 0.16 | 0.33 | 0.13 | 0.25 |
| Fossil Fuel Replacement Capability | 0.01 | 0.02 | 0.04 | 0.08 | 0.04 |
| Cost | 0.54 | 0.78 | 0.33 | 0.67 | 0.58 |

**Figure 6: Pairwise Attribute Comparison and Weight**

A comparison of the weight for each attribute is presented in a bar graph in Figure 7 with cost found to be the highest weighted attribute for the initial investment in a plasma gasification system.

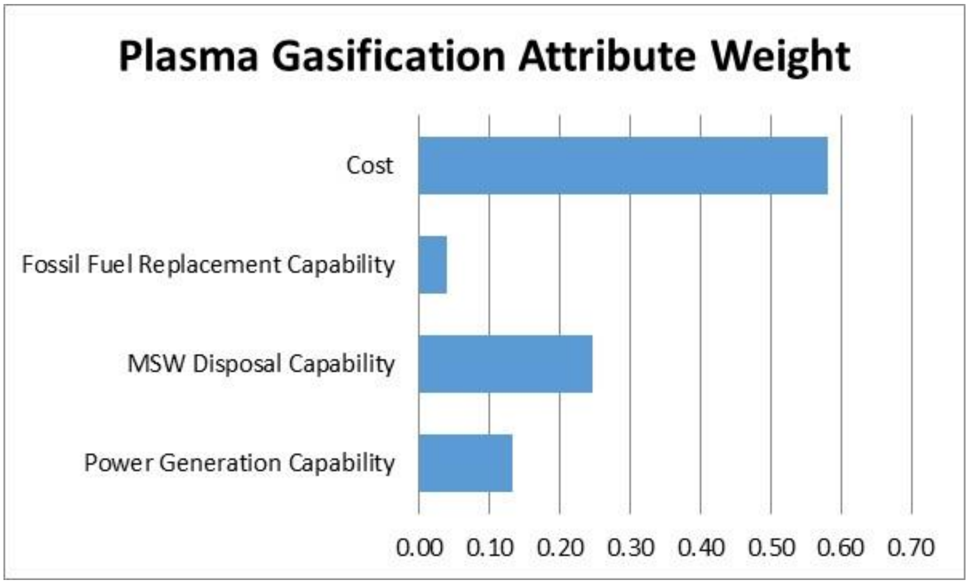


**Figure 7: Attribute Weight Comparison**

With the attribute weight calculated these attributes were then applied to the three models of plasma gasification systems previously shown in Table and Figure 2. Figure 8 shows the pairwise comparison of the gasifier models to attributes and the calculated weight for each model with respect to each attribute. The gasifier model weight with respect to attribute is also shown in Figure 9 in several bar graphs. While the weighted attributes show the G65 model having a larger weight in three of the four attributes. The P5 model has a significantly higher weight in the cost attribute. With cost being the highest weighted attribute, the P5 model is found to be the best choice for this analysis.

| | Power Generation Capability | | |
|---|---|---|---|
| Plasma Gasifier Model | P5 | W15 | G65 |
| P5 | 1.00 | 0.20 | 0.13 |
| W15 | 5.00 | 1.00 | 0.20 |
| G65 | 8.00 | 5.00 | 1.00 |
| Sum | 14.00 | 6.20 | 1.33 |

| | Fossil Fuel Replacement Capability | | |
|---|---|---|---|
| Plasma Gasifier Model | P5 | W15 | G65 |
| P5 | 1.00 | 0.20 | 0.11 |
| W15 | 5.00 | 1.00 | 0.17 |
| G65 | 9.00 | 6.00 | 1.00 |
| Sum | 15.00 | 7.20 | 1.28 |

| | Power Generation Capability | | | |
|---|---|---|---|---|
| Plasma Gasifier Model | P5 | W15 | G65 | Weight |
| P5 | 0.07 | 0.03 | 0.09 | 0.07 |
| W15 | 0.36 | 0.16 | 0.15 | 0.22 |
| G65 | 0.57 | 0.81 | 0.75 | 0.71 |

| | Fossil Fuel Replacement Capability | | | |
|---|---|---|---|---|
| Plasma Gasifier Model | P5 | W15 | G65 | Weight |
| P5 | 0.07 | 0.03 | 0.09 | 0.06 |
| W15 | 0.33 | 0.14 | 0.13 | 0.20 |
| G65 | 0.60 | 0.83 | 0.78 | 0.74 |

| | MSW Disposal Capability | | |
|---|---|---|---|
| Plasma Gasifier Model | P5 | W15 | G65 |
| P5 | 1.00 | 0.25 | 0.13 |
| W15 | 4.00 | 1.00 | 0.17 |
| G65 | 8.00 | 6.00 | 1.00 |
| Sum | 13.00 | 7.25 | 1.29 |

| | Cost | | |
|---|---|---|---|
| Plasma Gasifier Model | P5 | W15 | G65 |
| P5 | 1.00 | 5.00 | 7.00 |
| W15 | 0.20 | 1.00 | 4.00 |
| G65 | 0.14 | 0.25 | 1.00 |
| Sum | 1.34 | 6.25 | 12.00 |

| | MSW Disposal Capability | | | |
|---|---|---|---|---|
| Plasma Gasifier Model | P5 | W15 | G65 | Weight |
| P5 | 0.08 | 0.03 | 0.10 | 0.07 |
| W15 | 0.31 | 0.14 | 0.13 | 0.19 |
| G65 | 0.62 | 0.83 | 0.77 | 0.74 |

| | Cost | | | |
|---|---|---|---|---|
| Plasma Gasifier Model | P5 | W15 | G65 | Weight |
| P5 | 0.74 | 0.80 | 0.58 | 0.71 |
| W15 | 0.15 | 0.16 | 0.33 | 0.21 |
| G65 | 0.11 | 0.04 | 0.08 | 0.08 |

**Figure 8: Gasifier Model Comparison**

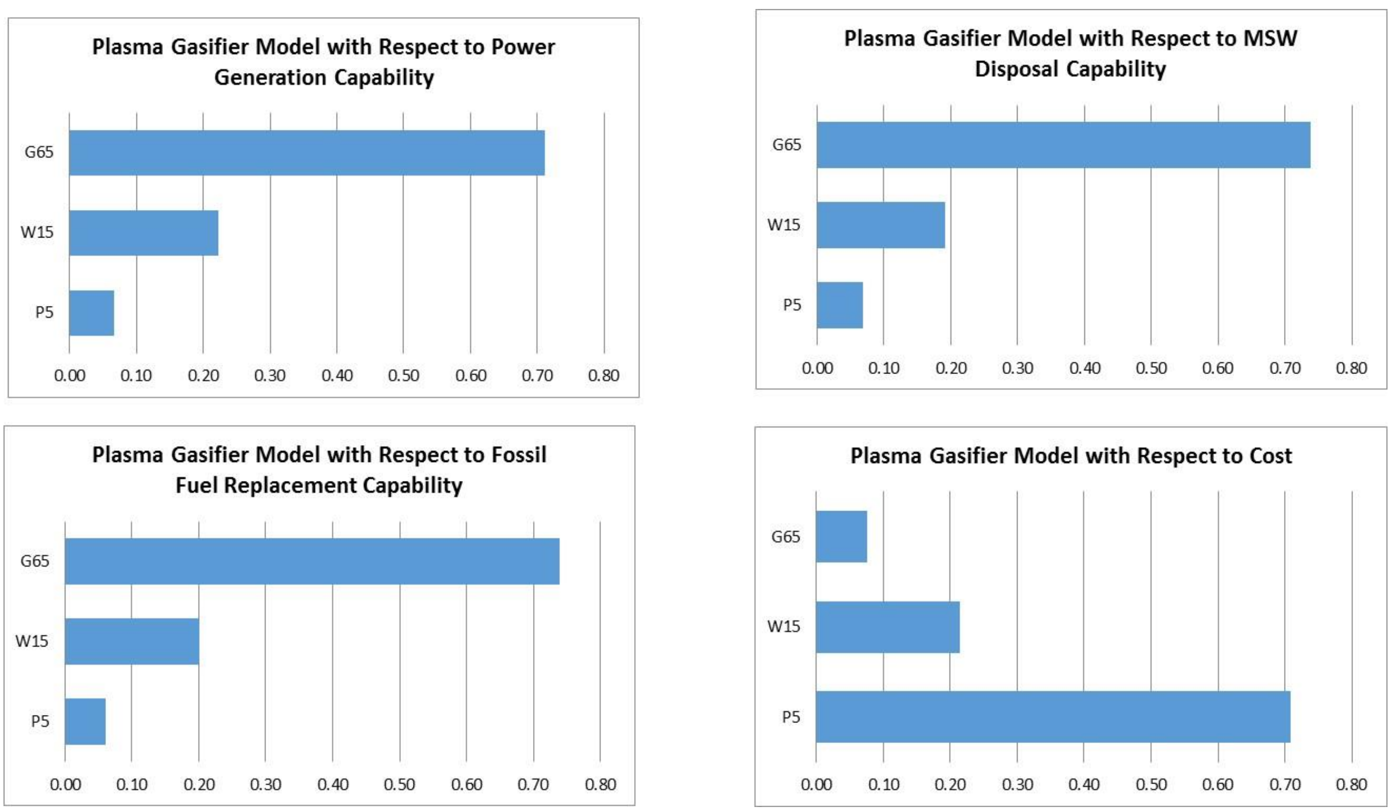


**Figure 9: Weighted Gasifier Model Comparison**

Once the P5 model was selected as the best option for this analysis, its initial investment cost ($120 million) and capabilities were applied to the economic analysis of the project, Appendix B shows the full economic analysis. The first savings to be analyzed were the projected savings for the disposal of MSW. This was expected to be an 80% reduction in annual disposal costs when compared to the current system. This savings was then applied to the 30 and 35 year analysis period.

The potential electrical energy savings of the selected P5 model were then calculated and applied to the economic analysis. With the P5 model being selected it was determined through linear interpolation that this model was capable of producing 4.38 MW of power daily. This is based on the calculated 87.6 tons per day of feedstock that could be provided. When the 4.38 MW is converted into megawatt hours generated per year a total of 15,189.84 megawatt hours is found. This value was then applied to the 30 year expected operational life of the gasifier. This value was also applied to the 35 year life with a reduction of 10% per year for years 31-35.

Once the projected annual savings of the plasma gasifier were calculated, a net present value calculation was performed with a MARR of 6%. This calculation was done for a 30 and 35 year operational life. The results of this calculation show that with a 30 year operational life a $118.6 million NPV occurs. This is just less than the predicted $120 million initial investment cost for the P5 model. When the 35 year operational life is used the NPV is $127.7 million, which provides a positive return when compared to the initial investment cost. Table 5 shows the comparison of the initial investment to the NPV for the 30 and 35 year time periods.

| | |
|---|---|
| Initial Investment for P5 Gasifier | $120,000,000.00 |
| NPV-30 years | $118,610,919.13 |
| NPV-35 years | $127,749,835.10 |

**Table 5: NPV Comparison**

## PROJECT MANAGEMENT PLAN

### Schedule

The schedule for this project with the major milestones is shown below.

| Milestone | Date |
|---|---|
| Project Proposal Submission | 20 June 2014 |
| Technology Research | 3 July 2014 |
| Data Collection | 15 July 2014 |
| Data Evaluation | 25 July 2014 |
| AHP Application | 31 July 2014 |
| Economic Analysis Application | 31 July 2014 |
| Evaluation of Results | 3 August 2014 |
| Conclusion | 5 August 2014 |
| Final Report Submission | 8 August 2014 |
| Program Assessment | 9 August 2014 |

### Deliverables

Old Dominion University:

1. Project Final Report in accordance with ENMA 605 Course Requirements.
2. Program Assessment in accordance with ENMA 605 Course Requirements.

US Navy:

1. Copy of final report to Naval Post Graduate School under code 031A.
2. Copy to Civil Engineer Corp Officer School for inclusion in reference library.

**Controls**

This project was undertaken with only the effort of the author for the requirements of ENMA 605. Due to this restriction the only required controls were to the project submission dates set in the syllabus. However in order to ensure the best project analysis possible, every effort was made to develop accurate cost estimates for this project.

## PROJECT DESIGN ISSUES

While this project was expected to be limited by publically available data regarding proprietary information on plasma gasification systems, there were still design issues that need to be addressed through the course of this analysis. The first design issue was discovered shortly after receiving the data on MSW tonnage produced by each base in the region. After some calculations and comparisons it was discovered that the amount of waste created by NAS Oceana-Dam Neck would not be sufficient to operate or even consider a plasma gasification system. Due to this low volume of feedstock the analysis was expanded to include JEB Little Creek, Naval Station Norfolk and the Norfolk Naval Shipyard as feedstock sources.

The next issue that was partly anticipated is the restricted information regarding plasma gasification system operations. While scientific journals discuss their capabilities, process and potential economic benefits, the data regarding real world operation and maintenance requirements is not readily available. This was confirmed after contact was made with various plasma gasification system manufactures and either no response or a response stating said information could not be made available was returned. Due to this limited information estimates regarding maintenance schedules and requirements, operating costs, operational optimization and energy production needed to be estimated.

## PROJECT RESULTS AND IMPLICATIONS

### Data Interpretation

The selected model P5 has a capacity of 100 tons per day, which is more than the expected 87.6 tons per day. If the volume of MSW was expected to significantly rise over the next 30-35 years the model W15 could be considered. If the W15 model was utilized it is possible the additional costs for purchase and construction of the larger model may greatly exceed any expected savings. Therefore the P5 model should remain the best selection.

The selection of the P5 model is expected to require a $120 million initial investment. If the system only remains operational for 30 years an anticipated loss of around $1.4 million is expected. If the operational life is extended to the 35 years, even with the reduced capacity, a NPV is found to be almost $128 million. This results in a positive gain of almost $8 million.

**Status of Deliverables**

Old Dominion University Deliverables:

1. Project Final Report will be submitted no later than 8 August 2014.
2. Project Assessment will be submitted no later than 9 August 2014

US Navy Deliverables:

The submission of these deliverables also require a copy of the author's final transcripts with degree conferred status. Due to this requirement these two deliverables will be closed no later than 30 September 2014.

**Recommendations Based on Project Results**

**Local Level Implications/Recommendations**

The NPV for the 35 year life show this project would result in a savings of almost $8 million. Based on these findings it is recommended that a more detailed and full analysis be conducted. This analysis should be done utilizing subject matter experts that have detailed experience in these type of studies and have access to proprietary data. Another alternative that could be considered is a partnership with the city of Virginia Beach. This partnership would conduct an analysis for a gasifier at Virginia Beach Landfill #2. Feedstock provided by both base and the local community could provide enough feedstock for a larger model gasifier to be economically beneficial. This could ultimately result in greater savings on disposal costs and a higher volume of energy generation.

Some local implications of this project, should it be developed, could be seen in new job opportunities for the area. Additionally, this could put the region in a leadership position in the use of new technology for sustainable clean energy.

**Local Level Issues Identified as a Result of the Project**

This project was to only conduct an analysis of plasma gasifier models and the economic benefits of the system. However, if a proposal to construct a plasma gasification system was presented there are likely to be two local issues that would quickly be brought to the attention of those in charge of the project. The first would be the impact on the local environment. While the scientific community states that plasma gasification is a sustainable and clean alternative to current methods. There are some that feel it is untested and its environmental impacts unclear. While a majority of the public may support the implementation of this system, feelings are often different when it will be in close proximity to their homes and businesses. This leads into the second expected local issue, proximity to base and local housing. It would be unlikely that the construction of this system would be tolerated within a few miles of substantial base and local housing.

**Project Implications/Issues beyond the Local Level**

While issues and implications of this project are mostly limited to the local area, some may extend beyond that. The most notable implication would be that the system could serve as a model for other communities and military bases. By establishing the plasma gasification as a suitable alternative for MSW disposal and energy generation many other regions may look here for future opportunities for their region.

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## Appendix A

| Facility/Ship Name | Commodity | Units | BurdenRate | FY Total | Qtr 1 | Qtr 2 | Qtr 3 | Qtr 4 |
|---|---|---|---|---|---|---|---|---|
| 'OCEANA-513 | EL | MWH | $102.55 | 5178.2 | 1463.2 | 1110.2 | 1239.1 | 1365.7 |
| 'OCEANA-200919 | EL | MWH | $102.55 | 3911.5 | 897.7 | 794.5 | 976.2 | 1243.1 |
| 'OCEANA-200920 | EL | MWH | $102.55 | 3911.5 | 897.7 | 794.5 | 976.2 | 1243.1 |
| 'OCEANA-WR406 | EL | MWH | $102.55 | 3911.5 | 897.7 | 794.5 | 976.2 | 1243.1 |
| 'OCEANA-LINELOSS | EL | MWH | $102.55 | 3503.9 | 896.6 | 821.9 | 839.3 | 946.1 |
| 'OCEANA-140 | EL | MWH | $102.55 | 3041.1 | 890.1 | 753.4 | 759 | 638.6 |
| 'OCEANA-292 | EL | MWH | $102.55 | 2222.2 | 625.3 | 502.5 | 508 | 586.4 |
| 'OCEANA-340 | EL | MWH | $102.55 | 2211.2 | 542.4 | 702.4 | 406.4 | 560 |
| 'OCEANA-200 | EL | MWH | $102.55 | 2052.4 | 534.5 | 503.6 | 527.9 | 486.4 |
| 'OCEANA-285 | EL | MWH | $102.55 | 1684.3 | 474.1 | 424.5 | 398.7 | 387 |
| 'OCEANA-122 | EL | MWH | $102.55 | 1583.9 | 468.6 | 305.9 | 306.5 | 502.9 |
| 'OCEANA-531 | EL | MWH | $102.55 | 1478.9 | 366.8 | 341.3 | 320 | 450.8 |
| 'OCEANA-137 | EL | MWH | $102.55 | 1420.8 | 344.5 | 276.6 | 392.6 | 407.1 |
| 'OCEANA-145 | EL | MWH | $102.55 | 1369.8 | 351.2 | 259.6 | 295.8 | 463.2 |
| 'OCEANA-111 | EL | MWH | $102.55 | 1287 | 224.5 | 322 | 315.5 | 425 |
| 'OCEANA-290 | EL | MWH | $102.55 | 1271.2 | 425.6 | 361.6 | 195.2 | 288.8 |
| 'OCEANA-240 | EL | MWH | $102.55 | 1238.9 | 345.6 | 283.8 | 302.5 | 307 |
| 'OCEANA-431 | EL | MWH | $102.55 | 1160.2 | 314.5 | 280.6 | 244.9 | 320.2 |
| 'OCEANA-460 | EL | MWH | $102.55 | 1160 | 259.5 | 231.9 | 255.4 | 413.2 |
| 'OCEANA-119 | EL | MWH | $102.55 | 1144.8 | 409.2 | 196.8 | 202.2 | 336.6 |
| 'OCEANA-404 | EL | MWH | $102.55 | 786.2 | 179.9 | 175.3 | 202.5 | 228.5 |
| 'OCEANA-520 | EL | MWH | $102.55 | 785.4 | 219.5 | 218.7 | 186.3 | 160.9 |
| 'OCEANA-3042 | EL | MWH | $102.55 | 729.7 | 202.3 | 165.6 | 170.1 | 191.7 |
| 'OCEANA-500 | EL | MWH | $102.55 | 713.4 | 185.2 | 189.2 | 184.8 | 154.2 |
| 'OCEANA-423 | EL | MWH | $102.55 | 660.6 | 253 | 161.4 | 140.8 | 105.4 |
| 'OCEANA-100 | EL | MWH | $102.55 | 649.3 | 168.1 | 172.2 | 174.5 | 134.5 |
| 'OCEANA-301 | EL | MWH | $102.55 | 635.3 | 169.8 | 149.4 | 156.4 | 159.7 |
| 'OCEANA-150 | EL | MWH | $102.55 | 625.7 | 179.7 | 148.1 | 151.9 | 146 |
| 'OCEANA-545 | EL | MWH | $102.55 | 622.9 | 156.8 | 113.7 | 130.8 | 221.6 |
| 'OCEANA-419 | EL | MWH | $102.55 | 532.4 | 146.8 | 129.6 | 129.2 | 126.8 |
| 'OCEANA-530 | EL | MWH | $102.55 | 507.6 | 158.3 | 114.8 | 111.5 | 123 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 'OCEANA-HSG FAIRWAY CRESENT | EL | MWH | $102.55 | 489.4 | 114.6 | 122.6 | 121 | 131.2 |
| 'OCEANA-223 | EL | MWH | $102.55 | 462.4 | 74.1 | 131.3 | 64.1 | 192.9 |
| 'OCEANA-56 | EL | MWH | $102.55 | 422.1 | 94 | 110.8 | 115.3 | 102 |
| 'OCEANA-F-105-X | EL | MWH | $102.55 | 394.9 | 99.4 | 93.2 | 105.1 | 97.2 |
| 'OCEANA-230 | EL | MWH | $102.55 | 388.7 | 100.4 | 93.4 | 98.7 | 96.2 |
| 'OCEANA-720 | EL | MWH | $102.55 | 385.9 | 99 | 95.5 | 91.8 | 99.6 |
| 'OCEANA-536 | EL | MWH | $102.55 | 385.6 | 107.2 | 82.8 | 86.8 | 108.8 |
| 'OCEANA-430 | EL | MWH | $102.55 | 383.1 | 126.3 | 83.3 | 80.5 | 93 |
| 'OCEANA-450 | EL | MWH | $102.55 | 381.4 | 94.9 | 88.4 | 86.7 | 111.4 |
| 'OCEANA-310 | EL | MWH | $102.55 | 380.1 | 101.4 | 102.3 | 110.1 | 66.3 |
| 'OCEANA-540 | EL | MWH | $102.55 | 366.5 | 82.6 | 95.4 | 79.6 | 108.9 |
| 'OCEANA-442 | EL | MWH | $102.55 | 353.6 | 96.2 | 78.8 | 79 | 99.6 |
| 'OCEANA-542 | EL | MWH | $102.55 | 352.6 | 100.1 | 76.2 | 78.7 | 97.6 |
| 'OCEANA-820 | EL | MWH | $102.55 | 352.4 | 111.9 | 74.6 | 73.1 | 92.8 |
| 'OCEANA-139 | EL | MWH | $102.55 | 347.4 | 76.1 | 76.2 | 104.2 | 90.9 |
| 'OCEANA-920 | EL | MWH | $102.55 | 342.3 | 72.9 | 77.5 | 106.2 | 85.7 |
| 'OCEANA-529 | EL | MWH | $102.55 | 330 | 76.8 | 84.3 | 87.9 | 81 |
| 'OCEANA-443 | EL | MWH | $102.55 | 315.8 | 78.9 | 71.8 | 71 | 94.1 |
| 'OCEANA-581 | EL | MWH | $102.55 | 297.3 | 84.5 | 57.7 | 56.1 | 99 |
| 'OCEANA-441 | EL | MWH | $102.55 | 292.7 | 79.4 | 62.6 | 65.5 | 85.2 |
| 'OCEANA-401 | EL | MWH | $102.55 | 285.7 | 71.7 | 74.5 | 68.5 | 71 |
| 'OCEANA-445 | EL | MWH | $102.55 | 283.5 | 70.4 | 59.3 | 64.1 | 89.7 |
| 'OCEANA-830 | EL | MWH | $102.55 | 281.9 | 45.7 | 81.2 | 72.8 | 82.2 |
| 'OCEANA-444 | EL | MWH | $102.55 | 278.2 | 57.6 | 66.2 | 72.2 | 82.2 |
| 'OCEANA-103 | EL | MWH | $102.55 | 260.7 | 57.8 | 54.9 | 65.7 | 82.3 |
| 'OCEANA-100-FENTRESS | EL | MWH | $102.55 | 257 | 26.7 | 67.9 | 96.3 | 66.1 |
| 'OCEANA-3025 | EL | MWH | $102.55 | 246.9 | 84.8 | 80.8 | 81.3 | 0 |
| 'OCEANA-232 | EL | MWH | $102.55 | 240.8 | 64.8 | 57.2 | 59.4 | 59.4 |
| 'OCEANA-446 | EL | MWH | $102.55 | 233.6 | 49.6 | 65.2 | 66.8 | 52 |
| 'OCEANA-3037 | EL | MWH | $102.55 | 229 | 34 | 67.6 | 73.4 | 54 |
| 'OCEANA-3038 | EL | MWH | $102.55 | 229 | 34 | 67.6 | 73.4 | 54 |
| 'OCEANA-3047 | EL | MWH | $102.55 | 229 | 34 | 67.6 | 73.4 | 54 |
| 'OCEANA-3048 | EL | MWH | $102.55 | 229 | 34 | 67.6 | 73.4 | 54 |
| 'OCEANA-582 | EL | MWH | $102.55 | 213.2 | 59.8 | 27.4 | 31.8 | 94.2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 'OCEANA-294 | EL | MWH | $102.55 | 202.9 | 57.1 | 45.8 | 46.4 | 53.6 |
| 'OCEANA-900 | EL | MWH | $102.55 | 202.1 | 89.6 | 109.6 | 0.9 | 2 |
| 'OCEANA-326 | EL | MWH | $102.55 | 193 | 52.3 | 48.3 | 48.1 | 44.3 |
| 'OCEANA-2005 | EL | MWH | $102.55 | 188.7 | 38.4 | 34.9 | 64.7 | 50.7 |
| 'OCEANA-SD600 | EL | MWH | $102.55 | 186.1 | 42 | 47.6 | 56.2 | 40.3 |
| 'OCEANA-345 | EL | MWH | $102.55 | 180 | 51.3 | 43.5 | 41.1 | 44.1 |
| 'OCEANA-3017 | EL | MWH | $102.55 | 177 | 39 | 49.2 | 41.8 | 47 |
| 'OCEANA-1116 | EL | MWH | $102.55 | 161.4 | 29 | 51.2 | 47.1 | 34.1 |
| 'OCEANA-220 | EL | MWH | $102.55 | 159.3 | 50.8 | 34.7 | 34.6 | 39.2 |
| 'OCEANA-480 | EL | MWH | $102.55 | 157.5 | 40.1 | 41.3 | 47.1 | 29 |
| 'OCEANA-730 | EL | MWH | $102.55 | 148.3 | 38.6 | 38.6 | 41.2 | 29.9 |
| 'OCEANA-320 | EL | MWH | $102.55 | 146.1 | 45 | 33.8 | 35.9 | 31.4 |
| 'OCEANA-3012 | EL | MWH | $102.55 | 145.1 | 36.1 | 34.8 | 36.8 | 37.4 |
| 'OCEANA-1020B | EL | MWH | $102.55 | 143.5 | 26.1 | 50 | 42.1 | 25.3 |
| 'OCEANA-528 | EL | MWH | $102.55 | 140.4 | 34.1 | 36.7 | 32.2 | 37.4 |
| 'OCEANA-481 | EL | MWH | $102.55 | 134.8 | 41.4 | 46.5 | 37 | 9.9 |
| 'OCEANA-540-SNACK_BAR | EL | MWH | $102.55 | 121.5 | 31.3 | 30 | 29.7 | 30.5 |
| 'OCEANA-107 | EL | MWH | $102.55 | 114.8 | 28.6 | 28.4 | 29 | 28.8 |
| 'OCEANA-531 | EL | MWH | $102.55 | 111.8 | 12.6 | 30.4 | 28.6 | 40.2 |
| 'OCEANA-321 | EL | MWH | $102.55 | 110.9 | 24.7 | 33.9 | 31 | 21.3 |
| 'OCEANA-430 | EL | MWH | $102.55 | 107 | 11.7 | 30.8 | 30 | 34.5 |
| 'OCEANA-403 | EL | MWH | $102.55 | 106.2 | 2.4 | 54 | 47.4 | 2.4 |
| 'OCEANA-541 | EL | MWH | $102.55 | 102.1 | 25.8 | 24.2 | 24.5 | 27.6 |
| 'OCEANA-847 | EL | MWH | $102.55 | 98.7 | 5.7 | 46.8 | 39.3 | 6.9 |
| 'OCEANA-102 | EL | MWH | $102.55 | 97 | 17.8 | 28.2 | 26.6 | 24.4 |
| 'OCEANA-722 | EL | MWH | $102.55 | 94.8 | 21.5 | 27.5 | 24.4 | 21.4 |
| 'OCEANA-3053 | EL | MWH | $102.55 | 87.5 | 18.5 | 54.1 | 14.9 | 0 |
| 'OCEANA-SUBWAY | EL | MWH | $102.55 | 83.4 | 22.8 | 21 | 19.7 | 19.9 |
| 'OCEANA-3025 | EL | MWH | $102.55 | 83 | 0 | 0 | 0 | 83 |
| 'OCEANA-543 | EL | MWH | $102.55 | 82.9 | 18.3 | 23.8 | 21.7 | 19.1 |
| 'OCEANA-542-TIM HORTON | EL | MWH | $102.55 | 81.2 | 19.4 | 12.9 | 38.2 | 10.7 |
| 'OCEANA-23 | EL | MWH | $102.55 | 80.3 | 16.6 | 27.3 | 21.1 | 15.3 |
| 'OCEANA-210 | EL | MWH | $102.55 | 76.7 | 27.1 | 9.3 | 22.3 | 18 |
| 'OCEANA-322 | EL | MWH | $102.55 | 75.4 | 8.4 | 31.3 | 26.1 | 9.6 |
| 'OCEANA-826 | EL | MWH | $102.55 | 71 | 15.8 | 19.6 | 18.9 | 16.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 'OCEANA-251 | EL | MWH | $102.55 | 70.3 | 14.1 | 21.7 | 19.8 | 14.7 |
| 'OCEANA-212 | EL | MWH | $102.55 | 69.3 | 20.1 | 19.6 | 17.6 | 12 |
| 'OCEANA-254 | EL | MWH | $102.55 | 66.5 | 18.3 | 19 | 18.1 | 11.1 |
| 'OCEANA-109-FENTRESS | EL | MWH | $102.55 | 66.4 | 40 | 22.2 | 4.2 | 0 |
| 'OCEANA-295 | EL | MWH | $102.55 | 60.3 | 15.2 | 17.6 | 16 | 11.5 |
| 'OCEANA-539 | EL | MWH | $102.55 | 58.8 | 20.3 | 23.6 | 14.9 | 0 |
| 'OCEANA-330 | EL | MWH | $102.55 | 58.2 | 12.9 | 12.2 | 14.7 | 18.4 |
| 'OCEANA-3001 | EL | MWH | $102.55 | 58.1 | 13 | 16.3 | 15.5 | 13.3 |
| 'OCEANA-280 | EL | MWH | $102.55 | 57.9 | 18.5 | 15.6 | 13.3 | 10.5 |
| 'OCEANA-26 | EL | MWH | $102.55 | 56 | 11.6 | 20.6 | 18 | 5.8 |
| 'OCEANA-2006 | EL | MWH | $102.55 | 55.5 | 12.3 | 11.6 | 14.1 | 17.5 |
| 'OCEANA-513A | EL | MWH | $102.55 | 53.3 | 15 | 11.4 | 12.8 | 14.1 |
| 'OCEANA-529 | EL | MWH | $102.55 | 53.1 | 12.4 | 13.6 | 14.1 | 13 |
| 'OCEANA-3053 | EL | MWH | $102.55 | 52.1 | 0 | 0 | 22.4 | 29.7 |
| 'OCEANA-292-GREAT STEAK | EL | MWH | $102.55 | 52 | 14.5 | 13.9 | 13.2 | 10.4 |
| 'OCEANA-3014 | EL | MWH | $102.55 | 51.7 | 12.9 | 12.4 | 13.1 | 13.3 |
| 'OCEANA-721 | EL | MWH | $102.55 | 47 | 11.8 | 10.4 | 10.7 | 14.1 |
| 'OCEANA-2026 | EL | MWH | $102.55 | 45.4 | 7 | 11.2 | 25.1 | 2.1 |
| 'OCEANA-518 | EL | MWH | $102.55 | 44.2 | 7.6 | 12.8 | 11.2 | 12.6 |
| 'OCEANA-117 | EL | MWH | $102.55 | 42.7 | 9.6 | 12.8 | 12 | 8.3 |
| 'OCEANA-582-SNACKBAR | EL | MWH | $102.55 | 41.9 | 10.2 | 9.1 | 10.1 | 12.5 |
| 'OCEANA-F7 | EL | MWH | $102.55 | 41.8 | 8.5 | 11.2 | 12.4 | 9.7 |
| 'OCEANA-409 | EL | MWH | $102.55 | 41.3 | 10.4 | 10.8 | 9.9 | 10.2 |
| 'OCEANA-SR9 | EL | MWH | $102.55 | 41.1 | 13.2 | 9.3 | 8.1 | 10.5 |
| 'OCEANA-FP121 | EL | MWH | $102.55 | 40.2 | 1.9 | 12.8 | 13.4 | 12.1 |
| 'OCEANA-3035 | EL | MWH | $102.55 | 39.4 | 8.7 | 8.3 | 9.9 | 12.5 |
| 'OCEANA-3003 | EL | MWH | $102.55 | 38.8 | 9.9 | 9 | 9.2 | 10.7 |
| 'OCEANA-408 | EL | MWH | $102.55 | 38.8 | 8.5 | 12.6 | 11.1 | 6.6 |
| 'OCEANA-603 | EL | MWH | $102.55 | 37.2 | 5.4 | 11.4 | 10.6 | 9.8 |
| 'OCEANA-400 | EL | MWH | $102.55 | 35.2 | 7.8 | 7.4 | 9 | 11 |
| 'OCEANA-3013 | EL | MWH | $102.55 | 34.6 | 8.6 | 8.3 | 8.8 | 8.9 |
| 'OCEANA-110 | EL | MWH | $102.55 | 33.4 | 7.4 | 7 | 8.4 | 10.6 |
| 'OCEANA-1140 | EL | MWH | $102.55 | 33.3 | 7.4 | 7 | 8.4 | 10.5 |
| 'OCEANA-2027 | EL | MWH | $102.55 | 33.3 | 7.4 | 7 | 8.4 | 10.5 |
| 'OCEANA-2028 | EL | MWH | $102.55 | 33.3 | 7.4 | 7 | 8.4 | 10.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 'OCEANA-125 | EL | MWH | $102.55 | 33 | 7.5 | 6.7 | 8.7 | 10.1 |
| 'OCEANA-410 | EL | MWH | $102.55 | 32.6 | 5.5 | 10.8 | 11.3 | 5 |
| 'OCEANA-546 | EL | MWH | $102.55 | 32.4 | 7.1 | 9.3 | 8.5 | 7.5 |
| 'OCEANA-320 | EL | MWH | $102.55 | 31.1 | 9.6 | 7.2 | 7.6 | 6.7 |
| 'OCEANA-4063 | EL | MWH | $102.55 | 29.7 | 5.1 | 11.3 | 10.8 | 2.5 |
| 'OCEANA-304 | EL | MWH | $102.55 | 28.8 | 6.3 | 7.6 | 7.4 | 7.5 |
| 'OCEANA-CFP_GROUP_TRL | EL | MWH | $102.55 | 28.6 | 3.3 | 11.5 | 9 | 4.8 |
| 'OCEANA-506 | EL | MWH | $102.55 | 28.6 | 7.2 | 8.2 | 7.6 | 5.6 |
| 'OCEANA-202 | EL | MWH | $102.55 | 28.3 | 7.4 | 7 | 7.3 | 6.6 |
| 'OCEANA-299 | EL | MWH | $102.55 | 27.6 | 7.4 | 5.1 | 6.7 | 8.4 |
| 'OCEANA-824 | EL | MWH | $102.55 | 27.6 | 3.3 | 8.7 | 9.9 | 5.7 |
| 'OCEANA-828 | EL | MWH | $102.55 | 27.6 | 3.3 | 8.7 | 9.9 | 5.7 |
| 'OCEANA-131 | EL | MWH | $102.55 | 27.5 | 6.1 | 5.8 | 6.9 | 8.7 |
| 'OCEANA-DEWY DR_WL | EL | MWH | $102.55 | 26.4 | 6.6 | 6.6 | 6.6 | 6.6 |
| 'OCEANA-F10 | EL | MWH | $102.55 | 26.4 | 5.8 | 6.5 | 7.9 | 6.2 |
| 'OCEANA-F8 | EL | MWH | $102.55 | 26.4 | 5.8 | 6.5 | 7.9 | 6.2 |
| 'OCEANA-F9 | EL | MWH | $102.55 | 26.4 | 5.8 | 6.5 | 7.9 | 6.2 |
| 'OCEANA-252 | EL | MWH | $102.55 | 25.3 | 6.9 | 7.2 | 7 | 4.2 |
| 'OCEANA-1105 | EL | MWH | $102.55 | 24 | 7.3 | 5.6 | 5.6 | 5.5 |
| 'OCEANA-527 | EL | MWH | $102.55 | 24 | 5.6 | 4.6 | 7.3 | 6.5 |
| 'OCEANA-2002 | EL | MWH | $102.55 | 23.8 | 5.3 | 5 | 6 | 7.5 |
| 'OCEANA-611 | EL | MWH | $102.55 | 23.8 | 3.7 | 7.2 | 6.6 | 6.3 |
| 'OCEANA-829 | EL | MWH | $102.55 | 23.7 | 2.9 | 9.3 | 10.4 | 1.1 |
| 'OCEANA-829B | EL | MWH | $102.55 | 23.7 | 2.9 | 9.3 | 10.4 | 1.1 |
| 'OCEANA-333 | EL | MWH | $102.55 | 23.6 | 5.1 | 5.8 | 6.4 | 6.3 |
| 'OCEANA-20-FENTRESS | EL | MWH | $102.55 | 23.5 | 1 | 6.6 | 9.4 | 6.5 |
| 'OCEANA-3030 | EL | MWH | $102.55 | 23.4 | 3.6 | 6.9 | 7.4 | 5.5 |
| 'OCEANA-306 | EL | MWH | $102.55 | 23.3 | 5 | 8.5 | 7.5 | 2.3 |
| 'OCEANA-3027 | EL | MWH | $102.55 | 23.2 | 3 | 9.2 | 8.5 | 2.5 |
| 'OCEANA-3000 | EL | MWH | $102.55 | 23.1 | 5.1 | 4.9 | 5.8 | 7.3 |
| 'OCEANA-102-FENTRESS | EL | MWH | $102.55 | 22.5 | 2.3 | 6 | 8.4 | 5.8 |
| 'OCEANA-833 | EL | MWH | $102.55 | 22.2 | 4.5 | 7.1 | 6.4 | 4.2 |
| 'OCEANA-4134 | EL | MWH | $102.55 | 22.1 | 2.9 | 8.6 | 8.2 | 2.4 |
| 'OCEANA-106 | EL | MWH | $102.55 | 21.9 | 2.3 | 5.8 | 8.1 | 5.7 |
| 'OCEANA-584 | EL | MWH | $102.55 | 21.7 | 2.9 | 7.5 | 7.4 | 3.9 |

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|---|---|---|---|---|---|---|---|---|
| 'OCEANA-630 | EL | MWH | $102.55 | 20.8 | 4.6 | 4.4 | 5.2 | 6.6 |
| 'OCEANA-77 | EL | MWH | $102.55 | 20.3 | 4.2 | 6.9 | 5.5 | 3.7 |
| 'OCEANA-1421 | EL | MWH | $102.55 | 20.3 | 4.5 | 4.3 | 5.1 | 6.4 |
| 'OCEANA-101-FENTRESS | EL | MWH | $102.55 | 20 | 2.1 | 5.3 | 7.5 | 5.1 |
| 'OCEANA-253 | EL | MWH | $102.55 | 19.8 | 5.4 | 5.7 | 5.4 | 3.3 |
| 'OCEANA-109 | EL | MWH | $102.55 | 19.5 | 4.3 | 4.1 | 4.8 | 6.3 |
| 'OCEANA-2004 | EL | MWH | $102.55 | 19.4 | 4.3 | 4 | 4.9 | 6.2 |
| 'OCEANA-2001 | EL | MWH | $102.55 | 19.3 | 4.3 | 4 | 4.9 | 6.1 |
| 'OCEANA-2003 | EL | MWH | $102.55 | 19.1 | 4.2 | 4 | 4.9 | 6 |
| 'OCEANA-292-FRESHEN | EL | MWH | $102.55 | 18.8 | 7.2 | 7.3 | 4.3 | 0 |
| 'OCEANA-799 | EL | MWH | $102.55 | 18.5 | 3.9 | 5.3 | 6.5 | 2.8 |
| 'OCEANA-797 | EL | MWH | $102.55 | 18.3 | 3.9 | 5.2 | 6.4 | 2.8 |
| 'OCEANA-798 | EL | MWH | $102.55 | 18.3 | 3.9 | 5.2 | 6.4 | 2.8 |
| 'OCEANA-542-SUBWAY | EL | MWH | $102.55 | 17.4 | 5 | 3.8 | 3.8 | 4.8 |
| 'OCEANA-88 | EL | MWH | $102.55 | 17.3 | 5.7 | 3.9 | 3.4 | 4.3 |
| 'OCEANA-89 | EL | MWH | $102.55 | 17.3 | 5.7 | 3.9 | 3.4 | 4.3 |
| 'OCEANA-3060 | EL | MWH | $102.55 | 16.7 | 1.9 | 7.4 | 5.2 | 2.2 |
| 'OCEANA-SR6 | EL | MWH | $102.55 | 15.7 | 5.1 | 3.6 | 3 | 4 |
| 'OCEANA-HOURIGAN_TRL | EL | MWH | $102.55 | 15.5 | 2.2 | 6.7 | 5.8 | 0.8 |
| 'OCEANA-1106 | EL | MWH | $102.55 | 14.4 | 2.4 | 5.5 | 4.3 | 2.2 |
| 'OCEANA-934 | EL | MWH | $102.55 | 13.5 | 3.6 | 3.7 | 3.2 | 3 |
| 'OCEANA-105 | EL | MWH | $102.55 | 13.4 | 1.4 | 3.5 | 5 | 3.5 |
| 'OCEANA-292-PANDA EXPRESS | EL | MWH | $102.55 | 13 | 0 | 0 | 6.1 | 6.9 |
| 'OCEANA-610 | EL | MWH | $102.55 | 13 | 2.9 | 2.7 | 3.3 | 4.1 |
| 'OCEANA-ACEPEX_CORP | EL | MWH | $102.55 | 12.7 | 2.7 | 4.3 | 3.7 | 2 |
| 'OCEANA-282 | EL | MWH | $102.55 | 12.6 | 4 | 3.4 | 2.9 | 2.3 |
| 'OCEANA-1115 | EL | MWH | $102.55 | 12.5 | 2.8 | 2.6 | 3.2 | 3.9 |
| 'OCEANA-480-KITCHEN | EL | MWH | $102.55 | 12.3 | 4.5 | 3.1 | 2.9 | 1.8 |
| 'OCEANA-2025 | EL | MWH | $102.55 | 12.2 | 2.7 | 2.6 | 3 | 3.9 |
| 'OCEANA-535 | EL | MWH | $102.55 | 11.9 | 3.6 | 2.7 | 2.7 | 2.9 |
| 'OCEANA-635 | EL | MWH | $102.55 | 11.9 | 4.3 | 1.6 | 1.6 | 4.4 |
| 'OCEANA-531B | EL | MWH | $102.55 | 11.3 | 2.7 | 2.7 | 2.4 | 3.5 |
| 'OCEANA-1116A | EL | MWH | $102.55 | 10.8 | 1.9 | 3.5 | 3.1 | 2.3 |
| 'OCEANA-3054 | EL | MWH | $102.55 | 10.6 | 2.2 | 6.7 | 1.7 | 0 |
| 'OCEANA-3056 | EL | MWH | $102.55 | 10.6 | 2.2 | 6.7 | 1.7 | 0 |

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|---|---|---|---|---|---|---|---|---|
| 'OCEANA-NORTHPAD | EL | MWH | $102.55 | 10.5 | 4.4 | 4.9 | 1.2 | 0 |
| 'OCEANA-505 | EL | MWH | $102.55 | 10.5 | 3.4 | 3.3 | 2.7 | 1.1 |
| 'OCEANA-3015 | EL | MWH | $102.55 | 9.9 | 0.9 | 4.3 | 3.8 | 0.9 |
| 'OCEANA-292-FRESHEN | EL | MWH | $102.55 | 9.8 | 0 | 0 | 3.1 | 6.7 |
| 'OCEANA-OC BLVD_WL | EL | MWH | $102.55 | 9.6 | 2.4 | 2.4 | 2.4 | 2.4 |
| 'OCEANA-GE AVIATION | EL | MWH | $102.55 | 9.5 | 1.7 | 3.5 | 2.9 | 1.4 |
| 'OCEANA-880 | EL | MWH | $102.55 | 9.2 | 3 | 0.1 | 0 | 6.1 |
| 'OCEANA-F17 | EL | MWH | $102.55 | 8.8 | 1 | 3.9 | 2.8 | 1.1 |
| 'OCEANA-130 | EL | MWH | $102.55 | 8.7 | 2 | 1.8 | 2.2 | 2.7 |
| 'OCEANA-WR145 | EL | MWH | $102.55 | 8.6 | 2.1 | 1.7 | 1.8 | 3 |
| 'OCEANA-2020 | EL | MWH | $102.55 | 8.3 | 1.8 | 1.7 | 2.1 | 2.7 |
| 'OCEANA-NADEPJAX_TRL | EL | MWH | $102.55 | 8.3 | 1.5 | 2.7 | 2.4 | 1.7 |
| 'OCEANA-71 | EL | MWH | $102.55 | 7.5 | 1.6 | 2.6 | 2 | 1.3 |
| 'OCEANA-109-FENTRESS | EL | MWH | $102.55 | 6.9 | 0 | 0 | 0 | 6.9 |
| 'OCEANA-325 | EL | MWH | $102.55 | 6.9 | 2.1 | 1.6 | 1.7 | 1.5 |
| 'OCEANA-LANE CONST. CORP | EL | MWH | $102.55 | 6.5 | 6.5 | 0 | 0 | 0 |
| 'OCEANA-416 | EL | MWH | $102.55 | 6.3 | 1.4 | 1.3 | 1.6 | 2 |
| 'OCEANA-826B | EL | MWH | $102.55 | 6.3 | 0.3 | 3.3 | 2.7 | 0 |
| 'OCEANA-3054 | EL | MWH | $102.55 | 6.2 | 0 | 0 | 2.7 | 3.5 |
| 'OCEANA-3056 | EL | MWH | $102.55 | 6.2 | 0 | 0 | 2.7 | 3.5 |
| 'OCEANA-NORTHPAD | EL | MWH | $102.55 | 6.2 | 0 | 0 | 2.8 | 3.4 |
| 'OCEANA-3050 | EL | MWH | $102.55 | 6.1 | 1.7 | 2.5 | 1.9 | 0 |
| 'OCEANA-WR500 | EL | MWH | $102.55 | 6 | 1.4 | 2.1 | 1.7 | 0.8 |
| 'OCEANA-250 | EL | MWH | $102.55 | 5.8 | 1.2 | 1.8 | 1.6 | 1.2 |
| 'OCEANA-29-FENTRESS | EL | MWH | $102.55 | 5.8 | 0.6 | 1.5 | 2.2 | 1.5 |
| 'OCEANA-SD6042 | EL | MWH | $102.55 | 5.8 | 1.3 | 1.2 | 1.5 | 1.8 |
| 'OCEANA-E3036 | EL | MWH | $102.55 | 5.6 | 2 | 1.9 | 0.8 | 0.9 |
| 'OCEANA-607 | EL | MWH | $102.55 | 5.3 | 1.2 | 1.1 | 1.3 | 1.7 |
| 'OCEANA-1104 | EL | MWH | $102.55 | 5.2 | 1.2 | 2.1 | 1 | 0.9 |
| 'OCEANA-232A | EL | MWH | $102.55 | 5.1 | 1.4 | 1.2 | 1.2 | 1.3 |
| 'OCEANA-3002 | EL | MWH | $102.55 | 5 | 1.1 | 1.1 | 1.2 | 1.6 |
| 'OCEANA-1111 | EL | MWH | $102.55 | 4.7 | 1 | 1 | 1.2 | 1.5 |
| 'OCEANA-541A | EL | MWH | $102.55 | 4.4 | 1.1 | 1 | 1.1 | 1.2 |
| 'OCEANA-1102 | EL | MWH | $102.55 | 4.4 | 0.9 | 1.7 | 0.9 | 0.9 |
| 'OCEANA-323 | EL | MWH | $102.55 | 4.3 | 0.5 | 1.8 | 1.4 | 0.6 |

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|---|---|---|---|---|---|---|---|---|
| 'OCEANA-2013 | EL | MWH | $102.55 | 4.2 | 0.9 | 0.9 | 1.1 | 1.3 |
| 'OCEANA-2014 | EL | MWH | $102.55 | 4.2 | 0.9 | 0.9 | 1.1 | 1.3 |
| 'OCEANA-2016 | EL | MWH | $102.55 | 4.2 | 0.9 | 0.9 | 1.1 | 1.3 |
| 'OCEANA-F18 | EL | MWH | $102.55 | 4.2 | 0.4 | 1.9 | 1.3 | 0.6 |
| 'OCEANA-2015 | EL | MWH | $102.55 | 4.1 | 0.9 | 0.9 | 1.1 | 1.2 |
| 'OCEANA-SD350 | EL | MWH | $102.55 | 4.1 | 0.8 | 1 | 1.5 | 0.8 |
| 'OCEANA-2000 | EL | MWH | $102.55 | 4 | 0.9 | 0.9 | 1 | 1.2 |
| 'OCEANA-200187 | EL | MWH | $102.55 | 3.9 | 0.9 | 0.7 | 1 | 1.3 |
| 'OCEANA-3005 | EL | MWH | $102.55 | 3.9 | 0.9 | 0.7 | 1 | 1.3 |
| 'OCEANA-3006 | EL | MWH | $102.55 | 3.9 | 0.9 | 0.7 | 1 | 1.3 |
| 'OCEANA-324 | EL | MWH | $102.55 | 3.9 | 1.2 | 0.9 | 0.9 | 0.9 |
| 'OCEANA-380 | EL | MWH | $102.55 | 3.9 | 0.9 | 0.7 | 1 | 1.3 |
| 'OCEANA-4161 | EL | MWH | $102.55 | 3.9 | 0.9 | 0.7 | 1 | 1.3 |
| 'OCEANA-622 | EL | MWH | $102.55 | 3.9 | 0.9 | 0.7 | 1 | 1.3 |
| 'OCEANA-627 | EL | MWH | $102.55 | 3.9 | 0.9 | 0.7 | 1 | 1.3 |
| 'OCEANA-640 | EL | MWH | $102.55 | 3.9 | 0.9 | 0.7 | 1 | 1.3 |
| 'OCEANA-128 | EL | MWH | $102.55 | 3.6 | 0.8 | 0.7 | 0.9 | 1.2 |
| 'OCEANA-504 | EL | MWH | $102.55 | 3.6 | 0.8 | 0.7 | 0.9 | 1.2 |
| 'OCEANA-F8B | EL | MWH | $102.55 | 3.6 | 0.8 | 0.9 | 1.1 | 0.8 |
| 'OCEANA-2520 | EL | MWH | $102.55 | 3.3 | 0.7 | 0.7 | 0.8 | 1.1 |
| 'OCEANA-515 | EL | MWH | $102.55 | 3.2 | 1.5 | 0 | 0.1 | 1.6 |
| 'OCEANA-4162 | EL | MWH | $102.55 | 3.1 | 3.1 | 0 | 0 | 0 |
| 'OCEANA-F8MCC | EL | MWH | $102.55 | 3.1 | 0.7 | 0.8 | 0.9 | 0.7 |
| 'OCEANA-2022 | EL | MWH | $102.55 | 3 | 0.7 | 0.6 | 0.8 | 0.9 |
| 'OCEANA-3034 | EL | MWH | $102.55 | 3 | 0.5 | 0.9 | 0.9 | 0.7 |
| 'OCEANA-WR404 | EL | MWH | $102.55 | 3 | 0.7 | 0.7 | 0.8 | 0.8 |
| 'OCEANA-493 | EL | MWH | $102.55 | 2.9 | 0.5 | 0.8 | 0.7 | 0.9 |
| 'OCEANA-SR8 | EL | MWH | $102.55 | 2.8 | 0.9 | 0.6 | 0.6 | 0.7 |
| 'OCEANA-209 | EL | MWH | $102.55 | 2.7 | 1.2 | 1.1 | 0.4 | 0 |
| 'OCEANA-2070 | EL | MWH | $102.55 | 2.7 | 0.6 | 0.6 | 0.7 | 0.8 |
| 'OCEANA-85 | EL | MWH | $102.55 | 2.6 | 0.6 | 0.9 | 0.7 | 0.4 |
| 'OCEANA-75 | EL | MWH | $102.55 | 2.4 | 0.4 | 0.9 | 0.7 | 0.4 |
| 'OCEANA-107-FENTRESS | EL | MWH | $102.55 | 2.4 | 0.2 | 0.7 | 0.9 | 0.6 |
| 'OCEANA-528A | EL | MWH | $102.55 | 2.3 | 0.6 | 0.6 | 0.5 | 0.6 |
| 'OCEANA-1100 | EL | MWH | $102.55 | 2.1 | 0.5 | 0.9 | 0.4 | 0.3 |

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|---|---|---|---|---|---|---|---|---|
| 'OCEANA-298 | EL | MWH | $102.55 | 2 | 0.6 | 0.3 | 0.5 | 0.6 |
| 'OCEANA-585 | EL | MWH | $102.55 | 1.9 | 0.5 | 0.3 | 0.4 | 0.7 |
| 'OCEANA-86 | EL | MWH | $102.55 | 1.9 | 0.4 | 0.6 | 0.5 | 0.4 |
| 'OCEANA-209 | EL | MWH | $102.55 | 1.9 | 0 | 0 | 0.8 | 1.1 |
| 'OCEANA-F-23 | EL | MWH | $102.55 | 1.8 | 0.4 | 0.4 | 0.5 | 0.5 |
| 'OCEANA-F-24 | EL | MWH | $102.55 | 1.8 | 0.4 | 0.4 | 0.5 | 0.5 |
| 'OCEANA-199 | EL | MWH | $102.55 | 1.7 | 0.2 | 0.5 | 0.4 | 0.6 |
| 'OCEANA-213 | EL | MWH | $102.55 | 1.7 | 0.4 | 0.4 | 0.4 | 0.5 |
| 'OCEANA-SR7 | EL | MWH | $102.55 | 1.7 | 0.6 | 0.4 | 0.3 | 0.4 |
| 'OCEANA-3050 | EL | MWH | $102.55 | 1.6 | 0 | 0 | 0 | 1.6 |
| 'OCEANA-20-FENTRESS | EL | MWH | $102.55 | 1.6 | 1.6 | 0 | 0 | 0 |
| 'OCEANA-527A | EL | MWH | $102.55 | 1.5 | 0.4 | 0.3 | 0.4 | 0.4 |
| 'OCEANA-608 | EL | MWH | $102.55 | 1.3 | 0.4 | 0.4 | 0.5 | 0 |
| 'OCEANA-3051 | EL | MWH | $102.55 | 1.2 | 0.3 | 0.5 | 0.4 | 0 |
| 'OCEANA-403 | EL | MWH | $102.55 | 1.2 | 1.2 | 0 | 0 | 0 |
| 'OCEANA-F-22 | EL | MWH | $102.55 | 1.2 | 0.3 | 0.3 | 0.3 | 0.3 |
| 'OCEANA-490 | EL | MWH | $102.55 | 1.1 | 0.3 | 0.2 | 0.3 | 0.3 |
| 'OCEANA-513B | EL | MWH | $102.55 | 1.1 | 0.2 | 0.3 | 0.3 | 0.3 |
| 'OCEANA-513C | EL | MWH | $102.55 | 1.1 | 0.2 | 0.3 | 0.3 | 0.3 |
| 'OCEANA-842 | EL | MWH | $102.55 | 1.1 | 0 | 0.5 | 0.5 | 0.1 |
| 'OCEANA-1115A | EL | MWH | $102.55 | 1 | 0.2 | 0.2 | 0.3 | 0.3 |
| 'OCEANA-255 | EL | MWH | $102.55 | 1 | 0.2 | 0.3 | 0.2 | 0.3 |
| 'OCEANA-3049 | EL | MWH | $102.55 | 0.9 | 0.1 | 0.3 | 0.3 | 0.2 |
| 'OCEANA-513D | EL | MWH | $102.55 | 0.9 | 0.2 | 0.1 | 0.3 | 0.3 |
| 'OCEANA-TESOROTRL | EL | MWH | $102.55 | 0.6 | 0 | 0.3 | 0 | 0.3 |
| 'OCEANA-1112 | EL | MWH | $102.55 | 0.6 | 0 | 0 | 0 | 0.6 |
| 'OCEANA-123 | EL | MWH | $102.55 | 0.6 | 0.1 | 0.1 | 0.2 | 0.2 |
| 'OCEANA-203 | EL | MWH | $102.55 | 0.6 | 0.1 | 0.1 | 0.2 | 0.2 |
| 'OCEANA-103-FENTRESS | EL | MWH | $102.55 | 0.5 | 0 | 0.2 | 0.3 | 0 |
| 'OCEANA-2007 | EL | MWH | $102.55 | 0.5 | 0.1 | 0.1 | 0.1 | 0.2 |
| 'OCEANA-2008 | EL | MWH | $102.55 | 0.5 | 0.1 | 0.1 | 0.1 | 0.2 |
| 'OCEANA-2009 | EL | MWH | $102.55 | 0.5 | 0.1 | 0.1 | 0.1 | 0.2 |
| 'OCEANA-2010 | EL | MWH | $102.55 | 0.5 | 0.1 | 0.1 | 0.1 | 0.2 |
| 'OCEANA-2011 | EL | MWH | $102.55 | 0.5 | 0.1 | 0.1 | 0.1 | 0.2 |
| 'OCEANA-2012 | EL | MWH | $102.55 | 0.5 | 0.1 | 0.1 | 0.1 | 0.2 |

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|---|---|---|---|---|---|---|---|---|---|
| 'OCEANA-671_OCEANA BLVD_WL | EL | MWH | $102.55 | 0.5 | 0.3 | 0.2 | 0 | 0 |
| 'OCEANA-200387 | EL | MWH | $102.55 | 0.4 | 0.4 | 0 | 0 | 0 |
| 'OCEANA-F-105 | EL | MWH | $102.55 | 0.4 | 0.1 | 0 | 0.2 | 0.1 |
| 'OCEANA-844 | EL | MWH | $102.55 | 0.4 | 0 | 0.2 | 0.2 | 0 |
| 'OCEANA-3051 | EL | MWH | $102.55 | 0.3 | 0 | 0 | 0 | 0.3 |
| 'OCEANA-827 | EL | MWH | $102.55 | 0.3 | 0.3 | 0 | 0 | 0 |
| 'OCEANA-1110 | EL | MWH | $102.55 | 0.3 | 0 | 0 | 0 | 0.3 |
| 'OCEANA-320T2 | EL | MWH | $102.55 | 0.2 | 0 | 0 | 0.2 | 0 |
| 'OCEANA-508T | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-TL_ENTERPRISES | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-DJ EVANS-CONTRACTING | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-3026 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-3028 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-3031 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-3032 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-3033 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-3039 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-3040 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-621 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-623 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-631 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-634 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-F-105A | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-F-20MCC | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-F-25MCC | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-F-26 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-1114 | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-E499A | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| 'OCEANA-E499B | EL | MWH | $102.55 | 0 | 0 | 0 | 0 | 0 |
| Totals | | | | 70,912 | 18,089 | 16,687 | 17,033 | 19,103 |
| Total Cost | | | | $7,271,994.84 | | | | |

## Appendix B

| | |
|---|---|
| Inflation rate | 2.30% |
| Electrical rate-MWH | $ 102.55 |
| MARR | 6.00% |
| Annual expected energy generation | 15189.84 MWh |

| Current System | Year | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| MSW disposal costs-current system (All Bases) | $ 6,667,019.00 | $ 6,820,360.44 | $ 6,977,228.73 | $ 7,137,704.99 | $ 7,301,872.20 | $ 7,469,815.26 |
| Current Electrical costs Oceana-Dam Neck | $ 14,810,739.24 | $ 15,151,386.24 | $ 15,499,868.13 | $ 15,856,365.09 | $ 16,221,061.49 | $ 16,594,145.90 |
| Total cost for electrical power and MSW disposal | $ 21,477,758.24 | $ 21,971,746.68 | $ 22,477,096.85 | $ 22,994,070.08 | $ 23,522,933.69 | $ 24,063,961.17 |

| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|
| $ 7,641,621.01 | $ 7,817,378.30 | $ 7,997,178.00 | $ 8,181,113.09 | $ 8,369,278.69 | $ 8,561,772.10 | $ 8,758,692.86 | $ 8,960,142.80 |
| $ 16,975,811.26 | $ 17,366,254.92 | $ 17,765,678.78 | $ 18,174,289.39 | $ 18,592,298.05 | $ 19,019,920.91 | $ 19,457,379.09 | $ 19,904,898.81 |
| $ 24,617,432.27 | $ 25,183,633.22 | $ 25,762,856.78 | $ 26,355,402.49 | $ 26,961,576.74 | $ 27,581,693.01 | $ 28,216,071.95 | $ 28,865,041.60 |

| 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|
| $ 9,166,226.08 | $ 9,377,049.28 | $ 9,592,721.42 | $ 9,813,354.01 | $ 10,039,061.15 | $ 10,269,959.56 | $ 10,506,168.63 | $ 10,747,810.50 |
| $ 20,362,711.48 | $ 20,831,053.84 | $ 21,310,168.08 | $ 21,800,301.95 | $ 22,301,708.89 | $ 22,814,648.20 | $ 23,339,385.10 | $ 23,876,190.96 |
| $ 29,528,937.56 | $ 30,208,103.12 | $ 30,902,889.50 | $ 31,613,655.95 | $ 32,340,770.04 | $ 33,084,607.75 | $ 33,845,553.73 | $ 34,624,001.47 |

| 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|
| $ 10,995,010.15 | $ 11,247,895.38 | $ 11,506,596.97 | $ 11,771,248.70 | $ 12,041,987.42 | $ 12,318,953.13 | $ 12,602,289.06 | $ 12,892,141.71 |
| $ 24,425,343.35 | $ 24,987,126.25 | $ 25,561,830.15 | $ 26,149,752.25 | $ 26,751,196.55 | $ 27,366,474.07 | $ 27,995,902.97 | $ 28,639,808.74 |
| $ 35,420,353.50 | $ 36,235,021.63 | $ 37,068,427.13 | $ 37,921,000.95 | $ 38,793,183.97 | $ 39,685,427.20 | $ 40,598,192.03 | $ 41,531,950.45 |

| 30 | 31 | 32 | 33 | 34 | 35 |
|---|---|---|---|---|---|
| $ 13,188,660.96 | $ 13,492,000.17 | $ 13,802,316.17 | $ 14,119,769.44 | $ 14,444,524.14 | $ 14,776,748.19 |
| $ 29,298,524.34 | $ 29,972,390.40 | $ 30,661,755.38 | $ 31,366,975.76 | $ 32,088,416.20 | $ 32,826,449.77 |
| $ 42,487,185.31 | $ 43,464,390.57 | $ 44,464,071.55 | $ 45,486,745.20 | $ 46,532,940.34 | $ 47,603,197.97 |

| Plasma Gasification System-Savings | Year | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Gasifier disposal costs savings-80% of current system | | $ 5,456,288.35 | $ 5,581,782.98 | $ 5,710,163.99 | $ 5,841,497.76 | $ 5,975,852.21 |
| Energy savings | | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 |
| Total annual savings | | $ 7,049,833.96 | $ 7,175,328.59 | $ 7,303,709.60 | $ 7,435,043.37 | $ 7,569,397.82 |
| | | | | | | |
| Initial Investment for P5 Gasifier | $120,000,000.00 | | | | | |
| NPV-30 years | $118,610,919.13 | | | | | |
| NPV-35 years | $127,749,835.10 | | | | | |

| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|
| $ 6,113,296.81 | $ 6,253,902.64 | $ 6,397,742.40 | $ 6,544,890.47 | $ 6,695,422.95 | $ 6,849,417.68 | $ 7,006,954.29 | $ 7,168,114.24 |
| $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 |
| $ 7,706,842.42 | $ 7,847,448.25 | $ 7,991,288.01 | $ 8,138,436.08 | $ 8,288,968.56 | $ 8,442,963.29 | $ 8,600,499.90 | $ 8,761,659.85 |

| 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|
| $ 7,332,980.87 | $ 7,501,639.43 | $ 7,674,177.13 | $ 7,850,683.21 | $ 8,031,248.92 | $ 8,215,967.65 | $ 8,404,934.90 | $ 8,598,248.40 |
| $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 |
| $ 8,926,526.47 | $ 9,095,185.03 | $ 9,267,722.74 | $ 9,444,228.81 | $ 9,624,794.53 | $ 9,809,513.25 | $ 9,998,480.51 | $ 10,191,794.01 |

| 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|
| $ 8,796,008.12 | $ 8,998,316.30 | $ 9,205,277.58 | $ 9,416,998.96 | $ 9,633,589.94 | $ 9,855,162.51 | $ 10,081,831.25 | $ 10,313,713.36 |
| $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 | $ 1,593,545.61 |
| $ 10,389,553.73 | $ 10,591,861.91 | $ 10,798,823.19 | $ 11,010,544.57 | $ 11,227,135.55 | $ 11,448,708.12 | $ 11,675,376.85 | $ 11,907,258.97 |

| | 10% per Year Reduction in Capacity | | | | |
|---|---|---|---|---|---|
| 30 | 31 | 32 | 33 | 34 | 35 |
| $ 10,550,928.77 | $ 10,793,600.13 | $ 11,041,852.94 | $ 11,295,815.55 | $ 11,555,619.31 | $ 11,821,398.56 |
| $ 1,593,545.61 | $ 1,434,191.05 | $ 1,290,771.94 | $ 1,161,694.75 | $ 1,045,525.27 | $ 940,972.75 |
| $ 12,144,474.38 | $ 12,227,791.18 | $ 12,332,624.88 | $ 12,457,510.30 | $ 12,601,144.59 | $ 12,762,371.30 |

**STUDENT BIO**

Matthew Yost is a native of Pittsburgh, Pennsylvania and currently a Lieutenant in the US Navy as a Civil Engineer Corp Officer. He is currently assigned to the NROTC unit at Old Dominion University and is completing a master's program in Engineering Management. He will be reporting to Naval Weapons Station Earle, NJ in August to serve as the Assistant Public Works Officer.

Matthew began his naval service in 1996 enlisting as a Hospital Corpsman. After completion of Corpsman School, he was assigned to 2nd Battalion 3rd Marine Regiment, Marine Corps Base Hawaii. While there, he served as a platoon and company corpsman with Golf Company. He later transferred to the Naval School of Health and Science in San Diego, CA for Surgical Technologist School. Afterwards he was assigned to the Naval Medical Center San Diego where he served as the Lead Surgical Technologist for the Plastic Surgery Service. Matthew was then assigned to 2nd Medical Battalion, 2nd Force Service Support Group, Camp Lejeune, NC and served as the Senior Surgical Tech for Charlie Company and later as a Leading Petty Officer. In November 2004, he was Honorably Discharged from the Navy.

After separating from the Navy Matthew began working for the University Of Pittsburgh Medical Center as a surgical technologist while completing course work at the University of Pittsburgh. In 2008 he graduated with a Bachelor of Science Degree in Civil Engineering and then worked briefly as a structural engineer before returning to the US Navy.

Matthew was commissioned through Officer Candidate School in February of 2009 and began his commissioned service at Joint Expeditionary Base Little Creek-Fort Story with Amphibious Construction Battalion Two where he served as a platoon commander and the battalion's embark officer from 2009-2010 and deployed to Haiti as part of Operation Unified Response. In July 2010 he reported to Construction Battalion Maintenance Unit Two Zero Two and served as the Battalion Training Officer until January 2012. He then briefly served as a construction manager at Little Creek until June 2012 when he reported to Camp Lemonnier, Djibouti for a Global War on Terrorism Support Assignment and served as a construction manager until May 2013.

Matthew is married to Jessica L. Oates of Pittsburgh, PA; they have one son, Liam Robert and one daughter, Maelee Susan.